Marconi Instruments

CATALOG NA5

ELECTRONIC MEASURING EQUIPMENT

ELECTRONIC MEASURING EQUIPMENT

Marconi Instruments - Sales, Service & Spares

Division of The English Electric Corporation

111 Cedar Lane,
Englewood, New Jersey 07631

Telephone: 201-567 0607
TWX: 710-991 9675

Coast to coast Representation

Quick reference list of States covered by M.I. Representatives on the right.

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ARKANSAS	(5)
CALIFORNIA	(19-20-21)
COLORADO	(24)
CONNECTICUT (North)	(4)
CONNECTICUT (South)	(1)
DELAWARE	(11)
DIS. OF COLUMBIA	(12)
FLORIDA	(15)
GEORGIA	(17)
HAWAII	(23)
ILLINOIS	(7)
INDIANA	(9)
IOWA	(7)
KANSAS	(29)
LOUISIANA	(6)
MAINE	(4)
MARYLAND	(12)
MASSACHUSETTS	(4)
MICHIGAN	(14)
MINNESOTA	(8)
MISSISSIPPI	(17)
MISSOURI (East)	(27)
MISSOURI (West)	(28)
NEBRASKA	(29)
NEVADA	(20)
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NEW YORK (Long Is.)	(3)
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PENNSYLVANIA (East)	(2)
PENNSYLVANIA West)	(13)
RHODE ISLAND	(4)
SOUTH CAROLINA	(16)
TENNESSEE	(16)
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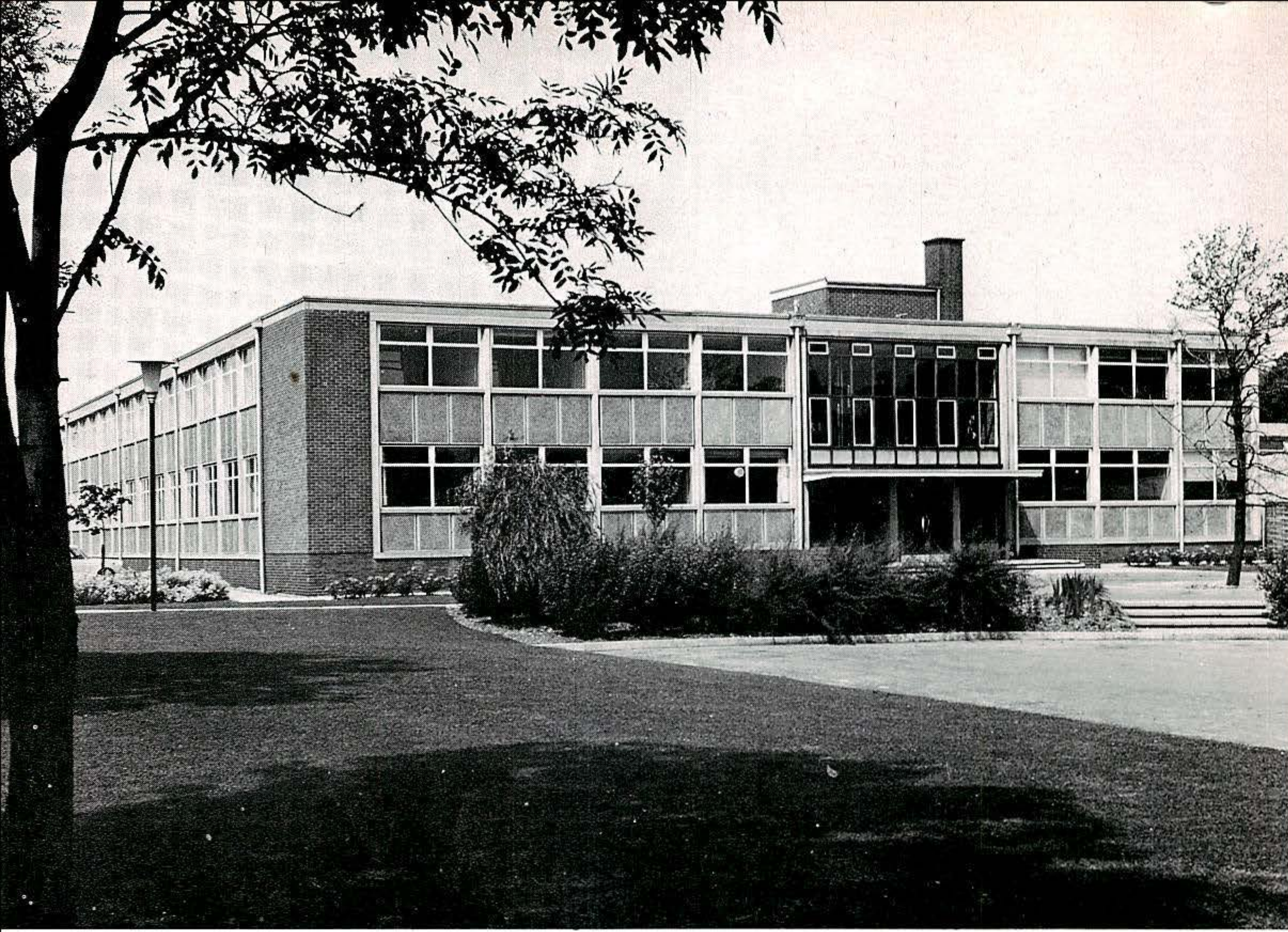
(29) 602E Front St., Bonner Springs, Kansas 66012 *Tel:* 913/441-3226

Contents

Although every effort is made to ensure the authenticity of the information published in this catalogue, we reserve the right to supply instruments embodying small specification changes without prior notice. It is our policy, however, to inform customers of significant changes whenever possible. For all purposes the performance specification included in the manual supplied with the instrument may be regarded as completely valid.



M.I. In Measurement: A Total Customer Service

Experience is one of the key components in any MI instrument: close understanding of the needs of instrument users which spans some 35 years. The application of this knowledge and experience with the most up to date design, engineering and manufacturing techniques, has gained for Marconi Instruments a place at the forefront of progress in electronic measuring instrumentation.

MI has become the principal European organisation in its field and an acknowledged world leader, not only by producing soundly engineered, well-specified and skilfully manufactured instruments, but also by recognising that it has a commitment to provide a complete service for customers covering every aspect of selecting and using advanced instrumentation for increasingly complex and critical applications.

This commitment starts at the outset of every new instrument design project with an exacting study of evolving user requirements and the technological developments which may be exploited in satisfying them. It continues for many years after any design has become a commercially available instrument, in the form of comprehensive maintenance and calibration services. And between these extremes it is the basis of a wide variety of customer services designed to help in selecting the best instruments for a given task, in modifying standard instruments to meet special requirements, in extending an instrument's scope of application and in guiding customers' own service engineers on routine maintenance.

The insistence at MI on high integrity of product performance, consistent value for money, and the provision of customer services based on practical appreciation of users' measurement problems has built the Company into a multi-million pound organisation with a reputation which is relied upon by discriminating users in over 100 countries throughout the world.

Summary of the M.I. Customer Commitment

☐ The continual development of technologically advanced equipment to meet carefully researched user needs. Instruments in which the benefits of the latest available component and design techniques are carefully balanced with the need for unvarying reliability.

☐ A 50-nation network of trained Sales Engineers able to give immediate advice on measurement problems and to make available to users the entire range of MI customer services.

☐ A meaningful guarantee, backed by effective after-sales service arrangements formulated to minimise turn-round times on repairs and spares supply, and to provide a comprehensive range of facilities to meet widely varying needs.

☐ A total service for calibration covering both special and general-purpose requirements, whether for calibration to full B.C.S. certification, to E.I.D. release conditions, to original sales specifications or others supported by a Measurement Standards Laboratory providing traceability to internationally recognised standards.

☐ Customer publications giving a continual flow of information to guide users in the selection, use and servicing of instruments, and communicating the latest developments in electronic measurement techniques.

☐ Technical services provided by a specialist team of applications engineers with full laboratory facilities able to undertake the physical modification of equipment for special purposes or to advise users on difficult measurement problems.

Profile of Marconi Instruments

For the first time all the electronic measurement activities of Marconi Instruments have been brought together into one catalogue. The equipment it describes clearly demonstrates the strength of the MI range, both in fields where its leadership is traditionally recognised, and in new areas of instrument application and measurement technique where the Company's experience and facilities are producing important advances.

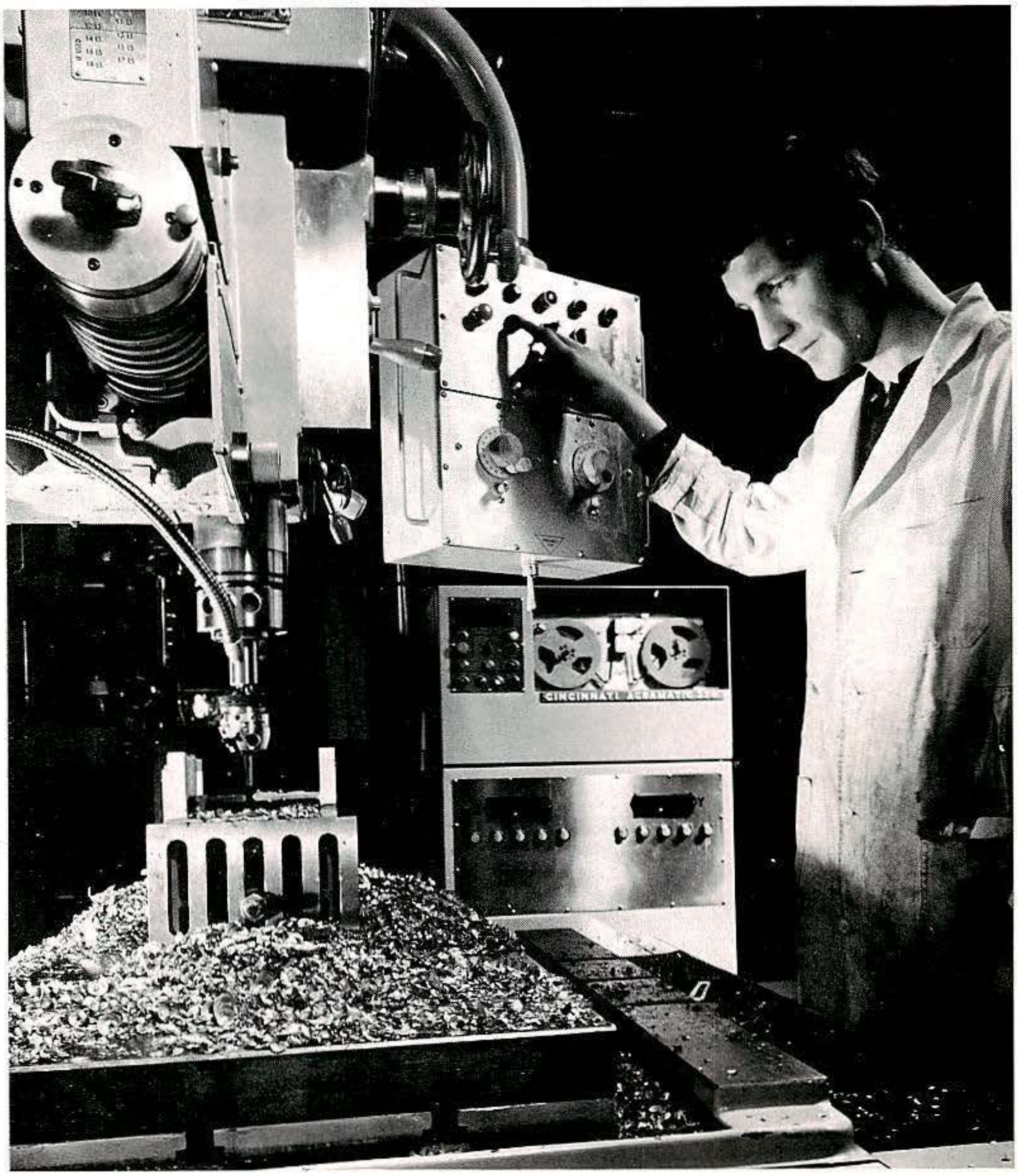
During the past few years MI has greatly expanded and diversified its activities. In the last three years alone this has led to the introduction of the most advanced and economical fully automatic test system of its type available—"Autotest". It has also led to the establishment of MI—Sanders as the leading British organisation for microwave equipment development. It has generated entire new ranges of test equipment for specialised purposes such as television transmission testing and pulse-code-modulation measurements.

Yet, at the same time, MI has maintained the development and introduction of progressively more advanced general-purpose measuring instruments such as signal generators, power meters, voltmeters, impedance bridges, response analysers and counters.

The MI production, sales and servicing units in the U.K. are located at St. Albans, Stevenage, and Luton and employ some 2,500 people. The Company has its own subsidiary companies and divisions providing local sales and servicing support in U.S.A., Germany and France. The 50-nation network of MI export distributors, together with the Company's own overseas organisations, accounts for half the total annual turnover.

To produce the advanced electronic instrumentation required to meet each new generation of measurement problems, demands a continuing and substantial investment in design and engineering, and the use of the latest production techniques and processes. At MI over half a million pounds is devoted each year to new product development, quite apart from investment in a range of supporting facilities and laboratory equipment. The manufacturing system employed is one of the most highly developed of its type anywhere, involving extensive use of programmable machine tools, automatic aids to manual production processes and automatic test assemblies.

Marconi Instruments has always been associated with high product reliability. This is more than ever the case today, and to ensure the maintenance of our stringent standards, considerable engineering and management effort, and financial investment, is concentrated on quality control and reliability, involving exhaustive environmental testing of all new designs and adherence to special test and inspection methods and procedures at various stages of production.

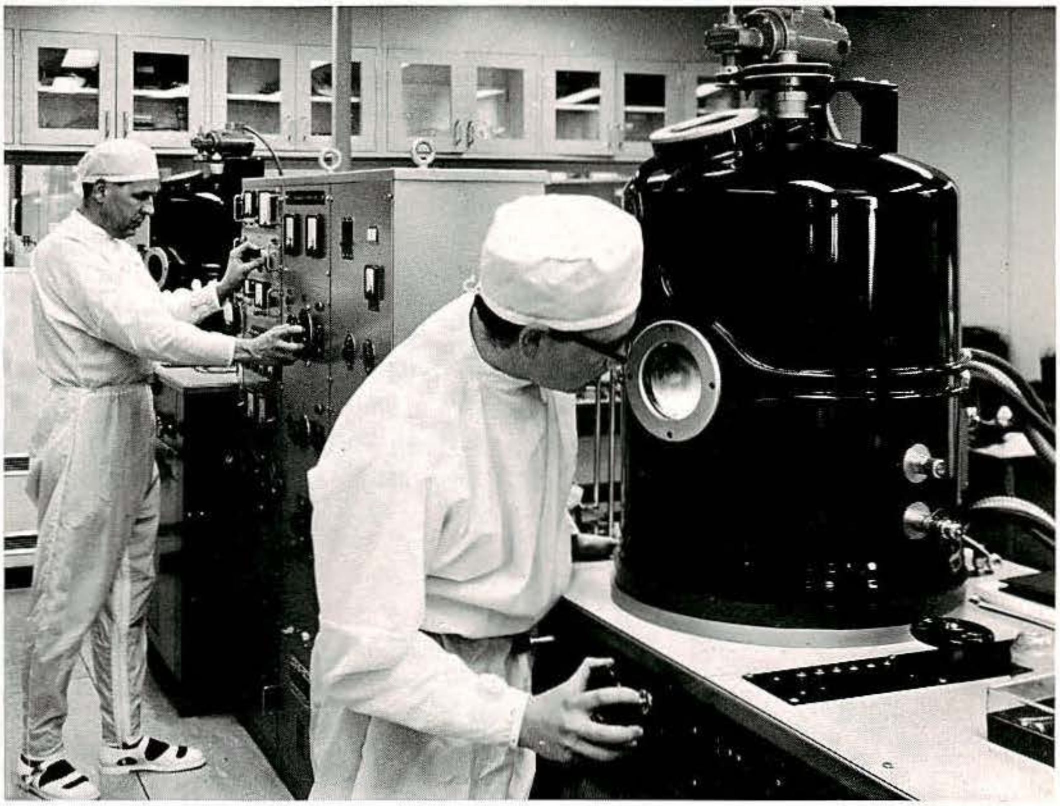


A tape controlled automatic drilling machine.

Our manufacturing system is among the most advanced in Europe, utilising fully programmable machinery and test equipment, together with automatic aids to manual routines where these are more suitable.

The Thin Film Laboratory.

Advanced techniques frequently call for special processes, requiring plant that would be outside the scope of a smaller establishment. For example, the "thin-film" load resistors and thermocouples in our new range of r.f. power meters are produced by high-vacuum evaporation in ultra-clean conditions



The Environmental Test Laboratory.

An instrument undergoing vibration testing. Considerable engineering effort is devoted to special test methods to ensure that our products maintain their performance in all reasonable environments. These methods include shock and vibration testing, checks on the results of various kinds of mishandling, measurements under conditions of overload, and subjection of equipment to simulated climatic extremes.

Selecting the Instrument for the Job

The selection of measuring instrumentation for even comparatively straightforward applications is a difficult operation requiring detailed appraisals of instrument specifications and close understanding of the functions which the equipment must perform. When questions such as the physical modifications to standard instrumentation are involved, selection becomes greatly complicated. Because it is essential to ensure the closest possible match between the measurement problem and the measuring instrumentation, MI provides services to assist at every stage of this process of selection and decision.

Product Literature

This is the starting point. The technical data sheets on individual MI products are written to *inform:* descriptions are designed to be concise, comprehensive and helpful, and the specifications to give an *accurate* statement of performance characteristics.

Field Sales

The MI sales organisation is world-wide. Sales Engineers receive regular and thorough training in the capabilities of MI equipment and the measurement problems they are designed to solve. They are able to deal at first hand with the large majority of users' questions. Their primary responsibility is to ensure complete customer satisfaction and to make available the benefit of the range of MI customer support services to every user. In the U.K. and in the principal overseas markets the field sales engineers are supported by equally experienced staff sales engineers at the local sales office. No user is further away from prompt assistance than his telephone!

The many MI distributors overseas are in regular and frequent contact with the headquarters operation in the U.K. and will immediately obtain assistance on users' measurement problems which cannot be answered locally.

Modifications and Technical Services

The MI team of applications engineers has available full laboratory facilities able to investigate specific measurement problems raised by customers and undertake the modification of standard instruments when requirements outside their original scope are encountered. The support provided by this service is available to all instrument users in the U.K. or overseas, through their M.I. sales engineer, or local M.I. sales office, or distributor.

Instrument Demonstrations

In selecting electronic measuring instrumentation, one of the surest ways of assessing the suitability and capabilities of an instrument is for a user to get the feel of it for himself.

MI provides many opportunities for this. A demonstration of any MI equipment on your premises may always be requested of course, and, in addition, MI participates in a large number of international, national and local exhibitions where a wide range of instruments is featured. Also, the MI mobile demonstration unit is visited each year by some 7,000 instrument users, to see a comprehensive selection of MI equipment in working demonstrations, and assess their performance under operational conditions.

The mobile demonstration unit.

Equipped with a representative selection of instruments from our range and staffed by trained engineers, this unit visits most of the major industrial districts of Europe and the U.K. about once a year. Your local M.I. distributor or representative will advise you when the demonstration unit will be in your area.

Inside the demonstration unit.

Measuring instruments are rack-mounted for convenience of operation and demonstration, and space is provided for suitable test pieces. Patchboard inter-connecting systems are included so that test rigs can be assembled without physically moving instruments. The unit normally utilises the mains a.c. supply, but carries its own a.c. generators for use in difficult situations.

M.I. After-Sales Services

While it is essential to select the right instrumentation for the measurement task, it is no less critical to ensure the availability of efficient maintenance arrangements to keep it working satisfactorily throughout its useful life. Today, costly development, manufacturing and maintenance programmes depend inevitably and increasingly on the ready availability of the measuring instrumentation. No matter how good an instrument may seem for a given purpose, without rapid and efficient maintenance in the event of failure, it soon becomes a liability rather than an asset.

In recognition of users' pressing needs for *effective* after sales service, MI has completely reshaped its facilities and policies for instrument maintenance. Proprietary instrument servicing and Government servicing requirements are now handled by one common organisation, fully equipped to handle the widely varying servicing needs of different users.

At MI, servicing is operated as a separate Division of the Company, with direct responsibility for ensuring customer satisfaction in all matters concerned with repair and calibration. In addition to strictly controlled turn-round targets, the comprehensive MI Maintenance Policy provides contract service arrangements which enable users to budget in advance for all their servicing requirements, with a single annual payment. This Policy also governs the provision of a full inventory of components, active elements and mechanical parts in phase with the production of each new instrument so that the majority of spares orders dealt with by MI are filled within 24 hours of receipt.

At the local level overseas, MI subsidiaries, associates and distributors in all principal markets are able to provide prompt maintenance and repair, backed by the full facilities of the headquarters servicing operation in the U.K.

Through their local MI distributor, and in turn the MI Service Division in the U.K., users of MI equipment have access to truly comprehensive maintenance facilities providing efficient turn-round for repair and spares supply; contract servicing arrangements tailored to varying needs; calibration repair and spares supply to full E.Q.D. approval; and calibration services supported by a Measurement Standards Laboratory which ranks amongst the best in the Industry.

Calibration Services

The broad range of calibration services available through MI Service Division include calibration with traceability to internationally recognised standards under the British Calibration Service, supported by B.C.S. certificates; to E.Q.D. release standards; or, where national standards are not available, a proprietary scheme in which the calibration certificates are authenticated by Marconi Instruments against strict cross-referencing procedures and our standing in the world of metrology.

The Measurement Standards Laboratory at St. Albans is fully environmentally controlled, and contains reference standards of voltage, power, impedance and time which are traceable to national standards. A similar laboratory at the M.I. Sanders Division, Stevenage, undertakes calibration at frequencies above 1GHz. The MI Measurement Standards Laboratory was one of the first to receive approval within the British Calibration Service and offers the widest range of approved parameters in its field of any laboratory in Britain. Full details of the MI calibration services are given in the publication "MI Calibration Services".

Service Division; Calibration and Test Dept., Luton.

Maintenance and repair of the product is one of the most important services that any manufacturer offers his customers. Our after sales service really meets the needs of the industry.

The Measurement Standards Laboratory.

The accuracy of any measuring instrument is dependent on the accuracy of the standards against which it is calibrated, so that the operation of an efficient standards laboratory is a vital element. The St Albans Measurement Standards Laboratory is fully environmentally controlled and operates under clean conditions, the air being filtered down to 100 microns. It contains reference standards of voltage, power, impedance, and time which are traceable to National Standards. We have a similar standards laboratory at Stevenage for calibration work at frequencies above 1 GHz

M.I. Customer Publications

The MI policy of providing a technical data sheet on each instrument which accurately describes its performance and specification is only one element of the Company's active customer-publications programme. In to-day's climate of rapid technological change MI recognises a responsibility to keep instrument users up-to-date with developments by communicating its knowledge and experience on new products and on trends and techniques which are shaping the future of electronic measurement.

To this end Marconi Instruments produces a wide variety of customer publications, each designed to convey information which will help in selecting, using or maintaining electronic measuring equipment. These publications take the form of regular journals such as "Marconi Instrumentation" and "MI Contact"; applications and servicing notes dealing with specific topics on the maintenance or use of MI equipment; and also detailed reviews of specialised areas such as television transmission measurements, automatic testing, etc. The principal MI customer publications are summarised below. If you are not already regularly receiving our house journals and bulletins, or require further information on the applications and servicing notes already available, please contact MI St. Albans or your local MI distributor.

Information about instrument design and the associated measuring techniques is given in *Marconi Instrumentation.* Written by engineers for engineers, it is highly authoritative and is recognised throughout the industry as a leading technical journal.

The bi-monthly news bulletin *Contact* summarises the Company's current activities, with items of technical interest, new product announcements, and notes on the Company's organisation. *Contact* is also a vehicle for bringing other new publications to your notice.

MI Service Division produces its own *Inside Information* notes, which are intended primarily for MI Instrument users who operate their own test gear maintenance departments. The notes give practical information on techniques employed in servicing individual instruments, and also contain useful information about the structure, and activities of the Service Division.

An important new aid to the application of measuring instrumentation is the series of *Measuretest Notes.* These notes, which are available on request, cover methods of using MI instruments to extend their scope of application, or to solve newly revealed measurement problems.

THE "2000" RANGE

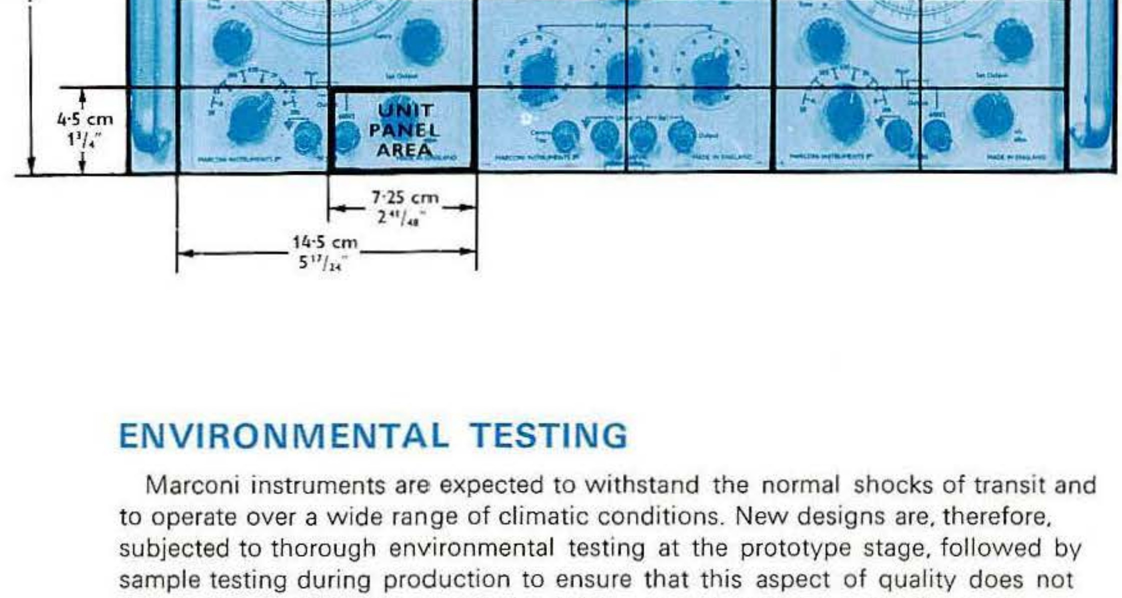
Most of the instruments in this catalogue have four-digit type-numbers beginning with the figure "2". We call these instruments our "2000" range, and this series of type-numbers has real significance apart from simple identification of a design. For example, every "2000" range instrument conforms to the modular dimensional standard, which also means that (oscilloscopes excepted) it can be supplied, without the need for modification, in a bench or rack-mounting case. Furthermore, with very few exceptions, each "2000" range instrument is environmentally tested, so that its suitability for use under abnormal conditions may be accurately assessed.

MODULAR DIMENSIONAL SYSTEM

The modular dimensional standard of the "2000" range of instruments offers to the user the advantage of easy grouping, either on the bench or as rack-mounted test assemblies.

The example illustrated shows a "full-module" assembly of three "one-third modules". Panel sizes are multiples of the *unit panel* dimensions as shown, the full module being six *unit* widths. Plug-ins or sub-assemblies may have panel sizes of any number of *unit* dimensions, either vertical or horizontal; but the panel sizes of complete instruments utilise even multiples only, the smallest being two horizontal *units* by four vertical *units*.

The full module width of approximately 17 inches fits conveniently into a standard 19-inch relay rack; and rack-mounting versions of all modular instruments except oscilloscopes are available. Instruments less than full-module width normally have a *four-unit* panel height. Such instruments fit into the Rack-Mounting Case TM 7010 (illustrated) either singly, with the unoccupied panel space filled by a blank panel unit, or as a multiple assembly of two or three instruments according to size.

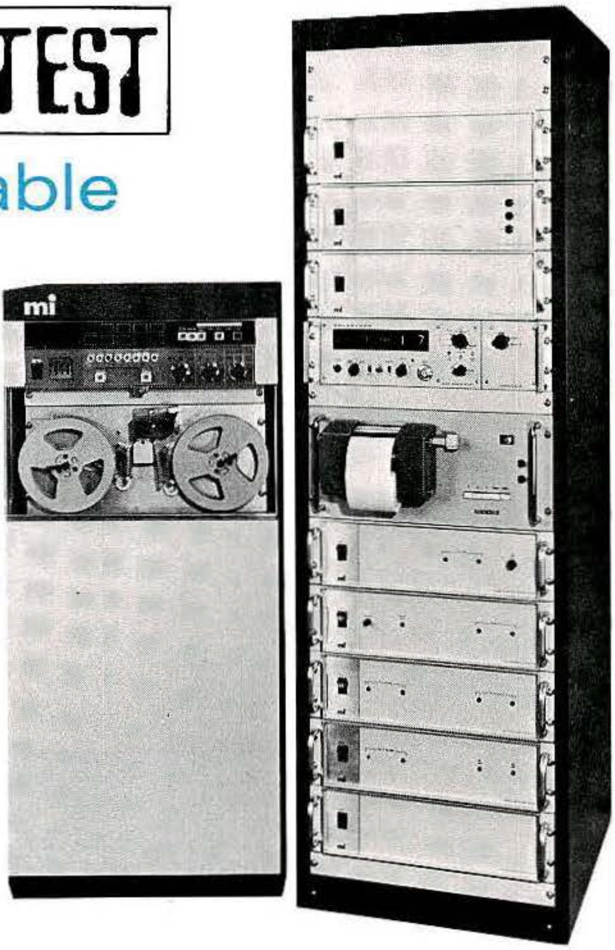


ENVIRONMENTAL TESTING

Marconi instruments are expected to withstand the normal shocks of transit and to operate over a wide range of climatic conditions. New designs are, therefore, subjected to thorough environmental testing at the prototype stage, followed by sample testing during production to ensure that this aspect of quality does not deteriorate. For this purpose MI has built a special environmental laboratory equipped with bump and vibration testing apparatus as well as the means of simulating extreme conditions of temperature and humidity.

mi AUTOTEST

Programmable Fully-Automatic Test Systems



As electronic equipment becomes progressively more complex, routine test and calibration absorbs an ever-increasing proportion of the total manufacturing cost, a trend which is aggravated by the universal shortage of skilled testers.

Significant reduction in test cost can be achieved by the use of instrumentation that can (*a*) be operated by comparatively unskilled personnel and (*b*) make accurate measurements very rapidly. These requirements are met in varying degree by a diversity of automatic and semi-automatic test equipment, ranging from single-purpose self-contained units to complete fully-programmable systems capable of conducting complete test sequences with virtually no manual control.

The *M.I. Autotest* is a fully automatic test system capable of reading its instructions directly from punched paper tape.*
Its flexibility and versatility are comparable to those of a computer controlled system, but it is normally less than half the price. Furthermore, programs can be written simply and quickly by any competent test engineer, without need for special training.

An *Autotest* set can conduct any sequence of tests within the scope of its instrumentation on complex or simple electronic devices at speeds of the order of sixty times those that can be achieved by manually operated test systems. One unskilled operator can, in many situations, supervise six or more sets, thus effecting an enormous saving in personnel and labour costs in comparison with the conventional manual test methods.

An *Autotest* system basically comprises four main function units as follows:
(i) The *Test Jig*, which provides the interface between the instrumentation and the device to be tested.
(ii) *The Programmable Instrumentation* which includes power sources, test-signal sources, and measuring instruments. These are digitally programmable analogue instruments, generally equivalent to the manually operated instruments for the required tests. Also included are programmable test-signal routing switches to provide the interconnections. All units are self-contained modules, which are easily interchanged in order to meet various test requirements.
(iii) The *Digitising and Data Output Peripherals* for conversion of the analogue output from the instrumentation into digital form, making the decision as to whether the digitised result is within programmed limits, and printing out results. This peripheral equipment is usually rack mounted together with the instrumentation.

**International E.I.A. 8 hole code is used. A typist can prepare tapes after only brief instruction.*

(iv) The *Controller*, which receives its instructions from punched paper tape, converts them into digital command signals suitable for operating the programmable equipment, and routes the commands to the appropriate instruments and peripherals.

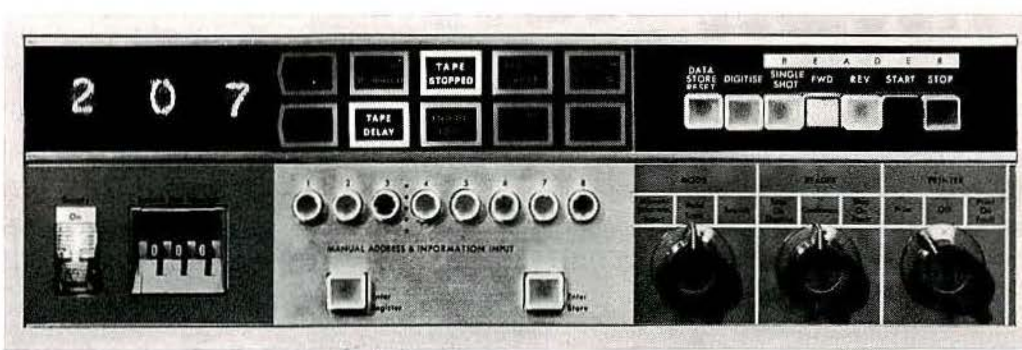
The *Controller* performs, in effect, the same function for *Autotest* as the human operator performs in a manual system. For each test in a sequence it connects the instruments into a test rig, sets the instrument "controls", and then makes the measurement by delivering to the peripheral equipment the appropriate command signals to initiate the selected form of test-result presentation.

DATA INPUT

Normally, the test instructions (or program) are fed into the system via a punched paper tape. Manual controls also provide the means of supplementing or overriding the programmed instructions.

The Autotest controller reads the tape at the rate of 120 lines per second, which is more than adequate for operation of a normal test system and gives a rate of testing compatible with the speed of the print out equipment.

The *Controller's* logic circuits, however, are capable of accepting the coded data at speeds up to 120,000 lines per second, and the unit could be arranged to receive its input data from a computer or similar data source. A single computer, for example, might then drive several medium capacity *Autotest* systems on a time division multiplex basis or, alternatively, one very large capacity *Autotest* system.



DATA OUTPUT

The results of the tests can be presented in several ways, with simple switch selection. These are:

(1) A full print out of each measurement showing the test number, the numerical result, and whether it is "high", "low", or within limits.

(2) A printed record of "out-of-limit" results only, also showing test number and direction of error.

(3) The "stop-on-fault" instruction; i.e., an out-of-limits test result arrests the action, the reason for the stoppage is indicated by an annunciator on the control panel, and the test result is indicated by the digitising peripheral. This mode can be used with or without print out.

In addition, a tape punch may be substituted for the output printer normally fitted, the punched tape then being suitable for off-line analysis of complex test sequence results by a computer. For normal purposes, however, the *Autotest* system itself gives an analysis of "out-of-limits" test results and recurring fault patterns are easily detectable.

SUPERVISORY REQUIREMENTS

Operator intervention is required only if programmed as a function of the test routine—e.g., for manual alignment or for changing test pieces at the end of the cycle. Even this last function can be obviated (if warranted by the volume of testing) by integration of automatic transfer devices into the system under the executive control of the *Controller* unit.

SYSTEM FLEXIBILITY

Flexibility, one of *Autotest's* most important attributes, stems partly from the system's modular design and partly from the simplicity of its programming system.

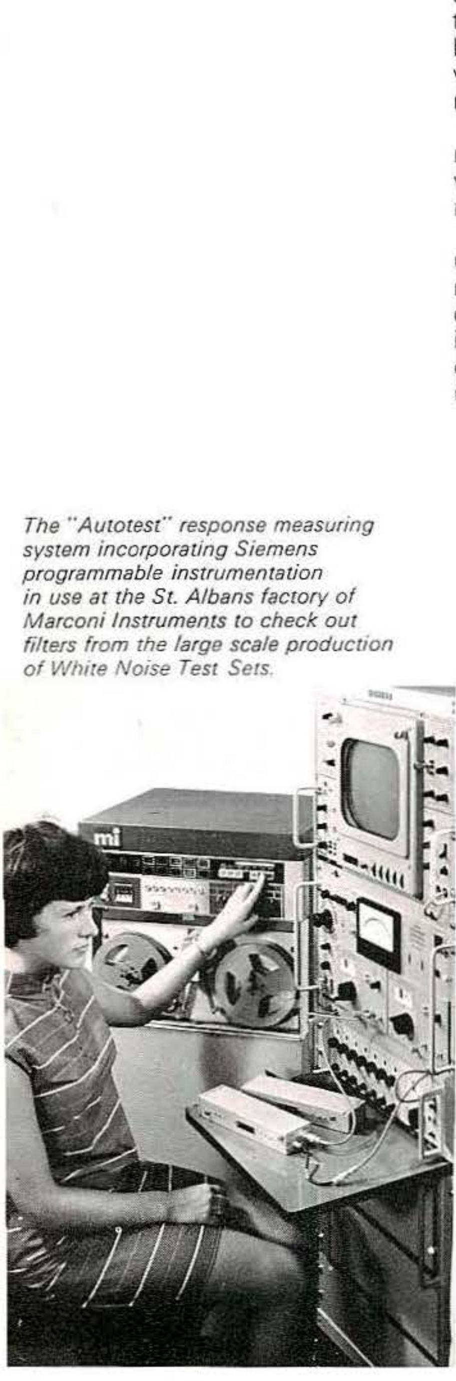
For any given set of instrumentation a wide variety of measurement sequences can be followed by simple substitution of the control tape. Changes to test parameters or specified tolerances can be effected very nearly as easily with *Autotest* as with manually controlled test systems.

Moreover, by including several test sequences on the same tape, batches of devices requiring the same instrumentation but with differing specifications can be tested without changing the tape. The relevant test sequence can readily be selected by use of the "search mode" on the manual control panel (see illustration) ; or, where differing devices arrive in random order, the system can be programmed to recognise the test piece and select the appropriate sequence automatically.

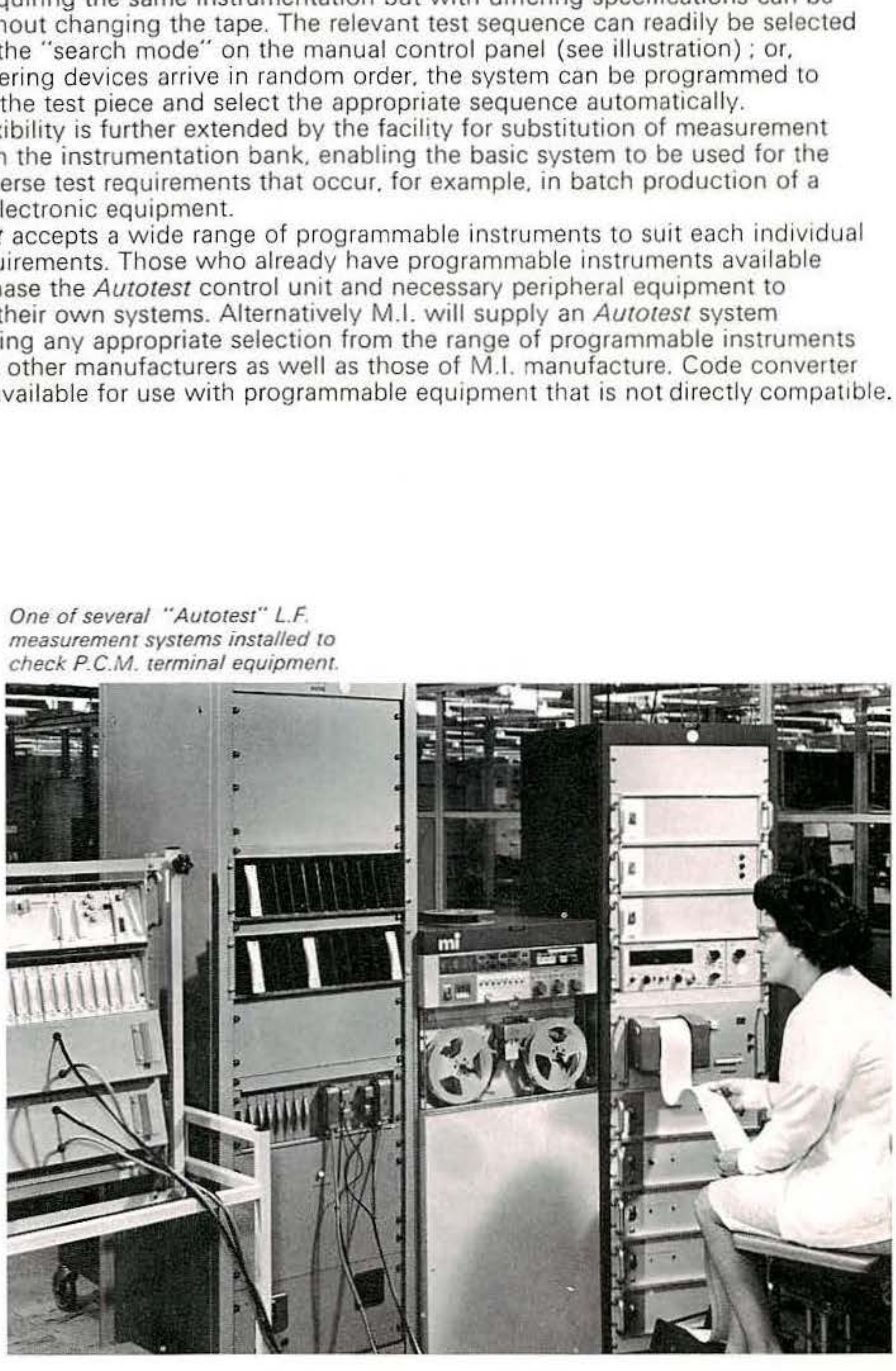
This flexibility is further extended by the facility for substitution of measurement modules in the instrumentation bank, enabling the basic system to be used for the widely diverse test requirements that occur, for example, in batch production of a range of electronic equipment.

Autotest accepts a wide range of programmable instruments to suit each individual user's requirements. Those who already have programmable instruments available may purchase the *Autotest* control unit and necessary peripheral equipment to complete their own systems. Alternatively M.I. will supply an *Autotest* system incorporating any appropriate selection from the range of programmable instruments offered by other manufacturers as well as those of M.I. manufacture. Code converter units are available for use with programmable equipment that is not directly compatible.

The "Autotest" response measuring system incorporating Siemens programmable instrumentation in use at the St. Albans factory of Marconi Instruments to check out filters from the large scale production of White Noise Test Sets.



One of several "Autotest" L.F. measurement systems installed to check P.C.M. terminal equipment.



Signal Generators and R.F. Attenuators

The term signal generator is sometimes used loosely to mean any instrument which delivers an a.c. output for test purposes. In this catalogue, however, the title is confined to those instruments that deliver a standard modulated signal of accurately known characteristics, and are primarily intended for measurements on radio receivers.

OUTPUT LEVEL AND SOURCE IMPEDANCE

For sensitivity measurements on receivers it is essential that the signal generator shall deliver an accurately calibrated r.f. output voltage from a source impedance equal to that of the aerial with which the receiver is to be used. (N.B. This is not normally equal to the true input impedance of the receiver.)

As this aspect of signal generator performance is sometimes controversial the following notes may be helpful.

OUTPUT VOLTAGE

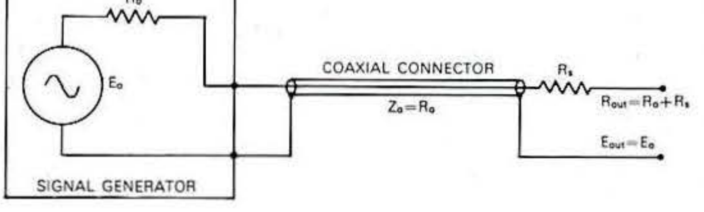
At frequencies up to about 1 GHz radio receivers are generally regarded as voltage sensitive devices, and their sensitivities are specified in appropriate terms. In Great Britain and Europe it is standard practice to state the sensitivity in terms of source e.m.f. available via the specified source impedance, the receiver input impedance, and hence the p.d. across it, usually being unknown. In some engineering circles, especially in the U.S.A., the sensitivity is stated in terms of the p.d. that would appear across a matched load; i.e., half the e.m.f. voltage. Although most authorities recommend the use of e.m.f.—as the more logical way of stating the voltage—it makes little difference which form is used providing the voltage statement is qualified by the appropriate initials; e.g., 100 µV e.m.f. or 50 µV p.d.

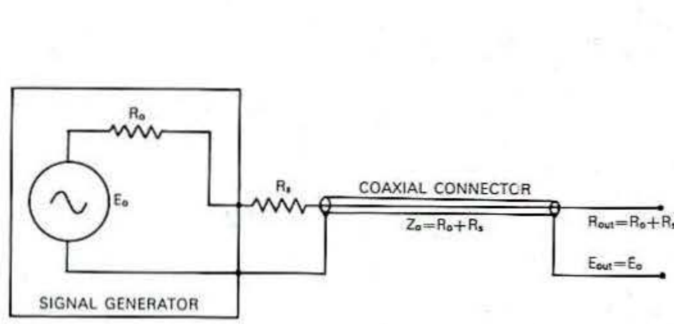
In the U.S.A. the terms "hard microvolts" for e.m.f. and "soft microvolts" for p.d. across a matched load are sometimes used.

Marconi Instruments signal generators are calibrated basically in terms of e.m.f., with provision for reading p.d. across a matched load directly from the attenuator if desired.

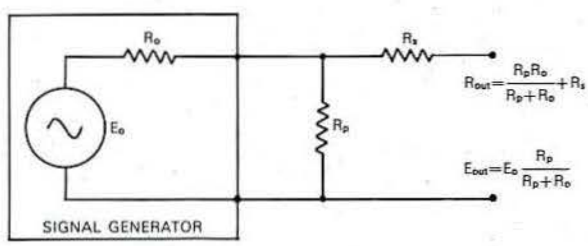
SOURCE IMPEDANCE

Marconi Instruments signal generators, used with standard accessories, offer the choice of 50Ω or 75Ω source impedance, with a 300Ω balanced output accessory available for most signal generators in the range. A standard dummy aerial is also available for use at frequencies below about 1·5 MHz. These source impedances cover most requirements, but other values are sometimes needed for special measurements. At frequencies up to several hundred megahertz, resistive impedance-conversion pads can be constructed using the following arrangements.





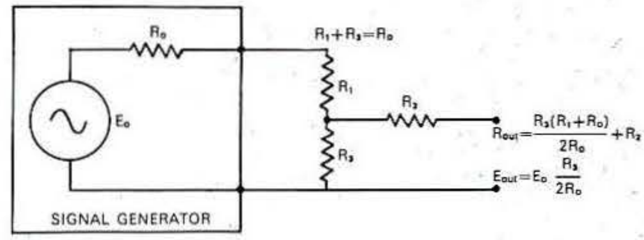
Increasing Effective Source Impedance This can be achieved by the addition of a single resistor, R_s, whose value is given by $R_s=R_{out}-R_o$, where R_{out} is the required source impedance and R_o is the source impedance of the signal generator. The additional resistor can be fitted at either end of the connecting cable, but, if it is at the sending end, the characteristic impedance of the cable must be equal to R_{out}.



Decreasing Effective Source Impedance The effective source resistance can be reduced by simply connecting a resistor, R_p, in parallel with the load, so that $R_{out}=R_pR_o/(R_p+R_o)$.

Unfortunately the output e.m.f., E_{out}, is then also reduced as $E_{out}=E_oR_p/(R_p+R_o)$. This can produce an inconvenient voltage conversion ratio, and it is usually more satisfactory to make up a two-element pad of the form shown above. Choosing a convenient value, N, for E_o/E_{out}, the resistor values are given by,

$$R_p=\frac{R_o}{N-1} \quad \text{and} \quad R_s=\frac{R_p\,R_o}{R_p+R_o}$$



Three-element Reduction Networks The two-element pad has the slight disadvantage that, unless N=2, the receiving end of the cable is mismatched regardless of the ultimate load impedance. Providing the source impedance, R_o, is accurately matched to the cable no voltage error is caused by this mismatch, but there may be other factors demanding correct termination at the receiving end; e.g., susceptibility to the effects of r.f. radiation fields. If the additional attenuation can be tolerated, such requirements can usually be satisfied by the use of the simple two-element network in conjunction with the 20 dB Attenuator Pad available as a standard accessory for the signal generator; but, for other cases, a three-element impedance conversion pad is useful.

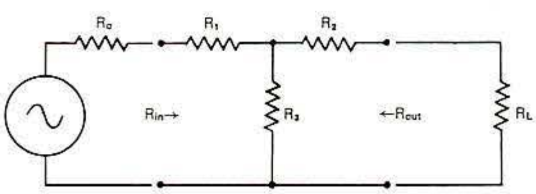
For applications where the ultimate load impedance is normally high compared with R_{out} there is some advantage in using a pad which terminates the cable correctly when the pad is unloaded. In this type of pad R_o, R_1, and R_3 form a simple potential divider, so that

$$R_3 = 2R_o/N$$

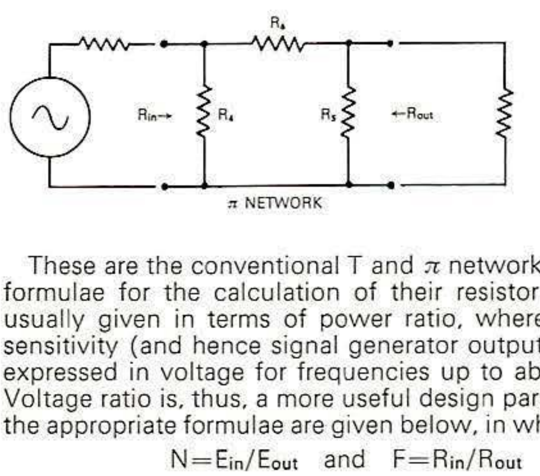
$$R_2 = R_o - R_3$$

$$R_2 = R_{out} - \left[R_3(R_1 + R_o)/2R_o\right]$$

The more usual requirement, however, is for an impedance-conversion attenuator of the form shown below, where $R_{in} = R_o$ when $R_1 = R_{out}$.



T NETWORK



π NETWORK

These are the conventional T and π networks. Standard formulae for the calculation of their resistor values are usually given in terms of power ratio, whereas receiver sensitivity (and hence signal generator output) is usually expressed in voltage for frequencies up to about 1 GHz. Voltage ratio is, thus, a more useful design parameter, and the appropriate formulae are given below, in which

$$N = E_{in}/E_{out} \quad \text{and} \quad F = R_{in}/R_{out}$$

T Networks

$$R_3 = R_{in} \cdot \frac{2N}{N^2 - F}$$

$$R_2 = \left[R_{out} \cdot \frac{N^2 + F}{N^2 - F}\right] - R_3$$

$$R_1 = \left[R_{in} \cdot \frac{N^2 + F}{N^2 - F}\right] - R_3$$

π Networks

$$\frac{1}{R_6} = \frac{1}{R_{out}} \cdot \frac{2N}{N^2 - F}$$

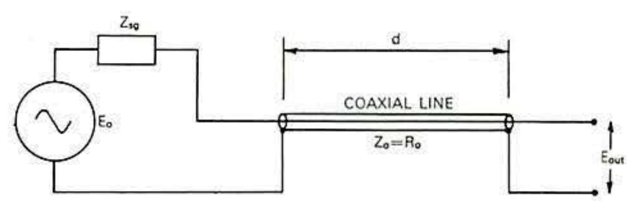
$$\frac{1}{R_5} = \left[\frac{1}{R_{out}} \cdot \frac{N^2 + F}{N^2 - F}\right] - \frac{1}{R_6}$$

$$\frac{1}{R_4} = \left[\frac{1}{R_{out}} \cdot \frac{N^2 + F}{N^2 - F}\right] - \frac{1}{R_6}$$

SOURCE IMPEDANCE ACCURACY

It has already been stated that, for quantitative measurements with a signal generator, it is essential that the output e.m.f. and the source impedance should be accurately known. The full significance of the need for accurate matching of the source impedance to the characteristic impedance of the output connecting cable stems from the fact that, when the cable is correctly terminated at the receiving end by R_o, the phase and magnitude of the voltage developed across R_o by the reflected power exactly matches the effect of the related standing wave. The e.m.f. and source impedance at the receiving end of the cable are, therefore, exactly equal to the e.m.f. and source impedance at the sending end regardless of the final terminating impedance. A complete explanation of this effect has been given by Flanagan, *Marconi Instrumentation*, vol. 4, p. 105, March, 1954.

The analogy can thus be made to the existence of an "image source" at the receiving end of the cable, which is identical to the real source. If the signal generator source impedance does not match the cable impedance, however, the image source will not be an exact facsimile of the real source, and there will be errors in the e.m.f. and source impedance of magnitude depending on the degree of mismatch and angular length of the cable.



REAL SOURCE + NETWORK

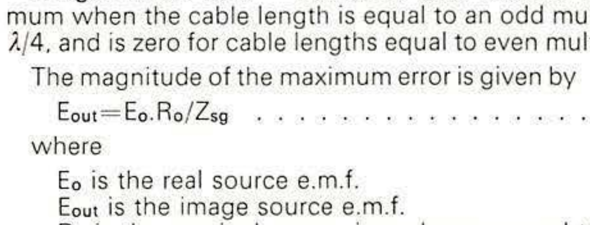


IMAGE SOURCE (LOADED)

Image E.M.F. Error The e.m.f. error reaches a maximum when the cable length is equal to an odd multiple of $\lambda/4$, and is zero for cable lengths equal to even multiples.

The magnitude of the maximum error is given by

$E_{out} = E_o . R_o/Z_{sg}$ . . . . (1)

where

E_o is the real source e.m.f.
E_{out} is the image source e.m.f.
R_o is the nominal source impedance—equal to the characteristic impedance of the cable.
Z_{sg} is the actual source impedance of the signal generator.

Image Source Impedance Error For cable lengths equal to odd multiples of $\lambda/4$, the image source impedance $Z_{out} = R_o^2/Z_{sg}$. . . . . (2)

For cable lengths equal to even multiples of $\lambda/4$, $Z_{out} = Z_{sg}$. . . . . (3)

For cable lengths equal to the intermediate multiples of $\lambda/8$, $Z_{out} = R_o$ . . . . (4)

V.S.W.R. It is now customary to state a signal generator's source impedance accuracy as voltage-standing-wave-ratio. This may be defined as the ratio between the voltages at the nodes and antinodes of the standing wave that would appear on a loss-free line, of characteristic impedance R_o, when terminated by the signal generator (i.e., with the signal generator's source impedance as the load).

The v.s.w.r. figure given bears no relationship to the standing wave pattern on the connecting cable when the signal generator is in use. This is entirely a function of the terminating impedance at the receiver end of the cable.

Interpreting the Accuracy Although nominally resistive, the signal generator's source impedance is inevitably complex, containing series and parallel reactive components of positive and negative sign, so that the actual impedance must vary with frequency. The v.s.w.r. figure given in Marconi Instruments specifications, therefore, represents the worst condition within the stated frequency range.

A simple statement of v.s.w.r. gives no indication of the phase angle of the source impedance, a statement of the angular displacement of the voltage node also being required in order to carry this information. As the phase angle is a function of frequency, however, its omission from the general performance statement is virtually unavoidable.

Nevertheless, the phase angle of the real source impedance is a relevant factor in assessing the image e.m.f. and image source impedance.

If $Z_{sg}=R_{sg}+jX_{sg}$, the impedance relationships for any given value of v.s.w.r. can be summarised as follows:

Let $S=$ v.s.w.r. (V_{max}/V_{min})

When $R_o/R_{sg}=1$ and $X_{sg}=0$, $S=R_o/Zsg$ . . . . . (5)

When $R_o/R_{sg}=1$ and $X_{sg}=0$, $S=Z_{sg}/R_o$ . . . . . (6)

When $(R_o^2+X_{sg}^2)^{\frac{1}{2}}=R_o$ so that $R_o/Z_{sg}=1$,
$(S^2-1)/2S=X_{sg}/R_{sg}$ or $\tan\delta$ . . . . . . (7)

Referring back to expression (1), it is apparent that, for any value of v.s.w.r., the e.m.f. error is greatest when Z_{sg} is purely resistive, and is zero when $Z_{sg}=R_o$.

Taking the worst case—if the connecting cable is equal to an odd number of quarter wavelengths and the signal generator's source impedance is purely resistive, the possible image e.m.f. error is given by

$E_{out}=E_o+E_o(S-1)$ or $E_o-E_o(1-1/S)$,

which, if the v.s.w.r. is close to unity, is very nearly equal to $E_o \pm E_o(S-1)$.

This magnitude of error is, however, never actually realised, because the v.s.w.r. figure quoted in the specification is invariably partly due to reactive components in the signal generator's source impedance.

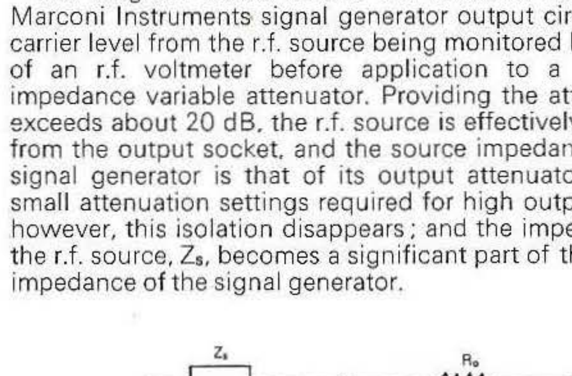
The limits of image source impedance error for both even and odd quarter wavelength cables are given by

$Z_{out}=R_o \pm R_o(S-1)$.

SOURCE IMPEDANCE AT HIGH OUTPUT VOLTAGE LEVELS

Restriction of the v.s.w.r. specification to output levels up to 20 dB below maximum output carries a generally accepted implication that this aspect of the signal generator's performance deteriorates over the highest voltage decade. But this is only true in certain circumstances; for, although the output impedance may appear to be seriously in error when measured by an r.f. bridge or the standing-wave-ratio method, the error in the test voltage is not necessarily significantly greater at maximum output than at the lower levels.

The diagram below shows the effective form of all Marconi Instruments signal generator output circuits, the carrier level from the r.f. source being monitored by means of an r.f. voltmeter before application to a constant impedance variable attenuator. Providing the attenuation exceeds about 20 dB, the r.f. source is effectively isolated from the output socket, and the source impedance of the signal generator is that of its output attenuator. At the small attenuation settings required for high output levels, however, this isolation disappears; and the impedance of the r.f. source, Z_s, becomes a significant part of the source impedance of the signal generator.



It is obvious that the passive impedance measured at the output terminal is likely to present a v.s.w.r. that is far from unity. But, when the signal generator is in use, the p.d. across Z_s is compensated for by adjustment of the carrier level control to produce the correct reference indication on the r.f. monitor; and it is the voltage across this monitor that should be regarded as E_o.

Therefore, providing the appropriate carrier level correction is made for any change in load impedance, the image source at the receiving end of the cable will retain the form giving $V_L=E_oZ_L/(R_o+Z_L)$ for all attenuator settings. Several of the signal generators in the Marconi Instruments range include an effective automatic level control system (a.l.c.), so that the correction is made automatically and the dynamic impedance of the internal r.f. source is very low indeed.

This effective source impedance is not, however, the impedance that the signal generator would present, while in operation, to an external source; e.g., a second signal generator used in two-signal tests on a receiver. It is therefore important, in such applications, to make due allowance for a possible mismatch, which would affect the voltage applied by the second generator—not the one giving near maximum output.

Swept-Frequency Signal Generators

The application of sweep-generator techniques to receiver alignment is now well accepted, but, for general measurements on receivers, it is an advantage if the sweep-generator also has the normal attributes of a standard signal generator; i.e., an output attenuator at the correct impedance, giving an accurately controlled amplitude down to the order of 1 μV, and full modulation facilities—a.m. or f.m.

Apart from television receivers, most receiver band-widths are within the deviation range of an f.m. signal generator. V.h.f. and u.h.f. signal generators are available which can be frequency modulated to deviations upwards of 100 kHz. For example, a Marconi TF 995B/2 Signal Generator can be modulated up to 200 kHz deviation at the standard broadcast i.f. of 10·7 MHz. This is equivalent to a total sweep width of 400 kHz, which is more than adequate for the 240 kHz bandwidth of an f.m. broadcast receiver—one of the widest bandwidths in common use.

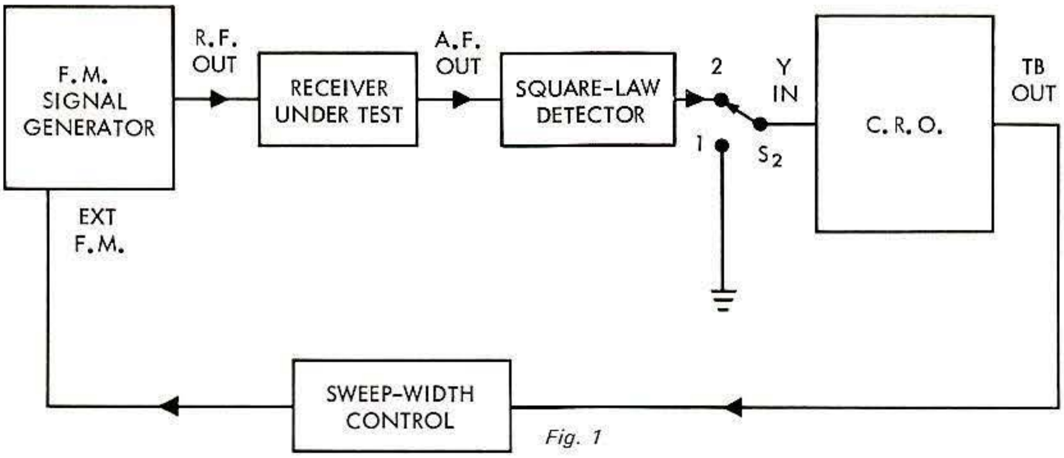


Fig. 1

Figure 1 shows the method of connecting a signal generator and oscilloscope to a receiver in order to display the i.f. or overall frequency/response characteristic. The diagram shows an external detector in use; this is necessary for f.m. receivers and may be convenient for a.m. receivers in which the internal detector is not readily accessible. With many a.m. receivers, however, it is possible to make direct connection to the internal detector so that an external one is unnecessary. But, if this is done, care must be taken to be sure that any time constants in the detector load do not modify the shape of the displayed curve. For example, if the receiver is fitted with a signal strength meter, the Y input to the oscilloscope can be connected in parallel with it. Although this makes connection very easy, such meters are usually by-passed by a fairly large capacitor, which must either be disconnected or allowed for by keeping the sweep speed so slow that the time constant of the capacitive detector-load does not modify the displayed characteristic.

This second course can only be taken if (1) the oscilloscope timebase operates at very low speeds—say 5 Hz; (2) the external modulation circuit of the signal generator will accept such low frequencies, and (3) the Y amplifier is d.c. coupled.

It is not usually possible to display frequency markers when a signal generator is used in this way; but, fortunately, Marconi Instruments f.m. signal generators are equipped with directly calibrated incremental frequency controls so that the width of the displayed characteristic can be measured by varying the tuning to bring relevant points on the curve to a central cursor line on the c.r.t. graticule.

F.M. signal generators do not normally operate at frequencies below about a megahertz; and, until recently, swept-frequency measurements on receivers in the m.f. and h.f. bands has been restricted to orthodox sweep-generators. The Marconi Instruments Signal Generator TF 2002AS, however, has f.m. and frequency sweep facilities at centre frequencies tunable from 100 kHz to 70 MHz. This instrument can be frequency swept from an external source with d.c. coupling to the voltage-controlled reactor, so that very low sweep speeds can be used if necessary.

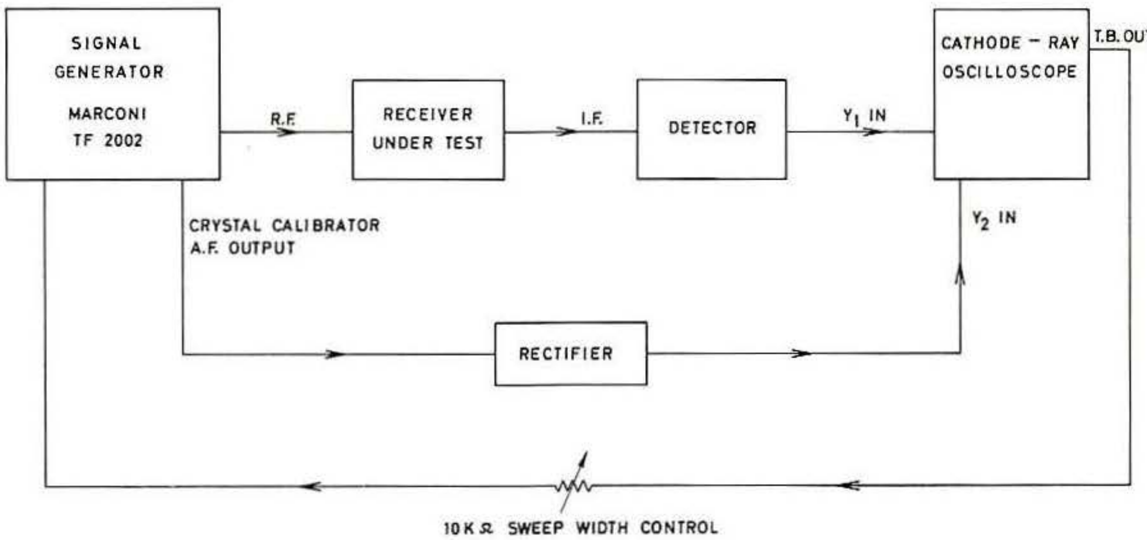


Fig. 2

The built-in crystal calibrator of the TF 2002AS gives calibration beats at 10 kHz intervals. When the signal is being frequency swept, the audio output from the crystal calibrator can be rectified and applied to the Y deflection or Z modulation terminal of the oscilloscope to provide frequency markers. At the comparatively narrow sweep widths used, however, these markers have a very definite double-pulse form with the zero point between the two pulses corresponding to the 10 kHz interval mark. Figure 2 shows the connections.

At these lower frequencies, receivers are used which have very narrow acceptance bands and crystal controlled ocal oscillators; e.g., single-sideband and independent-sideband receivers. When making protracted measurements on such receivers with a signal generator the problem of the generator's frequency stability can be quite serious. With a frequency swept signal generator this problem is greatly eased because, unlike the single-frequency signal which gradually drifts out of tune, the swept signal is continually traversing the acceptance band, and the only effect of a small amount of drift is a movement of the displayed characteristic curve across the oscilloscope trace. Thus the attributes of the frequency swept signal generator can offer advantages for purposes other than actual frequency/response measurement or circuit alignment.

F.M. Demodulator Response

A somewhat specialised case arises in the setting up of f.m. receivers.

Important as the shape of the frequency/response characteristic is in this type of receiver, the main application of the swept frequency measurement is probably for examination of the demodulation characteristic. For this particular application the dynamic display of the characteristic can be made using an oscilloscope and a frequency modulated signal generator of the type that would normally be used for general tests on the receiver. The method of connecting the test set-up is given in Figure 3.

In order to test the demodulation under realistic conditions the test voltage applied to it should be the full limiter voltage and it should also be derived from the correct source impedance. To obtain these conditions, it is convenient to use the i.f. amplifier of the receiver as the connecting network between the signal generator and the demodulator. So the output of the signal generator is fed into the input of the receiver's i.f. amplifier or into the aerial socket.

However, care must be taken that the displayed demodulation characteristic is not modified by frequency/response characteristic of the receiver's tuned amplifiers; and to do so the modulating frequency should be kept as low as conveniently possible, 50 Hz being quite satisfactory in normal circumstances. The bandwidth of the receiver must be sufficient to accommodate the multiple f.m. sidebands at much higher modulation frequencies, so all significant sidebands at 50 Hz spacing are easily handled.

It is necessary to modulate the signal generator from an external source; and, in this case, a sinewave source is more convenient than a sawtooth. With sinewave modulation the signal generator's modulation meter indicates the frequency deviation, which is, of course, half the sweep width. The horizontal deflection on the oscilloscope is obtained by also feeding the output of the modulating oscillator to the external time base terminal of the oscilloscope; and the total length of the trace then corresponds to twice the f.m. deviation as indicated on the modulation meter. With the comparatively restricted frequency sweep, errors due to non-linearity of the f.m. modulator are fairly small and the calibrated graticule of the oscilloscope can safely be used as a frequency scale.

The Y input of the oscilloscope is connected directly to the audio output terminal of the receiver's f.m. demodulator. The high input impedance of the oscilloscope is unlikely to affect the operation of the demodulator, so no special precautions are necessary from this point of view.

To adjust the demodulator, the signal generator is set accurately to the i.f. (or r.f.) centre frequency, and sufficient output is applied to operate the limiter of the receiver. The familiar "S" shaped demodulator response will then be displayed on the c.r.t. screen; and the demodulator trimming controls can be adjusted to bring it to the centre of the display. If the receiver contains a ratio detector, the normal precaution of replacing the bias capacitor with a suitable voltage source must be taken in the same way as for static methods of measurement.

The Derivative Curve

Providing the signal generator is suitable, it is possible to produce a very much more useful display by the use of two superimposed modulating frequencies.

For really comprehensive assessment of true linearity of the demodulator over the nominally linear part of its characteristic, the ideal display is that of the derivative of the demodulation curve; or, in other words, a display in which the instantaneous vertical position of the spot is proportional to the instantaneous slope of the demodulation curve. Such a display provides far better discrimination than the direct picture of the "S" shaped curve; for if the demodulator were perfectly linear, the display would take the form of a straight horizontal line, any deviation from this form representing non-linearity.

Figure 4 shows examples of direct and derivative curves for linear and non-linear demodulation. Note that the vertical locus of the derivative curve falls to zero at the turnover points of the direct curve where the slope is zero. The correct theoretical curve beyond these zero points is shown by the dotted lines in the diagram, but, for reasons that will become obvious, the displayed derivative curve takes the shape of the full line in the diagram. As only the part between the zero points is required, however, this does not matter very much.

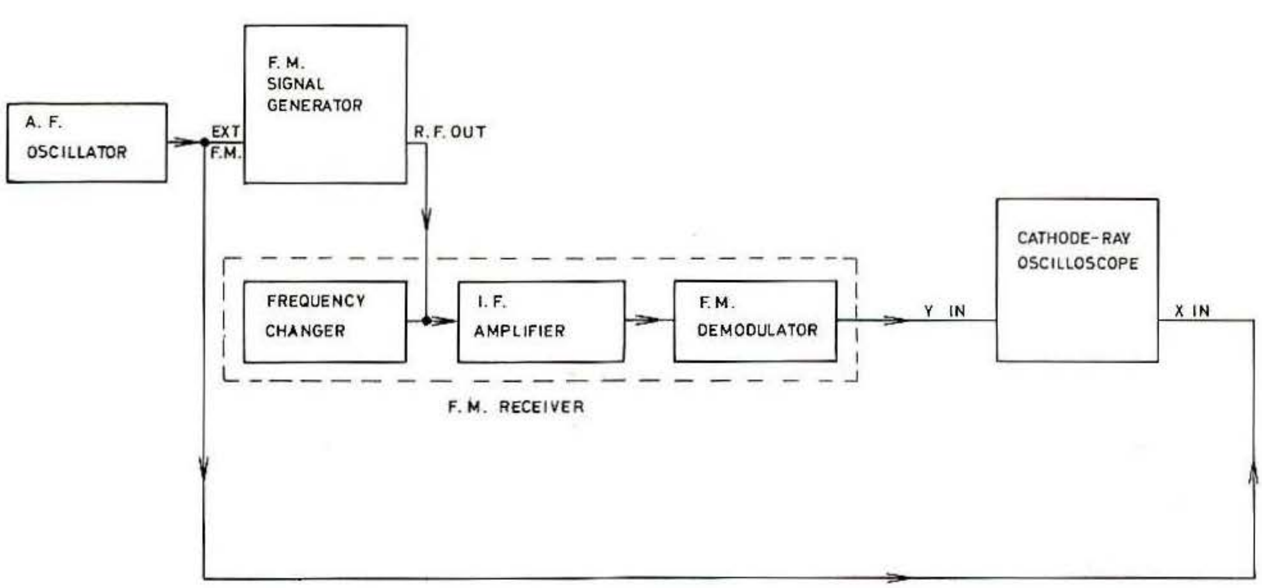


Fig. 3

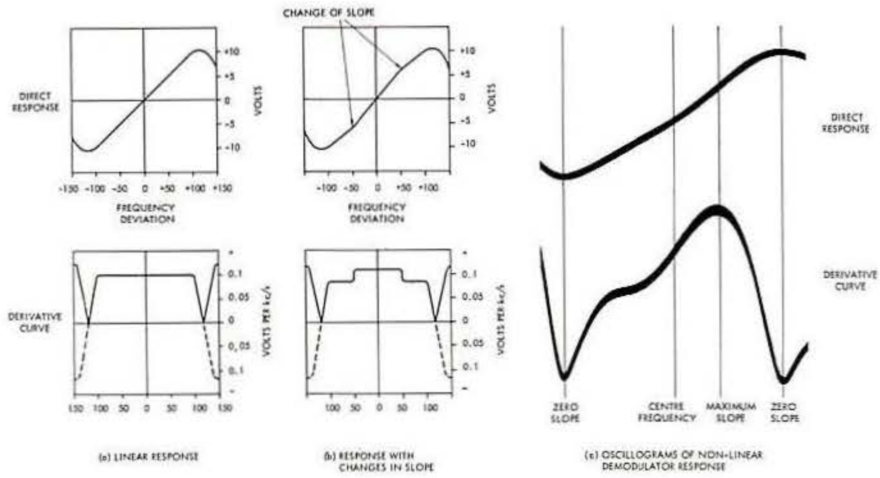


Fig. 4

The connections for obtaining this display are shown in Figure 5. A very slow sawtooth voltage (or very low frequency sinewave) is applied to the external modulation terminals of the signal generator and simultaneously to the X deflection system of the oscilloscope. In the diagram the internal timebase generator is used. This is the actual sweep voltage and its amplitude should be such as to give a frequency sweep which completely accommodates the demodulator characteristic. Its frequency should be below the l.f. response of the receiver's audio amplifier.

Superimposed upon this voltage, by means of transformer T_1, is an audio frequency voltage (say 1 kHz) of sufficient amplitude to give about 1% of maximum rated deviation.

The Y input terminal of the oscilloscope is connected via a rectifier to the a.f. output of the receiver, thus utilising both the gain and the l.f. cut of the audio amplifier. The 1 kHz output from the receiver at any instant is then directly proportional to the slope of the demodulation curve at the instantaneous input frequency, so that the spot traces out the derivative curve. Any non-linearity is easily detected by aligning the curve with one of the graticule lines on the oscilloscope. Furthermore, the relative magnitude of the non-linearity can be measured by comparing the amplitude of the departure from this line with the mean height of the display from the zero points.

Frequency calibration is best done by a slide back method against the signal generator's incremental frequency control.

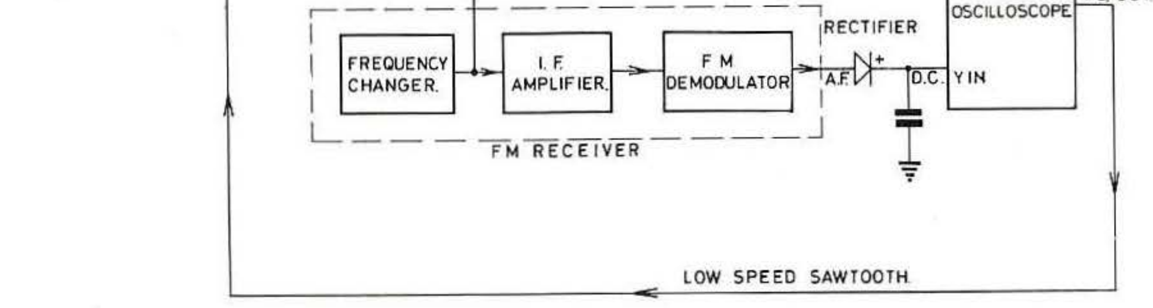
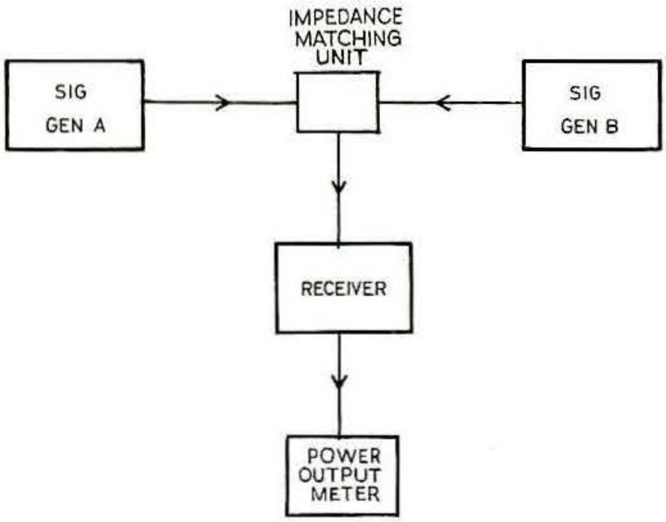


Fig. 5

Multi-Signal Receiver Selectivity Tests



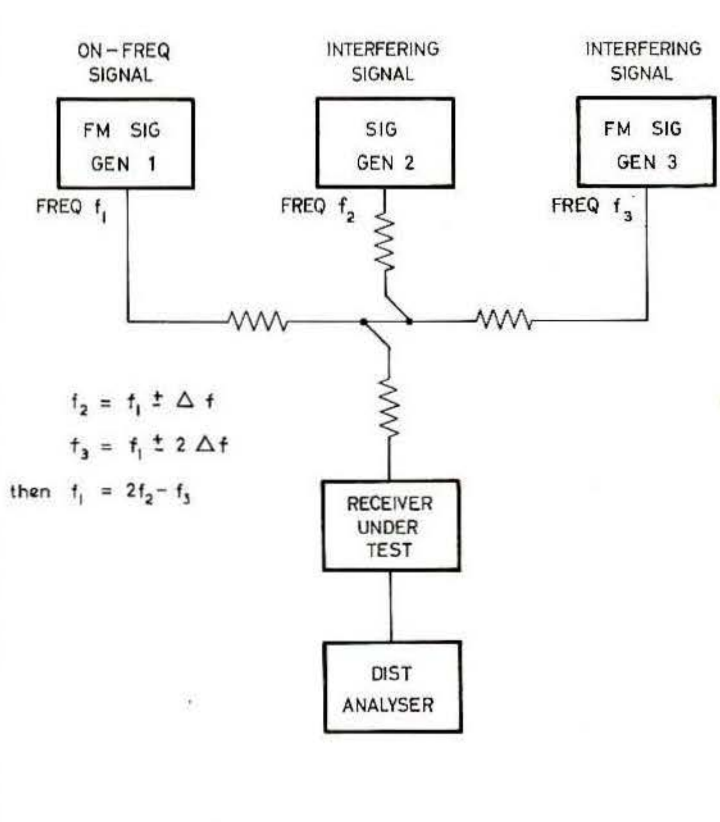
The TF 995B/5 (page 25) is particularly suitable for measurement of adjacent-channel-suppression or inter-modulation on fixed and mobile communications receivers.

Two-signal tests for assessing the receiver's response to unwanted adjacent-channel signals usually utilise the arrangement shown in the upper diagram. The output from signal generator A represents the wanted signal, and that from signal generator B the unwanted signal. The interfering signal is regarded as part of the noise, and the suppression is evaluated in terms of degradation of the signal-to-noise ratio.

For identification, and to avoid heterodyne beats, it is usual to modulate the two signals at different frequencies. Signal generator A is normally modulated at 400 Hz and signal generator B at 1 kHz, their a.m. depths or f.m. deviations being equal—usually 30% a.m. or 30% of maximum f.m. deviation.

With zero output from signal generator B, generator A is tuned to the receiver's centre frequency, and the r.f. level is adjusted to produce a signal-to-noise ratio of 20 dB (10 dB for mobile radio).

Signal generator B is then tuned to one channel spacing away from the centre frequency and its output is adjusted to produce a signal-to-noise+interference ratio which is 3 dB less than the ratio measured with signal generator A alone. The ratio between the input levels due to each of the signal generators, expressed in decibels, is the adjacent-channel suppression figure for the receiver. The suppression should be at least 70 dB.



The arrangement shown in the lower diagram is that recommended by the U.S. Electronic Industries Association for intermodulation measurement on f.m. communications receivers. With signal generators B and C delivering zero output, signal generator A is tuned to the receiver's centre frequency, and its r.f. output adjusted to produce 12 dB signal-to-noise ratio. Signal generator B is then tuned to one channel spacing above or below the centre frequency, and generator C to two channel spacings from the centre frequency in the same direction as B. The equivalent outputs of generators B and C are maintained equal, and the levels are increased until the signal-to-noise ratio is reduced to 6 dB.

The ratio of the level from B or C to that from generator A, expressed in decibels, is the measure of intermodulation. In the U.S.A. the recommended maximum is 50 dB, but in some European countries the standard is raised to 60 dB or 70 dB.

Signal Generators

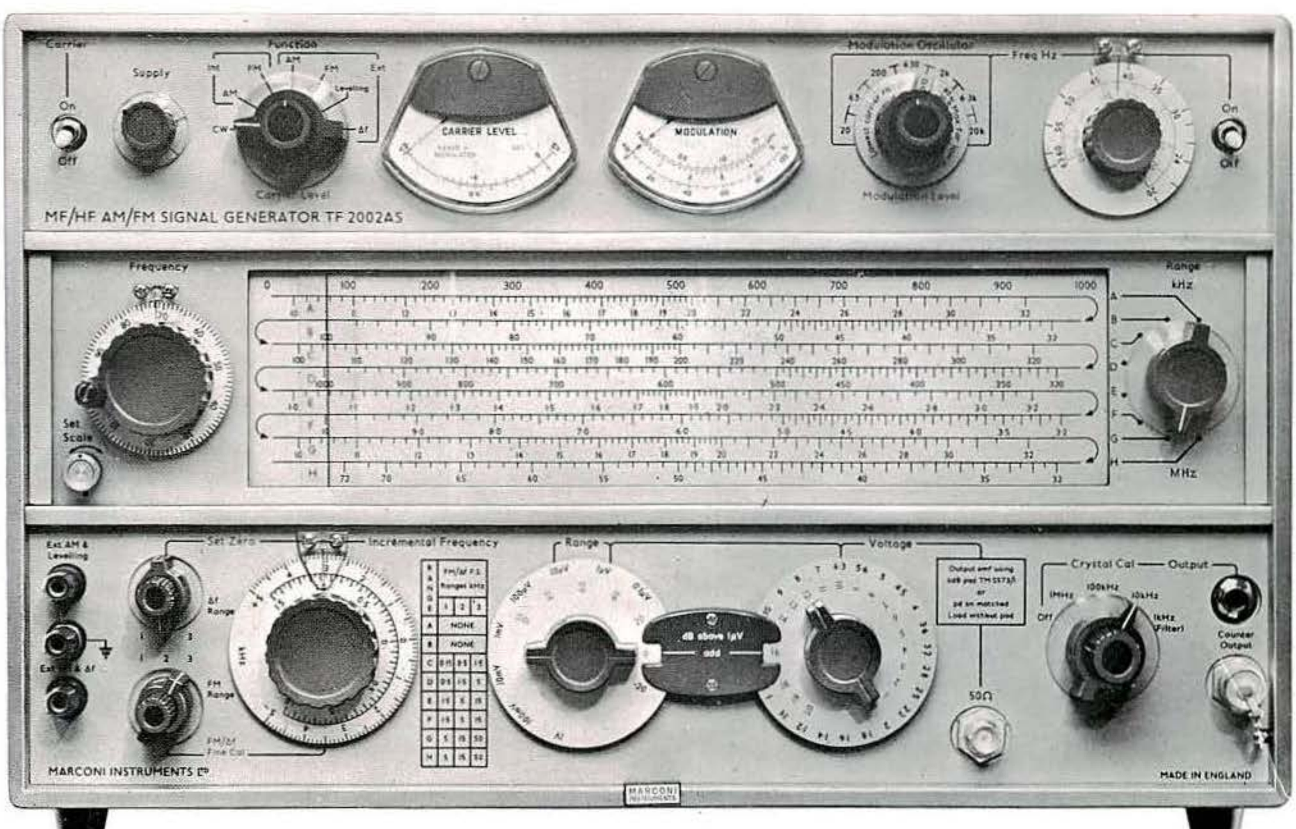
Listed in order of upper frequency limit

R.F. Attenuators

MF/HF AM/FM Signal Generator

- ☐ Frequency range: 10 kHz to 72 MHz
- ☐ High discrimination electrical fine tuning calibrated against comprehensive crystal calibrator
- ☐ Amplitude and frequency modulation
- ☐ Internal modulating frequency continuously variable from 20 Hz to 20 kHz
- ☐ External control of carrier level
- ☐ External frequency sweep or fine frequency control

The TF 2002AS is almost certainly the most advanced signal generator of its type at present available. The use of solid-state active circuit elements has enabled the designers to utilise completely new mechanical and electrical arrangements far removed from what is regarded as conventional signal generator design practice. By doing so, they have produced a signal generator which not only performs all the normal functions with more than normal efficacy, but also has a number of unusual facilities that considerably extend its usefulness.



CARRIER FREQUENCY

The full 10 kHz to 72 MHz frequency range of the signal generator is covered in eight switch-selected bands, each band having a maximum-to-minimum frequency ratio of approximately 3·16 : 1 up to 32 MHz. On the highest frequency band, however, the ratio is reduced to approximately 2 : 1 giving a rather more open scale.

Main Tuning The main tuning dial has eight hand-calibrated near logarithmic tuning scales—one for each band. These are arranged in a continuous zig-zag, with scales running alternately left and right, so that the main frequency control is rotated clockwise for range A, counter clockwise for range B, clockwise for range C and so on. This feature cuts out much of the tedium which can occur when tuning a signal generator close to the band change frequency.

The signal generator is tuned over the full cover of each band by ten turns of the main frequency control, which also carries a subsidiary dial with a linear logging scale numbered 0 to 100. Corresponding numerals engraved at the top of the main tuning dial show the rotational position of the control. Provision is also made for adjusting the mechanical position of the main tuning dial to correct the calibration, if necessary, when the frequency is set accurately against the internal crystal calibrator.

Crystal Calibrator The internal crystal calibrator provides check points at intervals of 1 MHz, 100 kHz, and 10 kHz. The heterodyne beat note is audible from a loudspeaker mounted within the instrument; but, if desired, a pair of head telephones may be used via the output jack socket mounted on the front panel.

It is also possible to switch into circuit a 1 kHz band stop filter which gives the effect of a second null when the carrier frequency is 1 kHz away from the 10 kHz check point.

Incremental Frequency The incremental frequency control facilitates high discrimination setting of frequencies above 100 kHz. Below this frequency the discrimination of the main tuning dial is such that incremental control is hardly necessary.

The incremental control is directly calibrated in three ranges, selected by means of a $\triangle$f Range switch, the total cover being dependent on the main frequency range in use as shown in a table on the panel beside the control. Provision is also made for setting up the scale length against the internal crystal calibrator, giving increased accuracy for bandwidth or similar measurements.

External Frequency Shift Incremental frequency shift can also be applied to the carrier by means of a control voltage fed to an appropriate terminal on the front panel. The frequency shift produced is directly proportional to the d.c. level of this voltage, ± 1 volt d.c. producing a shift equal to at least the limits shown in the table located beside the incremental frequency control. The facility can be used for manual or automatic frequency control—e.g., by the use of a phase discriminator the signal generator frequency could be locked to a standard frequency.

It can also be used for frequency sweep, a particular application being the display of the frequency response characteristic of a tuned amplifier or receiver on a cathode-ray oscilloscope. The sawtooth voltage of the oscilloscope's time base is applied to the frequency shift terminal of the TF 2002AS; the r.f. output from the signal generator is fed to the receiver or the amplifier in the normal way; and the output from the unit under test is applied via a suitable detector to the Y input of the oscilloscope.

R.F. OUTPUT

For carrier frequencies up to 32 MHz a maximum r.f. output of 2 volts e.m.f. can be obtained with 100% modulation. On the highest frequency range—32 to 72 MHz—a maximum of 2 volts unmodulated is obtainable but it is necessary to reduce the maximum carrier level to 1 volt e.m.f. if heavy modulation is applied. The output can be adjusted by means of two attenuators in cascade, one of which covers 120 dB in 20 dB steps and the other 20 dB in 1 dB steps, giving a total variation of 140 dB.

Calibrated output levels down to 0·2 μV are, therefore available. The attenuators are calibrated in both voltage and decibels.

The output impedance of the signal generator is 50Ω, and it is normally intended that the instrument should be used with the 6 dB pad—standard accessory—connected at the end of the output cable. The attenuator voltage calibration is then directly in e.m.f.; but if it is more convenient to have the attenuator calibration in terms of p.d. across a 50Ω load, this can be obtained by disconnecting the 6 dB pad and feeding the signal generator output directly to the receiver under test.

Carrier Level Monitor The carrier level monitor is calibrated in voltage from 0·5 to 1. The instrument is normally used with the meter set to 1 volt but, for small changes in r.f. output voltages, it is sometimes more convenient to use the carrier-level control than the attenuator controls, the final output voltage being given by the product of the meter reading and the attenuator setting. It is a feature of the TF 2002AS that the carrier level can be varied over the range of the monitor without affecting the modulation depth or the carrier frequency.

The converse also applies; for the signal generator is equipped with a very effective automatic level control system, which enables the operator to vary the frequency, change the frequency range, or adjust the modulation depth without affecting the carrier level.

Counter Output It is sometimes desirable to monitor the frequency of a signal generator by means of an electronic counter. But very few counters will operate correctly when the applied signal carries deep modulation; so the TF 2002AS is fitted with a separate "counter output" socket so that the carrier is available from a point in the circuit prior to the modulator. This point is, however, subsequent to a buffer amplifier so that connection of the counter does not affect the carrier frequency.

Radiation Many modern receivers are fitted with highly sensitive internal ferrite-rod aerials. For tests on such receivers it is, of course, extremely important that the signal generator shall be free from stray leakage field. To this end, the TF 2002AS employs no less than six screening layers plus the outer case to give a stray radiation figure some 40 dB better than most other signal generators operating in the same frequency range.

MODULATION

The TF 2002AS can be amplitude or frequency modulated internally or externally. Internal a.m. can also be applied simultaneously with external frequency shift, so that dynamic bandwidth measurements can be made using a modulated signal.

Modulating Oscillator The signal generator contains an internal modulating oscillator which is continuously variable over the frequency range 20 Hz to 20 kHz. This a.f. range is covered in six sub-ranges, each having a maximum to minimum frequency ratio of approximately 3·16 :1.

The output from the modulating oscillator is available for external use from a terminal at the rear, the level remaining constant at about 1 volt irrespective of modulation frequency or depth.

Amplitude Modulation A.M., continuously variable up to 100%, can be applied from the internal oscillator or from an external source over the frequency range 20 Hz to 20 kHz. At the lower carrier frequencies, however, it is obviously not possible to obtain deep modulation with high modulation frequencies. For guidance of the operator the range switch of the internal modulating oscillator carries markings indicating the lowest carrier frequency for which each a.f. range can be used. These markings also serve to show the approximate limitations when external modulation is used.

External Levelling When the FUNCTION switch is in the LEVELLING position the external a.m. terminal is connected directly to the modulation/level control system. This provides the facility for adjusting the carrier level by application of an external d.c. voltage. With the instrument in this operating condition a d.c. voltage of ±6 volts produces ±100% variation in carrier level. This control voltage is, however, relative to a −6·75 volt standing potential, which is present at the terminal when no input is connected. For use with fully floating d.c. sources a −6·75 volt reference is available from a terminal at the rear of the instrument.

Frequency Modulation At carrier frequencies exceeding 1 MHz the signal generator can be frequency modulated from the internal oscillator or an external source over the a.f. range 20 Hz to 20 kHz. Between 100 kHz and 1 MHz the maximum modulating frequency is reduced to 4 kHz.

Deviation is continuously variable in three ranges, the maximum for each being equal to the maximum incremental shift as shown in the table on the signal generator's front panel.

Modulation Monitor The a.m. depth or f.m. deviation is monitored by a panel meter, which is directly calibrated in per-cent a.m. depth and kHz f.m. deviation. When used as an f.m. monitor the sensitivity may be standardised by means of a trimmer control, with the built-in crystal calibrator as an ultimate reference.

POWER SUPPLY

The signal generator is normally intended for operation from an a.c. mains supply and is suitable for use from supplies in both the 110 volt range and 230 volt range. As it can be operated at frequencies up to 500 Hz it is very suitable for operation in aircraft or similar situations. The instrument can also be operated from external batteries, the required input voltage being from 19 to 32 volts, and the current consumption is 400 mA.

CARRIER FREQUENCY

Range
Eight bands, with scales graduated in frequency:
A: 10 kHz to 32 kHz
B: 32 kHz to 100 kHz
C: 100 kHz to 320 kHz
D: 320 kHz to 1,000 kHz
E: 1 MHz to 3·2 MHz
F: 3·2 MHz to 10 MHz
G: 10 MHz to 32 MHz
H: 32 MHz to 72 MHz

Scale accuracy
Scale position is adjustable against internal crystal calibrator. Using the index position the accuracy is ±1%.

Mechanical tuning discrimination
The frequency scales are near-logarithmic. A linear logging scale, with effectively 1,000 divisions, is provided.

Stability
At constant ambient temperature between 10° and 35°C, the frequency drift in the 15 minute period commencing 3 hours after switch-on is typically less than 30 p.p.m. +3 Hz and will not exceed 90 p.p.m. +3 Hz.
During the period 10 minutes to 3 hours after switch-on, the frequency drift will not exceed three times the amounts stated above.
Following a 10°C ambient temperature change (within the range 10° to 35°C) occurring after the above period of operation, the maximum frequency drift rate during the next 3 hours is typically 200 p.p.m. per 15 minutes.
The frequency variation produced by a 10% change in supply voltage is less than 20 p.p.m. +5 Hz.

Fine tuning
Operative above 100 kHz only.
Each carrier frequency band is provided with three ranges of electrical fine tuning as shown below:

Frequency	Band	△f Range in kHz 1	2	3	Fine Cal Points	△f Range
100–320 kHz	C	±0·15	±0·5	±1·5	±1·0 kHz	3
320–1000 kHz	D	±0·5	±1·5	±5·0	±1·0 ,,	2
1–3·2 MHz	E	±1·5	±5·0	±15	±10 ,,	3
3·2–10 MHz	F	±1·5	±5·0	±15	±10 ,,	3
10–32 MHz	G	±5·0	±15	±50	±50 ,,	3
32–72 MHz	H	±5·0	±15	±50	±50 ,,	3

Incremental frequency accuracy:
15% when not standardised.
The accuracy can be improved to 5% of full scale, on the +△f or −△f ranges, by use of the Fine Cal points shown in the table above.

Discrimination: better than 0·005% of carrier frequency.

External frequency shift
Incremental tuning is obtained from external d.c. sources, with the same ranges as the internal system. Further applications of this facility are covered under frequency modulation.

Crystal calibrator
Check points at 1 MHz, 100 kHz and 10 kHz intervals.
Crystal accuracy: $\pm 1 \times 10^{-4}$ over range 10°C to 35°C.
Additional check points at ±1 kHz on crystal points. *Accuracy:* ±10 Hz.

R.F OUTPUT

Level
Between 10 kHz and 32 MHz (c.w. or modulated up to 100%) 0·1μV to 1 volt e.m.f. using 6 dB pad or 0·1μV to 1 volt p.d. across a matched load.
Between 32 MHz and 72 MHz: as above for c.w.; maximum output half the above with 100% modulation. If working into an open circuit without a 6 dB pad, 2 volts e.m.f. is available using up to 30% modulation up to 32 MHz, or using c.w. above 32 MHz.

Attenuators
Seven position coarse attenuator with 20 dB steps. Marked −20 dB to +100 dB with respect to 1μV.
Twenty-one position fine attenuator, with 1 dB steps. Marked 0 dB to +20 dB.
Both marked with equivalent voltage at each setting.
External Attenuator Pad, TM 5573/1 provides 6 dB.

Carrier meter
Scale graduated in voltage.
Voltage Range: 0·5 volts to 1 volt, with graduations of 0·1 volts.

Total output accuracy
(Above 1μV with or without 6 dB pad, with meter at appropriate reference mark.)
Below 32 MHz: ±1 dB from 10°C to 35°C.
Above 32 MHz: ±2 dB of which approximately ±1 dB is caused by temperature effects over the range 10°C to 35°C.
Automatic level control maintains carrier level meter setting constant within 0·5 dB at all carrier frequencies.

Impedance
Effectively 50Ω at all level settings. BNC connector.
V.S.W.R.: Better than 1·15: 1 for outputs below 200 mV, with or without 6 dB Attenuator Pad, TM 5573/1.

Counter output
Not less than 10 mV into 50Ω.

AMPLITUDE MODULATION

Depth
Continuously variable up to 100%.

Monitor
Reads equivalent average modulation, and is not dependent on carrier level reference.

Accuracy (0 to 80%)
±5% modulation to 10 kHz and 10% modulation to 20 kHz at 23°C subject to mod. frequency limits at the lower carrier frequencies. An additional error of ±3% may occur at 10° and 35°C.

Internal modulation oscillator
Covers 20 Hz to 20 kHz in six ranges.
Frequency Accuracy: ±10%.

External A.C. modulation
Frequency range 20 Hz to 20 kHz subject to depth accuracy and distortion limits.
Requirements: Approximately 1·5 volts into 1 kΩ for 100% mod. depth.

Sync output
At fixed level from terminal, giving approximately 1 volt from 10 kΩ with 1·5% distortion factor, derived from internal modulation oscillator.

Envelope distortion
Less than 2% distortion factor using internal oscillator at a modulation frequency of 400 Hz for modulation depths up to 80% at carrier frequencies between 100 kHz and 32 MHz.

External levelling
Carrier level may be varied by d.c. A potential of −6·75 volts appears on the terminal when switched to this function.
Input: Approximately ±6 volts d.c. (into 15 kΩ) or 12 volts p-p about the −6·75 mean, gives full control of carrier.

FREQUENCY MODULATION

Deviation
Continuously variable with three ranges to maximum peak deviations as shown in the table under electrical fine tuning.

Modulation frequency range
20 Hz to 4 kHz at carrier frequencies between 100 kHz and 1 MHz.
With carriers above 1 MHz the modulation frequency range is extended to 20 kHz with a flatness of ±2·0 dB.

Monitor accuracy
15% without standardisation.
Above 1 MHz. ±6% of full scale when the Δf system has been standardised at the points shown under electrical fine tuning with modulation frequencies between 20 Hz and 4 kHz. An additional error of ±3% f.s.d. may occur at 10° and 35°C.

Distortion
Less than 3% at maximum deviation with modulation frequencies from 20 Hz to 4 kHz.

Internal oscillator
As for amplitude modulation.

External f.m.
20 Hz to 20 kHz, accuracy of deviation and frequency limitations as for internal modulation.
Input: Approximately 1·5 volts r.m.s. into 2·5 kΩ for maximum deviation given under electrical fine tuning. (Deviation adjustable at panel.)

External frequency shift
Carrier frequency may be varied by d.c. A potential of −6·75 volts appears on the terminal when switched to this function.
Input: Up to ±1 volt d.c. (into 100 kΩ) or 2 volts p-p about the −6·75 volts mean is needed for maximum deviations given in table under electrical fine tuning.

SPURIOUS SIGNALS

Leakage radiation
Allows measurements on sensitive receivers with ferrite aerials to be made close to the signal generator.

Carrier harmonics
Individual harmonics are less than 3% at full output.

Spurious A.M. on C.W.
Below −65 dB relative to 30% mod. depth in a 3 dB bandwidth of 650 Hz at frequencies below 100 kHz, and in 20 kHz above 100 kHz.

Spurious F.M. on C.W.
Less than 5 Hz +1 p.p.m., using mains operation.

Spurious F.M. on A.M
For 30% a.m. up to 1 kHz mod. frequency.
Below 32 MHz: Less than 100 Hz + 10 p.p.m.
Above 32 MHz: Less than 50 p.p.m.

POWER REQUIREMENTS

A.C. mains
95 volts to 130 volts, 190 volts to 264 volts, 45 Hz to 500 Hz; 15 VA.

External D.C.
19 volts to 32 volts: earthed positive; load 0·3 amps max.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
11 in	18 in	14 in	59 lb
28 cm	47 cm	36 cm	27 kg

ACCESSORIES

Supplied

TM 4969/3
Output Lead
50Ω coaxial cable 6 feet long fitted with BNC connectors.

TM 5573/1
6 dB Attenuator Pad
With pad in use, the TF 2002AS is direct reading in output e.m.f.

Trimming tool
To fit cores of r.f. trimming inductors. (Fits into clips inside the instrument.)

Hexagonal wrench
For removing r.f. box cover. (Fits into clips inside the instrument.)

Optional

TM 5573
20 dB Attenuator Pad.

TM 4726/152
Output Lead
An alternative lead fitted with a Belling-Lee type L778FP small Screenector at the output end.

TM 5569
Matching Pad
Converts from 50Ω to 75Ω impedance, with Belling-Lee type L734/P output plug.

TM 6599
Matching Pad
Converts from 50Ω to 75Ω impedance, with Burndept type PR4E output plug.

TM 5955/5
Matching Transformer
Converts from 50Ω unbalanced to 300Ω balanced.

TM 6123
Dummy Aerial and D.C. Isolating Unit
Provides "dummy" aerial output and also output via d.c. stopper capacitor suitable for d.c. voltages up to 300 volts.

TM 8269
Rack Mounting Kit
Converts bench model, TF 2002AS, for mounting in a standard 19 in. rack.

A.M. Signal Generator

- Frequency range: 10 kHz to 72 MHz
- Stability: 0·002%
- High discrimination, plus crystal calibrator
- Good r.f. waveform at all frequencies
- Protected thermocouple level monitor

TF 144H/4

This signal generator has all the desirable attributes that have been such important factors in the traditional popularity of its famous predecessors of the TF 144 series, but it is smaller and lighter, and with many features that greatly improve its utility value.

Tuning System

The tuning system is simple and of conventional form familiar to most users. Much attention, however, has been given to such aspects as operator convenience and clarity of indication.

The frequency range is divided into twelve switch-selected bands, each having a frequency cover of rather more than 2:1. Thus, a large effective scale length is obtained on the main tuning dial, which carries a separate scale for each band. The reading discrimination on this dial is such that a 2% frequency change on any band occupies more than a quarter of an inch of scale length. It is also significant that the medium-wave broadcast band coincides with a single tuning band of the signal generator.

An 8:1 reduction drive from the main tuning control permits easy and precise adjustment. The control knob also carries a dial calibrated with a linear logging scale of 100 divisions over the total circumference. As the variable tuning system follows a straight-line-frequency law on most bands, the logging scale provides the means of accurate interpolation between the direct calibration marks on the main tuning dial. Excellent discrimination is obtained by the use of this dial, four divisions correspond to a frequency change of about 1%.

For greater convenience the instrument is also fitted with an electrically coupled incremental frequency control calibrated directly in % frequency change. This control covers ±0·5 and has a travel of 315°. With it frequency changes of 0·01% can easily be discriminated.

Full use of this discrimination is possible, for the instrument has exceptionally good frequency stability. The use of fully regulated d.c., l.t. and h.t. supplies is an important factor in attaining this stability and in the reduction of spurious hum modulation.

To enable a high order of absolute accuracy to be obtained, the signal generator has a built-in crystal calibrator with two crystal frequencies, 400 kHz and 2 MHz, automatically selected by the band-change switch. A double mixer system is used to provide check points over the entire carrier frequency range. The crystal-calibrator circuit includes an a.g.c. system so that the audio volume of the heterodyne beat note does not vary widely over the tuning range of the signal generator.

Output Level

The output level is variable over the range 2 µV to 2 volts by means of coarse and fine resistive step attenuators calibrated in voltage and decibels. The carrier level control, used in conjunction with ±0·5 dB calibration marks on the level meter, allows continuous interpolation between the 1-dB steps of the fine attenuator. A plug-on 20 dB pad is supplied to extend the output range down to 0·2 µV.

The output impedance is 50Ω with a v.s.w.r. better than 1·25:1. Matching to higher impedance loads merely requires the use of a single series resistor. A matching pad for 75Ω output impedance and a composite dummy aerial and d.c. isolating unit are available as accessories.

The level of the signal applied to the attenuators is monitored by a thermocouple voltmeter. This gives a high order of absolute accuracy regardless of frequency. But the common disadvantage of the thermocouple – fragility – has been overcome in this instance by special circuit design. The circuit is so arranged that the thermocouple cannot be damaged by any form of misuse of the instrument. Automatic level control applied to the r.f. oscillator contributes to the thermocouple protection and largely eliminates the need for level-correction adjustment as the frequency is changed.

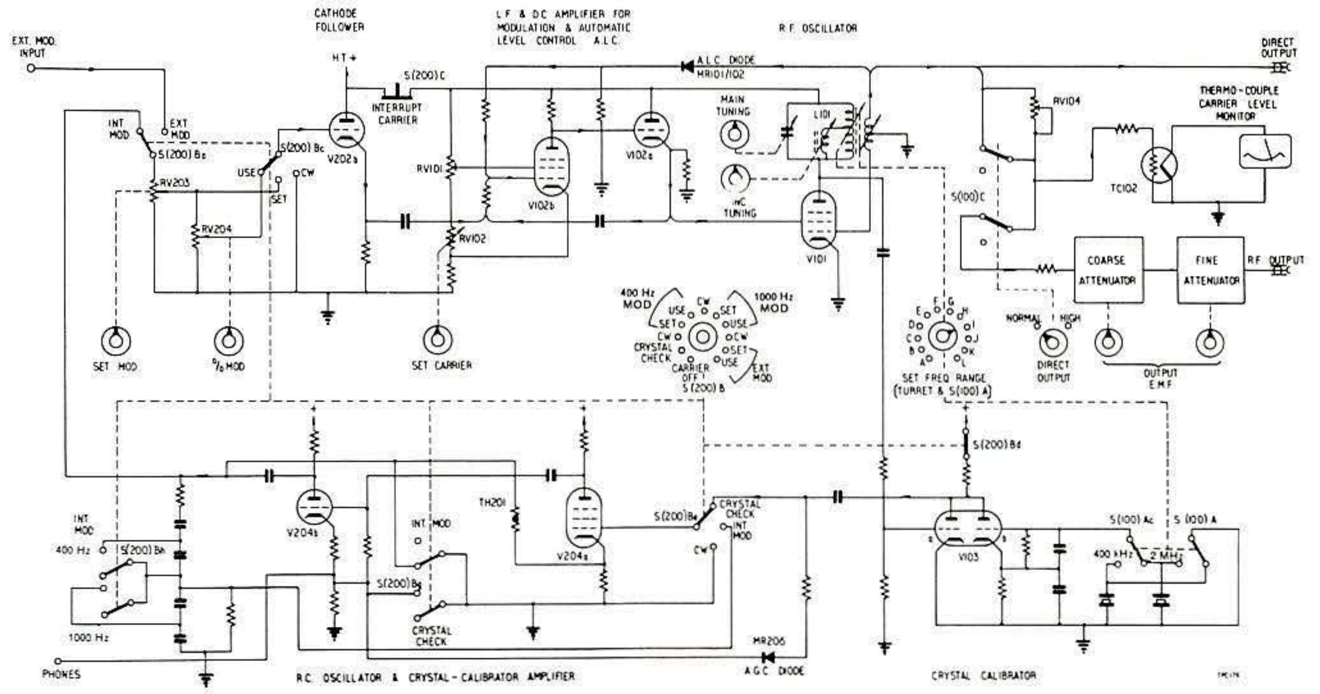
The maximum output is also available from a separate socket. The voltage from this outlet is not variable by the attenuators but is monitored by the carrier-level meter. For special tests where a level of 100 mW in 75Ω is required, the TF 144H/4 incorporates a NORMAL/HIGH switch, giving a choice of 2 volts or 2·75 volts at the direct output socket.

Modulation

Amplitude modulation can be applied to the carrier from an internal or external source, at depths up to 80% over most of the frequency range. It is monitored by means of the thermocouple meter in conjunction with a calibrated potentiometer.

TF 144H Series

Functional Diagram of TF 144H/4



CARRIER FREQUENCY

Ranges Twelve bands; scale marked directly in frequency:

A	10 to 20 kHz	G	1 to 2 MHz
B	20 to 40 kHz	H	2 to 4 MHz
C	40 to 80 kHz	I	4 to 8 MHz
D	80 to 200 kHz	J	8 to 16 MHz
E	200 to 535 kHz	K	16 to 32 MHz
F	535 to 1,600 kHz	L	32 to 72 MHz

Scale Accuracy: $\pm 1\%$.

Stability Drift $< \pm 2\times10^{-5}$/ten minutes.

Fine Tuning *Range:* $\pm$ 0·5%; scaled in percentage frequency change.
Discrimination: 1 division = 0·01%.
Accuracy: $\pm 10\%$ of reading, bands D to J.
$\pm 15\%$ of reading, bands K to L.

Crystal Calibrator *Frequency:* 400 kHz, or 2 MHz, according to band.
Accuracy: $\pm 5\times10^{-5}$.

OUTPUT

Voltage Range *Direct:* NORMAL: 2 volts.
HIGH: 2·75 volts.
Attenuated: 2 μV to 2 Volts, e.m.f. (0·2 μV to 200 mV, e.m.f., using TM 5573).

Meter Accuracy $\pm$0·5 dB.

Attenuator Accuracy $\pm$0·7 dB between 10 kHz and 30 MHz.
$\pm$1·0 dB between 30 and 72 MHz.

Impedance 50 Ω type BNC connector, *v.s.w.r.* better than 1·25 : 1.

MODULATION

Internal Modulation Frequencies 400 Hz and 1 kHz
External Modulation Frequencies 20 Hz to 20 kHz
Depth 0 to 80%
(Subject to limitations shown in table below)
Accuracy: $\pm$5% mod. depth. (r.m.s. mod.).

Carrier Frequency	Maximum Modulation Frequency at various modulation depths		
	0-30%	50%	80%
10 kHz	1 kHz	400 Hz	200 Hz
100 kHz	5 kHz	2 kHz	1 kHz
1 MHz	20 kHz	14 kHz	8 kHz
10 MHz	20 kHz	17 kHz	15 kHz
72 MHz	20 kHz	20 kHz	20 kHz

SPURIOUS SIGNALS

Leakage Radiation Negligible.

R.F. Harmonics Less than 2% distortion factor.

A.M. on C.W. Less than 0·1% modulation depth

F.M. on C.W. Deviation $< \pm1\times10^{-6}$

F.M. on A.M. Deviation $< \pm1\times10^{-4}$ or 100 Hz, whichever is the greater, at 30% mod. depth, on carriers less than 30 MHz.

Noise on A.M. Below —50 dB relative to 30% mod. depth.

POWER REQUIREMENTS

A.C. Mains 200 to 250 volts and 100 to 150 volts, 40 to 100 Hz, 80 watts

D.C. Supply L.T.: 6 volts, 2 amps. H.T.: 240 volts, 50 mA

DIMENSIONS

Height	Width	Depth	Weight
33 cm	48 cm	28 cm	26 kg
14 ¼ in	19 ¾ in	11 in	58 lb

ACCESSORIES

Supplied

TM 4969/3 Output Lead.

TM 4726/77 Mains Lead.

TM 5573 20 dB Attenuator Pad.

Optional

TM 4726/152 Output Lead.
An alternative lead fitted with a Belling-Lee type L778FP small Screenector at the output end.

TM 5573/1 6 dB Attenuator Pad.

TM 5569 Matching Pad.
Converts from 50 Ω to 75 Ω impedance, with Belling-Lee type L734/P output plug.

TM 6599 Matching Pad.
Converts from 50 Ω to 75 Ω impedance, with Burndept type PR4E output plug.

TM 5955/5 Matching Transformer.
Converts from 50 Ω unbalanced to 300 Ω balanced.

TM 6123 Dummy Aerial and D.C. Isolating Unit.
Provides "dummy" aerial output and also output via d.c. stopper capacitor suitable for d.c. voltages up to 300 volts.

TM 6122 Battery Lead.
6 ft long; terminated with accumulator clips for l.t., wander plugs for h.t.

Rack Mounting Arrangements

The TF 144H/4 is normally supplied in a case for bench use; but, if desired, the case may be removed and the signal generator mounted in a standard 19 in. rack. The panel is the correct size and is ready drilled for rack mounting.

A rack-mounting version – TF 144H/4R – fitted with a rack-type dust cover is available as an alternative to the standard instrument.

Military Versions

TF 144H/4S and H/6S are special military versions of the TF 144H/4. Electrically these versions meet the same specification as the standard instrument. They are, however, fitted with fully sealed meters and Plessey Mk IV mains plugs. The two military versions are identical to each other, the distinction between them being that the H/4S is supplied without accessories, whereas the H/6S includes a standard military set.

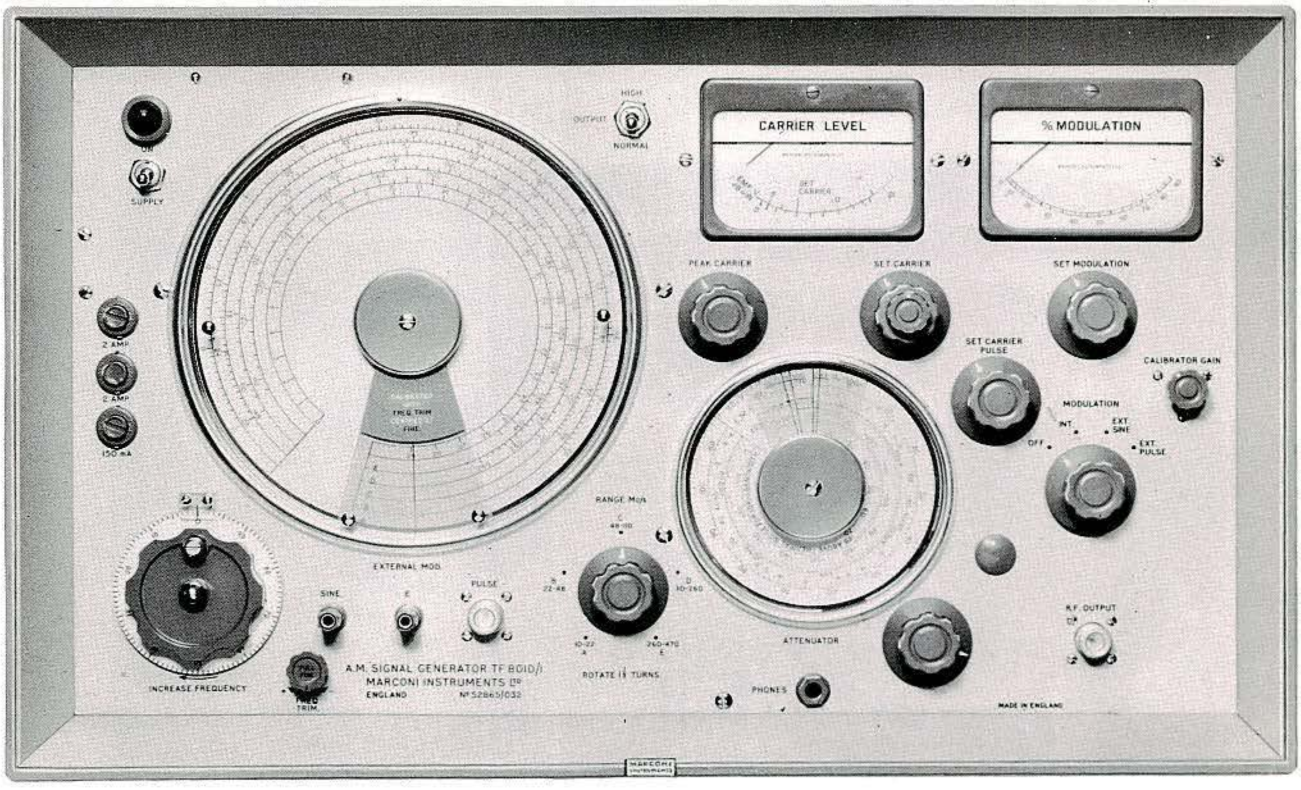
Military Type Nos.

TF 144H/4S:	Joint Services Ref. CT 452A NATO: 6625-99-924-8875
TF 144H/6S:	Joint Services Ref. CT 452 Set NATO: 6625-99-900-8337

TF 144H/4S

A.M. Signal Generator

- Frequency range: 10 to 470 MHz
  (485 MHz for military versions)
- Built-in crystal calibrator
- Internal and external sine a.m.
- External pulse modulation



Signal generators in the TF 801D series are general-purpose v.h.f./u.h.f. a.m. instruments with provision for pulse modulation. Two versions are available: the standard model, TF 801D/1, and the military model, which bears the type number TF 801D/8/S or TF 801D/9/S depending on the accessories supplied with it. The instruments are, of course, basically similar, utilising the master-oscillator/power-amplifier configuration, with a capacitive attenuator acting as a buffer stage. Isolation of the oscillator from unwanted feedback is adequate to prevent spurious f.m. on 30% a.m. exceeding 0·001% of the carrier frequency.

Tuning System

The frequency range of the instrument is divided into five switch-selected tuning bands, each having a frequency cover of the order of 2:1. The Marconi-patented system of contactless turret switching is used in both the oscillator and the amplifier, giving complete freedom from the noise and other adverse effects of passing heavy oscillatory circulating currents through metal-to-metal contacts.

The main tuning dial, hand calibrated directly in frequency, has approximately 70 inches of scale. The frequency calibration can be standardised against a built-in crystal oscillator at 5 MHz intervals, the dial cursor being movable to facilitate correction when necessary. The slow-motion tuning control carries an auxiliary interpolating dial, calibrated linearly 0–100 over its whole circumference. This is useful for accurate tuning between frequency calibration marks, or, in conjunction with a linear logging scale on the main dial, for accurate re-setting. There is also a dual range fine/extra-fine frequency trimmer to aid accurate tuning when testing narrow band receivers.

Ganging of the tuning capacitor of the r.f. amplifier to that of the master oscillator is achieved by means of a special mechanical link which enables the relative angle between the rotors to be varied, by means of a panel control, in order to facilitate accurate peaking of the amplifier's tuning. Over the whole of the lower four bands, however, the automatic level control system obviates the need for re-peaking when tuning adjustments are made.

R.F. Output

The final output is drawn via a piston attenuator calibrated in terms of source e.m.f. and in decibels relative to 1 µV. A second line on the cursor also indicates the p.d. across a matched load. The input level to the piston attenuator is monitored by means of a diode voltmeter, which is marked with a SET CARRIER reference level—where the attenuator dial is direct reading—and also carries a dB scale and voltage multiplier scale.

Modulation

Facilities are provided for internal and external sinewave modulation and for pulse modulation. The sinewave modulating signal is a.c. coupled to the centre tap of the decoupling choke between the grids of the double-pentode r.f. amplifier. But for pulse modulation there is a d.c. path from the input socket to the modulating grids, with a diode to prevent the grids being driven positive, so that the signal amplitude at peak pulse height is equal to that of the unmodulated carrier.

For sinewave modulation the depth is indicated by means of a demodulating-type monitor with the panel meter calibrated in a.m. depth up to 90%.

Military Versions

These versions differ from the standard instrument principally in their specially rugged construction and sealed meters. The military instruments are also fitted with a separate r.f. outlet for use with an electronic counter frequency meter.

Standard Version TF 801D/1

FREQUENCY	
Range	10 to 470 MHz in five bands.
Tuning control	The main dial has a total scale length of approximately 70 inches. Calibration every 2 MHz between 110 and 260 MHz; every 5 MHz above 260 MHz. The incremental dial has a uniform 0–100 calibration and makes 30 turns over each band.
Fine frequency control	A separate dual-range fine frequency control allows precise frequency setting for checks on highly selective receivers.
Calibration accuracy	Using crystal calibrator: within ±0·5% over entire frequency range.
Resettability	Better than ±0·1% after initial warm-up.
Crystal calibrator	Provides check points every 5 MHz over entire range. Accuracy better than 0·01% at normal ambient temperatures. Cursor on main dial adjustable to allow standardisation of calibration.
Frequency stability	After warm-up, drift is not greater than 0·005% in a 10-minute period at ambient temperatures between 15° and 35°C. Following band-switching, a further stabilising period is required.
R.F. OUTPUT	
Level	0·1 µV to 1 volt source e.m.f. Attenuator dial shows source e.m.f. in voltage units and in decibels relative to 1 µV, power in decibels relative to 1 mW in 50Ω, and power relative to thermal noise in a 10 kHz bandwidth.
Voltage accuracy	±1 dB overall for c.w. outputs up to 0·7 volts e.m.f. Level during mark periods of pulse modulation is within ±2 dB of corresponding c.w. output. Automatic level control stabilises output during tuning.
Source impedance	50Ω; v.s.w.r. not greater than 1·2.
Stray radiation	Negligible; permits receiver sensitivity measurements down to 0·1 µV.
MODULATION	
Internal sine A.M.	Modulation frequency: 1,000 Hz ±10%. Depth monitored and variable up to 90% at carrier levels of 1 mW and below.
External sine A.M.	Modulation frequency range: 30 Hz to 20 kHz. Modulation depth as for internal. Input requirements for 90% modulation: 1 to 5 volts, depending on frequency, across 1 MΩ.
Monitor accuracy	±10% of full scale.
Envelope distortion	Less than 5% at 30% internal modulation; less than 10% at 50% modulation.
Incidental F.M. on A.M.	Deviation less than 0·001% of carrier frequency at 30% a.m.
Residual A.M.	The a.m. due to hum and noise is better than 40 dB below 30% modulation.
External pulse modulation	Recurrence frequency range: 50 Hz to 50 kHz. Minimum pulse width varies between 1 µsec at 470 MHz and 10 µsec at 10 MHz. Combined rise and decay time less than 4 µsec from 40 to 260 MHz; and less than 1 µsec from 260 to 470 MHz. Carrier suppression at least 20 dB below peak pulse output. Input requirements: Positive pulses of 50 volts across 1 MΩ.
POWER REQUIREMENTS	
A.C. mains	180 to 250, or 100 to 150 volts, 40 to 100 Hz; 100 watts.
DIMENSIONS AND WEIGHT	

Height	Width	Depth	Weight
14½ in	23¾ in	10½ in	67 lb
37 cm	60 cm	27 cm	31 kg

Military Versions TF 801D/8/S and /9/S

These instruments differ from the standard version, TF 801D/1 only in the following respects:

FREQUENCY	
Range	10 to 485 MHz in five bands.
R.F. OUTPUT	
Counter output	Minimum voltage across a 50Ω matched load bands A to C 50 mV band D 75 mV band E (up to 470 MHz) 100 mV
MODULATION	
External sine A.M.	Modulation frequency range: 30 Hz to 50 kHz. Modulation depth input requirement as for TF 801D/1.
External pulse	Carrier suppression at least 20 dB below peak pulse output from 10 to 470 MHz. Other characteristics as for TF 801D/1.
ACCESSORIES	
Supplied	
TF 801D/8/S	Two coaxial free plugs Type N.
TF 801D/9/S	Type 9403 Mains Lead. TM 4824/1 Output Lead Two coaxial free plugs Type N.

FM/AM Signal Generators

- Frequency range: 200 kHz to 220 MHz
- Built-in crystal calibrator
- Direct-reading incremental frequency control
- Output range: 200mV to 0.1 μV
- Frequency and amplitude modulated; also simultaneous f.m. and a.m.

The TF 995B series of signal generators are conventional f.m./a.m. instruments for receiver measurements over the commonly used v.h.f. bands and the appropriate i.f's. There are three standard versions. TF 995B/2 is the general purpose model, suitable for measurements on broadcast receivers and medium or wide band communications receivers. TF 995B/5 is primarily intended for use with narrow band f.m. v.h.f. communications receivers and a.m. or f.m. mobile receivers.

Frequency

The total frequency range, 200 kHz to 220 MHz, is covered in five bands, the carrier being originally derived from a single range oscillator which is variable from 4·5 to 9·16 MHz. Output frequencies above 13·5 MHz are obtained by means of a series of harmonic multipliers, with range switching effected by selection of the appropriate multiplier as the output stage. This system has the advantages that noise and instability due to switching of heavy oscillatory circulating currents is avoided, and that amplitude modulation applied to the output multiplier stage is effectively isolated from the oscillator, thus preventing excessive spurious f.m. on a.m.

Frequencies between 200 kHz and 13·5 MHz are obtained by utilising the heterodyne beat between the output of the third multiplier stage and a fixed 30 MHz crystal oscillator.

A built-in crystal calibrator, which provides fourteen check points on each range, is automatically switched on when a plug is inserted into the telephone jack on the front panel. The calibration beats are obtained between the output of the master oscillator and the crystal harmonics.

For small, accurately known, changes in carrier frequency the signal generators in this series are fitted with directly calibrated incremental frequency controls, which vary the d.c. applied to the reactor valve associated with the r.f. oscillator. For larger changes, and for accurate interpolation between calibration points on the main tuning dial, the slow-motion control carries a dial with a linear logging scale of 100 divisions over its complete circumference.

On the TF 995B/2 the incremental frequency adjustment is made by a single control, whose frequency cover varies from ±50 kHz to ±400 kHz depending on the r.f. range in use.

In order to cater for tests on narrow-band receivers a rather more elaborate arrangement is used on the TF 995B/5. In addition to the slow motion drive, there is an electrical fine tuning control covering about 24 kHz on the top range and proportionately less on the lower ranges; the dial on this control bears an arbitrary calibration (20-0-20) for resetting purposes. Two calibrated incremental frequency controls are provided. One of these gives a stepped adjustment, and the other is continuously variable for interpolation between the steps. On the two highest frequency ranges the stepped control provides shifts of 20 and 40 kHz in either direction, and the calibration marks on the continuous control are only 1 kHz apart. On the lower ranges the total shift is determined by simple division of the reading on both dials.

Output

The output level direct from the permanently attached connecting cable is variable from 2µV to 200 mV e.m.f. the source impedance being 75 Ω. By using the plug-on terminating unit supplied with the instrument output levels over the range 1 µV to 100 mV e.m.f. may be obtained at source impedances of both 75 Ω and 52 Ω. For low outputs, down to 0·1 µV, a 20 dB attenuator pad is also available for insertion between the cable and the terminating unit.

Two resistive attenuators in cascade are used, in conjunction with the carrier level monitor, for setting the output level. One attenuator covers 80 dB in 20 dB steps and the other covers 20 dB in 2 dB steps, intermediate levels being set by adjusting the carrier level to the appropriate meter reading. The attenuators and the level monitor are calibrated to be direct reading in e.m.f. when the terminating unit is fitted.

Temporary interruptions of the output can be made by means of a carrier on/off switch in the h.t. supply to the oscillator and multipliers.

Modulation

Frequency and amplitude modulation can be applied to the carrier from an internal a.f. oscillator or an external source. The internal oscillator on the TF 995B/2 operates at 1 kHz only; but that of the TF 995B/5 can be switched to 400 Hz, 1 kHz or 1·5 kHz. External modulation is accepted by both instruments at frequencies up to 10 kHz for a.m. and up to 15 kHz for general purpose f.m.

The frequency modulator is of the conventional reactor valve type coupled to the tuned circuit of the r.f. oscillator. In order to maintain constant f.m. deviation as the output frequency is varied, the a.f. modulating signal is applied to the reactor valve via an attenuation system which is ganged to the main tuning control and frequency range switch.

The normal deviation ranges on all bands are 0 to 25 kHz and 0 to 75 kHz for the TF 995B/2 and 0 to 5 kHz and 0 to 15 kHz for the TF 995B/5. It is possible, however, to switch out of circuit the part of the a.f. attenuation system that is ganged to the range switch, so that the maximum deviation increases proportionally with the carrier frequency multiplication. TF 995B/2 also includes a switch-selected uncalibrated *maximum sensitivity* f.m. facility for use with external modulation only. When this facility is used the frequency/response characteristic modulation circuit is suitable for stereo modulation signals, and the sensitivity is adequate for use with commercially available stereo encoders.

Amplitude modulation can be set to any depth up to 50%. Both a.m. depth and f.m. deviation are monitored by switching the panel meter into the appropriate part of the circuit. The meter is, of course, scaled in per cent a.m. depth and kHz f.m. deviation as well as carrier level.

Simultaneous amplitude and frequency modulation is obtainable by setting up the instrument for internal a.m. and applying f.m. from an external source. This facility is useful, not only for measurement of the a.m. rejection on f.m. receivers, but also for swept frequency measurements on a.m. receivers in conjunction with a suitable oscilloscope.

TF 995B/2

FREQUENCY

Range
0·2 to 220 MHz in five bands:
0·2 to 13·5 MHz
13·5 to 27·5 MHz
27 to 55 MHz
54 to 110 MHz
108 to 220 MHz.

Calibration accuracy
From 0·2 to 13·5 MHz the frequency calibration has an accuracy of ±3% when the crystal calibration is used. From 13·5 to 220 MHz the calibration of the main frequency dial is accurate to within 1%. In addition, the built-in crystal calibrator provides 14 check points to an accuracy of 2 parts in 10^4, on each of the four higher-frequency bands.

Stability (bands 2, 3, 4 and 5 only)
After warm-up the frequency drift is not greater than 0·005% in a ten minute period, and is typically 0·002%.

Incremental control
The cover of this control is as follows:
±100 kHz on band 1 above 300 kHz.
±50 kHz on band 2,
±100 kHz on band 3,
±200 kHz on band 4,
±400 kHz on band 5,
The calibration is accurate to within ±10%.

OUTPUT

Voltage
Built-in coarse and fine 75 Ω attenuators connected in cascade provide—in conjunction with the 6-dB Terminating Unit—a source e.m.f. variable in 2-dB steps from 1 µV to 100 mV. Interpolation between the 2-dB steps is by means of a ±1 dB calibration on the r.f. level meter.

High outputs
Source e.m.f.'s up to 200 mV at an impedance of 75 Ω are obtained direct from the Generator output cable.

Low outputs
Source e.m.f.'s down to a nominal 0·1 µV at impedances of 75 and 52 Ω are obtained by inserting 20-dB Attenuator Pad TM 5552 between the Generator output cable and the Terminating Unit.

Accuracy
The accuracy of the joint indication of the attenuators and level meter is within 1 dB ±0·25 µV up to 100 MHz, and within 2 dB ±0·25 µV up to 220 MHz.

MODULATION

F.M.
Normal deviation continuously variable in two ranges ±25 kHz and ±75 kHz on all carrier bands. Accuracy at maximum deviation at 1 kHz is ±5% of f.s.d. with a possible additional variation of ±10% due to valve ageing or random replacement. High deviation of X2 normal is also available on band 3, X4 normal on band 4, and X8 normal on band 5. Internal modulation at 1 kHz, with modulation distortion not exceeding 2% at maximum deviation. On band 1 the high deviation facility should be used only with carrier frequencies above 350 kHz. In the normal deviation condition care must be taken at carrier frequencies below 300 kHz that the instantaneous output frequency never falls below 200 kHz. External modulation characteristic flat within 1 dB 50 Hz to 15 kHz, with respect to 1 kHz.
An uncalibrated *maximum sensitivity* facility is also provided for use with external f.m. only. When this facility is selected, the modulation frequency/response and frequency/phase characteristics are suitable for stereo modulation signals, and the sensitivity is such that an input signal of not more than 5 volts r.m.s. at 1 kHz will produce a peak deviation of 75 kHz.

Spurious f.m. on c.w.
Deviation less than ±50 Hz between 13·5 and 100 MHz and less than ±100 Hz between 100 and 220 MHz.*

* The wide frequency coverage on band 1 (1·5 to 13·5 MHz) is achieved by heterodyning the normal band 3 signal with a fixed oscillator. At some frequencies on band 1, spurious f.m. in excess of the figure quoted for the other bands may occur. At these frequencies the deviation accuracy will also be affected.

A.M.
Internal at 1 kHz to a depth variable up to 50%, with distortion not exceeding 6% at 30% depth. External modulation characteristic flat to within 1 dB, 50 Hz to 10 kHz (with input adjusted for constant modulation meter reading).

Synchronising signal
A nominal 100-volt high-impedance output from the internal 1000 Hz oscillator is available at the front panel.

POWER REQUIREMENTS

200 to 250 volts, or 100 to 150 volts after adjusting internal link, 40 to 65 Hz; 65 watts. Both the mains and h.t. circuits are fused.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
13 in	$17\frac{1}{2}$ in	$8\frac{1}{2}$ in	33 lb
33 cm	44 cm	22 cm	15 kg

ACCESSORIES

Supplied TM 5551
Terminating Unit.
75 Ω in, 75 Ω and 52 Ω out.

Optional TM 5552
20 dB Attenuator Pad.
For use between output cable and Terminating Unit.

TF 995B/5

- ☐ Narrow deviation model for mobile radio testing
- ☐ Stepped and extra fine incremental tuning
- ☐ Less than 25 Hz spurious f.m.
- ☐ Three modulation frequencies

Specification as for the TF 995B/2 except for the following:

FREQUENCY

Stability — After warm-up the frequency drift is not greater than 0·002% in a ten minute period except on the lowest band

Fine tuning — A fine tuning control is provided. This has an arbitrary cover of approximately 24 kHz on band 5, 12 kHz on band 4, 6 kHz on bands 3 and 1, and 3 kHz on band 2.

Incremental tuning — Both stepped and continuously variable calibrated controls are provided. The stepped control enables the carrier frequency to be shifted by ±40 and ±20 kHz on bands 5 and 4, ±20 and ±10 kHz on bands 3 and 1, and ±10 and ±5 kHz on band 2.
The continuous control has a cover of ±0·75 of one increment of the stepped control on any band; e.g., the cover is ±15 kHz on bands 5 and 4.

MODULATION

F.M. — Normal deviation continuously variable from 0 to 15 kHz and 0 to 5 kHz on all bands; accuracy and high deviation as for TF 995B/2. Internal modulation at 400 Hz, 1 kHz, or 1·5 kHz; distortion and external modulation characteristic as for TF 995B/2.
On band 1 the high deviation facility should be used only with carrier frequencies above 230 kHz. In the normal deviation condition care must be taken at carrier frequencies below 215 kHz that the instantaneous output frequency never falls below 200 kHz.
The uncalibrated *maximum sensitivity* facility is not provided in the TF 995B/5.

Spurious f.m. on c.w. — The spurious f.m. due to hum does not exceed 25 Hz deviation at any carrier frequency. The unusually low level of spurious noise modulation allows full use of the signal generator for adjacent channel testing on narrow band communication receivers.

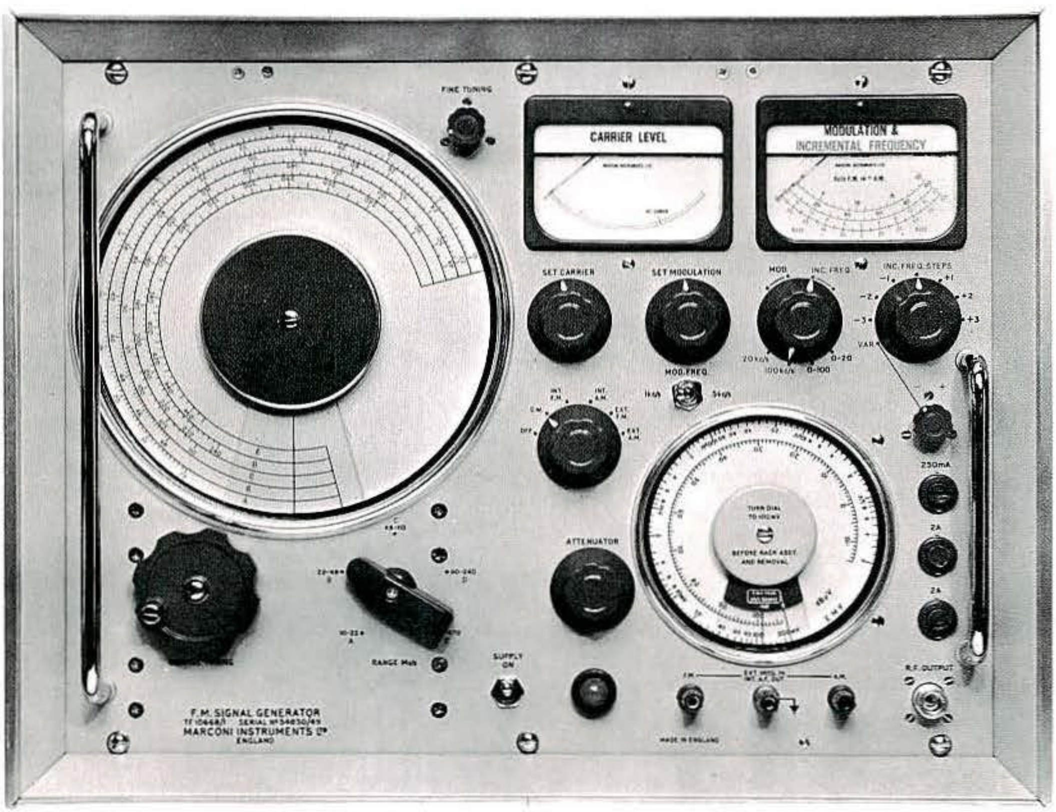
A.M. — Internal at 400 Hz, 1 kHz, or 1·5 kHz; depth and distortion as for TF 995B/2. External frequency characteristic—with input adjusted for constant modulation meter reading—is flat within 0·5 dB from 100 Hz to 10 kHz.

A.M. depth indication — Accurate to within 5% modulation.

Synchronising signal — Available at 400 Hz, 1 kHz or 1·5 kHz.

TF 1066B/1

- ☐ Frequency range: 10 to 470 MHz
- ☐ No multipliers or mixers
- ☐ Drift $<25\text{x}10^{-6}$/ten minutes
- ☐ Stepped as well as continuously-variable incremental tuning
- ☐ Internal modulation at 1 and 5 kHz



TF 1066B/1

The Marconi F.M. Signal Generator TF 1066B/1 covers the range 10 to 470 MHz. Direct carrier-frequency generation without multipliers ensures the complete absence of spurious sub-harmonics in the output, and its direct-reading incremental tuning system brings ease and accuracy to bandwidth measurement.

Stability and purity of signal are enhanced by the use of a rigid cast r.f. box and a transistor-regulated d.c. filament supply for the r.f. oscillator. There are preset potentiometers to simplify setting up and to enable the user to choose the values of stepped incremental shift.

F.M. deviation is variable up to 100 kHz and a.m. depth up to at least 40%. Modulation can be applied internally at 1 or 5 kHz, or externally between 30 Hz and 15 kHz. For both internal and external modulation, f.m. deviation or a.m. depth is directly indicated.

The open-circuit output voltage is continuously variable from 0·2 µV to 200 mV and is derived via a source impedance of 50 ohms. The level of output is controlled by a piston attenuator with a 4½-inch dial bearing two scales, one calibrated directly in units of voltage and the other in decibels relative to 1 µV.

R.F. Oscillator

The heart of the TF 1066B/1 Generator is its craftsman-built r.f. unit employing the Marconi-patented system of contactless waveband selection in a highly developed form. It is this system, supported by such measures as fully stabilised h.t. and l.t. supplies, which yields the excellent frequency stability figure of 0·0025% over a 10-minute period; this is equivalent to a drift of less than 800 Hz per minute at 300 MHz — a point of performance that allows the user to take full advantage of the incremental tuning facilities even when making protracted measurements.

Modulation

Frequency modulation is applied via a ferrite reactor coupled to the oscillator tuned circuit. For amplitude modulation, variation of carrier amplitude is obtained by applying the modulating voltage directly to the anode of the r.f. oscillator.

Modulation is monitored by a meter with two scales, both of which indicate either f.m. deviation in kHz or a.m. depth in percentage, depending upon the type of modulation in use.

Incremental Tuning System

An outstanding feature of the TF 1066B/1 is its incremental tuning system by which small, precise changes can be made in carrier frequency, either continuously variable or stepped, and read directly from a panel meter. The stepped control provides six preset incremental shifts up to ± 100 kHz — a feature which greatly facilitates rapid checking of receiver bandwidth during production testing. Both incremental frequency controls vary the d.c. applied to the reactor used for frequency modulation.

In addition to the incremental tuning arrangements there is a fine frequency control for setting the Generator accurately to the centre frequency of a narrow-band system under test.

Rack Mounting

An alternative version, TF 1066B/1R, is available for mounting in a standard 19-inch rack.

Accessories for the TF 1066B series are listed at the bottom of page 29.

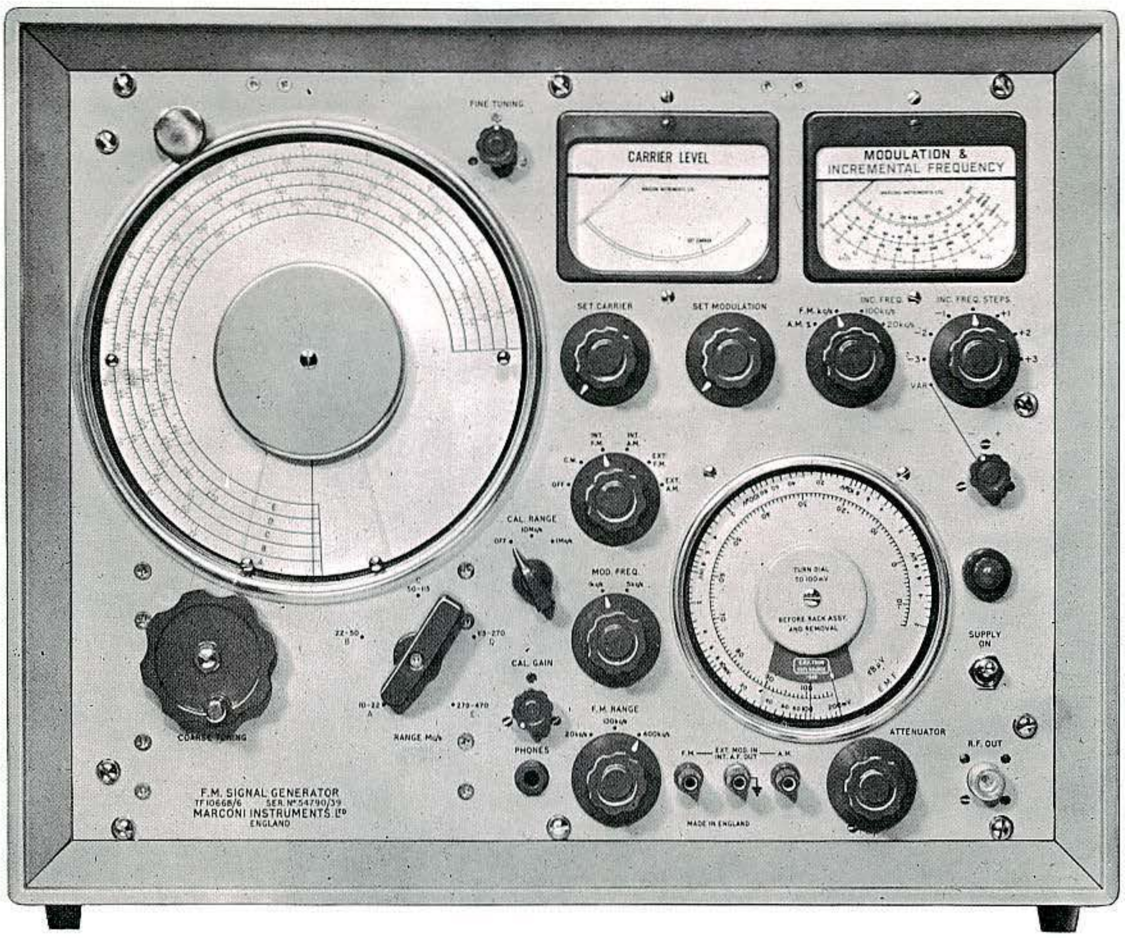
FREQUENCY	
Range	10 to 470 MHz in five bands: 10 to 22 MHz 22 to 48 MHz 48 to 110 MHz 110 to 240 MHz 240 to 470 MHz
Main Tuning	Controlled via precision slow-motion drive. Total scale length, approximately 60 inches.
Calibration Accuracy	1%.
Fine Tuning	Uncalibrated control provides cover of approximately 25 kHz.
Frequency Stability	After warm-up, 0·0025% or better in 10-minute period.
Attenuator Reaction	Negligible below 50 mV; not greater than 0·1% above.
Incremental Frequency Control	Carrier shift is variable from —100 to + 100 kHz by continuous and stepped control. The stepped control has three negative and three positive shift positions, each with independent preset adjustment, and one zero shift position. Shift is monitored by meter with two ranges, — 20 to + 20 kHz and — 100 to + 100 kHz.
Incremental Accuracy	Direct accuracy varies inversely with carrier frequency from within 10% to 20% of f.s.d. Using correction chart supplied, accuracy at all carrier frequencies is within 10% of f.s.d.
Spurious Signals	Total harmonic content is less than 10%. There are no sub-harmonics.
R.F. OUTPUT	
Level	The source e.m.f. is continuously variable from 0·2 µV to 200 mV. The attenuator dial shows the source e.m.f. both directly and in decibels relative to 1 µV. The dial cursor can be positioned to indicate voltage across a 50-ohm load instead of source e.m.f.
Output Accuracy	Incremental, 0·2 dB; overall, 2 dB.
Source Impedance	50 ohms; v.s.w.r. not greater than 1·25:1 using the 20-dB Pad, TM 4919, or 1·6 using the 6-dB Pad, TM 4919/1.
Stray Radiation	Negligible; permits full use of lowest output.

FREQUENCY MODULATION	
Internal	Modulation frequencies: 1 and 5 kHz. Deviation variable to 100 kHz maximum and indicated on two meter ranges, 0 to 20 kHz and 0 to 100 kHz.
External	Modulation frequency range: 30Hz to 15 kHz. Deviation as for internal. Input requirements: 25 volts across 5 kΩ for 100 kHz deviation.
Deviation Accuracy	Direct accuracy for internal modulation varies inversely with carrier frequency from within 7% of f.s.d. to within 20% of f.s.d.; using correction chart supplied, accuracy at all carrier frequencies is within 7% of f.s.d. Accuracy over external modulation frequency range is within 5% of accuracy at 1 kHz.
A.M. on F.M.	Typically, less than 5% modulation depth at maximum deviation.
Residual F.M.	The f.m. due to hum and noise is less than 100 Hz deviation.
AMPLITUDE MODULATION	
Internal	Modulation frequencies: 1 and 5 kHz. Modulation depth variable up to at least 40% and indicated on two meter ranges, 0 to 20% and 0 to 100%.
External	Modulation frequency range: 30 Hz to 15 kHz. Modulation depth as for internal. Input requirements: 10 volts across 1 MΩ for 40%.
Modulation Depth Accuracy	± 5% modulation on 0 to 20% range. ± 10% modulation up to 40% on 0 to 100% range.
F.M. on A.M.	For 30% a.m., varies typically from 4 kHz at 10 MHz to 60 kHz at 100 MHz.
Residual A.M.	The a.m. due to hum and noise is better than 50 dB below 30% modulation.
POWER REQUIREMENTS	200 to 250 volts, and 100 to 130 volts; 40 to 60 Hz; 90 watts. Fuses in mains, h.t. and l.t. circuits.
DIMENSIONS AND WEIGHT	

Height	Width	Depth	Weight
15½ in	21 in	10½ in	54 lb
39·5 cm	53·5 cm	27 cm	24·5 kg

TF 1066B/6

- ☐ Up to 400 kHz deviation with up to 100 kHz mod. frequency
- ☐ Stepped and continuously variable incremental tuning



TF 1066B/6

TF 1066B/6 is a wide deviation frequency modulated signal generator covering the frequency range 10 to 470 MHz. Direct generation at the final output frequency without the use of multipliers ensures complete absence of spurious sub-multiple frequency components in the output signal.

R.F. Oscillator

Stability and purity of signal are enhanced by the use of a rigid cast r.f. box, stabilised h.t., and a transistor regulated d.c. filament supply for the r.f. oscillator. The Marconi patented system of contactless waveband selection is employed in a highly developed form, giving complete freedom from the adverse effects resulting from the passing of heavy oscillatory circulating currents through metal to metal contacts.

The open circuit output voltage is continuously variable from 0·2 μV to 200 mV and is derived via a source impedance of 50 Ω. The level of output is controlled by means of a piston attenuator with a $4\frac{1}{2}$-inch dial bearing two scales, one calibrated directly in units of voltage and the other in decibels relative to 1 μV.

Modulation

Frequency modulation is applied by means of a ferrite reactor coupled to the tuned circuit of the oscillator. The deviation is variable up to 400 kHz at carrier frequencies between 50 and 270 MHz, the modulation frequency range (external) being 30 Hz to 100 kHz.

The carrier can also be amplitude modulated up to a depth of 40% at any frequency in the range 30 Hz to 15 kHz.

An internal modulating oscillator—for either a.m. or f.m.—can be switch tuned to either 1 or 5 kHz; and, for both internal and external modulation, f.m. deviation or a.m. depth is directly indicated. The modulation meter has two scales, both of which indicate either f.m. deviation in kHz or a.m. depth in percentage, depending on the type of modulation used.

Incremental Tuning System

An outstanding feature of the TF 1066B/6 is its incremental tuning system by which small precise changes can be made in carrier frequency, either continuously variable or stepped, and read directly from the panel meter. The stepped control provides six preset incremental shifts up to ±100 kHz—a feature which greatly facilitates rapid checking of receiver bandwidth. Both incremental frequency controls vary the d.c. applied to the ferrite reactor used for frequency modulation.

In addition to the calibrated incremental frequency control arrangement there is an uncalibrated fine tuning control for setting the signal generator accurately to the centre frequency of a narrow-band receiver under test.

Rack Mounting

An alternative version, TF 1066B/6R, is available for mounting in a standard 19-inch rack.

FREQUENCY	
Range	10 to 470 MHz in five bands: A 10 to 22 MHz; B 22 to 50 MHz; C 50 to 115 MHz; D 115 to 270 MHz; E 270 to 470 MHz
Calibration accuracy	±1%.
Crystal calibration	10 MHz and 1 MHz. *Accuracy:* ±0·02%.
Fine tuning	Uncalibrated control provides cover of approximately 25 kHz to 100 kHz depending on carrier frequency.
Frequency stability	Drift is not greater than 0·015% in a 10 minute period after 1 hour warm-up.
Attenuator reaction	Negligible below 50 mV; not greater than 0·1% above.
Incremental frequency control	Carrier shift is variable from −100 kHz to +100 kHz by continuous and stepped control. The stepped control has three negative and three positive positions, each with independent pre-set adjustment, and one zero-shift position. Shift is monitored by meter with two ranges, −20 to +20 kHz and −100 to +100 kHz.
Incremental accuracy	±15% of full scale at all carrier frequencies. Above 115 MHz this tolerance applies after use of correction chart. Direct accuracy above 115 MHz without chart is ±25% of full scale.
Spurious signals	There are no sub-harmonics of the carrier frequencies.
R.F. OUTPUT	
Level	The source e.m.f. is continuously variable from 0·2 μV to 200 mV. The attenuator dial shows the source e.m.f. both directly and in decibels relative to 1 μV. The dial cursor can be positioned to indicate voltage across a 50 Ω load instead of source e.m.f.
Output accuracy	Incremental, ±0·2 dB; overall, ±2 dB.
FREQUENCY MODULATION	
Internal	Modulation frequencies: 1 and 5 kHz. Deviation variable to 100 kHz maximum on ranges A and B, 400 kHz on ranges C and D, and 300 kHz on range E. Deviation indicated on meter with three ranges: 0 to 20 kHz, 0 to 100 kHz and 0 to 400 kHz.
External	Modulation frequency range: 30 Hz to 100 kHz. Deviation as for INTERNAL. Input requirements: 25 volts across 5 kΩ or more for maximum deviation.
Deviation accuracy	Accuracy for internal modulation is 10% of full scale at all carrier frequencies on deviation ranges 0 to 20 kHz and 0 to 100 kHz, and ±15% of full scale on the 0 to 400 kHz deviation range. Above 115 MHz, these tolerances apply only after use of the correction chart. Direct accuracy without the chart above 115 MHz is 20% of full scale. Accuracy over external modulation frequency range is within 12% of the accuracy at 1 kHz.
Demodulated distortion	Distortion introduced by the modulator is not greater than 10% at the maximum permissible deviation on each range. Between 215 and 265 MHz the distortion is not greater than 5% at maximum deviation.
A.M. on F.M.	Typically, less than 5% modulation depth at maximum deviation.
Residual F.M.	The f.m. due to hum and noise is less than 100 Hz deviation.
AMPLITUDE MODULATION	
Internal	Modulation frequencies: 1 and 5 kHz. Modulation depth variable up to at least 40% and indicated on a meter scaled 0 to 50%.
External	Modulation frequency range: 30 Hz to 15 kHz. Modulation depth as for INTERNAL. Input requirements: 12 volts across 270 kΩ for 50%.
Modulation depth accuracy	±5% modulation.
F.M. on A.M.	For 30% a.m., varies typically from 15 kHz at 10 MHz to 60 kHz at 100 MHz.
Residual A.M.	The a.m. due to hum and noise is better than 50 dB below 30% modulation.
POWER REQUIREMENTS	
A.C. Mains	200 to 250 volts and 100 to 130 volts: 40 to 60 Hz: 90 watts.
DIMENSIONS AND WEIGHT	

Height	Width	Depth	Weight
14½ in	21 in	10½ in	54 lb
39·5 cm	53·5 cm	27 cm	24·5 kg

ACCESSORIES

Supplied	TC 25688	Correction Chart
Optional	TM 4824	Output Lead
	TM 4919/1	6 dB Attenuator Pad
	TM 4919	20 dB Attenuator Pad
	TM 4918	Matching Unit
	TM 4916	Matching Unit 50 Ω unbal. to 300 Ω bal.
	TM 4917	D.C. Isolating Unit
	TM 5753	Coaxial Fuse

F.M. Signal Generator

- Total frequency cover: 4 to 1000 MHz
- Up to any 4 from 5 frequency ranges
- 300 kHz maximum deviation
- Low noise and microphony
- Internal and external Δf facilities
- Built-in crystal calibrator
- All solid-state active elements

This signal generator is suitable for measurements on all types of f.m. receivers operating in the frequency range 4 to 1000 MHz. Its good stability, low f.m. noise, and low microphony render it particularly suitable for tests on narrow-band fixed and mobile communications receivers, with complete freedom from the acoustic ringing that can often cause difficulty. On the other hand, the high maximum deviation, coupled with good performance over a wide range of modulation frequencies, permits the use of the TF 2006 for measurements on wide-band multiplex systems, including telemetry and f.m. stereo.

The R.F. Source

An unconventional arrangement is used, whereby each frequency range is covered by a separate r.f. oscillator unit, of which there are five, with provision for assembling up to four into the signal generator during its factory calibration and test. The respective ranges covered are given in the performance specification under the heading Frequency Range. Thus, with four r.f. oscillator units assembled, the instrument gives continuous cover from 4 to 500 MHz or 10 to 1000 MHz. For many purposes, however, adequate frequency cover is provided by fewer oscillator units; e.g. 10 to 500 MHz with three units. Where less than four oscillator units are fitted, the vacant space is occupied by blank panel units.

Range Selection and Tuning

Each oscillator unit is complete with its own tuning control and calibrated drum-type dial. The main scale law is substantially linear; and the slow-motion-drive control carries a 100 division logging scale, which can be used for interpolation between scale markings if desired. An adjustable drive brake is provided for prevention of accidental movement of the control and mechanical shift due to vibration. There is also a separate dial brake. This enables the operator to standardise the dial calibration against the built-in crystal calibrator by adjusting the oscillator frequency with the dial locked (i.e., by changing angular position of the dial drum on its spindle.)

Range selection is effected in the usual way, by means of a four-position panel switch. In order to prevent warm-up drift after band changing, the oscillator transistors remain energised at all times while the instrument is switched on. Oscillators not in use are prevented from oscillating by forward biasing a diode connected in parallel with the tuned circuit. This diode is, of course, biased to its non-conducting condition in the oscillator for the selected band.

Crystal Calibrator

The TF 2006 contains a built-in crystal calibrator capable of providing well defined standardising beats at switch-selected intervals of 10 MHz, 1 MHz, or 100 kHz over the entire tuning range of the instrument. This performance is achieved by the use of specially designed harmonic generators and mixers.

Although the a.f. hetrodyne beat, with adjustable output level, is available from a telephone jack for special purposes, zero-beat is also indicated positively by an a.f. integrating-type frequency meter. When the crystal calibrator is in use, the modulation monitoring panel meter functions as a null indicator; and the output frequency can be set accurately to the appropriate calibration harmonic by simply tuning for zero indication on the *Deviation* meter. (Internal modulation is automatically switched off when the crystal calibrator is used.)

Fine Frequency Control ($\triangle$f)

Accurate incremental tuning is facilitated by means of a fine frequency control system which utilises the frequency modulators built into the r.f. oscillator units.

This control is directly calibrated symmetrically about zero in three ranges, selected by means of a *$\triangle$f Range* switch, the incremental cover of each range being dependent on the main frequency range in use, as shown in a table on the front panel of each oscillator unit. Provision is also made for setting up the scale length against the internal crystal calibrator, giving increased accuracy when this is desirable.

External Frequency Shift

Incremental frequency shift can also be applied to the carrier by means of a control voltage fed to an appropriate terminal on the front panel. The frequency shift produced is directly proportional to the d.c. level of this voltage, a shift equal to the maximum obtainable with the internal $\triangle$f control system being produced by ±1·5 volts input relative to an off-set voltage of −2·5 volts.

The facility can be used for remote manual or automatic frequency control. It can, for example, be used for low-speed frequency-swept display of receiver or amplifier response characteristics on an oscilloscope.

R.F. Output

The r.f. output level is variable over the range 0·2 µV to 200 mV by means of a two stage resistive stepped attenuator. The first stage covers 0 to 100 dB in 20 dB steps and the second covers 20 dB in 1 dB steps. They are calibrated in both voltage and decibels.

Output impedance of the signal generator is 50 Ω, and it is intended that the instrument should normally be used with its 6 dB pad—a standard accessory—connected at the end of the output cable. The voltage calibration is then directly in e.m.f.; but if it is more convenient to have the attenuator calibration in terms of p.d. across a 50 Ω load, this can be obtained by disconnecting the 6 dB pad and feeding the signal generator output directly to the receiver under test.

Connection between the attenuator and the r.f. source is made via a detachable coaxial link. By removing this link the direct output from the r.f. source is made available, and access to the attenuator input is obtained.

An effective automatic-level-control system maintains a sensibly constant output over the whole frequency range, obviating the need for manual adjustment to the carrier level when the frequency is varied.

Counter Output

A separate outlet is provided to facilitate the use of an electronic counter for precise frequency monitoring—as an alternative to the built-in crystal calibrator. The r.f. amplitude from the Counter Output socket is adequate for stable triggering of all Marconi Instruments counters and most counters by other manufacturers.

Modulation Facilities

The TF 2006 can be frequency modulated internally or externally, or squarewave on/off modulation can be applied either internally or from an external sinewave or squarewave source.

Modulating Oscillator

The signal generator contains an internal modulating oscillator which is continuously variable over the frequency range 20 Hz to 125 kHz. This a.f. range is covered in nine sub-ranges, each covering a half-decade.

The output from the modulating oscillator is available for external use from a terminal at the rear of the instrument, the output level remaining constant at 0 dBm in 600 Ω irrespective of the setting of modulation frequency or f.m. deviation.

Frequency Modulation

The signal generator can be frequency modulated internally or externally to a maximum deviation of 300 kHz at carrier frequencies above 215 MHz, or to 100 kHz deviation at lower carrier frequencies. The wide modulation input frequency bandwidth and flat response characteristic ensure minimal phase distortion between the input signal and the f.m. envelope. The f.m. noise is small enough to permit signal-to-noise measurement ratio on the most sensitive receivers, and the f.m. microphony is amply suppressed to prevent audio ringing when testing receivers with built-in loudspeakers.

Modulation Monitor

The f.m. deviation is directly calibrated in kHz deviation. Four deviation ranges are provided, the monitor sensitivity being automatically adjusted to suit the deviation range in use. Provision is made for standardising the calibration of the modulation monitor against that of the $\triangle$f control. This, in turn, may be standardised against the internal crystal calibrator.

Power Supplies

The TF 2006 is intended for normal operation from a.c. mains supplies in the 110 volt range or 230 volt range. It can also be operated from external batteries where this offers some portability advantage. Battery operation, however, produces no advantage regarding the hum suppression; with normal a.c. mains supplies the hum content in the output is imperceptible.

FREQUENCY

Range
4 to 1000 MHz using 5 oscillator units, of which any 4 can be assembled into a generator.
(1) 4 to 10 MHz (2) 10 to 90 MHz
(3) 88 to 220 MHz (4) 215 to 500 MHz
(5) 440 to 1000 MHz

Mechanical tuning discrimination
Each carrier range unit has an independent 28 turn knob. The main scale is substantially linear and a vernier scale has 100 divisions.

Calibration accuracy
±½ of a scale division, but the internal crystal calibrator can be used to increase the accuracy to ±3 parts in 10^6 +1 kHz.

Frequency range	Frequency scale divisions
4 to 10 MHz	100 kHz
10 to 90 MHz	2 MHz
88 to 220 MHz	2 MHz
215 to 500 MHz	5 MHz
440 to 1000 MHz	10 MHz

Stability
At a constant ambient temperature in the range 10°C to 35°C, immediately after switching on, the drift is typically 10 kHz per 15 minutes at 10 MHz and 50 kHz per 15 minutes at 1000 MHz.

At a constant ambient temperature in the range of 10°C to 35°C and after thermal equilibrium has been reached, the drift does not exceed 15 p.p.m. +1·5 kHz per 15 minutes.

Thermal equilibrium is reached after the following times:

Frequency range MHz	Time (min)
4— 10	30
10— 90	90
88— 220	60
215— 500	45
440—1000	45

The thermal equilibrium times stated are not additive. If, on a given frequency range thermal equilibrium has been reached, and the instrument is switched to another range the drift specification will be met within 3 minutes.

One hour after a 10°C change in ambient temperature, within the range 10°C to 35°C, the drift does not exceed 100 p.p.m. +3 kHz per 15 minutes after 3 hours the drift rate does not exceed 15 p.p.m. +1·5 kHz per 15 minutes.

For a supply voltage change of ±10% about 230 volts or 115 volts, the frequency change is less than 500 Hz at the highest generated frequency.

Load reaction
With the coarse attenuator set to give at least 20 dB attenuation, the maximum frequency shift between the output open circuited and loaded with 50 Ω is 1 kHz.

Attenuator reaction
With the output loaded with 50 Ω, the maximum frequency shift between a coarse attenuator setting of 20 dB attenuation and any greater attenuation is 500 Hz.

Electrical fine tuning
Three calibrated ranges are provided for each carrier band.

Carrier oscillator units 4 to 10, 10 to 90, and 88 to 220 MHz have fine tuning ranges of ±10, 30 and 100 kHz. The smallest scale division is 200 Hz.

Carrier oscillator units 215 to 500 and 440 to 1000 MHz have fine tuning ranges of ±30, 100 and 300 kHz. The smallest scale division is 1 kHz.

Accuracy
When standardized independently for positive and negative excursion on the 100 and 300 kHz ranges, the accuracy is as follows:

Δf range (kHz)	Accuracy (kHz)
300	±6
100	±2
30	±1·5
10	±1

Internal crystal calibrator
A meter null indication is provided at all 10, 1 and 0·1 MHz points.

The meter readout gives 1 kHz discrimination at check points.

Accuracy
The oven controlled crystal reaches 3 parts in 10^6 after 15 minutes in the ambient temperature range of 10°C to 35°C. To reduce external d.c. consumption the crystal oven can be switched off.

R.F. OUTPUT

Level
200 mV e.m.f. down to 0·2 μV.

Attenuators
Coarse: 100 dB in 20 dB steps.
Fine: 20 dB in 1 dB steps.
External: 6 dB pad.

A.L.C.
With a terminated output, automatic level control maintains the level meter reading substantially constant so that no manual adjustment is necessary.

Total level accuracy (above 1 μV)
±1 dB to 500 MHz.
±2 dB to 1000 MHz.

Effective source/output impedance
V.S.W.R. better than 1·15 to 200 MHz
1·25 to 500 MHz
1·5 to 1000 MHz

Counter output
100 mV r.m.s. minimum across 50 Ω up to 600 MHz.
50 mV r.m.s. minimum across 50 Ω up to 1000 MHz.

C.W. distortion (total harmonic)
Less than 2½% from 90 MHz to 1000 MHz.
Less than 4% from 4 MHz to 90 MHz.

Leakage
With a two-turn loop of one inch diameter connected to a receiver, a signal cannot be detected at a distance greater than 1 inch from the signal generator at frequencies up to 500 MHz with the receiver sensitivity set at 1 μV, or above 500 MHz with the receiver sensitivity set at 2 μV.

FREQUENCY MODULATION

Monitor
A full-wave peak-reading meter is scaled 0-100 and 0-30.

Deviation range
Four ranges are provided for each carrier band. Carrier oscillator units 4 to 10, 10 to 90, and 88 to 220 MHz give monitor full scales of 3, 10, 30 and 100 kHz peak deviation. Carrier oscillator units 215 to 500, and 440 to 1000 MHz have deviation ranges of 10, 30, 100 and 300 kHz.

Modulation bandwidth
D.C. and 20 Hz to 125 kHz. Suitable for f.m. stereo. Typical channel separation figures are 33 dB at 50 Hz, 36 dB at 1 kHz, and 34 dB at 15 kHz.

Deviation accuracy
At 1 kHz modulation frequency the deviation accuracy, when standardized against the internal crystal calibrator is ±6% of f.s.d. on all ranges.

Without standardization the accuracy is ±12% on all ranges.

Fine tuning and frequency modulation can be used simultaneously, provided the total excursion does not exceed the range maximum shown for fine tuning, but the deviation accuracy will be impaired.

Modulation frequency characteristic
±0·5 dB relative to 1 kHz from 20 Hz to 125 kHz at carrier frequencies from 10 MHz to 1000 MHz.
±1 dB relative to 1 kHz from 20 Hz to 125 kHz at carrier frequencies from 4 MHz to 10 MHz.

F.M. distortion
Using the internal oscillator for maximum deviation, at modulating frequencies from 100 Hz to 20 kHz, the total harmonic distortion does not exceed 2%, except between 4 MHz and 20 MHz, or above 500 MHz carrier frequency where there may be an extra 2%. At modulating frequencies from 20 kHz to 125 kHz at maximum deviation, the total inter-modulation distortion (CCIF method) does not exceed 3%.

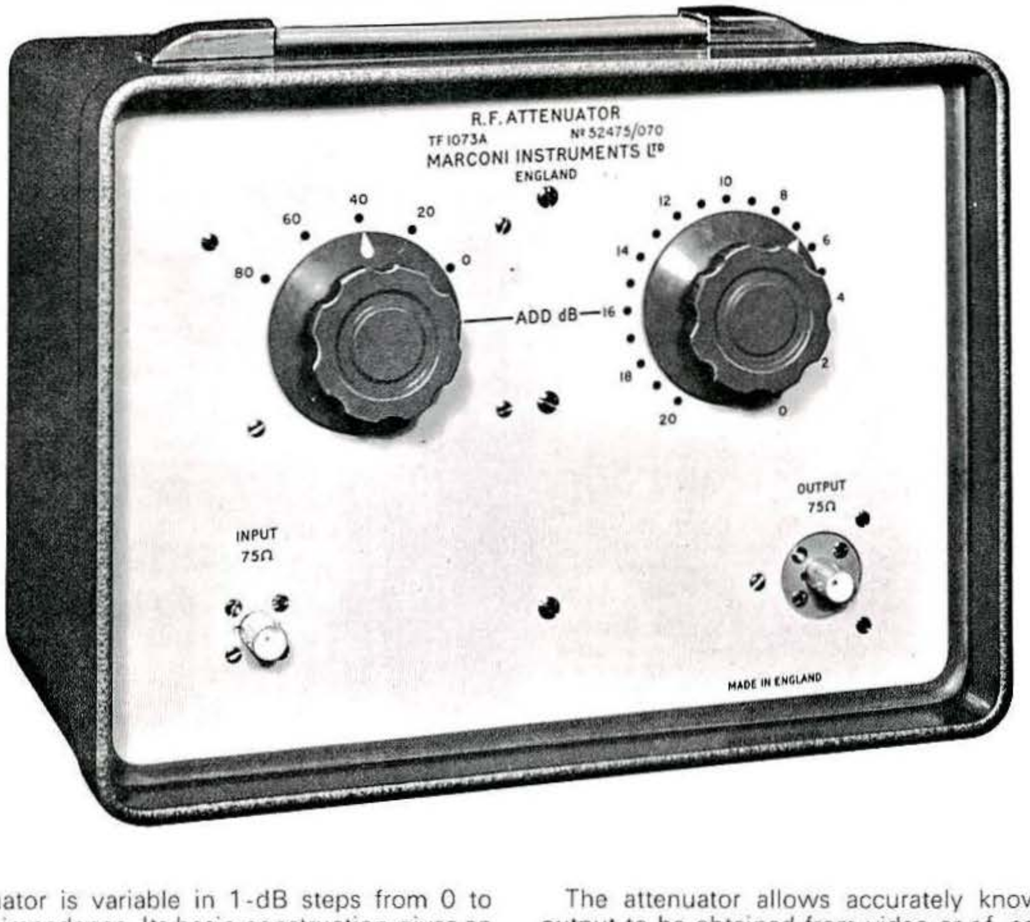
A.M. on F.M.	At maximum deviation on the ranges from 90 MHz to 1000 MHz, less than $2\frac{1}{2}$% a.m. At 75 kHz deviation on the ranges from 4 MHz to 90 MHz, less than 6% a.m.
F.M. noise	With psophometric weighting as follows: Telephone: less than 20 Hz equivalent deviation, typically 12 Hz. Flat: less than 60 Hz equivalent deviation, typically 40 Hz. (15 kHz bandwidth)
Internal modulation oscillator	Range: 20 Hz to 125 kHz. Dial accuracy: ±10%. Output level: 0 dBm ±0·5 dB into 600 Ω from 30 Hz to 125 kHz. Distortion: Less than 1% from 30 Hz to 125 kHz.
External modulation	Input terminals for external f.m. or fine tuning or both. Input level: 1·5 volts r.m.s. into 600 Ω for maximum frequency deviation. −1 volt to −4 volts for maximum fine frequency shift.
AMPLITUDE MODULATION	
Internal or external	ON/OFF square wave modulation. An internal squarer will square a sine wave input, or a square wave drive may be applied.
Frequency	630 Hz to 2 kHz.
External input	1·5 volts r.m.s. or 4·5 volts p-p into 600 Ω.
A.M. on c.w.	Greater than 60 dB down on 100% modulation, measured in a 20 kHz bandwidth.
MICROPHONY	When checked on a mechanical vibrator, less than 12 kHz deviation is caused by $\frac{1}{2}$ g. acceleration in the range of 10 to 80 Hz. (At 10 Hz, $\frac{1}{2}$ g corresponds to a displacement of 0·1 inch.) Each generator is checked on the mobile radio bands to ensure freedom from audio feedback between the receiver speaker and the generator under normal working conditions.

POWER REQUIREMENTS	
A.C. Mains	95 to 130 volts and 190 to 264 volts, 45 to 500 Hz, 25 VA.
External D.C.	23 to 32 volts positive earth, 0·55 amps or 0·35 amps with crystal oven off.
DIMENSIONS AND WEIGHT	Height 13 in (33 cms); Width 18 in (46 cms); Depth 16 in (41 cms); Weight 80 lb (36·4 kg)
ACCESSORIES	
Supplied	Mains lead, TM 7052, 6 ft long: Link, 50 Ω type N male—type N male, connects DIRECT OUTPUT to ATTEN INPUT sockets. Set of accessories in box, TM 9130 comprising: 6 dB pad, type N male—type N female. Impedance: 50 Ω. Frequency range: D.C. to 1000 MHz. Accuracy: ±0·3 dB. V.S.W.R.: Less than 1·1:1. Maximum input: 1 Watt Output Lead TM 4726/12 50 Ω type N male—type N male 3 ft long. Output Lead, TM 4969/3, 50 Ω BNC male—BNC male, 5 ft long. Adapter, type N male—BNC female. Telephone jack plug, for crystal calibrator output socket. Extension Board, TM 8884, permits the instrument to be operated, for servicing, with any one of the plug-in circuit boards clear of the instrument. Extension lead, 12-way, feeds the supplies and inputs to an r.f. oscillator when operated clear of the instrument. Extension lead, coaxial, TNC male—TNC female, feeds the output from an r.f. oscillator when operated clear of the instrument.
Optional TM 9927	Rack Mounting Kit

TM 9130, set of accessories

TF 1073A Attenuator

- D.C. to 150 MHz
- 1 dB steps
- Double-screened construction



This r.f. attenuator is variable in 1-dB steps from 0 to 100 dB at 75 Ω impedance. Its basic construction gives an exceptionally flat frequency characteristic. The attenuator is an instrument in its own right—not just a component which must be built on to the equipment with which it is to be employed.

The attenuator allows accurately known changes of output to be obtained from video or r.f. oscillators. It can be used in measuring amplifier gain, transmission loss of networks, frequency response of filters, power-level tests on transmitters and generally extending the usefulness of other test equipment.

Attenuation range	100 dB in 1-dB steps. Provided by coarse and fine controls; one giving 80 dB in 20-dB steps; the other giving 20 dB in 1-dB steps.
Frequency range	0 to 100 MHz; usable to 150 MHz with reduced accuracy.
Characteristic impedance	75Ω.
Accuracy at 100 MHz	Each step of the coarse section introduces 20 dB ±0·2 dB, but the cumulative error due to these steps never exceeds ±0·5 dB. Each step of the fine section is independent and introduces the nominal attenuation ±0·2 dB.
Power input	Inputs up to a maximum of 0·25 watts can be applied.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
8 in	10½ in	7 in	7½ lb
20·5 cm	26·5 cm	18 cm	3·4 kg

U.H.F. Attenuator TF 2163S

- 0 to 142 dB in 1 dB steps.
- V.S.W.R. 1.1 up to 200 MHz, 1.5 up to 1 GHz.
- 50Ω impedance.
- Low insertion loss.

TF 2163S is a 50 Ω switched attenuator suitable for use at all frequencies up to 1 GHz. Its accuracy and freedom from standing waves has been achieved by the use of a novel design in which special resistive pads are selected by cam-operated microswitches. Careful attention to internal screening prevents errors due to leakage fields at high attenuation settings.

Controls

Attenuation is selected by means of two rotary step controls, one covering 120 dB in 20 dB steps and the other covering 22 dB in 1 dB steps. The sum of the settings gives the overall attenuation.

Connections

Type N inlet and outlet sockets are provided.

Housing

The instrument conforms to the Marconi modular dimensional standard; and in its bench mounting form is housed in a one-third module casing. It can, of course occupy any position in a full-module rack mounting case. It is provided with a front panel lid equipped to stow a coaxial r.f. fuse unit, spare fuses, and two type N to BNC adapters.

FREQUENCY RANGE	D.C. to 1 GHz.
ATTENUATION	
Range	0 to 142 dB in 1 dB steps.
Accuracy	Up to 130 dB at 1 kHz ±0·5% ± 0·1 dB. Up to 100 dB at 1 GHz ±1% ±0·2 dB. Up to 130 dB to 1 GHz ±1·5% ±0·2 dB.
IMPEDANCE	50 Ω input and output.
V.S.W.R.	Not exceeding: 1·1 below 200 MHz. 1·25 below 500 MHz. 1·5 below 1 GHz.

MAXIMUM POWER INPUT	0·5 watts.			
INSERTION LOSS	Approx. 0·3 dB per 100 MHz.			
DIMENSIONS AND WEIGHT	Height	Width	Depth	Weight
	7¾ in.	5¾ in.	10½ in.	8 lb.
	19·5 cm	14·5 cm	27 cm	3·63 kg
ACCESSORIES				
Optional	TM 4726/286 Connecting lead. TM 5753 R.F. Fuse Unit. TM 7010 Rack Mounting Case.			

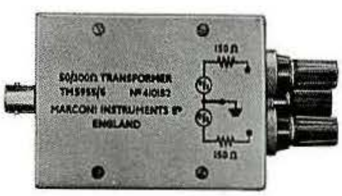
R.F. Connecting Cables

TYPE No.	R_o	LENGTH	CONNECTORS INPUT	CONNECTORS OUTPUT	SUITABLE FOR
TM 4969	50 Ω	36 in	BNC Plug	BNC Plug	Frequencies up to 500 MHz Signal Generators: TF 144H series TF 2002AS
TM 4969/3	50 Ω	60 in	BNC Plug	BNC Plug	
TM 4726/152	50 Ω	60 in	BNC Plug	Belling Lee L778FP Small Screenector	
TM 4824	50 Ω	36 in	N Plug	N Plug	Frequencies up to 500 MHz Signal Generators: TF 801D series TF 1066B series Attenuator TF 2163S
TM 4824/1	50 Ω	54 in	N Plug	N Plug	

Attenuator Pads

TYPE No.	ATTENUATION	IMPEDANCE	CONNECTORS	SUITABLE FOR
TM 5573	20 dB	50 Ω	BNC	Frequencies up to 500 MHz Signal Generators: TF 144H series TF 2002AS
TM 5573/1	6 dB	50 Ω	BNC	
TM 5552	20 dB	75 Ω	BNC	Signal Generator: TF 995B series
TM 4919	20 dB	50 Ω	N	Frequencies up to 500 MHz Signal Generators: TF 801D series TF 1066B series
TM 4919/1	6 dB	50 Ω	N	
TM 5554	10 dB	50 Ω	N	Frequencies up to 1200 MHz

Matching Units



TYPE No.	DESCRIPTION	SUITABLE FOR
TM 5569	50 Ω to 75 Ω Matching Pad. Comprises a single 25 Ω series resistor to convert the 50 Ω source resistance to 75 Ω. Input connector: BNC Plug. Output connector: Belling Lee L778FP.	Signal Generators: TF 144H series TF 2002AS
TM 6599	Similar to TM 5569 but with Burndept type PR4E output plug.	Signal Generators: TF 144H series TF 2002AS
TM 5955/5	Matching Transformer 50 Ω unbalanced to 300 Ω balanced. Comprises toroidal auto-transformer. Suitable for use at frequencies up to 100 MHz. Input Connector: BNC Plug. Output Connector: Miniature Terminals. Voltage ratio: 1 to 0·5+0·5.	Signal Generators: TF 144H series TF 2002AS
TM 6123	Composite Dummy Aerial and D.C. Isolating Unit. Includes connecting cable with BNC plug; spring-clip output terminals. For general receiver testing or for use on circuits with d.c. potentials up to 350 volts.	Signal Generators: TF 144H series TF 2002AS
TM 4918	50 Ω to 75 Ω Matching Pad. Comprises a single 25 Ω series resistor. Input connector: N socket. Output connector: Belling Lee L734P plug.	
TM 5548	50 Ω to 75 Ω Matching Pad. Comprises a single 25 Ω series resistor. Input connector: N socket. Output connector: Burndept PR4D plug.	Signal Generators: TF 801D series TF 1066B series Attenuator TF 2163S
TM 5549	50 Ω to 75 Ω Matching Pad. Similar to TM 5548 but with Plessey Major CZ71060 output plug.	
TM 4916	Matching Unit 50 Ω unbalanced to 300 Ω balanced. Uses resistive networks only for measurements on receivers with balanced transformer inputs. Input connector: N socket. Output connectors: Solder spills.	Signal Generators: TF 801D series TF 1066B series

Coaxial Fuse

TM 5753	For use with signal generators TF 801D series and TF 1066B series to prevent damage to the attenuator through accidental application of r.f. or h.t. power to the circuit under test. Rating: 0·4 watt. Insertion Loss: Nominally 0·5 dB. V.S.W.R.: 1·35 or less when terminated with a matched 50 Ω load. 1·6 or less when terminated with the signal generator attenuator via 20 dB Pad TM 4919. Connectors: Type N. Fuse: 1/16 A Littlefuse Cat. No. 316.062. 10 spares are provided.

D.C. Isolating Unit

TM 4917	For use with TF 801D series and TF 1066B series signal generators. Allows the signal generator to be used for testing at d.c. potentials up to 300 volts. Connectors: Type N.

Oscillators, Waveform Generators and Attenuators

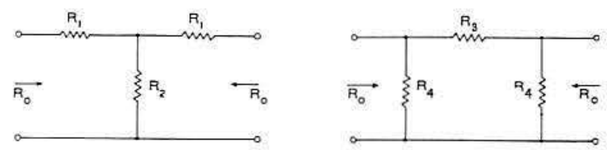
Frequency Nomenclature

In this catalogue the term oscillator is used for the simple sinewave source in order to distinguish it from the true signal generator designed for radio receiver measurements. Although the technical differences between the two types of instrument are too obvious for comment, there is considerable frequency overlap. But because of their differing applications, the frequency nomenclature used with signal generators is not meaningful for instruments in this section.

The terms in common usage are somewhat imprecise, but, as the main differences between the various signal sources in this section is that of frequency coverage, a somewhat arbitrary nomenclature is used for identification purposes. The term "medium frequency" is applied to instruments covering frequencies above the audio range but not high enough to be regarded as video frequencies. In this context the term has a different meaning from that given in the "Useful Data" Section, but no confusion is likely to arise as the frequency ranges of the instruments involved are clearly stated on all descriptive literature associated with them.

Attenuation Networks

At the frequencies covered by the instruments in this section, it is frequently convenient to build into test circuits simple attenuator pads of the form shown. The accompanying table should be helpful in calculating the values of the resistive elements.



Atten. in dB	Multiplying Factors			
	R_1	R_2	R_3	R_4
0·5	0·0287	17·361	0·0576	34·79
1	0·0575	8·669	0·115	17·39
2	0·115	4·305	0·232	8·726
3	0·171	2·838	0·352	5·848
4	0·226	2·094	0·478	4·425
5	0·280	1·645	0·608	3·569
6	0·333	1·339	0·747	3·007
7	0·382	1·116	0·896	2·614
8	0·431	0·945	1·058	2·323
9	0·476	0·812	1·232	2·101
10	0·519	0·703	1·423	1·925
12	0·599	0·536	1·865	1·670
14	0·667	0·416	2·405	1·499
16	0·726	0·325	3·078	1·377
18	0·776	0·254	3·907	1·288
20	0·818	0·202	4·950	1·222
25	0·894	0·113	8·876	1·119
30	0·939	0·0633	15·80	1·065
35	0·965	0·0356	28·13	1·036
40	0·980	0·0200	50·0	1·020

In order to find the actual values of R_1 and R_2 multiply the figures given in the table above by the characteristic resistance R_0.

Oscillators and Waveform Generators

Attenuators

Wide Range R-C Oscillator

- Frequency range (sinewave): 10 Hz to 10 MHz
- Squarewaves up to 100 kHz
- High outputs - 31·6 volts up to 1 MHz
- 1mV to 3·16 volts at 75, 100, 130, or 600 Ω via attenuator

The TF 1370A is a general-purpose sinewave generator covering the audio and video frequency bands. It also delivers a high quality squarewave output at frequencies between 10 Hz and 100 kHz.

The oscillator is primarily a signal source for measurements and tests on a.f. and v.f. amplifiers and networks. With its four output impedances—600, 130, 100 & 75Ω—it is very suitable for use with transmission lines, filters, attenuators, etc.

Sinewaves

The wide-range Wien-bridge oscillator covers 10 Hz to 10 MHz in six decade bands. The top band, with its exceptionally wide cover of 1 to 10 MHz and stable output characteristic, is ideal for response testing in the video and lower h.f. bands. A single scale is used for the four lower bands and separate scales for the two upper bands; this gives a total scale length of 105 inches and makes a 1% change in frequency easily discernible. Speed and precision of tuning are reconciled by a dual-ratio control, 3:1 for rapid adjustment and 18:1 for fine tuning.

Outputs from 1 mV to 3·16 volts are available via a switched attenuator covering 60 dB in 10 dB steps. The signal level applied to the input of the attenuator is continuously variable and is monitored by a meter calibrated in open-circuit voltage and decibels. The output impedance can be set to 75, 100, 130 or 600Ω, as required.

Low outputs down to 10 μV at 75 or 5Ω can be obtained by using the ×100 Attenuator Pad available as an optional accessory.

High outputs up to 31·6 volts, at frequencies up to 1 MHz, are delivered at a separate outlet. This output is controlled by a switched potential divider with a continuously variable input, with the meter indicating the voltage across the load. Switching to a higher frequency band during high-output operation automatically lights a warning lamp to show that this is not an operative condition.

Squarewaves

Squarewave outputs up to 31·6 volts peak are available at frequencies up to 100 kHz. The warning lamp facility provided for high output sinewave operation also applies for squarewaves if a higher frequency band is selected. Output arrangements are similar to those for sinewaves except that the meter indicates the peak amplitude with respect to zero, *i.e.* half the peak-to-peak voltage.

Both sag and mark/space ratio are adjustable by front panel presets. Below 50 Hz, the sag can be adjusted to zero for any particular load; above 50 Hz, one zero setting is valid for all loads. The mark/space preset enables the ratio to be brought exactly to unity.

Rack Mounting Facilities

The standard instrument is housed in a case for bench use. The front panel is, however, the correct size and ready drilled for mounting in a standard 19-inch rack. A rack-mounting version—TF 1370A/R—fitted with dust cover and panel rails, is also available.

FREQUENCY RANGE

Sinewave operation 10 Hz to 10 MHz, in six decade bands.

Squarewave operation 10 Hz to 100 kHz, in four decade bands.

Scale accuracy ±2% ±1 Hz.

Stability Drift less than 1×10^{-3}/fifteen minutes, after one hour's operation.

ATTENUATOR OUTPUTS

Sinewave operation Seven ranges of e.m.f. between 10 Hz and 10 MHz, with maximum r.m.s. values of 3–10–30–100–300 mV, and 1–3 volts.
Output/Frequency Characteristic—relative to 1 kHz: Between 10 and 100 Hz: Within ±0·5 dB.
Between 100 Hz and 1 MHz: Within ±0·25 dB.
Between 1 MHz and 10 MHz: Within ±1 dB.
Attenuation Range: Six 10 dB steps between −50 dB and +10 dB.

Squarewave operation Seven ranges of e.m.f. between 10 Hz and 100 kHz, with maximum peak values of 3–10–30–100–300 mV, and 1–3 volts. (For p-to-p values, multiply by 2.)
Output/Frequency Characteristic—relative to 1 kHz: Between 10 Hz and 100 kHz: Within ±0·3 dB.
Attenuation Range: Five 10 dB steps between −50 dB and 0 dB.

Output impedance Four switch settings giving values of 75Ω, 100Ω, 130Ω, and 600Ω unbalanced, at all attenuator settings, except on the maximum output step using squarewaves, when the source impedance is increased by 250Ω.

Attenuator accuracy The switch ranges are within ±1 dB overall.

DIRECT OUTPUTS (p.d. across loads greater than 2·2 kΩ)

Sinewave operation Two ranges of at least 10 volts and 31·6 volts r.m.s., between 10 Hz and 1 MHz.

Squarewave operation Two ranges of at least 20 volts and 73·2 volts p-to-p (±10 volts and ±31·6 volts peak with respect to zero), between 10 Hz and 100 kHz.

Impedance *10 volt Range:* Nominally 650Ω.
31·6 volt Range: Nominally 25Ω with 500 μF in series.

METER

Voltage scales Two ranges, graduated from 0 to 10 and 0 to 31·6.

Accuracy *Sinewave Operation:* ±3% of f.s.d. between 10 Hz and 1 MHz.
±3% of f.s.d. ±2% of reading between 1 and 10 MHz.
Squarewave Operation: ±3% of f.s.d. ±2% of reading between 10 Hz and 100 kHz.

Decibel scales One range from −20 dB to 0 dB relative to f.s.d.
The scale is also marked with two reference points for 1 volt p-to-p (p.d.) across a 75Ω load with sinewaves and squarewaves, when using the 1 volt (0 dB) attenuator setting and the 75Ω impedance setting.

DISTORTION

Sinewave operation The distortion factor is less than the levels in the table:

FREQUENCY RANGE	BANDS	PERCENTAGE ATTENUATOR OUTPUTS	DISTORTION DIRECT OUTPUTS
20 Hz to 100 Hz	A	2%	2%
100 Hz to 100 kHz	B, C & D	0·5%	1%
100 kHz to 1 MHz	E	1%	2%
1 MHz to 4 MHz	F	2%	—
4 MHz to 10 MHz	F	5%	—

Squarewave operation *Rise Time:* Not greater than 0·4 μsec at ⅓ f.s.d., and not greater than 0·75 μsec at f.s.d.
Sag: Approximately 5% at 20 Hz using 2·2 kΩ load.
Mark/Space Ratio: 50/50 ±5%.
Front-panel adjustments for sag and mark/space ratio are provided.

Hum Less than 0·1% of the output at f.s.d. above 10 mV.

POWER REQUIREMENTS

A.C. Mains 100 to 150 volts and 200 to 250 volts; 45 to 65 Hz; 150 VA.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
14 in	20 in	11 in	38 lb
35·9 cm	50·6 cm	27·5 cm	17 kg

ACCESSORIES

Supplied Coaxial Free Plug, Type BNC, 75Ω; for use with either output socket.

Optional

TM 6221 **Unbalanced-to-Balanced Transformer;** 600 to 600/200/150Ω.

TM 4726/136 **75Ω Coaxial Lead;** 3 feet long; with BNC 75Ω plugs to connect any of the above accessories to the instrument.

TF 1101 R-C Oscillator

- Frequency range: 20 Hz to 200 kHz
- Thermistor stabilized oscillator
- 60 dB step attenuator
- 0·1% distortion at 1 kHz using built-in filter

A wide frequency range together with high output, purity of waveform, and frequency stability, are primary requirements in any high-quality general-purpose oscillator. All of these features are combined in this compact Marconi R-C Oscillator.

The frequency coverage of 20 Hz to 200 kHz with $\frac{2}{3}$-watt output at low distortion can be put to good use in a variety of applications ranging from audio work to carrier telephony testing. For distortion measurements on high-quality audio amplifiers, a built-in band-pass filter can be connected in series with the output to provide a 1 kHz test tone with harmonic content less than 0·1%.

Frequency response measurements are facilitated by the semi-logarithmic frequency scale which gives the same order of setting accuracy at all frequencies, the overall frequency characteristic of ±0·5 dB, and the virtual absence of switching transients between ranges.

The large tuning dial has an effective scale length of over 48 inches and ensures excellent discrimination. The panel meter and 60 dB step attenuator are direct reading both in source e.m.f. and, for a 600 ohm load, in decibels relative to 1 mV.

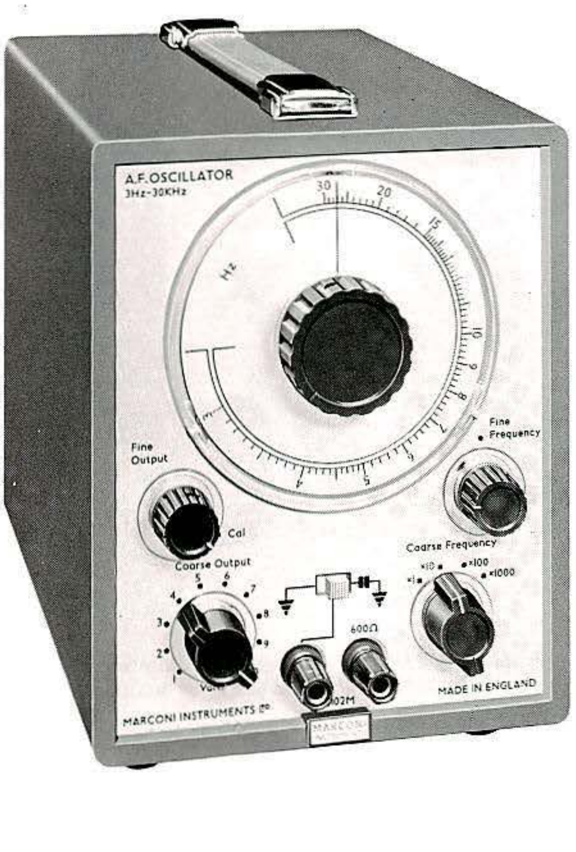
Fundamentally, the instrument comprises a two-stage thermistor-stabilized Wien-bridge oscillator in which the capacitive elements are varied by the frequency control and the resistive elements by the range switch. Even-order harmonics and hum are minimized by the use of a push-pull transformer-coupled output stage; at high frequencies the quality of output is maintained by the provision of a ferrite-cored output transformer. A high order of frequency stability is assured by a carefully designed oscillatory circuit and a series-stabilized power supply.

FREQUENCY	
Range	20 Hz to 200 kHz in four ranges of 20 to 200 Hz, 200 Hz to 2 kHz, 2 to 20 kHz, and 20 to 200 kHz.
Accuracy	±1·5% ±1 Hz.
Stability	±0·15% ±1 Hz after warm-up.
Response	For any given setting of the output controls, the output level remains constant to within ±0·5 dB from 20 Hz to 200 kHz.
OUTPUT	
Direct	Continuously-variable up to 20 volts for external loads of 600 ohms or greater.
Via the 600 Ω Attenuator	Continuously-variable up to 20 volts source e.m.f. in seven steps with maxima of 20 mV, 60 mV, 200 mV, 600 mV, 2 volts, 6 volts and 20 volts.
	The instrument is also calibrated from −60 to +28 dB relative to 1 mW to show the power delivered to an external 600 ohm load.

DISTORTION	
Via the 600 Ω Attenuator	Less than 0·5% between 50 Hz and 20 kHz; outside this range, less than 1%.
Direct	As above except that, for outputs above 10 volts and/or loads less than 1 kΩ, distortion may rise to 1·5%.
Filtered	At 1 kHz, using the built-in band-pass filter, less than 0·1% with reduced output.
HUM	200 Hz to 200 kHz: −60 dB. 20 Hz to 200 Hz: −50 dB.
POWER REQUIREMENTS	
A.C. mains	100 to 150 volts or 200 to 250 volts; 45 Hz to 65 Hz. (Permissible voltage variation of ±5% on tapping value).
DIMENSIONS AND WEIGHT	

Height	Width	Depth	Weight
12¼ in	8½ in	14¾ in	31 lb
31 cm	21·5 cm	37·5 cm	14 kg

- 3 Hz to 30 kHz
- Complete freedom from amplitude bounce
- 10 volts across 600 Ω



This all-solid-state oscillator, intended as a general purpose a.f. source, provides a moderately high output level over a range of frequencies extending well below the normal audio range. In addition to the usual applications as an a.f. test oscillator, therefore, the TF 2102M is suitable for use as a primary source in vibration equipment, and even for tests on servo systems.

An important feature of the instrument is its complete freedom from "amplitude bounce" when rapid frequency changes are made, or with frequency range switching. It is also particularly free from potentiometer noise effects as frequency is varied; and its low impedance circuitry gives a generally low figure for hum and noise.

It comprises an oscillator driving an output amplifier of the complementary symetric class B type. This amplifier operates at fixed gain, heavily stabilised by negative feed-back, output level control being effected by means of a potential divider system between the oscillator and amplifier. The total output level variation of 0 to 10 volts across 600 Ω is achieved by a switched *Coarse* control, having ten 1 volt steps, and a continuously variable *Fine* control covering 1 volt.

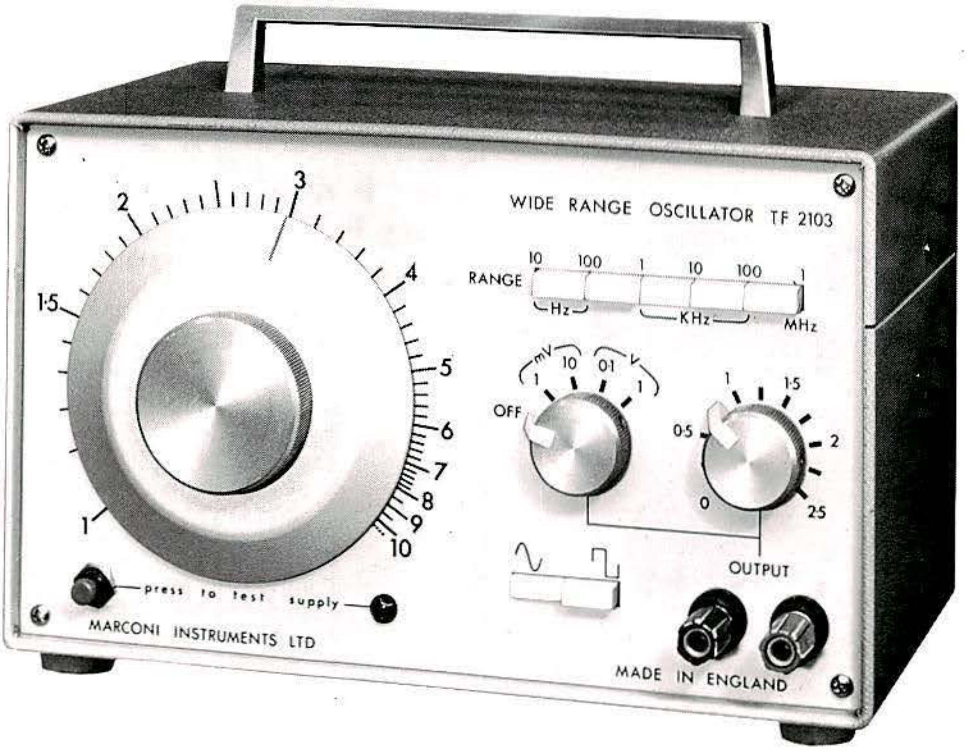
The output amplifier has a constant, very low, source impedance, the instrument's 600 Ω output resistance being obtained by internal connection of a fixed series resistor. The general performance and distortion are, therefore, unaffected by the impedance of the external load; and the instrument can be used as a current source, operating directly into a short circuit, if desired. By operation of a panel switch, the output circuit can be connected to or isolated from chassis.

FREQUENCY	
Range	3 Hz to 30 kHz in four decade bands.
Calibration accuracy	2%.
Stability	Drift less than 0·02% per 15 minutes after warm-up (assuming fairly constant ambient temperature).
OUTPUT	
Impedance	600 Ω ±5%, floating or unbalanced.
Level	0 to 10 volts across 600 Ω (20 volts e.m.f.) in 1 volt steps with fine control giving continuous cover between steps with at least 5% overlap.
Stability	Level remains constant within 1 dB over the full frequency range.

DISTORTION				
Harmonic content	Less than 1%.			
Hum and noise	Less than −80 dB relative to full output.			
POWER REQUIREMENTS				
A.C. mains	100 to 130 volts or 200 to 250 volts, 40 to 65 Hz, 5 VA.			
DIMENSIONS	Height	Width	Depth	Weight
	$7\frac{3}{4}$ in.	$5\frac{3}{4}$ in.	$10\frac{1}{2}$ in.	$8\frac{1}{2}$ lb.
	20 cm	15 cm	27 cm	3·8 kg
ACCESSORIES				
Optional				
TB 39868	Shielded Adapter (GE 51002).			
TM 4726/136	Coaxial Output Cable.			
TM 4726/208	Twin Balanced Output Cable.			

TF 2103 Wide Range Oscillator

- 10 Hz to 1 MHz
- Sinewave and squarewave
- Low price



The output frequency of this sinewave/squarewave portable oscillator is continuously variable from 10 Hz to 1 MHz.

A bank of five range-selecting push-buttons and a clearly calibrated dial are used to set the output frequency: the effective scale length for the band exceeds 3 ft. Output signal amplitude is continuously variable (in four switched ranges) from 0 to 2·5 volts.

The instrument is powered by two internal 9 volt batteries. A push-button operated indicator lamp facilitates occasional checking of the supply.

If mains operation is preferred, the batteries may be replaced by a Mains Power Unit TM 9808 which is available as an optional extra.

The TF 2103 employs a transistor Wien-bridge variable frequency oscillator as signal source; this is followed by an inverter/amplifier when sinewave output is selected, but by a Schmitt trigger circuit when squarewave output is selected. The signals of selected waveform and frequency are applied to a complementary emitter follower output stage and hence pass via an attenuator to the output terminals. Amplitude stabilisation is provided by thermistor-controlled negative feedback.

FREQUENCY	**Range**	10 Hz to 1 MHz. Continuously variable in 5 ranges: 10 Hz to 100 Hz; 100 Hz to 1 kHz; 1 kHz to 10 kHz; 10 kHz to 100 kHz; 100 kHz to 1 MHz. Calibration accuracy: ±3%.
OUTPUT	**Waveform**	Sinewave or squarewave. Squarewave rise-time: Not greater than 100 nsec (typically 30 nsec) between 10% and 90% amplitude points.
	Sinewave distortion	Typically 0·5% for frequencies 50 Hz to 10 kHz. Less than 2% for frequencies to 100 kHz.
	Output amplitude	0 to 2·5 volts r.m.s. Continuously variable in 4 ranges: 0 to 2·5 mV; 0 to 25 mV; 0 to 0·25 volts; 0 to 2·5 volts.
	Output impedance	600 Ω on 2·5 mV, 25 mV and 0·25 volts ranges. Not greater than 600 Ω on 2·5 volts range: typically 100 Ω at maximum output. Note: The attenuator is frequency compensated to feed a high impedance load. If excessive capacitance is connected across the output a fall off in high frequency response will result.
POWER REQUIREMENTS		Two series-connected 9 volt batteries: Vidor type VT9 or Ever Ready type PP9 or equivalent (Mains Power Unit optional extra). Minimum supply voltage: 12 volts DC. Consumption: 0·4 watts (25 mA: 16 volts).
	Temperature range	0° to +45° Centigrade.
DIMENSIONS AND WEIGHT		Height $4\frac{3}{4}$ in. 12 cm; Width $8\frac{1}{4}$ in. 21 cm; Depth 5 in. 12·7 cm; Weight 4·6 lb 1·9 kg. Weight without batteries 2·7 lb (1·1 kg)

Mains Power Unit TM 9808

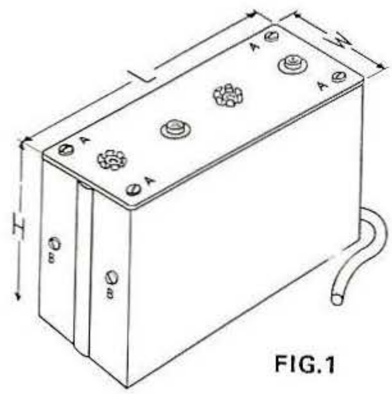


FIG.1

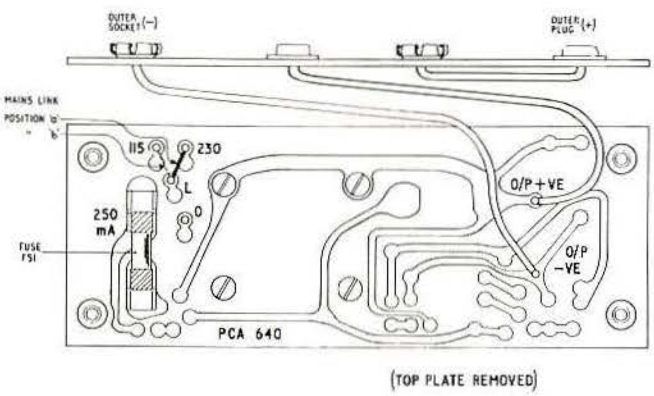
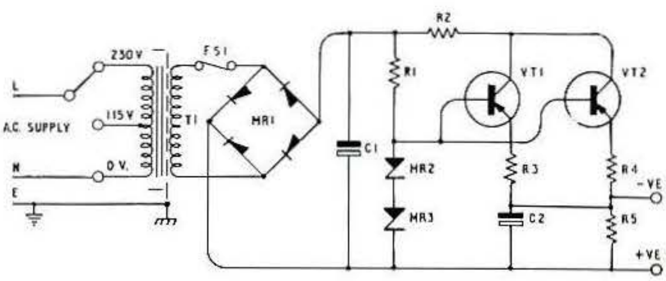


FIG.2



TM 9808 CIRCUIT DIAGRAM

FIG.3

This compact mains operated power unit is specially designed for use within Wide Range Oscillators type TF 2103. The need for two series-connected 9 volt batteries (type VT9 or equivalent) is eliminated when the TM 9808 is incorporated.

The circuit employs semi-conductor devices in a stabilizing configuration for which the reverse-breakdown voltages of two Zener diodes combine to serve as reference potential.

Voltage Setting Instructions

Unit type TM 9808 is normally supplied set for 200/250 volts mains operation. To change voltage setting for 100/125 volts operation proceed as below.

(i) Before connecting supply, remove the four screws referenced 'A' in Fig. 1 and raise top plate which is joined by two wires to the internal circuit.

(ii) The 'mains link' (Refer. Fig. 2) should be soldered in position 'b' for 100/125 volts operation (position 'a' for 200/250 volts operation).

(iii) When mains link' is appropriately positioned replace and secure top plate.

To install, fit the TM 9808 into the battery compartment of the oscillator and clip the battery connectors to the appropriate mating plugs and sockets on the top plate of the mains unit. Providing both battery connectors are clipped to the mains unit, their positions are interchangeable; i.e. it makes no difference which battery connector mates with either plug-and-socket pair.

Maintenance

Note: Disconnect mains supply before removing top plate or wrap.

Fuse: A 250mA fuse (FS1 in Fig. 3) is provided below the top plate (Refer. Fig. 2).

Removal of Wrap: Should it be necessary to gain access to the interior of the unit, withdraw the six screws referenced A and B in Fig. 1, raise and tilt top plate and lift off wrap via top of unit.

Do not remove screws from the base.

SPECIFICATION			
Input	100/125 volts or 200/250 volts at 40/60 Hz		
Consumption	Approx. 5 watts.		
Output	15-17 volts d.c. Max. current 50mA.		
Output Impedance	Typically 10 Ω.		
Weight	Approx. 1½ lb. (0·68 kg).		
DIMENSIONS	Length 5 1/32 in 12·8 cm	Width 2 in 5 cm	Height 3 in 7·6 cm

CONNECTIONS

(i) Input (mains cable):
Red core: mains live
Black core: mains neutral
Green core: earth

(ii) Output:
Inner plug: Positive
Outer socket: Negative
Outer plug: } Connected
Inner socket: } together

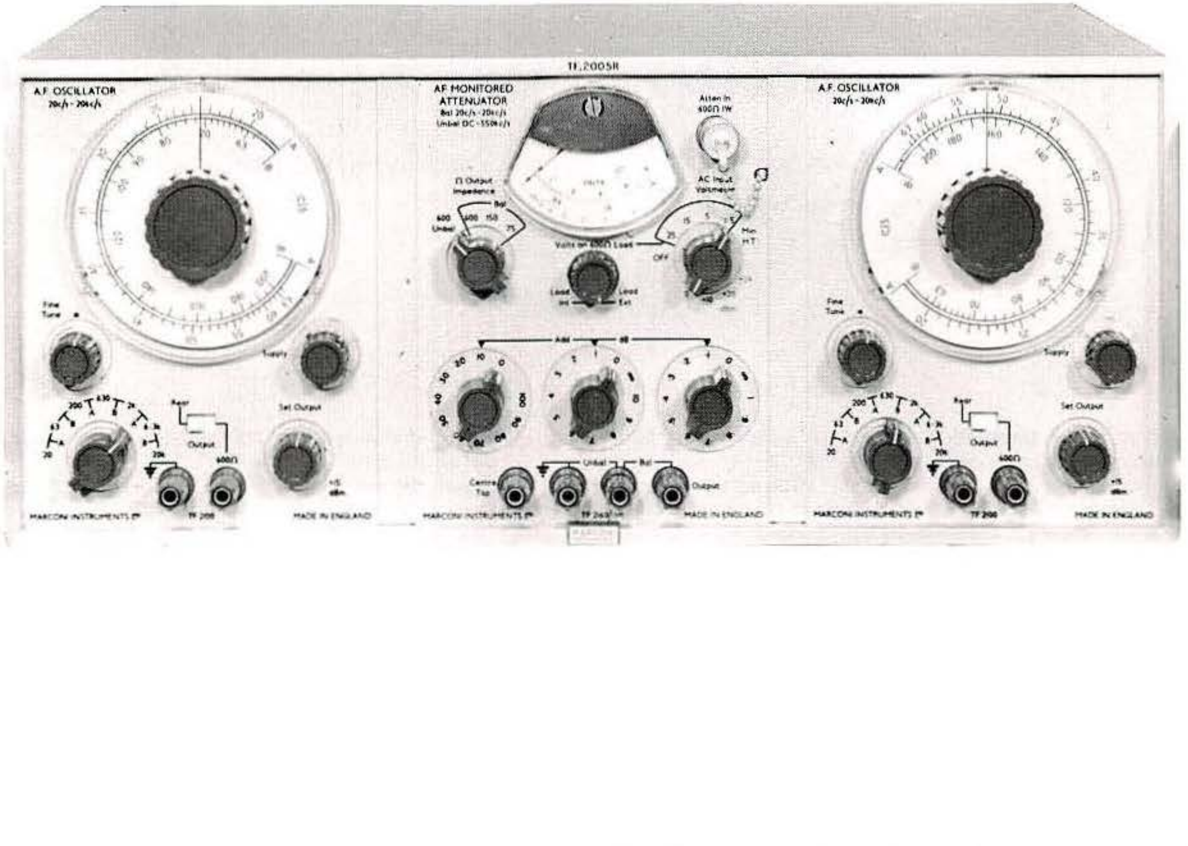
Refer to Fig. 2.

CONNECTORS

The TM 9808 is designed to unite with two connector strips as used for Vidor batteries type VT9 (or equivalent).

Two-Tone Signal Source

- ☐ Two identical oscillators covering 20 Hz to 20 kHz
- ☐ Less than 0·1% distortion
- ☐ For intermodulation measurements on high quality a.f. equipment

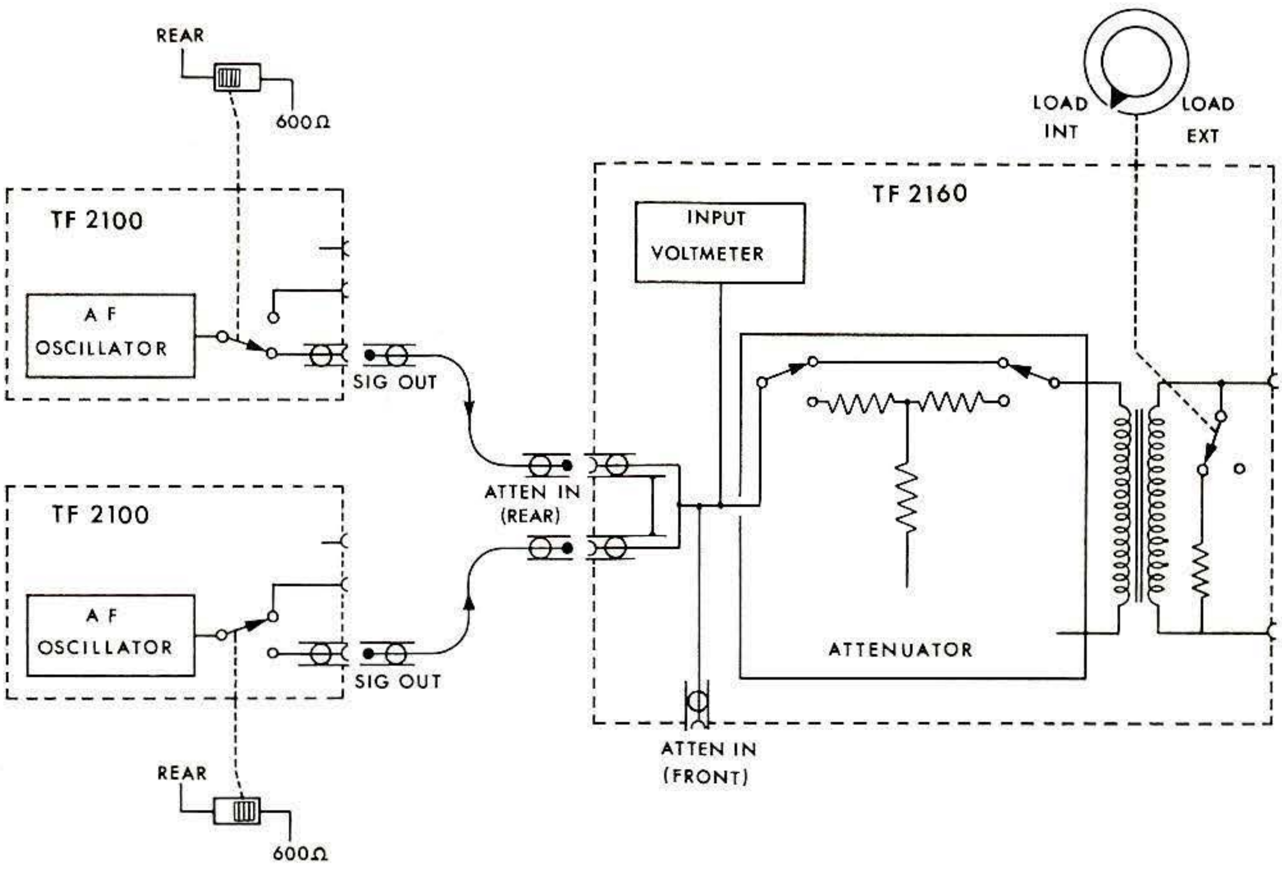


In certain types of a.f. amplifying or transmission equipment intermodulation distortion produced by non-linearity is more important than the harmonic distortion. Standard methods of measurement of inter-modulation distortion have, therefore, been recommended by S.M.P.T.E. and C.C.I.F. The TF 2005 Two-Tone Signal Source is an assembly of standard Marconi modular units arranged to form a convenient test set for measurements following these recommendations.

The instrument comprises two A.F. Oscillators type TF 2100 and an A.F. Monitored Attenuator type TF 2160/1 mounted together in a standard Marconi full-module case. Attenuator type TF 2160/1 is a special version of the A.F. Monitored Attenuator TF 2160, and differs from the standard instrument only in that it has two rear coaxial inlets which are connected in parallel to take the outputs from the two a.f. oscillators. The frequency of each oscillator is, of course, indicated on its own calibrated dial. Output levels are set up by temporarily isolating each oscillator in turn from the monitor—by means of the front panel switch—while the output level of the other is being checked. The overall amplitude of the composite signal is adjusted by means of the attenuator controls.

For general purpose applications either oscillator can be used singly with the attenuator to form an A.F. Signal Source having the same specification as the Marconi TF 2000. Or, of course, the a.f. output can be drawn directly from either oscillator separately.

The full technical specifications of the units comprising the TF 2005 are given in the appropriate data sheets; and the accompanying specification gives only those performance features which are applicable to the two-tone function.



	The complete equipment comprises two A.F. Oscillators TF 2100 and one A.F. Monitored Attenuator TF 2160/1.
Frequency Range	20 Hz to 20 kHz in six bands. (Each oscillator can be adjusted independently.)
Amplitude	*Reference Level:* Up to +10 dBm from each oscillator.
	Attenuator Range: 111 dB in 0·1 dB steps.
Harmonic Distortion	Less than 0·05% between 63 Hz and 6 kHz when using unbalanced output.
	Generally less than 0·1% under other conditions.
Intermodulation	Below −80 dB with respect to the wanted signal.
Hum	Below −80 dB with respect to the wanted signal.

POWER REQUIREMENTS	
A.C. Supply	95 volts to 130 volts a.c. or 190 volts to 260 volts a.c. 45 Hz to 500 Hz; or 105 volts to 130 volts a.c. or 210 volts to 260 volts ac.. 500 Hz to 1,000 Hz; 14 VA.
D.C. Supply	65 volts to 90 volts d.c.; load 60 mA.
ACCESSORIES	
Supplied	
TM 6958	Signal leads for coupling the oscillators to the Attenuator. (Two)
TM 7052	Mains Lead.
TM 7053	H.T. Lead.
	ASSOCIATED INSTRUMENT
TF 2330	Wave Analyser.

Double Pulse Generator

- ☐ Single or double pulse output
- ☐ Pulse width variable from 100 nsec to 10 msec
- ☐ Repetition frequency variable up to 2 MHz
- ☐ 10 nsec rise time

This instrument is a general purpose pulse generator capable of delivering positive or negative double-pulse waveforms at any repetition frequency up to 2 MHz, or single pulse waveforms at any frequency up to 2·5 MHz. Pulse duration is continuously variable from 0·1 μsec to 10 msec; and the output pulse amplitude is variable from zero to 20 volts e.m.f.

Internal or external triggering may be used. The internal trigger source frequency is adjustable over the range 2·5 Hz to 2·5 MHz by means of a concentrically mounted variable control and range switch. External triggering can be effected by application of a sine, square, or pulse waveform to the *Ext. Input* socket. The associated input circuit is d.c. coupled, so that the pulse generator may be triggered from isolated transients or at any frequency from zero to the maximum for the pulse mode used. Single cycles of the pulse waveform can also be triggered manually by means of a panel mounted push-button switch.

In addition to the main output waveform the instrument delivers a positive or negative pre-pulse from a separate socket. In the single-pulse mode, the delay between the pre-pulse and the main output pulse is continuously variable from 0·1 μsec to 10 msec. In the double-pulse mode, however, the delay between the pre-pulse and the first leading edge of the double pulse is fixed—nominally at 50 nsec, the variable delay controls being utilised to determine the interval between the leading edges of the double-pulse pair.

Stability of operation is ensured by the use of silicon semiconductor devices throughout; and careful attention in the design has been given to ease of operation and serviceability. Each main control comprises a concentrically mounted range switch and continuously variable element, giving a high degree of discrimination with simplicity of indication.

The instrument is housed in an easily detachable case, the front and rear panels forming part of the main chassis. The unit is fitted with an adjustable stand, which can also be used as a carrying handle.

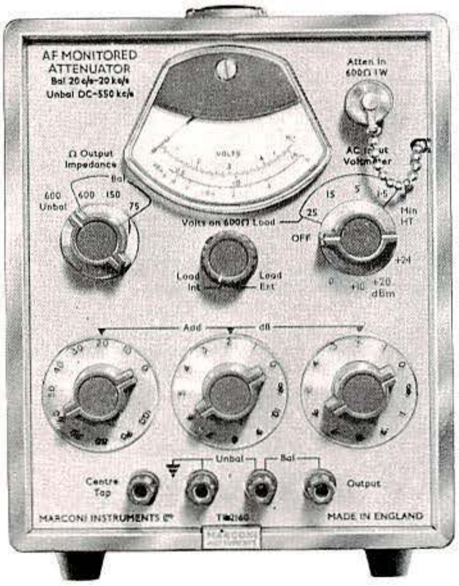
MAIN PULSES	
Polarity	Switch selected positive or negative.
Amplitude	Six ranges: 0– 0·5 volts e.m.f. 0– 1 volt e.m.f. 0– 2 volts e.m.f. 0– 5 volts e.m.f. 0–10 volts e.m.f. 0–20 volts e.m.f. Accuracy: 0·5 and 1 volt ranges ±10% other ranges ± 5%
Rise and fall times (10% to 90%)	Leading edge: 10 nsec. Trailing edge: 15 nsec.
Duration	100 nsec to 10 msec in five decade ranges. Continuously variable within each range. Accuracy: 5% at extremities of scale; 10% at intermediate points.
Output Impedance	100Ω on 20 volt amplitude range. 50Ω on all other ranges.
DELAY	
Range	100 nsec to 10 msec in five decade ranges. Continuously variable within each range. Accuracy: 5% at extremities of scale; 10% at intermediate points.
Single pulse mode	Main pulse delayed with respect to prepulse by *Delay* control setting plus fixed delay of (typically) 50 nsec.
Double pulse mode	First leading edge delayed with respect to prepulse by fixed time of (typically) 50 nsec. Second leading edge delayed with respect to first leading edge by *Delay* control setting. Minimum delay 200 nsec.

PRE-PULSE	
Polarity	Switch selected positive or negative (output a.c. coupled).
Amplitude	7·5 volts ± 2·5 volts e.m.f.
Duration	Between 100 and 250 nsec.
Output Impedance	Not greater than 1 kΩ.
TRIGGER SIGNALS	
Mode	Selected by *Frequency* switch: *Internal, External + or –, Manual.*
Internal	Frequency: 2·5 Hz to 2·5 MHz in six decade ranges. Continuously variable within each range. Accuracy: 2·5 Hz to 25 Hz, ±15%; other ranges, 5% at extremities of scale, 10% at intermediate points. Max. for double-pulse mode: 2 MHz.
External	Frequency: d.c. to 2·5 MHz single-pulse, d.c. to 2 MHz double-pulse. Waveform: Sine, Square, Pulse. Amplitude: 3 volts to 50 volts peak. Trigger Level: 3 volts positive or negative. Min. Pulse Width: 100 nsec. Input Impedance: approx. 10 kΩ.
POWER REQUIREMENTS	100 to 125 volts and 200 to 250 volts, 50 to 60 Hz, 35 VA.
DIMENSIONS AND WEIGHT	Height 4 in. (10 cm.) Width 14¼ in. (36 cm.) Depth 10½ in. (27 cm.) Weight 12 lb. (5·5 kg.)

- ☐ Three models for a.f./m.f.
- ☐ Steps of 0·1 dB
- ☐ Steps of 1 dB

AF Monitored Attenuator TF 2160

The basis of these attenuators, TF 2160, TF 2161 and TF 2162 is the resistive pad in tee or pi form, and the variety of facilities available suits numerous applications. The three models employ the same basic attenuator system. This comprises three switches, each with four symmetrical 600 Ω T-pads which are switched in series combinations to make one decade, and the three decades in series cover 111 dB in 0·1 dB increments, nominally up to 1 MHz.



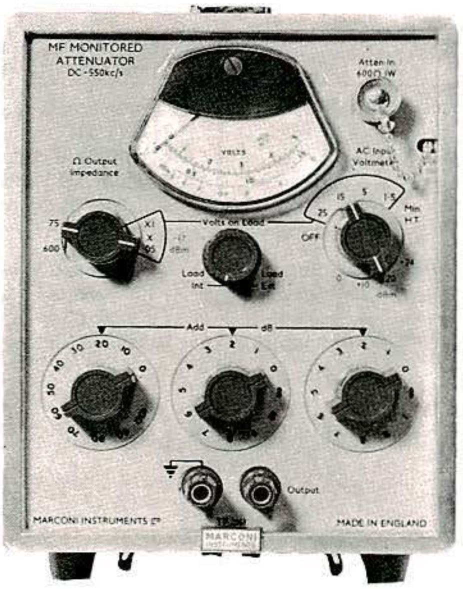
The TF 2160 combines the attenuators with a wide-range a.c. voltmeter and a high quality a.f. transformer so that accurate measurements can be made in the audio band. Without the transformer in circuit the operating range extends up to 550 kHz, and without the voltmeter to d.c.

IMPEDANCE		
	Input	600 Ω unbalanced, when terminated with 600 Ω, 150 Ω or 75 Ω. Switched terminating resistor is incorporated.
	Output	600 Ω unbalanced, or 600 Ω, 150 Ω or 75 Ω balanced and centre-tapped when 600 Ω source is connected.
FREQUENCY RANGE		
	Unbalanced output	D.C. to 550 kHz.
	Balanced output	20 Hz to 20 kHz.
ATTENUATION		
	Range	0 to 111 dB in 0·1 dB steps, and ∞
	Maximum input	+30 dBm or 1 watt or 25 volts into 600 Ω.
	Minimum attenuation	Less than 0·01 dB.
	Accuracy	*Unbalanced output:* ±1% of dB setting ±0·01 dB, at d.c.; ±2% of dB setting ±0·2 dB, at 550 kHz. *Balanced outputs:* ±1% of dB setting ±0·2 dB, between 20 Hz and 20 kHz.
INPUT VOLTMETER		
	Ranges	Four switch positions selecting 1·5–5–15–25 volts f.s.d. or 0 dBm, +10 dBm, +20 dBm and +24 dBm.
	Meter	Three scales: 0 to 1·5 and 0 to 5 volts, and −6 to +6 dBm.
	Accuracy	±5% of f.s.d. between 20 Hz and 550 kHz.
OUTPUT FREQUENCY RESPONSE		Within ±0·2 dB between 20 Hz and 20 kHz; within ±1 dB between 20 Hz and 550 kHz; with constant input voltmeter reading.
POWER REQUIREMENTS		
	Internal batteries	8 volts d.c., 2 mA.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
7 in	5 in	10 in	18 lb
19·5 cm	14·5 cm	27 cm	8·2 kg

MF Monitored Attenuator TF 2161



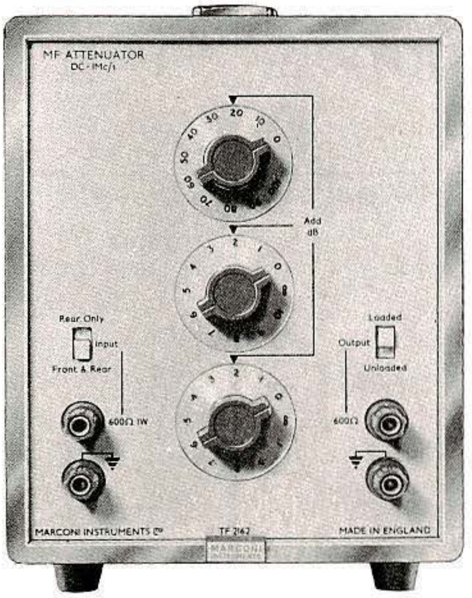
The TF 2161 also has the a.c. voltmeter, but incorporates an impedance-changing pad for 75 Ω in place of the transformer, and is usable with monitored levels over full frequency range of the voltmeter, or at d.c. without the voltmeter.

IMPEDANCE	
Input	600 Ω unbalanced, when terminated with 600 Ω or 75 Ω. Switched terminating resistors are incorporated.
Output	600 Ω or 75 Ω unbalanced, when 600 Ω source is connected.
FREQUENCY RANGE	D.C. to 550 kHz.
ATTENUATION	
Range	600 Ω output: 0 to 111 dB in 0·1 dB steps and ∞ 75 Ω output: 17 to 128 dB in 0·1 dB steps, and ∞
Maximum input	+30 dBm or 1 watt or 25 volts into 600 Ω
Minimum attenuation	600 Ω output: Less than 0·01 dB. 75 Ω output: 17 dB ±0·2 dB.
Accuracy	±1% of dB setting ±0·01 dB, at d.c. ±2% of dB setting ±0·2 dB, at 550 kHz.
INPUT VOLTMETER	
Ranges	Four switch positions, selecting 1·5–5–15–25 volts f.s.d. or 0 dBm, +10 dBm, +20 dBm, and +24 dBm.
Meter	Three scales, 0 to 1·5 and 0 to 5 volts, and −6 to +6 dBm.
Accuracy	±5% of f.s.d. between 20 Hz and 550 kHz.
OUTPUT FREQUENCY RESPONSE	Within ±0·2 dB between 20 Hz and 20 kHz; within ±1 dB between 20 Hz and 550 kHz: with constant input voltmeter reading.
POWER REQUIREMENTS	
Internal batteries	8 volts d.c., 2 mA.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
7 in	5 in	10 in	10 lb
19·5 cm	14·5 cm	27 cm	4·5 kg

MF Attenuator TF 2162



The TF 2162 employs only the three decade switches, and has an internal terminating resistor for use when working into high impedance loads.

IMPEDANCE	
Input	600 Ω unbalanced, when terminated with 600 Ω. Switched terminating resistor is incorporated.
Output	600 Ω unbalanced, when 600 Ω source is connected.
FREQUENCY RANGE	D.C. to 1 MHz.
ATTENUATION	
Range	0 to 111 dB in 0·1 dB steps, and ∞
Maximum input	+30 dBm or 1 watt or 25 volts into 600 Ω.
Minimum attenuation	Less than 0·01 dB.
Accuracy	±1% of dB setting ±0·01 dB, at d.c. ±2% of dB setting ±0·2 dB, at 1 MHz.

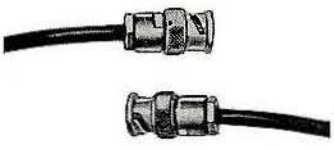
DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
7 in	5 in	10 in	6 lb
19·5 cm	14·5 cm	27 cm	2·8 kg

ACCESSORIES

Supplied		Shielded Adapter, type TB 39868. Coaxial Free Plug, type L 1465/FP/Ag.
Optional	TM 7010	Rack-mounting Case.

Connecting Cables



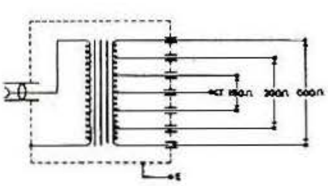
BNC Plugs

TYPE No.	DESCRIPTION	SUITABLE FOR
TM 4726/136	75 Ω Coaxial Lead, 36 in long with BNC plug at each end.	Output connection from TF 1370A. Can also be used in conjunction with Shielded Adapter TB 39868 for TF 2000 series instruments.
TM 4969	Coaxial Cable, 42 in long with BNC plug at each end.	Can be used in conjunction with Shielded Adapter TB 39868 for TF 2000 series instruments.
TM 4969/1	Coaxial Cable, 72 in long with BNC plug at each end.	

Shielded Adapter

TB 39868	Mates with output terminals of oscillators and signal sources in the TF 2000 series to provide a BNC socket connection.	

Matching Transformer



TM 6221	600 Ω unbalanced input; 600, 200, and 150 Ω balanced output. **Input connectors:** BNC plug **Output connectors:** Spring terminals	TF 1370A TF 1101

Attenuator Pad

TM 6454	X100 Attenuator Pad. **Impedance: Input:** 75 Ω **Output:** 75 Ω and 5 Ω BNC input and output connectors.	TF 1370A

Voltage and Power Meters

Voltage and Power Meters

Electronic Voltmeters

Electronic voltmeters come in two basic forms, which may be classified as a.c. amplifier types and d.c. amplifier types.

In the a.c. amplifier form, the voltage to be measured is applied directly to the input terminals of a wide-band gain-stabilised amplifier, whose output is rectified and applied to a moving coil meter. In the d.c. amplifier form, the input voltage is applied directly to a diode detector, and the resulting d.c. is amplified and monitored.

It is generally accepted that the a.c. amplifier type is usually the more sensitive of the two, but the usable frequency range is restricted by the amplifier bandwidth.

The d.c. amplifier configuration permits voltage measurement up to frequencies approaching the resonance of the diode unit. Sensitivity, however, is restricted by the linearity of the diode and the stability of the d.c. amplifier. The first of these limitations is relieved considerably by the use of semiconductor diodes, which maintain their low forward resistance down to very small voltage levels. High gain d.c. amplification is obtained by the use of an a.c. coupled amplifier in conjunction with a chopper and synchronous detector. This system is used in the TF 2603 R.F. Millivoltmeter, achieving a sensitivity comparable with that of the a.c. amplifier types, but at frequencies from 50 kHz to 1·5 GHz.

Diode Detectors

The types of detector used in electronic voltmeters normally deliver a d.c. output which is proportional to either the half-cycle average voltage or the peak voltage of the a.c. input.

Average Voltage Detectors The basic form of an average-voltage detector is shown in Fig. 1. Diode D_1 conducts during positive part of the cycle only, and providing the value of R_1 is high compared with the forward resistance of the diode, the voltage waveform appearing across R_1 must be a facsimile of the positive part of the input waveform.

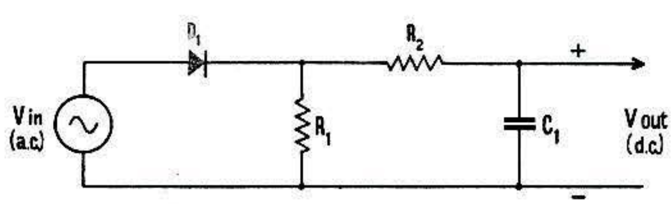


Fig. 1 Average Detector.

The d.c. component of this waveform is the average voltage of the positive portion of the cycle multiplied by the fraction of complete cycle that it occupies. This fraction would, of course, be half for a symmetrical input waveform such as a sine wave; and the terms positive or negative half cycle are usually used regardless of the symmetry of the waveform.

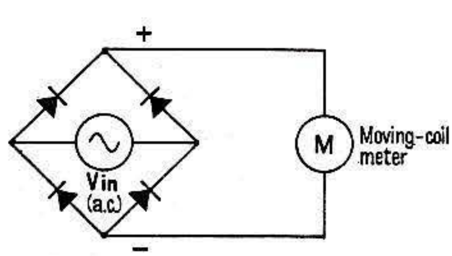


Fig. 2 Meter Rectifier.

The most common form of average detector in electronic instruments is the bridge rectifier connected directly to the meter, as shown in Fig. 2. Here the meter resistance takes the place of R_1 and the full-wave rectifier conducts during both the positive and the negative half cycle. The system is current (not voltage) sensitive, and the d.c. level is thus equal to the sum of average currents in the two half cycles. It is perhaps an academic point that this is not the same as the mean current (or voltage) over the whole cycle, which must be equal to zero in a purely a.c. waveform. As the moving coil meter responds only to the d.c. component, there is no need for any additional filtering.

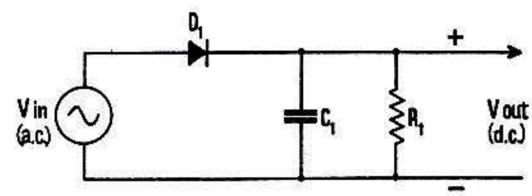


Fig. 3 Peak Detector (series configuration).

Peak Voltage Detectors. Fig. 3 shows the basic form of a series-diode peak voltage detector. For efficient operation it is essential that the time constant $T = C_1R_1$ is high compared with the a.c. waveform period. When the input voltage initially goes positive D conducts, and C_1 is charged to the positive peak potential. As soon as the input voltage begins to decrease the diode cuts off, and remains in the non-conducting condition until the input voltage again approaches its positive peak value on the next cycle.

By this time a small fraction of the charge on C_1 will have leaked away via R_1, so that the voltage across C_1 will be less than V_{peak} by $V_{peak}\ e^{-t/T}$. Immediately the rising input voltage reaches this value $[V_{peak}\ (I - e^{-t/T})]$ the diode will conduct, and capacitor C_1 will again charge to the positive peak voltage. So, providing the leakage between positive peaks is small, V_{out} will be very nearly equal to the positive peak voltage.

The rearrangement of the detector circuit in Fig. 4. is really nothing more than the transfer of R_1 to a position in parallel with the diode. If the mean voltage at the input is zero, the voltage across the diode must be equal to the voltage across the capacitor, so that V_{out} may be taken across either.

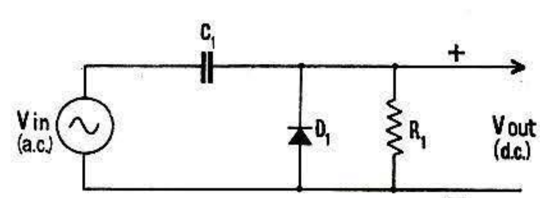


Fig. 4 Peak Detector (parallel configuration).

In the configuration of Fig. 4 the diode conducts initially when the input voltage goes negative, and C_1 charges to the negative peak voltage. Immediately the input voltage begins to go positive the diode cuts off so that the voltage across R_1 is equal to the instantaneous input voltage plus a d.c. voltage equal to the negative peak of the a.c. A voltage waveform thus appears across

R_1 comprising the input waveform with an added d.c. component equal to the negative peak voltage but inverted to give a positive voltage output. The a.c. component of this waveform is filtered out by the subsequent circuitry.

As d.c. amplifier type electronic voltmeters normally employ peak detectors as the input circuits, the input resistance of this form of detector assumes added importance. Owing to the high frequency application of this type of voltmeter it is usual to define the input resistance as $V_{r.m.s.}/I_{r.m.s.}$, which is the effective loading that the voltmeter presents to a tuned circuit. The specified input resistances of M.I. voltmeters TF 2604 and TF 2603 conform to this definition.

Theoretically, with the series circuit this resistance is equal to $R_1/2$ if it is assumed that V_{out} (d.c.) is equal to V_{in} (peak). It can be reasoned that, if the d.c. voltage developed across R_1 of Fig. 3 is equal to the peak a.c. input voltage, the power in R_1 is equal to V^2_{peak}/R_1. This is the power drawn from the source, and must, therefore, be equal to $V^2_{r.m.s.}/R_{in.}$ For a sinewave $V^2_{peak} = 2V^2_{r.m.s.}$, so that $R_{in.} = R_1/2$.

With the arrangement shown in Fig. 4, however, R_1 is also connected directly across the source so that a.c. power is also dissipated in this resistor. This is equivalent to connecting the value of R_1 in parallel with the input resistance as derived for Fig. 3. So the effective input resistance of Fig. 4. is theoretically $R_1/3$.

Nevertheless, the parallel-diode configuration is by far the more suitable for use with electronic voltmeters because the d.c. discharge path is independent of the source, and the detector is not affected by a d.c. component in the input voltage. In practice the value of R_1 can be made sufficiently high to give a low-frequency input resistance of several megohms; but, as the frequency is increased, absorption paths in the diode probe unit reduce the effective input impedance considerably.

The above reasoning is valid for the practical case of measurement across tuned circuits; but when the voltmeter is connected across a resistive source the input resistance, as it affects the measurement, must be assessed rather differently. Assuming the source to be an e.m.f., E, in series with resistance R_s, the effective input resistance would be derived from the expression

$$V_{ind.} = E.R_{in}/(R_{in} + R_s)$$

where R_{in} is the effective input resistance, R_s is the source resistance, $V_{ind.}$ is the indicated voltage, and E is the source e.m.f., so that $R_{in} = \dfrac{R_s}{E/V_{ind.} - 1.}$

The indicated voltage is less than the peak e.m.f. by the p.d. across the source resistance and the forward resistance of the diode during the charging time of capacitor C_1. This charging time covers a part of the cycle very nearly symmetrical about the peak voltage, and it can be defined in angular terms as $\pm\theta$, so that $V_{ind.} = E.\cos\theta$, and $V_{ind.}/E = \cos\theta$.

But θ is dependent on the ratio between the total source resistance (including the diode) and the load resistance (R_1) as given in the following expression

$$\frac{Rs}{R_1} = \frac{\tan\theta - \theta}{\pi}$$

As R_1 is likely to be several megohms the source resistance for significant error would normally be high enough to make the diode resistance negligible, and the effective input resistance is therefore a non-linear function of the source resistance. It has been shown by Scroggy (Wireless Engineer Feb. 1955) that for a 2% error due to the resistance of the source under test, the ratio R_s/R_1 should not exceed 0.001. A ratio of 0.01 would give about 10% error, and a ratio of 0.1 would give about 40% error.

In this context the value of R_1 can be taken as roughly three times the specified low frequency input resistance.

R.M.S. Voltage and Mean Power

All Marconi Instruments voltmeters are scaled in terms of r.m.s. voltage assuming a sinusoidal input waveform. When distortion is present there will be a theoretical error. For low-order harmonics up to about 10% distortion factor the error introduced in an average-voltage detector (as used in TF 2600) is less than the normal accuracy claims of the voltmeter. With peak-voltage detectors the error depends on the relative phase of the fundamental and the harmonics. Maximum error occurs when the peaks of the harmonics coincide with the peaks of the fundamental; and the magnitude of the error is then roughly equal to the distortion factor when this does not exceed 10%.

The instantaneous power dissipated in a load is proportional to the square of the instantaneous current or voltage; i.e., V^2/R or I^2R. So the power is always positive and varies from zero to its peak value and back to zero once every half cycle of the voltage or current waveform. The average or mean power over each complete cycle of the voltage or current waveform is obviously half the sum of the mean powers in the two half cycles; and, if the waveform is symmetrical (e.g., a sinewave), the mean power is, of course, equal to that in a single half cycle.

Dividing or multiplying this mean power by the load resistance gives the square of the effective current or voltage respectively; i.e., the mean square current or voltage. So the effective current or voltage is the square root of this mean value. Hence the abbreviation r.m.s., for ROOT of the MEAN of the SQUARE.

It is clear then that the initials r.m.s. are applicable only to voltage or current, and that to write or speak of r.m.s. power or so many watts r.m.s. is pure nonsense.

Figure 5 shows the principle applied to a sine wave. The V^2 curve takes the form of a cosine wave in which zero corresponds to the negative peaks. It is, in fact, a $\sin^2$ curve, for $\sin^2\theta = \frac{1}{2}(1 - \cos^2\theta)$. It is obvious from inspection that the mean value of V^2 is equal to 1/2 (i.e., half the peak-to-peak value), because the portion of the waveform below this level is an exact facsimile of the portion above it. Thus the r.m.s. value of a sine wave voltage of current is $\sqrt{1/2}$ times its peak value; i.e., E_{peak} or $I_{peak} \times 0{\cdot}707$.

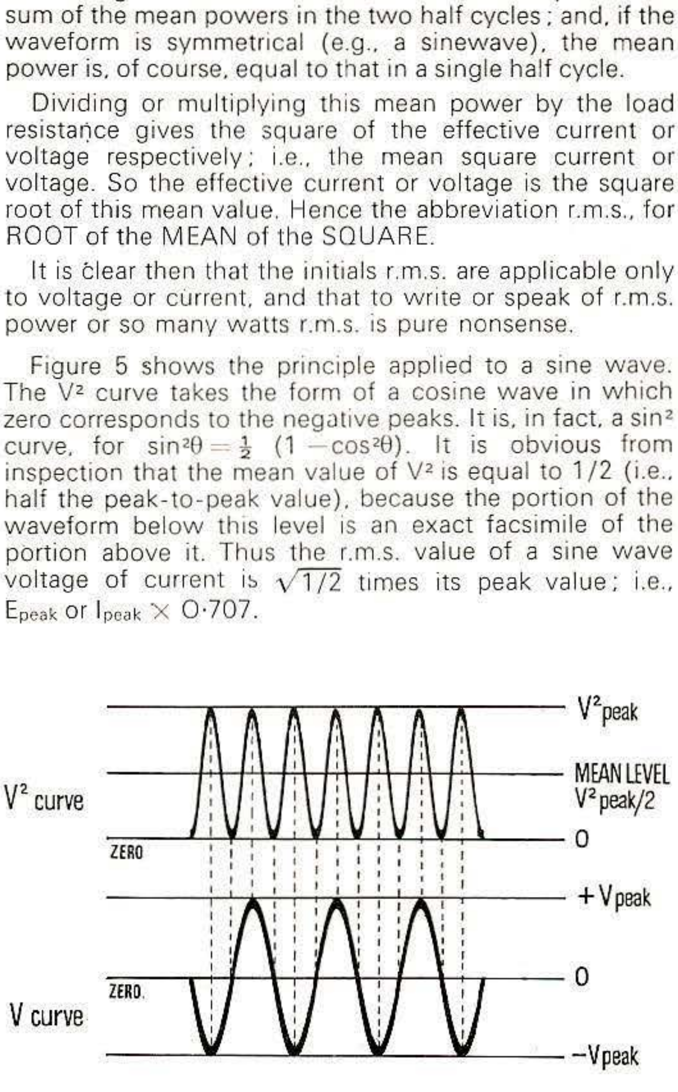


Fig. 5 Sinewave voltage and power waveforms.

R.F. Power Measurement

For accurate assessment of a transmitter's output power it is necessary, not only to monitor the actual power being delivered, but also to load the transmitter's output circuit correctly. The absorption type power meter fulfils both of these requirements, and is the generally accepted measuring instrument for testing and setting up transmitter output stages.

Providing the loading is truly resistive, the dissipation can be determined accurately by measurement of the current in the load or the voltage across the whole or part of the load. In order to avoid errors when measuring non-sinusoidal waveforms it is, obviously, important to monitor the voltage or current with a true r.m.s. indicator, such as the thermocouple system used in M.I. r.f. power meters. This type of monitor indicates true mean power, independent of waveform or frequency up to the high frequency limit of the instrument.

On early power meters the thermocouple unit used was a conventional vacuo-junction, which is a satisfactory r.f. to d.c. conversion unit in most ways, but has the disadvantages that its shape and dimensions preclude its use directly in a coaxial system, and the inductance of its heater (albeit small) is sufficient to cause irregularities in the meter response with frequency. It is clearly impossible to include the vacuo-junction type of thermocouple in the main r.f. current path. So it was connected as a voltage monitor across a small part of the resistive r.f. load, as shown in Fig. 6(a).

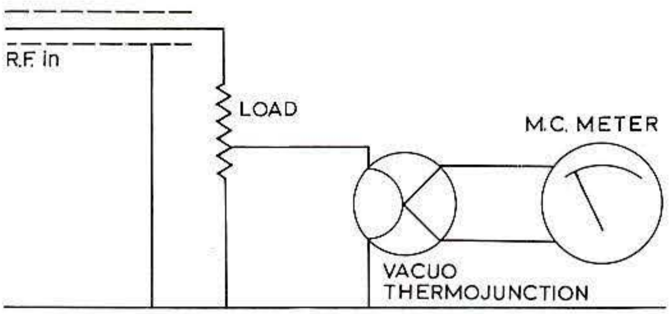


FIG 6(a)

With the introduction of new techniques and materials, a new generation of r.f. power meters has been developed utilising a coaxial thermocouple unit, whose heater element forms part of the input feeder to the r.f. load as shown in Fig. 6(b). With this improved design the characteristic impedance of the input feeder is sensibly free from discontinuity, so that negligible resonance effects occur and a good v.s.w.r. is maintained at all frequencies up to 1 GHz.

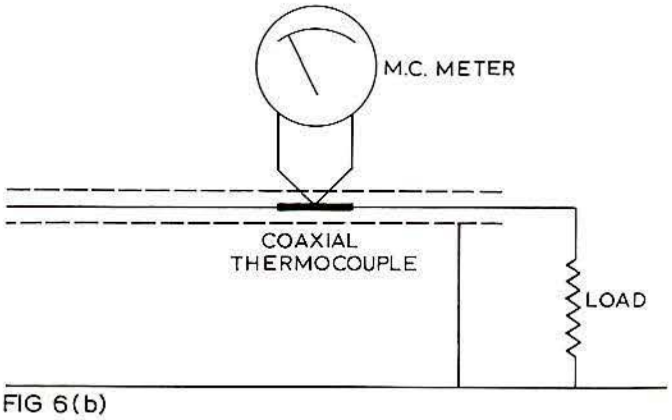


FIG 6(b)

These new power meters also employ load resistor units of sophisticated design, which permits high dissipation with small physical dimensions.

Transmitter Power Measurement. The mean power of an amplitude modulated signal is a function of modulation depth and also of the modulation waveform. From a knowledge of the power in the carrier, however, the output power in all modulated conditions is easily calculable. So it is normal to measure the output power of an a.m. transmitter in the unmodulated condition, with possible additional checks with sinewave modulation at known depth (see *Useful Data*, Power Methods of A.M. Depth Measurement).

Such procedure is not possible with single sideband transmitters for the obvious reason that without modulation the output power is zero. If the output level were limited entirely by voltage overload the maximum power output would be that resulting from single tone modulation at the maximum peak amplitude obtainable without distortion. In some cases, however, this continuous power level would overload the transmitter's output stages, and the limiting level is difficult to determine, even when the r.f. sideband waveform is examined, because the distortion components are filtered by the tuned output circuit.

Power output of an s.s.b. transmitter is, therefore, usually measured using a two tone modulating signal, giving an output waveform as shown in Fig 7(a). Limiting is clearly evident from an oscilloscope display, the shape of the envelope becoming distorted as shown in Fig. 7(b).

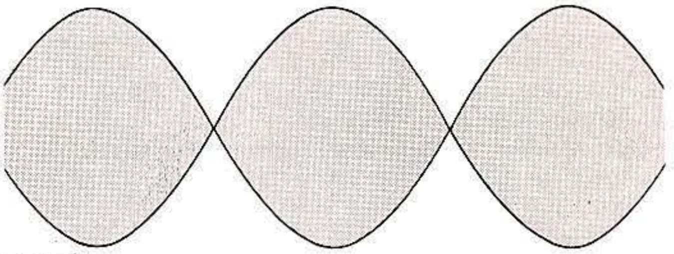


FIG 7(a)

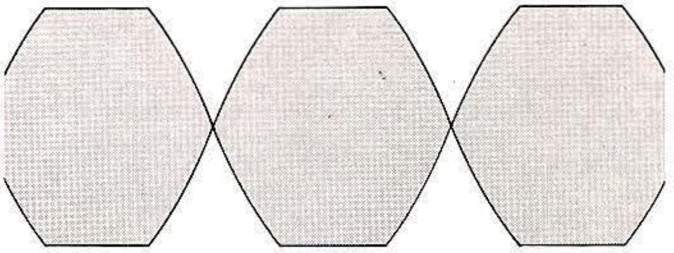


FIG 7(b)

The mean r.f. power at the envelope peak is, of course equal to the mean power of a single-tone modulation signal having the same peak amplitude. This power level is known as the peak-envelope power (p.e.p.), which is the standard method of expressing power output of an s.s.b. transmitter.

To assess the p.e.p., the mean power output is measured using a modulating signal comprising two equal amplitude sinewaves—usually 400 Hz and 1 kHz. This measured power is equal to half the p.e.p.

A.C. Electronic Voltmeters

Title and Type Number	A.C. Voltage Range	Frequency Range	Rack Mounting Kit	Pages
Sensitive Valve Voltmeter TF 2600	100 μV to 300 volts	10 Hz to 5 MHz	TM 7010/1M1	60–61
R.F. Electronic Millivoltmeter TF 2603	300 μV to 3 volts	50 Hz to 1·5 GHz	—	62–65
Electronic Voltmeter TF 2604	25 mV to 300 volts	20 Hz to 1·5 GHz	TM 7010/3M1	66–69
A.F. Power Meter TF 2500	1·5 to 150 volts	20 Hz to 1 MHz	TM 7010	78–79

D.C. Voltmeters

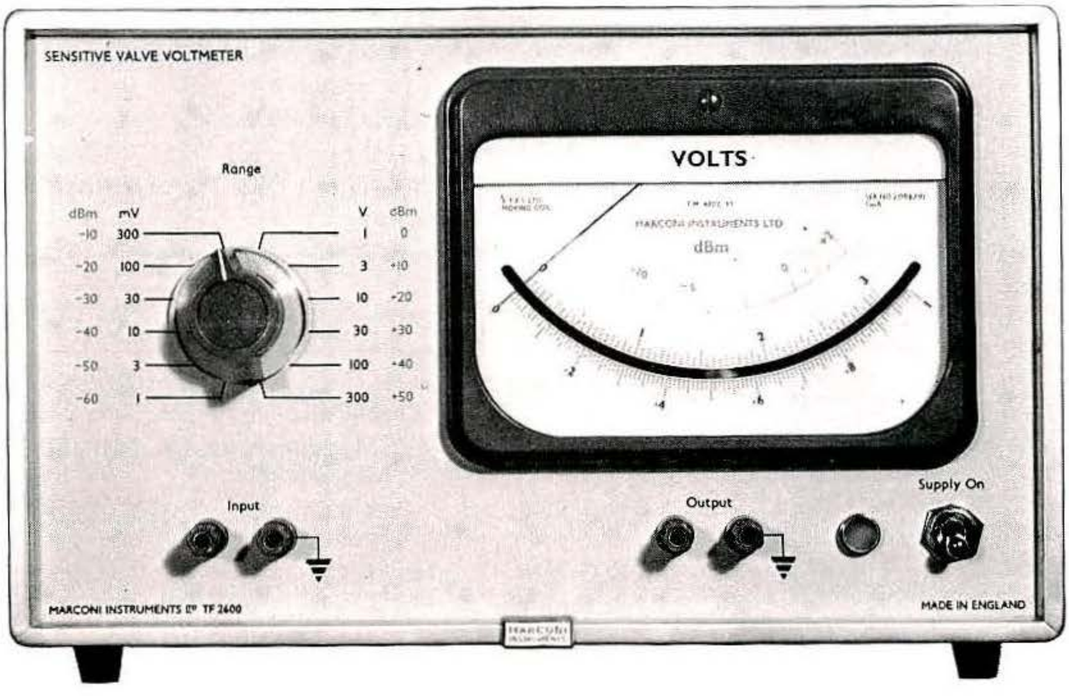
Title and Type Number	D.C. Voltage Range	Special Facilities	Rack Mounting Kit	Pages
Electronic Voltmeter TF 2604	10 mV to 1 kV	A.C. Measurement Ω Measurement	TM 7010/3M1	66–69
Differential D.C. Voltmeter TF 2606	0 to 1·1 kV	Potentiometric Measurement	TM 7010	70–71
Digital Voltmeter SM 523	0 to 1·2 kV	Fully programmable	—	74–75
Digital Voltmeter TF 2660	1 mV to 1 kV	—	—	72–73

Power Meters

Title and Type Number	Power Range	Frequency Range	Rack Mounting Kit	Pages
A.F. Power Meter TF 893A	0·1 mW to 10 watts	20 Hz to 35 kHz	—	76–77
A.F. Power Meter TF 2500	10 μW to 25 watts	20 Hz to 35 kHz	TM 7010	78–79
R.F. Power Meter TF 2501	0 to 3 watts	D.C. to 1 GHz	—	80
R.F. Power Meter TF 2502	0 to 10 watts	D.C. to 1 GHz	—	81
R.F. Power Meter TF 2503	0 to 100 watts	D.C. to 1 GHz	—	82

Sensitive Valve Voltmeter

- ☐ Twelve ranges: 1 mV to 300 volts f.s.d.
- ☐ Accuracy ± 1% up to 500 kHz
- ☐ Wide-band amplification up to 10 MHz



At the more commonly used frequencies in its range, voltage measurements are made with errors of less than 1% of full scale deflection with the aid of this voltmeter, and sufficient accuracy for many purposes is maintained up to 5 MHz or higher.

A four-stage amplifier operates at fixed gain, with the time constants of the successive inter-stage coupling and cathode bias circuits 'staggered', and compensated overall negative feed-back is applied via the meter rectifier system, so that a flat frequency response is maintained into the video range. The input signals pass either through a 1:1,000 voltage divider which is compensated for frequency and temperature, or directly, to a cathode follower stage whose cathode resistor is tapped so as to act as a second voltage divider. The two attenuators are selected by a single rotary switch, and the input to the cathode follower is limited to 300 mV, while that to the main amplifier does not exceed 1 mV, during measurements.

The last stage of the amplifier feeds the signal to the meter from its anode, but also acts as a cathode follower output stage for a separate output so that the instrument can be used as a wide-band amplifier up to 10 MHz with a maximum overall gain of 150, i.e., an output of 150 mV corresponds to full scale deflection on the meter. Neither damage to the instrument nor waveform limiting occur if 100% overload is applied.

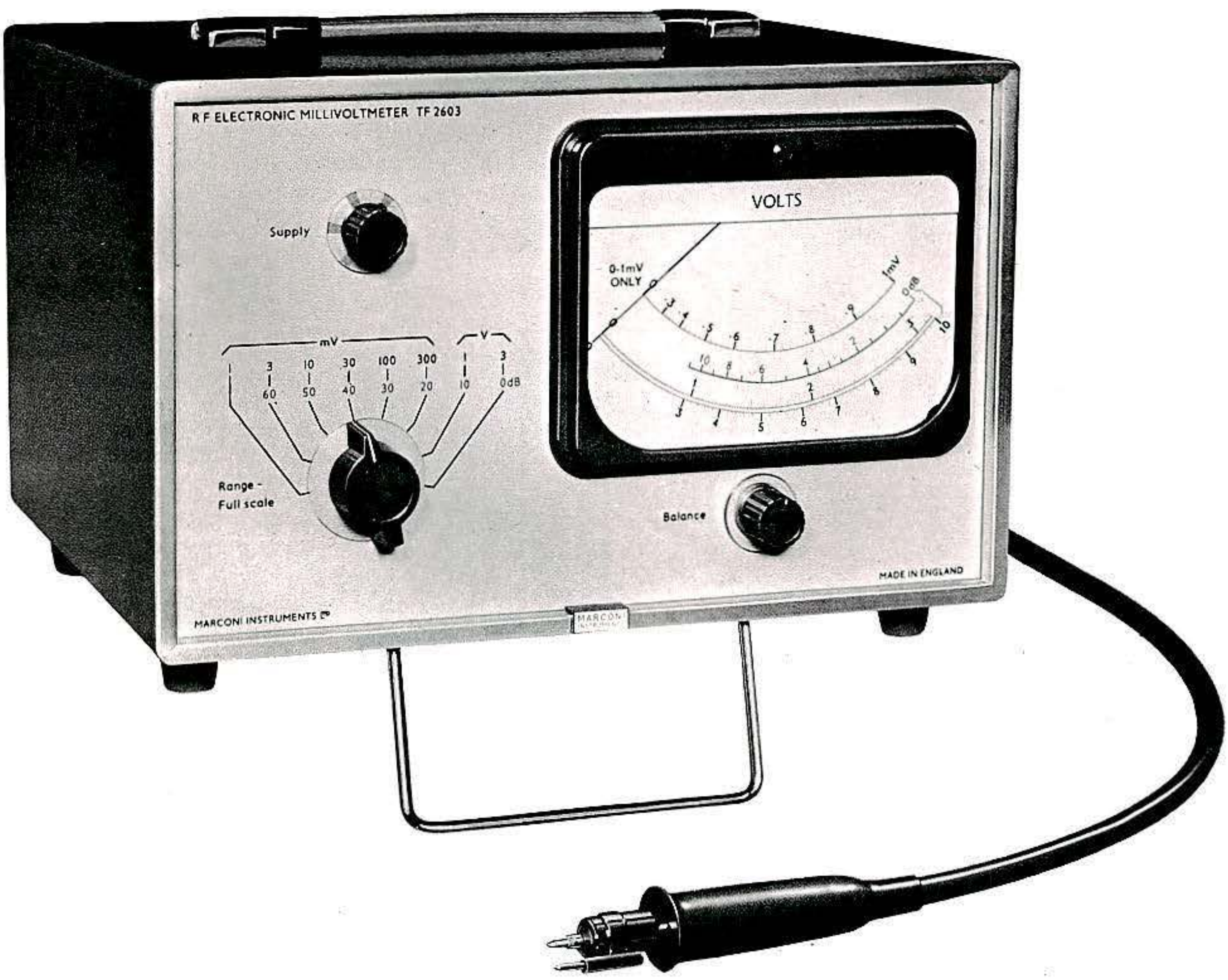
The 5-inch meter has an anti-parallax mirror, and a dBm scale as well as the two voltage scales, while the switch clearly indicates the multiplying factor.

Voltage or level measurements are made with remarkable ease and accuracy, and numerous applications will also be found for the instrument as a comparator, indicator, detector or pre-amplifier.

Measurement range	100 µV to 300 volts a.c., 10 Hz to 5 MHz, or up to 10 MHz uncalibrated, as detailed below.
A.C. VOLTAGE	
Twelve ranges	1–3–10–30–100–300 mV, and 1–3–10–30–100–300 volts f.s.d.
Accuracy and frequency response at 20°C	±1% of f.s.d. between 50 Hz and 500 kHz. ±2% of f.s.d. between 20 Hz and 50 Hz and between 500 kHz and 1 MHz. ±3% of f.s.d. between 1 and 2 MHz. ±5% of f.s.d. between 10 and 20 Hz. and between 2 and 5 MHz. *Temperature coefficient:* $2 \times 10^{-4}/°C$, up to 50°C (maximum ambient).
Stability	Between 50 Hz and 500 kHz the meter reading varies by less than ±0·2% for a change of ±10% in mains voltage. Additional error of less than ±1% of f.s.d. when input frequency is close to mains supply frequency.
Level	(In 600 Ω impedance). Twelve ranges between −72 and +52 dBm in 10 dBm steps.
Input conditions	*V ranges:* 10 MΩ with 16 pF in shunt. *mV ranges:* 10 MΩ with 30 pF in shunt.
Meter	*Two voltage scales:* 0 to 1 (100 divisions of 0·01); 0 to 3 (60 divisions of 0·05). *dBm scale:* −12 to +2 (14 divisions of 1 dBm). *Calibration:* In terms of r.m.s. value of a sine-wave, but responding to average value.
Wideband amplifier	*Frequency range:* 10 Hz to 10 MHz. (The response is approximately −6 dB at 10 MHz.) *Output:* With the meter reading f.s.d. the output is 150 mV; maximum outputs up to 300 mV can be obtained. *Output impedance:* 50 Ω.
POWER REQUIREMENTS	
A.C. mains	200 to 250 volts and 100 to 130 volts, 40 to 60 Hz, 75 watts.
DIMENSIONS AND WEIGHT	Height: 8 in, 20 cm; Width: 11½ in, 29 cm; Depth: 10½ in, 27 cm; Weight: 15 lb, 7 kg
ACCESSORIES Optional	
TM 8120/1	Probe Lead A low-capacitance coaxial cable assembly 42 ins. long with a test prod. It has a distributed shunt capacitance of approximately 35 pF.
TB 39868 (GE 51002)	Screened Adapter This plugs into the input terminals and has a BNC socket to which the Probe Lead may be connected.
TB 39867 (GE 51001)	As above but with a Type 83 socket.

R. F. Electronic Millivoltmeter

- ☐ Wide frequency range 50 kHz-1500 MHz
- ☐ High sensitivity: from 300 μV
- ☐ All solid state ensuring reliability



The TF 2603 is a highly sensitive, precision millivoltmeter for use at frequencies between 50 kHz and 1500 MHz. Reliability and freedom from microphony are assured by the use of semi-conductors throughout. Inherent noise within the instrument is low, enabling voltage measurements down to 300 µV r.m.s. to be made.

The basic configuration consists of a detector, located in a probe head, from which the d.c. output is passed via a balanced attenuator to an electro-mechanical chopper. The resultant 100 Hz square wave is then amplified and rectified to produce the d.c. required to drive the meter. Access to test points in closely packed circuits is eased by the small diameter of the detector probe—only $\frac{1}{2}$ inch. Full-wave detection, using a pair of gold bonded diodes, gives minimum errors when dealing with signals containing asymmetric waveforms or noise. A spring-loaded earthing spike facilitates low-inductance connection for measurements at high frequencies.

To achieve the low inherent noise level peculiar to the instrument a number of precautions have been taken. These include the use of a balanced output from the detector circuit, a 100 Hz chopper of the electro-mechanical variety, and low noise transistors in the narrow band a.c. amplifier. The choice of a synchronous detector not only discriminates against noise but retains polarity sense. This means that on the most sensitive ranges, any inherent noise will only show as a small dither about the mechanical zero mark.

Front panel controls have been reduced to two: a range switch and balance control. The latter is used only to balance out residual microvolts of d.c. developed in the instrument, and will have maximum effect on the 1 mV range, with no significant effect on the 30 mV range and above. A meter voltage scale, five inches long, gives good resolution and is virtually linear. Adjacent to the voltage scale there is a dB scale, the 0 dB coinciding with full scale deflection. The 1 mV range is an exception, being $3\frac{3}{4}$ in. long and square law; and the dB scale does not apply.

Only one supply rail is used, stabilised by means of a well-tried conventional series regulator circuit. Provision for external battery operation is included for portability, and conditions where accurate voltage measurement is difficult due to earth loops. Any battery supplying a voltage of 18 to 32 volts may be used; e.g., five PP8 batteries giving 120 hours at 4 hours per day rate.

Among the many tasks that this instrument can perform are:

(*a*) The search for spurious oscillations at frequencies between 1 and 1500 MHz in wide band video multi-stage amplifiers—carried out using a loop connected to the probe and holding it near to each part of the circuit in turn.

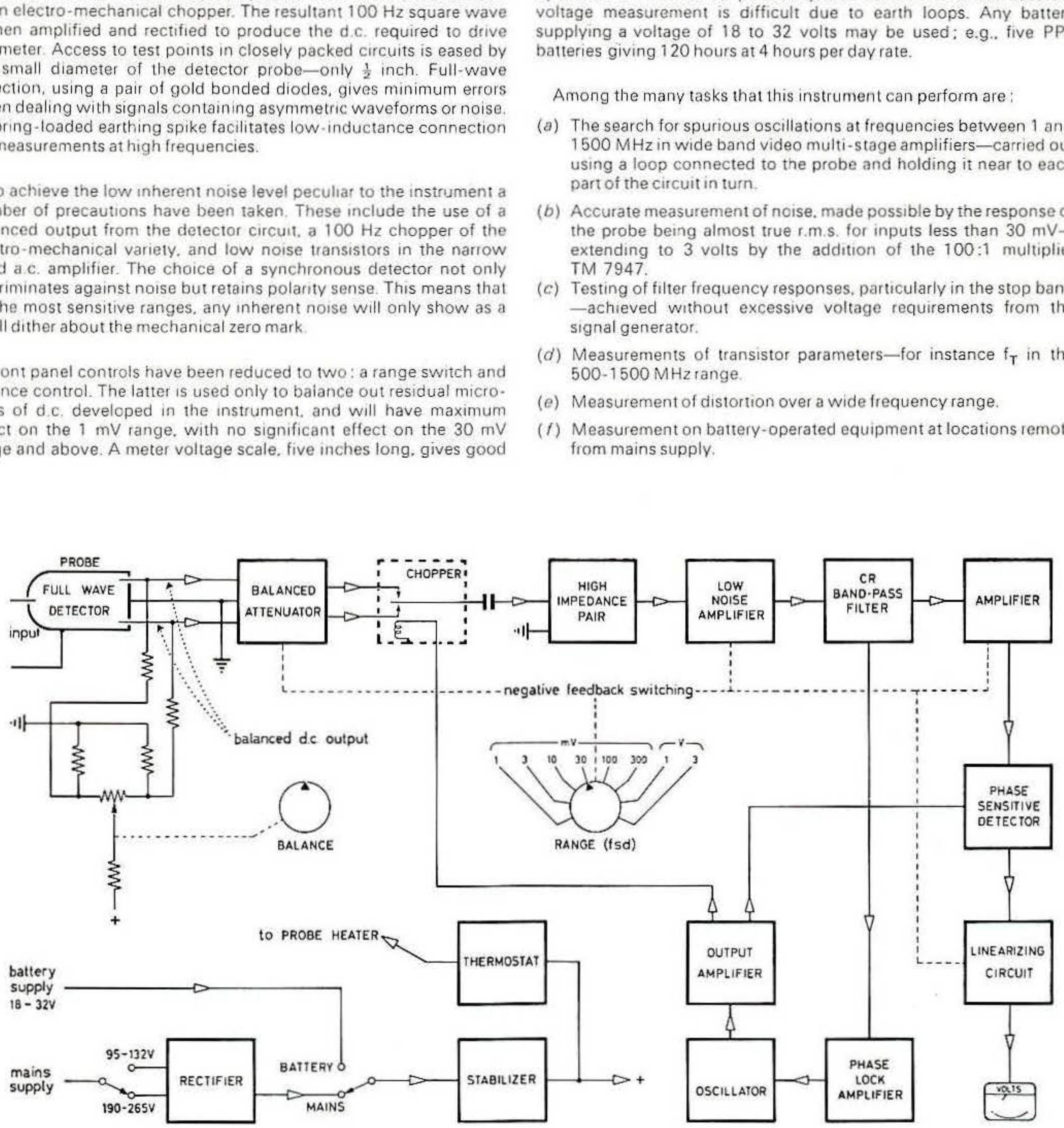
(*b*) Accurate measurement of noise, made possible by the response of the probe being almost true r.m.s. for inputs less than 30 mV—extending to 3 volts by the addition of the 100:1 multiplier TM 7947.

(*c*) Testing of filter frequency responses, particularly in the stop band—achieved without excessive voltage requirements from the signal generator.

(*d*) Measurements of transistor parameters—for instance f_T in the 500-1500 MHz range.

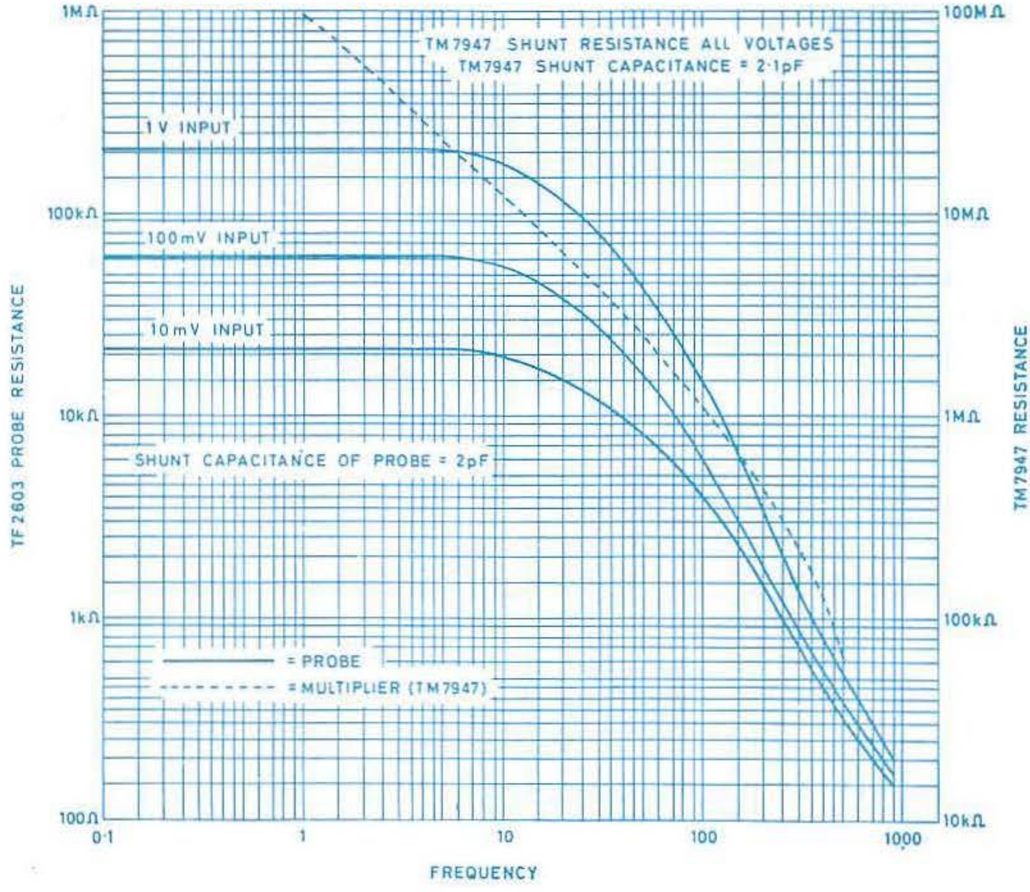
(*e*) Measurement of distortion over a wide frequency range.

(*f*) Measurement on battery-operated equipment at locations remote from mains supply.



Block diagram of R.F. Electronic Millivoltmeter type TF 2603

TF 2603



Typical input resistance of probe and multiplier

VOLTAGE RANGE	1 mV r.m.s. to 3 volts r.m.s. in 8 ranges. Maximum: input 8 volts r.m.s. Probe will withstand up to 300 volts d.c.
FREQUENCY RANGE	50 kHz to 1500 MHz.
ACCURACY	10 mV and higher ranges: ±3% of f.s.d. 3 mV range: ±5% of f.s.d. 1 mV range: ±5% of f.s.d. 200 kHz to 50 MHz. (From 18°C to 28°C.)
FREQUENCY/RESPONSE CHARACTERISTIC	With respect to 200 kHz: 50 kHz to 200 kHz: +0, −0·4 dB. 50 MHz to 200 MHz: ±0·4 dB. 200 MHz to 900 MHz: ±1·0 dB. 900 MHz to 1500 MHz: ±2·0 dB.
METER SCALES	0 to 3, and 0 to 10 virtually linear, 5 inches long. Calibrated in the r.m.s. value of a sinewave. Special scale for 1 mV range. Decibel scale 0 to −11 dB, 0 dB at full scale. Range switch in 10 dB steps dB scale not applicable to 1 mV range.
INPUT IMPEDANCE	*Input resistance:* >150 kΩ at 1 MHz and 1 volt r.m.s. *Input capacitance:* <2·5 pf at 1 MHz and 1 volt r.m.s.
POWER REQUIREMENTS	
A.C. Mains	190–265 volts, or 95–132 volts, 45–500 Hz (also 500–1,000 Hz at ±10% on 230 volts). Power, 6 watts.
External D.C.	18 volts minimum, 32 volts maximum. *Current:* 130 mA (heater on), 55 mA (heater off). Supply to be floating; i.e., neither side earthed.
DIMENSIONS AND WEIGHT	

Height	Width	Depth	Weight
8 in	11½ in	11 in	19½ lb
20 cm	29 cm	28 cm	8·75 kg

Accessories

SUPPLIED

TM 7936 Earthing Clip

TB 46843 Earthing Sleeve

TM 7947 100:1 Multiplier

100:1 capacitive divider giving 100 mV f.s.d. to 300 volts f.s.d., in 8 ranges over frequency range 500 kHz to 500 MHz.
Accuracy (with respect to exact 100:1 ratio):
0·5–20 MHz: ±0·1 dB.
20–100 MHz: ±0·3 dB.
100–300 MHz: ±0·7 dB.
300–500 MHz: ±1·5 dB.

Input impedance:
Resistance: >20 MΩ at 1 MHz, >1 MΩ at 50 MHz, >150 k at 300 MHz.
Capacitance: <2·5 pf.

Maximum input:
300 volts r.m.s. up to 100 MHz. Above 100 MHz, max. r.m.s. voltage is:
$$\text{voltage} = \frac{3 \times 10^6}{f^2}$$
where f is in MHz.

Peak a.c. plus d.c. shall not exceed 1,000 volts.

TM 7960 Accessory Case

OPTIONAL

TM 7948 Coaxial "T" Connector

V.S.W.R. not greater than 1·2:1 at 1500 MHz when terminated in 50Ω and TF 2603 probe plugged in side entry. When using this connector, the accuracy and frequency response figures given earlier apply to voltage across a 50Ω load.

TM 7949 Adapter type "N", terminated

Allows voltage measurement across load mounted in 50Ω type "N" plug. Maximum power input, ½ W. V.S.W.R. when mounted on TF 2603 probe: maximum of 1·1:1, 50 kHz–500 MHz; maximum of 1·2:1, 500 MHz–900 MHz.

TM 7950 Adapter, type "N", unterminated

50Ω type "N" adapter, as above, but without 50Ω load.

TM 7967 50Ω load, ½ W.

Load mounted in type "N" plug.
V.S.W.R. not greater than 1·05:1, d.c.—1500 MHz.

Electronic Voltmeter

- Excellent Zero Stability
- Seven a.c. ranges: 300 mV to 300 volts full scale, 20 Hz to 1500 MHz
- Input capacitance: 1·5 pF
- Eight d.c. ranges: 300 mV to 1 kV full scale
- Multipliers for up to 2 kV a.c. and 30 kV d.c.

The TF 2604 is an electronic voltmeter combining versatility with high accuracy and extremely good stability. It allows for precision measurements to be made within the range of 20 Hz to 1500 MHz with further facilities included for measuring a wide range of d.c. voltages and resistance.

The major variant affecting the reading stability of a valve voltmeter is its power supply. So it is not surprising that the greater emphasis was placed on this aspect throughout the design stages of the TF 2604. Thus the good reading stability inherent in this instrument is realised by the full stabilisation of valve heaters and the h.t. line; using a series valve circuit for the h.t.; and a transistor circuit controlled by a zener diode for the l.t. supply. This means that changes in the mains supply voltage by as much as 10% will cause a deflection change of less than 4 mV at full scale on all ranges.

Voltmeter Circuit

A well proven push-pull circuit is used to drive the meter, each half of the push-pull circuit consisting of a valve amplifier and cathode follower. To ensure that the accuracy is relatively independent of valve selection, the amplifier has a high loop gain with a large amount of negative feedback. The meter is protected from gross overload on the most sensitive ranges, and the effects of meter temperature coefficient are offset by a series thermistor. Both a.c. and d.c. inputs are isolated from the voltmeter chassis by 50 MΩ.

A.C. Measurements

The probe used for a.c. measurements houses a disk-seal diode rectifier of an advanced type. A low capacitance of only 1·5 pf, short transit time, and a 3000 MHz resonance frequency, together with a unique probe head design, make possible the frequency response of up to 1500 MHz. Small and cylindrical, this lightweight probe has been designed for easy handling.

A special plug-on ground connector is also supplied to facilitate the making of the ultra-short connection necessary at the higher frequencies. The high stability circuits combined with the special diode enable a wide range of voltages to be measured; down to 25 mV on the most sensitive range, and up to 300 volts on the highest range. An a.c. multiplier probe TM 5032 is available as an optional extra to extend the range to 2 kV r.m.s. at frequencies of 10 kHz and above.

D.C. Measurements

Volts and ohms measurement is simplified by the special dual purpose d.c. probe with its finger-tip V/Ω selector; set to V, an isolating resistor is introduced to shield the circuit under test from the effects of probe lead capacitance. For d.c. measurements the meter can be switched to give forward deflection with positive or negative voltages; for centre zero measurements, such as the precise determination of the null point in bridges or discriminators, a standing d.c. current is applied to bias the meter to mid-scale.

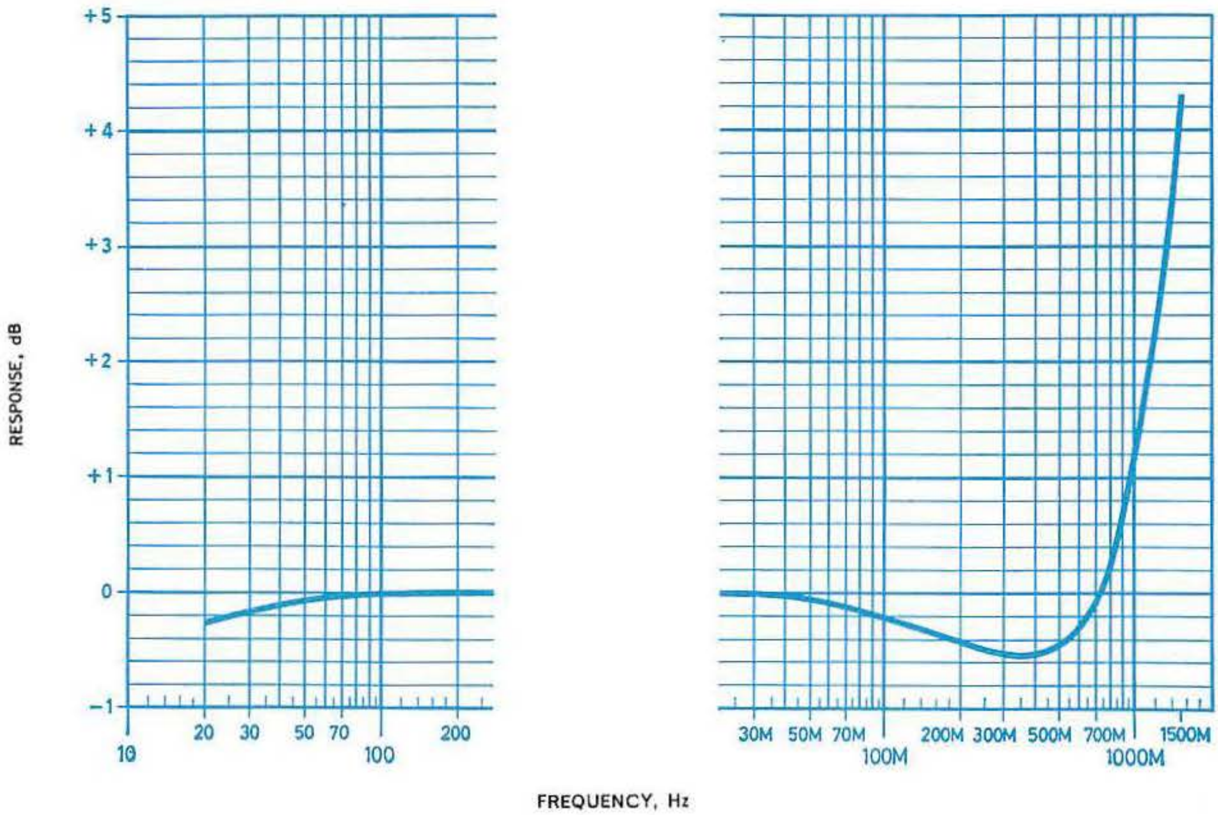
D.C. Measurements as low as 10 mV and as high as 1000 volts can be made, the input resistance being 100 MΩ. By using the optional d.c. multiplier type TM 5033A the higher limit can be extended to 30 kV, with an input resistance of 3000 MΩ.

Resistance Measurements

The d.c. supply for resistance measurement is derived from a stabilised l.t. supply, obviating the need for batteries. A common zero control is included to standardise at infinity ohms before connecting the unknown resistor.

Four optional accessories still further increase the usefulness of the TF 2604. High voltages up to 30 kV d.c. and 2 kV a.c. can be measured with plug-on d.c. and a.c. multipliers. For measuring voltages on a coaxial line, there is a plug-on T-connector for the a.c. probe; an accurately matched 50-ohm coaxial terminating load is also available.

TYPICAL FREQUENCY CHARACTERISTICS OF AC PROBE AT 600 mV



A.C. MEASUREMENTS Ranges	25 mV to 300 volts in seven ranges. Full scale deflections: 300 mV, 1, 3, 10, 30, 100 and 300 volts.
Accuracy	1, 3, 30, 100 and 300 volt ranges: ±2% of full scale ±10 mV. 300 mV range: ±3% of full scale ±10 mV. (At 1 kHz and between 18° and 28°C.)
Frequency response	Typical characteristic (measured at 600 mV using 'T' Connector TM 5031B) relative to response at 1 kHz: between 0 and −0·5 dB at 20 Hz; −0·2 dB at 50 Hz and 100 MHz; between 0 and −1 dB at 400 MHz; between 0 and +1 dB at 900 MHz; +4·5 dB at 1500 MHz. As the input voltage is increased the transit time effect decreases and as a result the error in the 100 MHz to 400 MHz region decreases. At 400 MHz the error could be positive and of a similar order of magnitude to that shown.
Input conditions	Shunt capacitance: approx. 1·5 pF. Resistance: approx. 5 MΩ at 1 kHz, approx. 500 kΩ at 10 MHz, and approx. 150 kΩ at 100 MHz.
D.C. MEASUREMENTS Ranges	10 mV to 1000 volt in eight ranges. Full scale deflections: 300 mV, 1, 3, 10, 30, 100, 300 and 1000 volts, positive or negative. Centre zero facility on all ranges.
Accuracy	±2% of full scale ±10 mV on all ranges (except for centre zero) between 18° and 28°C.
Input conditions	Resistance: 100 MΩ, plus 1 MΩ isolating resistor in probe. Capacitance to ground: approx. 2 pF.
STABILITY	A mains supply variation of 10% will cause a deflection change at full scale of less than 4 mV at full scale on all ranges.
RESISTANCE MEASUREMENTS Ranges	0·2Ω to 500 MΩ in seven ranges. Full scale deflections: 500Ω, 5 kΩ, 50 kΩ 500 kΩ, 5 MΩ, 50 MΩ and 500 MΩ.
POWER REQUIREMENTS	100 to 130 volts and 200 to 250 volts, 45 to 500 Hz; 36 watts.
DIMENSIONS AND WEIGHT	Height 8 in, 20·3 cm; Width 11½ in, 29·2 cm; Depth 10¼ in, 25·1 cm; Weight 12·75 lb, 5·8 kg
ACCESSORIES Supplied	Grounding Clip, Type TC 23535/3C, to fit a.c. probe. R.F. Grounding Sleeve, Type TC 23533/3, to fit a.c. probe.

Optional

TM 7010/3M1	Rack Mounting Kit.
TM 5031B	Coaxial 'T' Connector.
TM 5032	A.C. Multiplier.
TM 5033A	D.C. Multiplier.
TM 5582	50Ω Load.

Optional Accessories

Two multipliers, a coaxial 'T' junction, and a 50Ω coaxial dummy load are available for use with the Voltmeter. For stowing the multipliers and 'T' junction, a polished carrying case, Type TM 4935, can also be supplied.

A.C. Multiplier, Type TM 5032

Transmitter voltages up to 2 kV r.m.s. at frequencies of 10 kHz and above can be measured with this auxiliary probe cap which fits readily over the normal a.c. probe head. It comprises a capacitive divider with a ratio of 100:1, and places a capacitance of 2 pF across the circuit under test. The unit is accurate to within ±2%.

Coaxial 'T' Connector, Type TM 5031 B

This device can be fitted to the a.c. probe head to facilitate voltage measurements on 50Ω coaxial cables. For this purpose one of the two series arms of the 'T' is terminated in a type N plug and the other in a type N socket. The v.s.w.r. of the connector is of the order of 1·2 at 800 mHz.

5 W Dummy Load, Type TM 5582

This 50Ω wide band coaxial load is particularly useful as well matched termination in coaxial line measurements. It has a type N input socket, at which the v.s.w.r. is better than 1·1 up to 500 MHz and better than 1·2 up to 800 MHz. It is of robust, fully enclosed construction and completely non-radiating.

D.C. Multiplier, Type TM 5033A
(with connector TM 5749)

This enables high voltages, such as in television receivers, to be measured with safety. When connected to the Voltmeter, it gives a voltage reduction ratio of 30:1, and is usable up to 30 kV. The calibration of the Multiplier is accurate to within ±2% and it has an input impedance of 3000 MΩ.

Differential D.C. Voltmeter

- ☐ Voltage range: 0 to 1100 volts
- ☐ Accuracy: 0·02%
- ☐ Measurement discrimination: Better than 0·1 mV
- ☐ Input resistance: Over 1000 MΩ for voltages below 11 volts

The TF 2606 is a manually operated d.c. voltage measuring instrument with the full accuracy of a high-grade digital voltmeter. Comprising an accurate reference source, a five decade potentiometer, and a sensitive centre-zero electronic voltmeter, it is suitable for potentiometric measurement of voltages up to 1,100 volts d.c. in three main ranges of 11, 110 and 1,100.

Voltages up to 11 volts are measured by comparing the unknown with the potentiometer output voltage. The decade controls are adjusted for zero reading on the panel meter (which functions as a calibrated null indicator) to give a direct digital indication. A "plus-or-minus one digit" uncertainty is obviated in the overall measurement because any error voltage is indicated by the panel meter, the measured voltage being the sum of the potentiometer setting and the panel meter reading.

For voltages above 11 volts, a high impedance attenuator is introduced between the input terminal and the measuring circuit. To avoid ambiguity, the position of the decimal point is signified by neon indicators coupled to the voltage range (attenuator) switch.

The Electronic Voltmeter

This has five sensitivity ranges, switch selected in decade steps from 1 mV to 10 volts full-scale in each direction, so that the discrimination for digital measurement can be varied to suit the application. With the meter set to its most sensitive range, incremental voltage changes of less than 0·1 mV can easily be seen.

By setting all the potentiometer controls to zero, the electronic voltmeter can also be used independently for direct measurement of d.c. voltages; and, as the measuring circuits are effectively isolated from earth, the high sensitivity and centre zero can be utilised to employ the instrument as a null indicator in d.c. bridge circuits.

A pair of terminals at the rear of the instrument facilitate connection of a chart recorder in parallel with the panel meter. The full-scale e.m.f. is 75 mV from a source resistance of 1500 Ω. A convenient analogue output is thus available for remote monitoring of small voltage changes.

The Potentiometer

Derived from a highly stabilised source, with provision for standardising against an internal standard cell, the reference voltage is applied to the five decade divider. This comprises four switched decades and a continuously variable control, so that, for incremental comparative measurements, the potentiometer can be set to give a complete null indication on the meter, any incremental changes in the applied voltage then being read directly from the meter scale.

The potentiometer output voltage is available for external use. The instrument, thus, also serves as a standard d.c. voltage source, suitable, for example, for calibrating other voltmeters. Alternatively this output can be regarded as the reference level for incremental voltage measurement applications where it is more convenient to connect a sensitive chart recorder directly between the potentiometer and the unknown voltage source.

Applications

For certain applications, the TF 2606 has definite advantages over a digital voltmeter.

Below 11 volts it presents an almost infinite resistance to the unknown source when the potentiometer is set for a zero meter reading. It is very useful, therefore, for measurement of the output e.m.f. of high-resistance sources, and for other similar measurements where even the 1 MΩ normally regarded as an acceptable d.v.m. input resistance can cause errors.

The indication of voltage variation directly on the panel meter is extremely useful for measurement of voltage drift with temperature etc.; and, as previously mentioned, the instrument is capable of driving a chart recorder without the need for a digital to analogue converter. Furthermore, a true analogue-of-error voltage is available, free from the ±1 digit uncertainty.

For applications where it is necessary to adjust the unknown voltage to a particular level the Differential Voltmeter shows considerable advantage. The potentiometer controls are simply set to the required voltage, and the device under test is adjusted to give zero reading on the TF 2606 panel meter.

POTENTIOMETRIC MEASUREMENT	
VOLTAGE RANGE	1 mV to 1100 volts in three ranges of 11, 110, and 1100 volts maximum input.
DISCRIMINATION	0·0005% full-scale given by 5 decade dials. (Overall measuring discrimination on 11 volt range better than 0·1 mV.)
ACCURACY (18° to 28°)	
1 mV to 1 volt	±0·05% of reading ±100 μV.
1 to 1100 volts	±0·02% of reading ±100 μV. (Typical accuracy at 23°C is ±0·01% of reading.)
	From 18° down to 10°C and from 28° up to 35°C the tolerance increases by (±0·002% of reading ±20 μV) per °C.
INPUT RESISTANCE	
11 volt range	1 MΩ nominal, increasing to over 1000 MΩ at meter null.
110 and 1100 ranges	1 MΩ nominal.
MAXIMUM VOLTAGE TO EARTH	1100 volts.

INTERNAL VOLTAGE STANDARD	±0·01% reference cell.
STABILITY OF READING (without adjustment)	±0·002% of reading ±20 μV for 10% supply variation. ±0·005% of reading per °C change.
DIRECT MEASUREMENT	With the decade dials set to zero, the instrument functions as a direct-reading centre-zero voltmeter with the following performance specification.
VOLTAGE SENSITIVITIES	
11 volts max. input range	0·0011, 0·011, 0·11, 1·1, and 11 volts f.s.
110 volts max. input range	0·011, 0·11, 1·1, 11, and 110 volts f.s.
1100 volts max. input range	0·11, 1·1, 11, 110, and 1100 volts f.s.
INPUT RESISTANCE	1 MΩ nominal—increasing to 10 MΩ on 11 volts max. input range only.
ACCURACY	±5% of full-scale.
POWER REQUIREMENTS	
A.C. Mains	95 to 130 volts and 190 to 264 volts, 45 to 500 Hz, 5 VA.
DIMENSIONS AND WEIGHT	Height 8 in 20 cm; Width 11½ in 29 cm; Depth 11 in 28 cm; Weight 12 lb 5·5 kg

The standard cell in this instrument will not withstand excessive shock and vibration.

Digital Voltmeter

- ☐ 1 mV to 1000 volts d.c.
- ☐ Fully floating input
- ☐ Simple to operate
- ☐ Low price

TF 2660 is a low drift integrating digital voltmeter specially designed for applications where moderately high accuracy, simplicity of operation, and low cost are important. Its clear unambiguous readout, with decimal point indication, renders the instrument suitable for use by semi-skilled personnel in factory test rooms or training establishments as well as by trained laboratory staff.

Four clearly marked push buttons permit rapid selection of the appropriate voltage range from 1·9 volt full scale to 1 kV full scale in decade steps. No damage is caused if too low a range is selected, the input circuit being designed to withstand up to 1 kV between the terminals on all ranges.

Voltage is indicated on a four tube in-line readout, the first figure being used only at range full-scale to indicate "1", with over-range indication to 1900 on all except the 1000 volt range. The position of the decimal point is indicated automatically by lamps coupled to the range switching system. Polarity reversal can be effected by operating a push button switch located above the input terminals, the positive terminal for either switch position being identified by a neon indicator lamp. The measuring circuit is fully floating with respect to chassis, and either terminal may be earthed as convenient.

The sampling rate is continuously variable from zero (infinite display time) to 3 per second by means of a panel control. By setting the control to the zero position the indication may be held indefinitely. It is released by moving the control.

VOLTAGE MEASUREMENT	
Ranges	Positive or negative voltages from 0 to 1000 volts in four switch-selected ranges as follows:

Range	*Accuracy*
(1) 0 to 1·900 volts	±3 mV
(2) 0 to 19·00 volts	±30 mV
(3) 0 to 190·0 volts	±300 mV
(4) 0 to 1000 volts	±3 volts

INTERFERENCE REJECTION (With 1 kΩ unbalance in either lead)	
Common mode d.c.	Not less than 120 dB
Common mode 50 Hz	Not less than 60 dB (1 and 10 volt ranges only).
INPUT	
Resistance	1 MΩ on range (1) 10 MΩ on all other ranges.
Insulation (Terminals to earth)	Greater than 100 MΩ in parallel with 100 pF. Withstands common mode d.c. up to ±1000 volts.
OPERATION	
System	Voltage to frequency conversion with digital counter.
Sampling	Repetitive with rate variable from zero to 3 per second. Sampling time is less than 250 msec.
Range selection	Manual push button with decimal point indicator.
Polarity	Push button reversing switch. Positive terminal identified by glowing neon indicator.
Readout	4 tube in-line, with decimal point.
POWER REQUIREMENTS	
A.C. mains	100 to 120 volts and 200 to 250 volts. 50 to 60 Hz, 20 watts.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
$3\frac{3}{8}$ in	$10\frac{1}{2}$ in	$13\frac{1}{4}$ in	7 lb
8·6 cm	26·7 cm	33·7 cm	3·5 kg

Digital Voltmeter

Manufactured by MARCONI ITALIANA S.p.A.

- ☐ Measures 0 to ±1200 volts d.c.
- ☐ 5 digit readout
- ☐ 0·02% accuracy
- ☐ Automatic polarity indication
- ☐ Fully programmable
- ☐ Auto-ranging optional
- ☐ Fully protected input

This Digital Voltmeter not only meets all the stringent general requirements of an instrument of its type, but is also suitable for inclusion in data logging and automatic test systems (when used in connection with its optional plug-on logic converter), and includes special provision for use in applications—such as avionics—where a.c. rejection is particularly important.

The SM 523 is an all-solid-state five-digit d.v.m. with a measurement accuracy of 0·02% of range full scale. It has five voltage ranges—0·12 volts f.s. to 1200 volts f.s. in decade steps. These are normally panel-switch selected, but provision is made on all models for remote range selection. The input is fully protected, that is a voltage of 1200 volts can be applied to the input terminals without damaging the instrument, even if this is set on the lowest range (0·12 V). The instrument also accepts an autoranging unit, which can be built in as an optional extra, and with this unit fitted the voltmeter can select the most suitable range automatically.

Voltage is indicated on a five tube in-line readout, with fully automatic polarity indication and a decimal point indicator coupled to the range selector. The indicator tubes are actuated by a b.c.d. store, whose logic outputs are also taken to a socket at the rear of the instrument for operation of a printer or other external digital equipment. This output is b.c.d. four-line-per-digit negative logic with earthed common line. A plug-on accessory is available to convert the negative logic output to simple contact closures so that, by use of an external d.c. supply, compatibility with any digital system using 1-2-4-8 b.c.d. can be achieved.

The voltmeter utilises the successive approximation technique, in which the input voltage to the instrument is compared with an internal voltage derived via a digital potentiometer from a reference source. The difference potential goes to a logic circuit which converts it into command signals that adjust the digital potentiometer for minimum difference potential. It is effectively the setting of this potentiometer that is indicated by the in-line readout as the measured voltage.

Provision is made for calibrating the reference source against a built-in standard cell.

Very high input impedance and common mode rejection are characteristics of this instrument. The series mode a.c. interference is attenuated by the limited bandwidth of the input amplifier, and it is virtually eliminated by the provision for switching a low pass filter into circuit. The standard filter has a notch characteristic with maximum rejection at 50 Hz, but, if required, a notch filter can be fitted having maximum rejection at 400 Hz or any other audio frequency greater than 50 Hz.

Sampling time is approximately 10 msec; and the instrument can be set for repetitive sampling or for single samples, which are initiated either manually by a panel push button or by application of an external trigger pulse. In the repetitive mode the sampling rate is determined by the setting of the *Display* control, maximum display time being 5 seconds.

In addition to its use for accurate measurement of voltage, the SM 523 can function as an analogue-to-digital converter. The b.c.d. output taken in conjunction with the facilities for programmable ranging and triggering allows the instrument to be used in automatic measurement or control systems. For applications of this type, an optional plug-on logic converter is available, which converts earthed negative logic output to fully floating contact closures. Thus the SM 523 becomes compatible with any instrumentation system working in b.c.d. 1-2-4-8 code.

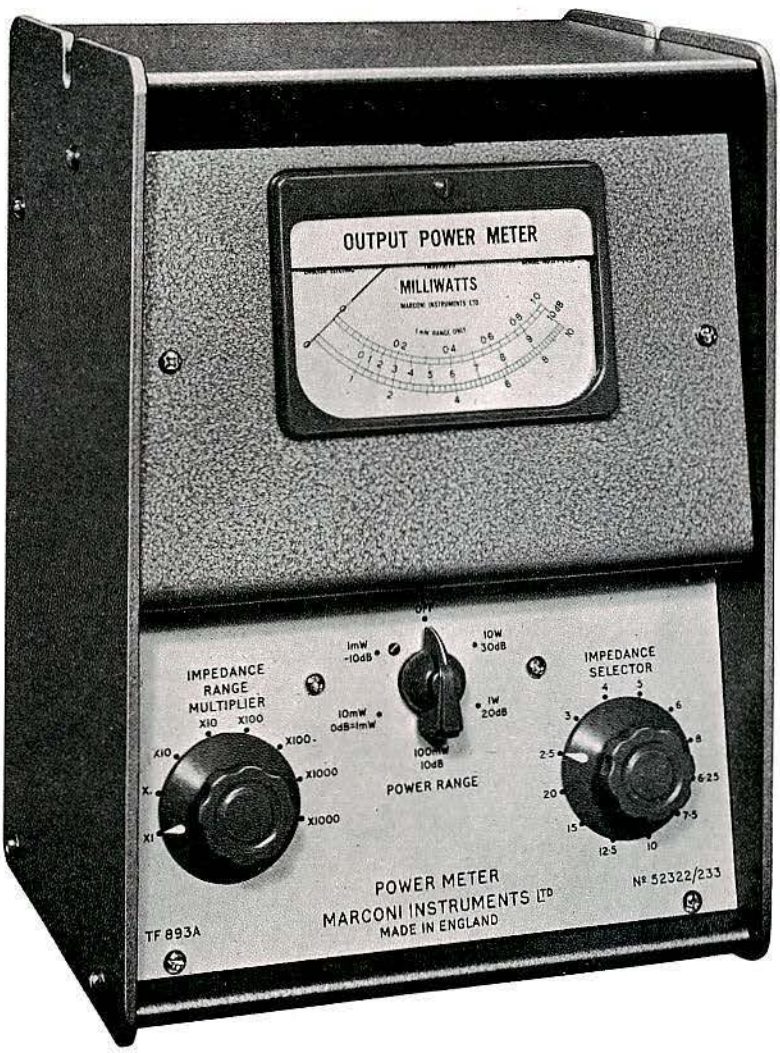
SM 523 is normally supplied as a bench instrument, but a rack mounting kit is readily available as an optional accessory.

VOLTAGE MEASUREMENT	
Ranges	(1) 0 to ±0·11999 volts. (2) 0 to ±1·1999 volts. (3) 0 to ±11·999 volts. (4) 0 to ±119·99 volts. (5) 0 to ±1199·9 volts.
Accuracy	±0·02% of range full scale.
INTERFERENCE REJECTION	
Common mode	Not less than 95 dB at 50 Hz (Using filter). Not less than 150 dB at d.c.
Series mode	Not less than 70 dB at 50 Hz (Using filter). Filters can be fitted having maximum rejection at 50 Hz, 400 Hz or any audio frequency above 50 Hz if requested at time of ordering.
INPUT	
Impedance	Greater than 1000 MΩ on ranges (1) and (2). 10 MΩ on all the other ranges.
Insulation (low terminal to earth)	Greater than 100 MΩ.
OPERATION	
System	Successive approximation.
Sampling command	(a) Manual—panel push button. (b) Repetitive—sampling time approx 10 msec, maximum display time 5 seconds. (c) External pulse. (d) Printer inhibit.
Range selection	Manual or remote (auto-ranging optional).
Polarity	Automatic selection and indication.
Readout	Polarity sign, 5 digits, decimal point.
PRINTER OUTPUT	
Code	1–2–4–8 sequence b.c.d.
Logic levels	'0' = 0 to −0·5 volts. '1' = −7 to −11·5 volts. Source impedence: 10 kΩ.
Print command signal	−11 volts from 10 kΩ. 1 μsec risetime. 10 msec duration.
POWER REQUIREMENTS	
A.C. mains	95 to 130 volts or 190 to 260 volts, 45 to 65 Hz, 60 VA.
DIMENSIONS	Height 5¼ in 130 mm; Width 17¼ in 435 mm; Weight 30¼ lbs. 13·75 kg
ACCESSORIES	
Optional	Plug-on logic converter. Converts earthed negative logic output to fully floating contact closures. Automatic ranging card.
On special order	Notch filter with maximum rejection at any audio frequency greater than 50 Hz.

10-watt A.F. Power Meter

- ☐ Frequency range: 20 Hz to 35 kHz
- ☐ Five power ranges: 1 mW to 10 watts full scale
- ☐ Impedance: 2·5Ω to 20 kΩ in 48 steps
- ☐ Balanced or unbalanced inputs
- ☐ Direct calibration in watts and dBm

This Audio Power Meter covers an exceptionally wide range of power and maintains its accuracy at both very high and very low frequencies



Power is measured by a temperature-compensated constant-resistance multi-range rectifier voltmeter, the required input impedance being obtained by the use of a tapped transformer and by a switched resistance-changing pad. Provision is made for measuring either balanced or un-balanced inputs.

The instrument is contained in a compact portable case, with the input terminals fitted in a recess in the case top; this protects the terminals from accidental mechanical damage. The lid of the recess may be swung back to support the instrument at a convenient viewing angle, while the sloping front panel hinges upward for ease of servicing.

Impedance selection

The Meter measures the power delivered by an audio-frequency source into a load provided by the instrument itself, and its excellence of performance over so wide a range of power, impedance and frequency is due primarily to two important points of design. Firstly, the patented feature—the use of a resistance network, forming an impedance-changing pad, to select the significant figures of the value of the input impedance; secondly, the use, for the decade multiplication of impedance, of a transformer using an English Electric wound-strip core of an isotropic magnetic alloy.

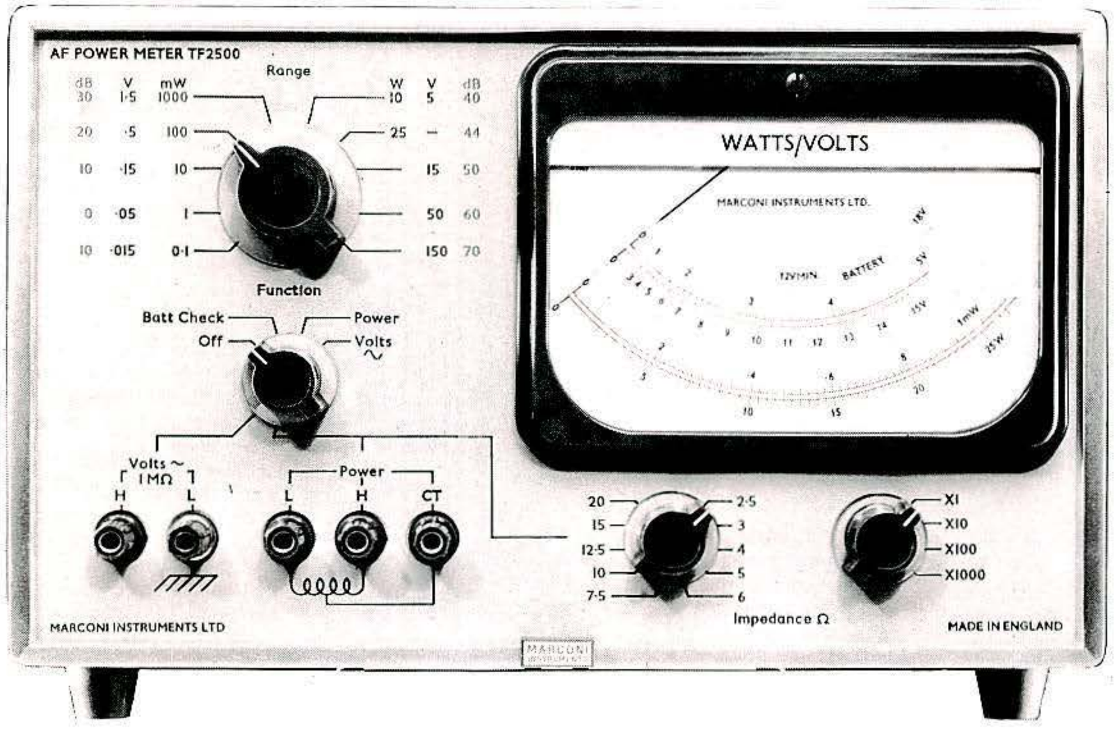
Centre-tapped input

There are five power measurement ranges, with calibration directly in watts or milli-watts and in decibels relative to 1 mW. The overall impedance range of 2·5 to 20,000Ω is in forty-eight steps arranged in two groups identified by the use of engraving in contrasting colours. The primary of the input (impedance-matching) transformer of low d.c. resistance, is isolated from the case and is provided with a centre tap for push-pull working; the centre tap also allows impedances down to 0·625Ω to be correctly terminated, but with some falling off in measurement accuracy.

RANGE	
Power	0 to 10 watts in five ranges. Full-scale deflections are: 1, 10 and 100 mW, 1 and 10 watts.
Impedance	2·5 to 20,000Ω thus: 2·5, 3, 4, 5, 6, 8, 6·25, 7·5, 10, 12·5, 15, 20 with multipliers ×1, ×10, ×100, ×1000. Impedances of one-quarter the above—extending the range down, to 0·625Ω—can be obtained by using the input centre tap, but with reduced accuracy. The impedance of the Power Meter falls when it is connected into a circuit carrying d.c. At 50 Hz, a drop of approximately 5% is produced by 60 mA at the 100Ω setting or 4 mA at 20 kΩ setting.
ACCURACY (at 1 kHz and 20°C)	
Power	$2\frac{1}{2}$% of full scale up to half-scale deflection. 5% of the reading from half-scale to full-scale deflection.
Impedance	5%.
FREQUENCY CHARACTERISTIC	With all controls at approximately mid-setting the response of a typical Power Meter is, relative to indication at 1 kHz flat to within −0·5 dB from 50 Hz to 10 kHz; at 20 kHz the response is approx. 1 dB down. At other control settings, the maximum variation from the above is ±1 dB at 50 Hz and ±1·5 dB at 20 kHz. The instrument can be used over the extended frequency range, 20 Hz to 35 kHz, with reduced accuracy.
DIMENSIONS AND WEIGHT	

Height	Width	Depth	Weight
11 in	$7\frac{1}{2}$ in	$6\frac{3}{4}$ in	9 lb
28 cm	19 cm	17 cm	4·1 kg

- ☐ Power measurement up to 20 kHz; voltage measurement up to 1 MHz.
- ☐ Seven power ranges: 100 μW f.s. to 25 watts f.s.
- ☐ Load impedance: 2.5Ω to 20 kΩ in 40 steps.
- ☐ Nine voltage ranges: 15 mV f.s. to 150 volts f.s.



The TF 2500 is not only a wide range a.f. absorption power meter but also an accurate electronic voltmeter suitable for use up to 1 MHz. Furthermore, the voltmeter section can be used with external loading for direct measurement of power over the whole of its frequency range. In addition to the normal audio frequency power applications, therefore, the instrument can be used as a directly calibrated level monitor for a wide variety of transmission systems, including f.d.m. baseband networks.

Its high sensitivity facilitates direct measurement of very low power levels down to less than 10 μW—so that the TF 2500 can be used for signal-to-noise ratio or noise-factor measurement on low-noise equipment, where most other general purpose output power meters give inadequate indication.

This high sensitivity is achieved by the use of an active measuring system based on what is essentially an amplifier-detector type voltmeter calibrated in terms of power, dBm, and voltage. For power measurement the measuring circuit receives its input via a transfer network comprising a transformer-coupled load, with resistive correction, to give switched selection of 40 impedance values, ranging from 2·5 Ω. to 20 kΩ. Voltage measurement is, of course, made by feeding the input directly to the measuring circuit. Sensitivity is varied by a switched *coarse* attenuator (preceding the amplifier) and *fine* interstage attenuator, to give 7 power ranges and 9 voltage ranges.

Power measurement can be made with unbalanced, balanced, or fully floating load, the methods of connection being clearly indicated on the front panel. The centre-tapped winding can also be utilised to obtain low values of load impedance. With the source under test connected between the ***CT*** and ***L*** terminal the load impedance is a quarter of the value indicated by the control settings, so that the lowest value obtainable becomes 0·625 Ω. When used in this way the instrument remains direct reading in power.

The accuracy of the a.f. power indication is not seriously affected by a moderate d.c. current in the input winding, an attribute that is sometimes very useful, as it permits connection of the instrument directly to active elements in experimental circuits. For example, the power meter can be connected directly between the anodes of push-pull thermionic output stage with the centre tap taken to h.t. A table of maximum d.c. current values for 5% accuracy reduction is given in the handbook.

As an a.c. voltmeter the total measurement range, extending from the lowest reading of 3 mV to the maximum of 15 volts is adequate for most a.f. applications. And the voltmeter's extended frequency range to 1 MHz can, of course, also be utilised for power measurement with external loading at frequencies outside the range of the power meter section. By connecting the voltmeter terminals across the appropriate portion of a tapped resistive load, the power can be read directly from the power scales of the panel meter. A table of suitable resistor values is given in the handbook.

Two sockets at the rear of the instrument provide a d.c. output for use with a chart recorder. For full scale deflection the output current is 0·944 mA.

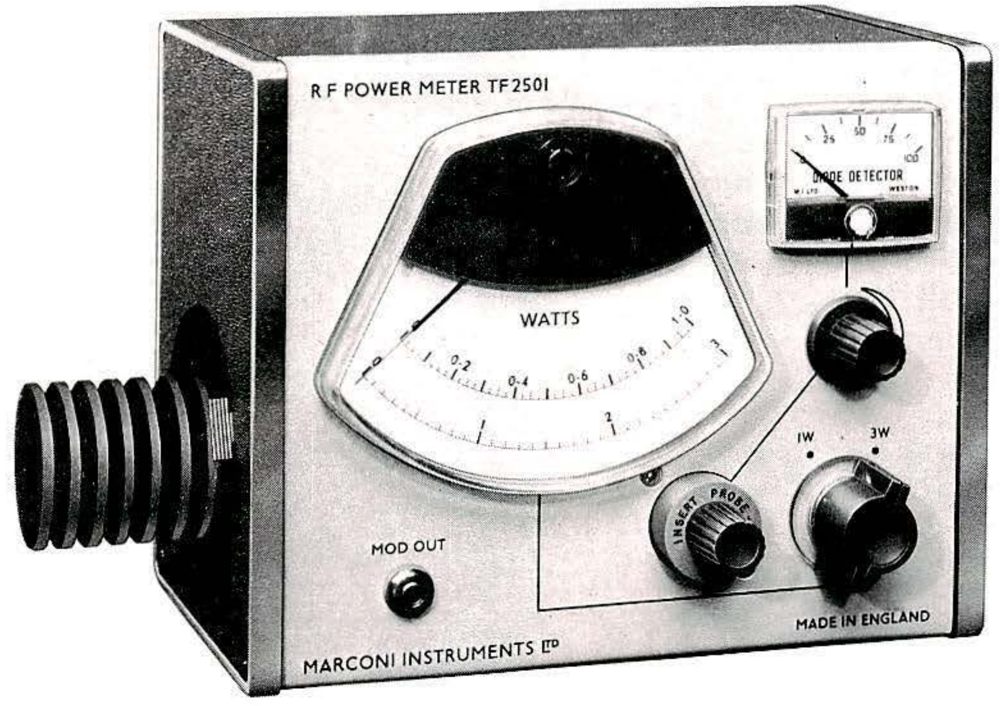
The instrument is powered by two internal 9 volt dry batteries; and provision is made for switching the meter to indicate their state.

POWER MEASUREMENT	
Range	7 ranges with full-scale deflections of: 100 μW. 1, 10 and 100 mW. 1, 10 and 25 Watts.
Accuracy at 1 kHz	± 2·5% of full-scale.
Frequency response relative to 1 kHz	*Below 1 mW:* ± 0·5 dB from 30 HZ to 20 kHz, ± 1 dB from 20 Hz to 30 Hz *1 mW to 3 watts:* ± 0·5 dB from 20 Hz to 20 kHz. *3 watts to 10 watts:* ± 0·5 dB from 35 Hz to 20 kHz. *10 watts to 25 watts:* ± 0·5 dB from 50 Hz to 20 kHz. Usable up to 35 kHz with reduced accuracy.
Input impedance	40 values from 2·5 Ω to 20 kΩ as follows: 2·5, 3, 4, 5, 6, 7·5, 10, 12·5, 15 and 20 Ω with multipliers of X1, X10, X100 and X1 000. *Accuracy at 1 kHz:* ± 4%. Impedances of one-quarter the above – extending the range down to 0·625 Ω – can be obtained using the input centre tap.
VOLTAGE MEASUREMENT	
Range	9 ranges with full-scale deflections of: 15, 50, 150 and 500 mV, 1·5, 5, 15, 50 and 150 volts.
Accuracy including frequency response	± 2% of full-scale from 20 Hz to 200 kHz. ± 3% of full-scale from 20 Hz to 1 MHz. ± 5% of full-scale from 10 Hz to 20 Hz.
Input impedance	1 MΩ with 25 pF in shunt.

POWER SUPPLY	18 volts d.c. from 2 internal DT9 batteries. Current drain approximately 18 mA average.
DIMENSIONS AND WEIGHT	Height Width Depth Weight 8 in 11½ in 10¾ in 23 lb 203 mm 292 mm 273 mm 10·5 kg
ACCESSORIES	
Supplied	Two 9 volt dry batteries type DT9. Two shorting links. One fitted across BAL D.C. OUTPUT terminals and the other across the volts L and POWER L terminals. One shielded adapter, providing BNC socket outlet from terminals; type TB 39868, Greenpar type GE 51002.
ENVIRONMENTAL SPECIFICATION TEMPERATURE RANGE	
Functional	0 to 55 °C with up to 60% r.h.
Meeting performance specification	10° to 35 °C with up to 95% r.h.
Storage and transport	−40° to + 70 °C.
TYPE TESTS	
Tropical exposure	14 days in simulated tropical conditions generally in accordance with Ministry requirements.
Shock tests	500 bumps per side on a standard SRDE designed bump test machine – approx. 25g.
Vibration tests	2¼ hours at 1g between 10 Hz and 100 Hz in all three planes.

TF 2501 R.F. Power Meter, 3 Watts

- ☐ **D.C. to 1 GHz**
- ☐ **3 watts f.s.d.**
- ☐ **V.S.W.R. 1.1 : 1**
- ☐ **Thermocouple for true mean power**
- ☐ **Uncalibrated fast-response diode meter for peaking**



TF 2501 is an r.f. absorption power meter of very advanced design, intended for use with low power transmitters at frequencies up to 1 GHz.

True mean power is indicated by means of a thermocouple meter, with switch-selected sensitivity of 1 watt or 3 watts f.s.d. As range selection is effected by changing the sensitivity of the d.c. side of the measuring circuit, it is impossible to damage the thermocouple by inadvertently switching to the wrong power range. A fast-response diode meter is also incorporated as a convenient indicator for transmitter tuning adjustments. The sensitivity of this second indicator is continuously variable for ease of operation; and the diode also functions as a demodulator for a.m. signals, the a.f. output being available from a telephone jack on the front panel.

The instrument is fully demountable; the thermocouple/load unit may be separated from the main body of the instrument for remote indication of output power when the r.f. connection is not easily accessible; or the r.f. load (TM 8587) can be removed from the power meter altogether and used independently.

POWER MEASUREMENT	**(Calibrated thermocouple meter)**
Range	1 and 3 watts f.s.d.
Accuracy	±5% of f.s.d. (true mean power).
Frequency range	D.C. to 1 GHz for stated accuracy.
Input impedance	50Ω.
V.S.W.R.	1·1 :1.
DIODE DETECTOR	**(Uncalibrated)**
Frequency range	From below 5 MHz to at least 1 GHz.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
5⅛ in	9½ in	4¾ in	3 lb
13 cm	24 cm	12 cm	1·4 kg

R.F. Power Meter, 10 Watts   TF 2502

The TF 2502 is basically similar to the TF 2501 (opposite), but has a higher power range. Its dissipative load, TM 8544, is rated at 10 watts and the thermocouple true-mean-power meter sensitivity is switchable to 3 watts or 10 watts f.s.d.

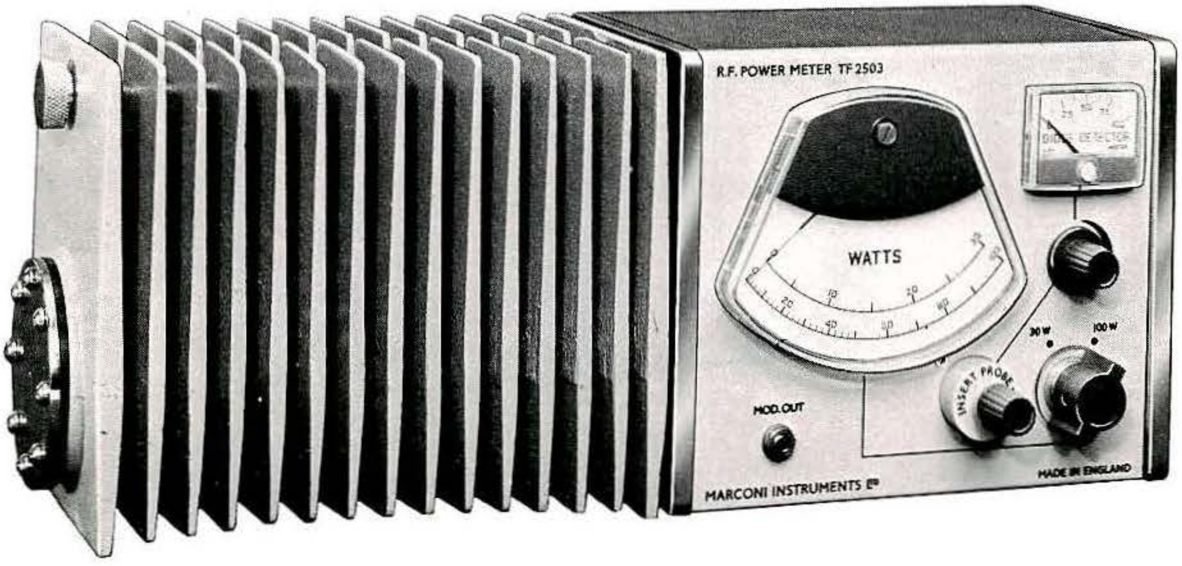
These two instruments are the first of a new range of power meters, in which the small size and unusually low v.s.w.r. are achieved by the use of new materials and the application of high-vacuum evaporation techniques. A Marconi patented thermocouple unit is employed, with its heater element forming part of the coaxial inner conductor, so that the correct characteristic impedance is maintained throughout the link between the input socket and the load.

POWER MEASUREMENT	**(Calibrated thermocouple meter)**
Range	3 and 10 watts f.s.d.
Accuracy	±5% of f.s.d. (true mean power).
Frequency range	D.C. to 1 GHz for stated accuracy.
Input impedance	50Ω.
V.S.W.R.	1·1:1.
DIODE DETECTOR	**(Uncalibrated)**
Frequency range	From below 5 MHz to at least 1 GHz.
DIMENSIONS AND WEIGHT	

Height	Width	Depth	Weight
5⅛ in	9½ in	4¾ in	3 lb
13 cm	24 cm	12 cm	1·4 kg

TF 2503 R.F. Power Meter

- D.C. to 1 GHz
- 100 watts f.s.d.
- V.S.W.R. 1·1:1
- Thermocouple meter for true mean power
- Uncalibrated fast-response diode meter for peaking



TF 2503 is an r.f. absorption power meter of very advanced design, intended for use with medium and low power transmitters at frequencies up to 1 GHz. It is one of a new range of power meters, in which the small size and unusually low v.s.w.r. have been achieved by the use of new materials and the application of high-vacuum evaporation technique.

True mean power is indicated by means of a thermocouple meter, with switch-selected sensitivities of 30 watts and 100 watts full scale. A Marconi patented thermocouple is employed, with its heater element forming part of the inner conductor of the coaxial line. This arrangement has the advantage that the load remains independent of the indicator, but the correct characteristic impedance is maintained throughout the link between the input socket and the load.

A fast-response diode meter is also incorporated as a convenient indicator for transmitter tuning adjustments. The sensitivity of this second indicator is continuously variable for ease of operation; and the diode also functions as an a.m. demodulator, the a.f. output being available from a telephone jack on the front panel.

The instrument is fully demountable; the thermocouple unit, with the load attached, may be separated from the main body of the instrument for remote indication of output power when the r.f. connection is not readily accessible; or the r.f. load can be removed from the power meter and used independently.

POWER MEASUREMENT	(calibrated thermocouple meter)
Range	30 and 100 watts f.s.d.
Accuracy	±5% (true mean power)
Frequency range	D.C. to 1 GHz for stated accuracy.
Input impedance	50 Ω
V.S.W.R.	1·1:1
DIODE DETECTOR	(uncalibrated)
Frequency range	From below 5 MHz to at least 1 GHz.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
6¼ in	11 in	4½ in	10 lb
16 cm	28 cm	11 cm	4 kg

Analysers and Test Sets

Waveform Analysis

The two main applications of audio frequency waveform analysis are (a) measuring purity of the output from sinewave sources and (b) linearity measurements on amplifiers and transmission networks. Providing a low-distortion source is available, the test methods suitable for (a) are also suitable for (b). These are the single frequency methods of distortion factor measurement and harmonic analysis.

Distortion Factor

The r.m.s. voltage of a distorted sinewave multiplied by its distortion factor gives the r.m.s. voltage of the total distortion content. This implies that a true r.m.s. indicator is necessary for the measurement, but the error introduced by the use of the simpler average voltage type of meter is usually negligible for practical purposes. It is important to stress that the term refers only to voltage ratio and not to power ratio, which can seem to be very much better; e.g., with a 10% distortion factor only 1% of the power is in the distortion components of the waveform.

In the distortion factor meter the total voltage of the unwanted frequency components is measured by filtering out the fundamental and measuring the voltage of the residue. This is compared with the total signal voltage in such a way that the instrument indicates the distortion factor directly. If the fundamental component is $\underline{S}$, harmonic distortion is $\underline{D}$, and the noise is $\underline{N}$, the total signal is $(\underline{S}+\underline{D}+\underline{N})$; and when $\underline{S}$ is eliminated $(\underline{D}+\underline{N})$ remains. The distortion, $\underline{D}$, will comprise a number of harmonic components, H_1, H_2, H_3, etc. So, if the final detector is a true r.m.s. indicator, the indicated distortion factor is given by:

$$DF_{r.m.s.} = \frac{\sqrt{H_1^2+H_2^2 \ldots\ldots +N^2}}{\sqrt{S^2+H_1^2+H_2^2 \ldots +N^2}}$$

This is the distortion factor as commonly defined. In a.f. distortion factor meters, however, an average level indicator is used, so that the indicated distortion factor is given by:

$$DF_{av} = \frac{H_1+H_2 \ldots\ldots\ldots\ldots +N}{S+H_1+H_2 \ldots\ldots\ldots +N}$$

Both expressions of distortion factor are commonly expressed as percentage. For certain purposes, the distortion factor is defined as the ratio between the noise plus distortion to the fundamental component only. This is occasionally called the true distortion factor, and is, of course, given by:

$$DF_{true} = \frac{\sqrt{H_1^2+H_2^2 \ldots\ldots +N^2}}{S}$$

In normal audio equipment the discrepancy is negligible; with distortion as high as 14%, the difference between DF_{true} and $DF_{r.m.s.}$ is less than 1 part in 100. The difference between DF_{av} and $DF_{r.m.s.}$ depends upon the phase and distribution of the harmonics—especially the third. The greatest difference will be about 1·5 dB, which is barely discernible by the human ear.

Distortion Factor Measurement

For measurement of distortion factor with the Marconi Instruments TF 2331, the sensitivity of the meter is first standardised to give 100% indication for the total signal. The fundamental component is then rejected by means of a tunable filter, and the instrument indicates the level of the residue directly as distortion factor (DF_{av}). Provision is made for external connection of a true r.m.s. indicator if desired.

When testing an a.f. amplifier or transmission network it is, of course, important that the distortion in the input test signal is small compared with the distortion likely to be introduced by the unit under test.

Amplifier Noise Measurement

For amplifier noise measurement the input test signal is used only to provide a reference level with which to standardise the sensitivity of the distortion factor meter. Once this has been done, the input signal is switched off, so that the residue measured by the distortion factor meter is the amplifier noise. This is likely to be composed of two main components; viz., the mains hum and the white noise generated in the early stages of the amplifier.

If the white noise is heard on a loud speaker, the sensation is that of a predominantly hissing sound, because the human ear is most sensitive to frequencies in the band 3 to 6 kHz. It is thus more realistic to assess the noise after it has been weighted according to the frequency/sensitivity characteristic of the average ear and reproducing device.

The CCIF has decided upon standard response characteristics for what are termed psophometric weighting filters. There are two of these. One is intended for high-quality music transmission (broadcast), and is similar to the characteristic of the human ear alone, while the other represents the combined response of the ear with a telephone earpiece.

The TF 2331 distortion factor meter is fitted with a broadcast type weighting filter which can be switched into circuit for noise measurements with the test tone off. Noise from an a.f. amplifier is normally expressed as equivalent input in terms of decibels below an 800 Hz reference input level. At this frequency the weighting filter introduces 8 dB attenuation, which should be subtracted from the indicated number of decibels.

Harmonic Analysers

Harmonic analysis is essentially measurement of the amplitude of each individual frequency component of a waveform separately. The instruments used for isolation and measurement of these components are known alternatively as selective voltmeters or wave analysers, depending on application.

There are two distinct categories of wave analyser—the constant-bandwidth and the proportional-bandwidth types.

The Marconi Instruments TF 2330 is a constant-bandwidth wave analyser; i.e., the bandwidth does not vary with the tuning frequency. The action of this type of instrument is closely analogous to that of a superheterodyne receiver; and it is used mainly for analysis of constant-frequency waveforms in tests on a.f. and communication equipment.

In the proportional bandwidth type instrument the pass band is a constant proportion of the tuning frequency. These instruments are analogous to t.r.f. receivers: and their main applications are generally outside the communications industry, in such fields as vibration analysis.

Waveform Analysis

The wave analyser can be used for measuring the amplitude of a waveform's frequency components either in absolute terms or in terms relative to the amplitude of the fundamental. It is the second of these two ways that is normally used for measurement of distortion.

The instrument is tuned to the fundamental, and its sensitivity is standardised to a reference indication. It is then tuned to each frequency component in turn and the indicated relative level is noted. Thus each harmonic is indicated as H_1/S, H_2/S, etc. The r.m.s. sum of these values is:

$$\frac{\sqrt{H_1^2+H_2^2 \ldots\ldots\ldots H_2^2}}{S}$$

which is equal to the true distortion factor (DF_{true}), neglecting the noise component. As each sinusoidal frequency component is measured individually, it makes no difference whether the final indicator responds to the r.m.s., the average, or the peak current or voltage.

Intermodulation Measurement
(Two-Frequency Methods)

The main advantage of two-frequency methods of measuring non-linearity is that distortion in the test signal has far less effect on the measurement than with single-frequency methods. Furthermore the intermodulation measurement usually gives a more realistic assessment of the adverse effects of the non-linearity in an audio system.

Two standard methods are in common use. These are respectively, the method recommended by the CCIF and that recommended by the SMPTE.

The CCIF Method

In this system the test signal consists of two sinewave voltages of equal amplitude, having frequencies P and Q which are relatively close together. A frequency difference of between 10% and 20% is normally used.

This composite signal is applied to the input of the amplifier being tested; and the resulting output is monitored by a peak reading voltmeter (M1) and fed, via a low-pass filter, which rejects frequencies P and Q, to a sensitive voltmeter (M2).

The frequency components reaching M2 are even order intermodulation products having frequencies (P—Q), 2(P—Q), 3(P—Q), etc. Meter M1 indicates the peak voltage of the total output from the amplifier—approximately equal to V_P+V_Q. Meter M2, of course, indicates the peak amplitude of the intermodulation products. The intermodulation distortion is given by the formula:

$$\frac{\text{Intermodulation Product Amplitude}}{V_P+V_Q}\times 100\%$$

This method of measurement gives no indication of the odd order intermodulation products or of the sum components, as these are stopped by the low-pass filter. It is very useful, however, for assessing the effects of non-linearity at the upper end of the amplifier's frequency/response characteristic, where simple harmonic analysis gives misleading results.

The SMPTE Method

For this method, the test signal consists of two tones widely separated in frequency, the amplitude of the low-frequency tone, Q, being four times that of the high-frequency tone, P. The order of frequencies normally used would be 10 kHz for P and 1 kHz for Q, assuming that both of these fall well within the pass band of the amplifier. With the two-tone signal applied to the input of the amplifier, any non-linearity in the transfer characteristic produces intermodulation in the form of sidebands spaced symmetrically about tone P; i.e. (P$\pm$Q), (P$\pm$2Q), etc.

The high-power low-frequency tone is eliminated from the final output by means of a suitable filter, leaving an a.m. waveform at carrier frequency P. This is passed to a conventional modulation monitor, comprising a carrier level meter (M1) followed by a demodulator and filter feeding a second meter (M2), which indicates the amplitude of the demodulated signal, i.e., the intermodulation products. The intermodulation distortion is equal to:

$$\frac{\text{the sidebands (M2)}}{\text{the carrier (M1)}}\times 100\%.$$

Intermodulation Analysis

More revealing results can be obtained by measuring the amplitude of each of the intermodulation products separately with a wave analyser. A two-tone test signal is applied to the amplifier, and the output is fed to a wave analyser either directly or via a suitable filter depending on the expected intermodulation distortion content. The same test set-up can be used for both CCIF and SMPTE methods of measurement.

Because the wave analyser measures each individual intermodulation product separately, external filtering is no longer a part of the basic measuring equipment. However, it is one of the virtues of the intermodulation method that it can be used for measuring degrees of non-linearity which are small compared with the distortion in the signal source. It follows then that the system is likely to be used for measuring very low distortion levels, and an external filter can extend the range of the wave analyser considerably.

Intermodulation analysis is made in a similar way to that used for harmonic analysis. The sensitivity of the wave analyser is first adjusted to set up a reference level, and then each intermodulation product is measured independently. In this way a measure is made of each order of non-linearity separately.

Amplitude Modulation

Modulation depth can be defined as the ratio between the peak carrier and peak envelope voltages.

For symmetrical modulation waveform this may be resolved into the expression

$$\frac{D-d}{D+d} \times 100\%,$$

where D is the peak-to-peak voltage at the envelope peaks.
d is the peak-to-peak voltage at the envelope troughs.

Although this formula is very convenient for calculation of modulation depth from an oscilloscope display, it is subject to error if the envelope waveform contains even harmonic components which destroy its symmetry.

A.M. monitors, of the type built into the Modulation Meter TF 2300, utilise a detector having time constants such that the d.c. component of its output voltage is equal to the peak carrier voltage and the a.c. component is a facsimile of the modulation envelope. The a.c. component is measured by means of a peak-reading voltmeter calibrated to indicate modulation depth directly when the carrier voltage is set to a predetermined reference level. In the TF 2300 provision is made for inverting the demodulated waveform so that both the carrier-to-peak and carrier-to-trough voltages may be measured. To obviate errors due to asymmetry, the average of the "peak" and "trough" readings should be taken as the modulation depth.

Frequency Modulation

The degree of f.m. is usually stated in terms of peak deviation from the unmodulated carrier frequency. For symmetrical modulation waveforms, this is equal to half the total frequency excursion. For asymmetric waveforms, however, the positive and negative deviations will be unequal; and provision is made in deviation meters—such as TF 2300 and TF 791D—for measuring the deviation in each direction separately. The total sweep is, of course, the sum of the two measured deviations, but it is incorrect to regard the average of the two readings as the f.m. deviation figure.

With sinewave modulation the sideband distribution depends on the deviation ratio—or modulation index—which is usually signified by the symbol β, and is given by

$$\beta = \delta f / f_{mod}.$$

where δf is the peak f.m. deviation and f_{mod} is the deviation frequency. β is also equal to the phase deviation in radians.

Where the modulation frequency is variable and known, f.m. deviation can be accurately measured by setting for deviation ratios at which the carrier or sidebands have zero amplitude as shown in Tables I and II.

Table I. *Deviation ratios at which the carrier or sideband components have zero amplitude.*

Order of Zero Point	Deviation Ratio			
	Carrier	1st Pair Sidebands	2nd Pair Sidebands	3rd Pair Sidebands
1	2·405	3·832	5·136	6·380
2	5·520	7·016	8·417	9·761
3	8·654	10·173	11·620	13·015
4	11·792	13·324	14·796	16·223
5	14·931	16·471	17·960	19·409

F.M. on A.M. (Sideband Asymmetry)

Sideband asymmetry always indicates the simultaneous presence of amplitude modulation and either frequency or phase modulation. This statement holds good regardless of the original cause of the asymmetry; e.g., even if the asymmetry is produced deliberately by means of filters on an a.m. signal, f.m. is automatically introduced. (There is no real difference between spurious f.m. and ph.m. so far as the effects on the wanted a.m. are concerned.)

If f.m. and a.m. are applied simultaneously to the carrier, the first order pair of sidebands—as viewed on the spectrum analyser—will be equal to the vector sum of the a.m. and f.m. sidebands. Assuming that peak deviation in the positive direction occurs at the same instant as the a.m. envelope peak—i.e., the f.m. and a.m. modulating waveforms are in phase—the lower sidebands will be equal to the sum and the upper one to the difference of the a.m. and first order f.m. sideband amplitudes.

This is, in fact, the condition for maximum asymmetry; and, since the a.m. and spurious f.m. are both usually derived from the same modulating waveform, it is the one most likely to occur. As the phase angle between the a.m. and f.m. increases the asymmetry decreases, until it disappears altogether when the phase difference becomes 90°.

Table II. *Modulating frequencies corresponding to deviations at which carrier amplitude is reduced to zero.*

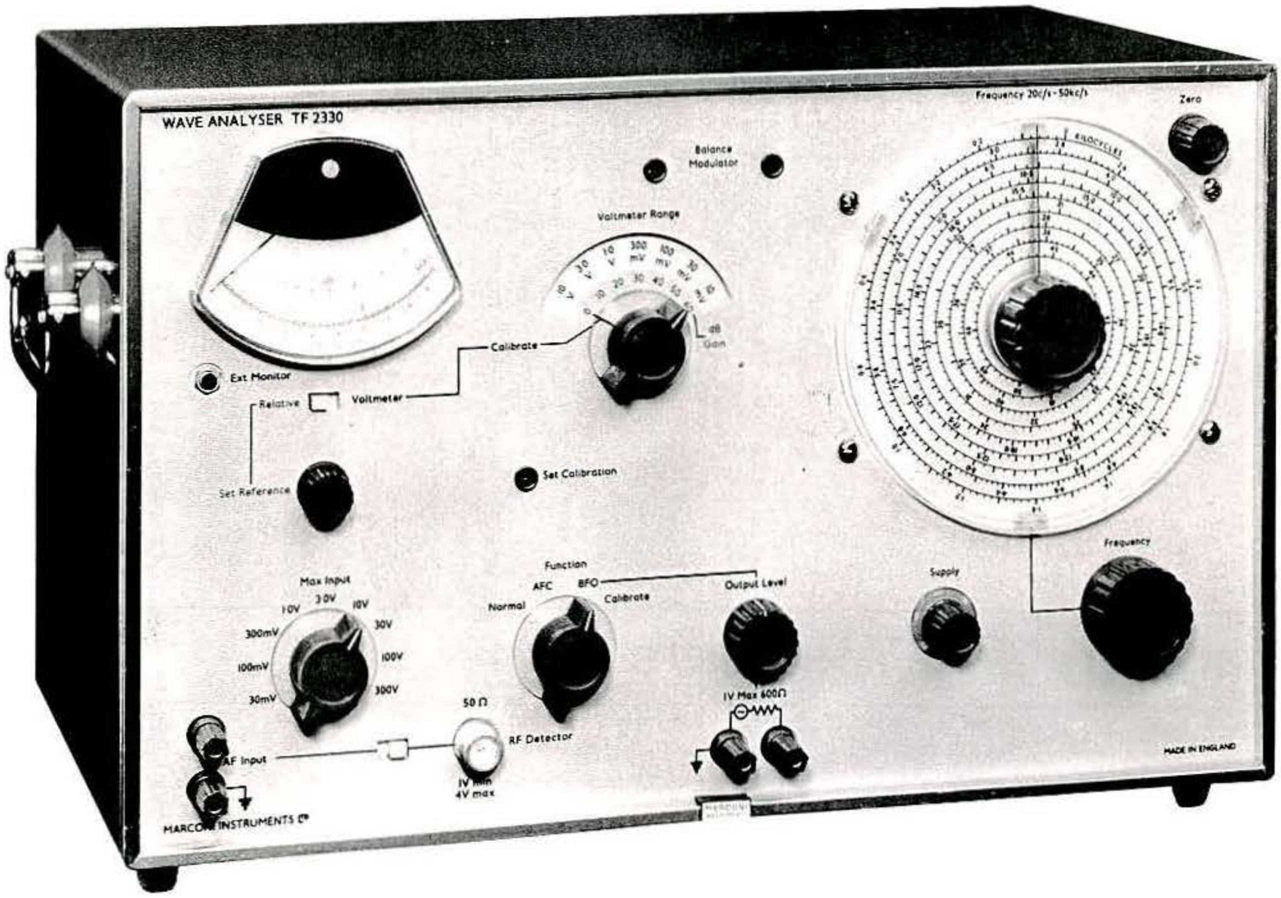
Carrier— first disappearance dev. ratio (2·4048)		Carrier— second disappearance dev. ratio (5·5201)	
Freq. Dev. in kHz.	Mod. Freq. in Hz.	Freq. Dev. in kHz	Mod. Freq. in Hz.
1	416	5	907
2	831	10	1,815
3	1,247	15	2,718
4	1,663	20	3,625
5	2,079	25	4,530
6	2,494	30	5,430
7	2,911	35	6,340
8	3,326	40	7,250
9	3,742	45	8,160
10	4,158	50	9,070
15	6,237	55	9,975
20	8,316	60	10,880
25	10,395	65	11,780
30	12,480	70	12,690
35	14,550	75	13,590

Analysers and Test Sets

Title and Type Number	Frequency Range	Rack Mounting Kit	Pages
Wave Analyser TF 2330	20 Hz to 50 kHz	TM 8271	88–89
Distortion Factor Meter TF 2331	20 Hz to 20 kHz	TM 7010	90–91
M.F. Transmission Measuring Set TF 2333	30 Hz to 550 kHz	TM 7010	92–93
	Measurement Facility		*Pages*
Carrier Deviation Meter TF 791D	F.M. Deviation	—	94–95
Modulation Meter TF 2300	F.M. Deviation A.M. Depth	TM 8340	96–97
H.F. Spectrum Analyser OA 1094A/3	R.F. Spectrum	—	98–99

Wave Analyser

- ☐ Frequency Range: 20 Hz to 50 kHz
- ☐ Measures amplitude of individual frequency components
- ☐ Restored-frequency output
- ☐ B.F.O. output
- ☐ Built-in r.f. demodulator



Wave Analyser TF 2330 is a narrow-band selective voltmeter tunable over the frequency range 20 Hz to 50 kHz in one continuous band. It is primarily intended for amplitude measurement of individual frequency components of complex waveforms; and it can be set to indicate directly in voltage or in terms relative to a fundamental datum level—either in decibels or in percentage.

Sensitivity and Selectivity

Discrimination between closely spaced frequency components is facilitated by the 7 Hz bandwidth. This implies a necessity for accurate tuning; but, once the component has been selected, internal automatic frequency control can be switched into operation, locking the Wave Analyser to the signal component and, incidentally, obviating continual retuning to correct for any small amount of frequency drift.

There are 15 ranges of voltage sensitivity from 30 µV full scale to 300 volts full scale, the lowest usable meter reading being at 3 µV. The minimum measurable level of a distortion component, however, depends upon the rejection ratio of the band pass filters within the instrument; and, for signal levels between 30 mV and 300 volts fed directly to the Wave Analyser, frequency components down to −75 dB relative to the fundamental can be measured. If it is desired to use the Wave Analyser on very low distortion systems, the range can be extended by feeding the signal to the instrument via the Marconi Tunable Rejection Filter TF 2334.

Restored Frequency Output

When the Wave Analyser is tuned to any frequency component of a waveform it delivers, at the panel terminals, a "restored-frequency" output; i.e., a voltage at the component's frequency. The output level is variable by means of a manual control; but, for any control setting, the output voltage is a direct function of the amplitude of the frequency component. This feature is useful for the application of particular frequency components to external measuring equipment; e.g., the isolation of the fundamental from very heavy noise. It also facilitates the use of an electronic counter for digital monitoring of any frequency component selected, an application which may be useful in identifying a particular frequency component which is not harmonically related to the others.

B.F.O. Output

The TF 2330 can also be switched to function as a b.f.o., delivering a continuous output at the tuning frequency of the selective voltmeter regardless of the input signal—as distinct from the restored-frequency output of normal operation. This feature provides a very convenient means of measuring the frequency response of active and passive networks. By applying the signal to the input of the network and monitoring the voltage at its output with the tuned voltmeter section the response of the network can easily be measured.

R.F. Demodulator

For convenience when checking distortion of modulation envelopes the TF 2330 is fitted with a linear r.f. detector, which may be switched into circuit in cascade with the normal a.f. input of the instrument.

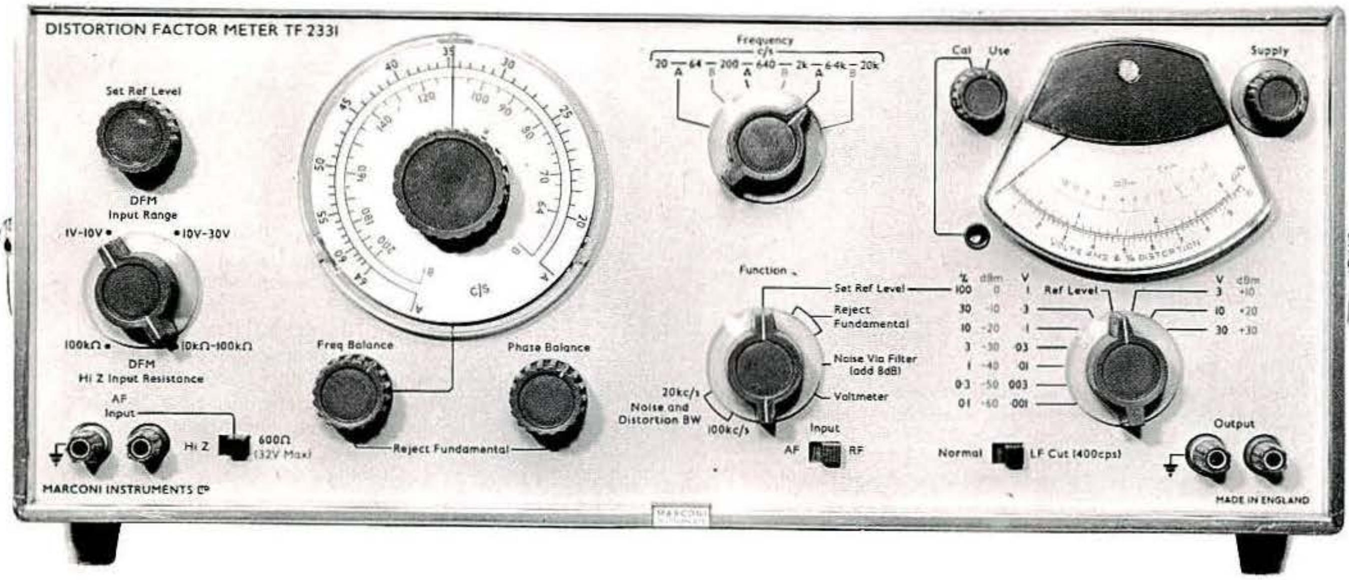
Construction Features

The TF 2330 Wave Analyser conforms to the modular standard; and is available in bench or rack-mounting form. All active circuit elements are solid state, with the advantages of portability, reliability, and low power consumption. Although the instrument is normally intended for mains operation, it can be driven from external batteries having voltages between 18 and 30 volts. This is a particularly useful attribute in the case of a wave analyser because, apart from the portability aspect, it may be desirable to use the instrument at frequencies close to the supply frequency or its low-order harmonics, where even the very small hum level resulting from mains operation may be troublesome.

INPUT FREQUENCY	
Working range	20 Hz to 50 kHz.
Accuracy	±1%, ±5 Hz.
A.F.C.	Tuning remains locked to input frequency over ±100 Hz drift.
AMPLITUDE RANGES	
Waveform analysis	*Range:* Measurements down to −75dB with respect to any fundamental level between 30 mV and 300 volts. For fundamental levels below 30 mV, the measurement range is progressively reduced.
SELECTIVE VOLTAGE MEASUREMENT	
Range	3 µV to 300 volts in 15 ranges of 30 µV to 300 volts f.s.d. in 1-3-10 sequence.
Accuracy	±5% of full scale.
Selectivity	±3½ Hz bandwidth, at least 3dB down. ±20 Hz bandwidth, at least 45dB down. ±40 Hz bandwidth, at least 63dB down. ±8 Hz and above, at least 80dB down.
Internal Noise and Distortion	Residual hum and noise, and distortion to measured signal at least 80 dB down.
Input resistance	100 kΩ on maximum attenuator settings between 30 mV and 1 volt; 1 MΩ on settings between 3 and 300 volts.
R.F. INPUT	
Frequency range	100 kHz to 500 MHz.
Input impedance	50Ω (type N connector).
Amplitude range	1 to 4 volts at maximum modulation depth.
Restored frequency output	*Range:* 20 Hz to 50 kHz. *Output:* Variable up to 1 volt r.m.s. out of 600Ω source, when meter reads f.s.d.
B.F.O. output	*Range:* 20 Hz to 50 kHz. *Output:* Variable up to 1 volt r.m.s. out of 600Ω source. *Response:* Flat to within ±0·1 dB over frequency range, terminated or unterminated.
Recorder output	100 µA into 2·5Ω. Recorder input to be isolated from ground.
POWER REQUIREMENTS	
A.C. mains	95 to 135 volts and 190 to 260 volts, 45 to 1000 Hz, 4 VA.
External D.C.	18 to 30 volts, 60 mA, positive earth.
DIMENSIONS AND WEIGHT	Height 11 in. 28 cm.; Width 18·5 in. 47 cm.; Depth 11 in. 28 cm.; Weight 24 lb. 11 kg.
ACCESSORIES	
Supplied: TB 39868	Shielded Adapter (Greenpar Type GE 51002) for converting input or output terminals to a BNC coaxial socket.
Rendar type MJP/600	Miniature Jack Plug, for use in Ext. Monitor socket.
MIP 45001	Mains Lead, for a.c. operation.

Distortion Factor Meter

- Fundamental range: 20 Hz to 20 kHz
- Input frequencies up to 100 kHz
- Distortion and noise from less than 0·05%
- Built-in r.f. demodulation
- Environmentally tested



The TF 2331 is for measuring the total noise and distortion content of audio signals with fundamental frequencies in the range 20 Hz to 20 kHz.

The measurement is made by the conventional method of suppressing the fundamental component, and then comparing the amplitude of the residue with that of the overall signal. A panel meter indicates the distortion factor both in per cent. and in decibels; and provision is made for standardising the sensitivity of the instrument so that the amplitudes are indicated directly in absolute terms; i.e., volts or dBm. The indicating system can also be switched directly to the input terminals and used independently of the filtering circuits so that the instrument functions as an electronic voltmeter with 1 MΩ input impedance over the frequency range 20 Hz to 100 kHz.

Suppression of the fundamental component is effected by the adjustment of a directly calibrated frequency control and a phase control. When these are correctly adjusted, the fundamental rejection ratio is at least 80 dB; and the frequency characteristic of the rejection filter is such that, for fundamental frequencies below 2 kHz, the second harmonic attenuation is less than 0·5 dB. For fundamental frequencies above 2 kHz, this attenuation increases slightly to 1 dB for 6 kHz and 2 dB for 20 kHz fundamentals. The overall bandwidth of the TF 2331 extends from 20 Hz to 100 kHz; and, for normal operation, the indicated impurity includes all the noise and distortion components within this band. Provision is made, however, for switching into circuit a low pass filter to restrict the upper limit of the noise and distortion measurement band to 20 kHz, thus eliminating frequency components which are beyond the audio range. There is also the facility for introducing an l.f. cut filter for the suppression of hum components that may produce misleading results. This filter reduces 100 Hz components by more than 20 dB, but has negligible attenuation for frequencies above 400 Hz.

With these band limiting filters, the TF 2331 is very suitable for signal-to-noise ratio measurements on amplifiers and receivers. And, to increase its usefulness in this application, a psophometric weighting network is incorporated having a frequency response following the characteristic recommended by CCIF for broadcast use.

For convenience when checking distortion of modulation envelopes the TF 2331 is fitted with a linear r.f. detector, which may be switched into circuit in cascade with the normal a.f. input of the instrument.

The minimum noise level that can be measured is −72 dBm. For distortion measurement, however, the low limit is determined by the amount of distortion introduced by the instrument itself. With fundamental frequencies between 200 Hz and 6 kHz, this is less than 0·025%, and outside this range it may rise to 0·04%. The output from the final amplifier of the instrument is available from a pair of terminals on the front panel, the output level being 150 mV from a source impedance of 1 kΩ. This facilitates the connection of an oscilloscope, for viewing the waveform of the signal or the impurity, or a true r.m.s. meter.

A two position switch selects input impedance of either 600 Ω, for termination purposes, or a high impedance that varies from 10 kΩ to 100 kΩ depending upon the voltage range.

The instrument employs all solid-state active elements, giving the inherent advantages of reliability, low power consumption, and small size and weight. It conforms to the Marconi full module dimensional standard so that it is automatically available in either a bench or rack-mounting case.

Being easily portable, the TF 2331 is well suited for field use; and, although normally powered by a.c. mains, it can be operated from an external battery if desired.

FREQUENCY RANGE	
Fundamental	20 Hz to 20 kHz in six ranges.
Total bandwidth	Upper −3 dB limit nominally 100 kHz or 20 kHz switch selected.
FILTER CHARACTERISTICS	
Calibration accuracy	±3%.
Fundamental rejection	At least 80 dB.
2nd Harmonic attenuation	Less than 0·5 dB for fundamentals up to 2 kHz; Less than 1 dB for fundamentals up to 6 kHz; Less than 2 dB for fundamentals up to 20 kHz.
L.F. cut	Can be introduced below 400 Hz to reduce hum components.
Weighting	Approximates to CCIF broadcast network; set for 8 dB attenuation relative to CCIF curve.
DISTORTION MEASUREMENT	
Range	Seven ranges in 1–3–10 sequence with full scale indications from 0·1% distortion factor to 100% distortion factor.
Instrument distortion	Less than 0·025% from 200 Hz to 6 kHz. Less than 0·04% elsewhere.
Measurement accuracy	±2% f.s. ±1% of reading between 200 Hz and 12 kHz. ±2% f.s. ±2% of reading between 20 Hz and 100 kHz.
Minimum input level	750 mV (less than 0 dBm in 600 Ω).
NOISE MEASUREMENT (Made with tone off)	
Range	0 to −72 dB relative to reference level.
Instrument noise	Less than 200 μV equivalent input.

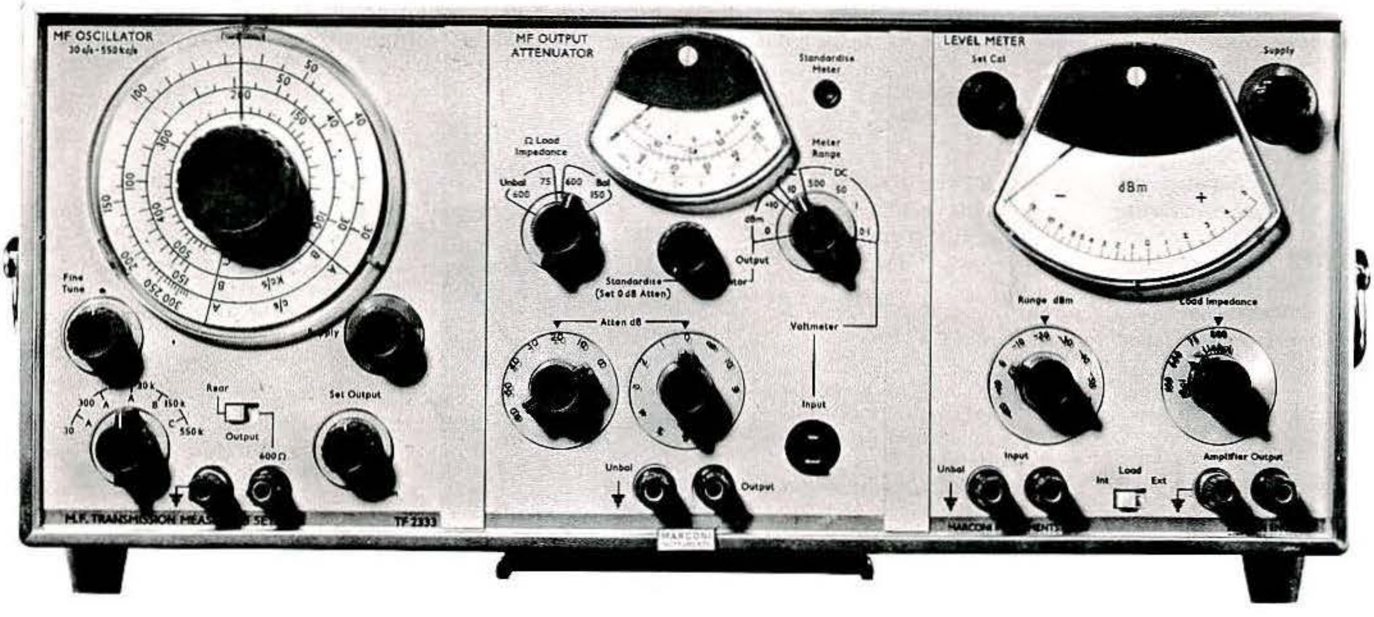
VOLTAGE MEASUREMENT	
Voltage range	Ten ranges: 1 mV f.s.d. to 30 volts f.s.d.
Accuracy	±2% f.s. ±1% of reading between 200 Hz and 12 kHz. ±2% f.s. ±2% of reading between 20 Hz and 100 kHz.
INPUT IMPEDANCE	
Noise and distortion	High Z: Nominally 10 kΩ/V up to 10 volts input. Nominally 100 kΩ/V from 10 to 30 volts input. Terminated: Nominally 600 Ω.
Voltmeter	Nominally 1 MΩ or 600 Ω.
INDICATOR	Mean-voltage-level meter calibrated in r.m.s. volts (sine-wave) and per-cent distortion, with additional dBm scale.
R.F. INPUT	
Frequency range	500 kHz to 500 MHz.
Input impedance	50 Ω type N connector.
Amplitude range	1 to 4 volts at maximum modulation depth.
POWER REQUIREMENTS	
A.C. mains	95 to 130 volts or 190 to 260 volts, 40 to 400 Hz; *Power consumption:* 3 watts.
External D.C.	18 to 45 volts, 25 mA.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
8 in	17¼ in	11 in	15 lb
20 cm	44 cm	28 cm	7 kg

M.F. Transmission Measuring Set

- Frequency range: 30 Hz to 550 kHz
- Measures response of active and passive transmission networks
- Suitable for multichannel applications up to basic supergroup bandwidth
- Environmentally tested



The TF 2333 is a transmission measuring set of the conventional type that normally forms part of the essential test gear for audio and baseband equipment of multichannel telecommunications systems.

It comprises a Signal Source, for energising the network under test, and a Level Meter for measuring the resulting output power from the network. It can be used for measurement of gain or attenuation and, therefore, frequency characteristic. The Level Meter can be applied to a.f. and m.f. power measurement. And a multi-range voltmeter facility provided in the instrument can also be used for fault finding.

The Signal Source consists of a variable frequency RC oscillator, covering the range 30 Hz to 560 kHz, followed by a monitored attenuator. The output level, indicated directly in dBm, is variable over the range −70 to +3 dBm. Source impedance is switch selected to suit the equipment under test, the choice being 600 Ω balanced or unbalanced, 150 Ω balanced, or 75 Ω unbalanced.

For normal t.m.s. operation, the oscillator is connected to the attenuator via a coaxial jumper at the rear. Its output can, however, be brought to the front panel terminals by the operation of a switch. In this condition it can be operated separately from the other sections of the instrument for general test purposes.

The input level applied to the attenuator is monitored by its panel meter. The equipment is normally used with the oscillator output set to give a constant deflection (usually 0 dBm)—variation of the test signal level being made by means of the attenuator controls. The sensitivity of the monitor is standardised at 1 kHz at the factory; but provision is made for re-standardisation at other frequencies against an external meter if desired.

The panel meter can also be switched to function as the indicator of a multi-range voltmeter. Four d.c. ranges, with full scale deflections from 0·1 to 500 volts, cover the requirements for checking supply voltages to most valve or transistor circuits; and a single a.c. range with 10 volts f.s.d. facilitates the checking of valve heater supplies.

The Level Meter is a wide-band amplifier/voltmeter designed for use over the frequency band 30 Hz to 560 kHz. It is calibrated directly in dBm and covers the range −70 to +25 dBm. A load impedance switch automatically adjusts the sensitivity of the voltmeter so that the power indication remains direct for each standard impedance used, and the need for calculation is obviated. The Level Meter can be switched to act as the terminating load of a network under test or to high impedance for monitoring the power in an external termination.

The amplified signal is also brought out to a pair of terminals on the front panel of the unit. This enables the amplified test signal to be applied to an oscilloscope or other external measuring equipment.

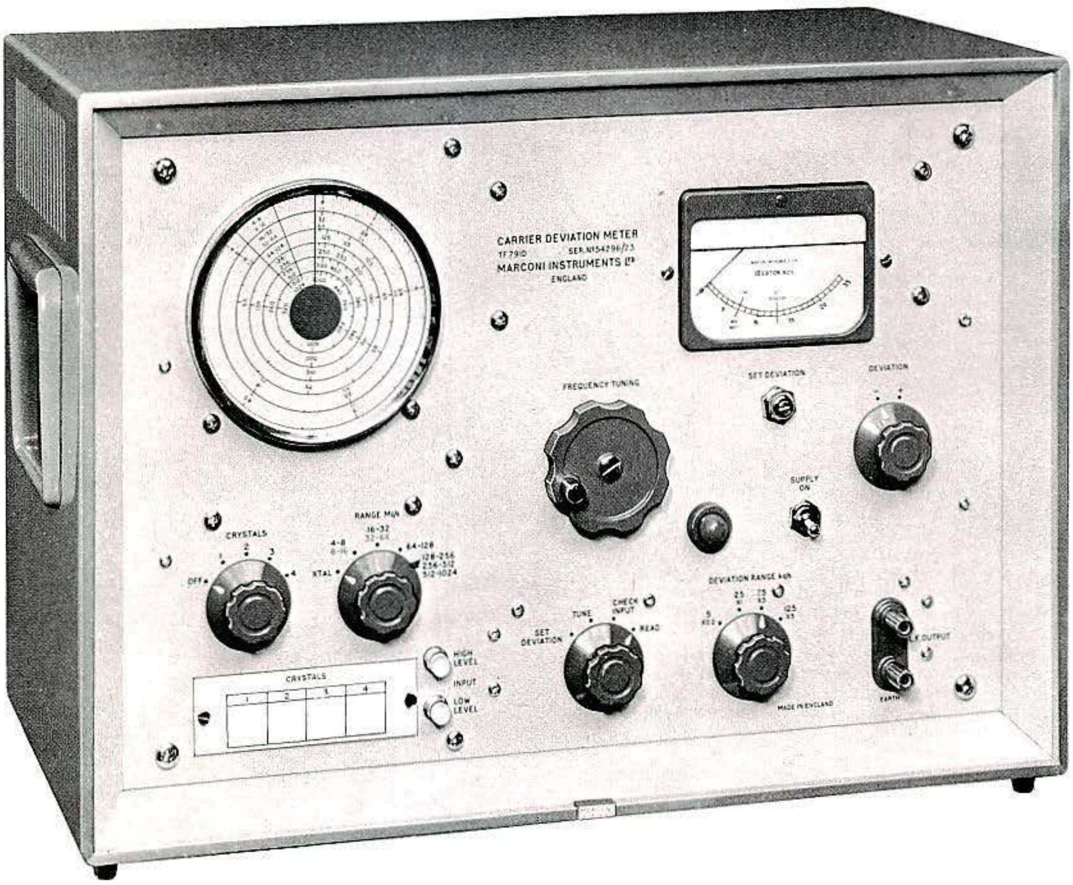
The instrument conforms to the Marconi modular standard, and comprises three one-third sub-modules. It is available for bench or rack mounting. The bench type can be fitted with a protective front cover which also houses leads and accessories.

Being fully transistorised, the TF 2333 is easily portable and well adapted for field use. Although it is normally intended for a.c. mains operation, it can be operated from external batteries if desired.

SIGNAL SOURCE	
OSCILLATOR	
Frequency range	30 Hz to 550 kHz in five ranges: A : 30 to 300 Hz. A×10 : 300 to 3,000 Hz. A×100 : 3 to 30 kHz. B : 30 to 150 kHz. C : 115 to 550 kHz. The dial is calibrated and performance maintained up to 560 kHz.
Frequency accuracy	±3%.
Maximum output	At least +3 dBm.
ATTENUATOR	
Range	70 dB in 10 dB and 1 dB steps.
Accuracy	50 Hz to 20 kHz: ±1% of dB setting ±0·2 dB. 20 kHz to 560 kHz: ±2% of dB setting ±0·2 dB.
Output impedance	*Unbalanced:* 600 Ω and 75 Ω. *Balanced:* 600 Ω and 150 Ω.
DISTORTION	Less than 1% at 0 dBm.
HUM	Less than −70 dBm.
MONITOR	
Ranges	0 dBm and +10 dBm centre-scale, meter graduated −6 dBm to +6 dBm.
Accuracy	±0·25 dB under the conditions at which standardisation was carried out. The normal conditions are 600 Ω unbalanced, 1 kHz, 0 dBm meter reading and zero attenuation. A panel preset control allows restandardisation at other impedances.
Frequency response (relative to 1 kHz)	±0·1 dB from 300 Hz to 50 kHz; ±0·5 dB from 100 Hz to 200 kHz; ±1·2 dB from 500 Hz to 560 kHz, not applicable to 600 Ω balanced above 200 kHz.
VOLTMETER	
Ranges	D.C.: 0·1, 1, 50 and 500 volts full-scale. A.C. (power line frequencies): 10 volts full-scale. Also percentage scale calibrated ±50% relative to 0·5 volts d.c.
Accuracy	±5% of full-scale.
LEVEL METER	
FREQUENCY RANGE	50 Hz to 560 kHz.
LEVEL MEASUREMENT RANGE	+25 to −70 dBm.
MEASUREMENT ACCURACY	Can be standardised against signal source at 0 dBm, 1 kHz.
FREQUENCY RESPONSE (relative to 1 kHz at 0 dBm)	200 Hz to 20 kHz; ±0·1 dB at all impedances; 50 Hz to 100 kHz; ±0·25 dB at all impedances; 100 kHz to 300 kHz; ±0·25 dB at 150 and 75 Ω; 300 kHz to 560 kHz; ±0·5 dB at 150 and 75 Ω.
RANGE SWITCHING ACCURACY	
Up to 100 kHz	±0·3 dB from +20 to −50 dBm ranges at all impedances. ±0·5 dB on −60 dBm range at all impedances.
Up to 560 kHz	+0·5 dB from +20 to −50 dBm ranges at 150 and 75 Ω. ±1 dB on −60 dBm ranges at 150 and 75 Ω.
METER SCALE ACCURACY	±0·1 dB per 1 dB increment relative to 0 dB between +5 and −5 dB.
INPUT RESISTANCE	
Terminated	*Balanced:* 600 Ω and 150 Ω. *Unbalanced:* 600 Ω and 75 Ω.
Unterminated	At least 15 kΩ on −10 to −60 dBm ranges; 100 kΩ (unbalanced) on 0 to +20 dBm ranges; 200 kΩ (balanced) on 0 to +20 dBm ranges.
REJECTION OF COMMON MODE SIGNALS ON BALANCED LINES	At least 40 dB at 1 kHz; at least 34 dB at 560 kHz (subject to maximum r.m.s. voltage limitations of 0·5 volts on −10 dBm ranges and below, 70 volts on 0 dBm to +20 dBm ranges at 50 Hz and 14 volts at 560 kHz).
MAXIMUM INPUT	A.C. or d.c. voltage between terminals or from terminals to chassis must not exceed 100 volts peak or 0·5 watts, whichever is more significant.
AMPLIFIER OUTPUT	Available at two front-panel terminals. Output approximately 85 mV r.m.s. when meter reads 0 dBm. Output impedance nominally 1 kΩ.
GENERAL	
POWER REQUIREMENTS	
A.C. mains	190 to 260 and 95 to 130 volts, 45 to 500 Hz; 210 to 260 and 105 to 130 volts, 500 to 1,000 Hz; 5 watts.
External d.c.	21·5 to 30 volts 50 mA.
DIMENSIONS AND WEIGHT (with front cover attached)	Height 7½ in 19 cm; Width 18½ in 47 cm; Depth 12¾ in 32 cm; Weight 28 lb 12·7 kg
ACCESSORIES	
Supplied TM 7052	Mains Lead.
TC 40069	Unbalanced Output Lead (two supplied).
TM 4726/208	Balanced Output Lead (two supplied).
TM 4726/196	Voltmeter Input Lead.
TM 40755	Voltmeter Input Lead Adaptor.
TM 7510	Protective Cover (Lid assembly).
Optional TM 7010	Rack Mounting Case.

Carrier Deviation Meter

- ☐ Carrier frequency range: 4 to 1024 MHz
- ☐ Measures deviation up to 125 kHz, or down to 10 Hz using external indicator
- ☐ Crystal locking gives freedom from microphony, permits measurement of f.m. noise



TF 791D is a direct reading f.m. deviation meter suitable for use at carrier frequencies up to 1024 MHz. Four deviation ranges—5, 25, 75, and 125 kHz—cater for both communication and f.m. broadcast systems.

The instrument is basically a superheterodyne f.m. receiver using an integrating counter type demodulator for high stability. The output from this demodulator energises a meter calibrated directly in deviation, and is also available externally at a separately buffered outlet for aural monitoring or measurement of very low deviation.

The local oscillator operates on harmonics over six of its eight ranges. This avoids the danger of frequency pulling at the higher frequencies, and the relatively narrow frequency cover of the oscillator has simplified the inclusion of a crystal locking facility. The frequency of the oscillator can be locked to that of a crystal within the range 4 to 10 MHz, thus eliminating spurious f.m. within the instrument so that reliable measurement can be made of f.m. hum and noise in transmitters for v.h.f. broadcasting and narrow-band mobile communications. Crystals can be supplied to suit any specified carrier frequency, and are selected in the instrument by a four position switch. Where the crystal harmonic power is adequate, the local oscillator can be switched out of circuit and the crystal oscillator coupled directly to the mixer stage.

To aid measurement of asymetric modulation, the instrument can be switched to indicate positive or negative deviation without the need for retuning.

CARRIER FREQUENCY	
Range	4 to 1024 MHz in eight bands each of 2:1 frequency coverage.
Calibration accuracy	±3%; the calibration is in terms of local-oscillator frequency.
Crystal locking	Local oscillator can be locked at any frequency within its range by crystals between 4 and 10 MHz—see Accessories.
DEVIATION MEASUREMENT	
Ranges	±5, ±25, ±75, and ±125 kHz full-scale. Using crystal lock, deviation down to about 10 Hz can be measured on an external indicator at the l.f. output terminals.
Accuracy	For modulation frequencies between 50 Hz and 25 kHz, ±3% of full-scale. For modulation frequencies between 25 and 35 kHz, ±3% of full-scale ±3% of the reading.
R.F. INPUT	
Impedance	Nominally 50Ω.
Signal E.M.F. at 50Ω source	Minimum: 25 mV up to 256 MHz, 50 mV up to 512 MHz, 1 volt up to 1024 MHz. Maximum: 5 volts.
L.F. OUTPUT	
Impedance	Approx. 1 kΩ unbalanced.
Level	Approx. 1·5 volts e.m.f. at full-scale.
F.M. Noise	Using crystal lock, hum and noise in the band 50 Hz to 20 kHz does not exceed −50 dB relative to full-scale deviation on the 5-kHz range. Without crystal lock, approx. −30 dB relative to 5 kHz deviation between 4 and 470 kHz.
POWER REQUIREMENTS	100 to 150 volts and 200 to 250 volts, 40 to 100 Hz; 100 watts.

DIMENSIONS AND WEIGHT

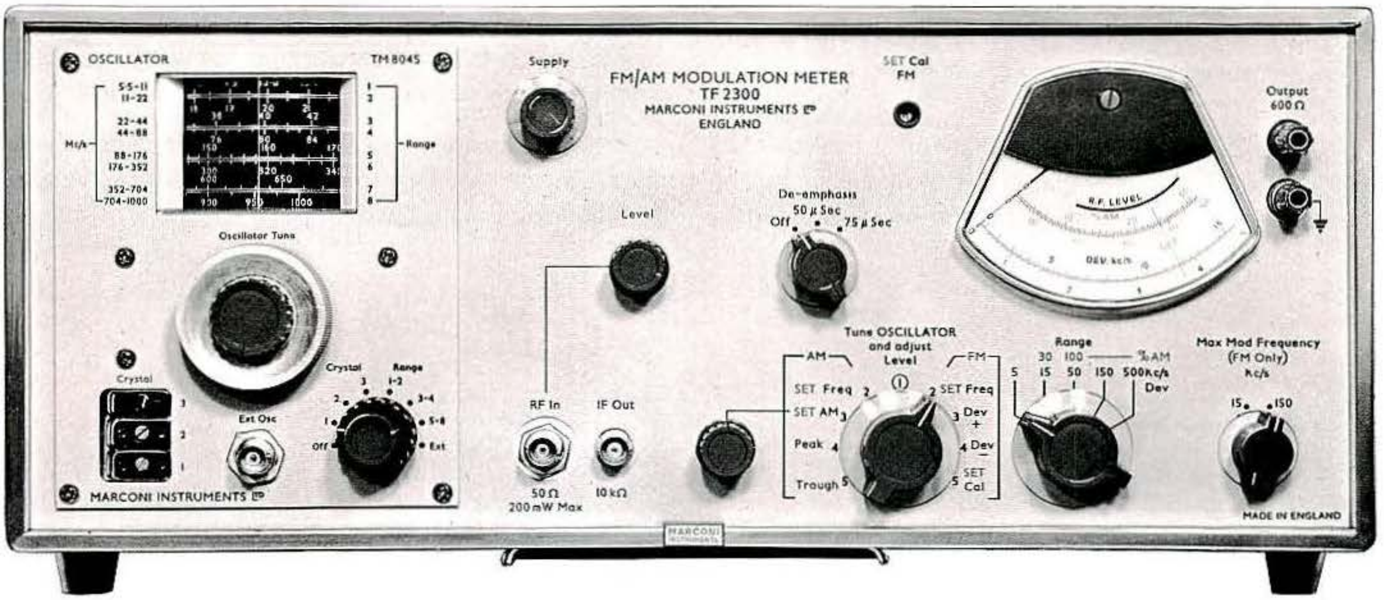
Height	Width	Depth	Weight
13 in	18 in	11 in	40 lb
33 cm	46 cm	28 cm	18 kg

ACCESSORIES

Supplied	**Coaxial Free Plug,** Type BNC, for use with either high- or low-level r.f. inlet.
Optional	**Coaxial Input Lead,** 50Ω, TM 4969; 36 inches long; Type BNC plug both ends.
	Local Oscillator Locking Crystals, miniature 2-pin; Marconi Type QO 1670 series; frequencies to suit any specified carrier frequencies between 4 and 1024 MHz.

FM/AM Modulation Meter

- ☐ Measures f.m. deviation up to 500 kHz at carrier frequencies up to 1000 MHz
- ☐ Measures a.m. depth up to 95% at carrier frequencies up to 350 MHz
- ☐ Modular construction with all-solid-state active elements gives maximum reliability



The TF 2300 basically comprises a low-sensitivity superheterodyne receiver having very linear (switch selected) f.m. and a.m. demodulators. The demodulated signal is amplified, rectified, and applied to a panel meter which is calibrated directly in kHz peak deviation and per cent. modulation depth as appropriate.

For f.m. measurement, the instrument is capable of indicating peak deviation up to a maximum of 500 kHz at modulation frequencies up to 150 kHz; but it is equally suitable for measurement of the very low values of deviation that are often produced by noise or spurious modulation of the signal under test. The sensitivity of the measuring system can be varied, by means of a five-position switch, from 5 kHz full scale to 500 kHz full scale; and the instrument can also be switched to indicate positive or negative peak deviation so that the symmetry of the modulation can be accurately assessed.

For measurement of very low values of deviation there is provision for connecting a sensitive external indicator, via a pair of terminals, to the output of the l.f. amplifier. This outlet is also useful for applying the demodulated signal to secondary test equipment—e.g., an oscilloscope or wave analyser—for checks on waveform, modulation frequency, etc. This facility for using the instrument as a test receiver is furthered by the provision for switching standard de-emphasis filters of 50 μsec or 75 μsec into the l.f. amplifier. It is also possible to introduce a 15 kHz low-pass filter in order to restrict the bandwidth to the audio range if desired.

In order to avoid masking of very small measured deviations it is important that the internally generated f.m. noise shall be commensurately small. In the TF 2300, this noise is mainly due to random frequency modulation of the local oscillator. It therefore increases with carrier frequency, but rarely—even at 1000 MHz—does it exceed −30 dB relative to 5 kHz deviation. Provision is made, however, for locking the local oscillator to a crystal for measurement at carrier frequencies above 20·5 MHz, the internally generated noise in this condition being less than −50 dB relative to 5 kHz deviation. Below 20·5 MHz the internally generated noise is of this order without the need for crystal locking.

There are three, switch selected, sockets on the front panel into which the appropriate series-resonant crystals may be inserted. The crystal frequencies should be between 22 and 44 MHz, harmonics being used for higher tuning frequencies. Locking of the oscillator is extremely positive and easily obtained; it is necessary only to tune the instrument approximately to the correct frequency and then switch to the appropriate crystal.

Provision is made for switching the internal local oscillator out of circuit altogether and utilising an externally generated heterodyne signal. This is applied via a BNC socket on the front panel of the instrument, the required input level being nominally 200 mV e.m.f. from a 50 Ω source. Electrical access is also obtainable to the output of the i.f. amplifier via a BNC panel socket.

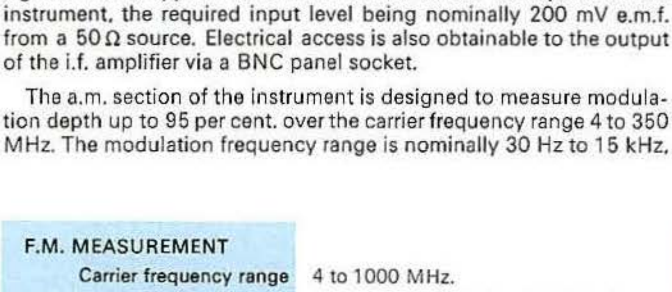
The a.m. section of the instrument is designed to measure modulation depth up to 95 per cent. over the carrier frequency range 4 to 350 MHz. The modulation frequency range is nominally 30 Hz to 15 kHz, but the bandwidth of the a.f. system actually extends up to 50 kHz to facilitate measurement of harmonics. In order to give an indication of the symmetry of the modulation envelope, the meter may be switched to indicate the peak or trough amplitude relative to the mean carrier level.

The instrument employs all-solid-state active elements, giving the inherent advantages of reliability, low power consumption, and small size and weight. It conforms to the Marconi full-module dimensional standard so that it is automatically available in either bench or rack-mounting form. In order to aid servicing, the instrument is so constructed that the electrical circuits take the form of easily detachable sub-modules, most of which can be removed from the main frame with little or no unsoldering of connections.

Being easily portable, the TF 2300 is well suited to field use; and although normally powered by a.c. mains, it can be operated from an external battery if desired.

F.M. MEASUREMENT

Carrier frequency range	4 to 1000 MHz.
Deviation range	Five ranges with full scale indications of 5, 15, 50, 150, and 500 kHz. Positive or negative deviations indication selected by means of a switch.
Accuracy	±3% of f.s. for deviations up to 150 kHz at modulating frequencies between 30 Hz and 15 kHz. ±5% of f.s. for deviations up to 500 kHz at modulating frequencies up to 150 kHz.
A.M. rejection	Additional deviation error less than 1 kHz when the a.m. depth is 80% and the modulating frequency is 1 kHz.
Inherent noise	Deviation less than −70 dB relative to 50 kHz deviation for a bandwidth of 30 Hz to 15 kHz when the local oscillator is crystal locked.



A.M. MEASUREMENT

Carrier frequency range	4 to 350 MHz.
Mod. depth range	Two ranges with full scale indications of 30% and 100% (maximum usable reading: 95%).
Accuracy	±5% of f.s. for modulating frequencies between 30 Hz and 15 kHz.

R.F. INPUT

Sensitivity	20 mV at frequencies between 4 and 250 MHz. 50 mV at frequencies between 250 and 500 MHz. 100 mV at frequencies between 500 and 1000 MHz.
Maximum input	3 volts r.m.s. (200 mW)
Input impedance	Nominally 50Ω.

LOCAL OSCILLATOR

Variable frequency operation	The internal oscillator has two ranges: 5·5 to 11 MHz and 22 to 44 MHz, harmonics being used for other local oscillator frequencies. Provision is made for connecting an external oscillator with an output of 200 mV.
Calibration accuracy	±3%.
Crystal operation	Up to three crystals within the frequency range 22 to 44 MHz may be fitted, for use with input frequencies between 20·5 and 1000 MHz.

I.F. OUTPUT

Frequency	1·5 MHz.
Amplitude	Between 250 and 750 mV e.m.f.
Output impedance	Nominally 10 kΩ.

L.F. OUTPUT

Frequency range	30 Hz to 150 kHz with switchable 15 kHz low pass filter on f.m. 30 Hz to 50 kHz on a.m.
De-emphasis	Switchable to 0, 50, or 75 μsec.
Level	Nominally 0 dBm into 600Ω when meter reads full scale.
Distortion	0·25% for f.m. deviations up to 75 kHz and modulation frequencies up to 15 kHz. 0·5% for f.m. deviations up to 300 kHz and modulation frequencies up to 25 kHz. 3% for f.m. deviations up to 500 kHz and modulation frequencies up to 150 kHz. 1% for a.m. depths up to 60%. 3% for a.m. depths up to 90%.

POWER REQUIREMENTS

A.C. Mains	95 to 130 volts a.c. or 190 to 260 volts, 45 to 500 Hz, 15 VA.
External d.c.	Between 21·5 and 30 volts d.c., 300 mA at 24 volts d.c.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
7¾ in	18¾ in	14¼ in	24 lb
19 cm	47 cm	36 cm	11 kg

ACCESSORIES

Supplied

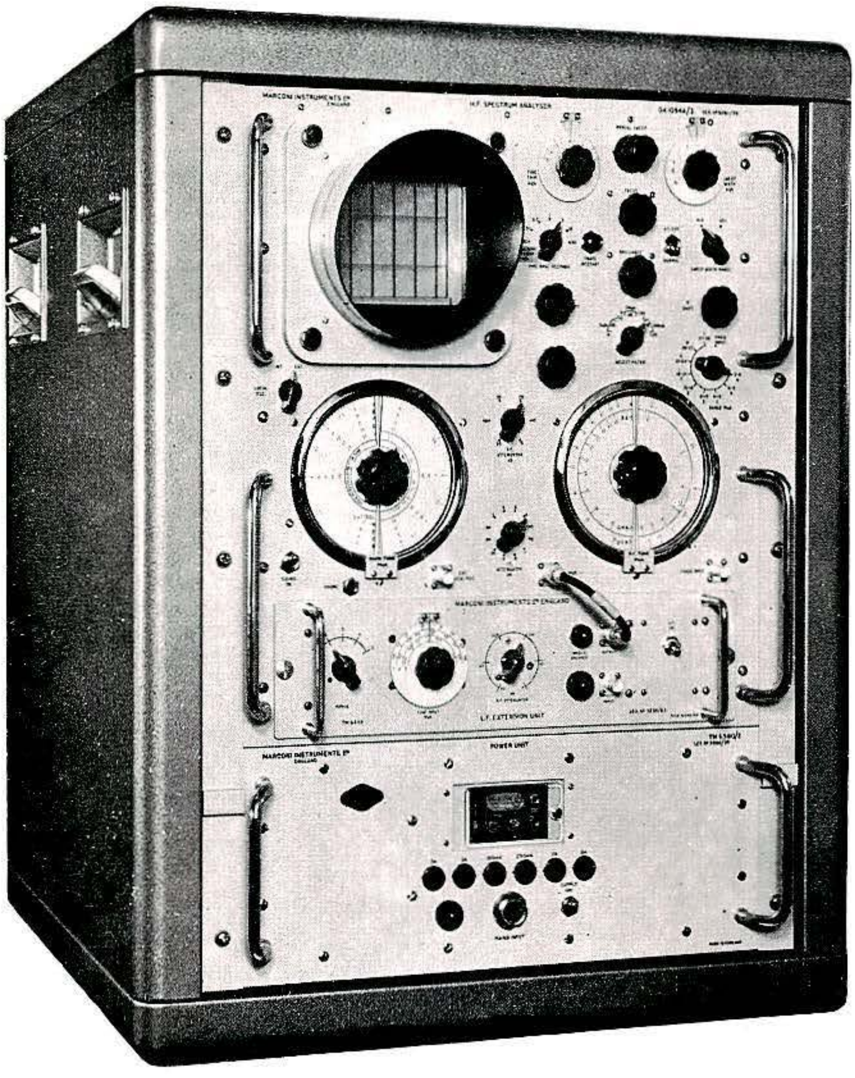
TM 7926	Extension board for use with plug-in printed boards. (Mounted internally)
TM 7052	Mains lead.

Optional

TM 9884	R.F. Fuse Unit.
TM 4969	Coaxial input lead, 50Ω, 36 in, BNC connectors.
TM 7958/3	Protective cover.
QO 1670F	Series-resonant crystals at appropriate frequencies between 22 and 44 MHz.
TB 39868	Shielded Adapter.

H.F. Spectrum Analyser

- ☐ Basic frequency range: 3 to 30 MHz; optional l.f. extension unit for 100 Hz to 3 MHz
- ☐ Sweep width variable from a few hertz to 30 kHz
- ☐ Measures relative amplitudes up to 60 dB



Spectrum Analyser Type OA 1094A/3 gives an immediate visual presentation of the frequency spectra of h.f. signals. The spectrum of the signal under test is displayed on a c.r.t. screen in the form of a series of vertical peaks whose heights and separations give the relative amplitudes and frequencies of the signal components.

The width of frequency spectrum displayed is continuously variable up to 30 kHz, which allows observation of the whole bandwidth of a broadcast transmission; at the other extreme, the display can be narrowed to a few hertz to facilitate the separation of closely spaced components.

Relative levels of signal amplitude can be measured over a range of 30 dB or, in two stages, 60 dB. A high order of selectivity ensures adequate discrimination between signals of widely differing amplitudes but as little as 50 Hz apart; alternative lower values of selectivity are available, primarily to facilitate tuning and also for making rapid measurements on the more widely-spaced components.

The time taken to scan the spectrum may be varied in steps from 0·1 to 30 sec, the slower speeds ensuring absence of ringing effects when using high selectivity. A manual position is also provided. Continuity of display is provided by the long-persistence cathode-ray tube.

Applications

The nature of the display makes the OA 1094A/3 particularly suitable for the identification and quantitative assessment of intermodulation products or hum components in the output of single-sideband transmitters and drive units, for making dynamic distortion tests during the transmitter setting-up procedure, or for studying the effective bandwidth of on/off or frequency-shift keyed emissions. With f.m. signals, it facilitates the accurate determination of modulation index by the Bessel Zero or disappearing carrier method.

Special care has been taken to provide a rugged mechanical design and minimise microphony.

TRIPLE SUPERHET CIRCUIT

The Analyser is essentially a triple-superhet receiver with a crystal-controlled first local oscillator; the third local oscillator is frequency-swept in synchronism with the c.r.t. timebase sawtooth, and the final i.f. is accepted by a selection of crystal band-pass filters. The detected filter output is applied to the c.r.t. Y-plates via a logarithmic amplifier.

A socket is provided for connecting to an external oscillator to take the place of the internal second local oscillator. This allows a crystal or synthesiser oscillator to be used for the highest stability when making narrow-band measurements under arduous conditions of vibration.

DISPLAY

The amplitudes of displayed components are measured by means of horizontal 10 dB lines on the c.r.t. screen and a 1 dB step i.f. attenuator; relative frequencies are measured by using the vertical marker lines on the screen in conjunction with the directly calibrated sweep width control.

AURAL MONITORING

A beat-frequency oscillator can be switched in to provide an audio output for use with headphones. This allows the r.f. stages to be quickly and accurately tuned by adjusting for zero beat.

INPUT SIGNALS	
Input frequency range	3 to 30 MHz in nine bands as follows: 3–6 MHz 12–15 MHz 21–24 MHz 6–9 MHz 15–18 MHz 24–27 MHz 9–12 MHz 18–21 MHz 27–30 MHz
Additional fixed frequency input (If specified at time of ordering)	3·1 MHz or 300 kHz.
Input impedance	75Ω.
Input level	For full display, the input required is not greater than: +50 dBμV between 3 and 6 MHz, +80 dBμV between 6 and 27 MHz, +90 dBμV between 27 and 30 MHz, and +118 dBμV at the fixed-frequency inlet.
MEASUREMENT CHARACTERISTICS	
Amplitude ranges	0 to −30 dB, and −30 to −60 dB, where 0 dB represents level of reference signal.
Selectivity	Three values of 3 dB bandwidth can be selected, viz., 6, 30, and 150 Hz, frequencies outside bandwidths of 120, 600, and 3,000 Hz respectively are rejected by more than 60 dB.
Spectrum width	0 to 30 kHz.
Sweep duration	0·1, 0·3, 1, 3, 10, 30 sec. and manual.
POWER REQUIREMENTS	
A.C. mains	200 to 250 volts, and 100 to 150 volts; 40 to 100 Hz; 185 watts.
DIMENSIONS AND WEIGHT (in case)	

Height	Width	Depth	Weight
30¼ in	24 in	27 in	278 lb
78 cm	61 cm	69 cm	126 kg

ACCESSORIES	
Supplied	
Three coaxial free plugs	Type BNC; for main r.f., fixed-frequency, and local oscillator inlets.
One telephone plug	Type P40; for phones jacks.
TM 4726/34	**Mains Lead:** 3-core; 18 feet long.
Optional	
TM 6448	**L.F. Extension Unit:** A heterodyne device with a crystal-controlled local oscillator. It employs wide-band, untuned stages in the signal path but includes switched input filters enabling restricted frequency bands to be selected within the overall 100 Hz to 3 MHz range. This accessory can be fitted below the Analyser display unit.
TM 6467	**Fixed Frequency Changer,** for 300 kHz, TM 6467/1 for 3·1 MHz: These can be fitted inside the Analyser for the benefit of users who wish to display a signal of one particular frequency. It allows the Spectrum Analyser to accept a fixed-frequency signal at a separate inlet without the necessity of adjusting the tuning controls. **Camera Mounting Hood:** Fits readily in place of the normal c.r.t. surround and is intended to accommodate a recording camera. A viewing aperture allows the trace to be viewed and photographed simultaneously.
TM 6612	**Trolley:** Sloping top, 2 feet high, 95 lb.
TM 6978	**Base Plate Assembly:** Steel plate with 6 anti-vibration mountings. For fitting between instrument and trolley or bench.
TM 6723	**R. F. Fuse Unit:** Overload protection, burns out at 90 mA, i.e. 6·75 volts. Connectors: Type BNC. Fuse: $\frac{1}{16}$ amp. Littelfuse Cat. No. 361,062; 10 spares are supplied. It can be plugged in series with the input to the Analyser or L.F. Extension Unit to protect the input attenuators from damage through the accidental application of high r.f. or h.t. voltages.

Television Measuring Equipment

Monochrome and colour television transmission system measurement

Monochrome test methods

The use of a sine square pulse is an important method of determining the amplitude/frequency and phase/frequency characteristic of a system through which it has passed. A sine squared pulse as shown in Fig. 1 is produced by applying a narrow pulse of some 20 nsec duration to a filter of the maximally flat delay type. This filter is designed to produce a sine squared pulse whose half amplitude duration (h.a.d.) is equal to one half period of the nominal cut-off frequency of the system. This is known as a "T" pulse.

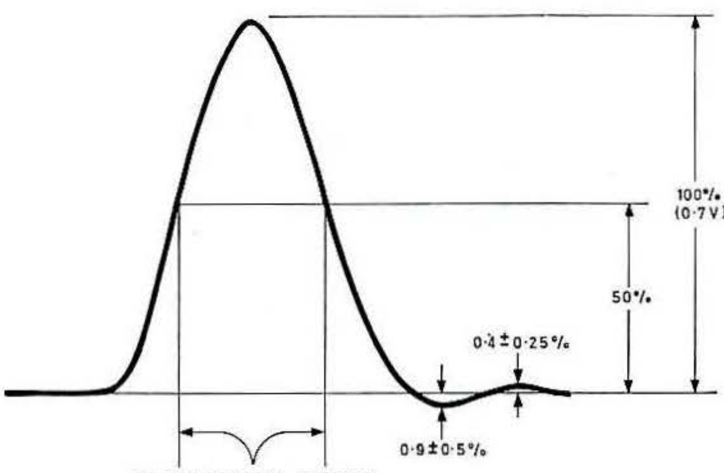


Fig. 1. Sine squared pulse showing shape and size of overshoots.

In the case of a 625 line system, with a bandwidth of 5 MHz, $T = 1/(2f) = 100$ nsec. This pulse is 6 dB down at 5 MHz and falls to zero at 10 MHz. The spectrum of this pulse (see Fig. 2) is such that it will only indicate distortion occurring within the band of interest, in this case 10 MHz. If the sine squared pulse is passed through a system with a falling frequency/response characteristic but linear frequency/phase characteristic, the received pulse is reduced in height. Should phase/frequency distortion be present the pulse acquires rings due to the incorrect time arrival of the components of the pulse.

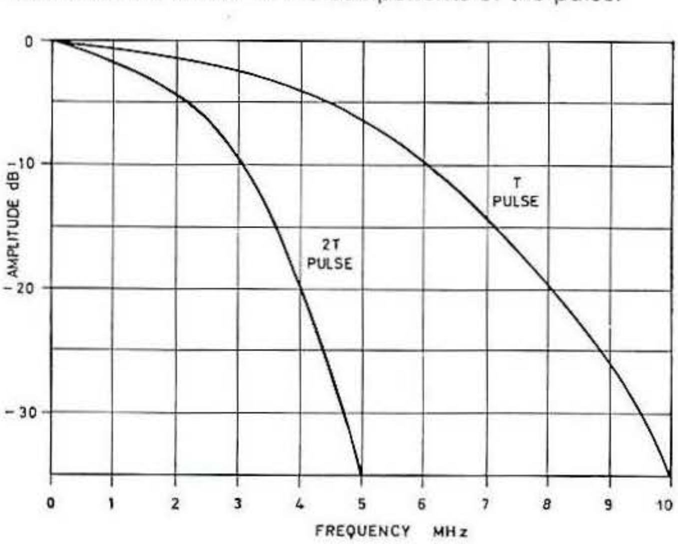


Fig. 2. Spectrum of a sine-squared pulse.

In order to check the low frequency response a bar waveform is used, and this waveform is also fed through the same filter. This indicates, if it departs from constant amplitude when fed through a system, that amplitude-frequency and/or phase-frequency distortion exists in the lower part of the frequency spectrum down to the line repetition rate. The duration of this bar is nominally 40 μsec for 405 lines and 25 μsec for 625 lines. The composite signal is shown in Fig. 1. In addition to these waveforms it is common to produce a 50 Hz square wave on line synchronizing pulses. This waveform indicates distortion in the region between the line and field frequencies. The transitions are smoothed by feeding this waveform through the same filter as produced the sine squared pulse and bar.

These waveforms are capable of measuring with a high degree of accuracy the forms of distortion mentioned. However, care should be taken that the display device is free from distortion before testing commences. Tests should also be made to determine that the system to be tested is free from non-linearity which would, if present, make the correct interpretation of the results impossible.

Measurement of linearity

Linearity may be measured using either the staircase or sawtooth waveform. The number of steps in the staircase may be from five to ten. This enables the linearity to be measured at the extremes of average picture level. An advantage of the staircase over the sawtooth waveform is that when it is differentiated and filtered the spikes resulting from the risers of the staircase show, by their departure from constant height, the degree of non-linearity. The generator which produces the full-line

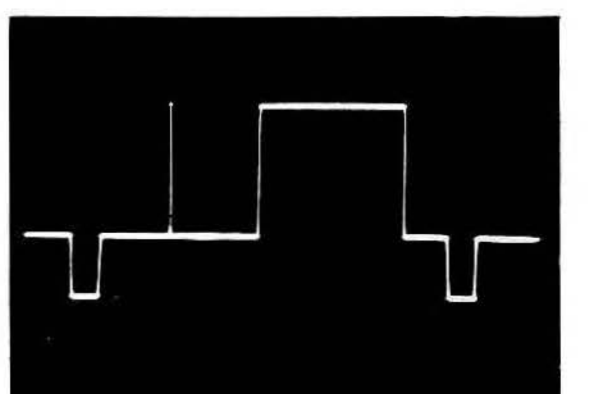


Fig. 3. Monochrome sine squared pulse and bar.

version of the staircase waveform can usually also produce a signal consisting of one line of staircase followed by three lines of black level, another staircase and then three lines of peak white level. This enables the linearity to be measured at the extremes of average picture level.

Differential Gain

Alternatively, a high frequency sine wave can be superimposed on the sawtooth (or staircase). The output waveform from the network under test is passed through a high pass filter (which eliminates the sawtooth or staircase components) and a detector before application to the Y input of the oscilloscope—see Fig. 4. The vertical deflection at any instant is then directly propor-

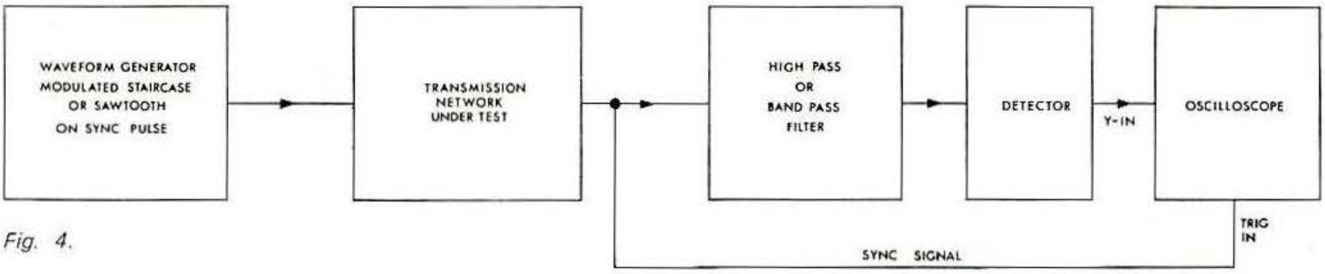


Fig. 4.

tional to the response of the network, so that a perfectly linear amplitude/response characteristic would produce a horizontal straight line on the c.r.t. screen, any deviation above or below this line being a measure of the non-linearity of the system.

This is known as the differential gain method of measurement, and it is the method that is most suitable for non-linearity tests of television transmission systems.

Measurement of Relative Phase

Differential phase may be measured by an extension of the above method using additional equipment which compares the phase of the sine wave on each step of a staircase with the phase at black level.

With the adoption of the PAL system in the United Kingdom, differential phase may be less important as a routine measurement on complete transmission systems but where NTSC signals are conveyed this is still a most important parameter. In the design of television equipment the measurement of differential phase is needed on both systems to ensure that it is kept to a minimum.

Testing colour television systems

These test signals have proved adequate with monochrome systems but with colour the amount of information that is obtained by the normal sine squared pulse in the sub-carrier region is quite small. In order to improve the available information about the upper end of the frequency band a new sine squared pulse waveform had to be devised.

Chrominance sine squared pulse and bar

The specification for the PAL colour system used in the United Kingdom calls for a chrominance bandwidth of 1 MHz. In order to cover this region a sine squared pulse with an h.a.d. of 1 μsec, which has a spectrum of 1 MHz, is produced with the normal filter. This signal together with a bar is modulated onto the sub-carrier. The resulting signal is then added to a pedestal to produce the complete waveform, as shown in Fig. 5, which may be used to examine the sub-carrier region of the video band.

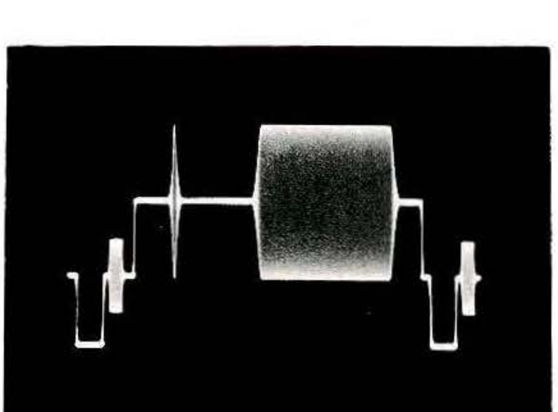


Fig. 5. Chrominance sine squared pulse and bar.

Combined luminance and chrominance pulse and bar

In order to make measurements in the region occupied by the luminance signal as well as that occupied by the chrominance signal the chrominance sine squared pulse and bar is added to the modulating waveform which, when correctly proportioned and timed, produces the waveform of Fig. 6. It will be seen that the spectrum of this combined signal has the distribution shown in Fig. 7. When this combined signal is passed through a system which has unequal gain in the luminance region compared with that in the chrominance region the combined pulse and bar becomes distorted as shown in Fig. 8.

Where the delay between luminance and chrominance regions is unequal the test signal becomes distorted in the manner shown in Fig. 9 owing to the incorrect time arrival of the components comprising the waveform.

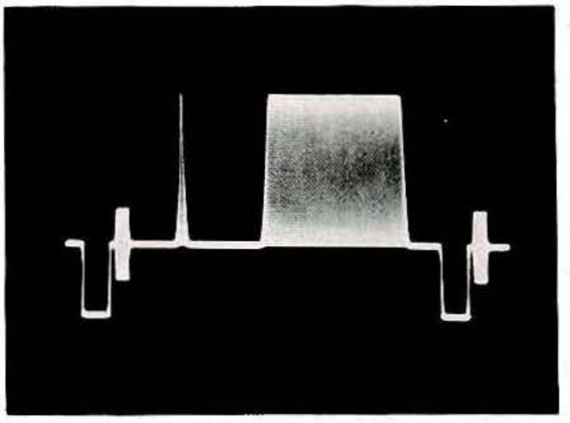


Fig. 6. Combined luminance and chrominance sine squared pulse and bar.

When the distortion is of an amount shown in Figs. 5 and 6 it is easily detected, but in cases where the amount is small, say of the order of 0·5 dB and 10 μsec, this needs a more elegant method to measure it accurately. A system proposed by the B.B.C. enables this to be achieved. In this, the combined pulse and bar waveform is fed to the equipment under test. The output signal from the equipment is fed to an instrument which splits the signal into its luminance and chrominance parts. The luminance signal is delayed or advanced by a known amount relative to the chrominance signal in the reverse fashion to the distortion in the equipment on test, so annulling the effect of the luminance to chrominance delay inequality. The amount of lead or lag necessary to bring the pulse back to its original shape may then be read off the instrument.

Colour Gain and Delay Test Set type TF 2904 is based on this B.B.C. design.

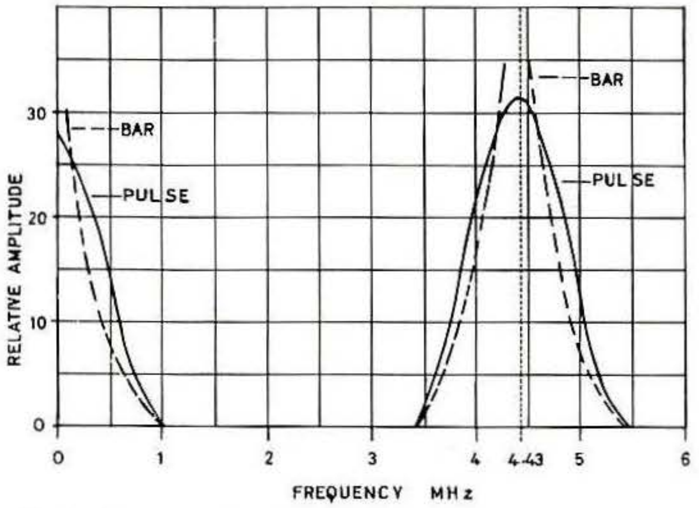


Fig. 7. Spectrum of combined luminance and chrominance sine squared pulse and bar.

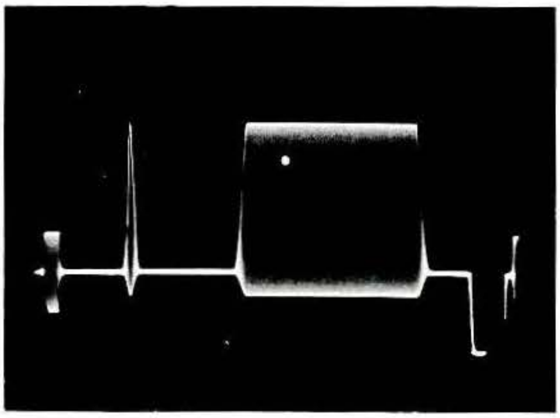


Fig. 8. Gain inequality indicated by combined luminance and chrominance sine squared pulse and bar.

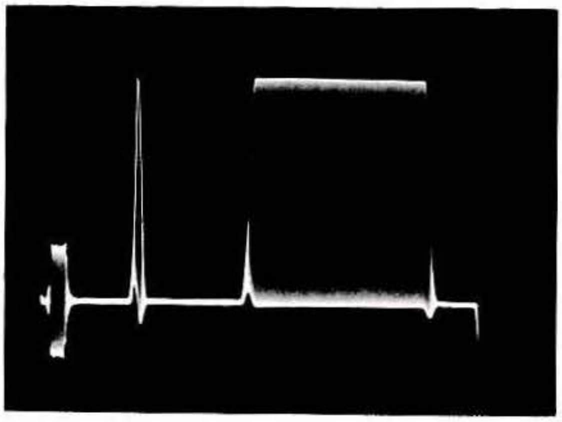


Fig. 9. Delay inequality indicated by the combined luminance and chrominance sine squared pulse and bar.

Vertical interval testing

With increasing television programme hours and the use of repeater transmitters to fill in low signal areas in the u.h.f. bands a test signal is necessary which can be included with the programme signal. This signal is inserted into the field blanking interval on one line in each field. Such signals have been variously known as "test line signals" and "vertical interval test signals" (VITS), whilst the CCIR study group recommend the term "insertion signals".

For international use the lines 17 and 330, that is one line in each field, should carry the insertion signal. The higher amplitude parts of the signal should occur at the beginning and end of the line to minimise its visual effect should the signal become visible on the receiver. The addition of a test signal in the field interval enables the performance of the complete chain of equipment to be monitored whilst the programme is transmitted.

With translater stations, which may be unmanned, the insertion signal is often monitored by a receiver which compares the transmitted signal with the signal at the input to the transmitter and is arranged to switch to standby equipment, or to give a remote indication in the event of a performance below a predetermined level. In order to measure as much as possible with a single line of test signal the size of the bar is reduced to 10 μsec and a 2T sine squared pulse plus a five step staircase is used—see Fig. 10. This enables tests of the mid-frequencies, high frequencies, and linearity to be made with only one line of test signal.

Sine Squared Pulse and Bar Generators type TF 2904/5 and TF 2905/5 may be used for this purpose.

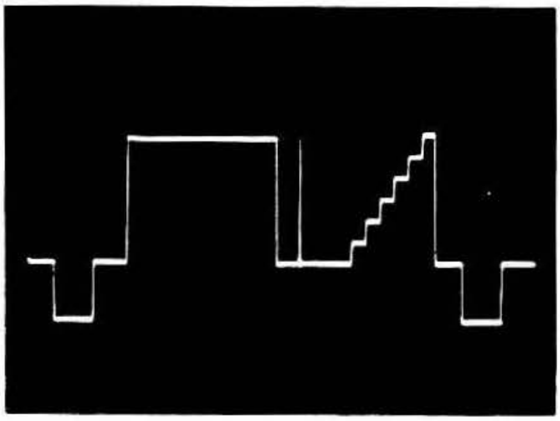
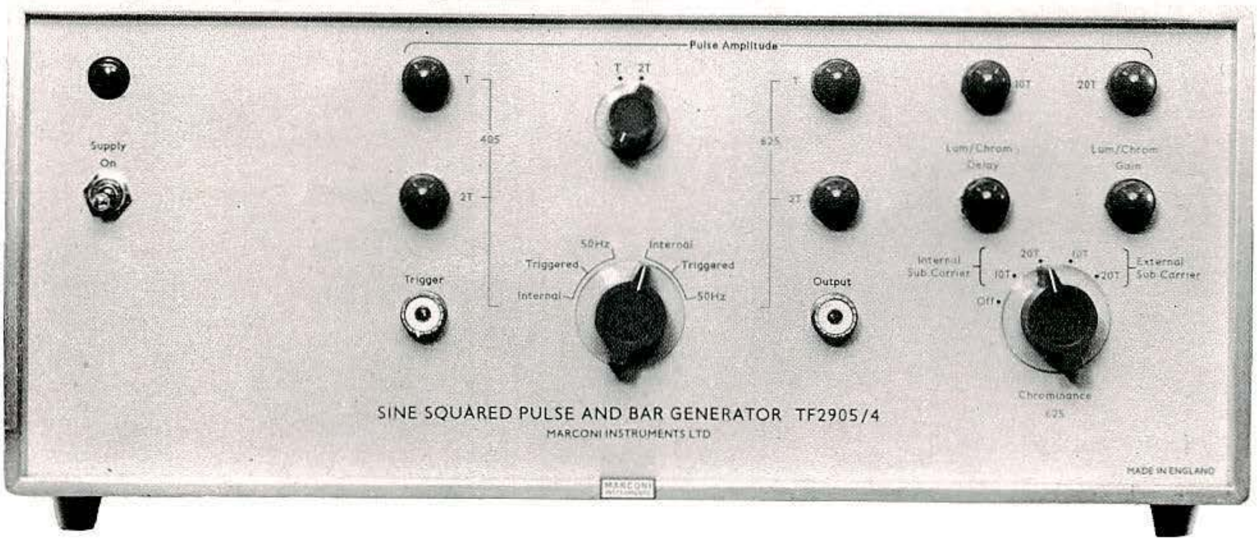


Fig. 10. Monochrome insertion signal for 625 lines.

Television Measuring Equipment

Sine-Squared Pulse and Bar Generator

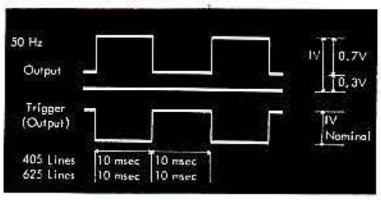
- Generates bar, sin² pulse, and staircase or sawtooth.
- For 405- and 625-line monochrome systems.
- For 625-line colour systems.
- Triggered internally from crystal oscillator or externally from television studio system.



TF 2905/4 generates standard monochrome and colour test waveforms conforming to the recommendations of the E.B.U. The waveforms are suitable for general performance tests on television transmission systems or for use as insertion (V.I.T.S.) signals for continuous monitoring.

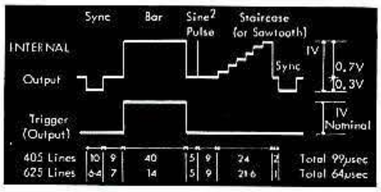
Test Waveforms

Three types of waveform are available from the instrument, selection of test waveform and of line standard (405 or 625) being made by a single switch.



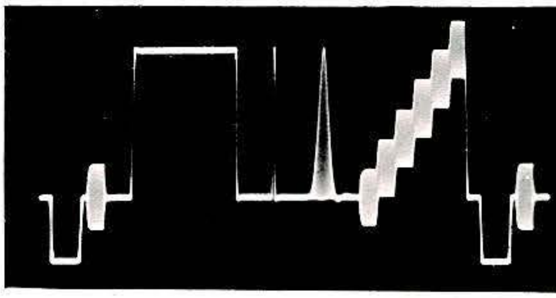
Waveform for l.f. response measurement

For low-frequency response analysis the generator produces a 50 Hz square wave superimposed upon, but not synchronised with, a train of line sync pulses.



Waveform for general assessment (monochrome) with internal trigger

For general K factor assessment on monochrome systems a line waveform is available comprising a sin² pulse (switchable to T or 2T), and a staircase or—as an optional modification—a sawtooth.



Colour test signal for 625-line systems

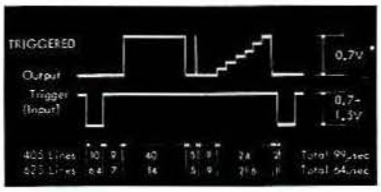
The instrument also provides a 625-line colour version of the bar, pulse, and staircase waveform which includes a colour burst, an additional colour sin² pulse (switchable to 10T or 20T), and sub-carrier added to the staircase or sawtooth. Provision is made for inserting an externally generated sub-carrier (instead of the internal one) if desired.

Oscilloscope Trigger Output

In addition to the test waveform an oscilloscope trigger pulse is available from a separate outlet. This pulse is coincident in time with the bar component of the line waveform. When the 50 Hz square-wave test signal is being used the square wave also appears at the trigger outlet.

Waveform Triggering

As an independent source, for measurements on transmission links, etc., the TF 2905/4 delivers its line waveform at a stable repetition frequency, which is controlled by an internal crystal oscillator.



Monochrome insertion waveform from external trigger

Provision is made, however, for triggering from externally generated line pulses or from a field insertion unit. When used in this way, the instrument produces a complete line waveform—consisting of the bar, pulse, and staircase or sawtooth—but the waveform does not contain line sync pulses, which would normally be added by the studio equipment.

To facilitate the addition of studio blanking and sync pulses the generator can be used in conjunction with a Marconi Instruments Blanking and Sync Mixer TF 2908.

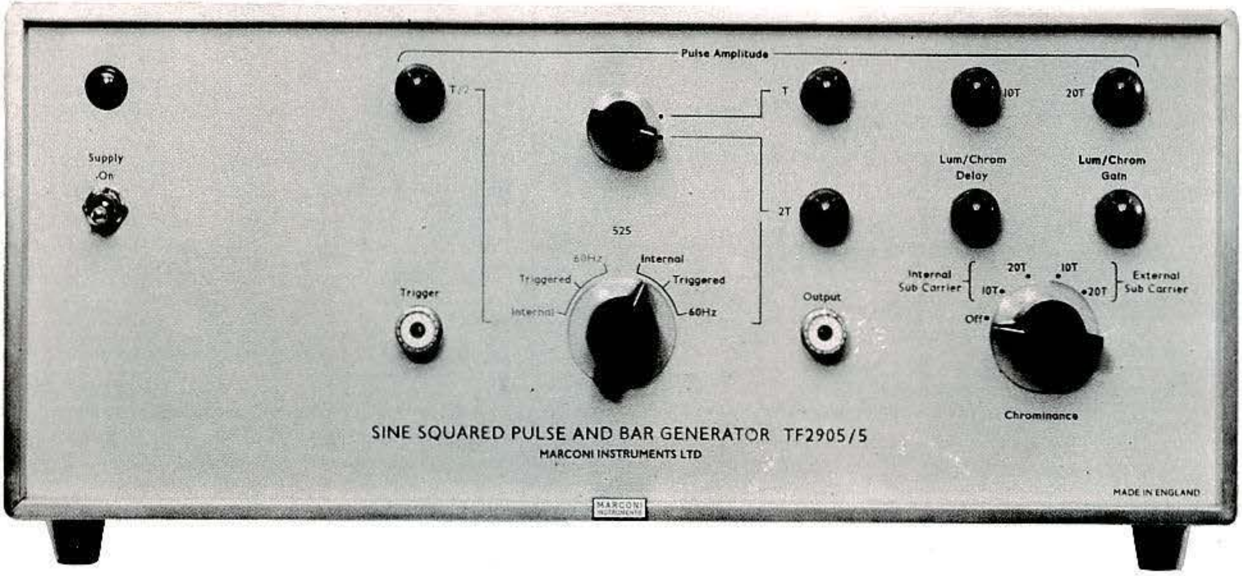
TELEVISION SYSTEMS	405 lines, 50 fields/sec. 625 lines, 50 fields/sec. Standard negative-going sync pulses.
MASTER OSCILLATOR	Crystal controlled for each line system.
COLOUR BURST	
Duration	2·3 ± 0·2 μsec.
Amplitude	Adjustable from 0·25 to 0·35 volts p-p. Normally set to 0·3 volts ± 3%.
BAR WAVEFORM	
Amplitude	Adjustable from 0 to 0·9 volts p-p. Normally set to 0·7 volts.
Duration (405 lines)	Adjustable from 12 to 43 μsec.
Duration (625 lines)	Adjustable from 9 to 43 μsec.
Tilt	Flat to within ± 0·2% ignoring the first and last μsec.
MONOCHROME SINE-SQUARED PULSE	
T pulse, 405 lines	167 nsec ± 3% half amplitude duration.
2T pulse, 405 lines	334 nsec ± 3% half amplitude duration.
T pulse, 625 lines	100 nsec ± 3% half amplitude duration.
2T pulse, 625 lines	200 nsec ± 3% half amplitude duration.
Amplitude	Adjustable from 0·6 to 0·8 volts p-p. Normally set to give pulse/bar ratio of unity.
First overshoot	0·9% ± 0·5% of pulse amplitude.
Second overshoot	0·4% ± 0·25% of pulse amplitude.
Jitter	Not greater than 1 nsec with respect to the bar trailing edge.
Long-term stability	Better than 1% of half amplitude duration.
COLOUR SINE-SQUARED PULSE	
10T pulse	1 μsec ± 2% half amplitude duration.
20T pulse	2 μsec ± 2% half amplitude duration.
Amplitude	Variable from 0·6 to 0·8 volts p-p. Normally set to give pulse/bar ratio of unity.
First overshoot	0·9% ± 0·5% of pulse amplitude.
Second overshoot	0·4% ± 0·2% of pulse amplitude.
STAIRCASE WAVEFORM	
Amplitude	Adjustable from 0·65 to 0·75 volts p-p. Normally set for staircase/bar ratio of unity.
Number of steps	Adjustable from 5 to 10.
Step duration	Adjustable from 2·3 to 5 μsec.
Linearity	Better than ± 0·5% with respect to amplitude of complete waveform.
SAWTOOTH WAVEFORM (optional in place of staircase)	
Amplitude	Adjustable from 0·65 to 0·75 volts p-p. Normally set for sawtooth/bar ratio of unity.
Duration	Adjustable from 20 to 40 μsec.
Linearity	Better than ± 2% with respect to amplitude of complete waveform.
SQUARE WAVEFORM	
Frequency	50 Hz ± 3 Hz.
Amplitude	Adjustable from 0·65 to 0·75 volts p-p. Normally set to 0·7 volts.
Tilt	Better than ± 0·25% with respect to amplitude of complete waveform.
SYNC PULSE	
Repetition frequency	Within 1% of system line frequency.
Amplitude	Adjustable from 0·25 to 0·35 volts p-p. Normally set to 0·3 volts.
Duration	10 μsec on 405-line system. 6·4 μsec on 625-line system.
SUB-CARRIER	
Internal Frequency	Set to 4·43361875 MHz ± 5 Hz. (Variation with temperature: less than ± 100 Hz 10° to 35°C.)
Harmonic content	Less than 1%.
External frequency	4·43361875 MHz ± 5 Hz.
External voltage	1 volt p-p. (Input impedance 75 Ω nominal.)
Sub-carrier leakage	At least 40 dB suppression relative to amplitude of complete waveform.
OUTPUT (complete waveform)	
Amplitude	Complete waveform adjustable from 0·7 to 1·4 volts p-p. Normally set to 1 volt including sync (or 0·7 volts excluding sync).
Residual disturbances	Amplitude less than 0·5% of the complete waveform.
Impedance	75 Ω. Return loss ratio better than 30 dB between 50 Hz and 10 MHz.
TRIGGER INPUT (triggered condition)	
Amplitude	0·7 to 1·5 volts p-p.
Impedance	75 Ω.
TRIGGER OUTPUT (internal and 50 Hz conditions)	
Amplitude	1 volt p-p nominal into high impedance.
Impedance	1 kΩ source.
POWER REQUIREMENTS	
A.C. mains	95 to 130 and 190 to 264 volts, 45 to 65 Hz 15 VA.
DIMENSIONS AND WEIGHT	

Height	Width	Depth	Weight
7¾ in	18½ in	14 in	20 lb
19·4 cm	47 cm	35·2 cm	9 kg

ACCESSORIES	
Supplied TM 8658	Extension printed board (attached to lower innerside of case).

Sine-Squared Pulse and Bar Generator

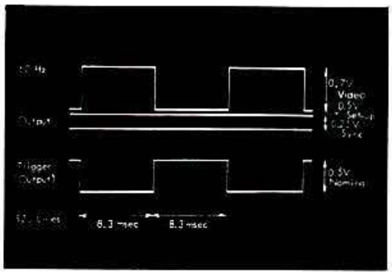
- Generates bar, sin^2 pulse, and staircase or sawtooth.
- For 525-line monochrome or colour television systems.
- Triggered internally from crystal oscillator or externally from television studio equipment.



The TF 2905 generates a composite test line waveform suitable for general performance measurement on 525-line television transmission systems or for use as an insertion (V.I.T.S.) signal for continuous monitoring. It is applicable to both monochrome and colour systems.

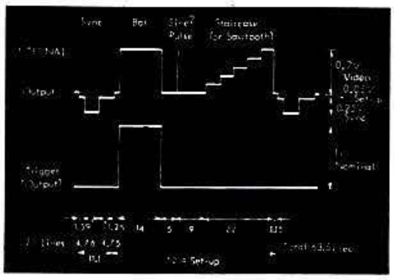
Test Waveforms

Three types of test waveform are available from the instrument, selection being made by means of a single switch.



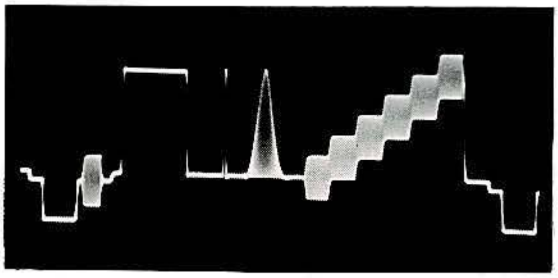
Waveform for l.f. response measurement

For low-frequency response analysis, the generator produces a 60 Hz square wave superimposed upon, but not synchronised with, a train of line sync pulses.



Waveform for general assessment (monochrome) with internal trigger

For general K factor assessment on monochrome systems a line waveform is available comprising a sync pulse, a bar, a sin^2 pulse (switchable to T/2, T, or 2T), and a staircase or—as an optional modification—a sawtooth.



Colour test signal for 525-line systems

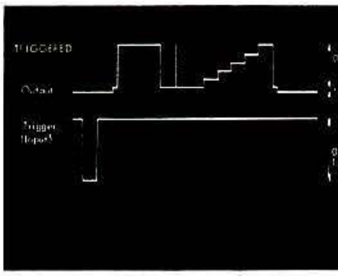
The instrument can also be switched to deliver a modified insertion waveform suitable for monitoring colour systems. In this waveform a colour burst and a colour sin² pulse (switchable to 10T or 20T) are introduced and sub-carrier is added to the staircase or sawtooth. Provision is made for using an externally generated colour sub-carrier instead of the internal one if desired.

Oscilloscope Trigger Output

In addition to the test waveform an oscilloscope trigger pulse is available from a separate outlet. This pulse is coincident in time with the bar component of the line waveform. When the 60 Hz square-wave test signal is being used the square wave also appears at the trigger outlet.

Waveform Triggering

As an independent source, for measurements on transmission links, etc., the TF 2905/5 delivers its line waveform at a stable repetition frequency, which is controlled by an internal crystal oscillator.



Monochrome insertion waveform from external trigger

Provision is made, however, for triggering from externally generated line pulses or from a field insertion unit. When used in this way, the instrument produces a complete line waveform—consisting of the bar, pulse, and staircase or sawtooth—but the waveform does not contain line sync pulses, which would normally be added by the studio equipment.

To facilitate the addition of studio blanking and sync pulses the generator can be used in conjunction with a Marconi Instruments Blanking and Sync Mixer TF 2908.

TELEVISION SYSTEMS	525 lines, 60 fields/sec.
MASTER OSCILLATOR	Crystal controlled at line frequency.
COLOUR BURST	
Duration	2·64 ± 0·2 μsec.
Amplitude	Adjustable from 0·25 to 0·35 volts p-p. Normally set to 0·3 volts ± 3%.
BAR WAVEFORM	
Amplitude	Adjustable from 9 to 43 μsec. Normally set to 0·7 volts p-p.
Duration	Adjustable from 9 to 43 μsec.
Tilt	Flat to within ± 0·2% ignoring the first and last μsec.
MONOCHROME SINE-SQUARE PULSE	
T/2 pulse	62·5 nsec ± 3% half amplitude duration.
T pulse	125 nsec ±3% half amplitude duration.
2T pulse	250 nsec ±3% half amplitude duration.
Amplitude	Adjustable from 0·6 to 0·8 volts p-p. Normally set to give pulse/bar ratio of unity.
First overshoot	0·9% ± 0·5% of pulse amplitude.
Second overshoot	0·4% ± 0·25% of pulse amplitude.
Jitter	Not greater than 1 nsec with respect to the bar trailing edge.
Long-term stability	Better than 1% of half amplitude duration.
COLOUR SINE-SQUARED PULSE	
10T pulse	1·25 μsec ± 2% half amplitude duration.
20T pulse	2·5 μsec ± 2% half amplitude duration.
Amplitude	Variable from 0·6 to 0·8 volts p-p. Normally set to give pulse/bar ratio of unity.
First overshoot	0·9% ± 0·5% of pulse amplitude.
Second overshoot	0·4% ± 0·2% of pulse amplitude.
STAIRCASE WAVEFORM	
Amplitude	Adjustable from 0·65 to 0·75 volts p-p. Normally set for staircase/bar ratio of unity.
Number of steps	Adjustable from 5 to 10.
Step duration	Adjustable from 2·3 to 5 μsec.
Linearity	Better than ± 0·5% with respect to amplitude of complete waveform.
SAWTOOTH WAVEFORM (optional in place of staircase)	
Amplitude	Adjustable from 0·65 to 0·75 volts p-p. Normally set for sawtooth/bar ratio of unity.
Duration	Adjustable from 20 to 40 μsec.
Linearity	Better than ± 2% with respect to amplitude of complete waveform.
SQUARE WAVEFORM	
Frequency	60 Hz ± 3Hz.
Amplitude	Adjustable from 0·65 to 0·75 volts p-p. Normally set to 0·7 volts.
Tilt	Better than ± 0·25% with respect to amplitude of complete waveform.

SET-UP (Pedestal)	
Amplitude	Adjustable from 0 to 1 volt p-p. Normally set to 0·05 volts.
Duration	Adjustable from 48 to 57 μsec. Normally set to 52·4 μsec.
SYNC PULSE	
Repetition frequency	Within 1% of system line frequency.
Amplitude	Adjustable from 0·23 to 0·33 volts p-p.
Duration	4·76 μsec.
SUB-CARRIER	
Internal frequency	Set to 3·57954 MHz ± 5 Hz. (Variation with temperature: less than ± 100 Hz 10° to 35°C.)
Harmonic content	Less than 1%.
External frequency	3·57954 MHz ± 5 Hz.
External voltage	1 volt p-p. (Input impedance 75 Ω nominal.)
Sub-carrier leakage	At least 40 dB suppression relative to amplitude of complete waveform.
OUTPUT (complete waveform)	
Amplitude	Complete waveform adjustable from 0·7 to 1·4 volts p-p. Normally set to 1 volt including sync (or 0·7 volts excluding sync).
Residual disturbances	Amplitude less than 0·5% of the complete waveform.
Impedance	75 Ω. Return loss ratio better than 30 dB between 50 Hz and 10 MHz.
TRIGGER INPUT (triggered condition)	
Amplitude	0·7 to 1·5 volts p-p.
Impedance	75 Ω.
TRIGGER OUTPUT	
Amplitude (internal)	1 volt p-p nominal into high impedance.
Amplitude (60 Hz)	0·5 volts p-p nominal into high impedance.
POWER REQUIREMENTS	
A.C. Mains	95 to 130 and 190 to 264 volts, 45 to 65 Hz 15 VA.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
7¾ in	18½ in	14 in	20 lb
19·4 cm	47 cm	35·2 cm	9 kg

ACCESSORIES

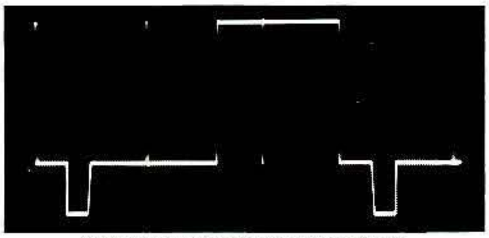
Supplied	TM 8658	Extension printed board (attached to lower innerside of case).

Sine-Squared Pulse & Bar Generator

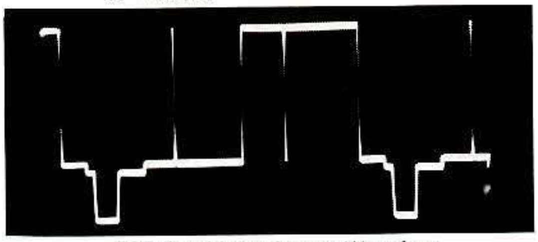
- Generates $\sin^2$ pulse and bar waveforms for monochrome and colour.
- Conforms with British Post Office recommendations.
- Triggered internally from crystal oscillator or externally from television studio equipment.
- TF 2905/8 for 625 line systems; TF 2905/9 for 525 line systems.

This sine-squared pulse and bar generator provides four switch-selected test waveforms, which cover the requirements for accurate K factor measurement as recommended by the British Post Office. Two versions are available: TF 2905/8 for 625 line 50 fields/sec systems, and TF 2905/9 for 525 line 60 fields/sec systems.

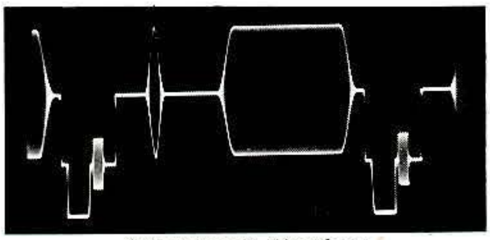
The two versions are basically similar and are suitable for commissioning and maintenance tests on transmission systems in the absence of a picture signal or for generation of an insertion waveform for continuous monitoring.



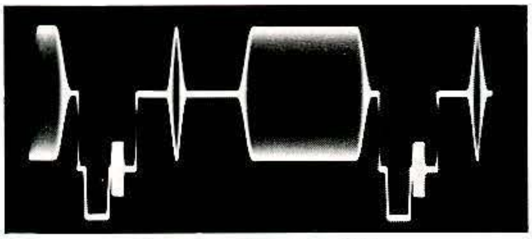
625 line Monochrome Waveform
TF 2905/8



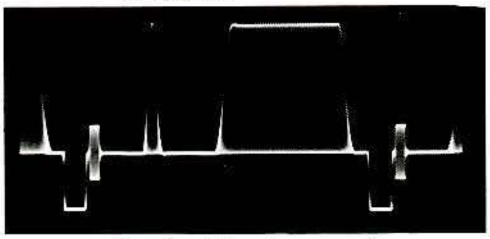
525 line Monochrome Waveform
TF 2905/9



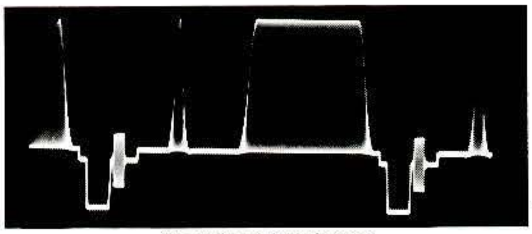
Chrominance Waveform
on Pedestal, 625 line
TF 2905/8



Chrominance Waveform
on Pedestal, 525 line
TF 2905/9



Combined Luminance and
Chrominance, 625 line
TF 2905/8



Combined Luminance
Chrominance, 525 line
TF 2905/9

Test Waveforms

For low frequency response analysis the generator produces a square wave at the mains supply frequency. This is superimposed upon, but not synchronised with, a train of internally generated line sync pulses—with set-up on the 525 line version. When the instrument is used with external composite sync (see *Waveform Triggering*) the square wave is synchronised with the incoming sync pulses from the studio system. It can be made asynchronous by connecting an internal link.

For monochrome K factor assessment, a line waveform is available comprising a $\sin^2$ pulse (switchable T or 2T) and bar on sync pulses. This waveform includes a second, inverted, $\sin^2$ pulse during the bar period, used mainly for checking quadrature distortion on suppressed sideband systems. Provision is made for removing this inverted pulse by disconnection of an internal link.

Two test line waveforms are obtainable for measurements on colour transmission systems. Both of these are based on a chrominance $\sin^2$ pulse and bar sequence comprising a 10 cycle sub-carrier burst, with a sub-carrier modulated $\sin^2$ pulse and bar (switchable to 5T, 10T, or 20T). The sub-carrier is normally derived from a crystal controlled oscillator at the appropriate frequency, but provision is also made for inserting an externally generated sub-carrier.

The instrument can be switched to deliver the chrominance waveform only or a combined luminance and chrominance waveform for such measurements as luminance to chrominance gain and delay inequalities, where the generator is used in conjunction with a Colour Gain and Delay Test Set (M.I. TF 2904 series).

Oscilloscope Trigger Output

In addition to the test waveforms, an oscilloscope trigger pulse is available from a separate outlet. Oscilloscope trigger pulses are coincident in time with the $\sin^2$ pulse and the inverted pulse, an arrangement which has the advantage that, by selection of appropriate sweep times, the oscilloscope can be set to display either a single coherent facsimile of the test waveform or a double overlapping facsimile in which any sag on the bar is easily measurable.

When the squarewave test waveform is used, the squarewave also appears at the trigger outlet.

Waveform Triggering

As an independent source for measurements on transmission links, etc. the generator delivers its line waveform at a stable repetition frequency derived from a crystal oscillator.

Provision is made, however, for external triggering; e.g., from line drive, from a field insertion unit, or from studio generated line pulses. Maximum flexibility is afforded by provision for either utilising the internally generated line sync pulses or injecting blanking and sync pulses from the studio equipment. The instrument contains a built-in mixer circuit for this purpose. Internally or externally generated sync pulses can be removed from the output waveform by operation of a front panel switch.

TELEVISION SYSTEMS

TF 2905/8	625 line monochrome 625 line colour with sub-carrier frequency 4·43361875 MHz 50 fields/sec.
TF 2905/9	525 line monochrome 525 line colour with sub-carrier frequency 3·579545 MHz 60 fields/sec.

MASTER OSCILLATORS

Line repetition	*TF 2905/8:* 15·625 kHz derived, via divider circuit, from 125 kHz crystal oscillator. *TF 2905/9:* 15·75 kHz derived via divider circuit from 126 kHz crystal oscillator.
Sub-carrier	*TF 2905/8:* crystal controlled at 4·3361875 MHz ± 5 Hz at 20 °C, ± 100 Hz over range 2 ° to 40 °C. *TF 2905/9:* crystal controlled at 3·579545 MHz ± 5 Hz at 20 °C, ± 100 Hz over range 2 ° to 40 °C.

SINE-SQUARED PULSE

T pulse, monochrome	*TF 2905/8:* 100 nsec ± 2% h.a.d. *TF 2905/9:* 125 nsec ± 2% h.a.d.
2T pulse, monochrome	*TF 2905/8:* 200 nsec ± 2% h.a.d. *TF 2905/9:* 250 nsec ± 2% h.a.d.
5T pulse, colour	*TF 2905/8:* 500 nsec ± 2% h.a.d. *TF 2905/9:* 625 nsec ± 2% h.a.d.
10T pulse, colour	*TF 2905/8:* 1000 nsec ± 2% h.a.d. *TF 2905/9:* 1250 nsec ± 2% h.a.d.
20T pulse, colour	*TF 2905/8:* 2000 nsec ± 2% h.a.d. *TF 2905/9:* 2500 nsec ± 2% h.a.d.
Amplitude	Adjustable from 0·65 to 0·75 volts p-p. Normally set to give pulse/bar ratio of unity.
First overshoot	0·9% ± 0·5% of pulse amplitude.
Second overshoot	0·4% ± 0·25% of pulse amplitude.

BAR WAVEFORM

Amplitude	Adjustable from 0·65 to 0·75 volts p-p. Normally set to 0·7 volts ± 2%.
Duration	25 μsec ± 5% h.a.d.
Tilt	Less than ± 0·2% relative to amplitude at middle of bar, ignoring first and last 0·625 μsec.
Edge Shape	Sine-squared (T or 2T mono, 5T, 10T, or 20T colour) as for corresponding sine squared pulse.
Rise and decay times	0·96 of h.a.d. of corresponding sine-squared pulse.
Corners	Free of exponential distortion on all four corners.
Overshoot	Less than 0·5% relative to amplitude at middle of bar. Decays to less than 0·2% within 0·625 μsec of half amplitude point of edge.

LUMINANCE/CHROMINANCE GAIN (Pulse and bar)

Inequality	Adjustable from −5% to +5%. Normally set to zero.
Stability	Better than ± 1% over range 2 ° to 40 °C.

LUMINANCE/CHROMINANCE DELAY (Pulse and bar)

Inequality	Adjustable from − 10 to + 10 nsec. Normally set to zero.
Stability	Better than ± 3 nsec over range 2 ° to 40 °C.

COLOUR BURST

Amplitude	Adjustable from 0 to 0·35 volts p-p. Normally set to 0·3 volts.
Duration	*TF 2905/8:* 10 cycles ± 1 cycle. *TF 2905/9:* 9 cycles ± 1 cycle.
Phase	Phase angle relative to pulse and bar is zero at all temperatures.

PEDESTAL	
Amplitude	Adjustable from 0·3 to 0·4 volts. Normally set to 0·35 volts ± 1%.
Duration	52 μsec ± 5%.
Edge Shape	T or 2T sine squared shapes.
SET UP (TF 2905/9 only)	
Amplitude	0·05 volts.
Duration	52 μsec ± 5%.
Edge Shape	T or 2T sine square shapes.
SQUARE WAVE (asynchronous)	
Frequency	*TF 2905/8:* 50 Hz. *TF 2905/9:* 60 Hz.
Amplitude	Adjustable from 0·65 to 0·75 volts p-p. Normally set to 0·7 volts ± 1%.
Duration	For each half cycle, *TF 2905/8:* 10 msec ± 5% h.a.d. *TF 2905/9:* 8·3 msec ± 5% h.a.d.
Tilt	Less than ± 0·25% of square wave amplitude (measured from mid points at white and black levels).
Line bar edges	T or 2T sine squared shape.
SYNC PULSE	
Amplitude	Adjustable from 0·25 to 0·35 volts p-p. Normally set to 0·3 volts p-p ± 2% on TF 2905/8 and to 0·25 volts on TF 2905/9.
Duration	*TF 2905/8:* 4·7 μsec ± 5%. *TF 2905/9:* 4·76 μsec ± 5%.
Edge shape	Approximately sine squared with rise and decay times. 0·3 μsec ± 0·1 μsec for TF 2905/8, and 0·25 μsec ± 0·1 μsec for TF 2905/9.
OUTPUT	
Amplitude	Complete waveform adjustable from 0·9 to 1·1 volts p-p. Normally set to 1 volt ± 1%.
Impedance	75Ω. Return loss greater than 30 dB between 50 Hz and 10 MHz. Reduction to 20 dB does not change shape of waveform.
Jitter	Not greater than 1 nsec relative to trailing edge of sync pulse.
Random h.f. noise	Less than − 50 dB (ref 0·7 volts) when bandwidth is restricted by low-pass filter (f_c = 5·8 MHz.)
Hum	Less than − 50 dB (ref 0·7 volts).
Sub-carrier leak	Measured at blanking level, less than − 46 dB (ref 0·7 volts) at 20°C. Less than − 40 dB over range 2° to 40°C.
Residual disturbances	Less than 1% of picture signal amplitude.
TRIGGER OUTPUT	
Sine-squared pulse and bar	5 volts p-p e.m.f.
Squarewave	10 volts p-p e.m.f.
Impedance	3·5 kΩ nominal.
INPUT WAVEFORM REQUIREMENTS	
Burst gate	2 to 6 volts p-p.
Sub-carrier	1 volt p-p nominal.
Blanking	2 to 6 volts p-p.
Sync pulses	2 to 6 volts p-p.
Input impedance (all waveforms)	Internally or externally terminated: 75Ω. Return loss: greater than 30 dB up to 5 MHz.
POWER REQUIREMENTS	
A.C. mains	95 to 130 volts and 190 to 264 volts, 45 to 65 Hz, 23 VA.
DIMENSIONS AND WEIGHT	

Height	Width	Depth	Weight
7⅝ in	18½ in	13⅞ in	21 lb.
194 mm	470 mm	352 mm	9·5 kg

ACCESSORIES	
Optional	
TM 9712/2	Rack Mounting Kit.

TF 2904 Series Colour Gain and Delay Test Set

- ☐ For NTSC and PAL colour television systems
- ☐ Measures relative gain and delay between luminance and chrominance channels

The Colour Gain and Delay Test Set is for measurement of inequalities in gain and delay between the chrominance and luminance channels of colour television systems. It is based on an original design by the B.B.C.

Two versions of the instrument are available:

TF 2904 – for use with systems having subcarrier frequencies in the region of 4·43 MHz; and

TF 2904/1 – for use with systems having subcarrier frequencies in the region of 3·58 MHz.

The test set is used in conjunction with a sine-squared pulse and bar generator giving combined luminance and chrominance test waveforms, a suitable oscilloscope also being used as the indicator. The measurement is made by introducing a calibrated amount of gain or phase inequality in the opposite sense to that of the system under investigation, the test set being adjusted to produce a fully equalised display on the oscilloscope.

Gain inequality can be measured over the range ± 3 dB, and delay inequality over the range 110 nsec lag to 110 nsec lead by operation of a push-button switch and a fine control. There is also a three position switch which enables the luminance or chrominance components to be displayed separately from the combined waveform.

TELEVISION SYSTEMS	
Type TF 2904	625 line NTSC or PAL with sub-carrier frequency of 4·43 MHz approximately.
Type TF 2904/1	525 line NTSC or PAL with sub-carrier frequency of 3·58 MHz approximately.
GAIN MEASUREMENTS	
Range	-3 dB to $+3$ dB, continuously variable. Calibrated in 0·5 dB steps.
Accuracy	$\pm 0 \cdot 1$ dB.
DELAY MEASUREMENTS	
Range	110 nsec lag to 110 nsec lead by coarse and fine controls.
Coarse	100 nsec lag to 100 nsec lead in switched 20 nsec steps.
Fine	10 nsec lag to 10 nsec lead continuously variable. Calibrated in 2 nsec steps.
Accuracy	± 2 nsec up to 10 nsec. ± 5 nsec above 20 nsec. Varies linearly from ± 2 nsec to ± 5 nsec over the range 10 nsec to 20 nsec.
COMBINED TEST SIGNAL	
Luminance component	Sine-squared pulse and bar waveform at video frequency.
Chrominance component	Sub-carrier with 100% amplitude modulation by sine-squared pulse and bar waveform.
Amplitude	0·35 volts peak-to-peak luminance. 0·7 volts peak-to-peak chrominance. 0·7 volts peak-to-peak combined luminance and chrominance. 0·3 volts peak-to-peak sync (when provided). 1 volt peak-to-peak overall including sync.
Sine-squared pulse	4Tc (20T) or 2Tc (10T) with the following half amplitude durations: 2 μsec or 1 μsec for 625 lines. 2·5 μsec or 1·25 μsec for 525 lines.
INSERTION LOSS	0 dB.
IMPEDANCE	
Input	75 Ω nominal.
Output	75 Ω nominal.
POWER REQUIREMENTS	
A.C. Mains	95 to 130 volts and 190 to 264 volts, 45 to 65 Hz, 6 VA.

DIMENSIONS AND WEIGHT

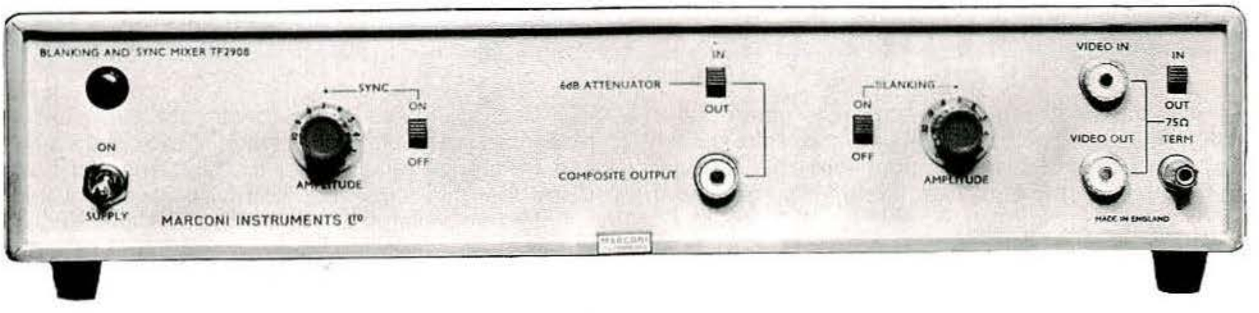
Height	Width	Depth	Weight
6 in	18½ in	14 in	15 lb
15·3 cm	47 cm	35·5 cm	6·8 kg

Blanking and Sync Mixer TF 2908

☐ For 405, 525 and 625 line television systems

☐ Reshapes and mixes blanking and sync pulse waveform with video test waveform

The Blanking and Sync Mixer is for use in conjunction with an external synchronising-pulse generator and a video-test-waveform source to provide a complete composite signal for performance measurements on television studio and transmission equipment. The incoming blanking and sync pulses are reshaped and mixed with the video test signal to produce a correctly proportioned standard-level output, so that equipment containing clamping or d.c. restoring circuits can be checked under normal working conditions.



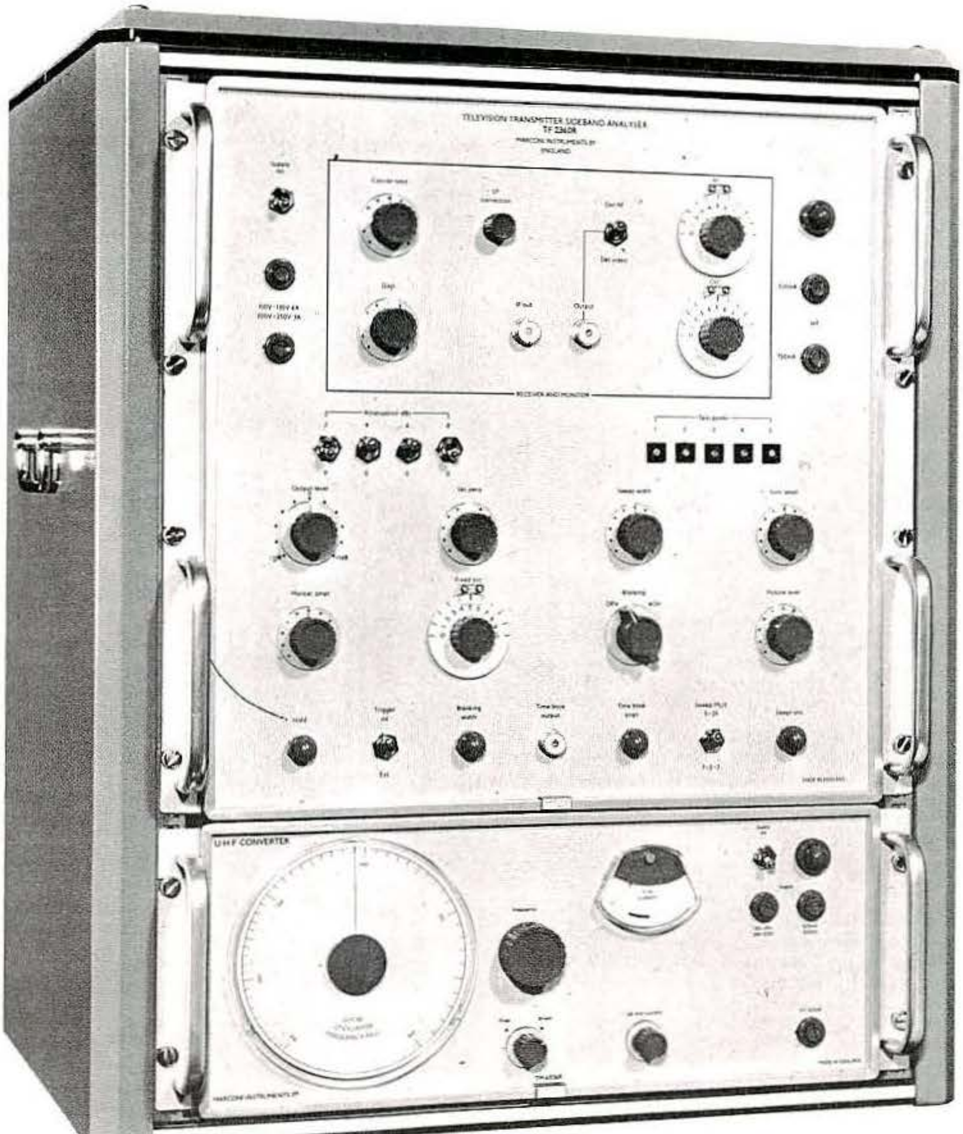
TELEVISION SYSTEMS	405, 525, and 625 lines. 50 or 60 filed/secs. Standard negative going blanking and sync pulses.
VIDEO SIGNAL	
Input	0·6 volts peak-to-peak maximum. Bridged or terminated in 75 Ω.
Input Impedance	75 Ω nominal terminated. Return loss ratio better than 30 dB from 25 kHz to 20 MHz. Greater than 50k Ω unterminated.
Output	1·2 volts peak-to-peak maximum.
Video gain	6 dB ± 0·3 dB.
Frequency response	Flat within 0·2 dB from 25 kHz to 10 MHz. Flat within 0·3 dB from 25 kHz to 20 MHz. Less than 2% tilt on 50 Hz square wave.
Harmonic distortion	Better than 46 dB below signal level.
BLANKING PULSES	
Input	2 volts peak-to-peak standard level. Usable range 1 to 4 volts peak-to-peak. Bridged or terminated in 75 Ω.
Input Impedance	75 Ω nominal terminated. Return loss ratio better than 28 dB from 50 Hz to 5 MHz. Greater than 30k Ω unterminated.
Output	Continuously variable from 0 to 1·4 volts peak-to-peak.
Rise and fall times	0·2 μsec (approximately) at output.
SYNC PULSES	
Input	2 volts peak-to-peak standard level. Usable range 1 to 4 volts peak-to-peak. Bridged or terminated in 75 Ω.
Input Impedance	75 Ω nominal terminated. Return loss ratio better than 28 dB from 50 Hz to 5 MHz. Greater than 30 kΩ unterminated.
Output	Continuously variable from 0 to 0·7 volts peak-to-peak.
Rise and fall times	0·2 μsec (approximately) at output.

PERMISSIBLE INPUT DISTORTION (Blanking and Sync)	
Hum	Up to 1 volt peak-to-peak superimposed on 2 volt peak-to-peak pulse.
Ringing	Up to 50% ringing on 2 volt peak-to-peak pulse.
Integration	Up to 10 μsec rise time on 2 volt peak-to-peak pulse.
COMPOSITE OUTPUT	
Maximum output (unattenuated)	2 volts peak-to-peak overall. Video pulse must not exceed 1·4 volts peak-to-peak, as indicated below for a normal signal and a peak white signal.
Normal signal (unattenuated)	1·2 volts peak-to-peak video. 0·2 volts set up. 0·6 volts peak-to-peak sync.
Peak white signal (unattenuated)	1·4 volts peak-to-peak, blanking 0·6 volts peak-to-peak sync.
Amplitude adjustment	All above amplitudes can be halved (to standard level) by switching in the 6dB attenuator. Alternatively, they can be set to different standards by adjusting the appropriate controls and video input.
Residual disturbances	On base line, less than 1% of complete waveform.
Impedance	75 Ω nominal. Return loss ratio better than 30 dB from 25 kHz to 10 MHz. Better than 23dB from 0 to 20 MHz.
OUTPUT ATTENUATOR	6 dB ± 0·2 dB over the frequency range 25 kHz to 20 MHz.
POWER SUPPLY	
A.C. Mains	95 to 130 volts and 190 to 264 volts, 45 to 65 Hz, 15 VA.
DIMENSIONS AND WEIGHT	Height 4¾ in, 11·8 cm; Width 18½ in, 47 cm; Depth 8 in, 20 cm; Weight 8½ lb, 3·85 kg
ACCESSORIES Optional	TM 9746 Rack Mounting Kit.

T.V. Transmitter Sideband Analyser

- Covers TV Bands I and III
- Converter for Bands IV and V
- Suitable for 625-, 525- and 405-line systems
- Measures over-all response of transmitters
- Simultaneous display of upper and lower side-bands characteristics
- Delivers simple sweep or composite signal
- Also checks video equipment responses

The overall band-width and side-band characteristics of television transmitters in Bands I, III, IV and V are quickly determined by means of this equipment, without disturbing clamping networks. It is equally suitable for systems with positive or negative modulation, and for 625-, 525-, or 405-line standards. The lower and upper side-band responses are displayed together, in their correct amplitude and frequency relationship to the carrier. In addition to these main functions, it can also be used for testing clamped or unclamped video amplifiers and auxiliaries.



Uses

This Side-band Analyser is used to test the overall response of a television transmitter, but also includes facilities for examining the frequency responses of video circuits and equipment, using sweep techniques in each case, and providing valid assessments of dynamic performance.

The TF 2360R incorporates a sweep generator which may be arranged to sweep symmetrically about zero, or asymmetrically over the video band, and when fed with suitable synchronising and blanking signals from an external generator, will deliver a fully composite video signal comprising mixed syncs and blanking, with a video sweep component centred in amplitude around any given picture level; the video sweep may also be obtained without the synchronisation components.

The test wave-forms thus produced are used as the input to the system under test, and the output—a video-modulated carrier in the case of transmitters, or a video signal from other equipment—is detected and processed for presentation on an oscilloscope.

Principles of Operation

For transmitter testing, a composite television wave-form is used, so that the transmitter is modulated under conditions simulating those of normal operation. A sample of the transmitter output is fed via a broad-band mixer with a swept local oscillator to a receiver whose detector delivers a fluctuating d.c. signal which is instantaneously proportional to one of the side-bands produced by the sweep component of the original video input. The same saw-tooth wave-form is used in producing the video sweep, in controlling the swept local oscillator, and for the time base of an oscilloscope. The detector output is applied to the latter to give the desired response indication.

When video frequency equipment is tested, the detected output signal is proportional to the instantaneous level of the sweep component in the video equipment output. In this case also, the same saw-tooth generator controls the video sweep and provides the oscilloscope time base.

In both cases, frequency markers are provided for calibrating purposes.

Generation of the Composite Signal

The mixed blanking input is amplified, and then combined with the video sweep (the generation of this is described separately) to produce a signal comprising the blanking pulses with the video superimposed. A clipping network, whose operating level may be adjusted both by a black level control as well as by the picture level control which sets the mean video level, removes the video during the blanking periods only.

The mixed syncs input is amplified and limited, and then passed through an inverter stage, which also provides a sync amplitude control, before being added to the amplified video and blanking; the complete composite signal is delivered via a cathode follower stage.

The blanking is also used for two other purposes:

Positive pulses are taken from the mixed blanking input amplifier, and after further amplification are passed through an integrating network which attenuates the line blanking component. The field blanking component (now in negative pulse form) may then be used to lock the saw-tooth oscillator which provides the display unit time base and controls the sweep signals.

The blanking pulses in negative form are also amplified, and used to paralyse the detector in the video amplifier during the sync/blanking periods as mentioned under VIDEO TESTS.

Transmitter Tests

A symmetrical sweep condition is normally used when checking transmitter response, and the advantage of being able to include the blanking and syncs is that the tests can be made at any level in the grey scale without the need of disconnecting black-level clamping networks.

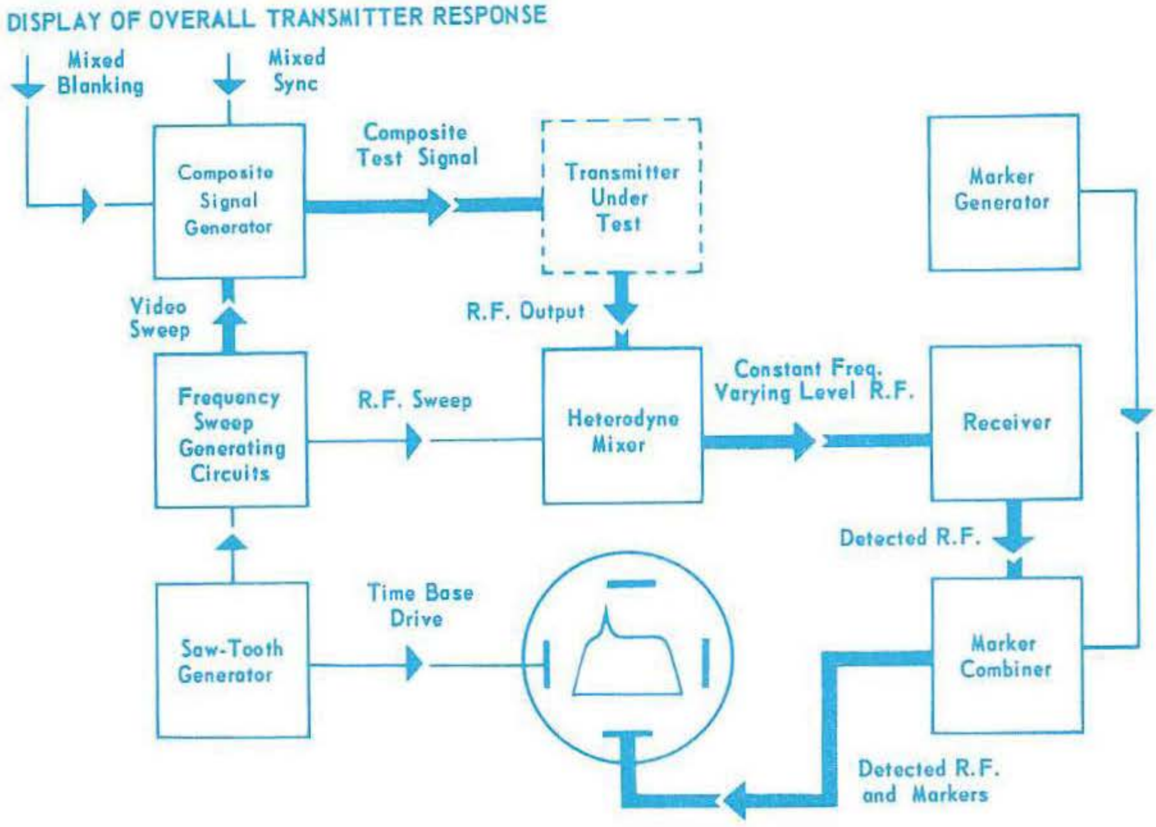
The test signal is generated in the following manner (see also GENERATION OF THE COMPOSITE SIGNAL):

A saw-tooth generator causes an oscillator to sweep symmetrically about 130 MHz, the excursion being continuously variable up to at least ±7 MHz. This sweep frequency is mixed with another oscillator whose frequency is fixed also at 130 MHz, so that a difference frequency which sweeps linearly from 7 MHz to zero and back again to 7 MHz is produced. The video sweep is combined with the mixed syncs and blanking so that in the resultant the sweep, set-up, and blanking components are independently adjustable, and the sweep repetition is locked at field frequency. The level of the sweep component is held within ±0·1 dB throughout the sweep by an a.g.c. circuit in the sweep generator.

The composite signal is set up to standard levels, with the various components in the desired proportions, and applied to the transmitter, whose output spectrum contains a pair of side-bands which move in and out with respect to the carrier and in synchronism with the sweep. These side-bands are produced by the sweep component, and their final amplitudes are moderated by the overall side-band response up to the final output, and by the video circuit responses before modulation.

(In setting up a transmitter, the modulator stages would normally be checked and aligned first, but for routine checking this might be omitted unless the overall response showed gross abnormalities. The TF 2360R incorporates means of checking the video circuits.)

TF 2360R



For Bands I and III the transmitter signal is fed at low level to a broad-band mixer which also receives the swept 130 MHz signal used in generating the video sweep. This combination gives rise to mixture products among which is present, at any instant during the sweep, a fixed frequency component equal in frequency to the difference between the transmitter carrier frequency and 130 MHz, and proportional in amplitude to the amplitudes of the lower side-band due to the sweep when the swept oscillator is below 130 MHz, to the amplitudes of the upper side-band due to the sweep when the swept oscillator is above 130 MHz, and to the carrier amplitude when the video sweep is at zero, i.e., swept oscillator at 130 MHz. (In practice, as the true carrier amplitude is much greater than the side-bands, steps have been taken to avoid masking effects, and the "carrier" component as displayed may be limited.) The receiver to which this fixed frequency component is fed has a range of approximately 40 to 100 MHz, and as normally adjusted provides a total coverage of transmitter frequencies from 32 to 88 and from 172 to 228 MHz.

For Bands IV and V transmitters, a separate frequency changer is used, whose range permits frequencies from 470 to 960 MHz to be covered. It is set to produce a convenient frequency within the range of the Bands I and III input, and the same operations as before are carried out.

A further change of frequency is made in the receiver to an i.f. of 4·5 MHz, the band-width being less than 40 kHz. If desired, an i.f. output can be used to give the side-band response. Otherwise, after amplification and detection, the final output consists of the fluctuating d.c. output of the detector, the instantaneous amplitude being proportional to the side-band (or carrier) amplitude. This signal is fed to an external oscilloscope, and the saw-tooth wave-form which drives the swept oscillator is also used as the time base of the oscilloscope. The oscilloscope display thus presents the full side-band response of the transmitter. Variation of the sweep width permits more detailed examination near to the carrier, particularly because of the narrow pass-band of the i.f. amplifier; and variation of the composite signal components enables the response to be examined throughout the grey scale.

Frequency identification is provided by markers at 1 MHz intervals, with distinctive markers at 5 MHz.

If desired, the tests can be carried out with a simple video sweep, but account must then be taken of clamping networks. Similarly, an asymmetrical sweep may be used, but this will give only the lower side-band response.

The alternative presentation obtained by using the 4·5 MHz output avoids any possible errors arising from detector non-linearity.

Video Tests

For these tests, an asymmetrical sweep is normally used, and the test signal is produced in the same general manner as for transmitters, but with these differences: The swept r.f. oscillator now swings between nominally 130 MHz down to at least 110 MHz; and the sweep does not in fact start at zero, but is locked to a frequency not exceeding 100 kHz, the sweep width being continuously variable up to 20 MHz.

The output signal may be in composite or simple sweep form, and after passing through the system under test is applied to the video amplifier of the TF 2360R; signals with either positive or negative syncs may be accepted. The detector which follows this amplifier is rendered inoperative during the sync/blanking period, so that only the video component is detected, and measurements can be made at peak white without disturbance from the syncs and blanking.

The oscilloscope presentation is obtained as before, but now represents the frequency response of the system. Frequency markers are also available for the whole 20 MHz sweep.

Although of more limited interest, the symmetrical sweep can also be used.

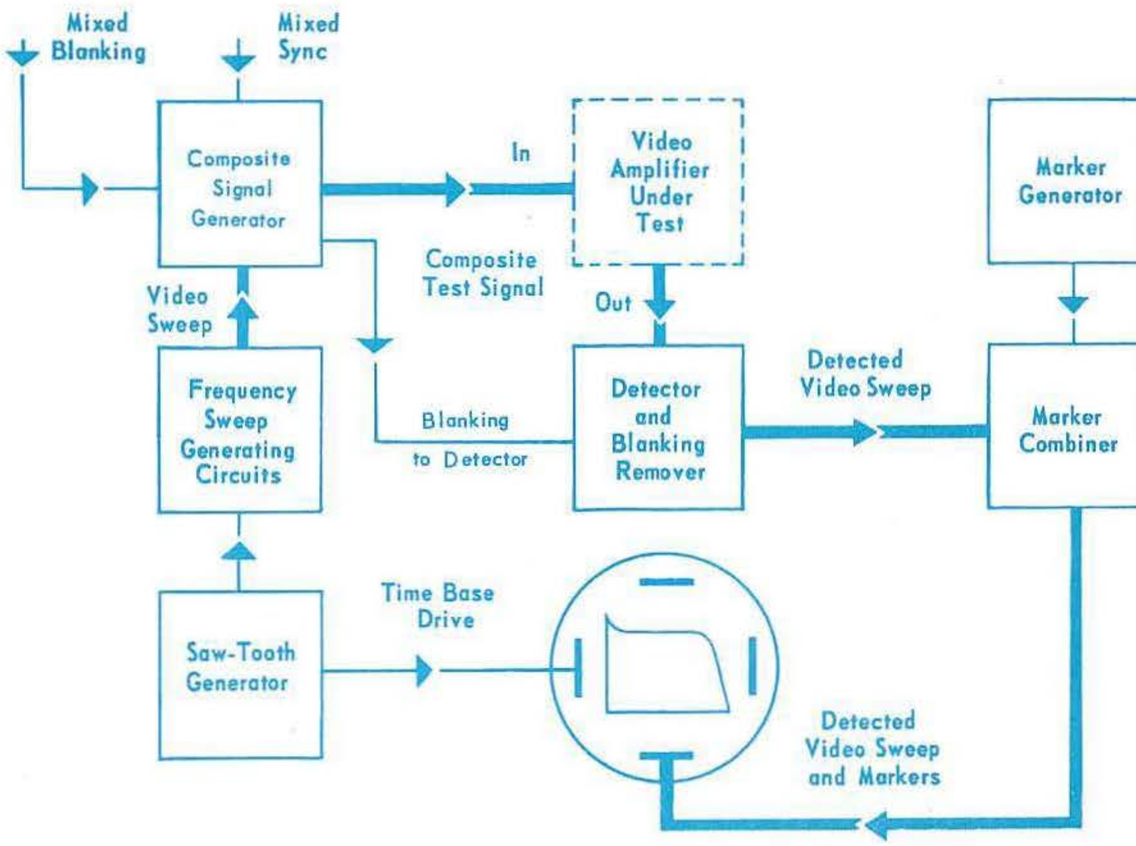
Construction

The complete equipment is fitted within one panel, of standard relay rack dimensions, and when supplied for rack mounting it bears the type number TF 2360R. The chassis are in two hinged sections, which permit easy maintenance in case of need, and printed wiring boards have enabled a compact design to be obtained without cramping the interior layout. Power supplies are incorporated.

U.H.F. Converter, TM 6936

This unit is self-contained with its own power supply, and requires only r.f. connection to the main equipment. A disc-seal triode is used in a variable impedance line oscillator, covering approximately 420 to 920 MHz, for the local mixing source. Conversion occurs in a crystal mixer with a low VSWR to the transmitter input. With the receiver section of TF 2360R tuned to 80 MHzthe equivalent Band I input is 50 MHz, which allows the whole of Bands IV and V to be covered by the Converter.

DISPLAY OF VIDEO AMPLIFIER RESPONSE



R.F. INPUT

Frequency Range	32 to 88, and 172 to 228 MHz. (Other frequencies to special order. Also 470 to 960 MHz using U.H.F. Converter, type TM 6936.)
Level	250 mV to 1 volt r.m.s. approximately.
Impedance	50 Ω. V.S.W.R.: Better than 1·05:1 up to 230 MHz, and better than 1·15:1 from 470 to 960 MHz.

VIDEO OUTPUT

Amplitude	*Simple video sweep:* 0·3 to 3 volts, peak-to-peak. *Composite Signal:* *Sweep Component:* 0·1 to 1 volt, peak-to-peak, centred on set-up level. *Set-up:* 0·1 to 0·8 volts, peak-to-peak, with respect to blanking level. *Mixed syncs:* 0 to 0·5 volts, peak-to-peak.
Impedance	75 Ω.
Sweep Width	*Symmetrical:* Continuously variable up to at least 7–0–7 MHz. *Asymmetrical:* Continuously variable, from a lower limit locked to a frequency not exceeding 100 kHz, up to 20 MHz.
Sweep Frequency Response	*Simple Sweep:* Within ±0·1 dB up to 20 MHz.
Composite Signal	Within ±0·1 dB up to 10 MHz, and within ±0·25 dB from 10 to 20 MHz.
Distortion	*Harmonic content of sweep:* —34 dB approximately.
L.F. Distortion of TV Waveform	Less than 2% tilt.

VIDEO AMPLIFIER INPUT

Level	0·1 to 1 volt, peak-to-peak, positive or negative syncs.
Impedance	75 Ω.
Frequency Response	Within ±0·1 dB from 100 kHz to 10 MHz, and within ±0·25 dB from 10 to 20 MHz.

MEASUREMENT ACCURACY

Overall Side-Band Response	The detector output level is within ±0·25 dB for a fixed side-band level throughout the sweep range.
Detector Linearity	A change of 20 dB in input level can be measured within ±1 dB. *Note: Use of the i.f. output avoids any possible errors arising from the detector responses.*

MARKERS

Frequency	1 MHz intervals (every 5 MHz distinctive).
Amplitude	1 volt, peak-to-peak, approximately.

POWER REQUIREMENTS

A.C. Mains	100 to 130 volts or 200 to 250 volts; 40 to 65 Hz; 375 watts.

ACCESSORIES

Supplied	1 Coaxial free plug, type N 6 Coaxial free plugs, type 83 3 Coaxial links (type 83 connectors) 1 Attenuator (9 dB) TM 5554/4
Optional TM 6936	U.H.F. Converter.

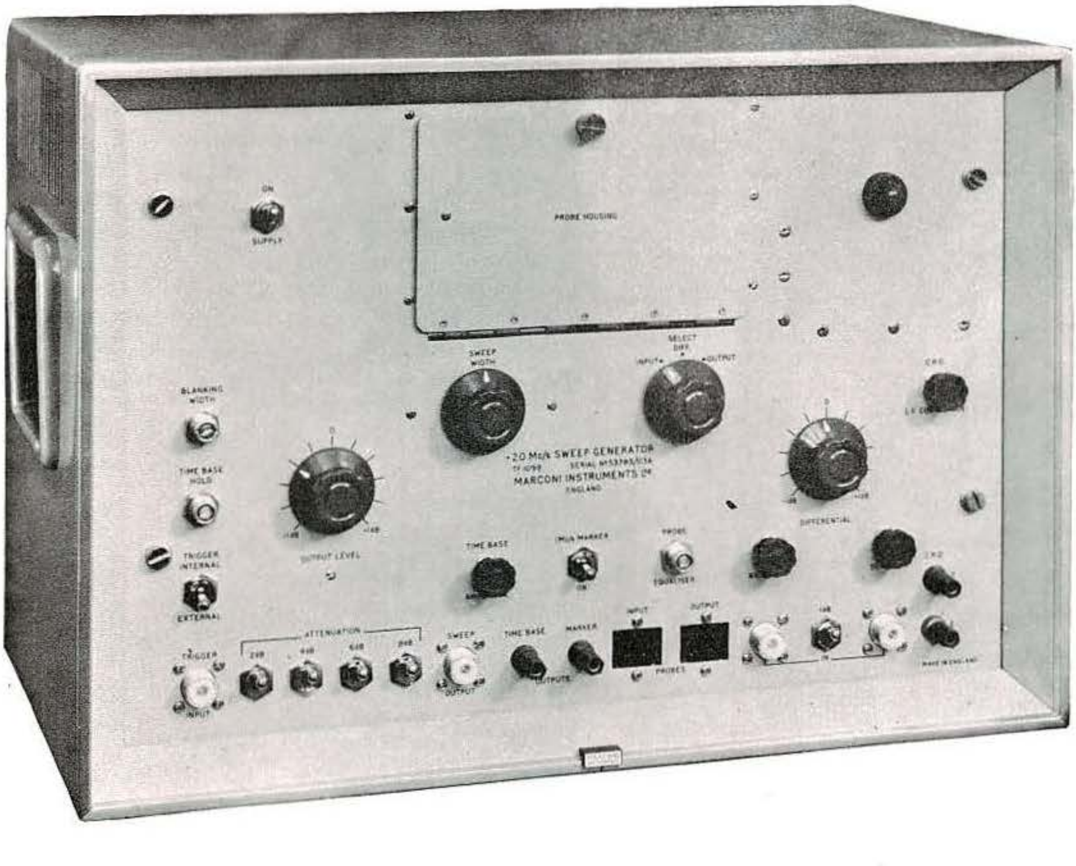
DIMENSIONS

Height	Width	Depth	Weight
45 cm	44 cm	41 cm	22 kg
17½ in	17 in	16 in	48 lb

20 MHz Sweep Generator

- ☐ **For precision video response measurement**
- ☐ **Sweep variable up to 20 MHz**
- ☐ **Crystal controlled markers**
- ☐ **Differential measurement facilities for maximum accuracy**

The TF 1099 is a high discrimination sweep generator covering the video frequency range. It may be used in conjunction with a suitable oscilloscope for the visual display of frequency response characteristics of wide-band amplifiers, transmission systems, etc., or for the display of standing waves and location of discontinuities in r.f. or video cable links.



Frequency Sweep

The sweep starts at a frequency of less than 100 kHz and extends to an upper frequency that is continuously variable up to 20 MHz, the lower frequency limit being locked at the start of the sweep by means of a special a.f.c. circuit. The level of the frequency swept signal is variable from 0.3 to 3 volts peak-to-peak, and the selected output level is held constant within 0.2 dB – a factor that contributes materially to the high order of measurement accuracy.

Time Base Output

A 250 volt time base output, synchronised with the frequency sweep, is provided for connection to the X input of the oscilloscope. This output takes the form of a continuous sawtooth waveform at a repetition frequency of 50 to 60 Hz, provision being made for internal synchronisation to the mains supply frequency or for the application of external trigger pulses; e.g., t.v. field sync pulses.

Frequency Markers

A series of marker pips can be superimposed on the display to facilitate accurate frequency identification. These are derived from a built-in marker generator, which produces a pulse output from heterodyne beats between the swept frequency and the harmonics of a 5 MHz crystal controlled signal. By means of internal filters a marker output is produced whenever the heterodyne beat frequency is zero, 1 MHz, or 2 MHz. Zero beat markers, occurring at 5 MHz intervals, appear to flicker and are easily identifiable.

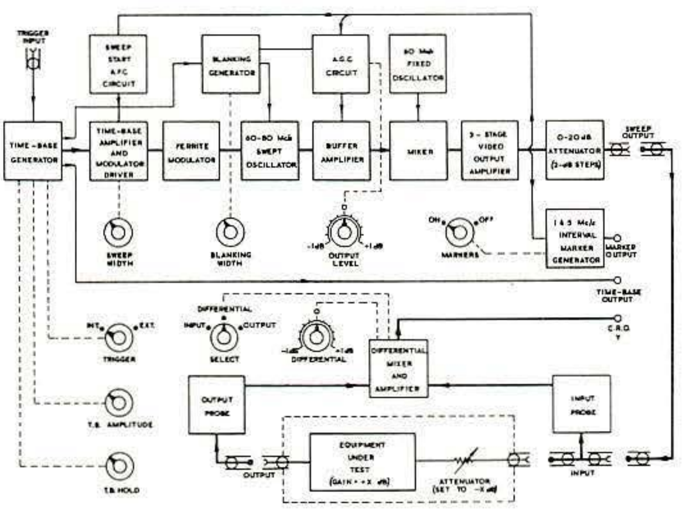
Differential Measurement

Considerable increase in discrimination and complete elimination of error due to the inevitable small variations in sweep level can be achieved by the use of the differential measurement facilities.

For the differential method, the effective mid-frequency gain of the network under test is reduced to unity by means of an external attenuator; and the sweep generator is connected to the overall network via a pair of detector probes, which monitor the input and output voltages. The two detector voltages are applied to a comparator system in the sweep generator; and the amplified difference voltage is displayed on the oscilloscope.

This system is particularly useful in the investigation of nominally flat sections of a response curve where high discrimination is of major importance.

For networks having high output impedance, a special output probe is available.



FREQUENCY-SWEPT OUTPUT	
Frequency Range	Lower limit locked to frequency not exceeding 100 kHz; upper limit continuously variable up to 20 MHz.
Output Level	Continuously variable from 0·3 to 3 volts peak-to-peak by means of a switched attenuator covering 20 dB in 2 dB steps and a continuous control with a range of 2 dB.
Level Accuracy	0·25 dB accuracy of indication. The selected level is held constant within 0·2 dB down to 250 kHz, or down to 100 kHz when the sweep width does not exceed 2 MHz.
Output Impedance	75 Ω.
Harmonic Distortion	Less than 2% at all frequencies.
TIME BASE	
Repetition Rate	50 to 60 Hz. Time base may be triggered internally from the mains supply, or externally from 50 to 60 Hz sync pulses.
Output Level	250 volts max.
FREQUENCY MARKERS	
Frequency Interval	1 MHz crystal controlled; 5 MHz pips easily identified from flickering appearance.
Pulse Height	Nominally 1 volt peak.
DETECTOR PROBES	Two probe units are supplied for detecting the input and output voltages of the network under test. The input probe provides a through connection for the sweep signal; the output probe has a 75Ω terminating impedance. With the swept-signal output set to 1 volt, a differential voltage of approximately 0·2 volts is produced by a change in response of 0·2 dB from level.
POWER REQUIREMENTS	200 to 250 volts, and 100 to 150 volts; 40 to 100 Hz; 140 watts.

DIMENSIONS AND WEIGHT	Height	Width	Depth	Weight
	13½ in	19½ in	11 in	53 lb
	35 cm	50 cm	28 cm	24 kg

ACCESSORIES	
Supplied	Coaxial Free Plug, Type 83; for use with trigger input socket. **TM 4726/18**; Coaxial Output Lead, 6 feet long; Type 83 plug at each end; for use with sweep output socket. **TM 5332**; Input Probe Assembly, cable, 6 feet long; Type 83 fixed socket for connection to sweep output lead; signal to unit under test available at Type 83 fixed plug. **TM 5331**; Output Probe Assembly, cable, 6 feet long; Type 83 fixed plug for connection to output of unit under test.
Optional	**TM 5997**; High-Impedance Probe, for measuring response of high-impedance circuits. Input impedance: 30 kΩ with 4 pF in shunt. Fitted with spear point and earthing clip for connection to output of unit under test; supplied complete with attached lead, 3 feet long.

Multi-channel Test Equipment

White Noise Testing of F.D.M. Links

In a multi-channel cable or radio link, each telephone channel occupies a frequency band of 300 Hz to 3400 Hz; and in the frequency division multiplex (F.D.M.) system a number of such channels, each channel allocated a bandwidth of 4 kHz, are placed side by side by means of frequency transposition. Twelve channels placed side by side in this manner is called a basic primary group and occupies the band of frequencies 12 kHz to 60 kHz. Secondary groups or supergroups are formed by assembling five such basic groups of twelve channels and transposing them to various positions in the frequency spectrum in the manner shown in Fig. 1.

The frequency spectrum occupied by the transposed channels is referred to as the baseband and is either transmitted direct along cables or used to frequency modulate the carrier in the case of a microwave radio link. The waveform of this total multiplex signal, consisting of the addition of a large number of transposed voice frequencies, closely resembles white noise having the same band of frequencies and distribution of peak amplitudes, i.e. gaussian distribution of peaks. For this reason it is convenient, when testing a link, to simulate fully loaded conditions by applying white noise having the correct level and baseband frequency spectrum.

Good intelligibility is the criterion of performance of a multichannel link system. To secure this, noise, which causes a deterioration in intelligibility, must be kept to a minimum. Main sources of noise are:

1. Intermodulation noise due to amplitude and phase non-linearity throughout the system.
2. Thermal noise generated in amplifiers and receivers.

It is the purpose of a white noise test set to provide a simple and accurate means of comparing the noise produced by the link with the level of an output signal due to the applied white noise. The resulting ratio is called the noise power ratio (N.P.R.) of the system.

A simple understanding of the method of measurement may be obtained if we assume that, say, a 600 channel system is completely loaded with normal speech traffic except for one channel. This channel is used as a listening-post and should be completely silent, but because of non-linearity throughout the link system, intermodulation products occur which are noticeable as noise. It is immaterial which channel is used as the quiet channel although intermodulation will in general be different at different points in the baseband.

These conditions may be simulated by a white noise test set. A white noise generator is used in place of the speech traffic. Its output frequency range, as shown in Fig. 2a, is limited by high- and low-pass filters according to the capacity of the system under test. A quiet channel is produced by switchable band-stop filters, as shown in Fig. 2b. The white noise signal is fed to the baseband input at the sending end of the link, by-passing the channelling equipment.

The second part of the test set is a receiver which is switch-tuned to the frequency of the band-stop filter used to produce the quiet channel. It is connected to the base-band output at the receiving end of the link—again excluding the channelling equipment.

A measurement is made by setting the generator to the correct output level with the band-stop filter out and adjusting the receiver meter to the reference mark. When a band-stop filter is switched in, a narrow band of frequencies is attenuated by about 90 dB and the receiver meter deflection will fall. If there is no noise generated in the link equipment the meter deflection would be restored by reducing the receiver input attenuator by this same amount, i.e. 90 dB. Because of intermodulation and thermal noise it will be found that attenuation will have to be reduced by, perhaps, only 50 dB, as shown in Fig. 2c. This change in attenuation is the noise power ratio of the system.

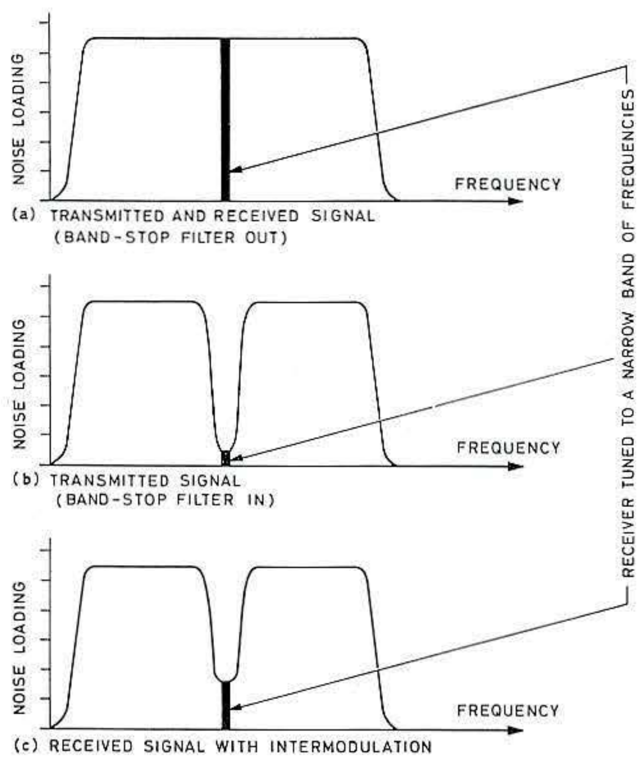


Fig. 2. Principle of operation of white noise test set.

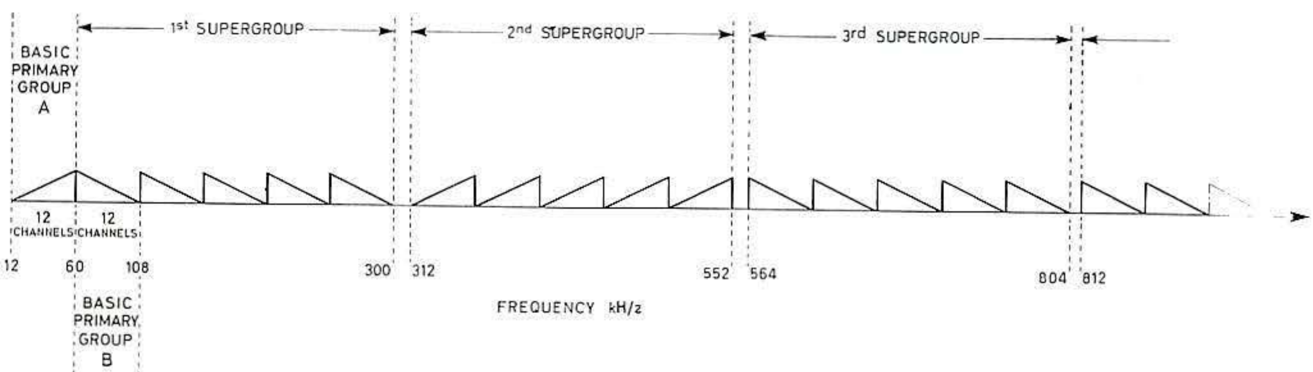


Fig. 1. Formation of the baseband.

Multi-channel Test Equipment

White Noise Test Set

- ☐ Measures noise and intermodulation on wide band multichannel telephony systems
- ☐ Suitable for 12 channel to 2700 channel systems

Two compact units form a complete equipment for measurement of noise interference in wideband telecommunication systems by methods based on recommendations of the C.C.I.R. (Radio Relay), the C.C.I.T.T. (Cable) and the D.C.A. These methods, which differ from each other only in small details, take advantage of the fact that a wideband multiplex signal closely resembles random noise evenly distributed over the total working bandwidth.

A noise signal, which simulates traffic at a specified level of loading, is applied to the communication system from Noise Generator TF 2091. A quiet test channel is produced by the introduction of a band-stop filter in the generator circuit; and the noise level in this test channel, at the output of the system, represents the level of interference due to intermodulation and residual noise in an equivalent operational channel. It is measured by means of Noise Receiver TF 2092A, which compares the noise interference with the noise in the same channel in its busy state; i.e., when the band-stop filter is taken out of circuit. The result of this comparison is known as the noise power ratio (n.p.r.).

This system of measurement is applicable to Microwave Relay Links, Tropospheric Scatter Systems, Multi Channel Cable Links, System Components (e.g., baseband amplifiers), and Video Tape Systems.

The Noise Generator

The generated noise bandwidth extends from below 12 kHz to above 12·388 MHz, and thus accommodates all basebands from 12 channel to 2700 channel—see Table I.

For realistic simulation of traffic conditions, however, the transmitted noise bandwidth must be equal to the baseband of the system. So the noise signal is passed through a pair of band-limiting filters—a high-pass filter at the low-frequency end and a low-pass filter at the high end. The band-limited signal is then amplified and fed, via the band-stop (slot) filter which produces the quiet test channel, to an output attenuator.

Flexibility

This is an important feature of the test set; and the mechanical arrangements are such that any of the filters can easily be changed to suit the operational equipment to be tested.

Each filter—band-limiting as well as band-stop—can be switched into and out of circuit by means of a toggle switch; all the filters are mechanically similar; and the instrument is designed to carry a total of nine, this total being made up of any number of high-pass, low-pass and band-stop filters as desired.

By fitting a suitable selection of filters the instrument can, therefore, be arranged for testing two or more different communication systems, the noise bandwidth being changed simply by the operation of the appropriate switches. For easy identification band-limiting filter switches are colour coded grey, and those of the band-stop filters are red.

Direct Reading Noise Power

The power level of the noise signal applied to the output attenuator is continuously variable and is monitored by a meter scaled directly in dBm from 0 to 20. The attenuator is variable from 0 to 50 dB in 1 dB steps, and the final output level is obtained by subtracting the attenuator setting from the meter reading.

Suitable test levels of noise power are recommended by the appropriate standardising authority; i.e., C.C.I.R. or C.C.I.T.T.

The Noise Receiver

The receiver, connected at the receiving end of the link system, is switch-tuned to the centre frequency of the test channel appropriate to the band-stop filter in use in the Noise Generator.

Up to six frequency selectors can be fitted, each comprising a band-pass input filter and a plug-in local-oscillator board. Like the Noise Generator, the Receiver is so constructed that the frequency selector units can be changed easily and quickly.

The Measurement

The standard way of measuring the n.p.r. is by a slide back method utilising the receiver's input attenuator.

With the communication system fully loaded with white noise, without any quiet channels, the receiver is set to the test frequency, and its sensitivity is adjusted for a deflection of the panel meter pointer to a reference mark. It is then responding to the mean noise level over its 1 kHz bandwidth. The appropriate band-stop filter in the Noise Generator is then switched into circuit, producing the quiet test channel not less than 3 kHz wide, and the receiver's input attenuator is adjusted to bring the meter pointer back to the reference mark. The noise power ratio is then equal to the change in attenuation. It is usual to measure the n.p.r. at three frequencies in the baseband, one near the top, one at the centre, and one near the bottom frequency limit—see Table I.

Direct Reading in N.P.R.

For convenience of operation the attenuator controls are scaled to be direct reading in noise power ratio; i.e., calibrated in reverse with 0 dB corresponding to high attenuation. It is scaled up to 110 dB in 1 dB steps.

The initial setting up on a busy channel is normally done with the attenuator at the 0 position. In order to cater for various mean power levels, the coarse attenuator dB scale can be rotated (with click stops) relative to the dial. An absolute calibration in pW is also provided.

Out of Band Testing

It is sometimes desirable to monitor the intermodulation and residual noise in a multi-channel system while it is carrying traffic. The usual method is to monitor the noise in a nominal test channel just outside the operational bandwidth of the system.

Noise Receiver TF 2092A can also be used for this type of measurement, frequency selector units for out-of-band test channels being available to special order.

In this type of measurement, the noise in the test channel is, of course, due to intermodulation products from the traffic signals and residual noise in the system; but a standard noise source is necessary as a reference signal for setting up the receivers' sensitivity.

The TF 2092A contains an internal standardising noise source delivering the equivalent of 1 pW per 3·1 kHz.

Recorder Output

For continuous monitoring of noise interference levels, the Receiver is provided with a recorder output jack. The voltage from this socket is derived by rectification of the I.f. noise signal, and the smoothed d.c. output is proportional to the mean noise level.

Reliability

Both units of the White Noise Test Set are fully transistorised, with the usual advantages of good reliability, virtually zero warm-up time, and low temperature operation.

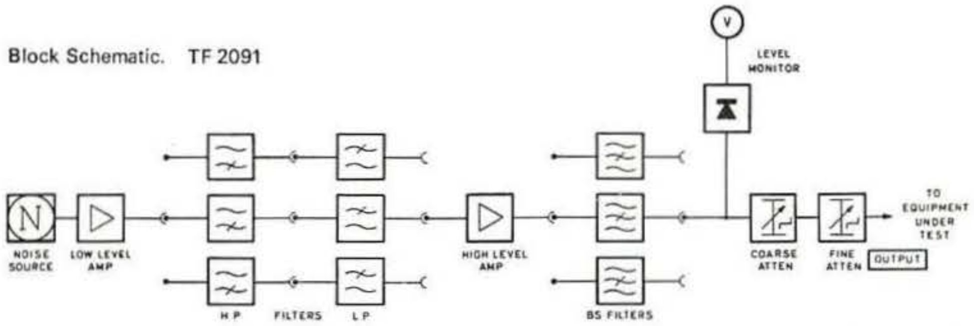
Furthermore, in common with other instruments recently introduced, the OA 2090A has been subjected to thorough environmental testing.

Bench or Rack Mounting

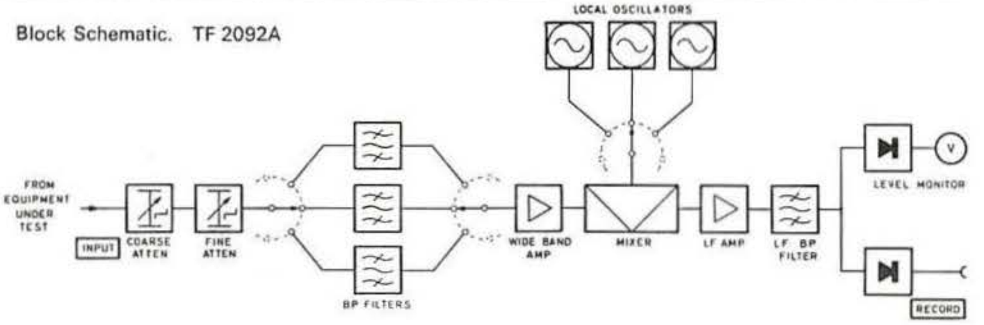
The two units are the same size, conforming to the Marconi module dimensional standard. As full-module units, they are normally in bench type cases with provision for fitting a protective front cover, which is available as an optional accessory. The instruments can also be supplied ready for mounting into a standard 19 inch rack; or, if required at a later date, a separate rack-mounting conversion kit is available.

OA 2090A

Block Schematic. TF 2091



Block Schematic. TF 2092A



Specification for Noise Generator TF 2091

NOISE BAND CHARACTERISTICS	
Generated Noise Bandwidth	From below 12 kHz to above 12,388 kHz (limited to required bandwidth by low-pass and high-pass filters).
Noise-Level Characteristics	With band limiting filters in circuit, noise level over the pass band is flat within 1 dB.
High Pass Filter Rejection Ratio	At least 25 dB at frequencies 20% below cut-off.
Low Pass Filter Rejection Ratio	At least 25 dB at frequencies 10% above cut-off.
STOP BAND CHARACTERISTICS	
Rejection Ratio	More than 80 dB over a bandwidth of at least 3 kHz and more than 3 dB at frequencies of (0·02 fc + 4) from the centre frequency, fc.
NOISE POWER OUTPUT	
Reference Level	Adjustable to above —15 dBm per kHz of noise bandwidth.
Maximum Total Power	+20 dBm into 75 Ω.
Noise Level Monitor	Measures total power in two ranges: 0 to +10 dBm, 10 to 20 dBm.
Monitor Accuracy	±1 dB between +5 and +10 dBm and between +15 and +20 dBm. ±2 dB between 0 and +5 dBm and between +10 and +15 dBm.
Output Attenuator	51 dB in 1 dB steps. *Accuracy:* 1% of setting ±0·1 dB
Output Impedance	75 Ω. Return loss greater than 20 dB when 6 dB or more attenuation is inserted.
POWER REQUIREMENTS	
Voltage	95 to 130 or 190 to 260 volts a.c.
Frequency	45 to 500 Hz.
Power Consumption	Approximately 50 watts.
DIMENSIONS	Height 19·5 cm 7¾ in; Width 47·5 cm 18¾ in; Depth 43·2 cm 17 in.
WEIGHT	Instrument without Filters: 11·8 kg (26 lb). Each Filter: 480 gm (1 lb 2 oz).
SUB-MODULES	High-Pass Filters, Low-Pass Filters, Band-Stop Filters — As required (*see Table II*)

Specification for Noise Receiver TF 2092A

RECEPTION CHANNELS	
Up to Six	Switch selected.
Nominal Channel Bandwidth	1 kHz.
SENSITIVITY	Better than −115 dBm per kHz noise bandwidth. The gain of each reception channel is individually adjustable for equalising sensitivity over the six bands.
INPUT ATTENUATOR	Direct reading in noise power ratio and pW noise power per unit (3·1 kHz) channel bandwidth.
Range	0 to 111 dB in 10 steps of 10 dB and 11 steps of 1 dB.
Accuracy	±1% of attenuation value ±0·1 dB.
INPUT IMPEDANCE	75 Ω.
Return Loss	Greater than 20 dB when switched to OPERATE and when indicated level exceeds 0·1 pW per channel. When switched to STANDARDISE the return loss is greater than 26 dB.
STANDARDISING NOISE SOURCE	
Level	1 pW or −90 dBm per 3·1 kHz channel bandwidth (−95 dBm per kHz bandwidth).
Noiseband Characteristic	Noise is generated over the band 10 kHz to 13 MHz. Within these frequency limits the level does not vary by more than ±0·25 dB.
Noise Power Accuracy	±0·5 dB at 1 pW per channel.
RECORDER OUTPUT	Suitable for use with 1 mA recorders.
POWER REQUIREMENTS	
Voltage	95 to 130 and 190 to 260 volts a.c.
Frequency	45 to 500 Hz.
Power Consumption	Approximately 15 watts.
DIMENSIONS	Height 19·5 cm 7¾ in; Width 47·5 cm 18¾ in; Depth 43·2 cm 17 in
WEIGHT	Instrument without filters: 11·4 kg (25 lb). Each filter: 480 gm (1 lb 2 oz).
SUB-MODULES	Band-Pass Input Filter, Local Oscillator Units — As required (*see Table II*).

TABLE I. Typical Filter Frequencies for Various System Capacities

No. of Channels	Band Limits		In-Band Test Channels			Out-of-Band Test Channels	
	High Pass	Low Pass	Lower	Centre	Upper	Lower	Upper
12	12 kHz	60 kHz	27 kHz	40 kHz	50 kHz	—	—
24	12 kHz	108 kHz	40 kHz	70 kHz	105 kHz	—	—
36	12 kHz	156 kHz	40 kHz	70 kHz	105 kHz	—	—
48	12 kHz	204 kHz	40 kHz	105 kHz	185 kHz	—	—
60	12 kHz	252 kHz	40 kHz	185 kHz	245 kHz	—	—
60	60 kHz	300 kHz	70 kHz	185 kHz	270 kHz	50 kHz	331 kHz
120	60 kHz	552 kHz	70 kHz	270 kHz	534 kHz	50 kHz	607 kHz
240	60 kHz	1,052 kHz	70 kHz	534 kHz	1,002 kHz	50 kHz	—
300	60 kHz	1,300 kHz	70 kHz	534 kHz	1,248 kHz	50 kHz	1,499 kHz
600	60 kHz	2,660 kHz	70 kHz	1,248 kHz	2,438 kHz	50 kHz	3,200 kHz
960	60 kHz	4,028 kHz	70 kHz	2,438 kHz	3,886 kHz	50 kHz	4,715 kHz
960	316 kHz	4,188 kHz	534 kHz	2,438 kHz	3,886 kHz	270 kHz	4,715 kHz
1,200	316 kHz	5,564 kHz	534 kHz	3,886 kHz	5,340 kHz	—	—
1,800	316 kHz	8,204 kHz	534 kHz	3,886 kHz	8,002 kHz	—	—
2,700	316 kHz	12,388 kHz	534 kHz	3,886 kHz	12,150 kHz	—	—

TABLE II

Frequency in kHz	Noise Generator Filters			Receiver Frequency Selectors	
	High Pass	Low Pass	Band Stop	Filters	Oscillators
12	TM 7728	—	—	—	—
14	—	—	TM 7729	TM 7730	TM 7793
27	—	—	TM 7729/21	TM 7730/21	TM 7793/4
34	—	—	TM 7729/12	TM 7730/12	TM 7793/2
40	—	—	TM 7729/1	TM 7730/1	TM 7793/1
56	—	—	TM 7729/13	TM 7730/13	TM 7793/3
60	TM 7728/1	TM 7720/8	—	—	—
70	—	—	TM 7729/2	TM 7730/2	TM 7794
105	—	—	TM 7729/3	TM 7730/3	TM 7794/1
108	—	TM 7720	—	—	—
140	—	TM 7720/17	—	—	—
152	—	—	TM 7729/19	TM 7730/19	TM 7794/7
156	—	TM 7720/14	—	—	—
185	—	—	TM 7729/4	TM 7730/4	TM 7794/2
204	—	TM 7720/10	—	—	—
245	—	—	TM 7729/22	TM 7730/22	TM 7794/9
252	—	TM 7720/15	—	—	—
270	—	—	TM 7729/5	TM 7730/5	TM 7794/3
290	—	—	TM 7729/14	TM 7730/14	TM 7794/5
300	—	TM 7720/1	—	—	—
316	TM 7728/2	—	—	—	—
342	—	—	TM 7729/16	TM 7730/16	TM 7794/6
534	—	—	TM 7729/6	TM 7730/6	TM 7794/4
552	—	TM 7720/2	—	—	—
695	—	—	TM 7729/20	TM 7730/20	TM 7794/8
1,002	—	—	TM 7729/15	TM 7730/15	TM 7795/5
1,052	—	TM 7720/11	—	—	—
1,248	—	—	TM 7729/7	TM 7730/7	TM 7795
1,300	—	TM 7720/3	—	—	—
2,438	—	—	TM 7729/8	TM 7730/8	TM 7795/1
2,540	—	TM 7720/4	—	—	—
2,660	—	TM 7720/12	—	—	—
3,886	—	—	TM 7729/9	TM 7730/9	TM 7795/2
4,028	—	TM 7720/5	—	—	—
4,188	—	TM 7720/13	—	—	—
4,300	—	TM 7720/18	—	—	—
5,340	—	—	TM 7729/17	TM 7730/17	TM 7795/6
5,564	—	TM 7720/9	—	—	—
6,022	—	—	TM 7729/18	TM 7730/18	TM 7795/7
6,200	—	TM 7720/16	—	—	—
8,002	—	—	TM 7729/10	TM 7730/10	TM 7795/3
8,204	—	TM 7720/6	—	—	—
12,150	—	—	TM 7729/11	TM 7730/11	TM 7795/4
12,388	—	TM 7720/7	—	—	—

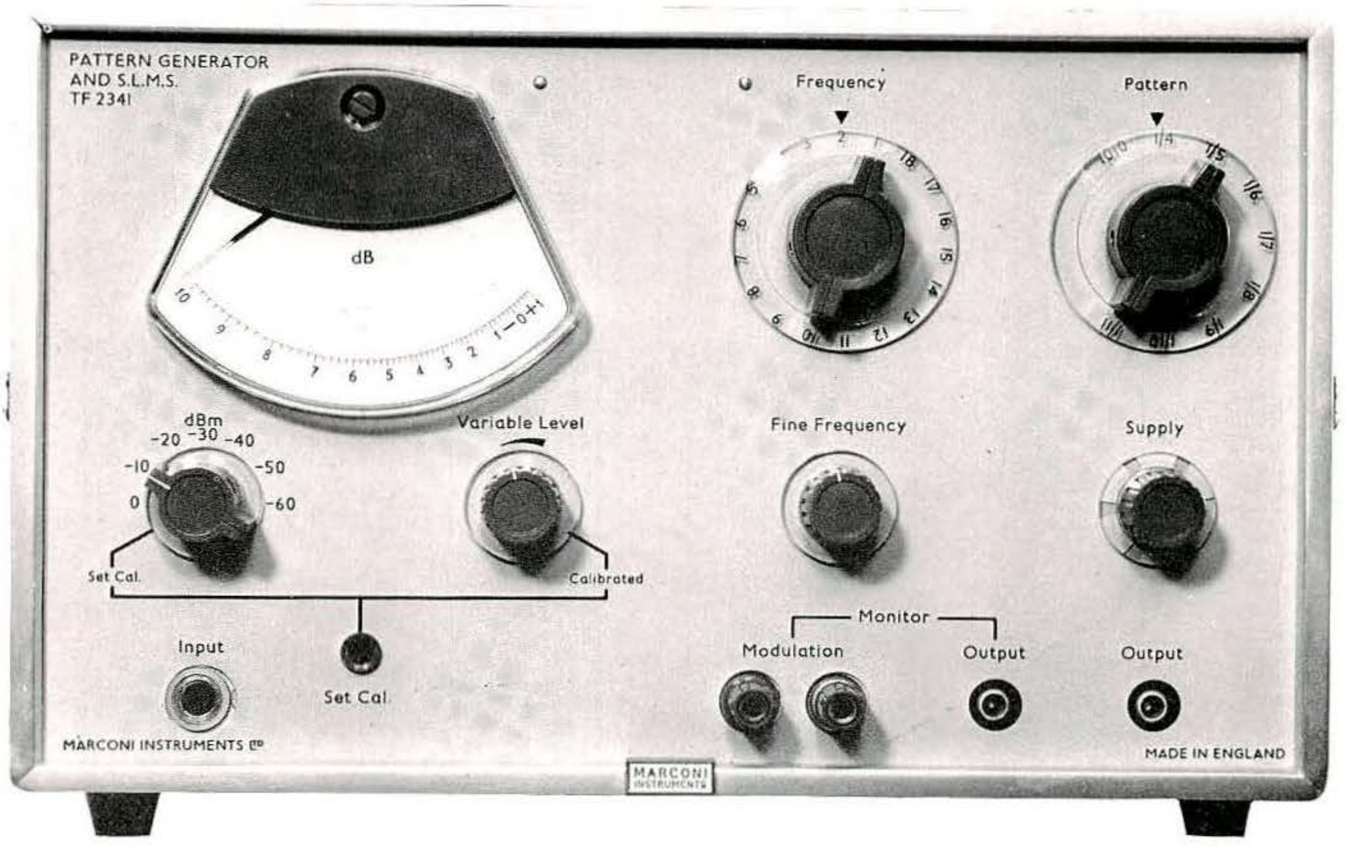
Optional Accessories for OA 2090A

Matching Transformer, TM 5955, 75 Ω to 150 Ω unbal. to bal.
Front Cover (Lid), **TM 7510**, with lead stowage.
Front Cover (Lid), **TM 7958/3** without lead stowage.
Connecting Lead (coaxial), **TM 4726/260.**

Rack Mounting TM 8270 **Kit** comprising: Bracket Assembly TM 7000/2.
Cover (Top and Bottom) TD 42443/1
Back Cover TD 41948/2.
Clip Plate TM 7956.
Front Plate TM 7957

Pattern Generator and S.L.M.S.

- ☐ For p.c.m. links containing up to 18 regenerators
- ☐ Combined pulse pattern generator and selective level meter
- ☐ Operates from 50 or 24 volts d.c. supply



TF 2341 is a combined pulse pattern generator and selective level measuring set for periodic testing and fault finding on a p.c.m. link consisting of up to 18 regenerators.

The instrument produces two forms of test signal: (1) a general purpose bipolar test signal, and (2) a simulated p.c.m. signal of bipolar triple pulse trains at any one of eight pattern densities, modulated at any of 18 audio frequencies by reversal of polarity. The pattern differs from a normal p.c.m. signal in that bipolar violations (consisting of two consecutive pulses of like polarity) are introduced, causing a shift in mean d.c. level of the signal. The selective level-measuring set and the pattern generator are synchronously tuned, and a panel meter indicates the level of the returned a.f. component from any selected regenerator to be observed as the pattern density is increased.

Operating power is derived from an external 50 volt or 24 volt d.c. supply. Voltage selection is not necessary because the power unit is self-adjusting to accommodate either supply voltage. A safeguard is also incorporated against accidental connection of the supply in the wrong polarity. A 20 volt supply is fed via the supervisory pair to activate the bandpass filters on the regenerators in the p.c.m. link.

PATTERN GENERATOR OUTPUT	
Bit rate	1·536 Mbits/sec ±75 bits/sec.
Digit slot	651 nsec.
Pulse half-amplitude duration	326 nsec ±30 nsec.
Output (into 75 Ω load)	Mean: 0 volts. Positive and negative pulses: 2·37 volts ±1%. Overshoot: less than 10%.
Pulse patterns	(1) 010101 . . . . (2) Variable from 1 pulse-group/4 digit time slots to 1 pulse-group/11 digit time slots, with 3 consecutive pulses of alternate sign in each group.
Modulation	The polarity of the pulse groups are reversed at any one of 18 rates, variable from 1185 to 3100 Hz.
Modulation mark/space	1:1 ±5%.
Output impedance	75 Ω unbalanced.
PATTERN GENERATOR MONITORING FACILITIES	
Monitor output plug	Provides a sample of the pattern output signal for connection to an oscilloscope. Source impedance: 1 kΩ (output level is 1 volt p-p when output is loaded with 75 Ω.
MONITOR MODULATION terminals	Provides the modulating signal at a level of 800 mV r.m.s. for connection to a counter or an oscilloscope.
SELECTIVE LEVEL MEASURING SET	
Input range	−70 dBm to +1 dBm in 7 ranges
Accuracy	±1 dB
SET LEVEL control range	10 dB
Tuning range	Synchronously tuned with pattern generator.
Bandwidth	30 Hz at −3 dB points.
Input impedance	1200 Ω ±10% balanced.
Channel amplifier supply	20 volts ±0·2 volts from 1 kΩ source resistance.
POWER REQUIREMENTS	
External d.c.	20 to 29 or 46 to 52 volts, positive to chassis. 7 watts.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
7 in	$11\frac{1}{2}$ in	$10\frac{1}{2}$ in	14 lb
18 cm	29·5 cm	27 cm	6·4 kg

ACCESSORIES

Supplied	Clip-on front panel cover holding supply lead TM 4726/350 and input lead TM 4726/355.
Optional	
TM 9742	Extender Board
TM 8089	Board Extractor.

Quantization Distortion Tester

- Checks a.f. to a.f. distortion of p.c.m. systems
- Utilises system power supply

This instrument, applicable to any p.c.m. system, is used to check overall performance of a link from audio input to audio output.

The test signal is band limited noise, 450-550 Hz, and the receiver uses an r.m.s. voltmeter in conjunction with filters, to measure the distortion introduced, from 0 dB to −40 dB, in 0·5 dB steps.

The level of the test signal, calibrated in 1 dB steps from +2 dBm to −50 dBm, is ganged to the sensitivity of the r.m.s. voltmeter, so that a complete set of readings can be made without resetting a reference.

This instrument is intended for exchange use and is powered from either 24 volt or 50 volt d.c. No damage will be caused if the supply is accidently reversed.

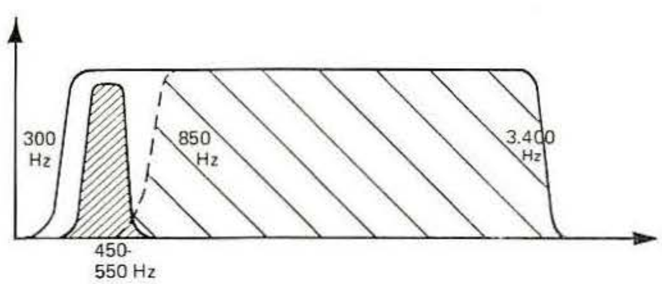
NOISE SOURCE	
Output level	Variable, in 1 dB steps, from −50 to +2 dBm.
Accuracy	±0·2 dB at +2 dBm, ±0·5 dB incremental
Output spectrum	The equivalent of white noise passed through a filter: ±1 dB from 450-550 Hz. >6 dB at 420,580 Hz. >30 dB at 350,690 Hz. >40 dB at 310,810 Hz. >50 dB at 250 Hz.
Output impedance	600 Ω ±10% balanced 2 or 4 wire facility.

RECEIVER METER	
Input range	Variable in 1 dB steps, from −50 to +2 dBm. (Ganged with output level), with additional ±10 dB continuously variable.
Quantization distortion	0 to −40 dB in 0·5 dB steps.
Accuracy	±0·5 dB (−30 dB). ±1 dB (−40 dB).
Meter indication	True r.m.s.
Input impedance	600 Ω ±10% balanced.
POWER REQUIREMENTS	
A.C. mains	50 or 24 volts d.c. (positive earthed).
DIMENSIONS AND WEIGHT	Height 8 in (20 cm); Width 19 in (48 cm); Depth 11 in (28 cm); Weight 24 lb (11 kg)
ACCESSORIES	
Supplied	Front cover and power lead.

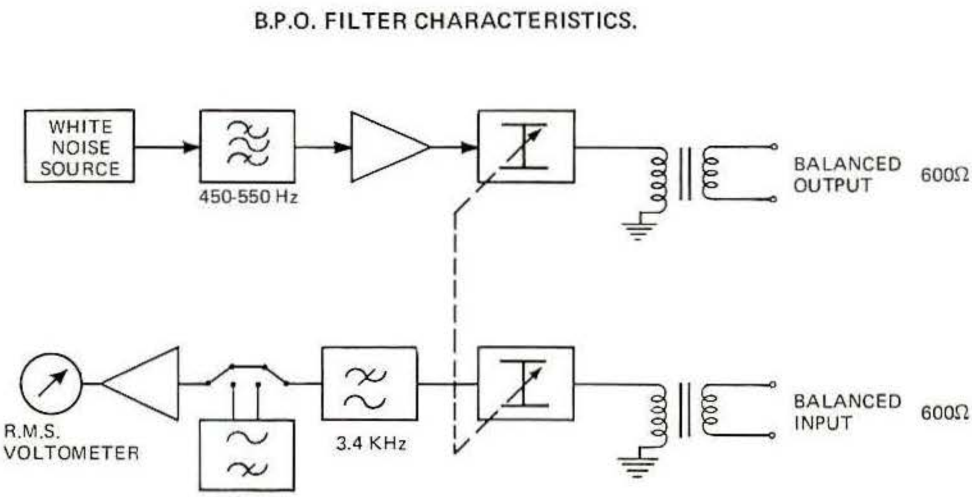
Quantization Distortion Testing

In any p.c.m. link, a certain amount of distortion is introduced when the analogue signal is quantized into discrete levels. Similarly more distortion is introduced when the signal is reformed into the analogue form. The Quantization Distortion Tester measures the noise produced by the p.c.m. system at different speech amplitudes. In this way the TF 2343 measures the overall performance of the link, in particular the coding and decoding processes.

The test signal is band limited white noise (450-550 Hz), this tvpe of signal having distinct advantages over a sine wave. The test signal is transmitted over the p.c.m. link and its r.m.s. level measured at the receive terminal, this includes all distortion components in the band 300-3,400 Hz. A high pass filter is then inserted before the r.m.s. voltmeter removing the fundamental noise; the new measurement in dB's gives the ratio of test signal + noise to noise, this indicates the overall audio to audio performance of the link, at the particular test signal amplitude.



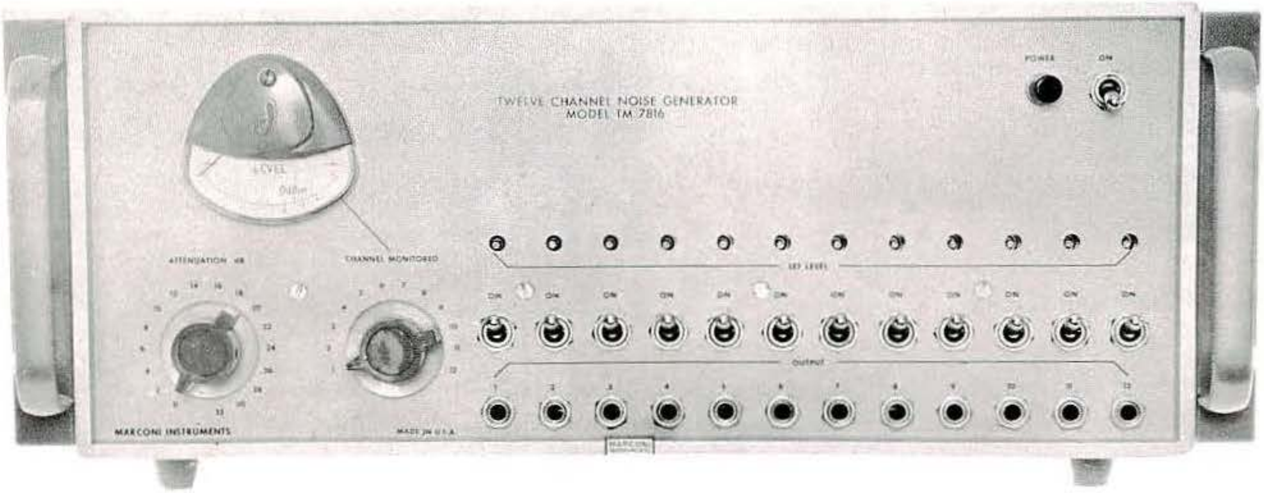
B.P.O. FILTER CHARACTERISTICS.



SIMPLIFIED BLOCK DIAGRAM

TM 7816 Twelve Channel Noise Generator

- ☐ Simulates up to twelve voice or data channels
- ☐ Measures complete system line-in to line-out
- ☐ Tests multiplex intermodulation and cross-talk



Model TM 7816 extends the usefulness of noise loading techniques to systems having 24 channels or less (or equivalent bandwidths). The twelve voice-frequency-range noise signals produced can be used to simulate traffic input to Troposcatter, SSB, FM or other multi-channel systems. Cross-talk and intermodulation distortion in multiplex equipment can be measured by connecting the multiplex back-to-back.

The instrument has been designed to generate twelve independent voice-frequency-range (300–3400 Hz), gaussian distribution, noise signals.

Semiconductor noise sources are used and the circuitry is completely transistorised. The twelve bank, 32 dB range attenuator is slave driven from the front panel control using a rotary solenoid selector switch.

To test a complete system the noise generator outputs are connected to the telephone or data line inputs of the multiplex equipment at the transmitter. The noise level is adjusted to load the system under test to the desired amount and the resulting noise output (P1) from a given test channel at the remote receiver, measured. Then the noise loading is removed from the test channel and the remaining spurious noise (P2) measured. If P1 is plotted against P2 an overall performance curve of the system will be obtained over its full dynamic range. Also using these results, the NPR, signal-to-noise ratio, weighted spurious noise and error rate to the test channel can be deduced. Tests can be made on several channels to measure the NPR distribution over the baseband.

The distortion and noise measured include components from the complete communication system, from the telephone line input of the sender, to the line output of the remote receiver. Separation of cross-talk and inter-modulation can be achieved by connecting the multiplex back-to-back.

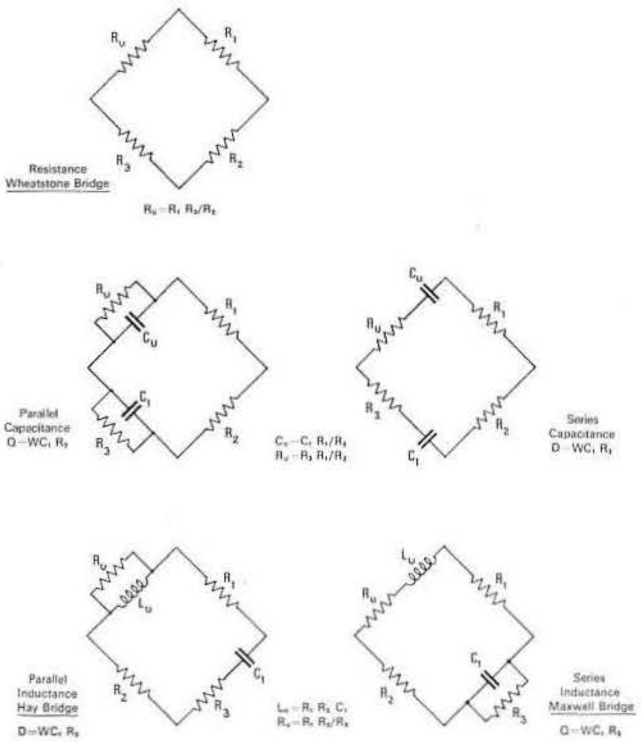
EACH NOISE GENERATOR CHANNEL	
Noise bandwidth	±1·5 dB over the range 300 to 3400 Hz.
Noise power output	0 dBm maximum (1 mW in 600 Ω).
Attenuator	0 to −32 dBm (each channel) in 2 dB steps.
Attenuator accuracy	±0·25 dB incremental, ±1 dB overall.
Noise output meter accuracy	±0·5 dB.
Statistical peak to RMS ratio of noise signal	8 dB for 1% of time. 10 dB for 0·1% of time.
Output impedance	600 Ω balanced.
Return loss	Greater than 20 dB.

Spurious noise in a nominally "OFF" channel, with all other channels "ON"	Less than 10 dBa. (−75 dBm F1A weighted).
POWER REQUIREMENTS	
A.C. mains	100 to 125 volts or 210 to 250 volts. 40 to 100 Hz. 20 watts.
External D.C.	24 volts.
DIMENSIONS	Case suitable for bench use or rack mounting. Panel height 7". Case depth 12·5".
WEIGHT	25 lb. approx.

Impedance Measuring Equipment

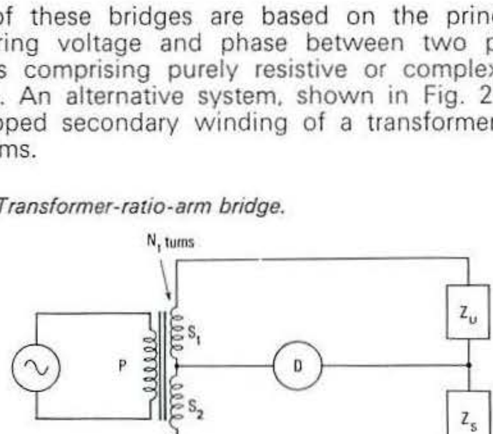
Bridge methods are commonly accepted as the most convenient for accurate measurement of impedance values; and a wide variety of bridge configurations have been devised. Fig. 1 shows the more common arrangements for measurement of resistance, capacitance, and inductance, together with conditions of balance.

Fig. 1 Impedance-ratio-arm bridges.



All of these bridges are based on the principle of comparing voltage and phase between two potential dividers comprising purely resistive or complex impedances. An alternative system, shown in Fig. 2 utilises the tapped secondary winding of a transformer as the ratio arms.

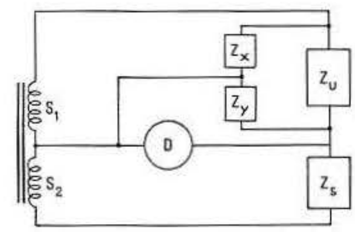
Fig. 2 Transformer-ratio-arm bridge.



$$Z_U = Z_S \; N_1/N_2$$

This type of impedance bridge has the advantage that the effect of a series combination of impedances (Z_X and Z_Y) in parallel with the unknown can be obviated by connection of the junction between Z_X and Z_Y to a common (earth) terminal as shown in Fig. 3. Impedance Z_X is in parallel with winding S_1 of the ratio-arm transformer; but any reduction in voltage due to the loading effect of this impedance is automatically compensated for by a proportionate reduction in voltage across S_2, due to the coupling between the two secondary windings. The voltage ratio is thus maintained, and no error is produced. Impedance Z_Y is in parallel with the detector. As the voltage across the detector is zero when the bridge is balanced, Z_Y has no effect on the measuring accuracy.

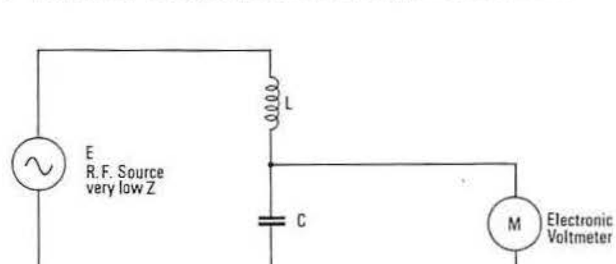
Fig. 3



The three terminal facility of the transformer-ratio-arm bridge has particular advantages for testing components *in situ* and for elimination of stray capacitance when it is necessary to use long connecting leads to a high-impedance unknown. In this case screened connecting leads are used, with the screen taken to the common terminal.

For certain types of impedance measurement at higher frequencies resonance methods, applied by means of a circuit magnification meter (Q-meter), have certain advantages. The basic configuration of this instrument is shown in Fig. 4.

Fig. 4 Functional arrangement of circuit magnification meter.



It comprises a series resonant circuit, energised by an accurately controlled r.f. voltage, which is derived via a very low source impedance. The voltage developed across the capacitance is monitored by an electronic voltmeter calibrated directly in Q. The capacitive element of the tuned circuit forms part of the instrument, and is both variable and calibrated, the inductive element normally being the unknown.

Although the instrument is used mainly for measuring the Q of inductors, the inductance value is easily calculated from the frequency and capacitance calibration. Capacitance can also be measured, by slideback method for small capacitors, or by resonance method, for larger capacitors, against a previously measured inductor.

Bridges

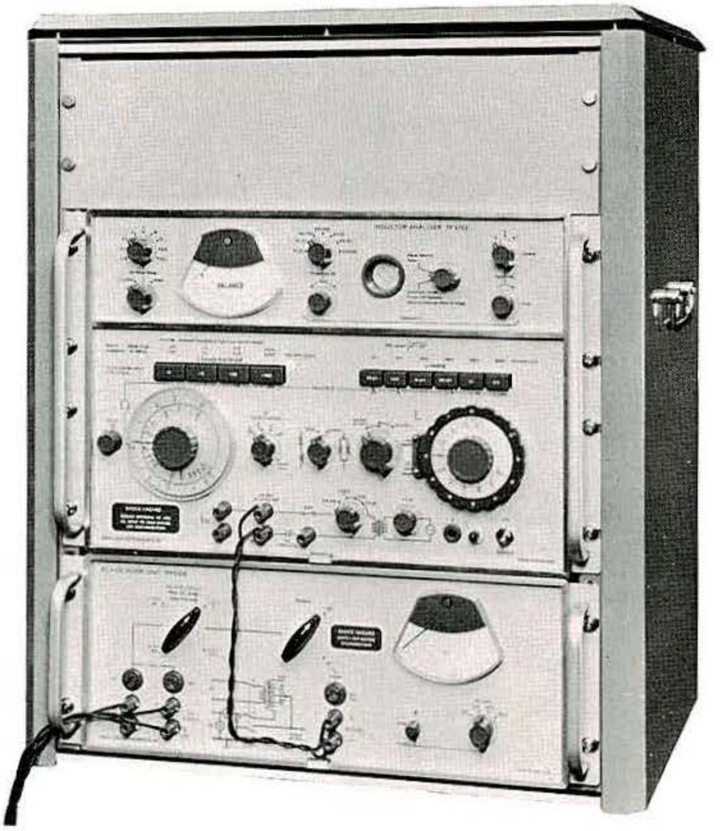
Title and Type Number	Range	Rack Mounting Kit	Pages
Inductor Analyser TF 2702	L: 0·3 μH to 21 kH	TM 9740	138—141
Mixer Unit (for above) TM 8339		TM 9741	142—143
Universal Bridge TF 2700	L: 0·1 μH to 110 H C: 0·5 pF to 1,100 μF R: 0·01Ω to 11 MΩ	TM 7010	150—151
In Situ Universal Bridge TF 2701	L: 1 μH to 110 kH C: 0·002 pF to 11,000 μF R: 0·002 Ω to 110 MΩ	TM 7010	152—153
0·1% Universal Bridge TF 1313A	L: 0·1 μH to 110 H C: 0·1 pF to 110 μF R: 0·003 Ω to 110 MΩ	—	154—155

Circuit Magnification Meter

Title and Type Number	Frequency Range	Q Range	Pages
Circuit Magnification Meter TF 1245A	1 kHz to 300 MHz	5 to 1,000	158—161

Inductor Analyser

- Measurement range: 0·3 μH to 21,000 henries
- Internal frequencies: 10 kHz, 1 kHz, and power line
- External frequency range: 20 Hz to 20 kHz
- D.C. bias and variable a.c. current facilities
- Cathode-ray tube detector for search, tuned detector for final balance
- Calibrated variable reactance-standard gives easy balancing



For currents exceeding 0·5 amps, the bridge should be used in conjunction with Mixer Unit TM 8339. Both the Inductor Analyser and the Mixer Unit are available in bench or rack mounting form.

The measuring facilities of the TF 2702 cover virtually every aspect of inductor analysis at frequencies up to 20 kHz. The instrument is basically an impedance-ratio-arm bridge which may be switched to the Maxwell or Hay configuration for measurement in terms of series or parallel inductance respectively. Provision is also made for the injection of d.c. bias for incremental inductance measurement; and the bridge elements are sufficiently robust to permit measurement under simulated operational conditions where heavy a.c. and/or d.c. currents are flowing in the inductor windings. The bridge is, however, equally suitable for measurements where very low current levels must be used; e.g., on small components wound on high permeability cores.

Variable Reactance-Standard

The common practice of using a fixed value capacitor as the reactive standard, with one of the resistive arms as the inductance-calibrated variable, has certain advantages, but it can lead to considerable difficulty in obtaining the final balance condition when the Q of the unknown inductor is low. This difficulty arises from the fact that the loss-balance and inductance-balance controls (being in separate bridge arms) are interdependent, so that it is necessary to approach balance by adjusting the two controls alternately for minimum detector deflection.

The difficulty is avoided altogether in the TF 2702 by the use of a variable capacitive standard, which utilises a ten-step switched sequence and a continuously variable control. With this arrangement, the loss-balance control is calibrated directly in series or parallel resistance, terms which are often more convenient than those of phase factor for assessment of performance of l.f. inductors.

Range Multipliers

The wide total measurement range is achieved by switched selection of suitable values for both of the resistive arms of the bridge. Two push-button-switch groups are used, one being marked in inductance range maxima and the other in multiplication factors. The operator, therefore, has control over all three arms of the bridge, and is able to set up the conditions most suitable to the measurement in hand.

Detector System

For final balance adjustment, the out-of-balance voltage is indicated by a sensitive selective voltmeter, which is tunable to any frequency within the range of the bridge. Harmonic components, which can give rise to errors in measurement of non-linear (cored) inductors, are thus filtered out. Effective screening of this detector eliminates signal breakthrough, coupling to the inductor under test, and coupling to other parts of the bridge, all of which could otherwise produce measurement errors and difficulties due to standing detector readings.

A second detector, with a cathode-ray tube indicator, is also included. This performs the dual function of showing the direction of unbalance and indicating the effect of any iron distortion that may be present.

When the bridge is balanced the cathode-ray tube trace takes the form of a straight line sloping to the left at an angle of 45° between a pair of black marker lines on the viewing screen. Iron distortion deforms the display at balance into an elongated triple loop, but the axis remains inclined at an angle of 45° to the left.

The angle of inclination indicates the inductance balance condition; i.e., if the line tends towards vertical the unknown inductance is higher than the indication, and if it tends towards horizontal the unknown is lower. The circuit arrangement is such that the trace inclination follows the inductance control's direction of rotation.

Incomplete loss (or phase) balance causes the trace to form an ellipse of breadth proportional to the degree of unbalance, the resistance-balance control being used to reduce the ellipse to a straight line.

If the test frequency is such that the component under test presents a capacitive impedance, the trace will be inclined to the right.

The cathode-ray tube detector is extremely useful for range searching when the value of the component under test is completely unknown.

Sensitivity of both the voltmeter and the c.r.t. detector is adjustable by means of coarse and fine controls which are common to the two systems. The coarse control takes the form of a three position switch and the fine control is a continuously variable resistor.

Internal A.C.

The bridge may be excited from an internal source at 1 kHz, 10 kHz, or power line frequency. Provision is made for varying the excitation voltage; and it is also possible to switch the panel meter to monitor the voltage across the unknown or the current passing through it. For voltage measurement the meter then indicates the potential between the test terminals, and can, therefore, be used for external measurements.

External A.C.

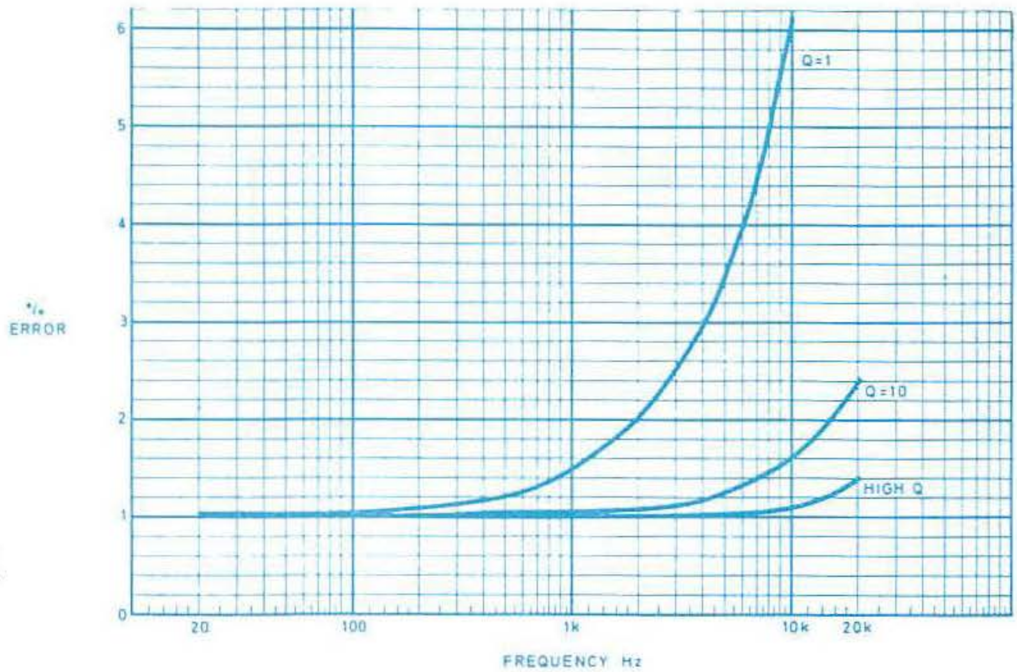
External a.c. excitation can be applied to the bridge at any frequency in the range 20 Hz to 20 kHz. Connection can be made via a jack socket to the primary winding of the bridge input transformer, insertion of the plug into this socket automatically switching the internal source out of circuit. Or, alternatively, the external source can be connected directly to the appropriate points on the bridge circuit, provision being made for switching out the internal input transformer. The arrangement of the measuring network is such that no isolating transformer is necessary for use with an oscillator having an output system with one side earthed.

External D.C.

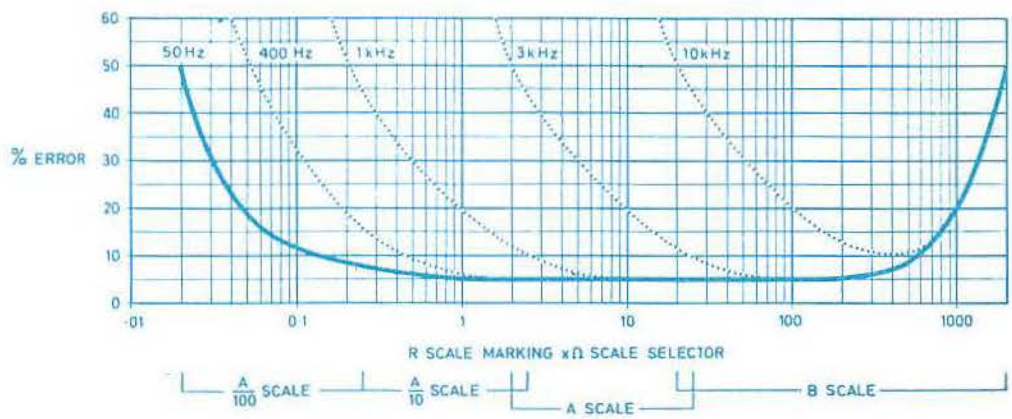
Provision is made for applying bias current by the series method; i.e., it flows through the secondary winding of the bridge input transformer and through the appropriate bridge arm, the current rating of this arm being the ultimate limiting factor.

For low and medium currents, where the r.m.s. sum of the a.c. and d.c. is up to 0·5 amps, the bias current can be applied directly to the bridge via a pair of terminals on the front panel. Currents exceeding 0·5 amps, however, would overload the internal input transformer, and provision is made for operating the bridge in conjunction with an external a.c./d.c. mixing transformer, such as the A.C./D.C. Mixer Unit Type TM 8339.

TF 2702



Inductance Accuracy
This graph shows the percentage of error of the inductance measurement at representative values of Q.



Typical resistance scale accuracy at representative frequencies.

RANGES

Inductance 0·3 μH to 21,000 henries by means of 6 range switches and 4 multiplier switches. The scale on each range is divided into 20 equal steps and has an interpolating dial with 100 divisions.

Resistance Series or parallel resistance may be selected giving equivalent Q from less than 0·1 to approaching infinity. The scale is calibrated from 0·02 Ω to 2 kΩ in 4 steps for series resistance, and from 0·2 Ω to 2 kΩ in 3 steps for parallel resistance with multiplying factors of from 10^{-3} to 10^{4} in decade steps.

CURRENT RATING
r.m.s. ***sum of a.c. and d.c.***
i.e., $\sqrt{a.c.^2+d.c.^2}$

Up to 21 henries	10 amps r.m.s.
Up to 210 henries	3 amps r.m.s.
Up to 2,100 henries	0·3 amps r.m.s.
Up to 21,000 henries	0·03 amps r.m.s.

ACCURACY (Inductance)

±1% of reading ±0·05% of range full scale, subject to current limitations of:
7 amps up to 21 henries
2 amps up to 210 henries
0·3 amps up to 2,100 henries
0·03 amps up to 21,000 henries
and the following qualifications:

(a) At high currents, add ±0·25% of reading within the following limits:
10 amps up to 21 henries
3 amps up to 210 henries

(b) At low inductance, the residual inductance (0·25 μH) must be subtracted from the indicated inductance.

(c) With inductance values above 1 kH the maximum frequency is 1 kHz, and an external source must be used, as the discrimination with the internal source is too low to maintain the basic accuracy.

(d) At high frequency and/or low Q add $\pm\left(0{\cdot}001f^2 + \frac{0{\cdot}5f}{Q}\right)$ % of reading, where f = frequency in kHz.

ACCURACY (Resistance)

Scale A	$\pm5\% \pm \left(\frac{A}{4}\right)\% + \frac{f^2}{10^7}\,\Omega$
Scale $\frac{A}{10}$	$\pm10\% \pm 0{\cdot}02 + \frac{f^2}{10^7}\,\Omega$
Scale $\frac{A}{100}$	$\pm10\% \pm 0{\cdot}02 + \frac{f^2}{10^7}\,\Omega$
Scales B	$\pm5\% \pm \left(\frac{100B}{2k+B}\right)\% + \frac{f^2}{10^7}\,\Omega$

A and B are scale readings; Scale A is 2 Ω to 25 Ω and Scale B is 20 Ω to infinity.

The above accuracy applies after the residual resistance (30 mΩ) has been deducted from the readings.

BRIDGE EXCITATION

Internal a.c. An e.m.f. of at least 10 volts r.m.s. is available at the supply frequency from a source resistance of typically 25 Ω. An internal oscillator provides frequencies of 1 kHz and 10 kHz at an e.m.f. of at least 2·0 volts r.m.s. from a source resistance of typically 70 Ω.

External a.c. External supplies from 20 Hz to 20 kHz may be used within the following limitations, provided the current ratings given earlier are not exceeded.

Max level	*Range*
500 volts	0·11 to 21,000 henries
300 volts	11 mH to 21,000 henries
100 volts	1·1 mH to 21,000 henries
30 volts	110 μH to 21,000 henries
10 volts	11 μH to 21,000 henries

External d.c. The internal a.c./d.c. mixing transformer may be used with external d.c. up to 0·5 amps providing the rated current maxima are not exceeded. Internal a.c. as specified above or external a.c. via the front panel jack may be applied. This external a.c. must not exceed f/5 volts (where f is the frequency in Hz) up to a maximum of 100 volts r.m.s. Above 0·5 amps d.c. an external mixing unit is required—e.g., A.C./D.C. Mixer, Type TM 8339.

DETECTOR

This uses a 1 inch c.r.t. for preliminary balance and search, and a meter for final balance. The c.r.t. also indicates any core non-linearity of the inductor under test.

Frequency range Untuned and search: 20 Hz to 20 kHz
Tuned: Continuously variable over the following ranges:—
42 to 60 Hz
80 to 120 Hz
320 to 500 Hz
800 to 1,200 Hz
2 kHz to 3 kHz
10 kHz to 16 kHz

MONITOR

Measures a.c. voltage across and a.c. current through the inductor. This meter may be used independently for measurement of voltage and current.

Voltmeter Nine ranges with full scale deflections of 50, 200, and 500 mV, 2, 5, 20, 50, 200, and 500 volts over the range 20 Hz to 20 kHz.
Accuracy: 50 Hz to 10 kHz: ±3% of reading ±2% f.s.d.
20 Hz to 50 Hz: ±6% of reading ±2% f.s.d.
10 kHz to 20 kHz: ±6% of reading ±2% f.s.d.

Ammeter Covers six ranges with full scale deflections of 50, 200, and 500 mA, and 2, 5, and 20 amps.
Accuracy: 50 Hz to 10 kHz: ±3% of reading ±2% f.s.d.
20 Hz to 50 Hz: ±6% of reading ±2% f.s.d.
10 kHz to 20 kHz: ±6% of reading ±2% f.s.d.

POWER REQUIREMENTS

A.C. Mains 100 to 130 volts or 200 to 250 volts, 45 to 65 Hz 60 VA.

DIMENSIONS AND WEIGHT

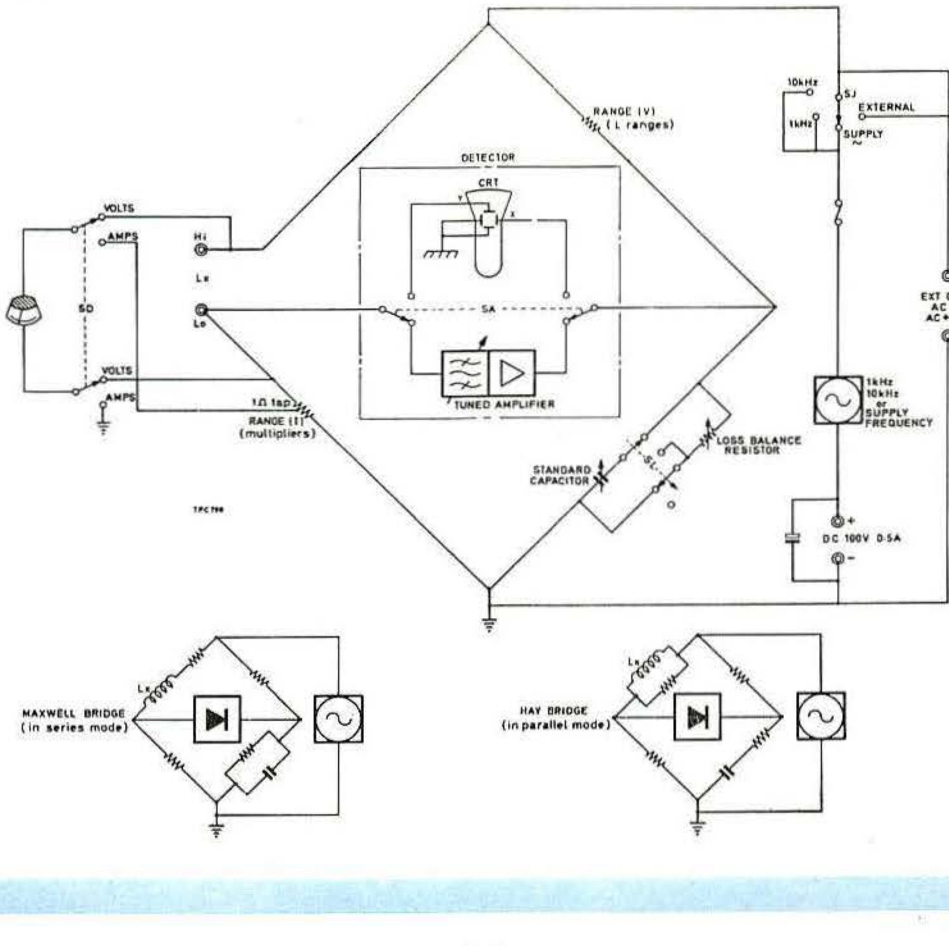
Height	Width	Depth	Weight
13 in (33 cm)	18 in (46 cm)	14 in (36 cm)	30 lb (13·6 kg)

ACCESSORIES

Supplied One telephone plug type P40 to connect with the external a.c. jack.

Optional TM 8339 A.C./D.C. Mixer Unit

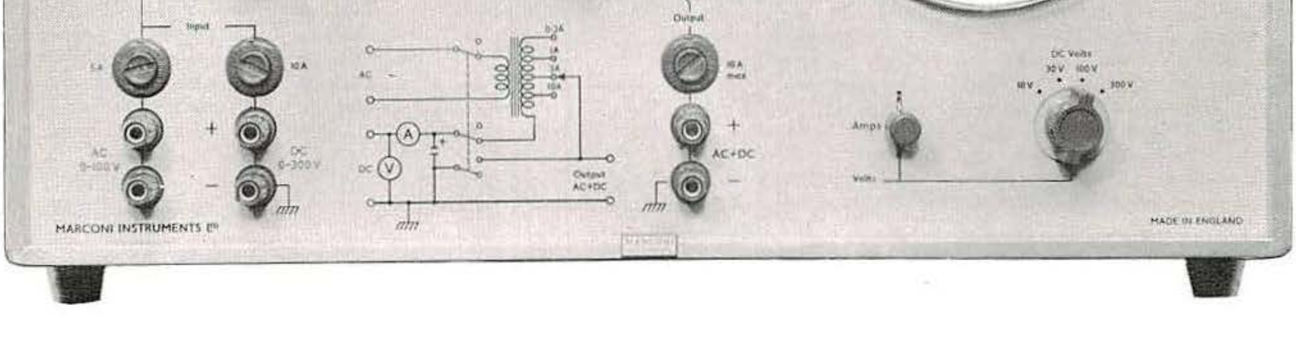
Functional diagram



AC/DC Mixer

- For use with Inductor Analyser TF 2702
- Up to 10 amps r.m.s. a.c. and d.c.
- D.C. voltage and current monitor
- Built in protection circuits

This is an auxiliary unit for use with Inductor Analyser TF 2702. It connects to the bridge circuit in place of the Analyser's built-in input transformer, and facilitates application of a.c. and d.c. currents up to the full rating of the bridge.



The mixer unit basically comprises a transformer capable of operating with a comparatively high d.c. current flowing in its secondary winding. The magnitude of the permissible current is given in the specification, and varies inversely with the maximum output voltage—determined by switch selection of the appropriate tap on the secondary winding.

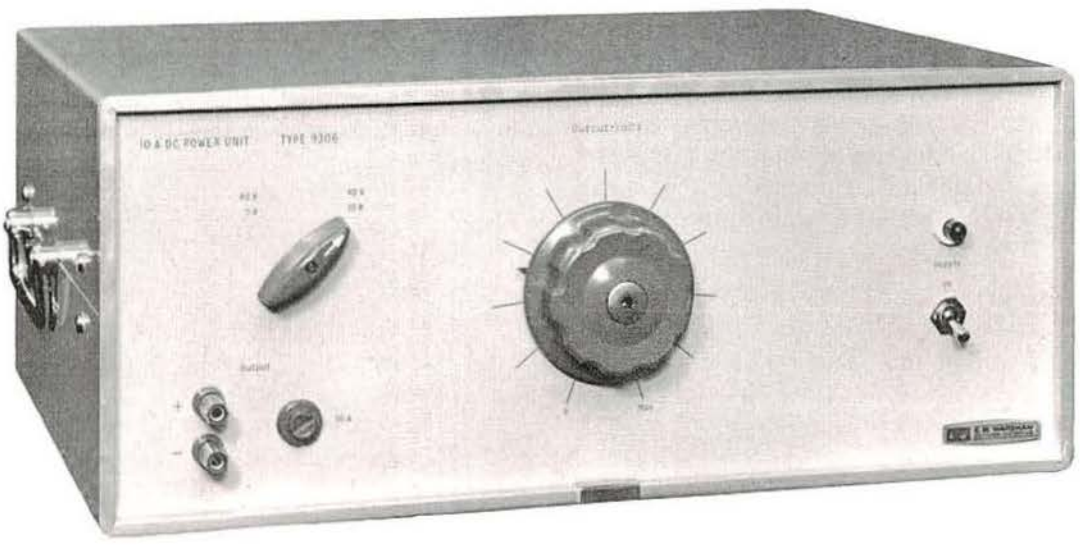
A panel meter can be switched to monitor the d.c. voltage or current. (The a.c. can be monitored by the TF 2702 panel meter.) The d.c. is applied to the bridge in series with the transformer winding, and it is introduced via a smoothing circuit in order to eliminate any unwanted ripple. This smoothing circuit also protects the bridge and the mixer unit from high voltage transients that could otherwise result from sudden interruption of the d.c. supply.

In the event of failure of the external d.c. supply, the high-value smoothing capacitor discharges through the circuit so that the current falls exponentially to zero, the time constant being sufficient to prevent a rapid collapse of flux in the internal transformer or in the in uctor being tested. Furthermore, it is a feature of the TM 3339 that its output can be switched off by means of the panel switch without the necessity for gradual reduction of the input supplies. Surge current, resulting from the disconnection, triggers an s.c.r., which provides a discharge path and prevents the build-up of high voltages between the switch contacts. As with the TF 2702, gas discharge tubes are also included to protect the instrument from transient overloads.

A.C.+D.C. OUTPUT	30 volts a.c. max with 10 amps d.c. max. 100 volts a.c. max with 3 amps d.c. max. 300 volts a.c. max with 1 amp d.c. max. 500 volts a.c. max with 300 mA d.c. max.
	The above outputs are obtained by varying the input voltage over the range 0-100 volts r.m.s. A 10 amp fuse protects the output circuit.
A.C. INPUT	Input terminals are isolated from chassis and earth. A 5 amp fuse provides protection.
Max. voltage	100 volts r.m.s., 40 to 5000 Hz, linearly derated from 100 volts at 40 Hz to 50 volts at 20 Hz, and from 100 volts at 5 kHz to 50 volts at 20 kHz.
D.C. INPUT	Negative terminal is earthed. A 10 amp fuse provides protection.
Max. voltage	±300 volts
Input load	Parallel combination of output terminal load (e.g., TF 2702 and test inductor), 3000 μF smoothing capacitor, voltmeter, and 100 kΩ discharge resistor.
MONITORING FACILITIES (d.c. only)	The panel meter normally indicates the current flowing. A 'press to read voltage' switch, biased to 'current' facilitates measurement of input voltage.
METER RANGES Current	10 amps f.s. (associated with 30 volts a.c. max.) 3 amps f.s. (associated with 100 volts a.c. max.) 1 amp f.s. (associated with 500 volts a.c. max.)
Voltage	300, 100, 30, and 10 volts f.s.
ACCURACY	±3% of reading ± 2% of full scale.
DIMENSIONS AND WEIGHT	Height 7¾ in 20 cm; Width 18¾ in 48 cm; Depth 13½ in 34 cm; Weight 72 lb 32.7 kg

Type 9306 10 Amp D.C. Power Unit

- ☐ For use with Inductor Analyser TF 2702
- ☐ Up to 10 amps d.c. at 40 volts
- ☐ Up to 5 amps d.c. at 80 volts



This unit, designed and produced for Marconi Instruments by E. M. Wareham (Measuring Systems) Ltd, is intended as a d.c. bias current source for Inductor Analyser TF 2702. Its mechanical and electrical construction is such that it forms a companion unit to the A.C./D.C. Mixer TM 8339; and it is available either as a free-standing bench unit or fitted for mounting into a standard 19 inch rack.

The unit will deliver a continuous output power of 300 watts, with a maximum intermittent rating of 400 watts. In order to achieve higher voltages without exceeding the rating, there are two switch-selected voltage ranges—0 to 80 volts at 5 amps, and 0 to 40 volts at 10 amps. The output level is adjustable by means of a single control which varies the setting of a built-in continuously variable transformer. No meters are fitted to the power unit, voltage and current normally being monitored on the A.C./D.C. Mixer, but an approximate voltage scale is provided for rough guidance as to the control setting.

OUTPUT	0 to 80 volts up to 5 amps. 0 to 40 volts up to 10 amps.
Power rating	300 watts continuous. 400 watts intermittent.
Ripple	Less than 2% p-to-p when working with 3000 μF capacitor across terminals or directly into A.C./D.C. Mixer TM 8339.

AMBIENT TEMPERATURE Operating	0 to +40° C.		
Storage	−40 to +70° C.		
POWER REQUIREMENTS A.C. mains	220 to 250 volts, 50 Hz or 100 to 115 volts, 60 Hz, changed by internal selector.		
DIMENSIONS	Height	Width	Depth
	7¾ in	18¾ in	13½ in
	20 cm	48 cm	34 cm

Remote Switching Unit Type 9287

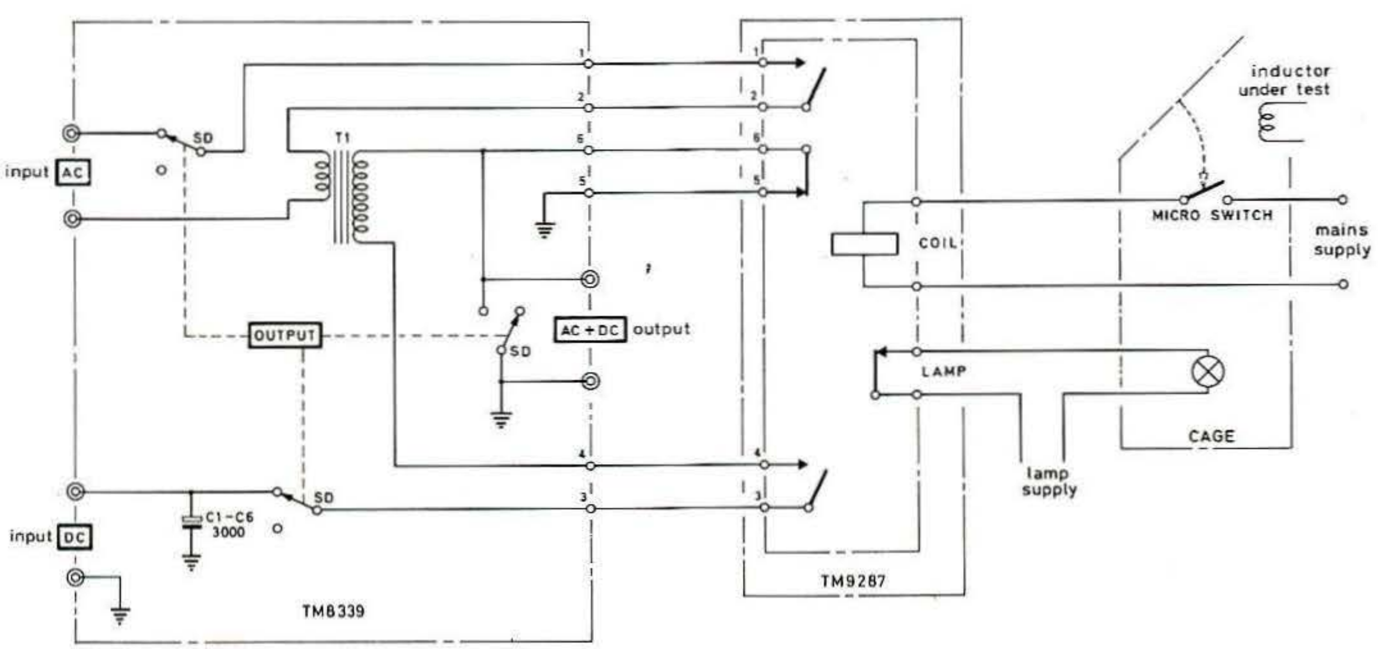
- ☐ Safety relay for TF 2702 and TM 8339
- ☐ Interrupts test current when control supply is broken

This unit, designed and produced for Marconi Instruments by B and R Relays Ltd., is intended as part of a safety circuit in inductor test assemblies utilising Inductor Analyser TF 2702 and AC/DC Mixer TM 8339.

It comprises an a.c. energised relay fitted with two sets of normally open and two sets of normally closed contacts. The relay coil is wound in two sections for use on 230 or 110 volt a.c. supplies.

The unit connects to the AC/DC Mixer in such a way that the test supplies to the Inductor Analyser are present only if the relay is energised and the OUTPUT switch of the TM 8339 is in the ON position. In any other condition the a.c. and d.c. supply circuits are disconnected and the output terminals of the Mixer Unit are short circuited.

An auxiliary contact on the relay is intended to operate a fail safe warning lamp, which lights only when the relay is de-energised so that the supplies have been removed. Alternatively, the contact may be used to operate a mechanical interlock preventing the safety cage door opening while the relay is energised.



Type D 347 XO·1 Range Multiplier Unit

□ Extends TF 2702 current rating to 70 amps continuous or 100 amps intermittent

Manufactured for Marconi Instruments by E.M. Wareham (Measuring Instruments) Ltd.

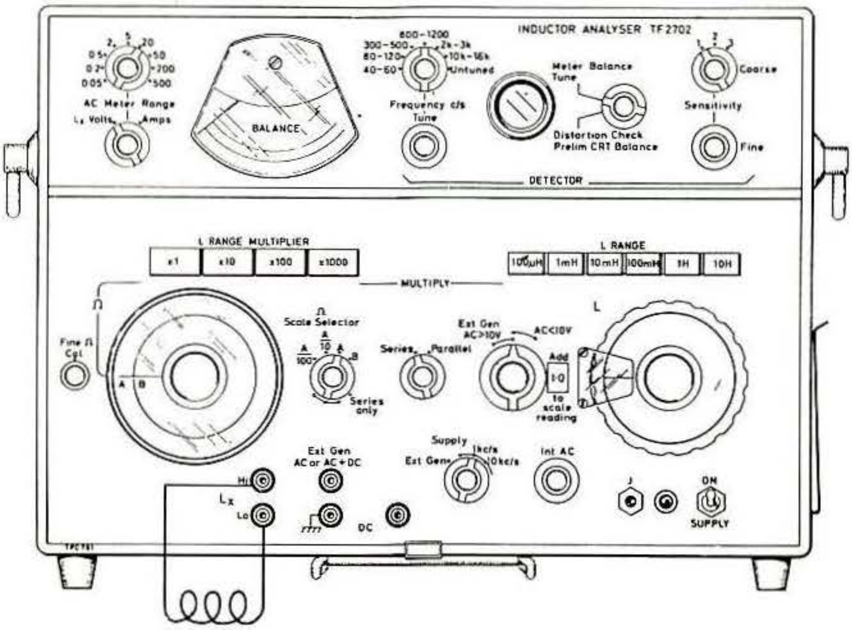
The unit comprises an accurate 0·1 Ω heavy current resistor, which is connected in parallel with the appropriate resistive bridge arm to increase the bridge's current rating to 70 amps for protracted measurements or 100 amps for short periods—10 to 15 minutes.

A four-terminal connecting arrangement obviates errors due to lead resistance; and the shunting effect of the built-in bridge arm resistance is rendered negligible by operating the X1000 RANGE MULTIPLIER button on the TF 2702 panel when the external multiplier is in use. The X1000 multiplication factor is, of course, ignored and a factor of 0·1 used instead, giving an inductance measuring range of 0·3 μH to 2·1 henries.

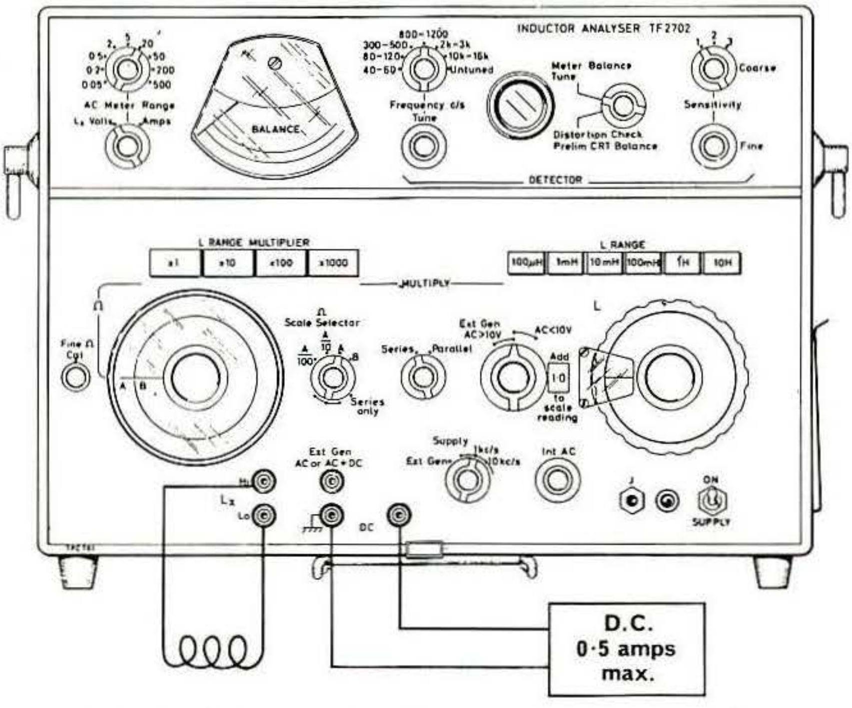
The additional inductance and resistance measuring error introduced by the D347 is less than 1% over the frequency range 20 Hz to 3·5 kHz.

RESISTANCE	0·1 Ω ±0·25%.
RATING	
Maximum continuous current	70 amps r.m.s. ($\sqrt{a.c.^2+d.c.^2}$)
Maximum intermittent current	100 amps r.m.s. for 10 to 15 minute period.

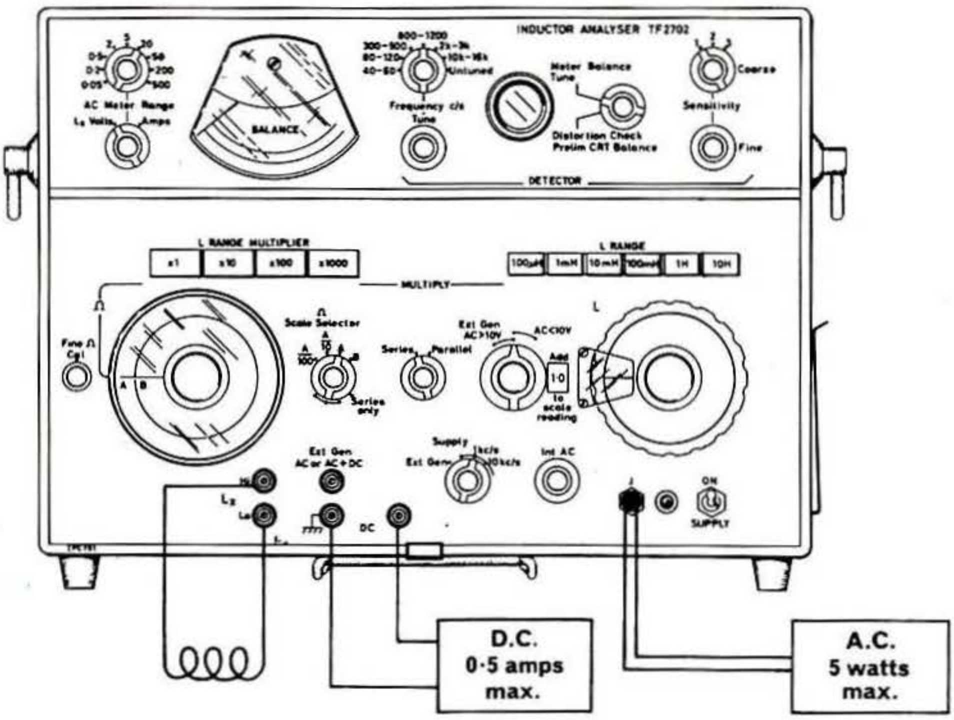
Arrangements of a.c. excitation and d.c. bias supplies



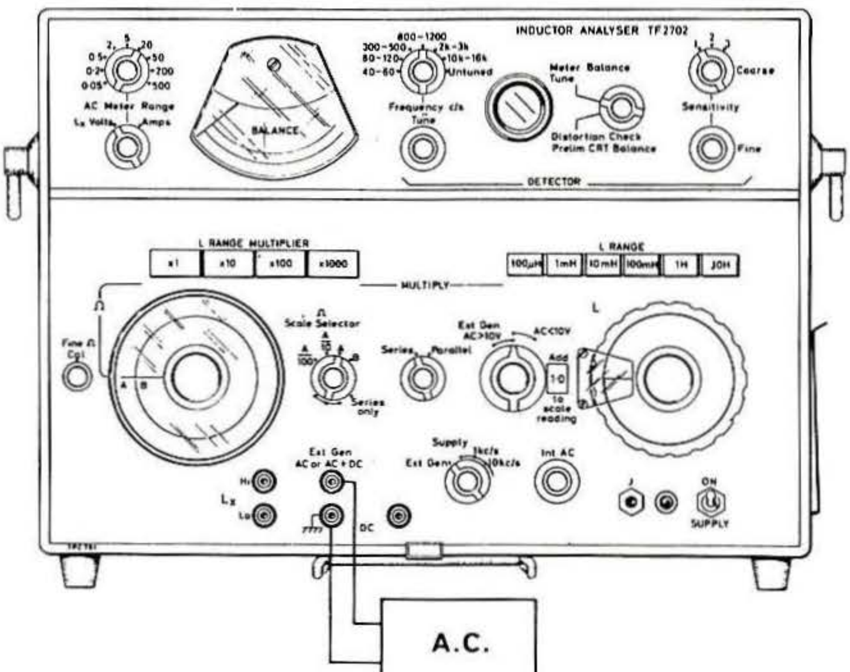
As a self-contained instrument, using internal a.c. excitation, the TF 2702 is suitable for measurements at low test currents (a.c. only) with voltages up to 10 volts at 1 kHz and 10 kHz, and up to 20 volts at the mains supply frequency.



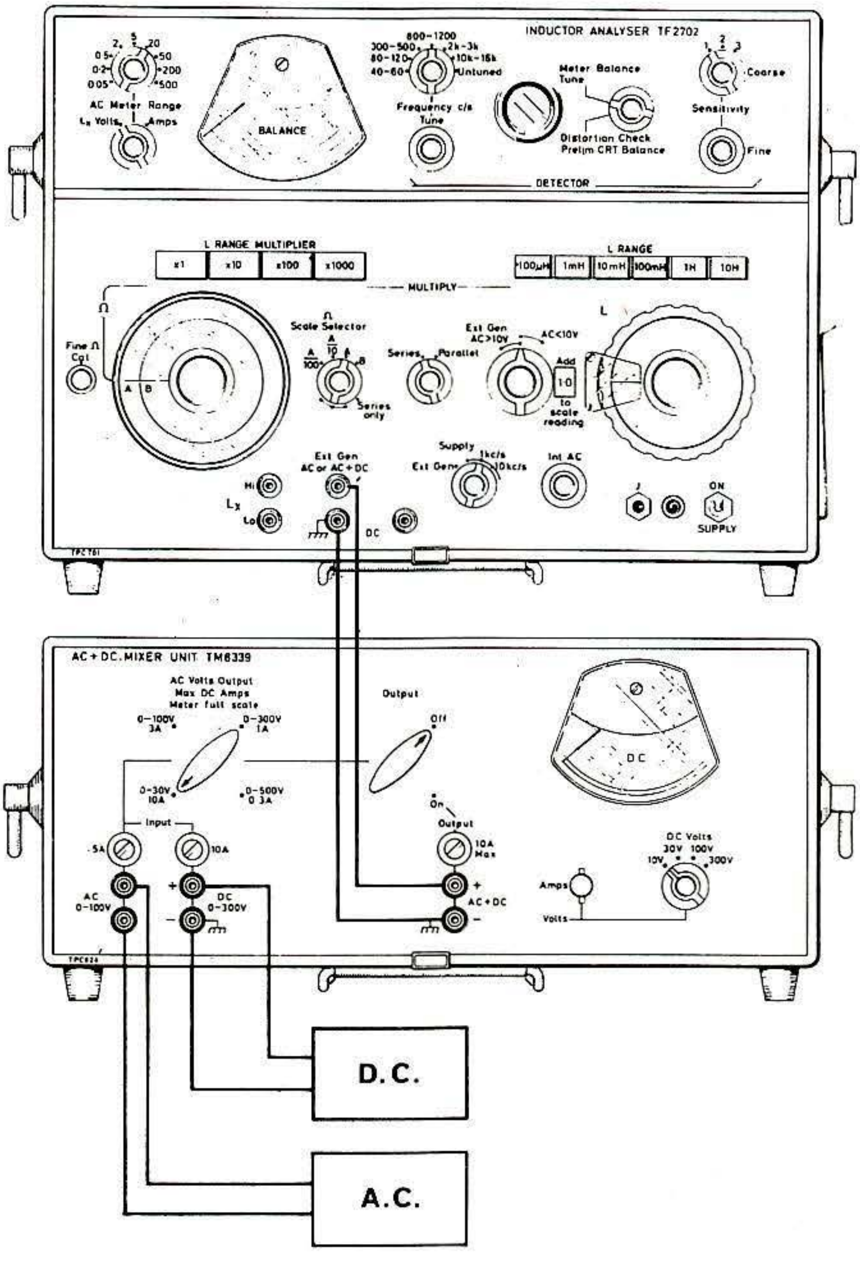
External d.c. bias, up to a maximum of 0·5 amps, can be applied directly to the panel terminals when the instrument is used with its internal a.c. source.



External a.c. up to 5 watts can be applied via the jack socket on the front panel. In this condition the internal mixing transformer is used so that d.c. bias up to 0·5 amps can also be applied.



External a.c. up to the full rating of the bridge can be applied to the panel terminals. In this arrangement the internal mixing transformer is switched out of circuit, and d.c. bias cannot be applied.



External a.c. and d.c. up to the full rating of the bridge can be applied via Mixer Unit TM 8339.

SUPPLY UNITS

Low-Level A.C.: A.F. Oscillator TF 2102M or R.C. Oscillator TF 1101.

D.C. (up to 10 amps): D.C. Supply Unit Type 9306.

High-Level A.C. (recommended examples)

Mains Supply Frequency: Variac, 0-100 volts r.m.s. output.

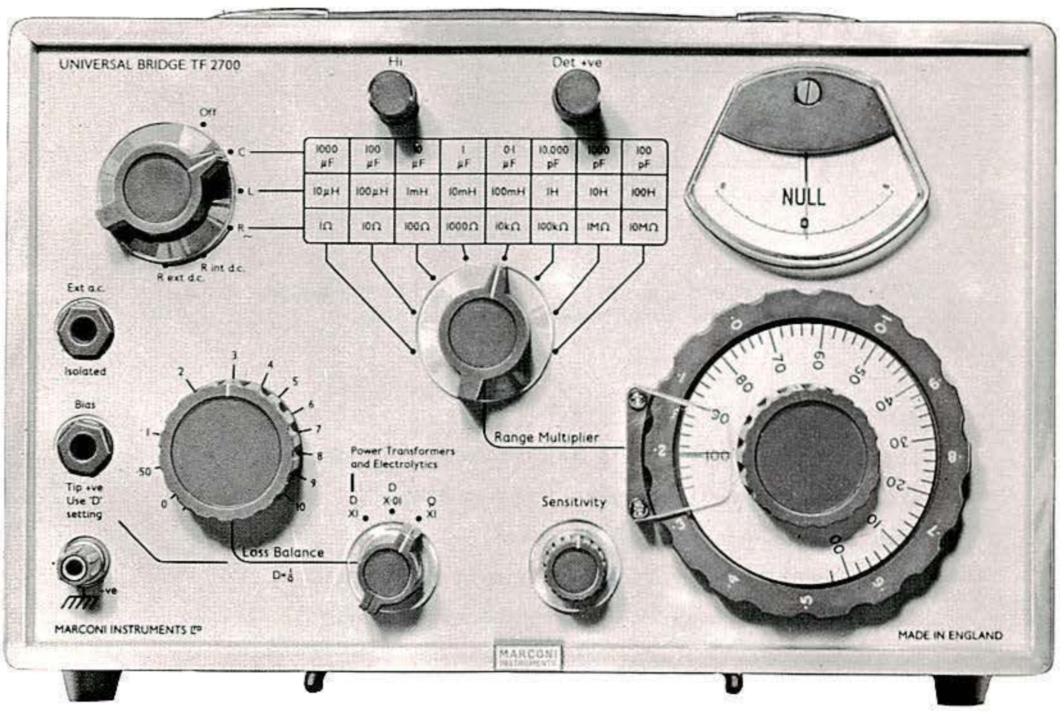
Variable Frequency: A.F. Oscillator+Amplifier such as Vortexian Model S120/200.

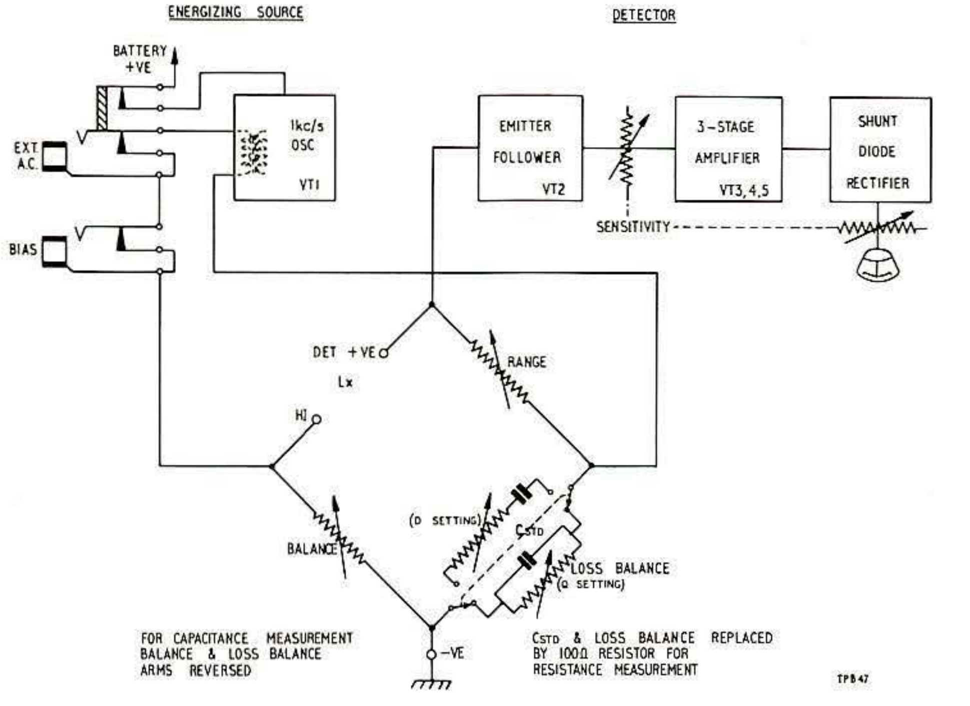
Universal Bridge

- Transistorised oscillator/detector
- Battery operation
- Remarkable versatility

Although this bridge uses the conventional bridge configurations, provision has been made for the connection of a large number of external facilities, so that a wide-range general-purpose instrument can be rapidly converted for a specialised measurement, without need of modification or special accessories.

The internal battery-powered transistor oscillator provides a bridge source for measurements of L, C, and R at 1 kHz, or an external source can be used between 20 Hz and 20 kHz. The internal aperiodic detector also uses battery-powered transistors, and may be used with both the internal and external bridge drive; an external detector can be used instead with either source. Resistance can also be measured with d.c. using the internal battery and galvanometer, or with either replaced by external equivalents. Finally, mixed a.c. and d.c. can be applied to the bridge when measuring components that require polarisation, or for the determination of incremental properties.





Functional Diagram for A.C. Measurements

MEASUREMENT RANGES	0·1 μH to 110 henries, and 0·5 pF to 1,100 μF, each in eight decades, with phase defect value, at 1 kHz from internal source, or 20 Hz to 20 kHz from external source; and 0·01 Ω to 11 MΩ in eight decades, at d.c. or 1 kHz from internal sources, or at d.c. or 20 Hz to 20 kHz from external sources, as detailed below.
INDUCTANCE MEASUREMENT	
Ranges	Maxima 11–110 μH, 1·1–11–110 mH, and 1·1–11–110 henries. *Accuracy at 1 kHz:* ±1% of reading ±0·1% of range maximum above 11 μH. ±2% of reading ±0·1% of range maximum below 11 μH. *Residual Correction:* —0·2% of reading +0–0·3 μH.
Q	*At 1 kHz:* 0 to 10.
CAPACITANCE MEASUREMENT	
Ranges	Maxima 110 pF, and 0·0011–0·011–0·11–1·1–11–110–1,100 μF. *Accuracy at 1 kHz:* ±1% of reading ±0·1% of range maximum below 110 μF. ±2% of reading ±0·1% of range maximum above 110 μF. *Residual:* 0·2 pF.
D	*At 1 kHz:* Two ranges, 0 to 0·1 and 0 to 10.

RESISTANCE MEASUREMENT	
Ranges	Maxima 1·1–11–110 Ω, 1·1–11–110 kΩ, and 1·1–11 MΩ. *Accuracy:* ±1% of reading ±0·1% of range maximum above 1·1 Ω. ±2% of reading ±0·1% of range maximum below 1·1 Ω. *Residual:* 0·002 Ω.
BRIDGE SOURCES	
A.C.	1 kHz (±5%) from internal oscillator, or 20 Hz to 20 kHz from external source, for L, C or R measurement.
D.C.	9 volts from internal battery, or external supply for greater discrimination.
POWER REQUIREMENTS	Internal 9 volt battery (consumption approx. 7 mA).
DIMENSIONS	

Height	Width	Depth	Weight
8 in	$11\frac{1}{2}$ in	8 in	$8\frac{1}{2}$ lb
23·5 cm	29 cm	23·5 cm	3·8 kg

ACCESSORIES	
Supplied	Jack Plugs, type P 40 (Two).
Optional	TM 7120 Isolating Transformer.

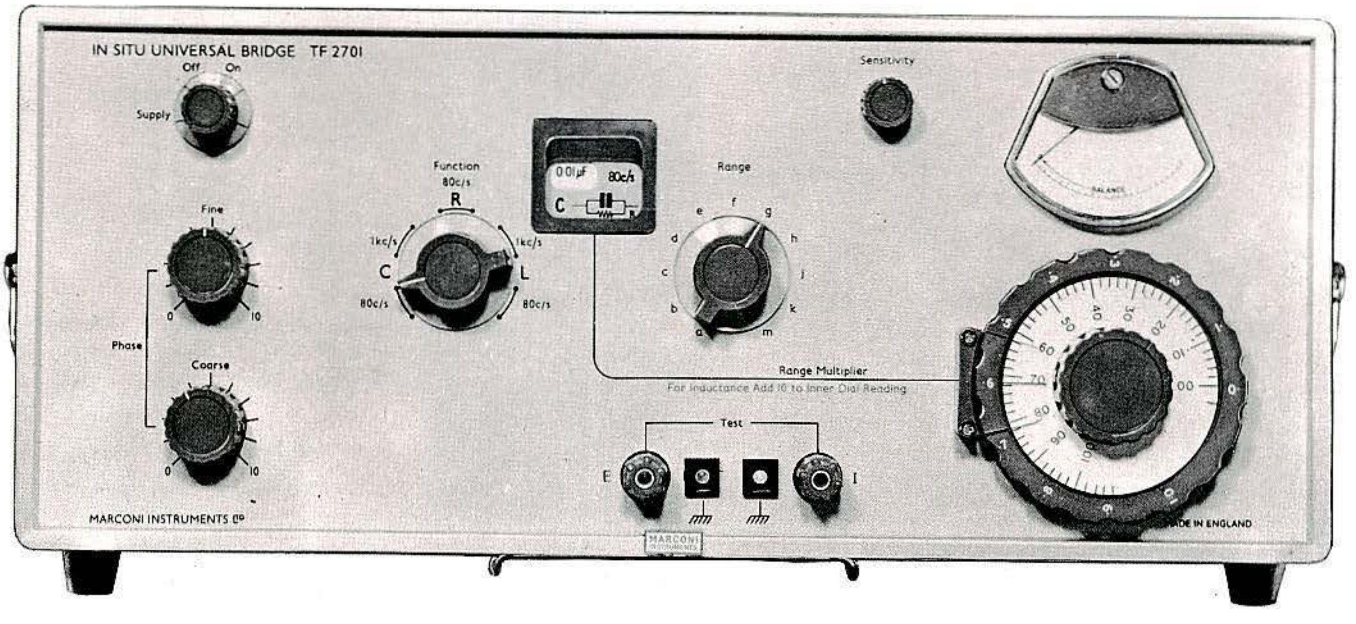
In Situ Universal Bridge

- Transformer ratio-arm technique
- Two and three terminal measurements
- Battery operated

By the use of a transformer ratio-arm design, Marconi Instruments have produced a bridge which measures components in conditions that are beyond the scope of most conventional universal bridges. The measurements may be made in the presence of heavy shunting, whether in two- or in three-terminal connections. These factors, together with the independence of true earth granted by battery operation, also adapt it to the measurement of components already wired into circuits or equipment without the necessity for unsoldering connections—a particular advantage when printed wiring boards are concerned.

Semi-conductor devices are used in both the oscillator and in the detector, so that long-life battery operation is obtained.

A pictorial display of the equivalent circuit of the unknown, and colour identification of frequency, are coupled mechanically to the range switches, so that ambiguity of reading is removed. The ease of operation, and the portability recommend this bridge for uses when the highest accuracies are not required or are less important than the undoubted conveniences.



NORMAL CAPACITANCE MEASUREMENTS

At 1 kHz — *Eleven ranges:* Maxima of 1·1–11–110 pF, 1·1–11–110 nF, and 1·1–11–110–1,100–11,000 µF.

At 80 Hz — *Ten ranges:* Maxima of 11–110 pF, 1·1–11–110 nF, and 1·1–11–110–1,100–11,000 µF.

Accuracy on 11 µF range and below — *At 1 kHz:* ±1% of reading; *At 80 Hz:* ±1·5% of reading; ±0·1% of range $\pm\frac{2}{Q}\%$

Accuracy on 110 µF range and above — ±5% of reading ±0·1% of range $\pm\frac{2}{Q}\%$

Dissipation factor — Obtainable from calibration curves.

SHUNTED CAPACITANCE MEASUREMENTS

Ranges — As NORMAL at 1 kHz and at 80 Hz.

Permissible shunt resistance (in ohms) — Greater than $\frac{10}{C \text{ range in } \mu F}$

Accuracy — As NORMAL, but with additional error which varies inversely with shunting resistance and is within ±3% of range when the R value is greater than 100Ω and the RC value is greater than 10^{-5}.

NORMAL RESISTANCE MEASUREMENTS

At 80 Hz only — *Nine ranges:* Maxima of 1·1–11–110 Ω, 1·1–11–110 kΩ, and 1·1–11–110 MΩ.

Accuracy (after deduction of $R_o \simeq 0{\cdot}03\,\Omega$) — *110 Ω range and above:* ±1% of reading; 1·1 and 11 Ω ranges: ±2% of reading; ±0·1% of range.

SHUNTED RESISTANCE MEASUREMENTS

Ranges — As NORMAL at 80 Hz only.

Permissible shunt capacitance (in microfarads) — Less than $\frac{5\times10^{4}}{R \text{ range in ohms}}$

Accuracy — (After deduction of $R_o \simeq 0{\cdot}03\ \Omega$, and subject to an additional negative error depending on the value and loss of the shunting capacitance.) *110 Ω range and above:* ±1·5% of reading; *1·1 and 11 Ω ranges:* ±2·5% of reading; ±0·1% of range.

INDUCTANCE MEASUREMENTS

At 1 kHz — *Nine ranges:* Maxima of 110 µH, 1·1–11–110 mH, 1·1–11–110 H, and 1·1–11 kH.

At 80 Hz — *Nine ranges:* Maxima of 1·1–11–110 mH, 1·1–11–110 H, and 1·1–11–110 kH.

Cursor position adjustment — A correction of 10 is added to the FINE dial reading.

Accuracy on 11 mH to 110 H range — ±2% of reading ±0·1% of range $\pm\frac{2}{Q}\%$.

Accuracy on 1·1 mH ranges — *At 1 kHz:* ±2% of reading; *at 80 Hz:* ±3% of reading ±1 µH: ±0·1% of range $\pm\frac{2}{Q}\%$.

Accuracy on 110 µH range — ±3% of reading ±1 µH ±0·1% of range $\pm\frac{2}{Q}\%$.

Accuracy on 1·1 kH ranges and above — ±5% of reading ±0·1% of range $\pm\frac{2}{Q}\%$.

Q Factor — Obtainable from calibration curves.

Three-terminal measurements — The additional error is approximately ±2%, providing the two shunting arms are within the limits shown in the table.

BRIDGE SOURCE

Frequencies — 80 Hz and 1 kHz, each ±3%.

Test terminal power — Approximately 50 mW.

Power requirement — Two 9 volt batteries.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
8 in	17 in	11 in	16 lb
20·5 cm	44 cm	28 cm	7 kg

ACCESSORIES

Supplied

TM 7137 — Lead Assembly.

THREE-TERMINAL MEASUREMENTS—SHUNTING IMPEDANCE LIMITS

Range	Range Maxima				Minimum Shunt R		Maximum Shunt C	
	R at 80 Hz	*C at 80 Hz & 1 kHz*	*L at 80 Hz*	*L at 1 kHz*	*E-terminal*	*I-terminal*	*E-terminal*	*I-terminal*
a	—	11,000 µF	—	—	2 Ω	2·5 Ω	100 µF	100 µF
b	1·1 Ω	1,100 µF	1·1 mH	110 µH	2 Ω	2·5 Ω	100 µF	100 µF
c	11 Ω	110 µF	11 mH	1·1 mH	2 Ω	5 Ω	100 µF	10 µF
d	110 Ω	11 µF	110 mH	11 mH	10 Ω	2·5 Ω	100 µF	100 µF
e	1·1 kΩ	1·1 µF	1·1 H	110 mH	10 Ω	5 Ω	100 µF	10 µF
f	11 kΩ	0·11 µF	11 H	1·1 H	20 Ω	5 Ω	10 µF	10 µF
g	110 kΩ	0·011 µF	110 H	11 H	20 Ω	120 Ω	10 µF	1 µF
h	1·1 MΩ	1,100 pF	1·1 kH	110 H	120 Ω	120 Ω	1 µF	1 µF
j	11 MΩ	110 pF	11 kH	1·1 kH	120 Ω	2,500 Ω	1 µF	0·1 µF
k	110 MΩ	11 pF	110 kH	11 kH	2,500 Ω	2,500 Ω	0·1 µF	0·1 µF
m	—	1·1 pF	—	—	2,500 Ω	2,500 Ω	0·1 µF	0·1 µF

0.1% Universal Bridge

- ☐ Measures L: 0.1 μH to 110 henries at 1 and 10 kHz
- ☐ Measures C: 0.1 pF to 110 μF at 1 and 10 kHz
- ☐ Measures R: .003Ω, to 110 MΩ, at d.c.
- ☐ 0.1% accuracy
- ☐ Discrimination: 0.01% of full-scale

The TF 1313A is a wide-range general-purpose impedance bridge with a measurement accuracy of 0·1%.

At balance, the Inductance, Capacitance, or Resistance value is read from the concentric dials of the coarse and fine main balance controls. The coarse control is, in fact, a 110-position switch; and its associated dial is directly calibrated, with the units and numerical markings appearing in shuttered windows coupled to the function and range selector switches to avoid any possibility of confusion. The continuously variable fine control also has a directly calibrated dial – the reading being added to that of the coarse control – and it permits accurate interpolation between the switched steps to an ultimate reading discrimination of 0·01% of full-scale.

Comprehensive phase balance arrangements permit measurement of all a.c. impedances within the range of the instrument in either the series loss or parallel loss configuration at 1 kHz or above. Most of the cases met in practice can be measured in the appropriate configuration at lower frequencies; but, in order to permit measurement in those comparatively rare instances where the loss factor of the impedance is outside the range of the balance controls, the facility is provided for connecting an external variable resistor to panel terminals.

Provision is also made for the injection of a d.c. polarising voltage for use when testing electrolytic capacitors. Incremental inductance measurement can be made by the use of the D.C. Choke Adaptor TM 6113 connected externally.

The out-of-balance voltage is indicated by an a.c. amplifier detector, which has adequate sensitivity over the whole of the measurement range. When the bridge is d.c. energised for resistance measurement, the amplifier is preceded by a photo-electric chopper to convert the d.c. out-of-balance voltage to an a.c. signal. The internal a.c. excitation source can be switched to operate at either 1 kHz or 10 kHz, the amplifier detector being switch tuned to the appropriate frequency in order to avoid errors due to distortion or to non-linearity in the impedance under test.

For measurement at frequencies other than 1 or 10 kHz, an external source may be connected via a telephone jack on the front panel; inserting the plug into this jack automatically stops the internal oscillator.

The output from the detector amplifier is available at a second jack socket on the front panel. This is useful when it is desirable to connect the bridge to a special form of balance indicator such as an oscilloscope or selective voltmeter for use at frequencies other than 1 or 10 kHz. Insertion of the plug into the jack disconnects the filters from the amplifier but leaves the meter in circuit, permitting the use of the internal detector, in an untuned condition, when an external oscillator is used.

RESISTANCE MEASUREMENT	
Range	·003Ω to 110 MΩ in eight ranges with maxima of 11Ω to 110 MΩ in decade steps.
Accuracy	Basic measurement error: Less than ±0·1% of reading, or ±0·015% of range maximum, whichever is greater. Range errors: 110 Ω to 1·1 MΩ ranges, inclusive – basic errors only. 11 Ω and 11 MΩ ranges – basic errors, and additional ±0·1% of reading. 11 MΩ×10 range – basic errors, and additional ±0·15% of reading.
Residual resistance	Less than 0·003 Ω.
INDUCTANCE MEASUREMENT	
Range	0·1 μH to 110 henries in seven ranges with maxima of 110 μH to 110 henries in decade steps.
Accuracy	Basic measurement error at 1 kHz: Less than ±0·1% of reading, or ±0·015% of range maximum, whichever is greater. Basic measurement error at 10 kHz: Less than ±0·2% of reading, or ±0·025% of range maximum, whichever is greater. Range errors: 1·1 mH to 11 henry ranges inclusive – basic errors only. 110 μH and 110 henry ranges – basic errors, and additional ±0·1% of reading. Additional errors at low Q: $\pm(0{\cdot}1\times\frac{f}{Q})$%, where f is in kHz.
Residual inductance	Less than 0·05 μH.
CAPACITANCE MEASUREMENT	
Range	0·1 pF to 110 μF in seven ranges, with maxima of 110 pF to 110 μF in decade steps.
Accuracy (when D is not greater than 0·031)	Basic measurement error at 1 kHz: Less than ±0·1% of reading, or ±0·015% of range maximum, whichever is greater. Basic measurement error at 10 kHz: Less than ±0·2% of reading, or 0·025% of range maximum, whichever is greater. Range errors: 0·0011 to 11 μF ranges inclusive – basic errors only. 110 pF and 110 μF ranges – basic errors, and additional ±0·1% of reading.
Residual capacitance	Less than 0·05 pF.
TEMPERATURE RANGE	
Temperature coefficient	18°C to 28°C for the stated accuracies. Additional error of ±0·01% per degree C, for temperatures between 10°C and 18°C, 28°C and 35°C.
Q AND D MEASUREMENT	
Range	1 kHz / 10 kHz Low Q: 0 to 3 / 0 to 30 Normal Q: 0·5 to 31 / 5 to 310 Normal D: ·0005 to ·031 / ·005 to ·031 High D: ·005 to 3 / Not required
Accuracy	Normal Q: ±5% of reading, ±0·5% of full-scale. Normal D: ±5% of reading. Low Q and High D: ±10% of reading, ±3% of full-scale. Additional D or $\frac{1}{Q}$ error below 1 kHz Less than ±·0005 with correction supplied or less than ±·0015 without correction. (Above 1 kHz multiply by f kHz.)
BRIDGE SOURCES AND DETECTOR	
Internal sources	1 kHz and 10 kHz oscillators for L and C measurement, accuracy ±2·5%; output level, depending on loading, up to 750 mV. D.C. supply for R measurement: Less than 100 mW component loading.
External oscillators	Frequency range: 20 Hz to 35 kHz. Input level required: 3 to 20 volts depending on frequency. (An external tuned detector is also necessary to achieve the quoted measurement accuracies.)
Additional L and C errors	Typically: Frequency / % error 20 Hz / ±·05 100 Hz / ±·03 20 kHz / ±0·2 35 kHz / ±0·35
CAPACITOR BIAS	Up to 350 volts d.c. may be applied for polarising electrolytic capacitors.
POWER REQUIREMENTS	
A.C. mains	100 to 130 volts and 200 to 250 volts, 45 to 180, 275 to 300, 366 to 400 Hz, 25 VA.
DIMENSIONS AND WEIGHT	Height 11½ in. (30 cm); Width 19½ in. (50 cm); Depth 10 in. (26 cm); Weight 29 lb. (13·2 kg)
ACCESSORIES	
Supplied	Three telephone plugs, type P40, for external oscillator and detector and bias jacks.
Optional	**TM 6113 D.C. CHOKE ADAPTOR** Enables d.c. currents up to 200 mA from an external supply to be passed through inductors under test at 1 kHz in the range 100 mH to 100 henries; fitted with test leads for attaching to bridge terminals. Errors introduced by the adaptor do not generally exceed 3% and may be eliminated by simple substitution methods.

Circuit Magnification Meter

The symbol Q and the term Circuit Magnification are generally taken to be synonymous; but technical usage has produced a second—more common—meaning for Q, which is sufficiently different from magnification to cause ambiguity in certain circumstances.

Magnification is a term really applicable only to series tuned circuits at resonance, where Q is equal to the ratio of the voltage developed across either reactance to the applied e.m.f.; i.e., V/E in Fig. 1. The current in the circuit at resonance is equal to E/R_T, where R_T is the *total* effective series resistance in the circuit. At resonance the inductive and capacitive reactances are, of course, equal, and we can write

$$V = X.E/R_T, \text{ so that } V/E = X/R_T = Q.$$

But in this context R_T is the total effective series resistance in the circuit, as distinct from the loss resistance of either of the reactive elements.

Taking the point that in practical tuned circuits most of the loss is in the inductor, it has become customary to specify the loss in inductors in terms of Q, on the assumption that the associated capacitor is virtually loss free; and the philosophy is then extended to regard Q as a general statement of X/R for any reactive component, either capacitive or inductive.

It is, however, often more convenient to use the reciprocal term, D or dissipation factor, which is equal to R/X. For low loss components, this is numerically nearly equal to the power factor or ratio of true power to VA. Power factor may be represented by the cosine of phase angle ϕ between the voltage and current vectors. In other words, $\cos\phi$ is the ratio between resistance and impedance —as distinct from reactance (see Fig. 2). The dissipation factor, D, is equal to the tangent of the complementary angle, δ, and the expression $\tan\delta$ is frequently used as an alternative to the symbol D.

Circuit Q

Expressed as X/R_T, Q is the magnification of a series resonant circuit, but, in practical selective amplifiers, etc., parallel tuned circuits are probably more common. With these, the term magnification has very little meaning, and the significance of the circuit Q is in its relevance to dynamic resistance and bandwidth.

If resonance of a parallel circuit is defined as the frequency at which the circuit becomes purely resistive, the dynamic resistance is equal to the parallel combination of the effective shunt loss resistances of the reactive circuit elements—R_p in Fig. 3. If R_p is then regarded wholly as the shunt loss in either element, $D = \tan\delta = X/R_p$, and hence, $Q = R_p/X$.

The dynamic resistance is thus equal to ωLQ or $Q/\omega C$ For Q values above 10, the dynamic resistance is very nearly equal to L/CR_s, where R_s is the effective series resistance, but it must be remembered that this expression is an approximation, which is not valid for very low Q values.

The $-$ 3dB bandwidth of a series tuned circuit is taken as the interval between the two frequences (f_1 and f_2) either side of resonance where the voltage (V_b) across either reactance is equal to $\frac{1}{\sqrt{2}}$ of the voltage (V_r) at resonance. If $\Delta f = f_1 - f_2$, $Q = f_o/\Delta f$, where f_o is the resonance frequency. The same expression is applicable to a parallel circuit when f_1 and f_2 are defined as the frequencies at which the dynamic impedance of the circuit falls to $\frac{1}{\sqrt{2}}$ times the dynamic resistance at resonance. When a parallel tuned circuit is fed from a constant current source (e.g., a transistor or pentode) the voltage across it is directly proportional to the dynamic impedance, so that the symbols V_r and V_b can be applied to both series and parallel networks.

The general expression for bandwidth at any voltage ratio can then be written as

$$Q = \frac{f_o}{\Delta f}\left(\frac{V_r^2}{V_b^2} - 1\right)^{\frac{1}{2}}$$

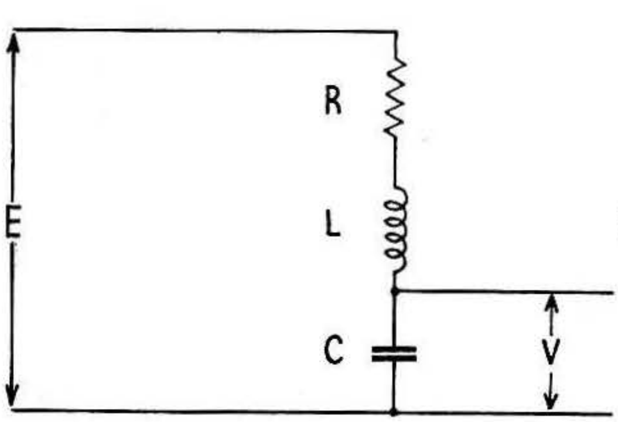


Fig. 1

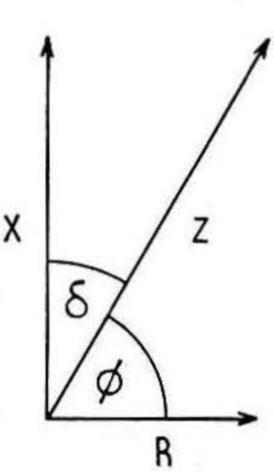


Fig. 2

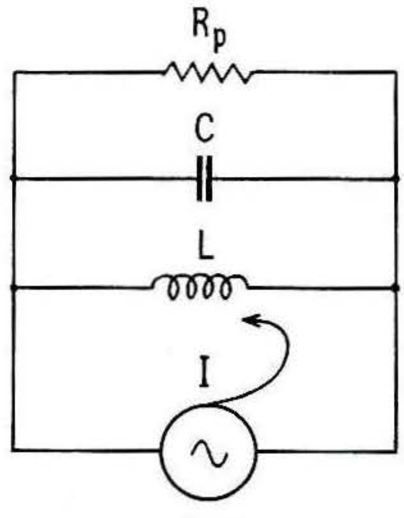


Fig. 3

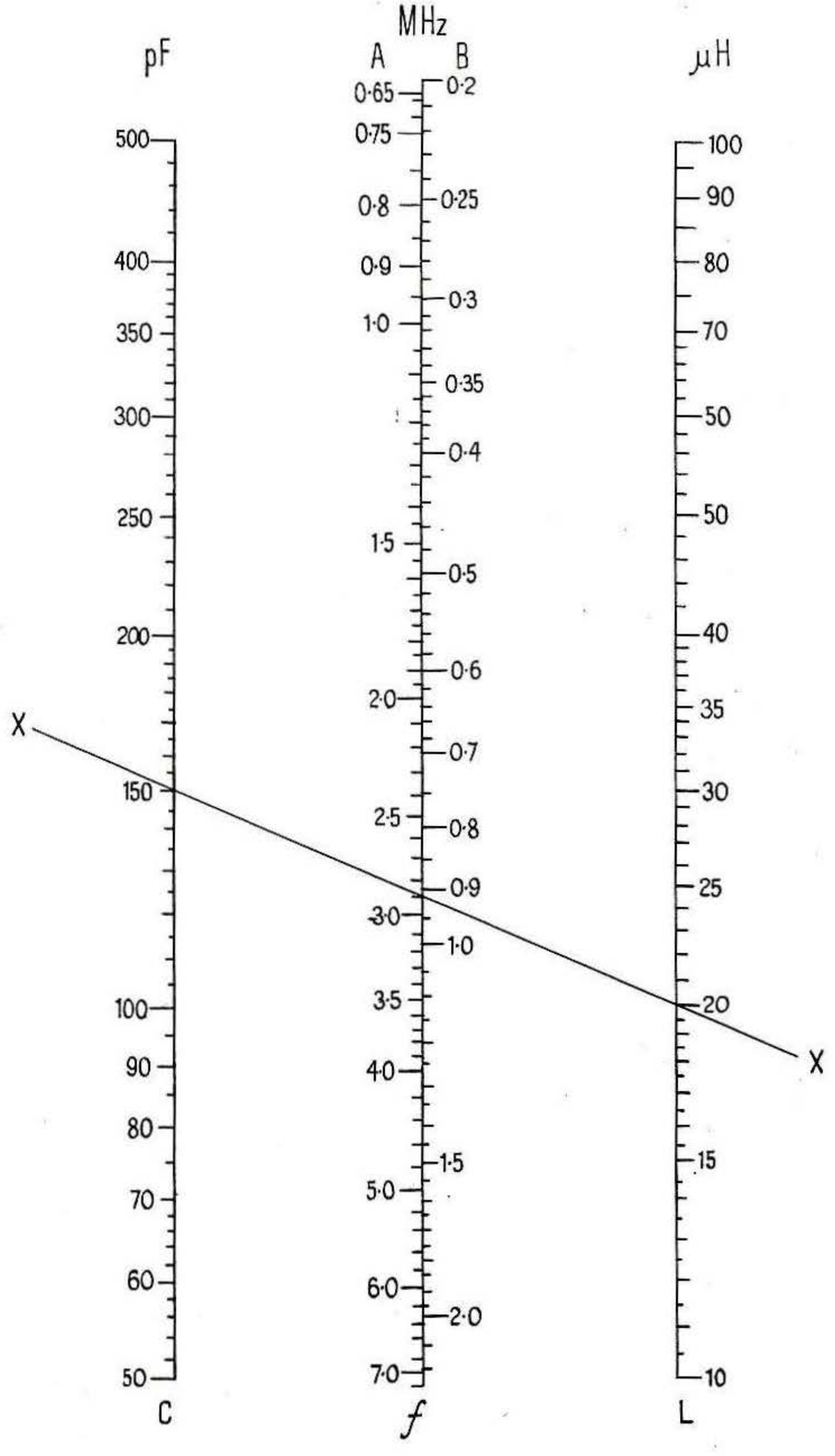
Resonance Frequency Chart

This abac gives the resonance frequencies of series tuned circuits over the capacitance range of the Circuit Magnification Meter TF 1245A, and the inductance range 10 μH to 100 μH. Within this range the frequency is read directly on scale A. The capacitance or inductance range can be extended in decades in either direction by multiplying by the appropriate power of ten; i.e., 10^n. The frequency must then be multiplied by $10^{-n/2}$, and to avoid unnecessary calculation scale B indicates the frequencies of scale A multiplied by $10^{-1/2}$.

If the capacitance is equal to the scale reading multiplied by 10^{n_c} and the inductance is equal to the scale reading multiplied by 10^{n_L}, $n=n_C+n_L$.

Example: C=150 pF, L=20 μH; line X–X gives frequency on scale A as 2·9 MHz.

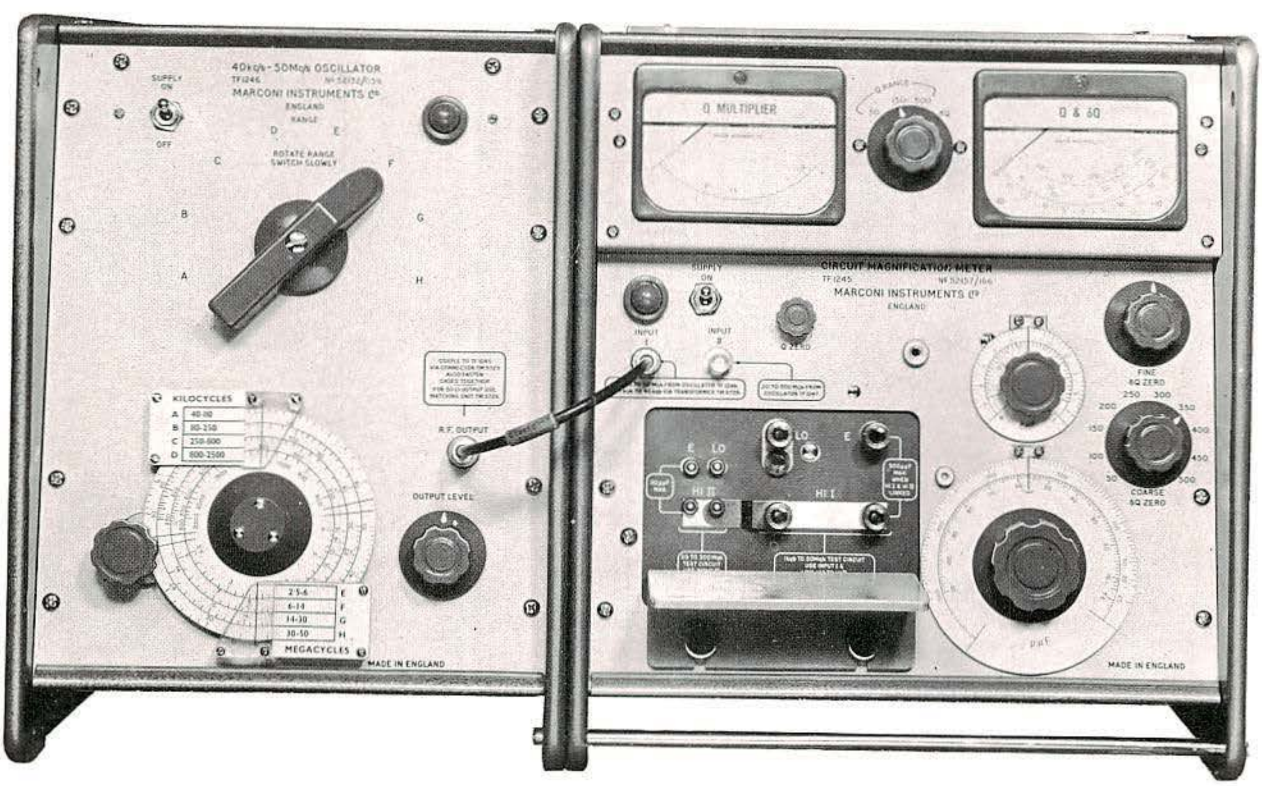
But if C=150 pF, L=200 μH (20×10), frequency is read from scale B as 0·92 MHz.



Circuit Magnification Meter

with Oscillators, types TF 1246 and TF 1247

- Frequency range: 1 kHz to 300 MHz
- Very low residual loss
- Capacitance range: 7.5 to 500 pF
- Measures Q from 5 to 1,000
- Delta-Q and Q multiplier facilities
- External oscillators, customer selected



Q Meter and TF 1246 Oscillator

TF 1245A is a wide range Circuit Magnification Meter suitable for direct measurement of Q values from 5 to 1000 at any frequency between 1 kHz and 300 MHz. It utilises the well known series-resonance method of measurement; and the constant very low loss of its test circuit is an important feature, particularly at high frequencies, where difficulty is experienced with some Q meters due to variations in a significant residual shunt loss.

The TF 1245A gives accurate and repeatable indication of Q up to 1000 at all frequencies within its range regardless of the dynamic impedance of its resonant circuit.

External oscillators

The Q-indicator and test-circuit section is a separate unit energised by one of two specially designed external oscillator units TF 1246 and TF 1247: these have ranges of 40 kHz to 50 MHz and 20 to 300 MHz respectively, and one or both can be supplied as required. Below 40 kHz an l.f. oscillator such as the Marconi TF 1101 may be used.

This flexible arrangement means economy for the customer, whether the initial requirement is for wide-band or restricted coverage; it also allows for the addition of extra units at a later date.

Matching units are available to allow the oscillators to be used as general-purpose signal sources.

Test circuits

TF 1245A incorporates two separate low-loss test circuits to ensure optimum operating conditions over the complete 1 kHz to 300 MHz range. Both are of the conventional series-resonant type, in which Q is measured in terms of the voltage developed across the tuned-circuit capacitance. The l.f. test circuit uses 0·02 Ω resistive injection and operates in the range 1 kHz to 50 MHz; whereas the h.f. test circuit, range 20 to 300 MHz employs 0·1 nH inductive injection.

All surfaces of r.f. conductors in the test circuits are gold plated to avoid the formation of resistive oxides, which would otherwise cause deterioration of the very low residual loss.

The test circuits are coupled to separate panel inlets to which the appropriate oscillator unit is connected by means of a special lead provided. Q is read directly on a 3-scale panel meter common to both test circuits and operated by a transductor-stabilised valve voltmeter. A second meter monitors the input level to the test circuits and is calibrated in terms of Q-reading multiplication factor.

For certain measurements it is desirable to read small changes in Q very precisely. The TF 1245A therefore has provision for backing off the meter reading in steps of 50 Q, so that any portion of the Q range above 50 can be expanded. This expanded – or δ Q-scale is directly calibrated to ± 25 Q from a centre zero which corresponds to the setting of the switched backing-off control.

Specification for TF 1245A

FREQUENCY RANGE	1 kHz to 300 MHz using external oscillators.
MAGNIFICATION FACTOR (Q) Ranges:	5 to 50, 10 to 150, and 60 to 500, with Q multiplier at x 1.
Q Multiplier range	x 0·9 to x 2.
Accuracy of Q reading	With the Q multiplier at x 1 and a Q reading of 50, ± 5% up to 100 MHz, rising to ± 12% at 200 MHz, and ± 20% at 300 MHz. At Q readings of 150 and 500, measurement accuracy falls by about ± 1% from figures quoted above.
Delta-Q range	25–0–25.
NOMINAL TEST CIRCUIT PARAMETERS 1 kHz to 50 MHz test circuit	*Injection impedance:* resistive, 0·02 Ω. *Shunt loss:* 12 M Ω at 1 MHz.
20 to 300 MHz test circuit	*Injection impedance:* inductive, 0·1 nH. *Shunt loss:* 0·3 M Ω at 100 MHz.
TUNING CAPACITOR (1 kHz to 50 MHz test circuit) Main capacitor	20 to 500 pF; accuracy, ± pF ± 1%.
Incremental	5–0–5 pF with 0·2 increments; accuracy, ± 0·2 pF above 50 pF.
TUNING CAPACITOR (20 to 300 MHz test circuit) Main capacitor	7·5 to 110 pF; accuracy, ± 0·5 pF ± 1%.
Incremental	1–0–1 pF with 0·05 pF increments; accuracy, ± 1 pF above 16 pF. The h.f. test circuit capacitor can be used in the l.f. test circuit by external cross-connection.
POWER REQUIREMENTS A.C. mains	95 to 130 volts and 190 to 260 volts, 40 to 100 Hz, 22 watts.
DIMENSIONS AND WEIGHT	Height 14 in (36 cm); Width 17½ in (43 cm); Depth 9½ in (24 cm); Weight 23 lb (10·5 kg)
ACCESSORIES Supplied TC 28850	Inductor Support Platform for supporting small test components.
TM 5725	Coaxial Lead for coupling TF 1245A to either TF 1246 or TF 1247 oscillators.
TB 28691	Two Tie Bars for bonding TF 1245A to either TF 1246 or TF 1247 oscillators.

TF 1245A

OPTIONAL ACCESSORIES

Oscillators TF 1246 and TF 1247

TF 1247

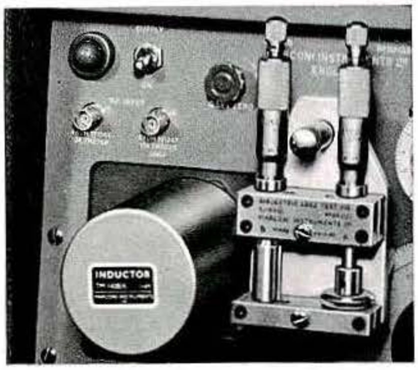
Specification

RANGE	
TF 1246	40 kHz to 50 MHz in 8 bands.
TF 1247	20 to 300 MHz in 6 bands.
Frequency Accuracy	±1%.
Output	Suitable for use with TF 1245; or with optional Matching Unit added, approx. 4 volts across 50 Ω load.
POWER REQUIREMENTS	
A.C. mains	100 to 150 volts and 200 to 250 volts, 40 to 100 Hz.
DIMENSIONS AND WEIGHT	

Height	Width	Depth	Weight
14 in	10¼ in	9½ in	27 lb
36 cm	26 cm	24 cm	12 kg

ACCESSORIES	
Optional	
TM 5726 for TF 1246 / TM 5727 for TF 1247	50 Ω Matching Units. Enables oscillator to be used as 50 Ω general-purpose test source.
TM 5728A	600 to 0·5 ohm, 1 to 40 kHz Transformer. For coupling to a conventional l.f. oscillator.

Dielectric Loss Test Jig TJ 155C/1



This Jig is primarily designed for the measurement of the dielectric loss of flat specimens of insulating material by the bandwidth-comparison method. It is also suitable for any measurements where small, accurately known changes of capacitance are required, e.g., self-capacitance and r.f. resistance of resistors.

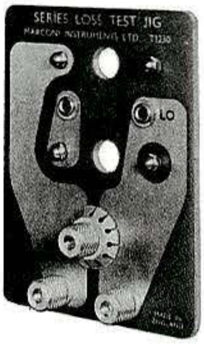
The unit comprises a precision circular-plate capacitor to contain the sample under test, and a linear-law incremental capacitor by which the bandwidth is determined; adjustment is by micrometer head calibrated in millimetres. It is mounted on a low-loss ceramic base and the assembly is arranged for attachment to the l.f. test circuit terminals of the Q Meter. The Jig is supplied in a felt-lined wooden case.

Specification

RANGE	
Tan δ	Varies with capacitance of specimen within overall limits 0·001 to 0·07.
R	Varies with frequency within overall limits 100 kΩ to 10 MΩ.
Accuracy	Approx. ±5%.
Thickness of Specimen	Up to 9·5 mm.
Electrodes	1 in. diameter, with edges bevelled to minimise fringing.
Equivalent shunt-loss of Jig	About 10 MΩ at 1 MHz.

OPTIONAL ACCESSORIES

Series Loss Test Jig TJ 230



TJ 230 enables the measurement of small values of R and L and large values of C to be made by connecting them in series with the test circuit of the Q Meter.

The unit consists of a printed-circuit base on which are mounted sockets to accept the TM 1438 series of inductors, and a pair of low inductance series-connection terminals across which the unknown is connected. The Jig is arranged for connection to the l.f. test circuit terminals of the Q Meter.

Specification

MEASUREMENT RANGE	
C	480 pF to 0·25 μF.
L	0·005 μH at 50 MHz to 25 mH at 40 kHz.
R	0·003 Ω at 50 MHz to 1·5 kΩ at 40 kHz.
ACCURACY	
C and L	Maximum accuracy of about 4% when C reading changes by 2:1.
R	Maximum accuracy of about 10% when Q of circuit is halved.

Inductors TM 1438 series and TM 4947 series

A range of twenty-one inductors, any of which can be supplied separately, is available for use with the Q Meter. Two basic series are available:

TM 1438 series: for l.f. test circuit; eighteen fully screened inductors on ceramic formers, fitted with "banana" plug connectors. Values range from 0·2μH to 25 mH; each adjusted to within ±3% ±0·05μH of its nominal value. Can be supplied as a complete set, type TM 4520, in a polished hard-wood case.

TM 4947 series: for h.f. test circuit; three fully screened inductors fitted with spade-lug connectors.

The inductors available and details of their frequency coverage are given in the table below.

Type	Nominal Inductance	Approx. Magnification	Approx. Self-Capacity pF	Approx. Frequency Range
TM 1438A	0·2 μH	200	8	40–15 MHz
TM 1438B	1·0 μH	200	8	22–8·5 MHz
TM 1438P	1·5 μH	200	8	18–6·5 MHz
TM 1438C	2·5 μH	200	8	14–5·2 MHz
TM 1438D	5·0 μH	200	8	9–3·5 MHz
TM 1438E	10 μH	200	8	6·5–2·5 MHz
TM 1438F	25 μH	200	8	4·3–1·6 MHz
TM 1438G	50 μH	200	8	2·9–1·1 MHz
TM 1438R	75 μH	200	8	2·4–0·9 MHz
TM 1438H	100 μH	200	8	2·0–0·8 MHz
TM 1438Q	200 μH	200	8	1·5–0·6 MHz
TM 1438I	250 μH	200	8	1·3–0·5 MHz
TM 1438J	500 μH	160	9	970–370 kHz
TM 1438K	1·0 mH	160	9	680–270 kHz
TM 1438L	2·5 mH	150	10	410–150 kHz
TM 1438M	5·0 mH	130	10	280–110 kHz
TM 1438N	10 mH	80	11	220–80 kHz
TM 1438O	25 mH	80	11	140–50 kHz
TM 4947/1	2·5 μH	350	4·0	20–30 MHz
TM 4947/2	0·5 μH	350	1·5	25–70 MHz
TM 4947/3	0·05 μH	300	1·2	70–230 MHz

Oscilloscopes

Oscilloscope

- ☐ 30 MHz bandwidth at 50 mV/cm
- ☐ Comprehensive measurement facilities
- ☐ Plug-in X and Y deflection units
- ☐ Solid state active elements

The Basic Unit

This contains the cathode-ray tube with the appropriate brilliance and focussing control systems, the power supply units, and the main X and Y amplifier systems. Semiconductors are used for all the active circuit functions except for input stages, where there is a possibility of damaging transistors by excessive overload. Valves used in these positions are connected as cathode followers, a configuration in which changes in parameters due to ageing or supply variations, are fully compensated for. The valve types have been specially chosen for low noise and low microphony.

The Display

A 10 kV p.d.a. cathode-ray tube ensures an adequately bright trace even at the highest writing speeds.The medium persistence P 31 phospher is regarded as standard, but other phosphers are available and, if required should be requested when ordering.

Following current Marconi styling, the TF 2201 is fitted with a c.r.t. bezel having a rectangular viewing aperture, the display area being nominally 6 cm x 10 cm. This bezel carries the measurement graticule and accepts the current range of viewing attachments. Of these, the Graticule Projector completely obviates parallax error. Details of the available measurement graticules and of the Graticule Projector are given in a separate leaflet about Oscilloscope accessories.

The Deflection Systems

The main deflection amplifiers, which are housed in the basic unit, form the links between the plug-in X and Y deflection units and the plates of the cathode-ray tube.

A 180 nsec signal-delay network in the later stages of the vertical deflection system allows observation of the leading edge of a triggering waveform. The early vertical amplification stages are, of course, contained in the plug-in pre-amplifier units, which also carry the appropriate Y gain and shift controls.

The horizontal deflection waveform is normally derived from the time base generator in the plug-in time base unit. The X gain (expansion) and shift controls, however, form part of the main amplifier housed in the basic unit. The expansion control is continuously variable up to 5 times the normal 10 cm sweep width, giving the equivalent of 5 times the calibrated time base speed.

Closely associated with the deflection systems is the provision for Z modulation via a terminal at the rear of the instrument giving electrical access to the cathode of the c.r.t.

Voltage and Time Measurement

The TF 2201 has provision for two methods of amplitude and time measurement. For rapid measurement or photographic recording, the Y amplifier gain and horizontal sweep velocity can be standardised to facilitate direct reading from the calibrated graticule. Or, for higher discrimination, directly calibrated shift controls can be used to measure amplitudes or time intervals by slide back method.

These calibrated controls apply accurate d.c. shift voltages to the input stages of the appropriate deflection amplifiers so that the measurement accuracy is completely independent of sensitivity and linearity of the overall deflection system. As the accuracy is, thus, unaffected by the setting of Y gain or X expansion, absolute voltage and time measurements can be made on very small parts of the displayed waveform. The usefulness of this facility is further increased by the inclusion of a potential divider which can be switched into circuit to reduce the d.c. shift voltage by a factor of ten to give effectively ten times the normal measurement discrimination.

For operational convenience, a reversing switch is also provided by the amplitude measurement control, and this effectively doubles the scale length.

Low Power Consumption

The power consumption of the TF 2201 is only 130 watts compared with the 600 watts consumed by the equivalent type of valve operated oscilloscope. A cooling fan, with its associated noise and dust, is therefore not required. Very efficient voltage regulation is achieved due to this low consumption, and the stability of the instrument is maintained over supply voltage variations of at least 10%.

The generally lower operating temperature also contributes to the long term operational stability, so that the Y amplifier drift is virtually negligible, and the need for adjustment to pre-set controls occurs much less frequently than in valve operated oscilloscopes.

Environmental Testing

In common with other Marconi equipment, the TF 2201 has been subjected to thorough environmental tests at all stages in its development; and the ability of the instrument to withstand shock, vibration, and the extremes of temperature and humidity has been fully proved.

Its full performance specification is retained at temperatures up to 40°C, and it can be used safely at temperatures up to 55° C.

Basic Unit TF 2201

Modular Construction

Ease of maintenance is an important factor in the reliability aspect of an instrument's performance. It is, of course, essential that failures are infrequent; but it is equally necessary that, in the event of a breakdown, the fault can be located and repaired quickly. With this philosophy in mind, the TF 2201 has been so constructed that the electrical circuits take the form of easily detachable modules. Most of these can be removed from the main frame with little or no unsoldering of connections.

The handbook supplied with the instrument includes instructions for tracing a fault to a particular module.

Electrical circuits take the form of easily detachable modules — see MODULAR CONSTRUCTION

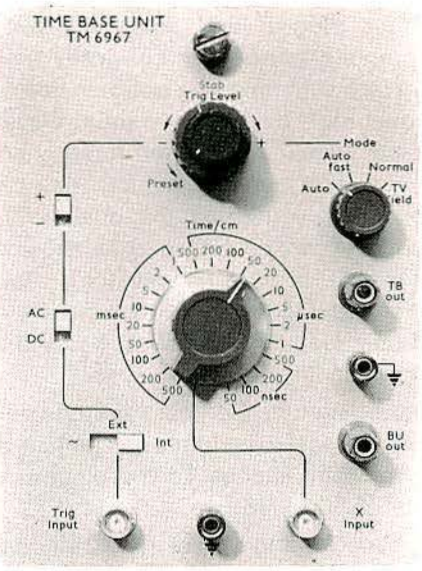
CATHODE RAY TUBE	English Electric 948H or Mullard D13-228H flat face mesh tube with P31 phosphor. Other phosphors available to special order. Direct access to deflector plates.
Diameter	5 in.
Display area	6 x 10 cm.
Y-plate sensitivity	Nominally 3 volts.
X-plate sensitivity	Nominally 9 volts for English Electric tube or 10 volts for Mullard tube.
Z Modulation	Via C.R.T. CATH jack socket. Requires negative going pulses of from 5 volts to 30 volts peak, depending on frequency. Input impedance is 22 kΩ in series with 0·02 μF.
TIME MEASUREMENT	
By time scale potentiometer	X10 (NORMAL) mode gives 10 cm shift at minimum expansion with an accuracy of ± 2% of full scale. X1 mode gives 1 cm shift at minimum expansion with an accuracy of ± 5% of full scale.
Using standard graticule	Accuracy is ± 3% of 10 cm display.
VOLTAGE MEASUREMENT	
By volts scale potentiometer	X10 (NORMAL) mode gives 10 cm shift with an accuracy of ±2% of full scale. X1 mode gives 1 cm shift with an accuracy of ± 5% of full scale.
Using standard graticule	After standardisation against internal 5 cm CAL waveform the accuracy is ± 3% of 6 cm display.
X AMPLIFIER	
3 dB bandwidth	D.C. to greater than 4·5 MHz.
Expansion	Continuously variable from X1 to greater than X5.
Sensitivity	800 mV/cm at minimum expansion, increases to greater than 160 mV/cm at maximum expansion.
Sweep width	At least 10·5 cm at minimum expansion.
X-Shift	The display can be moved through at least 11 cm at minimum expansion.
POWER REQUIREMENTS	95-135 volts or 90-260 volts; 45-500 Hz 130 watts

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
$16\frac{1}{4}$ in (41·3 cm)	$11\frac{1}{2}$ in (29·2 cm)	$25\frac{1}{4}$ in (64·1 cm)	64 lb (29·2 kg)

Time Base Unit TM 6967

The twenty-two switch-selected time base ranges of this plug-in unit provide calibrated sweep velocities from 50 nsec/cm to 0·5 sec/cm. By using the X expansion facility of the TF 2201 the maximum sweep velocity can, of course, be increased to 10 nsec/cm. The sawtooth sweep waveform and the trace brightening waveform are available from panel terminals. There is also provision for stopping the internal time base generator and applying an external horizontal deflection voltage via a BNC socket on the front panel.



An external trigger signal can be applied via a BNC socket, or the time base can be triggered internally either from the displayed waveform or at the mains supply frequency.

Four trigger modes are available as follows:

NORMAL — With the STABILITY control fully counter clockwise, the time base operates in the truly triggered condition, and there is provision for triggering at any voltage level on positive or negative going transients.

AUTO — The time base free runs at about 40 Hz in the absence of a triggering signal, but locks positively to it when a signal is present. The STABILITY control is out of use.

AUTO FAST — This is similar to the AUTO mode except that the free run is at 10 kHz to provide a brighter baseline at high sweep velocities.

TV FIELD — A passive integrating circuit is introduced to permit locking to field synchronising pulses while ignoring line pulses. This mode is otherwise similar to NORMAL.

TIME BASE OUTPUTS	
Sweep rate	10 nsec/cm to 500 msec/cm in 22 ranges.
Sweep output at TB OUT terminals	Negative-going sawtooth of +6 volts and −2 volts peaks with waiting potential of +2 volts.
Gate output at BU OUT terminals	Negative-going at start of each sweep. 2 volts peak amplitude (from cathode follower). Pulse has duration of time base sweep.
TRIGGER FACILITIES	
Modes	The TRIG MODE selector gives choice of AUTO, AUTO FAST, NORMAL and TV FIELD.
Source	The ∼-EXT-INT switch selects source from mains supply, external signal, or internal Y signal.
Coupling	The trigger source can be a.c. or d.c. coupled to the time base.
Slope	The +/−switch allows the triggering point to be set on either the positive or negative slope of the triggering waveform.
Trigger input	TRIG INPUT has impedance of 1 MΩ ±10% with 40 pF in shunt.
TRIGGER REQUIREMENTS	The following frequency limits are for 3 mm p-p of sinusoidal display for internal trigger source, or 600 mV p-p of sinusoidal signal for external trigger source.
NORMAL mode D.C. coupled	d.c. to 20 MHz
NORMAL mode A.C. coupled	15 Hz to 20 MHz.
AUTO	45 Hz to 15 MHz.
AUTO FAST	10 kHz to 15 MHz.
H.F. sync	Up to at least 40 MHz using STABILITY control. When no triggering signal is available the time base will free run in the AUTO positions at the following frequencies: AUTO approximately 40 Hz. AUTO FAST approximately 10 kHz.
TV FIELD mode	Triggering is by integration of the vertical sync pulses in a composite TV waveform. Suitable for use with 50 Hz or 60 Hz field repetition rates. The time base triggers once every field provided that the sync pulse is at least 5 mm p-p amplitude on the screen.
TRIG LEVEL control for internal source	Covers one window height (6 cm.)
TRIG LEVEL control for external source	Covers ± 6 volts. In the AUTO and AUTOFAST position the TRIG LEVEL control is inoperative.

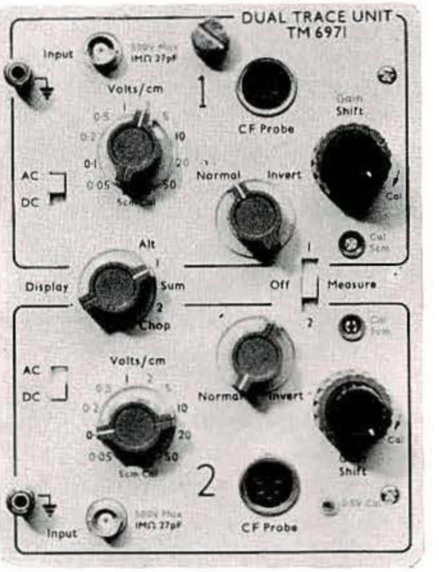
DIMENSIONS AND WEIGHT	Height	Width	Depth	Weight
	$7\frac{1}{4}$ in (18·4 cm)	$5\frac{1}{2}$ in (14 cm)	$13\frac{3}{4}$ in (34·9 cm)	4 lb (1·82 kg)

Dual Trace Unit TM 6971

The Dual Trace plug-in unit comprises two identical pre-amplifier input channels, each basically similar to that of the Single Trace Unit, and an electronic beam switch to provide the dual trace display. Two input waveforms can be displayed separately, the desired input channel being selected by means of a panel switch; they can be displayed simultaneously utilising the dual trace mode of operation; or they can be added algebraically and displayed as a single composite waveform. As there are polarity reversing switches for both input channels, this last mode of operation can effectively be used to provide differential input facilities.

For dual trace operation, the beam switch can be set to display the two channel waveforms on alternate sweeps, or it can chop from one channel to the other at a nominal switching rate of 500 kHz.

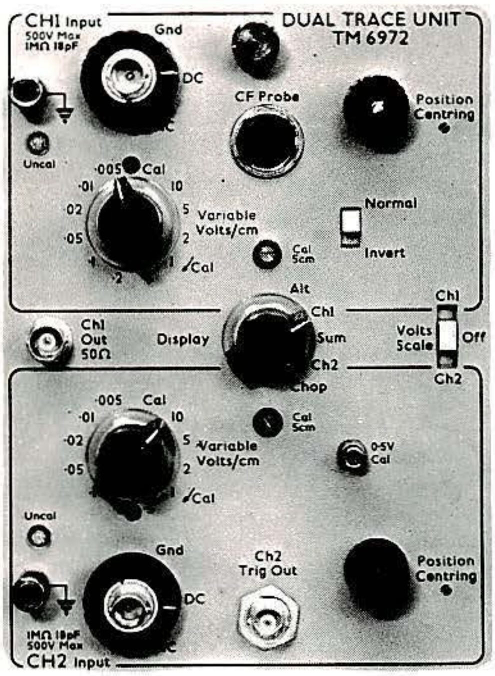
Provision is made for the use of two Cathode Follower Probes – one for each input channel – and a 0·5 volt calibrating voltage is brought to an output point as for the Single Trace Unit. The gain of each of the input channel amplifiers can be standardised independently against an internally generated calibrating waveform for amplitude measurement utilising the calibrated graticule. For slide back measurements – using the calibrated verticle shift controls – the shift voltage can be connected to either input channel or disconnected from both by means of a three position switch.



DISPLAY SELECTION	The DISPLAY selector gives:
ALT	Channels 1 and 2 displayed on alternate time base sweeps.
1	Channel 1 only.
SUM	Algebraic sum of both channels.
2	Channel 2 only.
CHOP	Chopped display of both channels at 500 kHz switching rate.
3 dB BANDWIDTH	
D.C. coupled input	D.C. to at least 30 MHz.
A.C. coupled input	2Hz or lower to at least 30 MHz
TRANSIENT RESPONSE	
Rise time	Not greater than 12 nsec } At any position of GAIN and Y-SHIFT controls
Overshoot	Not greater than 5% } At any position of GAIN and Y-SHIFT controls
SENSITIVITY	
Range	Each VOLTS/CM switch provides ten switched ranges in 1–2–5 sequence from 50 mV/cm to 50 V/cm. In addition the uncalibrated GAIN control provides variable adjustment over a nominal 2·5:1 range at each step.

Gain standardisation	CAL position of VOLTS/CM switch displays 250 mV ± 2% calibration waveform at the maximum sensitivity of 50 mV/cm (see manual EB 2201 for voltage measurement accuracy).
Y-SHIFT	Separate Y-SHIFT controls are provided for each channel. With each control the display can be moved through at least 12 cm with the GAIN control at CAL.
INPUT IMPEDANCE	1 MΩ with 27 pF in shunt at all input sensitivities.
POLARITY REVERSAL	To simplify the comparison of signals 180° out of phase, the polarity of either channel may be reversed.
TIME DIFFERENCE BETWEEN CHANNELS	Less than 1 nsec.
PROBE OPERATION	
Probe 0·5 volt CAL signal	A 0·5 volt ± 1·5 Hz square wave is provided at a stud on the front panel. Output impedance is nominally 1 kΩ.
C.F. PROBE socket	Provides supplies for operating Cathode Follower Probe TM 6942A.
DIMENSIONS AND WEIGHT	Height $7\frac{1}{4}$ in (18·4 cm); Width $5\frac{1}{2}$ in (14 cm); Depth $13\frac{3}{4}$ in (34·9 cm); Weight $5\frac{1}{2}$ lb (2·5 kg)

High Sensitivity Dual Trace Unit TM 6972



This plug-in unit provides basically similar facilities to those of Dual Trace Unit TM 6971, but has an input sensitivity of 5 mV/cm from d.c. to 30 MHz on each channel.

Outputs from both Y preamplifiers are also available from appropriately marked panel sockets. The Channel 1 output gain is 10:1 over the bandwidth d.c. to 20 MHz. For single channel operation, therefore, the Channel 1 preamplifier can be cascaded with Channel 2, giving an overall maximum sensitivity of 500 μV/cm. Channel 2 output is primarily intended for coherent triggering on dual trace displays, the output socket being connected externally to the trigger input for this purpose. The gain between Channel 2 input and output sockets is 80:1 when the attenuator is set to its most sensitive position. This gives stable triggering up to 30 MHz for 1 cm vertical deflection. For X-Y applications the Channel 2 output can be fed to the X input socket, to give an effective horizontal deflection sensitivity of 10 mV/cm with the X expansion control at minimum. By adjustment of this control the X sensitivity can be matched to the Y sensitivity to give a 5 mV/cm X-Y facility with less than 3° phase shift for frequencies up to 50 kHz.

DISPLAY SECTION	The DISPLAY selector gives:—
ALT	Channels 1 and 2 displayed on alternate time base sweeps.
1	Channel 1 only.
SUM	Algebraic sum of both channels (i.e. Channel 2 ± Channel 1).
2	Channel 2 only.
CHOP	Chopped display of both channels at 1 MHz switching rate. Beam blanking to suppress transients.
3db BANDWIDTH	
D.C. coupled input	D.C. to 30 MHz.
A.C. coupled input	4 Hz to 30 MHz. L.F. response 0·4 Hz when used with TM 8110 probe switched to x 10 (3 dB point).
TRANSIENT RESPONSE	
Rise time	Not greater than 12 ns
Overshoot	Not greater than 5%
SENSITIVITY	
Range	Each VOLTS/CM switch provides eleven switched ranges in 1-2-5 sequence from 5 mV/cm to 10 V/cm.
Accuracy	±3% using graticule. ±2% using the measuring dials. A twelfth position on the switch permits gain standardisation to 3%.
Pre-set variable gain	Screwdriver adjustment.
Uncalibrated gain control	Cover greater than 2·5 : 1.
VERTICAL POSITION RANGE	Separate VERTICAL POSITION controls are provided for each channel. With each control the display can be moved through at least 24 cm.
INPUT IMPEDANCE	1 MΩ with 18 pF in shunt at all sensitivities.
MAXIMUM INPUT VOLTAGE	500 volts combined d.c. and a.c. peak.

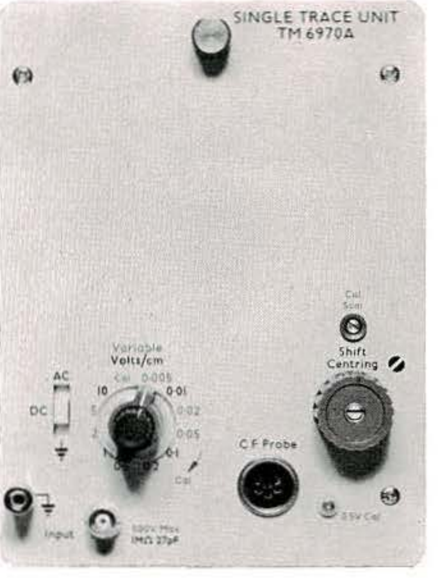
POLARITY INVERSION	Signals on Channel 1 only may be inverted.
TIME DIFFERENCE BETWEEN CHANNELS	Less than 1 nsec.
VOLTS SCALE	A three-position switch CH1-OFF-CH2, permits volts scale measurement on either channel.
BREAKTHROUGH	
Common mode	Rejection greater than 20 dB at 30 MHz.
Socket to socket	Rejection 80 dB over the bandwidth.
Gate breakthrough	40 dB over the bandwidth.
CH1 OUTPUT	
Output bandwidth	D.C. coupled, d.c. to 20 MHz. A.C. coupled, 4 Hz to 20 MHz.
Output impedance	Nominally 50Ω.
Gain	x 10.
CH2 OUTPUT	A signal output from Channel 2 to enable triggering from one channel on the ALT and CHOP positions. An external connection to the time base must be made.
Sensitivity	Will trigger off a picture greater than 1 cm up to 30 MHz.
CH1 AND CH2 IN CASCADE	
Sensitivity	Maximum sensitivity 500 μV/cm.
Bandwidth	D.C. coupled, d.c. to 15 MHz. A.C. coupled, 4 Hz to 15 MHz.
Noise	Less than 4 mm at maximum sensitivity with the input grounded.
C.F. PROBE SOCKET	Provides supplies for operating Cathode Follower Probe TM 6942A.
Calibration signal	0·5 volts ± 1·5%. 50 Hz square wave is provided at the front panel.
Output impedance	1 kΩ nominal.
DIMENSIONS AND WEIGHT	Height $7\frac{1}{4}$ in (184 mm); Width $5\frac{1}{2}$ in (140 mm); Depth $13\frac{3}{4}$ in (349 mm); Weight $5\frac{1}{2}$ lb (2·5 kg)

TM 6970A Single Trace Unit

This is a simple plug-in Y pre-amplifier giving a maximum sensitivity of 5 mV/cm and a 3 dB bandwidth of at least 30 MHz. It can be operated either d.c. or a.c. coupled, and it accepts peak input amplitudes up to 500 volts.

The 10-step input attenuator is fully compensated to operate at frequencies well in excess of the nominal Y amplifier bandwidth. Its switch positions are marked with the calibrated sensitivities in terms of input voltage per cm deflection from 0·005 to 10 V/cm. These calibrated sensitivities correspond to maximum (CAL) setting of the variable gain control, provision being made for standardising the amplifier gain, against an internally generated calibrating waveform, by means of a preset control.

The BNC input socket is suitable for connection of any of the current Marconi range of input accessories, and the front panel also carries a supply socket for operating the Cathode Follower Probe TM 6942A and 0·5 volt output point for calibrating the probe.



3db BANDWIDTH		
D.C. coupled input	D.C. to at least 30 MHz.	
A.C. coupled input	4 Hz to 30 MHz.	
TRANSIENT RESPONSE		
Rise Time	Not greater than 12·5 nsec	At any position of gain and Y-SHIFT controls
Overshoot	Not greater than 5%	At any position of gain and Y-SHIFT controls
SENSITIVITY		
Range	The VOLTS/CM switch provides eleven switched range in 1–2–5 sequence from 5 mV/cm to 10V/cm. The accuracy of the attenuation ratios is 2%. In addition the uncalibrated GAIN control provides variable adjustment over a nominal 2·5:1 range at each step.	
Gain standardisation	Using the CAL position of the VOLTS/CM control the gain can be standardised to the accuracy of 2%.	
Y-SHIFT	With the Y-SHIFT control the display can be moved through at least 24 cm with the GAIN control at CAL.	
INPUT IMPEDANCE	1 MΩ with 27 pF in shunt at all sensitivities.	

PROBE OPERATION	
Probe 0·5 volt CAL signal	A 0·5 volt ± 1·5%, 50 Hz square wave is provided at a stud on the front panel. Output impedance is nominally 1 kΩ.
C.F. PROBE socket	Provides supplies for operating Cathode Follower Probe TM 6942A.

DIMENSIONS AND WEIGHT	Height	Width	Depth	Weight
	$7\frac{1}{4}$ in (18·4 cm)	$5\frac{1}{2}$ in (14 cm)	$13\frac{3}{4}$ in (34·9 cm)	3 lb (1·36 kg)

Accessories for TF 2201

Supplied:	TM 8110	2-Attenuator Probes (X10-X1).
Optional:	TM 8120	Low Capacitance Probe.
	TM 6942A	Cathode Follower Probe.
	TM 8098	Graticule Projector.
	TD 43245	Rubber Hood.
	TM 6943	Extension Cable.
	TM 7279	Camera Adapter

Oscilloscope Accessories

TM 7424/1M1 Oscilloscope Trolley

A trolley with adjustable tilting platform which allows the viewing angle of the oscilloscope to be adjusted. Includes an accessory drawer and housing for two plug-in units.
Suitable for the TF 2201

TD 43245 Rubber Hood

Viewing hood for the exclusion of ambient light.

TM 6943 Extension Cable

24 way, 18 inches long; for use when servicing plug-in units.

Standard graticules available

1 cm Squares (5x10 cm)
- TB 43535 Projection type

1 cm Squares (6x10 cm)
- TC 38264 Perspex type, marked on the back only
- TB 43536 Projection type

Decibel Scale
- TB 44808 5 x 10 cm Projection type
- TB 44809 6 x 10 cm Projection type
- TC 45075 6 x 10 cm Perspex type

K–Factor
- TB 43596 Projection type

TM 6942A Cathode-Follower Probe

Tips and Attachments (supplied)

Prod TB 39082

Hook TB 39083

Plastic Hook

High speed transients derived from fairly-high impedance sources can be conveyed to an oscilloscope by means of the cathode-follower probe, which effectively brings the input stage of the oscilloscope's amplifier to a position physically close to the output terminal of the source. The cathode-follower probe presents a high input impedance without introducing a large amount of attenuation.

The Marconi TM 6942A drops the voltage by approximately 2:1.

Input Impedance:	10 MΩ in parallel with 8 pF.
Maximum Input:	3 volts p-to-p.
Frequency Range:	4 Hz to 30 MHz
Gain:	Nominally 0·5.
Valve Type Used:	EC 1000.
Connector:	BNC Plug.

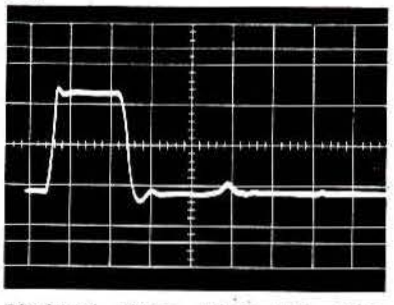
☐ Switchable 10:1–1:1 Attenuator Probes

☐ 100:1 Attenuator Probes

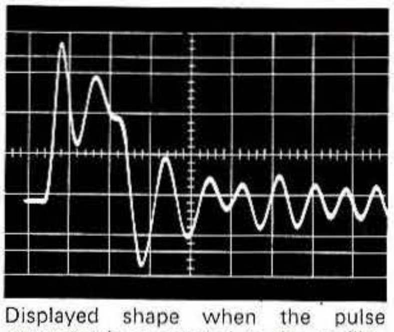
☐ 1:1 Straight–Through Probe

☐ Probe Tips and Attachments

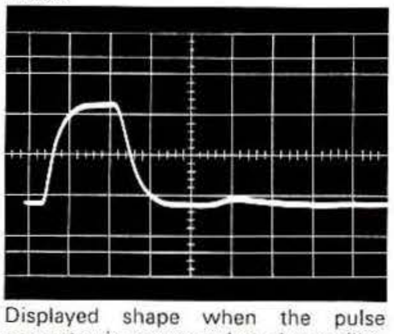
The true shape of the pulse, measured on a wide band oscilloscope fed by a properly terminated coaxial cable. The rise time of the pulse shown is 12 nano sec.



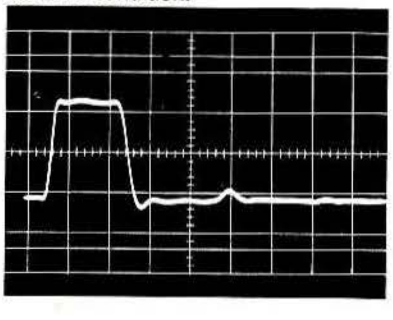
Displayed shape when the pulse generator is connected to the oscilloscope by means of unterminated coaxial cable.



Displayed shape when the pulse generator is connected to the oscilloscope via TM 8120 Straight-Through Probe.



Displayed shape when the pulse generator is connected to the oscilloscope via TM 8110 Attenuator Probe in the X 10 condition.



Your oscilloscope, with its wide bandwidth and a high input impedance, is capable of faithfully displaying fast-rise or high-frequency waveforms derived from quite high-impedance sources. But, if the connection between the source and the oscilloscope is not made correctly, the waveform at the oscilloscope's input terminal is likely to be deformed and the fidelity of the instrument will be wasted.

A connector consisting of a stray bit of wire and a crocodile clip behaves like a badly mismatched transmission line. It not only distorts the waveform but picks up any interference signal that may be radiated in the vicinity. A piece of coaxial cable may not be very much better, unless the impedance of the waveform source is such that the cable can be correctly terminated. So, in order to take full advantage of the oscilloscope's capabilities, it is often necessary to use a special connecting cable which meets the following requirements:

It must be fully screened to avoid interference from stray fields;

Its effective shunt capacitance must be low so that it will not load the waveform source unduly;

It must have just sufficient resistive loss to absorb any reflected power without introducing significant attenuation.

This type of connector is available in the convenient form of a straight-through probe, TM 8120, suitable for use with oscilloscopes having an input impedance of 1 MΩ in parallel with 30 pF. The special cable used with this probe ensures that the waveform at the oscilloscope's input terminal is a true facsimile of that at the probe tip.

The capacitance of the cable, however, is inevitably added to the capacitance of the oscilloscope, and the resulting reactive loading of the source may deform the waveform at the probe tip if the source impedance is high. Such deformation is reduced considerably by the use of an attenuator probe designed to present much smaller capacitive and resistive loading. The Marconi Instruments range includes 10:1 and 100:1 attenuator probes suitable for use with oscilloscopes having input capacitances of 30 pF and 15 pF.

Switchable Attenuator Probes

☐ TM 8110
for 1 MΩ, 30 pF oscilloscope input impedance

☐ TM 8561
for 1 MΩ, 15 pF oscilloscope input impedance

These probes are no bigger or heavier than any others, but they can be twice as useful because each of them is virtually two probes in one.

By twisting its nose through 60° the probe's action can be changed from that of a 10 MΩ 10:1 divider to that of a straight-through probe with negligible attenuation. The switch positions are designated X10 and X1 respectively.

In order to make the probe truly aperiodic, it is important that its time constant should be made equal to that of the oscilloscope input circuit. The TM 8110 is intended for use with oscilloscopes with input impedance of 1 MΩ in parallel with 30 pF, and the TM 8561 is for those with input impedance of 1 MΩ in parallel with 15 pF. But, by rotating the barrel of the handle, the probe time constant can be matched to 1 MΩ oscilloscopes having input capacitances other than the optimum values shown above. The range of the capacitive compensation for each probe is given in the specification.

TM 8110

ATTENUATION RATIO	Switchable 1:1 or 10:1.
INPUT IMPEDANCE	When used with a 1 MΩ, 30 pF oscilloscope: X1 position: R=1 MΩ. C<70 pF. X10 position: R=10 MΩ. C<10 pF.
RISE TIME X10 position only	Approximately 5 nsec.
CAPACITIVE COMPENSATION	Adjustment to the probe allows use with oscilloscopes of 12 to 60 pF input capacitance. Best pulse response with 30 pF oscilloscopes.
MAXIMUM INPUT VOLTAGE	±600 volts d.c. or 600 volts peak-to-peak a.c., derated at frequencies above 15 MHz in X10 position and above 600 kHz in X1 position.
CABLE LENGTH	3 ft 6 in.

TM 8561

ATTENUATION RATIO	Switchable 1:1 or 10:1.
INPUT IMPEDANCE	When used with a 1 MΩ 15 pF oscilloscope: X1 position: R=1 MΩ. C typically= 85 pF. X10 position: R=10 MΩ. C typically= 10·5 pF.
RISE TIME X10 position only	Approximately 3 nsec.
CAPACITIVE COMPENSATION	Adjustment to probe allows use with oscilloscopes of 8 to 30 pF input capacitance. Best pulse response with 15 pF oscilloscopes.
MAXIMUM INPUT VOLTAGE	In X1 position, ±160 volts d.c. or 160 volts peak-to-peak a.c., derated above 5 MHz. In X10 position, ±600 volts d.c. or 600 volts peak-to-peak a.c.
CABLE LENGTH	3 ft 6 in.

TM 8110/1 Switchable Attenuator Probe (Extra long cable version) for 1 MΩ, 30 pF Oscilloscope Input Impedance

This is a special version of the TM 8110 probe for which the cable length has been increased to 9 feet. It is electrically similar to the standard version except for a slight increase in shunt capacitance and rise time.

TM 8110/1

INPUT CAPACITANCE	X1 position: less than 100 pF. X10 position: 11·1 pF.
RISE TIME	Approx. 6 nsec in X10 position only.
CABLE LENGTH	9 feet.

Non-Switchable Probes

☐ TM 8119
for 1 MΩ, 30 pF oscilloscope input impedance

☐ TM 8563
for 1 MΩ, 15 pF oscilloscope input impedance

The 100 :1 probes are intended for high voltage measurements or measurements where very low shunt capacitance loading is essential. These two probes are basically similar to the 10 :1 probes, without the facility for switching to the 1 :1 ratio, but including the provision for matching to the time constant of the oscilloscope by rotating the barrel of the handle.

	TM 8119
ATTENUATION RATIO	100 :1.
INPUT IMPEDANCE	R=9·1 MΩ. C<3 pF. When used with a 1 MΩ, 30 pF oscilloscope.
RISE TIME	Approx. 7 nsec.
CAPACITIVE COMPENSATION	Adjustment to the probe allows use with oscilloscopes of 12 to 60 pF input capacitance. Best pulse response with 30 pF oscilloscopes.
MAXIMUM INPUT VOLTAGE	1·5 kV d.c. or 4·25 kV peak-to-peak a.c., derated at frequencies above 4 MHz.
CABLE LENGTH	3 ft 6 in.

	TM 8563
ATTENUATION RATIO	100 :1.
INPUT IMPEDANCE	R=9·1 MΩ. C<2·5 pF. When used with a 1 MΩ, 30 pF oscilloscope.
RISE TIME	Less than 3 nsec.
CAPACITIVE COMPENSATION	Adjustment to the probe allows use with oscilloscopes of 8 to 30 pF input capacitance. Best pulse response with 15 pF oscilloscopes.
MAXIMUM INPUT VOLTAGE	1·5 kV d.c. or 4·25 kV peak-to-peak a.c., derated at frequencies above 10 MHz.
CABLE LENGTH	3 ft 6 in.

TM 8120 Straight-Through Probe for 1 MΩ, Oscilloscope Input Impedance

A direct-connecting probe for use with oscilloscopes having input resistance of 1 MΩ or above, the TM 8120 is of similar construction to the attenuator probes. No equalisation is necessary for matching to the oscilloscope input circuit time constant; but the capacitance of the probe adds to the input capacitance of the oscilloscope.

	TM 8120
ATTENUATION RATIO	1 :1
INPUT CONDITIONS	Has series resistance of approximately 400 Ω with distributed shunt capacitance of approximately 35 pF.
MAXIMUM INPUT VOLTAGE	±600 volts d.c. or 600 volts peak-to-peak a.c., derated above 2 MHz.

 Actual Size

The Cable

The real secret of the high performance of the probes lies in the design of the connecting cable.

The kinky resistive inner conductor is bonded to the walls of the inner sheath at the points where it touches to avoid microphony and to prevent variations in cable capacitance. It is, of course important that this capacitance should be kept as low as possible; so the inner conductor is well separated from the screening braid and is made of very thin wire – about 0·002 in diameter.

Nevertheless, there is nothing fragile about the cable – or, indeed any other part of the probes. If you pull it hard the cable will stretch to the limit of its elasticity, but the inner conductor will not break; and the grey silicone-rubber outer cover is not only extremely flexible but very tough indeed. It is resistant to all sorts of mishandling, including accidental contact with hot soldering irons.

The Oscilloscope Connection

All Marconi passive probes are fitted with B.N.C. plugs for connection to the oscilloscope, but adapters are available for use with oscilloscopes having U.H.F. 83 type input sockets.

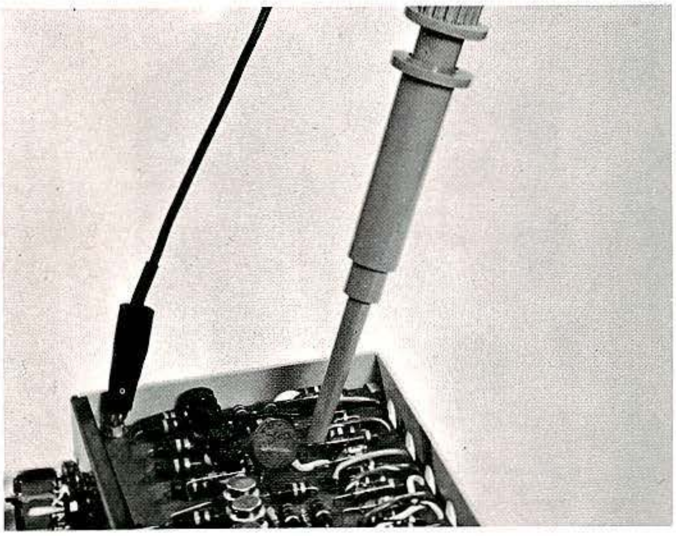
Earth Leads

TM 8191	12 inch
TM 8191/1	6 inch
TM 8191/2	3 inch

Clip Tip TM 8189

(Supplied as standard with each probe.)

Facilitates easy connection to wires and soldering tags. The clip is opened by drawing its moulded casing back along the body of the probe.



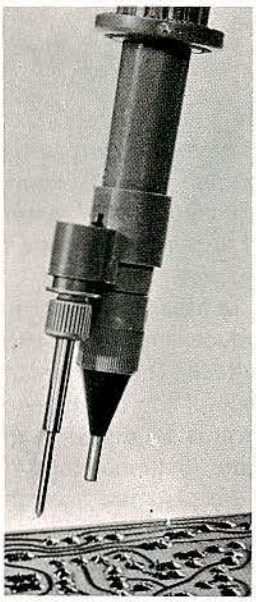
PROBE ACCESSORY KIT TM 8188
(Supplied as standard with each probe.)

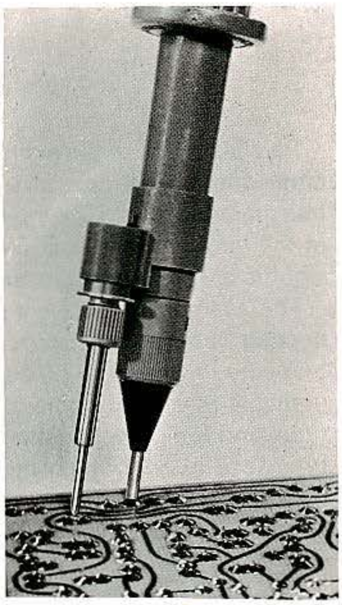
Pin Tip TM 8193	—Pin fits into 50Ω type N or B.N.C. socket.
Flexible Pin Tip TM 9144	—Flexible pin prevents damage to the socket if the probe is knocked.
Prod Tip TB 39082	—End of prod is cupped to take soldered joint.
Hook Tip TB 39083	
Banana Plug Tip TB 43843	—For use with 4 mm sockets.
Probe support Clip TB 44005	—Fits into a standard 4mm socket to form a parking support for the probe.

Earthing Bayonet TM 8194

(Optional accessory supplied if specially ordered.)

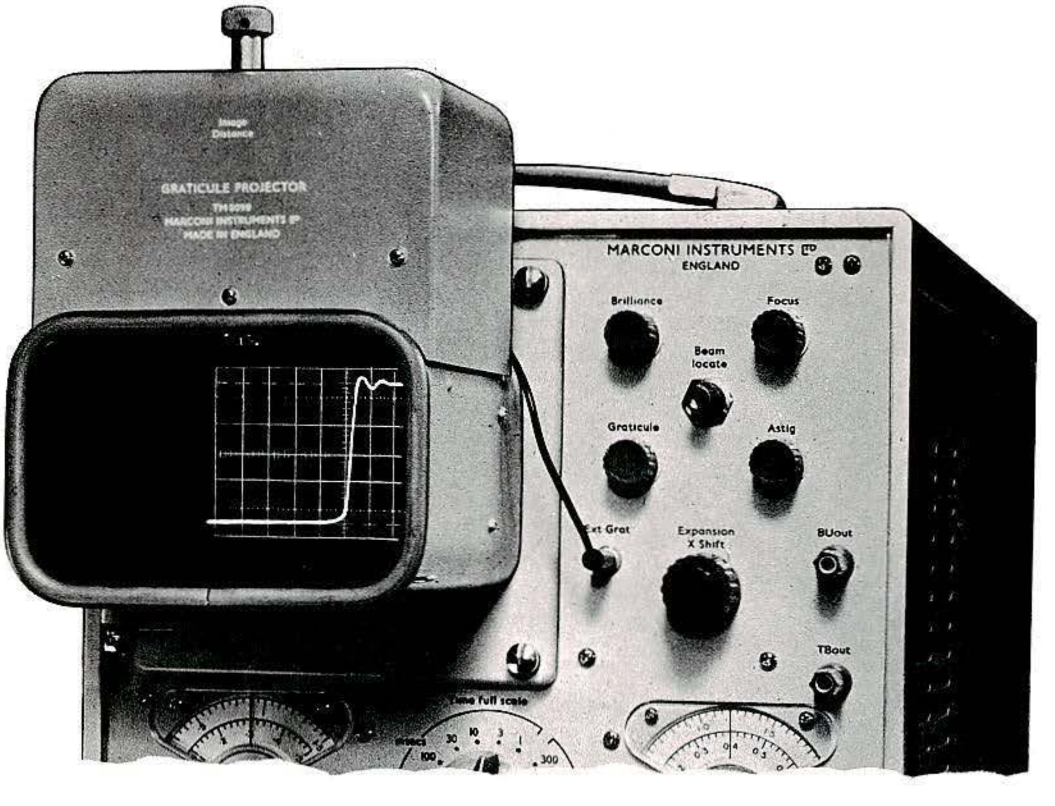
Used in conjunction with the prod or hook tip. Provides short-path earth connection.





TM 8098 Graticule Projector

- ☐ Completely eliminates parallax error
- ☐ Accurate measurements without "sighting"
- ☐ Range of standard graticules
- ☐ Special graticules easily made



Parallax is one of the main sources of viewing error when conventional graticule arrangements are used. A normal transparent graticule may be spaced as much as $\frac{3}{8}$" in front of the trace, so that error is avoided only when the line of sight is at right angles to the screen.

The Marconi Graticule Projector utilises a partially reflecting (transparent) mirror to produce an image of the graticule in the same plane as the trace. The illuminated graticule is at right angles to the face of the cathode-ray tube, and the partially reflecting mirror is set at 45° to the tube face in such a position that the distance from the mirror to the graticule is equal to the distance from the mirror to the tube face. To compensate for small dimensional variations, an adjusting screw is provided to facilitate precise alignment for zero parallax.

Marconi Instruments oscilloscopes provide the illumination power via a miniature jack socket on the front panel. Insertion of the plug automatically disconnects the supply from the tube-face graticule lamps. The normal graticule illumination control remains operative, however, when the graticule projector is in use, so that the brilliance may be adjusted to suit the intensity of the trace. A red filter can be inserted, if desired, for additional clarity.

Graticule Masks

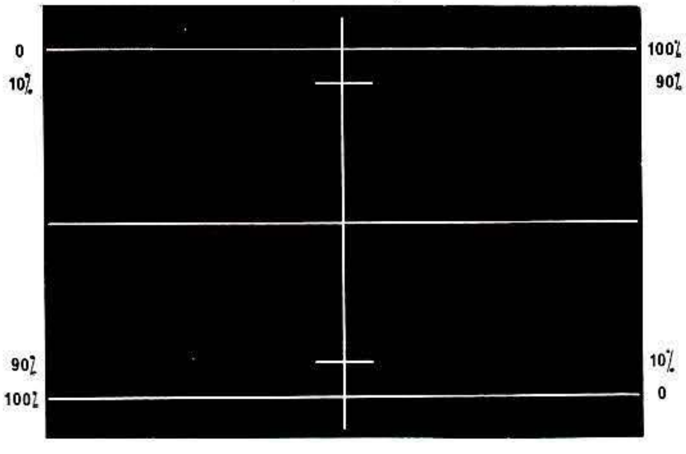
The standard graticules available are listed below. Special graticules can easily be made by the user to suit particular purposes – they can be drawn on Ilford 'Scribecoat' for direct insertion into the projector; or photo negatives can be made from ordinary ink drawings. A sample waveform can be projected by simply inserting a positive transparency photograph of the correct waveform into the graticule holder.

General purpose graticules are marked with easily distinguishable lines denoting the 100% and 90% dimensions for measurement of rise times, etc. With the waveform fitting exactly between the 100%, the 10% and 90% levels are clearly indicated.

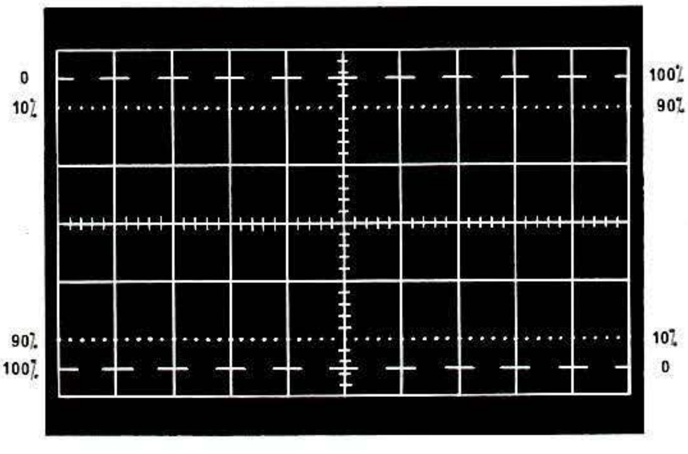
General Purpose Masks

One set of graticule masks is supplied with each projector as follows:

TB 43595 Three Line (5×10 cm)

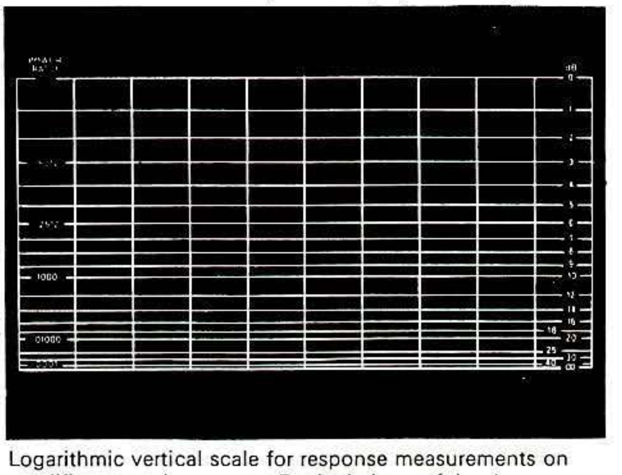


TB 43535 Centimetre Grid (5×10 cm)
TB 43536 Centimetre Grid (6×10 cm) (Illustrated)



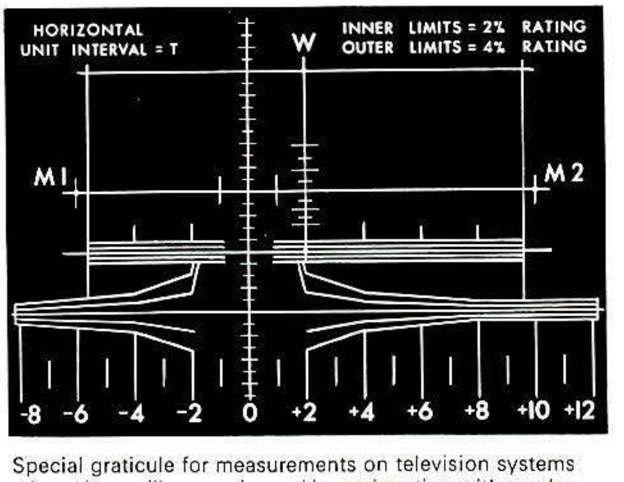
Special Purpose Masks

TB 44808 Decibel Scale (5×10 cm)
TB 44809 Decibel Scale (6×10 cm) (Illustrated)



Logarithmic vertical scale for response measurements on amplifiers, receivers, etc. Particularly useful when an oscilloscope is used as the indicator in a dynamic response measurement system.

TB 43596 K-Factor (5×10 cm)



Special graticule for measurements on television systems where the oscilloscope is used in conjunction with a pulse and bar generator or a grey scale generator.

Scribecoat

Three blank Scribecoat masks are supplied with each Graticule Projector.

Bezel Adapter Kits

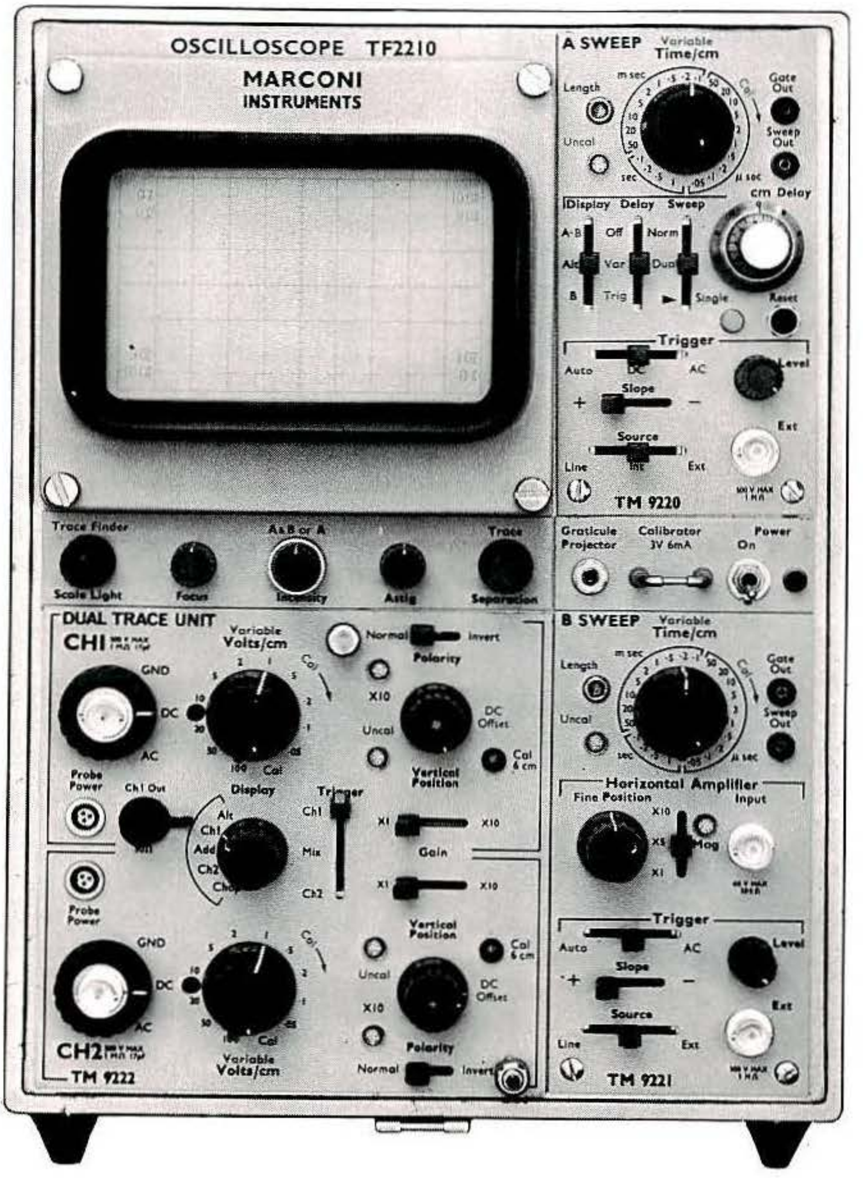
Graticule Projector TM 8098 is designed to fit the rectangular bezel of the current range of Marconi oscilloscopes.

Older oscilloscopes, having the 5⅝" round bezel, can be converted to take the Graticule Projector by the use of Adaptor Kit TM 8729.

Oscilloscopes with 5" round bezels of the four-stud fixing type, as used on the Tektronix '500' series, can be converted to take the Graticule Projector by use of Adapter Kit TM 8513.

Oscilloscope

- ☐ D.C. to 100 MHz bandwidth
- ☐ Dual trace, dual time bases
- ☐ Very comprehensive sweep facilities
- ☐ Suitable for computer servicing



The TF 2210 is a wide band measuring oscilloscope suitable for detailed observation of electrical waveforms and transients with rise times down to 3·5 nsec. Computer servicing presents some of the more exacting requirements that can be met by this instrument, the fast response, low drift, and comprehensive sweep facilities being particularly pertinent to this application.

Reliability This oscilloscope has been designed for continuous use in circumstances where development of any significant calibration errors could cause as much difficulty as total failure. Careful attention has, therefore, been given to the aspect of reliability. Solid-state active circuit elements are used throughout the instrument, with the exception of seven cathode followers. These are Nuvistor valves, which are largely unsusceptible to microphony but afford adequate protection against accidental input overload. Use of transistors for all other electronic actions eliminates effects caused by valve aging, so that the calibration remains constant over very long periods.

Care has also been taken to protect the instrument from damage by accidental misuse. Its power supply, for example, contains two protective features – a warning is given by flashing of the indicator lamp if the wrong mains supply voltage is used; and a short circuit on any internal power line causes no damage as a protection circuit immediately shuts down the power supply completely.

With such refinements included in its design the TF 2210 can safely be entrusted to the less skilled personnel or used under the rugged conditions often imposed by routine maintenance applications.

THE DISPLAY

A rectangular-screen cathode-ray tube of advanced design is used, incorporating a distributed plate deflection system to reduce the effect of transit time when displaying high speed waveforms.

The display area is 6 cm (vertical) by 10 cm (horizontal). Parallax error is obviated by an internal graticule, which takes the form of a 6×10 cm grid with the 10% and 90% vertical full-scale levels marked with a dotted line. Provision is also made for use of the Graticule Projector TM 8098 when a special graticule is required.

Adequate brightness for full utilisation of the instrument's performance is assured by the 13·5 kV p.d.a. voltage; and, in addition to the normal ***Intensity*** and ***Focus*** controls, the display system of the TF 2210 has special provision for adjusting relative brilliance of various portions of a multi-trace display. Intensity modulation of the beam can be applied externally via a socket on top of the instrument.

VERTICAL DEFLECTION

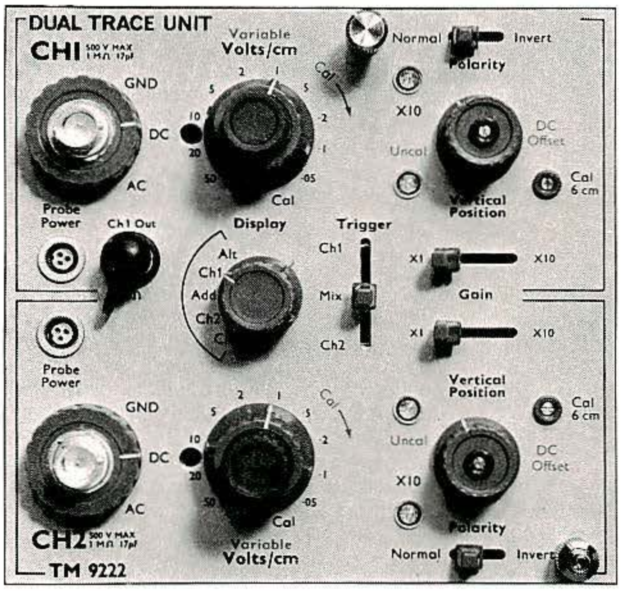
The whole of the dual-trace vertical amplifier is contained in a plug-in unit. This has obvious advantages for servicing, and is a form of construction that provides a capability for possible future extension of performance.

The dual-trace unit comprises two identical input channels with provision for displaying two input waveforms in any one of the following ways:

(a) They can be displayed separately, the desired input channel being selected by means of a switch.

(b) They can be displayed simultaneously utilising the beam-switched dual-trace mode of operation. The beam switch can be set to display the two channel waveforms on alternate sweeps, or it can chop from one channel to the other at a nominal switching rate of 1 MHz.

(c) They can be added algebraically and displayed as a single composite waveform. As there are polarity reversing switches for both input channels this mode can be used to provide differential input facilities.



Input Sensitivity The effective sensitivity of each Y channel is determined by the settings of its input attenuator and variable gain control, which gives continuous cover between attenuator steps. These two controls are mounted coaxially for ease of identification and economy of panel space. With the variable gain control set fully clockwise the nominal sensitivity is indicated directly in volts/cm by the attenuator setting. When the variable gain control is rotated away from its fully clockwise setting an ***Uncal*** warning lamp lights up.

In addition to the variable gain control, which does not affect the bandwidth of the Y amplifier, there is a ***X1 – X10 Gain*** switch for each channel. In the *X1* position of this switch the sensitivity is that indicated by the attenuator setting and the Y bandwidth is d.c. to 100 MHz. With the switch in the *X10* position the sensitivity is increased ten times, but the upper cut-off frequency is reduced to 75 MHz. A warning lamp lights when the *X10* position is selected.

Calibrating Waveform By setting the attenuator switch to its *Cal* position an amplitude-stabilised 1 kHz squarewave may be displayed for standardising the Y amplifier gain. An additional preset gain control for each channel is accessible from the front panel. With this control adjusted for a calibrating squarewave amplitude of 6 cm p–p the channel sensitivity is within 3% of nominal at all attenuator settings.

The calibrating squarewave is also available at the front panel so that the overall gain may be standardised when an active probe or current probe is in use. The outlet takes the form of a bare metal bar, carrying a 6 mA p–p squarewave current for use with current probes, at 3 volts p–p squarewave potential with respect to chassis.

Cascading Channels The output from the *Channel 1* preamplifier is brought to a front panel socket, which can be linked to the *Channel 2* input socket, thus connecting the two preamplifiers in cascade. With the gain of each channel switched to *X10*, the oscilloscope can then function as a single channel instrument with an overall sensitivity of 500 μV/cm.

The bandwidth in this condition is nominally 15 MHz; but, in order to restrict the noise, it is possible to reduce the upper cut-off frequency to 1 MHz by operation of an internal switch. Access to this switch is obtained by withdrawing the dual trace unit from the oscilloscope.

TF 2210

Vertical Shift A separate shift control for each channel enables the display to be moved vertically through at least 16 cm. The shift voltage is injected at a late stage in the amplifier in order to avoid interaction between the vertical position of the trace and the triggering voltage.

An auxiliary preset *D.C. Offset* control is also provided. This control adjusts the level of a d.c. shift voltage applied to the amplifier input, and enables the operator to compensate for a d.c. component of up to 0·15 volts in the input waveform that would possibly bias the displayed waveform off the viewing screen when the *X10 Gain* position is selected. This control gives 30 cm of shift at *X10 Gain*.

HORIZONTAL DEFLECTION

The comprehensive sweep facilities of the TF 2210 are obtained by the use of two identical time base generators, built into separate plug-in sweep units designated ***A Sweep*** and ***B Sweep***. For normal operation the horizontal deflection waveform is derived from the ***B Sweep*** unit, which, in addition to its time base generator and associated trigger system, contains the horizontal amplifier with the X shift and gain controls. Although horizontal deflection can also be obtained over the same range of sweep speeds from the ***A Sweep*** unit, this unit functions as the delay generator when the oscilloscope is used in one of its delayed sweep modes. It therefore carries the sweep mode selector controls and, of course, a calibrated variable delay control.

Sweep and Trigger The sweep velocity of each time base is controlled by means of a 23-position selector switch in conjunction with a coaxially mounted continuously variable control. With the variable control set fully clockwise, the selector switch setting indicates the sweep velocity directly in time/cm. When the variable control is turned back from its "calibrated" setting an *Uncal* warning lamp lights up.

The horizontal amplifier provides switch selected magnifications of X1, X5 and X10, so that, by using the magnifier in conjunction with the velocity selector switch, the total range of calibrated sweep speeds extends from 0·1 sec/cm to 5 nsec/cm. By use of the variable gain control the uncalibrated range can be further extended to obtain slow sweep speeds of 2·5 sec/cm.

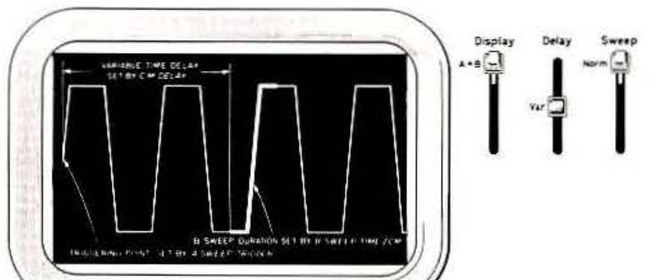
Both time base generators can be triggered internally or externally. The design of the trigger system achieves maximum trigger stability with extreme simplicity of operation.

Normal a.c. or d.c. coupled triggering with slope and level selection can be used at all frequencies up to 40 MHz. For general purpose operation where the trigger point is unimportant and for display of r.f. waveforms up to 100 MHz the auto-triggering facility may be used. At low and medium frequencies the system is indeed fully automatic, requiring no adjustment whatsoever to obtain a stable display. At high frequencies some adjustment of the trigger ***Level*** control may be necessary to obtain perfect synchronisation. With the oscilloscope set for auto-triggering a visible trace is present at all settings of the ***Level*** control whether or not a signal is applied.

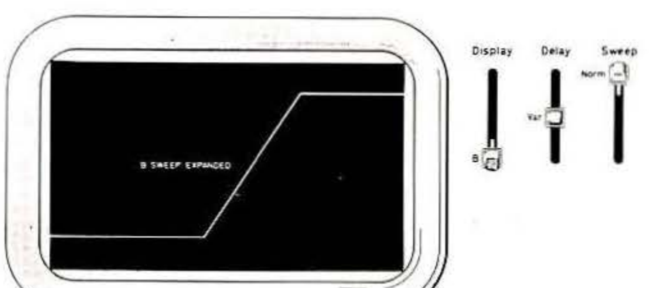
Sweep Functions The waveform under observation can be displayed using either the *A* or *B* time base, or the two time base generators can be used together in a number of different ways. The mode of operation is determined by the settings of three lever switches on the ***A Sweep*** unit panel.

Probably the most common delayed sweep requirement is that of examining in detail some part of a waveform which is remote from a convenient triggering transient. Any part of a waveform displayed on the *A* sweep can be displayed in expanded form, using a higher sweep speed, on the *B* sweep by means of the delay facility.

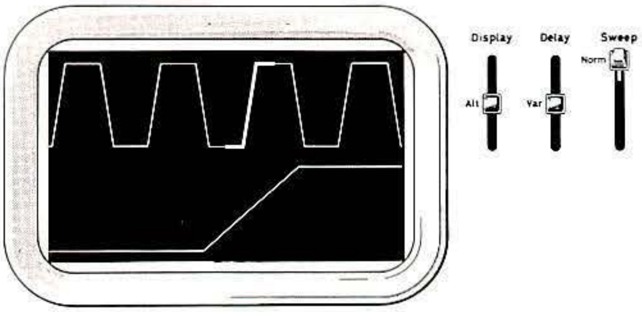
Variable Delay When the ***Delay*** switch is set to *Var* the ***B Sweep*** generator is triggered from the *A* sawtooth, the actual trigger point being selected by the continuously variable ***cm Delay*** control.



With the ***Display*** switch at *A+B* the waveform is displayed on the *A* time base, and a bright patch on the trace indicates the duration of the *B* sawtooth. The relative brilliance of the bright patch and the rest of the trace can be adjusted by use of the outer ring on the *Intensity* control.

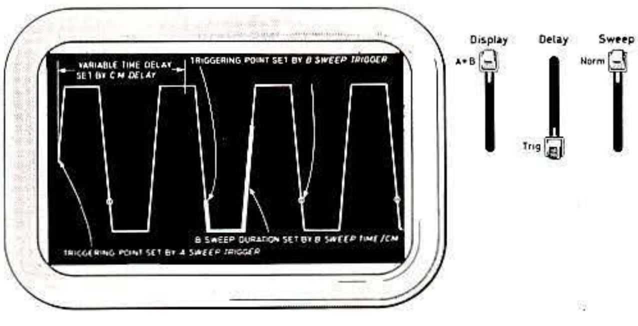


Setting the ***Display*** switch to *B* applies the *B* sawtooth to the horizontal deflection circuit, so that the part of the waveform which was in the bright patch is expanded to fill the whole trace.

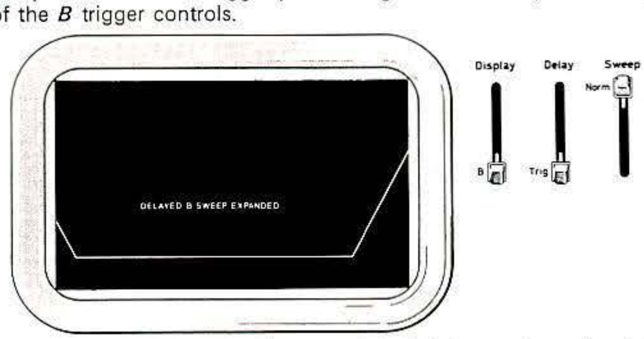


When the switch is set to *Alt* the trace is derived from the *A* and the *B* time bases on alternate sweeps. In single channel operation two traces then appear on the screen, one showing the complete waveform with the bright patch *(A+B)* and the other showing the brightened portion expanded to fill the whole trace. Separation between the two traces is adjustable over the full 6 cm.

Triggered Delay When the delay time is long compared with the duration of the *B* sweep, difficulty is sometimes experienced due to jitter caused by slight variations in the observed waveform or slight trigger instability. Very often the portion of the waveform to be examined in detail contains a suitable triggering transient; and, if so, jitter can be eliminated altogether by setting the *Delay* switch to *Trig*.



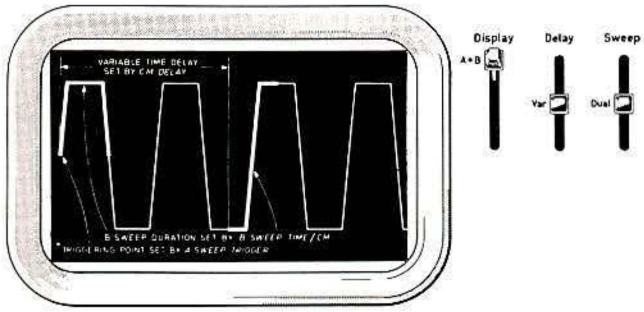
With the switch in this position the *A* sawtooth does not trigger the *B* time base directly, but operates a gating circuit to connect the observed waveform to the *B* trigger input. The *B* time base is thus started by the first suitable transient occurring after the selected delay time, the exact trigger point being determined by the setting of the *B* trigger controls.



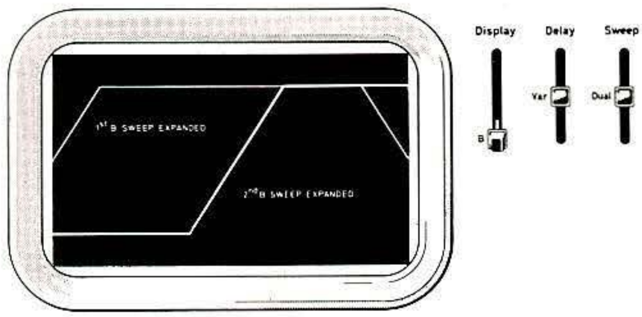
As the *cm Delay* control is rotated the bright patch on the *A+B* display does not move continuously across the trace but jumps from one trigger transient to the next.

This facility is particularly useful for examining individual pulses in a computer logic signal or for line-by-line examination of a television field waveform.

Dual Trigger The delay system can also be used as a means of providing a double image display of a waveform with variable overlap, a facility which is extremely useful for assessing the flatness of a rectangular pulse top.



With the *Sweep* switch set to *Dual* and the other sweep function switches set for variable delay, the initial trigger pulse starts both the *A* and the *B* time bases. After a delay, determined by the setting of the *cm Delay* control, the *B* time base is triggered again to produce the second image. By adjustment of the *cm Delay* control this second image can be so positioned on the trace that the amplitudes of any two parts of the waveform can easily be compared.



Single Sweep Operation By setting the ***Sweep*** switch to the *Single* position, the condition is produced where the triggering system responds to the first triggering transient to occur after the ***Reset*** button is pressed, but ignores any subsequent ones.

The single sweep mode can be used with either form of delayed sweep to produce an *A+B* or a *B* display for photographic purposes.

Time Measurement With the ***Variable*** sweep speed control in its *Cal* position, time measurements can be made directly from the cathode-ray tube's internal calibrated graticule. For greater discrimination the waveform may be displayed with the oscilloscope set for *A+B* display with variable delay, and the bright patch used as a time marker. The *cm Delay* control, read in conjunction with the ***Time/cm*** setting gives an accurate indication of time interval.

TF 2210

CATHODE RAY TUBE	Philips D13 450GH/03 with P31 phosphor and internal graticule.
Display area	6 cm x 10 cm.
Trace locate	The ***Trace Finder*** button brings the trace into the window for all positions of the shift controls and causes the time base to free-run.
Vertical plate sensitivity	Nominally 3 volts/cm.
Horizontal plate sensitivity	Nominally 11 volts/cm.
Z modulation	Requires positive-going current pulses of 5 mA p–p into 50 Ω to increase trace brightness. Bandwidth from d.c. to 10 MHz.
CALIBRATION UNIT	Available at front panel loop marked *Calibrator*.
Square wave	3 volts p–p ±1% at 1 kHz from a source impedance of less than 500 Ω.
Switched current	6 mA p–p ±1% at 1 kHz.
VERTICAL AMPLIFIER	
3 dB bandwidth	
D.C. coupled input	x 1 (50 mV/cm) d.c. to 100 MHz. x 10 (5 mV/cm) d.c. to 75 MHz.
A.C. coupled input	x 1 (50 mV/cm) 4 Hz to 100 MHz. x 10 (5 mV/cm) 4 Hz to 75 MHz. L.F. response extended to 0·4 Hz when used with TM 8561 probe switched to *x 10*.
Pulse response	With the switched gain control at *x 1*, the rise time is better than 3·5 nsec. for an overshoot of not greater than 5% for any position of the ***Variable Volts/cm, Polarity*** and ***Vertical Position*** controls. With the switched gain control at *x 10*, the rise time is better than 4·7 nsec. for an overshoot of not greater than 5% for any position of the ***Variable Volts/cm, Polarity*** and ***Vertical Position*** controls.
Sensitivity ranges	Eleven switched ranges in 1–2–5 sequence from 50 mV/cm to 100 volts/cm. A twelfth position *(Cal)* on the attenuator switch permits gain standardisation by screwdriver adjustment of a preset control. x 10 magnifier giving a sensitivity of 5 mV/cm to 10 V/cm.
Accuracy	x 1 position ±3%, x 10 position ±3% } using internal calibrator. x 10 gain ±3% internally set.
Variable gain control	Cover: greater than 2·5:1. Indicator lamps show when the unit is being operated in uncalibrated and x 10 gain conditions.
Window	±30 cm at all sensitivities. (In calibrated positions at low frequencies.)
Input impedance	1 MΩ, with 17 pF in shunt, at all sensitivities.
Maximum voltage	500 volts combined d.c. and a.c. peak.
Apparent signal delay	Greater than 40 ns.
Power socket	Provides for connection to a FET probe, (i.e. Tektronix P6045).
Vertical position range	Uncalibrated control enables the display to be moved through at least 16·0 cm.
D.C. offset	±0·15 volts at all sensitivities. (Screwdriver adjustment.)
Polarity inversion	Signals on channel 1 and channel 2 may be inverted independently.
Vertical display modes	
Alternate	Display alternates between channel 1 and channel 2.
Channel 1	Channel 1 only.
Add	Algebraic sum of channel 1 and channel 2 (i.e. ± channel 1 ± channel 2).
Channel 2	Channel 2 only.
Chop	Chop repetition rate approximately 1 MHz.
Trigger selection for time base	Channel 1 only. Mixed. Channel 2 only.
Common mode breakthrough	Suppression better than 40 dB at 1 MHz
Socket-to-socket breakthrough	Suppression better than 70 dB at 100 MHz.
Gate breakthrough	Suppression better than 35 dB at 100 MHz.
Vertical linearity	Less than 0·5 mm compression or expansion of a 2 cm signal when positioned to the vertical extremes of the display area.
Time difference between channels	Less than 0·5 nsec.
Channel 1 output	Switched internally (normally used in *Narrow* position).
3 dB bandwidth	Wide band: D.C. coupled: d.c. to 15 MHz. A.C. coupled: 4 Hz to 15 MHz. Narrow band: D.C. coupled: d.c. to 1 MHz. A.C. coupled: 4 Hz to 1 MHz.
Output impedance	Nominally 50 Ω.
Gain	x 1 or x 10 according to the position of the magnifier.
Channel 1 and channel 2 in cascade	
Sensitivity	Maximum sensitivity 500 µV/cm (nominal).
Bandwidth	Switched internally (normally in *Narrow* position). Wide band: D.C. coupled: d.c. to 15 MHz. A.C. coupled: 4 Hz to 15 MHz. Narrow band: D.C. coupled: d.c. to 1 MHz. A.C. coupled: 4 Hz to 1 MHz.
Noise	Less than 3·5 mm at maximum sensitivity (500 µV/cm; minimum bandwidth).
HORIZONTAL AMPLIFIER	
Magnifier	Three switched ranges, x 1, x 5 and x 10, extending the fastest sweep range to 5 nsec/cm.
External horizontal magnifier	Three switched ranges x 1, x 5 and x 10, giving a sensitivity of 1 volt/cm, 0·2 volts/cm and 0·1 volt/cm.
Bandwidth	From d.c. to 5 MHz (typically).
Accuracy	±3%.
Input impedance	Approximately 10 kΩ shunted by approximately 60 pF.
Maximum input voltage	40 volts combined d.c. and a.c. peak.
Horizontal positioning controls	Coarse: typically ±9 cm of control. Fine: typically ±0·9 cm of control.
SWEEP GENERATORS	Two identical sawtooth generators. A (delaying time base) and B (normal or delayed time base).
Sweep rate	Twenty-three switched ranges in 1:2:5 sequence covering the range 50 nsec/cm to 1 sec/cm.
Variable sweep rate	Uncalibrated control gives a velocity reduction of not less than 2·5:1. The indicator light shows when the time base is being operated in an uncalibrated condition.
Overall accuracy	±3%.
Trace length	Nominally 7 to 13 cm, set by panel preset.
Trigger modes	*Auto:* 50 Hz to 10 MHz from a 4 mm display, degrading to 1 cm at 100 MHz. *D.C.* coupled: d.c. to 10 MHz from a 3 mm display, degrading to 1 cm at 40 MHz. *A.C.* coupled: 20 Hz to 10 MHz from a 3 mm display, degrading to 1 cm at 40 MHz.
Trigger source	*Internal:* positive or negative. *External:* positive or negative. *Line:* positive or negative.
External trigger	
Sensitivity	Better than 75 mV at 100 kHz.
Input impedance	1 MΩ shunted by 25 pF.
Maximum input voltage	500 volts.
Trigger level	Internal window greater than 12 cm. External window greater than 3 volts.
Sweep output	Positive-going with respect to earth.
Amplitude	4 volts p–p nominal (for a 10 cm trace).
Output resistance	Less than 500 Ω.
Gate output	Positive with respect to earth.
Amplitude	4·5 volts p–p nominal.
Output resistance	Less than 250 Ω.
SWEEP DELAY	
Sweep display modes	Three switches, each with three positions, give the following sweep display combinations:
Normal	*(A)+(B)*: *(A)* sweep is triggered by the signal. *(+B)* is only operative on delay positions. *(B) only*: *(B)* sweep is triggered by the signal. *Alt*: *(A)* and *(B)* sweeps alternately displayed.

Variable delay — *(A)+(B)*: The delaying sweep, *(A)*, is triggered by the signal and, after an adjustable delay, triggers sweep *(B)*. The brightened portion of the sweep indicates the position and duration of the delayed sweep (the position being adjustable to the left or right by the delay time multiplier).
(B) delayed: This expands the brightened portion of the sweep (as displayed in the *(A)+(B)* mode of operation) to the full width of the c.r.t.
Alt: *(A)+(B)* and *(B)* delayed modes displayed alternately.

Triggered delay — *(A)+(B)*: The delaying sweep *(A)* is triggered by the signal and, after an adjustable delay, opens a gate which allows sweep *(B)* to be triggered. The brightened portion of the sweep indicates the position and duration of the *(B)* sweep. The gate is closed after one *(B)* sweep excursion.
(B) delayed: This expands the brightened portion of the sweep (as displayed in the *(A)+(B)* mode of operation), to the full width of the c.r.t.
Alt: *(A)+(B)* and *(B)* delayed modes displayed alternaltely.

Sweep delay — 0·05 µs to 10 sec continuously variable with the *cm Delay* control.

Sweep delay accuracy — ±2% (+ 100 nsec fixed delay).

Sweep delay jitter — Better than 1 part in 20 000 of maximum delay.

DUAL TRIGGERING

Variable delay — *(A)+(B)*: The delaying sweep *(A)* is triggered by the signal. Sweep *(B)* is triggered twice, first undelayed and coincident with the start of the *(A)* sweep, and second after an adjustable delay. The brightened portions of the sweep indicate the position and duration of the *(B)* sweeps (the position of the delayed *(B)* sweep being adjustable by the delay time multiplier).
(B) delayed: This expands both of the brightened portions of the sweep (as displayed in the *(A)+(B)* mode of operation) to the full width of the c.r.t. Hence signals on the *(B)* sweep may be superimposed.
Alt: *(A)+(B)* and *(B)* delayed modes displayed alternately.

Triggered delay — *(A)+(B)*: The delaying sweep *(A)* is triggered by the signal. Sweep *(B)* is triggered twice, first undelayed and coincident with the start of the *(A)* sweep, and secondly after an adjustable delay opens a gate which allows the delayed sweep *(B)* to be triggered. The brightened portions of the sweep indicate the position and duration of the *(B)* sweeps (the position of the delayed *(B)* sweep being adjustable by the delay time multiplier).
(B) delayed: This expands both of the brightened portions of the sweep (as displayed in the *(A)+(B)* mode of operation) to the full width of the c.r.t. Hence signals on the *(B)* sweep may be superimposed.
Alt: *(A)+(B)* and *(B)* delayed modes displayed alternately.

Single sweep — A three-position switch having *Normal*, *Dual Trigger*, and *Single Sweep* positions, permits single shot operation on all sweep display modes except *Alternate*.

POWER REQUIREMENTS

200 to 250 volts or 100 to 130 volts a.c. 45 Hz to 500 Hz. 180 VA.
All regulated lines are overload protected.

DIMENSIONS AND WEIGHT

Height	Width	Depth	Weight
13 in	9 in	21·5 in	49·5 lb
(325 mm)	(225 mm)	(538 mm)	(22·5 kg)

ACCESSORIES

Supplied

- Green Filter B37533–710 and Rubber Mask Part No. 37186–105.
- Two 2 mm Belling Lee (black) plugs Part No. 23431–057.
- Two 2 mm Belling Lee (red) plugs Part No. 23421–056.

Optional

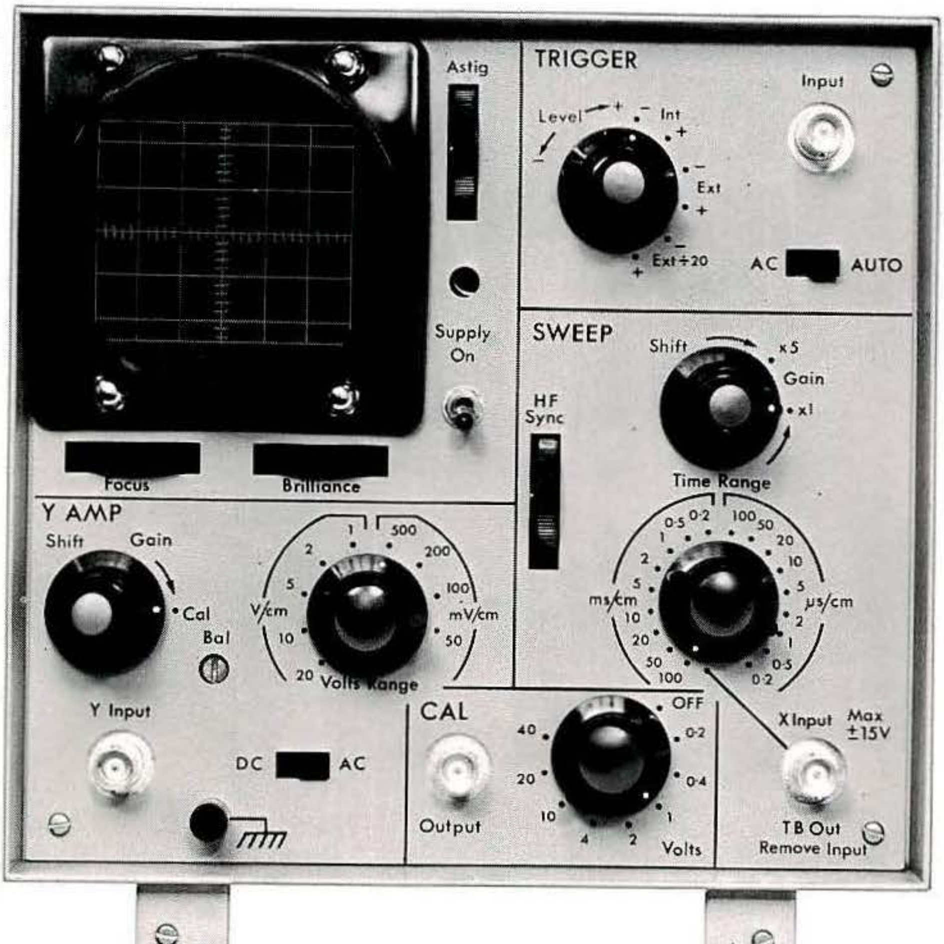
TM 8098	Graticule Projector
TM 7424M	Oscilloscope Trolley
TM 8550M	Mini-trolley
TM 7991	Polarizing Filter
	Extension cables for servicing plug-in units
TD 43245	Viewing Hood.

PROBES The following probes are suitable for use with this oscilloscope:

TM 8563M	Passive probe ×100
TM 8561	Passive probe ×1, ×10 (70 MHz bandwidth).
	Tektronix Passive probe ×10, P6047.
	Tektronix FET probe, P6045.

PLUG-IN UNITS Dual Trace Unit TM 9222 and 'A' Sweep Unit TM 9220 are manufactured separately. When ordering the complete equipment, therefore, these items should be listed together with Oscilloscope TF 2210 and any optional accessories required.

- Light weight
- Full 20 MHz bandwidth
- Stable trigger over full bandwidth
- Long term reliability
- Low power consumption
- Mains or battery operation



Oscilloscope TF 2203 is intended to meet the increasing demand for an accurate, portable, but inexpensive oscilloscope. An ergonomically designed front panel presents a neat appearance, coupled with the minimum number of operations to produce a steady display. Transistors have been used to achieve high performance, low power consumption, and long term reliability. Compactness and easy servicing is made possible by the use of printed boards, thereby reducing maintenance costs.

The vertical amplifier is d.c. coupled, with a 3 dB bandwidth extending to 20 MHz. Voltage measurement, to an accuracy better than 5%, is carried out using a removable perspex graticule, ruled in centimetre squares. The input circuit of the amplifier has an impedance of 1 MΩ in parallel with 28 pF. Constant input capacitance is maintained on each of the attenuator ranges, a useful feature when using the instrument in conjunction with a frequency compensated, high impedance probe. To avoid damage when a large unattenuated voltage is inadvertently applied, a cathode-follower valve is used to couple the signal to the input transistors. Adequate overscan of the screen without distortion is possible, and a shift of at least 15 cm is available.

The internal horizontal sweep generator has 18 preset calibrated sweep speeds, from 100 msec/cm to 200 nsec/cm. By using the X5 sweep expansion the range can be extended to 40 nsec/cm. Measurement of time is made using the ruled graticule, giving an accuracy better than 5%. The horizontal amplifier is d.c. coupled with a 3 dB bandwidth of 4 MHz at a sensitivity of 1·5 V/cm. In the X5 position a sensitivity of 300 mV/cm can be realised with a reduced bandwidth.

The sweep generator may be triggered with a pulse obtained from an external source or derived internally from the waveform being examined. Provision is made for level control to allow triggering at any selected level on positive or negative going transients. The simplest mode of operation is with the sweep generator free running, made possible by setting the AC/AUTO switch to AUTO. In this mode the repetition rate of the sweep generator is varied in three steps, depending on the sweep range selected. Sensitivity is 0·2 cm on internal and 0·2 volts on external, and stable triggering is obtainable from 5 Hz to 20 MHz. If the amplitude of a large external signal is beyond the range of the level control, a 20:1 attenuator may be switched into circuit.

A voltage calibrator is included which produces a square wave at approximately 7 kHz with a rise time of less than 1 μsec. 8 switched levels are provided, with the facility for the highest level of 40 volts to be accurately set by reference to an external d.c. voltmeter.

High resolution, flat screen, with display area of 5 cm × 6 cm are the features of the 3 inch cathode ray tube. Facilities are also provided for an external input to modulate the brilliance of the display.

All d.c. circuit voltages are obtained from a stabilised d.c. to d.c. converter. The oscilloscope therefore requires a 12 volts d.c. primary supply, which is produced by either a battery or from the mains by rectification. Overall power consumption is low being 25 watts a.c. or 20 watts d.c.

Provision is made for operation directly from the a.c. mains supply or from an external battery; and there is also a housing for an internal battery, with the charger built into the instrument. Suitable batteries for internal or external use are available as optional accessories.

The instrument is soundly constructed yet light in weight. Use is made of plastic covered aluminium for the case, with a silk screen printed front panel.

TF 2203

Vertical Deflection System

Y-AMPLIFIER	
Bandwidth	D.C. to 20 MHz (−3dB) at cal
Rise time	23 nsec.
Overshoot	Less than 1%.
Sensitivity	50 mV/cm. Maximum usable input: a signal producing a deflection of ±7·5 cm peak, when the fine gain control is set to maximum, can be displayed without distortion.
INPUT SELECTION	An a.c./d.c. coupling slider switch is included. The a.c. response is −3 db at 3 Hz.
Input impedance	1 MΩ in parallel with 28 pF.
Connectors	U.H.F. 83.
AMPLITUDE CONTROLS	
Fine gain	3:1 in combination with the attenuator enables sensitivity to be continuously adjusted over the range 50 mV/cm to 60 V/cm.
Attenuator	A 9 position switch gives calibrated sensitivities of 50 mV/cm to 20 V/cm in a 1–2–5–10 sequence.
Maximum input	500 volts d.c. or d.c.+a.c. peak.
MEASUREMENT AND SHIFT	
Voltage measurement Accuracy	Better than ±5%.
Y-shift range	At least 15 cm.

Horizontal Deflection System

INTERNAL TIME BASE	
Sweep speeds (unexpanded)	An 18-position switch gives calibrated speeds from 200 nsec/cm to 100 msec/cm in 1–2–5–10 sequence.
Sweep expansion	Continuously variable up to X5, calibrated at X1 and X5.
Linearity	±2%.
Sweep mode	Triggered, with variable hold-off time for steady locking.
MEASUREMENT AND SHIFT	
Measurement Accuracy	Better than ±5%.
X-shift range	At least 18 cm of shift available.
TRIGGER FACILITIES	
Sources	External signal, internal signal, or external attenuated 20:1, positive or negative in each case.
Modes	*A.C.:* (level control operative). *Automatic:* (level control inoperative).
Bandwidth	5 Hz to 20 MHz.
Sensitivity	*Internal:* 0·2 cm. *External:* 0·2 volts.
Input impedance	1 MΩ in parallel with 25 pF approximately at X1 and 5pF at 20:1.
EXTERNAL TIME BASE	
X Amplifier bandwidth	D.C. to 4 MHz (−3 dB) at X1.
Input sensitivity	1·5 V/cm approximately at X1.
Input impedance	2000 Ω approximately.
VOLTAGE CALIBRATOR	
Frequency	7 kHz approximately.
Rise time	Less than 1 μsec.
Levels	200 and 400 mV, 1, 2, 4, 10, 20 and 40 volts.
Accuracy	The 40 volts level can be accurately set by reference to an external d.c. voltmeter. All other levels are related to it with a maximum error of ±2%.

Additional Facilities

Z modulation	Facilities are provided for an external input. Approximately 50 volts fully modulates the brilliance of the display.
CATHODE RAY TUBE	
Type	(EMI) 3 inch diameter, high resolution flat screen.
Display area	5 cm×6 cm.
E.H.T.	3 kV approximately.
POWER REQUIREMENTS	
AC mains	110 volts a.c. nominal (97 volts to 132 volts absolute), 50-60 Hz or 220 volts a.c. nominal (195 volts to 265 volts absolute), 50-60 Hz
External D.C. or internal battery	12 volts d.c. nominal (11 volts to 14 volts absolute), positive side earthed. Power consumption: 25 watts a.c., or 20 watts d.c. Fuses: 1 amp when operated on a.c. 3 amps when operated on 12 volts d.c.
DIMENSIONS AND WEIGHT	Height 8½ in, 21·6 cm; Width 8½ in, 21·6 cm; Depth 13 in, 35·6 cm; Weight 15 lb, 6·80 Kg
FINISH	Light and dark green and stove enamel with a silk screen printed front panel.
AMBIENT TEMPERATURE	−5°C to +40°C (dry).
ACCESSORIES	
Supplied	Two U.H.F. plugs, type 83. One B.N.C. female/U.H.F. male adapter.
Optional TM 8110	X1 - X10 Attenuator Probe.
TM 8120	Low Capacitance Probe.
TM 9714	Leather carrying case
	Internal Battery

Electronic Counters

120 MHz Frequency Counter

- Direct indication from 10 Hz to 120 MHz.
- Plug in converters for frequencies up to 3.4 GHz.
- Plug in amplifier for 1 mV sensitivity.
- Positive or negative logic b.c.d. output.
- Programmable version to special order.

The TF 2410 is a wide-range digital frequency measuring instrument. With its *Frequency Count* plug-in function unit it is capable of direct indication of frequency from 10 Hz to 120 MHz: or the measurement range can be extended to 3·4 GHz by the use of plug-in heterodyne converter units. Two of these units are available—type TM 8334, covering 50 to 600 MHz, and type TM 8094, covering 402 MHz to 3·3 GHz (heterodyne reference frequency).

The main body of the instrument contains the power unit, the internal frequency standard with its associated divider units, the counting decades, and the display. It is necessary to insert a plug-in function module to operate the instrument, the action and specification of each of the plug-in modules available being given later.

The Display

The display system comprises an eight-digit Nixie readout, with automatic indication of decimal point and units of measurement (kHz or MHz). An important feature is the display memory, which maintains the display while the count is in progress. A continuous coherent readout is provided, with only those digits that alter being affected by successive counts. Steadily drifting frequencies can, therefore, be monitored at a high sampling rate without ambiguity. The memory can be switched on or off so that, if desired, the display can be made to follow the decades as the count proceeds.

The display time is continuously variable, by means of a vertical edge-wise control, from about 0·1 to 5 seconds. With the control in its fully 'down' position the display is held indefinitely until the *Reset* button is pressed.

The Time Standard

The gate times are derived internally from a 16 MHz oven controlled crystal oscillator, having a very short warm-up time. It reaches a frequency within 0·4 p.p.m. of its final value in less than 90 seconds from switching on. The output from this oscillator passes through a series of binary dividers to give a standard frequency of 1 MHz, which is available from a socket at the rear and is also applied to the time-base divider circuits.

An external 1 MHz frequency standard can be used, if desired, instead of the internal one, the standard-frequency signal being applied via a BNC socket at the rear of the instrument.

Gate Times

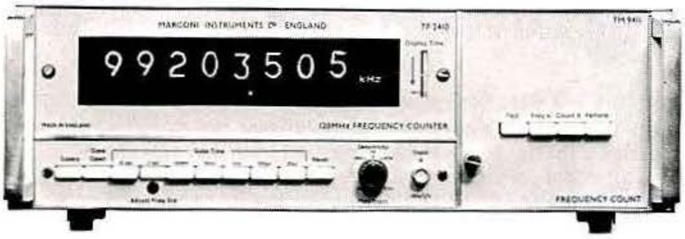
Seven push-button switches select gate times from 10 sec down to 10 µsec, the decimal point being positioned and the appropriate units of measurement shown automatically when the gate time is selected. The gate can be opened manually by pressing the *Gate Open* button, which remains in the depressed position until it is pressed a second time to release it. When the switch is released the counter reverts immediately to normal automatic operation.

Sensitivity

The sensitivity of the counter is controlled by the setting of a three position switch, marked in nominal sensitivity and maximum input voltage. Providing adequate input is applied the level for reliable triggering is not critical, but, for convenience, an indicator lamp on the display panel glows when a suitable triggering level is reached.

Printer Output
A four-line b.c.d. 1-2-4-8 output for driving a printer or other peripheral equipment is available via a plug-in logic unit at the rear of the instrument. TF 2410 accepts either of two units, available as optional accessories, which deliver positive or negative logic output respectively.

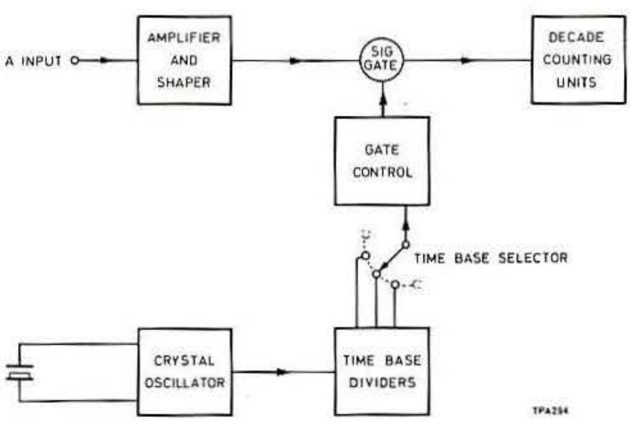
Frequency and Count to 120 MHz



TF 2410 with plug-in Frequency Count Module TM 9411.

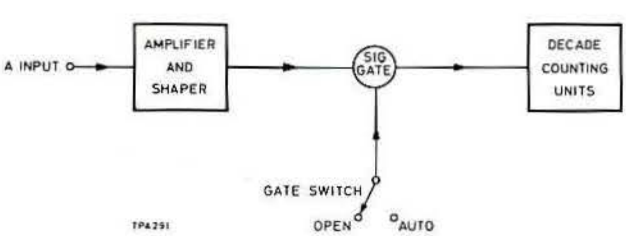
With this plug-in module the TF 2410 can be used for direct indication of frequency up to 120 MHz or simple totalisation at speeds up to 12 x 10^7 events per second. There is also a self test facility and, as an optional extra, provision for remote programming. These functions are selected by push button switches on the front panel of the plug-in module.

Frequency Measurement
Direct measurement of frequency between 10 Hz and 120 MHz can be made with gate times ranging from 10 μsec to 10 seconds – push-button switch selected in decade steps.



With the *Freq A* push button depressed the instrument measures the frequency of a signal applied to *Input A* by counting the number of cycles of the input over a selected time interval. The signal gate is opened and closed by the selected output of the time base as controlled by the push-button *Gate Time* switches. During the time that the gate is open, each cycle of the input signal is counted by the decade counting units.

Totalising
With both the *Count A* button on the plug-in module and the *Gate Open* button on main panel depressed, the instrument indicates the total number of pulses fed into *Input A*.



The input is applied to the *Input A* connector. The decade counting units count the total number of cycles that occur while the gate is open. When the *Gate Open* button is released the selected time base comes into operation and, unless the *Display Time* control is set to infinity, reset is automatic.

Frequency Measurement on Low-Level Signals

TF 2410 with Video Amplifier Module TM 8517

The Video Amplifier plug-in module increases the trigger sensitivity of the counter to facilitate reliable frequency measurement with sine wave inputs as low as 1 mV r.m.s. The effective gain of the amplifier is continuously variable, so that it can also be used to assist in the selection of a suitable trigger level when measuring the fundamental frequency of a signal having a significant noise content.

In addition to increasing the counter's sensitivity, the Video Amplifier presents a high input impedance, so that frequency measurements can be made with negligible loading of the source. This attribute may be further enhanced, when higher signal levels are available, by the use of an attenuator probe, a 10 : 1 and a 100 : 1 probe being available as optional accessories.

Frequency up to 600 MHz

TF 2410 with plug-in Converter TM 8334

Frequencies above 120 MHz are measured by applying to the counter the heterodyne beat – obtained in the Converter – between the appropriate harmonic of the internal 10 MHz frequency standard and the incoming unknown signal. This harmonic is selected by adjustment of a tuning control, the settings where the beat frequency is less than 10 MHz being indicated by means of a panel meter. The tuning control carries a dial which indicates the frequency of the selected harmonic: and the beat frequency is indicated by the counter readout. So, providing the heterodyne converter is set to the harmonic immediately below the unknown frequency, the result of the measurement is obtained by adding the tuning dial reading to the counter indication.

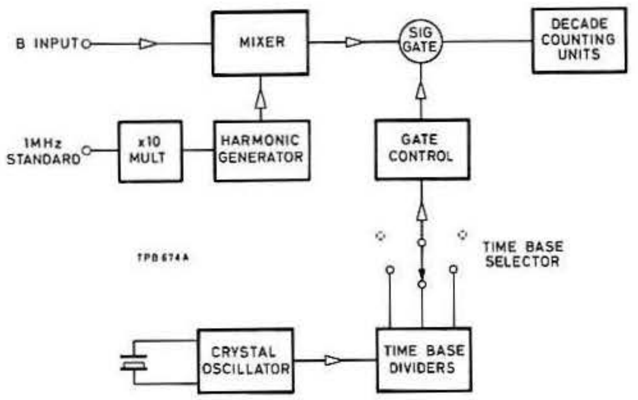
It is, of course, possible to select the harmonic immediately above the unknown frequency and still obtain a beat frequency below 10 MHz. If this is done, the counter indication should be subtracted from the tuning dial reading. It is, however, a simple matter to find the two adjacent dial settings and select the lower one, so that there is no real ambiguity.

The function modes available with this arrangement are as follows:

1. Direct measurement of frequency up to 120 MHz.
2. Frequency measurement by heterodyne conversion up to 610 MHz.*
3. Totalising.

TF 2410

* The upper frequency limit is, of course, the sum of the highest 10 MHz harmonic that can be selected and the maximum counter reading. Although the TF 2410 can respond to much higher frequencies, the maximum frequency that can be applied to the counting decades from the converter is limited by a low-pass filter having a cut-off frequency of about 11 MHz. This prevents possible confusion or ambiguity, but allows sufficient overlap for convenient measurement of frequencies close to a 10 MHz harmonic.



With the Converter's *Function* switch set to *Convert B* the instrument measures the frequency of a signal applied to *Input B* by counting the number of cycles of the difference between the input and the appropriate harmonic of 10 MHz over a selected time interval.
The signal gate is opened and closed by an output of the time base selected by the push-button *Gate Time* switches. During the time that the gate is open, the heterodyne difference frequency from the input signal and the selected 10 MHz harmonic is passed through the gate to the decade counting units.

Frequency up to 3·3 GHz

With the 3·3 GHz Converter Module in position the TF 2410 can be used for direct measurement of frequency up to 120 MHz and measurement by the heterodyne method from 300 MHz to 3·3 GHz. Measurement of frequency between 120 MHz and 300 MHz cannot be made with this combination; and for continuous coverage it is also necessary to use the 50 – 600 MHz Converter, TM 8334, as an alternative plug-in.

The tuning control of the TM 8094 Converter selects the appropriate harmonic of 100 MHz derived from the internal frequency standard of the counter. The general system of operation is otherwise similar to that of the 50 – 600 MHz Converter.

The function modes available with this arrangement are:

1. Direct measurement of frequency up to 120 MHz.
2. Frequency measurement by the heterodyne conversion from 300 MHz to 3·404 GHz*.

* The highest frequency that can be measured is determined by taking the sum of the highest 100 MHz harmonic (3·3 GHz) and the highest heterodyne frequency that can be passed to the decade counting units. In the TM 8094 the output frequency is limited to 104 MHz (nominal) by the amplifier characteristics, giving adequate overlap for convenience when measuring frequencies close to a 100 MHz harmonic.

120 MHz Frequency Counter Type TF 2410 with plug-in Frequency Count Module TM 9411

FREQUENCY RANGE		10 Hz to 120 MHz
ACCURACY		$\pm$ 1 count $\pm$ stability.
STABILITY	**Short term**	$\pm\ 2 \times 10^{-9}$ with a measurement time of 1 second, with constant temperature and supply voltage.
	Variation with temperature	$\pm\ 1 \times 10^{-8}$ per °C over the range 0°C to 50°C.
	Variation with mains supply voltage	$\pm\ 6 \times 10^{-9}$ for 10% change in voltage.
	Age rate	1×10^{-7} per month, after 30 days. The oscillator reaches a frequency within 4×10^{-7} of its final value in less than 90 seconds from switch on. The oscillator frequency may be adjusted by means of a variable capacitor.
INPUT VOLTAGE RANGE		Maximum sine wave input of 3 volts r.m.s., 30 volts r.m.s., or 70 volts r.m.s., as selected by a front panel switch.
INPUT SENSITIVITY		Nominally 0·1 volts r.m.s., 1 volt r.m.s., or 10 volts r.m.s., as selected by front panel switch. Typically better than 50 mV r.m.s. from 50 Hz to 110 MHz.
INPUT IMPEDANCE		Voltage range / Input resistance / Shunt capacitance: 3 volts, 10 kΩ ± 20%, 15 pF 30 volts, 100 kΩ ± 20%, 10 pF 70 volts, 1 MΩ ± 20%, 10 pF
STANDARD FREQUENCY		Internal 16 MHz oscillator or external from 1 MHz source.
TIME BASE		10 µsec to 10 seconds in decade steps.
DISPLAY		8 digit in line, with memory.
DISPLAY TIME		Continuously variable from approximately 0·1 to 5 seconds or held indefinitely until manually reset.
READOUT		Directly in kHz or MHz depending on the gate time selected.
SINE WAVE INPUT MONITOR		Lamp indicates when there is sufficient input to trigger the counter correctly.
REAR PANEL FACILITIES	**B.C.D. output**	Provided by optional plug-in units, TM 9412 and TM 9413.
	1 MHz standard frequency output	Square wave, 1·0 volt p-p minimum from a source impedance of 500Ω approx. Available on BNC connector.
	1 MHz external standard frequency input	Square wave or sine wave between 2 volts and 15 volts p-p into approximately 600Ω. Connected to BNC socket.
POWER REQUIREMENTS		100 to 130 volts or 200 to 250 volts, 45 to 500 Hz, 50 VA.
DIMENSIONS AND WEIGHT		Height 150 mm (5⅞ in); Width 420 mm (16½ in); Depth 380 mm (15 in); Weight 11·4 kg approx. (25 lb)
ACCESSORIES	**Supplied**	*TM 9719*, Extender Board. 16 way double sided for printed circuit boards that are accessible from the front of the instrument. Trimming tool for adjusting the crystal oscillator.
	Optional	*TM 9412*, Negative Logic Unit. Delivers negative logic b.c.d. output. *TM 9413*, Low Level Positive Logic Unit. Delivers positive logic b.c.d. output. Extender boards for holding p.c. boards clear of instrument for servicing. *TM 9720*, 24-way double sided. *TM 9721*, right angled 16-way. *TM 9722*, right angled 24-way.

PROGRAMMING INPUT	An input socket for digital programming of the functions and gate time switches can be provided to special order.

Plug-in B.C.D. Output Units
Negative Logic Unit TM 9412

B.C.D. OUTPUTS	
Weighting	1-2-4-8.
Logical '0'	0 volts nominal.
Logical '1'	− 4·5 volts minimum.
Code line impedance	10 kΩ approx.
PRINT COMMAND	
Pulse	0 volts nominal to − 6 volts minimum; approx. 100 μsec wide, occurring at end of gate time.
Output impedance	500 Ω approx.
INHIBIT	Applied contact closure between two pins on printer connector.

Low Level Positive Logic Unit TM 9413

B.C.D. OUTPUTS	
Weighting	1-2-4-8.
Logical '0'	0 volts nominal.
Logical '1'	+ 4·5 volts minimum.
Code line impedance	3·9 kΩ approx.
PRINT COMMAND	
Pulse	0 volts nominal to + 6 volts nominal; approx. 100 μsec wide, occurring at end of gate time.
Output impedance	500 Ω approx.
INHIBIT	Applied contact closure between two pins on printer connector.

Plug-in Function Modules

50 to 600 MHz Converter TM 8334

FREQUENCY RANGE	50.5 MHz to 610.8 MHz
INPUT SENSITIVITY	
Above 100 MHz	Better than 50 mV r.m.s.
Below 100 MHz	Better than 100 mV r.m.s. Typically the sensitivity that can be expected is about 25 mV r.m.s.
MAXIMUM INPUT	2·0 volts r.m.s.
INPUT IMPEDANCE	50 Ω approximately.
LEVEL INDICATOR	Meter indicates tuning and minimum input signal level required.

0·3 to 3·3 GHz Converter TM 8094

FREQUENCY RANGE	0·302 to 3·404 GHz in 100 MHz steps.
INPUT SENSITIVITY	100 mV for dial settings between 0·3 and 0·4 GHz. 50 mV for dial settings between 0·5 and 3·3 GHz.
MAXIMUM INPUT	1 volt r.m.s.
INPUT IMPEDANCE	50 Ω nominal.
LEVEL INDICATOR	Meter indicates tuning and minimum input signal level required.

Video Amplifier module TM 8517

FREQUENCY RANGE	10 kHz to 100 MHz.
SENSITIVITY	Typically 1 mV r.m.s. (Always better than 2·5 mV).
LEVEL INDICATOR	Lamp indicates adequate level for correct count.
SENSITIVITY CONTROL	Continuously variable. Assists in measurement of noisy signals by reduction of h.f. sensitivity.
INPUT IMPEDANCE	1 M Ω shunted by 15 pF.
MAXIMUM INPUT	2 volts r.m.s. sine a.c. ± 250 volts d.c.
ACCESSORIES	
Optional	TM 8561 10 : 1 Probe. Input impedance 10 MΩ, 10·5 pF. TM 8563 100 : 1 Probe. Input impedance 10 MΩ, 2·5 pF.

Useful Data

Power and Voltage Ratios in Decibels

The decibel notation is basically a method of expressing power ratio the number of decibels (N dB) being given by

$$N \text{ dB} = 10 \log_{10} \frac{P_2}{P_1}$$

where P_1 and P_2 are the two power levels under comparison.

On the assumption of constant impedance the notation is also used for voltage ratio, giving

$$N \text{ dB} = 20 \log_{10} \frac{V_2}{V_1}$$

where V_1 and V_2 are the two voltage levels.

In the above expressions the denominator (P_1 or V_1) is the reference level, so that a power or voltage may be expressed as "N dB with respect to x watts or volts". This is often contracted to dB μV (to mean decibels with respect to 1 μV), dBm (with respect to 1 mW), dB W (with respect to 1 watt), etc.

Where the numerator of the ratio is less than the denominator N becomes negative; this may be expressed as "$-N$ dB" or "N dB down", positive values of N being regarded as "N dB up" by analogy.

Tables I and II facilitate rapid conversion between decibels and voltage or power ratios. To convert decibels to voltage or power ratio use Table I; to convert voltage or power ratio to decibels use Table II.

Table I covers dB ratios up to 20 dB only. For values of N greater than 20 proceed as follows.

Let X be the whole number of times that 20 can be divided into N, to leave a remainder that falls within the range of the table. Look up the voltage or power ratio corresponding to this remainder on the appropriate side of the table. For voltage ratio "up" multiply by 10^X, and for voltage ratio "down" divide by 10^X. For power ratio multiply or divide, as appropriate, by 10^{2X}.

Table II covers voltage and power ratios from 1 to 10. For power ratios outside this range move the decimal point to the left or right to bring the figure within the range, then add 10 dB for each position that the point is moved to the left, or subtract 10 dB for each position that it is moved to the right. For voltage ratios use the same procedure, but add or subtract 20 dB instead of 10 dB. Ratios close to 1 and to 10 are given in smaller increment than the rest of the table for convenience of conversion when errors are to be expressed in decibels.

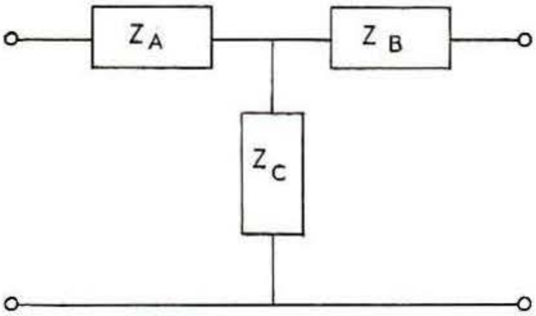
Table I

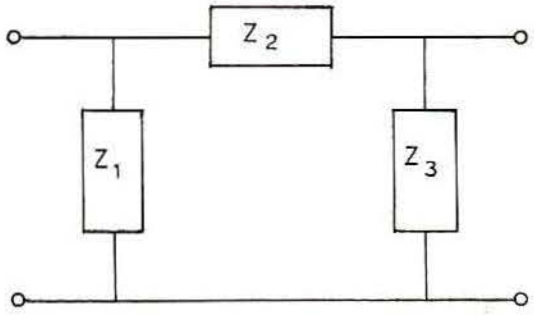
Ratio Down			*Ratio up*	
VOLTAGE	*POWER*	*DECIBELS*	*VOLTAGE*	*POWER*
1·0	1·0	0	1·0	1·0
·9886	·9772	·1	1·012	1·023
·9772	·9550	·2	1·023	1·047
·9661	·9333	·3	1·035	1·072
·9550	·9120	·4	1·047	1·096
·9441	·8913	·5	1·059	1·122
·9333	·8710	·6	1·072	1·148
·9226	·8511	·7	1·084	1·175
·9120	·8318	·8	1·096	1·202
·9016	·8128	·9	1·109	1·230
·8913	·7943	1·0	1·122	1·259
·8710	·7586	1·2	1·148	1·318
·8511	·7244	1·4	1·175	1·380
·8318	·6918	1·6	1·202	1·445
·8128	·6607	1·8	1·230	1·514
·7943	·6310	2·0	1·259	1·585
·7762	·6026	2·2	1·288	1·660
·7586	·5754	2·4	1·318	1·738
·7413	·5495	2·6	1·349	1·820
·7244	·5248	2·8	1·380	1·905
·7079	·5012	3·0	1·413	1·995
·6683	·4467	3·5	1·496	2·239
·6310	·3981	4·0	1·585	2·512
·5957	·3548	4·5	1·679	2·818
·5623	·3162	5·0	1·778	3·162
·5309	·2818	5·5	1·884	3·548
·5012	·2512	6	1·995	3·981
·4467	·1995	7	2·239	5·012
·3981	·1585	8	2·512	6·310
·3548	·1259	9	2·818	7·943
·3162	·1000	10	3·162	10·000
·2818	·07943	11	3·548	12·59
·2512	·06310	12	3·981	15·85
·2239	·05012	13	4·467	19·95
·1995	·03981	14	5·012	25·12
·1778	·03162	15	5·623	31·62
·1585	·02512	16	6·310	39·81
·1413	·01995	17	7·079	50·12
·1259	·01585	18	7·943	63·10
·1122	·01259	19	8·913	79·43
·1000	·01000	20	10·000	100·00

Table II

Voltage *or* *Power* *Ratio*	*dB* *Voltage*	*dB* *Power*
1·0	0·0	0·0
1·1	0·83	0·41
1·2	1·58	0·79
1·3	2·28	1·14
1·4	2·92	1·46
1·5	3·52	1·76
1·75	4·86	2·43
2·0	6·02	3·01
2·5	7·96	3·98
3·0	9·54	4·77
3·5	10·88	5·44
4·0	12·04	6·02
4·5	13·06	6·53
5·0	13·98	6·94
5·5	14·81	7·40
6·0	15·56	7·78
6·5	16·26	8·13
7·0	16·90	8·45
7·5	17·50	8·75
8·0	18·06	9·03
8·5	18·58	9·29
9·0	19·08	9·54
9·25	19·32	9·16
9·5	19·55	9·27
9·6	19·65	9·32
9·7	19·74	9·87
9·8	19·83	9·91
9·9	19·91	9·95
10·0	20·0	10·0

Star-Delta Transformations





$$Z_A = \frac{Z_1 Z_2}{Z_1 + Z_2 + Z_3} \qquad Z_1 = \frac{Z_A Z_B + Z_B Z_C + Z_A Z_C}{Z_B}$$

$$Z_B = \frac{Z_2 Z_3}{Z_1 + Z_2 + Z_3} \qquad Z_2 = \frac{Z_A Z_B + Z_B Z_C + Z_A Z_C}{Z_C}$$

$$Z_C = \frac{Z_1 Z_3}{Z_1 + Z_2 + Z_3} \qquad Z_3 = \frac{Z_A Z_B + Z_B Z_C + Z_A Z_C}{Z_A}$$

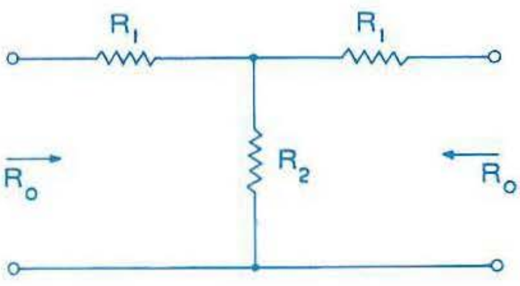
Resistive Attenuators

$R_{in} = R_{out} = R_o$

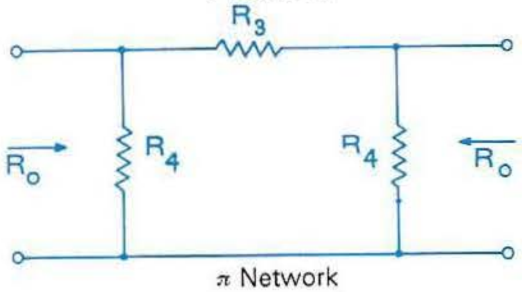
Attenuation in decibels $= 10 \log_{10} A$ or $20 \log_{10} N$

where A = power ratio; i.e., P_{in}/P_{out}

N = voltage ratio; i.e., E_{in}/E_{out}



T Network



π Network

T Networks

$$R_2 = R_0 \cdot \frac{2\sqrt{A}}{A-1} = R_0 \cdot \frac{2N}{N^2 - 1}$$

$$R_1 = \left[R_0 \cdot \frac{A+1}{A-1}\right] - R_3 = \left[R_0 \cdot \frac{N^2+1}{N^2-1}\right] - R_3$$

π Networks

$$R_3 = R_0 \cdot \frac{A-1}{2\sqrt{A}} = R_0 \cdot \frac{N^2 - 1}{2N}$$

$$\frac{1}{R_4} = \left[\frac{1}{R_0} \cdot \frac{A+1}{A-1}\right] - \frac{1}{R_3} = \left[\frac{1}{R_0} \cdot \frac{N_2+1}{N_2-1}\right] - R_3$$

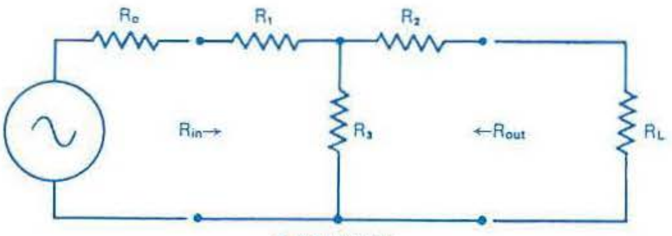
Table I below gives the multiplying factors for the design of attenuator pads from 0·5 dB to 40 dB. In order to find the actual resistive values multiply the figures given in the table above by R_0.

Table I

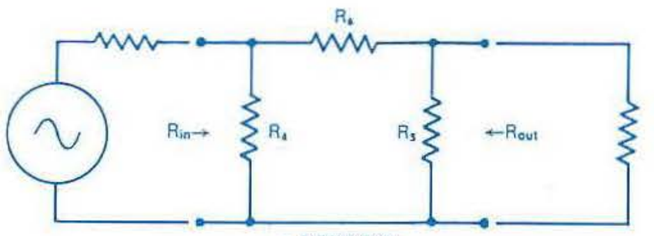
Atten. in dB	Multiplying Factors			
	R_1	R_2	R_3	R_4
0·5	0·0287	17·361	0·0576	34·79
1	0·0575	8·669	0·115	17·39
2	0·115	4·305	0·232	8·726
3	0·171	2·838	0·352	5·848
4	0·226	2·094	0·478	4·425
5	0·280	1·645	0·608	3·569
6	0·333	1·339	0·747	3·007
7	0·382	1·116	0·896	2·614
8	0·431	0·945	1·058	2·323
9	0·476	0·812	1·232	2·101
10	0·519	0·703	1·423	1·925
12	0·599	0·536	1·865	1·670
14	0·667	0·416	2·405	1·499
16	0·726	0·325	3·078	1·377
18	0·776	0·254	3·907	1·288
20	0·818	0·202	4·950	1·222
25	0·894	0·113	8·876	1·119
30	0·939	0·0633	15·80	1·065
35	0·965	0·0356	28·13	1·036
40	0·980	0·0200	50·0	1·020

Matching Pads

$R_{in}/R_{out} = F, \quad E_{in}/E_{out} = N, \quad P_{in}/P_{out} = A$



T NETWORK



π NETWORK

T Networks

$$R_3 = \frac{2\sqrt{A\,R_{in}\,R_{out}}}{A-1} = R_{in}.\frac{2N}{N^2 - F}$$

$$R_2 = \left[R_{out}.\frac{A+1}{A-1}\right] - R_3 = \left[R_{out}.\frac{N^2+F}{N^2-F}\right] - R_3$$

$$R_1 = \left[R_{in}.\frac{A+1}{A-1}\right] - R_3 = \left[R_{in}.\frac{N^2+F}{N^2-F}\right] - R_3$$

π Networks

$$\frac{1}{R_6} = \frac{2}{A-1}\cdot\sqrt{\frac{A}{R_{in}\,R_{out}}} = \frac{1}{R_{out}}\cdot\frac{2N}{N^2-F}$$

$$\frac{1}{R_5} = \left[\frac{1}{R_{out}}\cdot\frac{A+1}{A-1}\right] - \frac{1}{R_6} = \left[\frac{1}{R_{out}}\cdot\frac{N^2+F}{N^2-F}\right] - \frac{1}{R_6}$$

$$\frac{1}{R_4} = \left[\frac{1}{R_{in}}\cdot\frac{A+1}{A-1}\right] - \frac{1}{R_5} = \left[\frac{1}{R_{in}}\cdot\frac{N^2+F}{N^2-F}\right] - \frac{1}{R_6}$$

In practice *T* and π impedance matching pads are usually designed to give some convenient voltage ratio, which may be stated in decibels even though the input and output impedances are different. The table shows resistive values for commonly used impedance and attenuation ratio. The figures in the column *N* (dB) are those equivalent to $20 \log \frac{E_{in}}{E_{out}}$ and should not be regarded as the true $\left(\frac{P_{in}}{P_{out}}\right)$ decibel attenuation.

Attenuation Ratio		Resistance values in ohms							
N (dB)	N	R_{in}	R_{out}	R_1	R_2	R_3	R_4	R_5	R_6
10	$\sqrt{10}$	75	50	45·7	11·9	55·8	31·8	81·4	67·2
14	5	74	50	52·7	24·5	31·9	154	71·4	118
20	10	75	50	62·2	36·3	15·2	97·5	58·5	286
6	2	75	60	34·1	5·5	109	827	13·2	41·3
10	$\sqrt{10}$	75	60	42·3	23·0	54·3	197	107	83·2
14	5	75	60	51·0	24·5	31·6	129	87·7	143
20	10	75	60	67·7	40·2	15·2	97·1	73·2	296
6	2	60	50	25·7	7·1	85·7	417	116	35·0
10	$\sqrt{10}$	60	50	33·2	20·4	43·2	146	91·0	69·6
14	5	60	50	40·9	30·0	25·2	100	73·5	119
20	10	60	50	49·4	39·1	12·2	73·5	59·7	247

Equivalent Series and Parallel Networks

Parallel Circuit

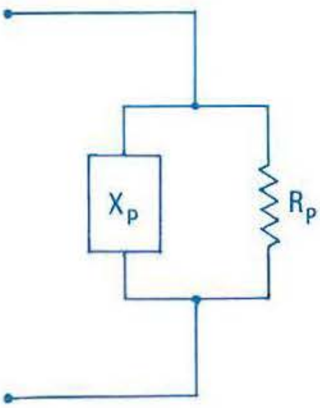
$$\text{Impedance } |Z| = \frac{Rp\,Xp}{\sqrt{Rp^2 + Xp^2}}$$

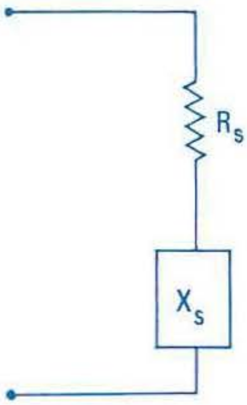
$$\text{Phase angle } \phi = \tan^{-1}\frac{Rp}{Xp}$$

Series Circuit

$$\text{Impedance } |Z| = \sqrt{Rs^2 + Xs^2}$$

$$\text{Phase angle } \phi = \tan^{-1}\frac{Xs}{Rs}$$





When the two circuits are equivalent

$$Xs = \frac{Xp\,Rp^2}{Rp^2 + Xp^2} = \frac{Z^2}{Xp}$$

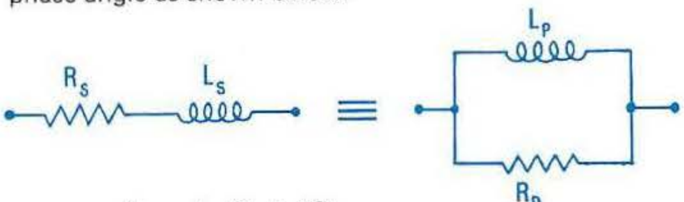
$$Rs = \frac{Rp\,Xp^2}{Rp^2 + Xp^2} = \frac{Z^2}{Rp}$$

$$Xp = \frac{Rs^2 + Xs^2}{Xs} = \frac{Z^2}{Xs}$$

$$Rp = \frac{Rs^2 + Xs^2}{Rs} = \frac{Z^2}{Rs}$$

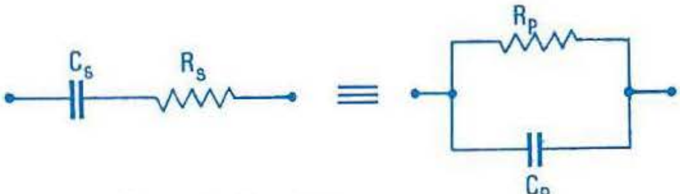
A nominally inductive or capacitive component is usually equivalent to reactance and resistance in a network that is predominantly series or parallel. For realistic measurement it is important that the correct configuration is chosen, especially if the loss in the component is significant.

At any given frequency a series network has an equivalent parallel network giving the same impedance and phase angle as shown below.



$$L_P = L_S\,(1 + D^2)$$

$$R_P = R_S\,(1 + Q^2)$$



$$C_S = C_P\,(1 + D^2)$$

$$R_P = R_S\,(1 + Q^2)$$

The following table gives correction factors for converting L_P to L_S or C_S to C_P and vice versa. Below $D = 0{\cdot}1$ the error is negligible.

D	Multiply by	
	$(1 + D^2)$ L_P to L_S, C_S to C_P	$\left(\frac{1}{1 + D^2}\right)$ L_S to L_P, C_P to C_S
0·10	1·01	0·99
0·15	1·023	0·98
0·20	1·04	0·962
0·25	1·063	0·943
0·30	1·09	0·917
0·33	1·109	0·901
0·35	1·123	0·893
0·40	1·16	0·862
0·45	1·203	0·833
0·50	1·25	0·8
0·60	1·36	0·735
0·70	1·49	0·671
0·8	1·64	0·610
0·9	1·81	0·553
1·0	2·0	0·5

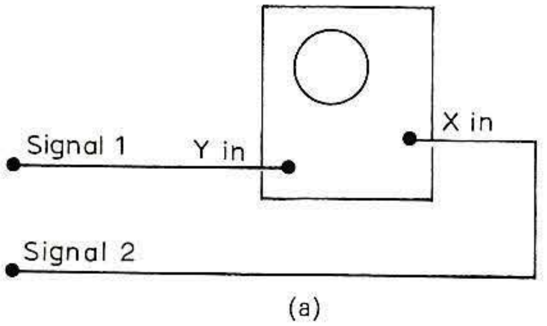
Phase Angle Measurement

A standard method of measuring the phase angle between two equal-frequency sinewaves is shown in Fig. 1. Signal "1" is applied to the *X* input of the oscilloscope, and signal "2" to the *Y* input. The phase difference, θ, is assessed from the dimensions of the resulting ellipse as shown in Fig. 1 (b).

With the single ellipse, however, it is difficult to determine the exact position of the vertical centre line in order to find dimension *B*. This difficulty can be obviated by the use of a double trace oscilloscope, signal "2" being applied to both *Y* inputs in parallel.

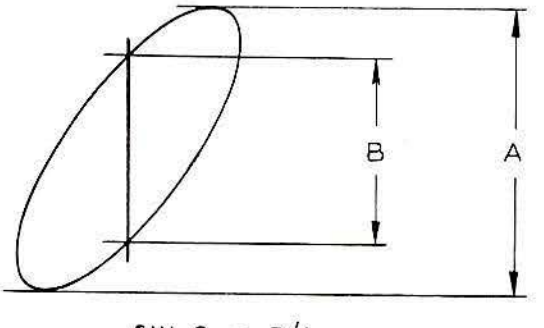
To obtain the pattern shown in Fig. 2, it is, of course, necessary to switch one *Y* channel to the "invert" condition. The gains of the two channels must be adjusted for equality before dimension *A* is measured. The vertical centre line, giving dimension *B*, is then easily identified by the intersecting points of the ellipses.

The phase angle may be read from the accompanying nomogram (opposite) by connecting the appropriate points on scales *A* and *B*, and then reading the phase angle directly from scale *C*. For measurement of phase angle between 45° and 90° improved discrimination can be obtained by use of the *A'*, *B'*, and *C'* scales.



(a)

Fig. 1



$\sin\theta = B/A$

(b)

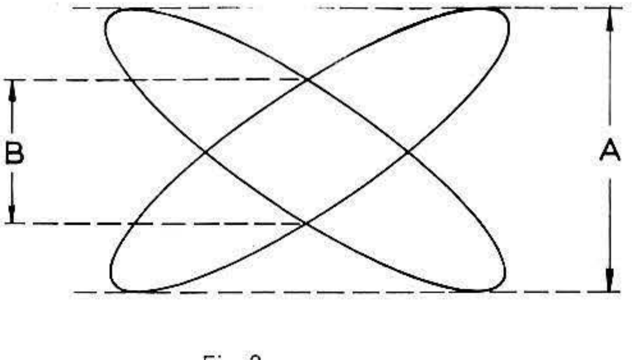
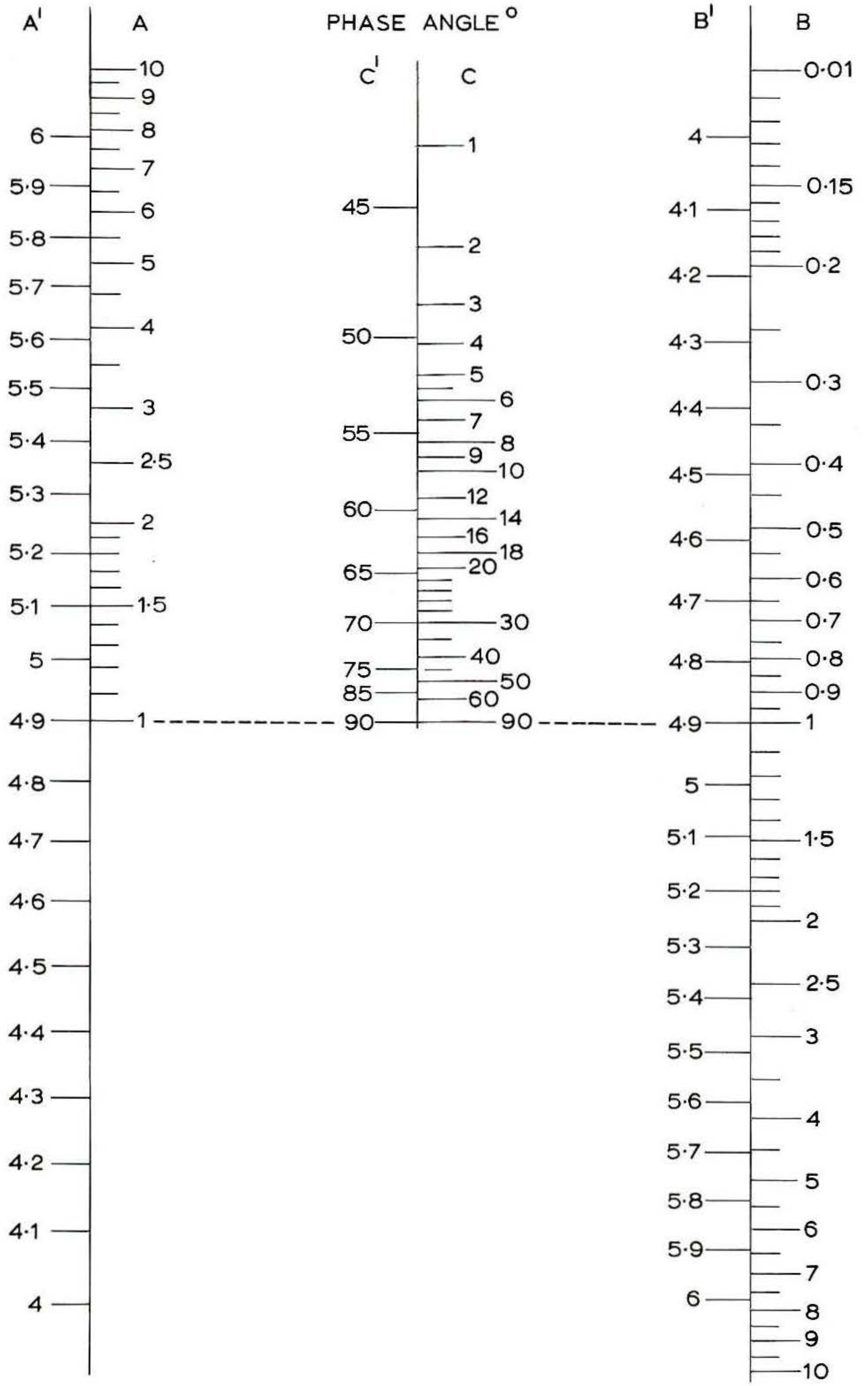


Fig 2


A'
A
PHASE ANGLE °
C'
C
B'
B
10 9 8 7 6 5 4 3 2.5 2 1.5 1
6 5·9 5·8 5·7 5·6 5·5 5·4 5·3 5·2 5·1 5 4·9 4·8 4·7 4·6 4·5 4·4 4·3 4·2 4·1 4
45 50 55 60 65 70 75 85 90
1 2 3 4 5 6 7 8 9 10 12 14 16 18 20 30 40 50 60 90
4 4·1 4·2 4·3 4·4 4·5 4·6 4·7 4·8 4·9 5 5·1 5·2 5·3 5·4 5·5 5·6 5·7 5·8 5·9 6
0·01 0·15 0·2 0·3 0·4 0·5 0·6 0·7 0·8 0·9 1 1·5 2 2·5 3 4 5 6 7 8 9 10

Measurement of Fast Pulse Rise Times

When using an oscilloscope to measure pulse rise times which are long compared with the rise time of the oscilloscope Y amplifier, negligible error is introduced by the amplifier. However, it is sometimes desired to use an oscilloscope for measurement of a pulse rise time which is of the same order as that of the Y amplifier; and it is then necessary to apply a correction to the measured time.

The rise time of an amplifier is defined as the time of rise, from 10% to 90%, of the output voltage when a perfect step, i.e. one having zero rise time, is applied to the input terminals.

The shape of the output pulse is a function of time, $f_{amp}(t)$, which depends upon the high-frequency response characteristic of the amplifier. Similarly, an input step voltage of finite rise time may follow a different function of time, $f_{pulse}(t)$. The output voltage then follows the product of the two functions; i.e. $v_{instant}=f_{amp}(t)\times f_{pulse}(t)$.

Thus the ultimate rise time of the output pulse depends, not only upon the two rise times, but also upon the functions f_{amp} and f_{pulse}. In practice, however, the case is simplified by the fact that providing the overshoot is small there is little variation of shape over the portion of the transient between 10% and 90% of the pulse height; and a close approximation to the rise time relationships is given by the expression:

$$t_{display}=\sqrt{t^2_{pulse}+t^2_{amp}}$$

Where $t_{display}$ is the rise time of the output pulse,

t_{pulse} is the rise time of the input pulse,

t_{amp} is the rise time of the amplifier.

The accompanying abac on Page 211, is based upon the above expression and provides a convenient means of converting the rise time measured on an oscilloscope to the true rise time of the input pulse.

To use the abac, find the point corresponding to the rise time of the oscilloscope on Scale 1 and the point corresponding to the measured rise time on Scale 2. Use a straight-edge to project the line joining these two points on to Scale 3. The point where the line crosses Scale 3 is the rise time of the input pulse.

As an example, line x–x gives the rise time of a pulse which is measured as 40 nsec (Scale 2) on an oscilloscope having a Y-amplifier rise time of 25 nsec (Scale 1A). The rise time of the input pulse is read from Scale 3 as 31.2 nsec.

The abac is scaled to 50 nsec, which should cover most practical measurements of this kind with adequate discrimination. However, the range can be extended by multiplying the three time-scale readings by any convenient number. But, to preserve the correct relationship between Scale 1A and Scale 1B the frequency given by B must be divided by the same number.

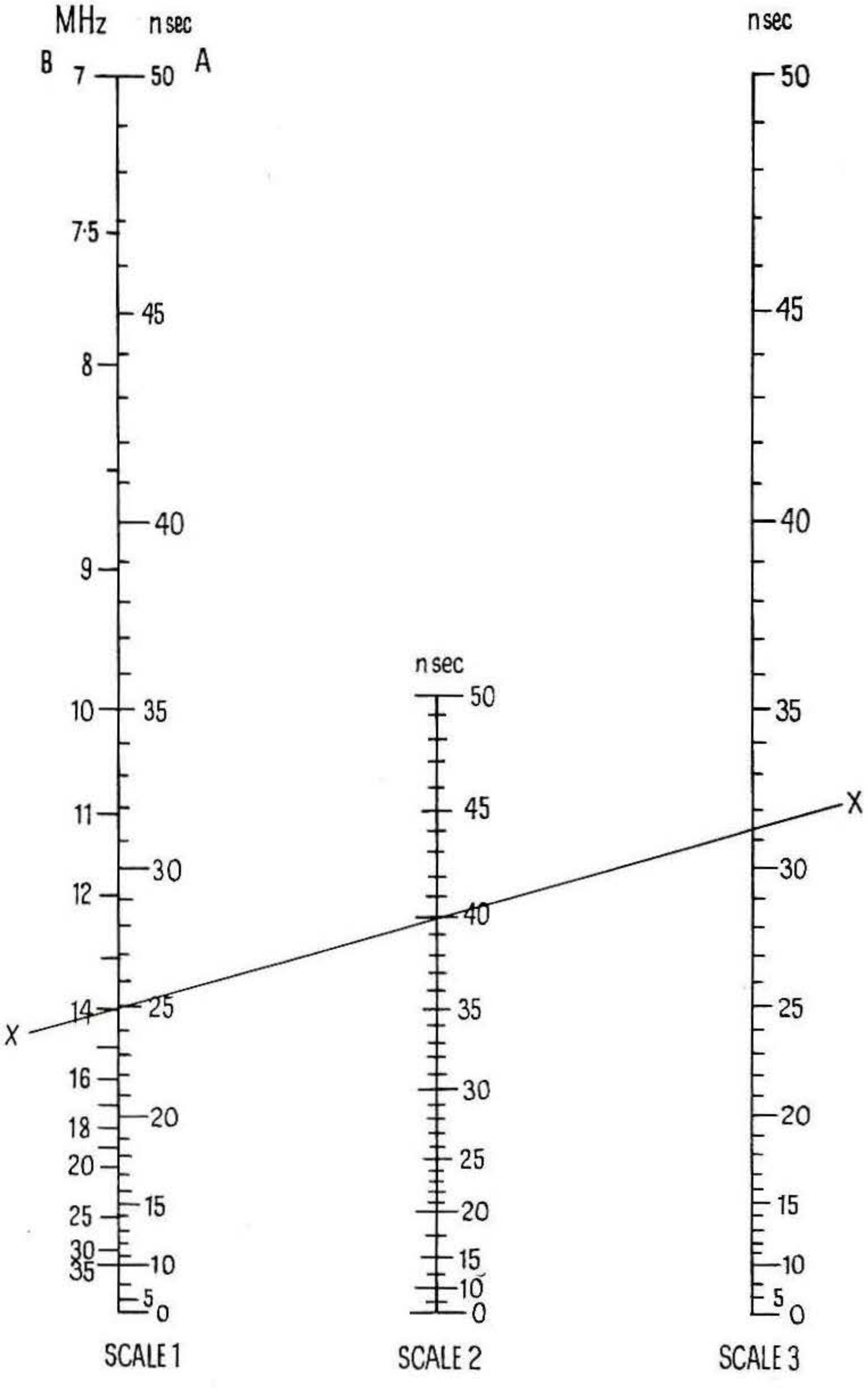
The use of the abac is, of course, not confined to oscilloscope amplifiers. It can be used in conjunction with any amplifier or system carrying fast-rise pulses. If the rise time of the system is known, the deterioration of a pulse can be read directly from the abac by using Scale 1 for the rise time of the system, Scale 3 for the rise time of the input pulse, and Scale 2 to give the output rise time.

To measure the rise time of an amplifier or system, apply a fast rise pulse to its input, and measure the rise time of the output pulse on an oscilloscope, applying abac corrections where necessary. The rise time of the system can then be obtained from the abac by the method given. Providing the overshoot is less than 5% of the pulse height, the bandwidth of the system can be calculated from the expression:

$$F_{-3\,dB}=0{\cdot}35/t_{amp}$$

Where $F_{-3\,dB}$ is the upper frequency limit at which the response is 3 dB below the mid-frequency response,

t_{amp} is the rise time of the system.



Oscilloscope Rise Time

Measured Rise Time

Rise Time of Input Pulse

With sinewave modulation the sideband distribution depends on the deviation ratio—or modulation index—which is usually signified by the symbol β, and is given by

$$\beta = \delta f/f_{mod},$$

where δf is the peak f.m. deviation and f_{mod} is the modulation frequency. β is also equal to the phase deviation in radians.

Where the modulation frequency is variable and known, f.m. deviation can be accurately measured by setting for deviation ratios at which the carrier or sidebands have zero amplitude as shown in Tables I and II.

Table I. Deviation ratios at which the carrier or sideband components have zero amplitude.

Order of Zero Point	Deviation Ratio			
	Carrier	1st Pair Sidebands	2nd Pair Sidebands	3rd Pair Sidebands
1	2·405	3·832	5·136	6·380
2	5·520	7·016	8·417	9·761
3	8·654	10·173	11·620	13·015
4	11·792	13·324	14·796	16·223
5	14·931	16·471	17·960	19·409

Table II. Modulating frequencies corresponding to deviations at which carrier amplitude is reduced to zero.

Carrier—first disappearance dev. ratio (2·4048)		Carrier—second disappearance dev. ratio (5·5201)	
Freq. Dev. in kHz.	Mod. Freq. in Hz.	Freq. Dev. in kHz.	Mod. Freq. in Hz
1	416	5	907
2	831	10	1,815
3	1,247	15	2,718
4	1,663	20	3,625
5	2,079	25	4,530
6	2,494	30	5,430
7	2,911	35	6,340
8	3,326	40	7,250
9	3,742	45	8,160
10	4,158	50	9,070
15	6,237	55	9,975
20	8,316	60	10,880
25	10,395	65	11,780
30	12,480	70	12,690
35	14,550	75	13,590

F.M. on A.M.

If f.m. and a.m. are applied simultaneously to the carrier, the first order pair of sidebands—as viewed on the spectrum analyser—will be equal to the vector sum of the a.m. and f.m. sidebands. Assuming that peak deviation in the positive direction occurs at the same instant as the a.m. envelope peak—i.e., the f.m. and a.m. modulating waveforms are in phase—the lower sidebands will be equal to the sum and the upper one to the difference of the a.m. and first order f.m. sideband amplitudes.

As a guide to the degree of asymmetry to be expected from a given spurious f.m. deviation, Table III gives the maximum asymmetry that can be produced by various values of spurious f.m. deviation on 30% a.m. Most spectrum analysers are calibrated in decibels; so the apparent sideband amplitudes are given in dB relative to the unmodulated carrier, with the larger sideband amplitude above the smaller.

Table III. Sideband asymmetry caused by spurious f.m. on 30% wanted a.m. (f.m. in phase with a.m.).

F.M. Deviation	Apparent Sideband Amplitudes (dB relative to unmodulated carrier)			
	100 Hz Mod. freq.	400 Hz Mod. freq.	1 kHz Mod. freq.	10 kHz Mod. freq.
0	16·5 dB	16·5 dB	16·5 dB	16·5 dB
5 Hz	15·1 dB 18·1 dB	16·1 dB 16·8 dB	16·3 dB 16·7 dB	
10 Hz	14·0 dB 20·0 dB	15·8 dB 17·2 dB	16·2 dB 16·8 dB	
20 Hz	12·0 dB 26·0 dB	15·1 dB 18·1 dB	15·9 dB 17·1 dB	
40 Hz	9·1 dB 26·0 dB	14·0 dB 20·0 dB	15·4 dB 17·7 dB	
80 Hz	5·7 dB 13·2 dB	12·0 dB 26·0 dB	14·4 dB 18·2 dB	
100 Hz	4·6 dB 10·8 dB	11·4 dB 30·5 dB	14·0 dB 20·0 dB	16·2 dB 16·8 dB
200 Hz		8·2 dB 21·0 dB	12·0 dB 26·0 dB	15·9 dB 17·1 dB
400 Hz		4·6 dB 10·8 dB	9·1 dB 26·0 dB	15·4 dB 17·7 dB
800 Hz			5·7 dB 13·2 dB	14·4 dB 18·2 dB
1 kHz			4·6 dB 10·8 dB	14·0 dB 20·0 dB
2 kHz				12·0 dB 26·0 dB
4 kHz				9·1 dB 26·0 dB
8 kHz				5·7 dB 13·2 dB
10 kHz				4·6 dB 10·8 dB

Amplitude Modulation

Peak Modulation Measurement

A fundamental method of peak a.m. depth measurement with an oscilloscope is illustrated in Fig. 1. The display in Fig. 1 (a) is obtained with the oscilloscope's internal saw-tooth time base, and for that in Fig. 1 (b) the modulating signal is utilised to produce the horizontal scan. In either case a.m. depth is given by

$$\frac{A-B}{A+B}.100\%$$

Peak modulation depth measurement by the oscilloscope method is limited in accuracy mainly by any non-linearity of the oscilloscope vertical deflection system and by the lack of discrimination resulting from the need to compress the complete peak-to-peak display into the 6 cm window of the c.r.t. screen. The lack of discrimination becomes particularly acute at low modulation depths, where the A and B dimensions are comparable.

Considerably more discrimination is afforded by the standard type of modulation meter (e.g., TF 2300), which indicates the peak modulation directly. This type of instrument basically comprises a low sensitivity receiver, with a d.c. coupled diode demodulator. The d.c. component of the demodulator output is equal to the carrier voltage, and the l.f. output is equal to the modulation component of the incoming waveform. In use the sensitivity to the instrument is adjusted to bring the carrier level to a reference value, and the amplitude of the l.f. component is monitored by means of a peak-reading diode voltmeter, calibrated directly in % modulation depth. Provision is normally made for reversing the voltmeter diode to permit measurement of the crest/carrier or trough/carrier modulation factor.

Providing the even order harmonic distortion is low (5% or less), obviation of the asymmetry error by taking the average of the positive and negative (crest and trough) peak modulation readings gives the effective modulation depth with negligible error.

Sideband Power Method

With an undistorted sinusoidal envelope, the sideband power would be equal to $M^2/2$ times the carrier power; i.e.

$$M\% = \left[\frac{2P_s}{P_c}\right]^{\frac{1}{2}} \times 100$$

where M is the modulation depth, P_s is the power in the sidebands, and P_c is the carrier power.

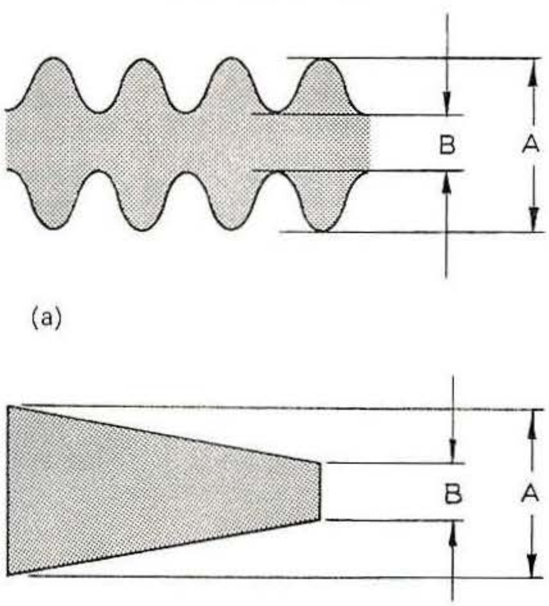
The carrier power can be measured directly by means of a true mean power (thermocouple) meter when no modulation is applied, but there is no direct way of measuring the sideband power separately from the carrier. The standard method is, therefore, as follows.

First measure the r.f. power with no modulation applied, and call this power P_c. Apply the modulation, note the new power reading, and call this P_m. P_s is equal to $P_m - P_c$, so equation (4) can be rewritten.

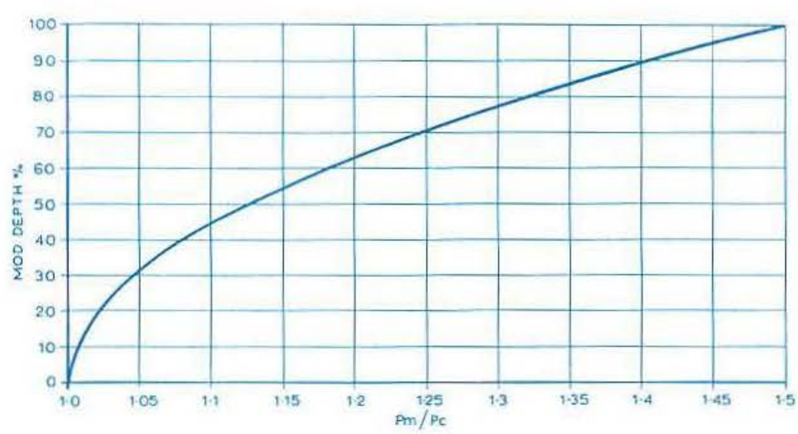
$$M\% = \left[\frac{2P_m}{P_c} - 2\right]^{\frac{1}{2}} \times 100$$

If properly conducted, with suitable measuring instruments, the power-measurement method can give a very accurate assessment of r.m.s. modulation depth. However, it suffers from lack of discrimination when the modulation depth is low. With 30% modulation, for example, the value of P_m/P_c would be 1·045. The utility of this method can, therefore, be realised only for the higher modulation depths; and, for most applications, the methods utilising a modulation meter are generally more suitable.

The curve below gives values of P_m/P_c for modulation depths from 0 to 100%.



(b) Fig. 1.



Nomenclature of Radio Frequency Bands

In accordance with Article 2, Section III, Paragraph 112, § 7 of the Radio Regulations (Geneva, 1959) of the International Telecommunications Union, it is recommended that frequencies shall be expressed:

From 30 kHz to 3,000 kHz in kHz
From 3 MHz to 3,000 MHz in MHz
From 3 GHz to 3,000 GHz in GHz

and that the radio spectrum is divided into nine frequency bands, designated by a Band Number "N", where the band extends from $0{\cdot}3\times10^N$ to 3×10^N hertz, the lower limit being excluded, and the upper limit included.

The following table indicates the relationship between this and other systems:

Band No.	Frequency Range	Adjectival Designation		Metric Sub-division
4	3– 30 kHz	Very Low Frequency	V.L.F.	Myriametric
5	30– 300 kHz	Low Frequency	L.F.	Kilometric
6	300–3,000 kHz	Medium Frequency	M.F.	Hectometric
7	3– 30 MHz	High Frequency	H.F.	Decametric
8	30– 300 MHz	Very High Frequency	V.H.F.	Metric
9	300–3,000 MHz	Ultra High Frequency	U.H.F.	Decimetric
10	3– 30 GHz	Super High Frequency	S.H.F.	Centimetric
11	30– 300 GHz	Extra High Frequency	E.H.F.	Millimetric
12	300–3,000 GHz	—		Decimillimetric

Frequency Allocations

GENERAL BROADCASTING

Frequency allocations by ITU for broadcasting for primary services.

	Region 1 Europe & Africa	Region 2 N. & S. America	Region 3 Asia	Comments Probable use
	150–285 kHz			Sound
	525–1605 kHz	535–1605 kHz	535–1605 kHz	Sound
Several bands between 2·3 and 26·1 MHz allocated to broadcasting				Sound
Band I	41–68 MHz		44–50 MHz	Television
		54–73 MHz	54–68 MHz	Television
Band II	87·5–100 MHz	75·4–108 MHz	87–108 MHz	FM Sound
Band III	174–223 MHz	174–216 MHz	170–216 MHz	Television
Bands IV and V	470–960 MHz	470–890 MHz	470–960 MHz	Television

U.H.F. Television (Bands IV and V) in Europe and Africa

There are five systems which can be adopted. All are 625 line systems and the frequency bands are 470 MHz to 850 MHz. (Further details from E.B.U. or World Radio and TV Handbook, 1965.)

TELEVISION BROADCASTING

Line Standards and vision frequencies used are:

U.K.	405 lines	41·5 MHz– 66·75 MHz 176·25 MHz–219·75 MHz
	625 lines	U.H.F. started April, 1964 and the band 470–790 MHz is scheduled.
Continental Europe (excluding France, Monaco, Italy and O.I.R.T. members)	625 lines	41·25 MHz– 67·75 MHz 82·25 MHz– 87·75 MHz 175·25 MHz–229·75 MHz
France and Monaco	819 lines	41·25 MHz– 65·55 MHz 164·00 MHz–214·60 MHz
Italy	625 lines	53·75 MHz– 87·75 MHz 175·25 MHz–222·75 MHz
U.S.S.R. and O.I.R.T. Members	625 lines	49·75 MHz– 65·75 MHz 77·25 MHz– 99·75 MHz 175·25 MHz–229·75 MHz
New Zealand	625 lines	45·25 MHz– 67·75 MHz 175·25 MHz–215·75 MHz
Australia	625 lines	46·25 MHz– 51·75 MHz 57·25 MHz– 69·75 MHz 86·25 MHz– 92·75 MHz 95·25 MHz–107·75 MHz 138·25 MHz–143·75 MHz 175·25 MHz–201·75 MHz 209·25 MHz–221·75 MHz
Japan	525 lines	91·25 MHz–107·75 MHz 171·25 MHz–221·75 MHz 663·25 MHz–769·75 MHz
U.S.A.	525 lines	55·25 MHz– 87·75 MHz 175·25 MHz–215·75 MHz 471·25 MHz–889·75 MHz

INTERNATIONAL AIRCRAFT BANDS 1 MHz to 3000 MHz

74·6–75·4 MHz	Marker beacons (74·8–75·2 MHz Region 1).
108–132 MHz	(Much of the band 235–400 MHz is also used for aircraft although not internationally allocated.)
328·6–335·4 MHz	ILS.
960–1215 MHz	Airborne navigation and its ground-based facilities. (TACAN, DME, S.S.R., etc. are in this band.)
1300–1350 MHz	
1540–1660 MHz	
2700–2900 MHz	

MOBILE COMMUNICATIONS above 30 MHz and below 3000 MHz.

Frequencies allocated by ITU for mobiles for primary services.

Region 1 Europe and Africa	Region 2 N. & S. America	Region 3 Asia	Comments
29·7–41 MHz	29·7–50 MHz	29·7–50 MHz	U.K. uses 29·7–41 MHz for aeronautical
	54– 73	54– 100	
68– 74·8			
75·2–87·5*	74·6–88		
100– 108*			
118– 136†	118– 132†	118– 132†	
136– 137	132– 136	132– 137	
138– 144†	138– 144	138– 144	
146– 149·9*	148– 149·9	148– 149·9	
150·05–174*	150·05–216	150·05–216	
235– 399·9	225– 399·9	225– 399·9	
406– 430*	406– 420	406– 420	
440– 450*			
450– 470	450– 470	450– 470	Australia 470–500 MHz
1350–1400		610– 960	
1427–1525*	1427–1429*	1427–1429*	
	1429–1525	1429–1525	
	1710–2290	1710–2300	
2250–2690	2550–2690	2550–2690	

* Except aeronautical mobile.

† Aeronautical mobile.

In most cases other services are also allocated to these bands.

The mobile bands about which we hear most often are:

U.K. Land Mobiles	U.S. Land Mobiles	Japanese Mobiles
71·5–88 MHz "low" band	25– 50 MHz	23·35–41 MHz
156–173·05 MHz "high" band	144–174 MHz	118–170 MHz
450–470 MHz.	400–470 MHz	225–328·6 MHz
	890–960 MHz	406–412 MHz
		450–470 MHz
		770–920 MHz

Australia has the band 470–500 MHz allocated to mobiles and may use mobiles above 500 MHz. Japan has a large number of mobile bands. They are given below but some may not be land mobiles.

FIXED COMMUNICATIONS (i.e. Point to Point)—1 MHz to 3000 MHz International.

a) **Line Communications** (Wire and Cable)

60 kHz–12·5 MHz

b) **Radio Communications**

1·6–28 MHz	but not continuously and exlusively for fixed communications.
29·7–41 MHz	also allocated to other services.
150·05–174 MHz* 235–399·9 MHz* 450–470 MHz* 890–960 MHz*	Some multichannel radio links in these bands.
1427–1535 MHz*	also Space: (Multichannel links 1485–1550 MHz in U.K.)
1700–2300 MHz	microwave links.

* Also allocated to mobiles.

c) **Satellite Communications**

There are a number of bands allocated to satellite communications (in addition to bands for space research, spuce telemetry, etc.) but these are all above 3000 MHz.

OTHER FREQUENCY BANDS (excluding land mobiles, broadcasting and fixed communications).

U.K.	74·8–75·2 MHz	Aircraft (ILS markers at 75 MHz).
	108–144 MHz	Aircraft (108–112 MHz ILS localiser, 112–118 MHz VOR, 118–139·5 MHz Ground Controlled Approach).
	216–235 MHz	Aircraft.
	328·6–335·4 MHz	ILS Glide Slope.
	225–400 MHz	Military Airborne.
U.S.	225– 420 MHz	Mainly Government.
	215– 265 MHz	Telemetry.
	400– 550 MHz	Range safety.
	1435–1535 MHz	Telemetry.
	2200–2300 MHz	Telemetry.

I.F's Used

465 kHz, 1·6 MHz	
10·7 MHz	FM receivers.
70 MHz	FM receivers, multichannel links.
5·5, 6 and 6·5 MHz	Intercarrier sound.

Selected Radio Formulæ

CAPACITANCE

Parallel plate capacitor

$$C(\text{in pF}) = \frac{A\varepsilon}{11\cdot 31d}$$

where A = area of one plate in sq. cms
ε = permittivity
d = dielectric thickness in centimetres.

Plates 1 mm apart in air have a capacitance of 0·884 pF per sq. cm of plate area. Plates 1/10" apart have 2·245 pF per sq. inch.

Reactance of a capacitor

$$X \text{ (in ohms)} = 1/\omega C$$

where C = capacitance in farads
$\omega = 2\pi \times$ frequency in Hz.

Power Factor

$$\cos\varphi = R/Z = R/\sqrt{R^2 + X^2}$$

where R = series resistance
i.e. $\cos\varphi = \omega CR$ when R is small compared with X

Magnification

$$Q = X/R = 1/\omega CR$$

Loss angle

$\delta = \tan\delta$ (when loss is small)
and $\tan\delta = \cos\varphi$ (when loss is small, i.e., capacitor has good power factor)

Therefore, for good capacitors, loss angle = power factor = 1/Q.

INDUCTANCE

Reactance

$$X \text{ (in ohms)} = \omega L$$

where L = inductance in henries
$\omega = 2\pi \times$ frequency in Hz

Power Factor

$$\cos\varphi = R/Z = R/\sqrt{R^2 + X^2}$$

where R is series resistance
i.e., $\cos\varphi = R/\omega L$ when R is small compared with X

Magnification

$$Q = X/R = \omega L/R$$
$= 1/\cos\varphi$ when R is small compared with X

TUNED CIRCUITS

Frequency (in Hz) $= 1/2\pi\sqrt{LC}$

Where L and C are in henries and farads respectively and series resistance can be ignored

Wavelength (in metres) $= 1{,}885\sqrt{LC}$

where L and C are in μH and μF respectively.

For single tuned circuit

$$Q = \frac{f_0}{f_1 - f_2} = \frac{\text{Frequency at resonance}}{\text{Bandwidth at 0·707 of max. response}}$$

Dynamic resistance at resonance

$$R_d = L/CR$$

where R is series resistance.

TRANSMISSION LINES

$$Z_0 = \sqrt{L/C}$$

where L and C are inductance and capacitance per unit length.

Parallel Wires in Air

$$Z_0 \text{ (in ohms)} = 276 \log_{10} d/r$$

where d = distance between centres in cms
r = radius of wire in cms

Concentric Cables

$$Z_0 \text{ (in ohms)} = (138 \log_{10} r^2/r^1)/\sqrt{\varepsilon}$$

where r_1 = inner radius
r_2 = outer radius
ε = permittivity of dielectric between conductors

MAINS TRANSFORMERS

Turns per Volt

$$E \text{ in volts} = 4\cdot 44BANf \times 10^{-8}$$

where B = flux density
A = cross-sectional area of core
N = number of turns
f = frequency in Hz

Note: B and A must be in corresponding units (lines/sq. in. and sq. ins; gauss and sq. cms).

Since N/E = turns per volt
turns per volt $= 10^8/4\cdot 44$ BAf

Selected Mathematical Formulæ

Trigonometrical Functions

$\sin(A+B) = \sin A\cos B + \cos A\sin B$
$\cos(A+B) = \cos A\cos B - \sin A\sin B$
$\sin(A-B) = \sin A\cos B - \cos A\sin B$
$\cos(A-B) = \cos A\cos B + \sin A\sin B$
$\sin 2A = 2\sin A\cos A$
$\cos 2A = \cos^2 A - \sin^2 A = 1 - 2\sin^2 A = 2\cos^2 A - 1$

$\sin^2 A + \cos^2 A = 1$
$1 + \tan^2 A = \sec^2 A$
$1 + \cot^2 A = \operatorname{cosec}^2 A$

Hyperbolic Functions

$\sinh x = \frac{1}{2}(e^x - e^{-x})$
$\cosh x = \frac{1}{2}(e^x + e^{-x})$
$\tanh x = \dfrac{e^x - e^{-x}}{e^x + e^{-x}}$

Series

Taylor's

$$f(x) = f(a) + (x-a)f'(a) + \frac{(x-a)^2}{2!}f''(a) + \frac{(x-a)^3}{3!}f'''(a) + \dots$$

Maclaurin's

$$f(x) = f(0) + xf'(0) + \frac{x^2}{2!}f''(0) + \frac{x^3}{3!}f'''(0) + \dots$$

Binomial

$$(1+x)^n = 1 + nx + \frac{n(n-1)}{2!}x^2 + \frac{n(n-1)(n-2)}{3!}x^3 + \dots \quad (x<1)$$

$$(1-x)^n = 1 - nx + \frac{n(n-1)}{2!}x^2 - \frac{n(n-1)(n-2)}{3!}x^3 + \dots$$

Logarithmic

$$\log(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \dots \quad (x<1)$$

$$\log(1-x) = -x - \frac{x^2}{2} - \frac{x^3}{3} - \frac{x^4}{4} - \dots$$

Exponential

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \frac{x^4}{4!} + \dots$$

Differentials

$d(ax) = a\,dx$
$d(uv) = u\,dv + v\,du$
$d\dfrac{(u)}{(v)} = \dfrac{v\,du - u\,dv}{v^2}$
$dx^n = nx^{n-1}\,dx$
$de^{ax} = ae^{ax}\,dx$
$da^x = a^x \log a\,dx$
$d(\sin x) = \cos x\,dx$
$d(\cos x) = -\sin x\,dx$
$d(\tan x) = \sec^2 x\,dx$
$d(\cot x) = -\operatorname{cosec}^2 x\,dx$
$d(\sec x) = \tan x\sec x\,dx$
$d(\operatorname{cosec} x) = -\cot x\operatorname{cosec} x\,dx$

Integrals

1. $\int x^n\,dx = \dfrac{x^{n+1}}{n+1} \quad (n \neq -1)$
2. $\int \dfrac{1}{x}\,dx = \log x$
3. $\int e^{ax}\,dx = \dfrac{e^{ax}}{a}$
4. $\int \log x\,dx = x\log x - x$
5. $\int u\dfrac{dv}{dx}\,dx = uv - \int v\dfrac{du}{dx}\,dx$
6. $\int \sin x\,dx = -\cos x$
7. $\int \cos x\,dx = \sin x$
8. $\int \operatorname{sh} x\,dx = \operatorname{ch} x$
9. $\int \operatorname{ch} x\,dx = \operatorname{sh} x$
10. $\int \dfrac{1}{a^2+x^2}\,dx = \dfrac{1}{a}\tan^{-1}\dfrac{x}{a}$
11. $\int \dfrac{1}{\sqrt{a^2-x^2}}\,dx = \sin^{-1}\dfrac{x}{a}$
12. $\int \dfrac{1}{\sqrt{(x^2+a^2)}}\,dx = \operatorname{sh}^{-1}\dfrac{x}{a} = \log(x + \sqrt{a^2+x^2})$
13. $\int \dfrac{1}{\sqrt{x^2-a^2}}\,dx = \operatorname{ch}^{-1}\dfrac{x}{a} = \log(x + \sqrt{x^2-a^2})$
14. $\int \dfrac{f'(x)}{f(x)}\,dx = \log f(x)$
15. $\int \tan x\,dx = -\log(\cos x)$
16. $\int \cot x\,dx = \log(\sin x)$
17. $\int \operatorname{cosec} x\,dx = \log(\tan \frac{1}{2}x)$
18. $\int \sec x\,dx = \log\left\{\tan\left(\dfrac{\pi}{4} + \frac{1}{2}x\right)\right\} = \log(\sec x + \tan x)$
19. $\int \dfrac{dx}{a+bx} = \dfrac{1}{b}\log(a+bx)$

Microwave Equipment

mi Sanders

The Sanders Division of Marconi Instruments

The formation of the Sanders Division of MI and the expansion of the Company's product range into the microwave spectrum followed the acquisition in 1965 of W. H. Sanders (Electronics) Ltd. The high level of craft skills built up by W. H. Sanders combined with the technical and financial resources of Marconi Instruments and now the powerful backing of GEC-Marconi Electronics Ltd. have created the most dynamic microwave instrumentation and components company outside the U.S.A.

The policy of MI-Sanders is to provide a range of microwave test equipment designed to performance and price standards which meet the needs of large-scale systems use and also of laboratory and production testing applications. Further, arising from a design and manufacturing programme concentrated on producing equipment to the highest practicable levels of quality and reliability, a very extensive range of components has been established which has proved highly successful in international markets.

The Sanders Division of MI is actively exploiting the potential of the newly-emerging active solid-state devices suitable for microwave frequencies, from which work many advanced new products are projected. While deriving the maximum advantage for new techniques, however, Sanders Division maintains the majority of its microwave sub-contracting facility, which was the original basis for its skills: the expertise and experience of craftsmen who are totally involved in highly demanding precision techniques of microwave manufacturing geometry are qualities of vital importance to customers. The manufacture of waveguide, a traditional Sanders service, continues against a background of energetic development.

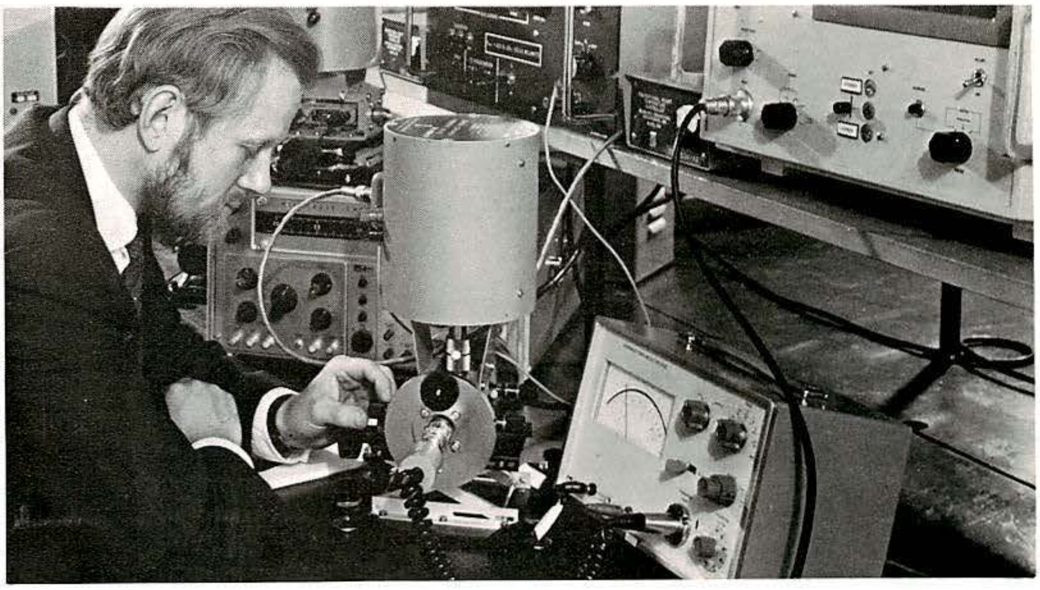
The high standards of design and workmanship which characterise Marconi Instruments products are equally evident across the Sanders Division range and unstinting effort is applied to attaining every possible improvement in reliability and quality, while maintaining strongly competitive prices.

In its environmentally controlled standards rooms, electrical and mechanical standards at microwave frequencies and tolerances are maintained to the same levels as those provided by international standards laboratories and close liaison exists with the Marconi Instruments Measurement Standards Laboratory at St. Albans. This aspect of the Sanders service is continuously expanding.

The Sanders Division development programme is currently aimed at an entire new generation of microwave products. Amongst these are planned microwave sources as narrow band devices, as broad band tunable devices and in special form, based on fully solid state techniques using components of British design and manufacture: in addition new power and impedance measuring techniques using both waveguide and coaxial inputs on the appropriate sector of the spectrum and working up to 90 GHz are planned for the near future.

M.I. Sanders Standards Laboratory

Equipped with measurement standards for a wide range of parameters at microwave frequencies, the M.I. Sanders Standards Laboratory ranks with the finest in Europe. The photograph shows the calibration of precision thermistor mounts against a Coaxial R.F. Power Transfer Standard whose own calibration is traceable to N.B.S. standards



Calibration and Test

Part of M.I. Sanders main test room, where routine calibration of all products is carried out.

Receivers and Selective Amplifiers

Calibration Receiver type 6592

A high-gain calibrated receiver utilising an external microwave mixer unit.

I.F. CHARACTERISTICS	
Frequency	45 MHz ±0·5 MHz.
Bandwidth	2 MHz ±0·2 MHz.
Noise figure	Less than 2 dB.
ATTENUATOR	
Range	100 dB in four steps of 20 dB and 20 steps of 1 dB.
METERING	Output level and mixer current.
R.F. RANGE	2·6 to 40 GHz depending on mixer used.
RECOMMENDED MIXERS	Types 6001 series, 6004 series, and 6521 series (see page 4).

V.S.W.R. Indicator/Selective Amplifier type 6593

FREQUENCY		
Selective operation	1 kHz or 3 kHz.	
Wide band operation	800 Hz to 3·5 kHz.	
BANDWIDTH (Selective operation)	100 Hz at 1 kHz, 400 Hz at 3 kHz.	
NOISE LEVEL		
Selective operation	Less than 0·1 μV.	
Wide band operation	Less than 0·3 μV.	
SENSITIVITY	*Selective*	*Wide band*
Normal	1·0 μV f.s.	2·0 μV f.s.
Expanded scale	0·4 μV f.s.	0·8 μV f.s.
ATTENUATORS		
Ranges	0 to 30 dB in steps of 10 dB ±0·5 dB.	
	0 to 10 dB in steps of 1 dB ±0·2 dB.	
	0 to 1 dB continuously variable.	

V.S.W.R. Indicator type 6596

INPUT CHARACTERISTICS	
Maximum sensitivity	Better than 1 μV r.m.s. full scale.
Internal noise	Less than 0·1 μV r.m.s. (equivalent input).
Maximum input level	1 mV.
Input impedance	1 kΩ (approx.).
Connectors	BNC sockets.
GAIN CONTROLS	
Fine control	4 : 1 voltage-gain variation.
Coarse control	300 : 1 voltage-gain variation.
FREQUENCY CHARACTERISTIC	
Centre frequency	1 kHz ±50 Hz.
Bandwidth	80 Hz ±30 Hz.
LINEARITY	Better than 3% of full scale.

Modulators, Detectors and Mixers

P.I.N. Diode Modulators type 6053 series

	TYPE 6053/1	TYPE 6053/3
Frequency range	0·5 GHz to 12·4 GHz	7·5 GHz to 12·4 GHz
Insertion loss (at zero bias)	Less than 2 dB at 8 GHz	0·75 dB maximum.
Maximum isolation	35 dB at 100 mA bias	Greater than 20 dB
V.S.W.R. (at zero bias)	Better than 2 : 1	Typically 1·5 : 1 (2 : 1 max.)
Connectors	R.F. line: Stainless steel type N; Modulation: Type BNC silver plated brass.	OSM female connectors for r.f. and bias on standard version. Alternatively supplied with male connectors for r.f. and female for bias.

Coaxial Detectors type 6002 series
(formerly CD series)

Type No.	Formerly	Frequency Range	RF Input Connector	Internal DC Return	Diode Required
6002/1	CDN/S/D	200 MHz–12 GHz	Type N male	Yes	
6002/2	CD/PM/D	200 MHz–12 GHz	Type N female	Yes	CV2154
6002/3	CDC/S	200 MHz–12 GHz	Type C male	No	CV2155
6002/4	CD/BNC/S/D	200 MHz–12 GHz	Type BNC male	Yes	CS9B
6002/5	CDC/S/D	200 MHz–12 GHz	Type C male	Yes	
6002/6	CDN/S18	12 GHz–18 GHz	Type N male	No	IN26

Wide Band Detector type 6060

FREQUENCY	Range	10 MHz to 12·4 GHz.
	Response	Flat within ±0·2 dB per octave from 10 MHz to 8 GHz. Flat within ± 0·5 dB from 8 to 12·4 GHz.
INPUT	Impedance	50Ω
	V.S.W.R.	Less than 1·5 : 1 over the full frequency range.
	Maximum power	100 mW.
SENSITIVITY	Unloaded	0·25 mV per μW up to 30 mV output.
	With load resistor Part No. 2200154	0·15 mV per μW up to 100 mV output
OUTPUT	Capacitance	10 pF.
	Polarity	Negative (Positive polarity to order or by reversing diode element).
CONNECTORS	Input	Precision Type N Male.
	Output	Type B.N.C. Female.
		Matched pairs available suitable for sweeper levelling.

Broad Band Waveguide Detectors type 6000 series and Mixers type 6001 series

Waveguide Size	Frequency Coverage	Diode	Flanges Fitted	DETECTORS Type No.	DETECTORS Formerly	MIXERS Type No.	MIXERS Formerly
R320(WG.22)	26·5–40GHz	IN53	Round	6000/1	BCD22	6001/1	BCM22
R100(WG.16)	8·2–12·4GHz	CV2154 CV2155	Round	6000/2	BCD16RF	6001/2	BCM16R
R100(WG.16)	8·2–12·4GHz	CV2154 CV2155	Square	6000/3	BCD16SF	6001/3	BCM16SF

Features: V.S.W.R. better than 2 : 1 over full waveguide frequency range.
Output capacitance less than 10 pF.


type 6000 series

Waveguide Detectors type 6003 series and Mixers type 6004 series

WG Size	Frequency Coverage	Flanges Fitted	DETECTORS Type No.	DETECTORS Formerly	MIXERS Type No.	MIXERS Formerly
R140(WG.18)	12–18 GHz	Square	6003/1	CD18	6004/1	CM18
R100(WG.16)	8·5–12·0 GHz	Round	6003/2	CD16RF	6004/2	CM16RF
R100(WG.16)	8·5–12·0 GHz	Square	6003/3	CD16SF	6004/3	CM16SF
R84 (WG.15)	7·0–10·0 GHz	Square	6003/4	CD15	6004/4	CM15
R70 (WG.14).	5·85– 8·2 GHz	Round	6003/5	CD14	6004/5	CM14
R48 (WG.12)	3·95– 5·85 GHz	Round	6003/6	CD12	6004/6	CM12
R32 (WG.10)	2·6– 3·95 GHz	Round	6003/7	CD10	6004/7	CM10


type 6004/2

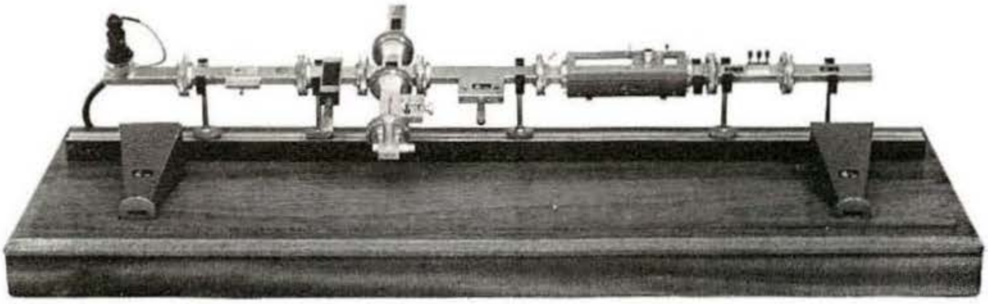
'X' Band Mixer type 6521 series

Type No.	Flanges Fitted	Output Connector	WG Size	Frequency Coverage	V.S.W.R.
6521/1	Round	Type BNC	R100(WG.16)	9·0–11·8 GHz	Better than 3 : 1
6521/2	Square	Type BNC	R100(WG.16)		
6521/3	Round	Solder Pin	R100(WG.16)		
6521/4	Square	Solder Pin	R100(WG.16)		

Features: Designed specifically to accept the new Mullard sub-miniature germanium mixer diode type AAY39 which has an overall noise figure of 6 dB.


type 6521/1

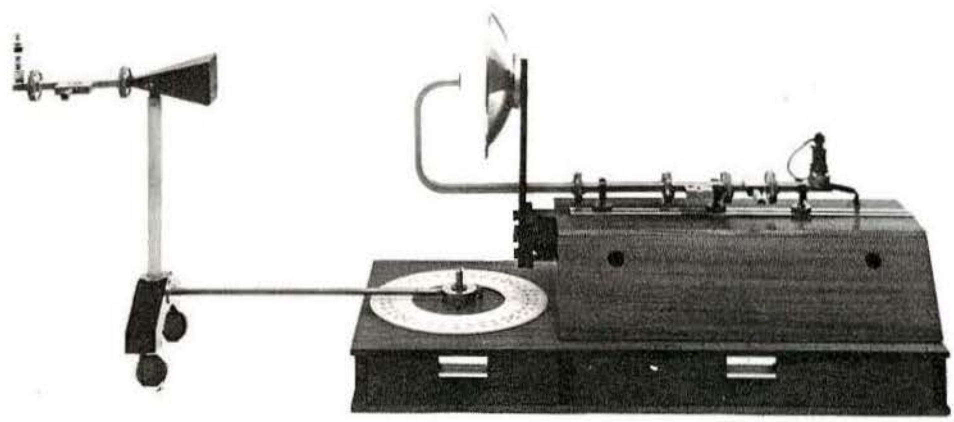
Educational Equipment



Microwave Educational Test Bench type 6599 series *(formerly 599)*

Waveguide size:	R100 (WG16)	
Frequency range: (using oscillator supplied)	8·5—9·5 GHz	
Microwave measurement capabilities:	ATTENUATION	PHASE SHIFT
	IMPEDANCE	POLARISATION OF RADIATION
	FREQUENCY	HORN ANTENNAE (POLAR DIAGRAMS)
Type No.:	6599/1 Round flange version 6599/2 Square flange version	

Features: Compact stowage, extreme versatility and rapid component set-up.



Educational Antenna Test Bench type 6452A series

Operates in 'X' Band.

Supplied with a wide selection of antennae for determination of polar diagrams and relative gain.

Complete with: Waveguide mounted Klystron
Wavemeter. Detector (coaxial)
Attenuators. Manual of experiments.

Type No. 6452A/1 Round flange version
6452A/2 Square flange version

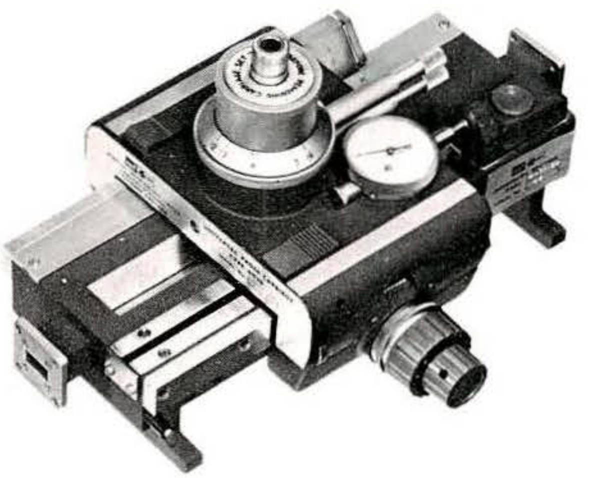
Features: Compact stowage and rapid assembly of components

Note: Optional Klystron Power Unit and VSWR Indicator are available with these benches and the following instruments are recommended:

VSWR Indicator Type 6596
VSWR Indicator/Selective Amplifier Type 6593
Klystron Power Supply Type 6597
Klystron Power Unit Type 6594

Gunn diode oscillator Type 6061 with power supply 6590 can be used instead of the klystron oscillator.

Impedance Matching and Measuring Instruments



Universal Slotted Line System

Incorporating: UNIVERSAL PROBE CARRIAGE TYPE 6010 (Formerly UPC 10-16)
SLOTTED WAVEGUIDE SECTIONS TYPE 6011 Series (formerly WS Series)

Universal Probe Carriage type 6010

A precision probe carriage for use with any one of the 6011 Series Slotted Waveguide Sections. Frequency range 2·6 to 18 GHz.

Features: Probe penetration into waveguide slot can be set by means of a continuously variable coupling adjuster calibrated in waveguide size, with a stop at each calibration mark to permit rapid selection of coupling when interchanging waveguide sections. Interchangeability between waveguide sections in less than 20 secs.

Slotted Waveguide Sections type 6011 series

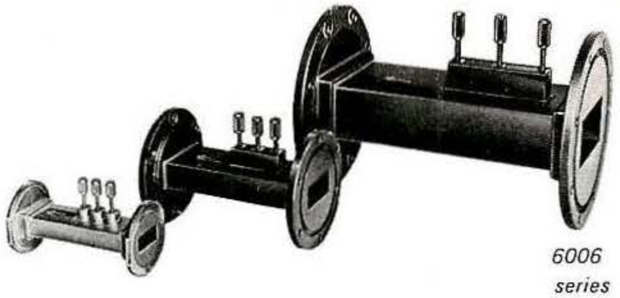
Type No.	Formerly	WG. Size	Flanges	Performance with 6010 Probe Carriage		
				Frequency Range GHz	Residual VSWR	Attenuation Slope dB/cm
6011/1	WS16RF	R100(WG16)	Round	8·20–12·40	1·003 : 1	0·0030
6011/2	WS16SF	R100(WG16)	Square	8·20–12·40	1·003 : 1	0·0030
6011/3	WS15	R84(WG15)	Square	7·05–10·00	1·003 : 1	0·0020
6011/4	WS14	R70(WG14)	Round	5·85– 8·20	1·004 : 1	0·0020
6011/5	WS13	R58(WG13)	To order	4·90– 7·05	1·004 : 1	0·0015
6011/6	WS12	R48(WG12)	Round	3·95– 5·85	1·004 : 1	0·0014
6011/7	WS11A	R40(WG11A)	To order	3·30– 4·90	1·004 : 1	0·0012
6011/8	WS10	R32(WG10)	Special 14 hole	2·60– 3·95	1·003 : 1	0·0010
6011/9	WS11	—(WG11)	To order	3·30– 4·90	1·004 : 1	0·0013
6011/10	New Development	R140(WG18)	Square	12·4 –18·00	1·009 : 1	0·0050
6011/11	—	R120(WG17)	—	10·0 –15·00	1·007 : 1	0·0040

Features: Coupling is in the range of 20—30 dB in all cases.

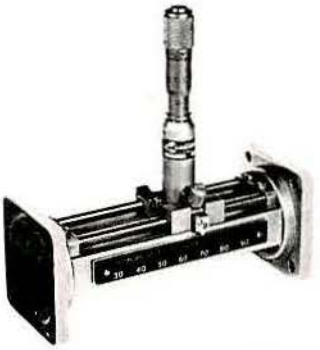
OPTIONAL ACCESSORIES: Type 6002/1 Coaxial Detector
Type 6002/6 Coaxial Detector

ANCILLARY INSTRUMENTS: Type 6593 VSWR Indicator/ Selective Amplifier
Type 6596 VSWR Indicator

6005 series



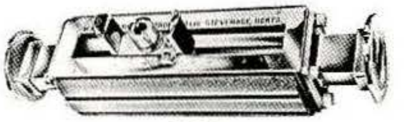
6006 series



6007 series

6008 series

Variable Short Circuits type 6005 series *(formerly SC series)*
Waveguide Stub Tuners type 6006 series *(formerly ST series)*
Variable Impedance type 6007 series *(formerly VI series)*
Variable Transformers type 6008 series *(formerly VX series)*



6009 series

COMMON INFORMATION			VARIABLE SHORT CIRCUITS TYPE 6005 SERIES			STUB TUNERS TYPE 6006 SERIES	
WG Size	Frequency Range GHz	Flanges	Type No.	Formerly	Min. VSWR of Plunger	Type No.	Formerly
R320(WG22)	26·5 –40	Round	6005/1	SC22	40dB	—	—
R140(WG18)	12·4 –18	Square	6005/2	SC18	50dB	—	—
R100(WG16)	8·2 –12·4	Round	6005/3	SC16RF	50dB	6006/1	ST16RF
R100(WG16)	8·2 –12·4	Square	6005/4	SC16SF	50dB	6006/2	ST16SF
R84(WG15)	7·0 –10·0	Square	6005/5	SC15	50dB	6006/3	ST15
R70(WG14)	5·85– 8·2	Round	6005/6	SC14	50dB	6006/4	ST14
R48(WG12)	3·95– 5·85	Round	6005/7	SC12	50dB	6006/5	ST12
R32(WG10)	2·60– 3·95	Round	6005/8	SC10	50dB	6006/6	ST10
FEATURES			Micrometer head adjustment enabling the plunger position to be determined to within 0·005cm.			The tuning block is mounted nearer one flange so that block position is changed on reversal.	

COMMON INFORMATION			VARIABLE IMPEDANCES TYPE 6007 SERIES				VARIABLE TRANSFORMERS TYPE 6008 SERIES (C–H Tuners)	
WG Size	Frequency Range GHz	Flanges	Type No.	Formerly	Probe travel inches	Probe penetration inches	Type No.	Formerly
R320(WG22)	26·5 –40	Round	6007/1	VI22	0·70	0·125	—	—
R140(WG18)	12·4 –18	Square	6007/2	VI18	1·00	0·295	—	—
R100(WG16)	8·2 –12·4	Round	6007/3	VI16RF	2·25	0·400	6008/1	VX16RF
R100(WG16)	8·2 –12·4	Square	6007/4	VI16SF	2·25	0·400	6008/2	VX16SF
R84(WG15)	7·0 –10·0	Square	6007/5	VI15	2·50	0·488	—	—
R70(WG14)	5·85– 8·2	Round	6007/6	VI14	3·00	0·600	—	—
R48(WG12)	3·95– 5·85	Round	6007/7	VI12	5·00	0·800	—	—
R32(WG10)	2·60– 3·95	Round	6007/8	VI10	7·00	1·220	—	—
FEATURES			Adjustable probe penetration by means of a micrometer assembly mounted on a sliding carriage which can be locked in any desired longitudinal position.				Standard-Knob adjustment. Special Order—Micrometer adjustment for accurate re-setting	

Standing Wave Detector, Grade 2. type 6009 series *(formerly SWM series)*

Waveguide Size:	R100 (WG16)
Frequency Range:	8·2—12·4 GHz
Attenuation Slope:	Typically 0·005 dB/cm
Probe Discontinuity:	Less than 0·01 voltage reflection coefficient
Coupling of Probe:	23 dB ± 2·0 dB over frequency range
Variation of Coupling:	0·05 dB (over length)
Mechanical re-set accuracy:	0·01 cm

Features: Magnifying lens allows scale readings to 0·1 mm. Phase measurements normally better than 1%.

Type No. 6009/1 Round flange version. (formerly SWM16/2/RF)
Type No. 6009/2 Square flange version. (formerly SWM16/2/SF)

R.F. Sources,

Signal Generators type 6012 *formerly SG478 (M.O.A. CT478)*
type 6013 *formerly SG480 (M.O.A. CT480)*

6013

	TYPE 6012	TYPE 6013
FREQUENCY COVERAGE	1·5–4·2 GHz in two bands: 1·5–2·2 GHz 2·1–4·2 GHz	7·0–11·5 GHz
MAXIMUM POWER OUTPUT	approx. 20 mW	approx. 10 mW
NOMINAL LEVEL	1 mW	1 mW
ATTENUATION	0 to −100 dBm	0 to −100 dBm 0 to +10 dBm over limited band
ACCURACY OF 1mW LEVEL	±2·5 dB from 1·5–4·0 GHz	±2·5 dB from 8·0–11·0 GHz
OUTPUT TERMINATION 50Ω	Type N female	Type N female
MODULATION		
Internal	Squarewave	Pulse
Depth	100%	100%
Frequency	2700–3300 Hz	2700–3300 Hz
Mark space ratio	0·95–1·05	0·95–1·05
Rise and fall time of r.f. output pulse	Less than 0·2 µsec.	Less than 0·2 µsec.
Sync output	+5 volts	+5 volts
Pulse width at half amplitude		1 to 2 µsec.
External	Pulse	
Input amplitude	5 volts positive	
Input width	0·1 µsec. minimum	
Input Frequency	100 Hz to 250 kHz	
R.F. output pulse width	approx. 0·7 µsec.	
Rise time	0·1 µsec.	
Delay on trigger	(a) with 1 µsec. input pulse: approx. 0·5 µsec. (b) with 0·1 µsec. input pulse: approx. 0·3 µsec.	

Gunn Diode Oscillator type 6061

Waveguide size	R100 (WG.16)
Frequency range	8·0–10·5GHz
Power output	Typically 5mW.
Bias	Negative
CONNECTORS	
Output	R100 (WG.16) plain face square flange.
Input	Type BNC.
DIODE SUPPLIED	MI-SANDERS Part No. 22000169
FEATURES	Micrometer head tuning.
Recommended power unit	M.I. SANDERS POWER SUPPLY TYPE 6590.

Klystron Mount type 6015 series
(formerly KM 723)

Waveguide size	R100 (WG 16)
Frequency range	Approx. 8·5–9·6GHz depending on klystron
Output power	Typically 20 to 30mW.
Flanges	*Type 6015/1:* Round Flange *Type 6015/2:* Square Flange
Features	Suitable for use with723A/B or 2K25 series reflex klystrons.

We also produce a range of solid state microwave oscillators for systems applications.

Signal Source type 6055

FREQUENCY	
Range	850 to 2150 MHz
Scale accuracy	±1%
Scale resetability	0·1%
OUTPUT	
Impedance	50Ω
Available power	Not less than 10mW (typically 60 mW) into 50Ω load; variable over 25dB range by internal and external control.
AMPLITUDE MODULATION	
Internal	900Hz to 1·1kHz square wave.
External (P.I.N. Diode)	At least 25dB suppression for —20 volts; rise time 1 μsec. (10dB suppression).
SIGNAL PURITY	
Harmonic content	No greater than —20dB relative to fundamental
Residual f.m.	Typically 1ppm.
FEATURES	Solid state active elements throughout. Four digit mechanical counter for better frequency discrimination.

Signal Source type 6058

FREQUENCY	
Range	7·0 to 12·5 GHz
Scale accuracy	± 1%
Scale resetability	0·1%
OUTPUT	
Impedance	50 Ω
Available power	Not less than 5mW (typically 10mW) into 50 Ω load; variable over 20dB range by internal and external control.
AMPLITUDE MODULATION	
Internal	900Hz to 1·1kHz square wave
External (P.I.N. Diode)	At least 20dB suppression for —20 volts; rise time 1 μsec (10dB suppression).
SIGNAL PURITY	
Harmonic content	No greater than —20dB relative to fundamental.
Residual f.m.	Typically 10 ppm
FEATURES	Solid state active elements throughout. Four digit mechanical counter for better frequency discrimination.

UHF Signal Generator type TF 1060/2

FREQUENCY	
Range	450 to 1200MHz (66 to 25 cm) in one band.
Accuracy	Main tuning 1%; incremental 5%.
Stability	After warm-up drift is less than 0·005% in 10 min. period.
Attenuator reaction	Below 10μW: negligible
Spurious signals	Above 10μW: less than 0·05%. Total harmonic content is less than 2%.
R.F. OUTPUT	
Level	continuously variable from —143dB to at least —30dB relative to 1 watt.

Typically:

	(emf)	From
11mW	1·5 volts	600 to 800MHz
45mW	3·0 volts	800 to 1000MHz
31mW	2·5 volts	1000 to 1200MHz

Accuracy	2dB overall
Impedance	50Ω; v.s.w.r. less than 1·5 : 1.
MODULATION	
Internal sine a.m.	1000Hz at a depth between 10% and 40%.
External pulse modulation	Recurrence frequency range: 50Hz to 50kHz input requirements: positive pulses of not less than 30 volts across 10kΩ. Output characteristics:

Carrier frequency MHz	Max. rise time nsec.	Max. delay time nsec.	Min. pulse length μsec.	Max. jitter nsec.
470–600	200	400	1·0	300
600–1000	200	400	0·5	100
1000–1050	100	200	0·3	60
1050–1200	200	400	0·5	100

Spurious f.m. on a.m.	Typically, for 30% a.m., f.m. varies from 125 kHz at 450 MHz to 350 kHz at 1200 MHz.
Residual a.m.	The a.m. due to hum and noise is less than 40dB below 30% modulation.
Residual f.m.	The f.m. due to hum and noise is less than 2·5 kHz deviation.
ACCESSORIES	
Optional	Output lead TM 4726/12.

Radar Test Set type TF 890A

Combined in one compact unit is a cavity wavemeter, thermistor power monitor, c.w. and f.m. klystron signal generator, spectrum analyser, complete with c.r.t. display, and a directive feed assembly. Frequency range 8·5 to 9·68 GHz.

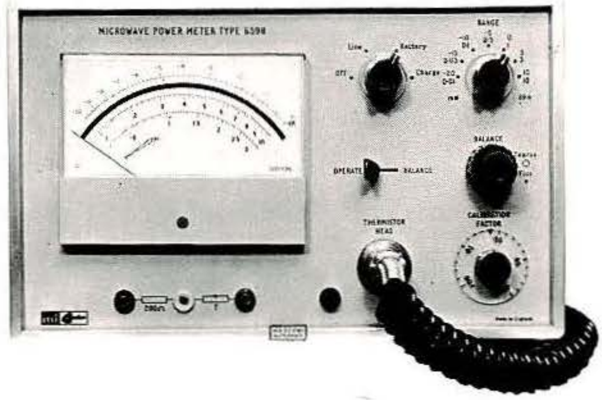
	POWER MONITOR	SIGNAL GENERATOR	SPECTRUM ANALYSER	VARIABLE ATTENUATOR and WAVEMETER
RANGE	At WG Coupling to Test Set, +33dBm to −10dBm (i.e. 2 watts to 0·1mW) using Directive Feed Assy. and Flexible Coupling. FORWARD: +47dBm to nominally +15dBm. (50 watts to nominally 32mW) RETURN: +41dBm to nominally +5dBm. (12·5 watts to nominally 3mW)	Output Range at WG Coupling to Test Set: +6dBm to −54dBm (assuming a Klystron output of 4mW) Output Range using Directive Feed Assy. at Forward, Flexible Coupling and External Variable Attenuator. Nominal −21dBm to −109dBm.	Pulse width range 0·1 to 2·0μsec.	WAVEMETER 8,500 to 9680MHz in 5MHz Steps. VARIABLE ATTENUATOR Not Less than 30dB 1 dB divisions.
ACCURACY	Of Thermistor Bridge and Meter. ±0·5dB at 9,100 MHz at 1mW. ±1·0dB at other Frequencies at 1mW.			WAVEMETER Calibration Accuracy ±3MHz. VARIABLE ATTENUATOR Calibration accuracy ±1dB at 8800 and 9400MHz ±2dB at other frequencies.
OTHER INFORMATION	METER SCALE: 0·1 to 2mW 1mW at MID SCALE VSWR: Minimum Power required for the measurement of a VSWR of 1·2 is 0·4 watt.	Type of output (i) C.W. (ii) Frequency modulated by sawtooth waveform. Sweep duration 33·3 to 100msec. (iii) Frequency modulated by a pulse waveform which can be synchronised from 300 to 3,000Hz. Sweep rate approximately 30MHz per sec. The pulse has a delay adjustable from not greater than 1μsec. to not less than 60μsec.	I.F. Circuits: 1ST I.F. 40MHz 2ND I.F. 2MHz overall bandwidth less than 50kHz at −3dB and less than 200kHz at −10dB. SWEEP DURATION: 33·3 to 100msec. SENSITIVITY: A c.w. signal of −10dB relative to 1mW at WG coupling to the Test Set.	WAVEMETER Discrimination 2MHz VARIABLE ATTENUATOR Max. dissipation 2 watts.

OTHER FACILITIES	WAVEGUIDE SWITCH APERTURE	FLEXIBLE COUPLING	DIRECTIVE FEED ASSEMBLY
	Attenuation nominally 30dB.	Attenuation Nominal 5dB; actual value measured at 8,800 and 9400MHz to an accuracy of ±0·5dB marked on coupling.	Power Coupling Attenuation. FORWARD 20dB RETURN 10dB (accuracy ±0·75dB) Maximum mean power FORWARD 50 watts RETURN 12·5 watts

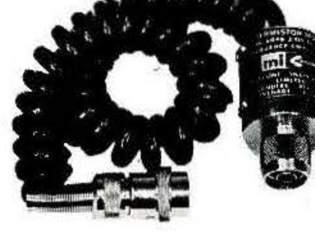
Power and Frequency Meters

Microwave Power Meter type 6598

FREQUENCY RANGE	5MHz—18GHz Dependent on waveguide or coaxial measuring head employed.
ACCURACY	±3% absolute.
MEASUREMENT RANGES	10μW to 10mW in seven switch selected ranges of :- 10, 30, 100, 300μW. 1,3 and 10mW f.s.d. (meter also scaled in dBm)
RECORDER LEVELLER OUTPUT	0–1mA.
FEATURES	12 volt (re-chargeable) battery operation as an optional extra.



WG. Thermistor Mounts type 6045 series
Coaxial Thermistor Mounts type 6046 series



TYPE No.	WAVEGUIDE SIZE	FREQUENCY RANGE	V.S.W.R.	MAX. AVERAGE POWER	OPERATING RESISTANCE (OHMS)	R.F. CONNECTORS	MAX. ENERGY PER PULSE	POWER RANGE WITH TYPE 6598 POWER METER
6045/1	R140(WG.18)	12·4 –18GHz	1·5 :1 max.	30mW	200	Square Flg.	10W-μsec per pulse: at PRF's less than 1kHz.	
6045/3	R100(WG.16)	8·2 –12·4GHz	1·5 :1 max.	30mW	200	Square Flg.		
6045/4	R70 (WG.15)	5·85– 8·2GHz	1·5 :1 max.	30mW	200	Round Flg.		
6045/5	R48 (WG.14)	3·95– 5·85GHz	1·5 :1 max.	30mW	200	Round Flg.	5W-μsec per pulse at PRF's greater than 1kHz.	1μW–10mW
6045/6	R32 (WG.10)	2·6 – 3·95GHz	1·5 :1 max.	30mW	200	Round Flg.		
6046/3	Coaxial	5MHz–11GHz		30 Mw	200	Type 'N'		
		5MHz–25MHz	1·5 :1			Male		
		25MHz– 7GHz	1·3 :1			Stainless		
		7GHz–11GHz	1·5 :1			Steel		

MOUNT CALIBRATION: Calibration factor and efficiency are traceable to NBS Standards at the frequencies where power standards exist.

6049/1 with accessories

Frequency Meter type 6049/1

FREQUENCY		
Range	2·6 to 8·2GHz.	
Overall accuracy	±0·1%	
Calibration increments	5MHz between 2·6 and 5·0GHz. 10MHz between 5·0 and 8·2GHz.	
INPUT CONDITIONS		
VSWR	Passing coaxial attachment (Part No. 2523009): Less than 1·5 : 1 (relative to 50Ω). All waveguide attachments less than 1 : 1.	
RESPONSE		
Q-factor	Typically 1000.	
Dip at resonance	Passing coaxial attachment: greater than 0·5dB. All waveguide attachments: greater than 1·0dB.	
ACCESSORIES	Part No.	Description
Supplied	2523009	Passing coaxial attachment complete with two female Type 'N' connectors.
	2523048	Stand for coaxial attachment.
	2523015	Auxiliary outlet with Type 'N' female connector.
	2523041	Cover plate.
Optional	2523008	Waveguide attachment R70 (WG14)
	2523006	Waveguide attachment R48 (WG12)
	2523007	Waveguide attachment R40 (WG11A)
	2523005	Waveguide attachment R32 (WG10)
	2523011	Crystal Detector with BNC connector.

Frequency Meter type 6049/2

FREQUENCY		
Range	5·3—18·0 GHz.	
Overall accuracy	±0·1%	
Calibration increments	20 MHz between 5·3 and 6·0 GHz. 10 MHz between 6·0 and 18·0 GHz.	
INPUT CONDITIONS		
VSWR	Passing coaxial attachment (Part No. 2524009): Less than 2·0:1 (relative to 50Ω. All waveguide attachments 1·1 : 1.	
RESPONSE		
Q-factor	Typically 1000.	
Dip at resonance	Passing coaxial attachment: greater than 1·0 dB. All waveguide attachments: greater than 1·0 dB.	
ACCESSORIES	Part No.	Description
Supplied	2524009	Passing coaxial attachment complete with 2 female type N connectors.
	2524047	Stand for coaxial attachment.
	2524030	Auxiliary outlet with type N female connector.
	2524048	Cover plate.
Optional	2524008	Passing coaxial attachment complete with 2 female O.S.M. connectors.
	2524013	Waveguide attachment R140 (WG18)
	2524010	Waveguide attachment R120 (WG17)
	2524012	Waveguide attachment R100 (WG16)
	2524011	Waveguide attachment R70 (WG14)
	2524014	Crystal detector with BNC connector.

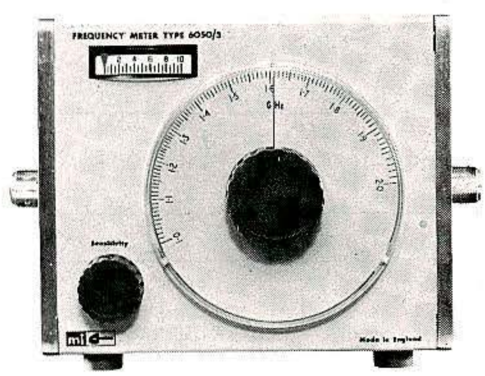
Features: A precision frequency meter that may be used either with its standard passing coaxial attachment, and associated removable stand as an absorption or transmission wavemeter or alternatively, coupled directly into waveguide systems from R140 (WG18) to R32 (WG10) using any one of the waveguide attachments available.

Wavemeters Grade 1 type 6016 series *(formerly WM series)*
Grade 2 type 6017 series *(formerly WM series)*

TYPE No.	FORMERLY	WG. SIZE	FREQUENCY COVERAGE GHz	MODE USED	RESOLUTION	FLANGES FITTED
6016/1	WM22/1	R320(WG.22)	26·5 –40·0	TE111	10MHz at 40GHz 3MHz at 26·5GHz	ROUND
6016/2	WM18/1	R140(WG18)	11·7 –18·0 14·8 –18·0	TE111 TE112	2·1MHz at 18GHz 0·15MHz at 11·7GHz	SQUARE
6016/3	WM16/1RF	R100(WG.16)	8·2 –11·0	TE011	0·5MHz at 12·4GHz	ROUND
6016/4	WM16/1SF	R100(WG.16)	10·0 –12·4	TE012	0·08MHz at 8·2GHz	SQUARE
6017/1	WM16/2RF	R100(WG.16)	8·2 –12·4	TE011	2·1MHz at 12·4GHz	ROUND
6017/2	WM16/2SF	R100(WG.16)			1·0MHz at 8·2GHz	SQUARE
6017/5	WM12/2	R48 (WG.12)	3·95– 5·85	TE011	0·75MHz at 5·85GHz 0·5MHz at 3·95GHz	ROUND

Frequency Meter type 6050/3

FREQUENCY	
Range	1 to 2GHz.
Overall Accuracy	±0·2%.
Calibration increments	10MHz.
INPUT CONDITIONS	
Normal impedance	50Ω
VSWR	Less than 1·5 : 1.
Connectors	TYPE N (wavemeter). BNC (External meter).
RESPONSE	
Sensitivity	Less than 4mW f.s.d.: 0·4mW per division.
Dip at resonance	3 dB
NOTE	This instrument is a development of the well known Marconi Instruments Portable Frequency Meter TF.1026/3 which it supersedes.



Frequency Meter type 6051

FREQUENCY	
Range	8·2 to 12·4GHz
Overall Accuracy	±0·2%.
Calibration increments	10MHz
INPUT CONDITIONS	
VSWR	1·1 :1.
Connectors	SQUARE FLANGES R100 (WG16)
RESPONSE	
Q-factor	Typically 1000.
Dip at Resonance	Greater than 10% of incident power.

Attenuators and Phase Shifters

6019 series

6021 series

Waveguide Attenuators type 6018, 6019, 6020, and 6021 series *(formerly CA, SA and VA series)*

Frequency Range GHz	Waveguide Size	Flanges Fitted	Input VSWR	Insertion Loss dB	Maximum Dissipation of Element (W)	Attenuating Element
26·5–40	R320(WG.22)	ROUND	1·075 :1	0·3	0·2	40dB Metallised Glass
			1·1 :1	0·3	—	20dB Glass Fibre
12·4–18·0	R140(WG.18)	SQUARE	1·075 :1	0·2	0·5	40dB Metallised Glass
			1·1 :1	0·2	—	20dB Glass Fibre
12·4–18·5			1·075 :1	0·2	0·475	20dB Glass Fibre
8·2–10·5	R100(WG.16)	ROUND SQUARE	1·075 :1	0·1	1·0	40dB Metallised Glass
		ROUND SQUARE				20dB.Glass Fibre
8·2–12·4	R100(WG.16)	ROUND SQUARE	1·1 :1	0·15	1·0	20dB Glass Fibre
7·05–10·0	R84(WG.15)	SQUARE	1·075 :1	0·1	1·0	40dB Metallised Glass
7·05– 9·5						
5·85– 8·2	R70(WG.14)		1·075 :1	0·1	1·0	40dB Metallised Glass
5·85– 7·5						
3·95– 5·85	R48(WG.12)	ROUND	1·075 :1	0·1	2·0	40dB Metallised Glass
2·6 – 3·6	R32(WG.10)	ROUND	1·075 :1	0·1	2·5	40dB Metallised Glass
2·6 – 3·95					—	20dB Metallised Glass

6018 series

6020 series

CALIBRATED VARIABLE GRADE 1 TYPE 6018 SERIES			CALIBRATED VARIABLE GRADE 2 TYPE 6019 SERIES			PRE-SET TYPE 6021 SERIES		SET-LEVEL TYPE 6020 SERIES	
TYPE No.	FORMERLY	RESET ACCURACY	TYPE No.	FORMERLY	RESET ACCURACY	TYPE No.	FORMERLY	TYPE No.	FORMERLY
6018/1	CA22/1	0·05dB	6019/1	CA22/2	0·07dB	—	—	—	—
—	—	—	—	—	—	—	—	6020/1	VA22
6018/2	CA18/1	0·08dB	6019/2	CA18/2	0·06dB	—	—	—	—
—	—	—	—	—	—	—	—	6020/2	VA18
—	—	—	—	—	—	6021/1	SA18	—	—
6018/3	CA16/1RF	0·4dB	6019/3	CA16/2RF	0·07dB	6021/4	SA16/RF/40	—	—
6018/4	CA16/1SF	0·4dB	6019/4	CA16/2SF	0·07dB	6021/5	SA16/SF/40	—	—
—	—	—	—	—	—	6021/2	SA16/RF/20	—	—
—	—	—	—	—	—	6021/3	SA16/SF/20	—	—
—		—	—	—	—	—	—	6020/3	VA16/RF
—	—	—	—	—	—	—	—	6020/4	VA16/SF
—	—	—	—	—	—	6021/6	SA15	—	—
6018/5	CA15/1	0·03dB	6019/5	CA15/2	0·05dB	—	—	—	—
—	—	—	—	—	—	6021/7	SA14	—	—
6018/6	CA14/1	0·03dB	6019/6	CA14/2	0·05dB	—	—	—	—
6018/7	CA12/1	0·03dB	6019/7	CA12/2	0·05dB	6021/8	SA12	—	—
6018/8	CA10/1	0·01dB	6019/8	CA10/2	0·02dB	—	—	—	—
—	—	—	—	—	—	—	—	6020/5	VA10

Attenuators and Phase Shifters, *continued*

Precision Rotary Vane Attenuators type 6052 series

TYPE No.	WG Size	Frequency Range (GHz)	Power Rating	Maximum V.S.W.R.	Insertion Loss (dB)	Phase Shift	Temp. Range	ATTENUATION	
								Range	Accuracy
6052/2	R140 WG.18	12·4–18·0	5W						
6052/3	R100 WG.16	8·2–12·4	10W	1·15 : 1	0·75 max.	2° max.	0°–50°C.	0–60dB	0–10dB : 0·1dB 10–40dB : 1% 40–50dB : 2% 50–60dB : 3%
6052/5	R70 WG.14	5·85–8·2	10W						

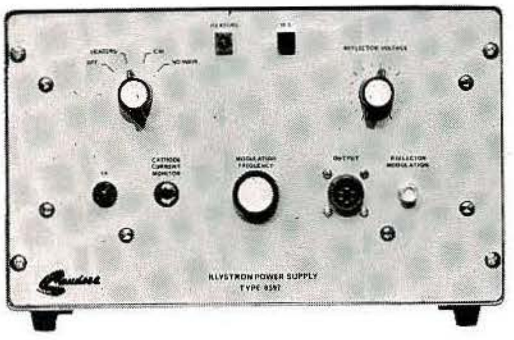
Features: Small overall size and low weight achieved by addition of new features to the conventional rotary attenuator design, such as the use of Tchebysheff quarter wavelength stepped transition and improved simplified drive system which increases accuracy. (This is typified by the very clear read-out system).

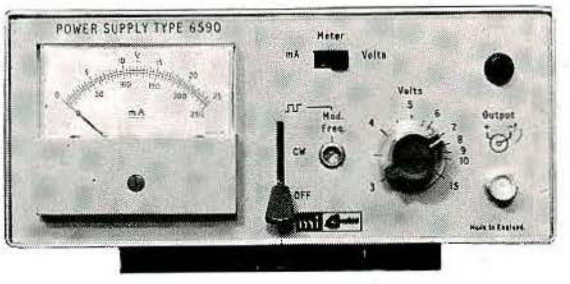
Phase Shifters type 6022 series *(formerly PS series)*

Type No.	Formerly	Frequency Range GHz	WG. Size	Flanges	Minimum Total Phase Shift	V.S.W.R.
6022/1	PS22	26·5–40	R320(WG.22)	ROUND		
6022/2	PS18	12·4–18·0	R140(WG.18)	SQUARE		
6022/3	PS16/RF	8·2–12·4	R100(WG.16)	ROUND		
6022/4	PS16/SF	8·2–12·4	R100(WG.16)	SQUARE	180°	less than 1·2 : 1
6022/5	PS15	7·0–10·0	R84 (WG.15)	SQUARE		
6022/6	PS14	5·85– 8·2	R70 (WG.14)	ROUND		
6022/7	PS12	3·95– 5·85	R48 (WG.12)	ROUND		
6022/8	PS10	2·6 – 3·95	R32 (WG10)	ROUND		

Features: The position of the vane is controlled by a micrometer, and calibration is provided at intervals of 36° (one tenth of a guide wavelength) up to 180°.

Power Supply Units





Klystron Power Supply type 6597

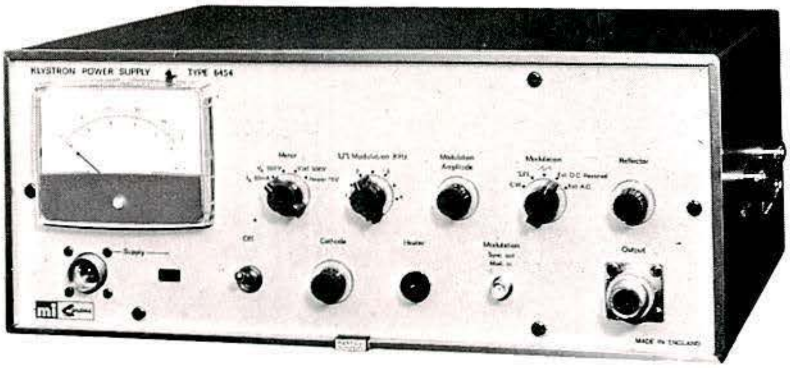
Provides drive voltages and modulation for klystron oscillators requiring a beam supply of 300 volts at up to 30 mA—in particular the 723 A/B and 2K25. Reflector voltage is variable 0 to 300 volts negative with respect to cathode, and square-wave modulation is provided at 1 kHz. Suitable for use with both educational test benches types 6599 and 6452A.

KLYSTRON CATHODE SUPPLY	
Voltage	295 volts ±15 volts negative with respect to resonator (earth)—not adjustable.
Maximum current	30 mA.
Source impedance	Less than 200Ω.
Ripple	Less than 5 mV r.m.s.
KLYSTRON REFLECTOR SUPPLY	
Voltage	Adjustable from 0 to 300 volts negative with respect to cathode.
Minimum d.c. source impedance	200kΩ.
Ripple	Less than 5 mV r.m.s.
KLYSTRON HEATER SUPPLY	
Voltage	6·3 volts a.c.
Maximum current	1 amp.r.m.s.
INTERNAL MODULATION	
Cathode waveform	Positive going squarewave. Approximately 150 volts amplitude.
Frequency	Adjustable between 850 and 1150 Hz.
Duty ratio	0·95 :1 to 1·05 :1.
EXTERNAL MODULATION	
Reflector waveform	Sawtooth or sinewave.
Maximum input	300 volts peak-to-peak.
Frequency range	Sawtooth: 25 to 1500Hz. Sinewave: 15 to 5000Hz.
Input impedance	200kΩ in parellel with 60pF.

Gunn Diode Power Supply type 6590

Specially designed for use with the M.I. Sanders Gunn Diode Oscillator type 6061. The power unit delivers a maximum of 250 mA and the output voltage is variable up to 25 volts. Internal squarewave modulation can be applied at 1 kHz nominal repetition frequency.

OUTPUT	
Voltage	3 to 15 volts d.c.
Current	Up to 250mA.
Ripple	Less than 1mV p-p.
Stability	10mV max. drift for ±10% supply voltage variation.
MODULATION (Squarewave on/off)	
Frequency	1 kHz ±20%.
Amplitude	100%.
Rise and fall	Less than 5μsec.
MONITOR	
Voltage	0 to 25 volts (d.c. or peak squarewave).
Current	0 to 250 mA (d.c. or squarewave average).



Klystron Power Supply type 6454

Primarily designed for use with Microwave Oscillators types 6455 and 6456, this unit can also be used with any klystron requiring a resonator voltage between 250 and 400 volts and a reflector voltage from −10 to −500 volts. The unit has provision for internal and external modulation of the reflector voltage—d.c. restored for squarewave a.m. and simple a.c. coupled for f.m.

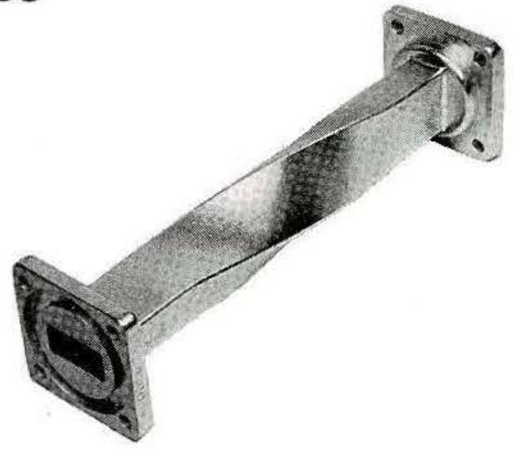
TYPE 6454. Heater output unstabilised d.c.

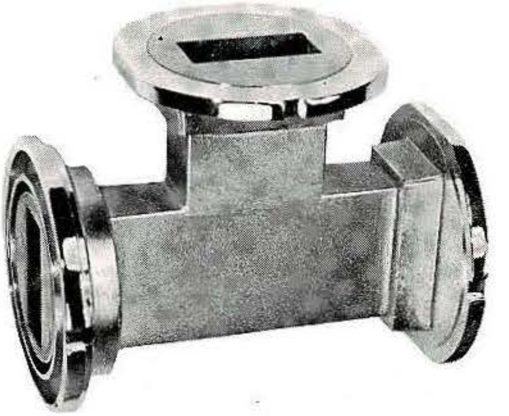
KLYSTRON CATHODE SUPPLY	
Voltage	Adjustable from 250 volts to 400 volts negative with respect to earth.
Regulation	0·05% for ±7·5% mains variation.
Load current	50 mA.
Int. impedance	Less than 3 Ω.
Ripple	Less than 1 mV r.m.s.
Metering	Voltage 0 to 500 volts ±2%. Current 0 to 50 mA ±5%.
KLYSTRON REFLECTOR SUPPLY	
Voltage	Adjustable from 10 volts to 500 volts negative with respect to cathode.
Regulation	0·03% for ±7·5% mains variation.
Int. impedance	25 kΩ in c.w. 330 kΩ when modulated.
Ripple	Less than 5mV r.m.s.
Metering	Voltage only 0 to 500 volts ±2%.
KLYSTRON HEATER SUPPLY	
Voltage	Adjustable from zero to 10 volts d.c. floating unregulated. Stabilised d.c. supply optional.
Load current	1·5 amps max
Int. impedance	Approximately 50 Ω.
Ripple	Typically 30mV r.m.s.
Metering	Voltage only 0 to 15 volts ±2%.

INTERNAL MODULATION (APPLIED TO REFLECTOR)	
Reflector Waveform	Squarewave.
Amplitude modulation	Amplitude 5 to 200 volts d.c. restored.
Frequency	Adjustable between 900 and 4000 Hz.
Reflector Waveform	Sawtooth at 1 kHz.
Frequency modulation	Adjustable between 5 to 180 volts a.c. coupled.
EXTERNAL MODULATION (APPLIED TO REFLECTOR)	
Amplitude modulation	D.C. restoration at reflector.
Frequency modulation	A.C. coupled to reflector without d.c. restoration.
CONNECTORS	
Mains input	Cannon WK-3-31SL mates with socket WK-3-21C 1$\frac{1}{4}$.
Output socket	Cannon WK-5-31SL mates with plug WK-5-22C-$\frac{3}{4}$.
Modulation input	B.N.C.
ACCESSORIES	
Supplied	2200157 Mains lead 1·7 m. (72") long. 2200158 Inter-connecting cable 1·2 m. (48") long. Complete with Connection-Cannon: WK-5-21C-$\frac{3}{4}$ socket WK-5-22C-$\frac{3}{4}$ plug.
Optional	2200161 Modulation input cable 1·2 m. (48") long. B.N.C. at one end.

TYPE 6454/1 AS ABOVE, except for heater output stabilised d.c. at extra cost.

Components and Accessories





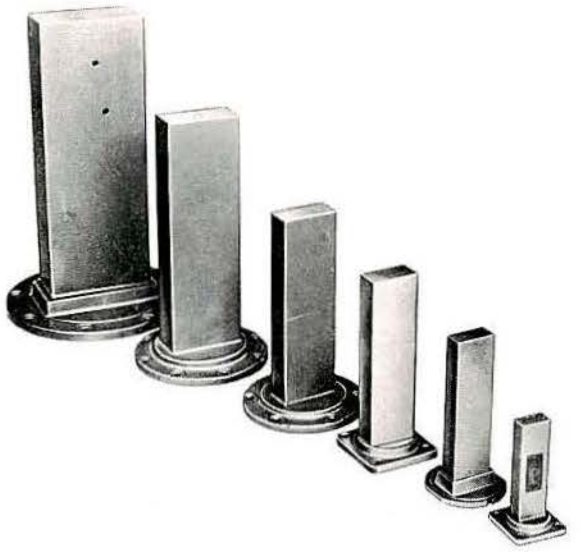
Waveguide: 'E' Plane Junctions type 6023 series *(formerly EJ series)*
'H' Plane Junctions type 6024 series *(formerly HJ series)*
'E' Plane Bends type 6025 series *(formerly EB series)*
'H' Plane Bends type 6026 series *(formerly HB series)*
Twists type 6027 series *(formerly T series)*

			E-PLANE JUNCT.		H-PLANE JUNCT.		E-PLANE BENDS		H-PLANE BENDS		TWISTS		
Frequency Range GHz	Waveguide Size	Flanges Fitted	Type No.	Formerly	Type No.	Formerly	Type No.	Formerly	Type No.	Formerly	Type No.	Formerly	VSWR
26·5 –40·0	R320(WG.22)	ROUND	—	—	—	—	6025/1	EB22	6026/1	HB22	—	—	—
12·4 –18·0	R140(WG.18)	SQUARE	6023/1	EJ18	6024/1	HJ18	6025/2	EB18	6026/2	HB18	6027/1	T18	1·05 : 1
8·2 –12·4	R100(WG.16)	ROUND	6023/2	EJ16/RF	6024/2	HJ16/RF	6025/3	EB16/RF	6026/3	HB16/RF	6027/2	T16/RF	1·05 : 1
8·2 –12·4	R100(WG.16)	SQUARE	6023/3	EJ16/SF	6024/3	HJ16/SF	6025/4	EB16/SF	6026/4	HB16/SF	6027/3	T16/SF	1·05 : 1
7·5 –10·0	R84(WG.15)	SQUARE	6023/4	EJ15	6024/4	HJ15	—	—	—	—	6027/4	T15	1·05 :1
7·05–10·0	R84(WG.15)	SQUARE	—	—	—	—	6025/5	EB15	6026/5	HB15	—	—	—
5·35– 8·2	R70(WG.14)	ROUND	—	—	—	—	—	—	—	—	6027/5	T14	1·05 : 1
5·85– 8·2	R70(WG.14)	ROUND	6023/5	EJ14	6024/5	HJ14	6025/6	EB14	6026/6	HB14	—	—	—
3·95– 5·85	R48(WG.12)	ROUND	6023/6	EJ12	6024/6	HJ12	6025/7	EB12	6026/7	HB12	6027/6	T12	1·05 : 1
2·65– 3·95	R32(WG.10)	ROUND	6023/7	EJ10	6024/7	HJ10	6025/8	EB10	6026/8	HB10	6027/7	T10	1·05 : 1

Components and Accessories, *continued*

Directional Couplers : type 6028 series *(formerly FS series)*
type 6029 series *(formerly DC series)*
type 6030 series *(formerly MH series)*

				MULTI-SLOT TYPE 6028 SERIES DIRECTIVITY: 25dB			CRUCIFORM TYPE 6029 SERIES DIRECTIVITY: 22dB			MULTI-HOLE TYPE 6030 SERIES DIRECTIVITY: 40dB except for 6030/1, 2 & 3 (35dB)				
Frequency Range GHz	Waveguide Size	Nominal Coupling dB	Flanges Fitted	Type No.	Formerly	V.S.W.R.	Type No.	Formerly	V.S.W.R.	Type No.	Formerly	V.S.W.R. Main Line	V.S.W.R. Side Arm	
26·5 –40·0	R320(WG.22)	3	ROUND	—	—	—	—	—	—	6030/1	MH3/22/3	1·1 : 1	1·1 : 1	
		10	ROUND	—	—	—	—	—	—	6030/2	MH3/22/10	1·1 : 1	1·2 : 1	
		20	ROUND	—	—	—	—	—	—	6030/3	MH3/22/20	1·1 : 1	1·2 : 1	
12·4 –18·0	R140(WG.18)	3	SQUARE	—	—	—	—	—	—	6030/4	MH3/18/3	1·1 : 1	1·1 : 1	
		10	SQUARE	—	—	—	—	—	—	6030/5	MH3/18/10	1·06 : 1	1·1 : 1	
		20	SQUARE	—	—	—	—	—	—	6030/6	MH3/18/20	1·06 : 1	1·1 : 1	
8·5 – 9·5	R100(WG.16)	3	ROUND	6028/1	FS16/3RF	1·1 : 1	—	—	—	—	—	—	—	
		3	SQUARE	6028/2	FS16/3SF	1·1 : 1	—	—	—	—	—	—	—	
8·2 –12·4	R100(WG.16)	3	ROUND	—	—	—	—	—	—	6030/7	MH3/16/3RF	1·1 : 1	1·1 : 1	
		3	SQUARE	—	—	—	—	—	—	6030/8	MH3/16/3SF	1·1 : 1	1·1 : 1	
	R100(WG.16)	10	ROUND	—	—	—	—	—	—	6030/9	MH3/16/10RF	1·04 : 1	1·1 : 1	
		10	SQUARE	—	—	—	—	—	—	6030/10	MH3/16/10SF	1·04 : 1	1·1 : 1	
8·6 –10·2	R100(WG.16)	10	ROUND	6028/3	FS16/10RF	1·1 : 1	—	—	—	—	—	—	—	
	R100(WG.16)	10	SQUARE	6028/4	FS16/10SF	1·1 : 1	—	—	—	—	—	—	—	
8·5 –10·5	R100(WG.16)	20	ROUND	—	—	—	6029/1	DC16/20	<1·05 : 1	—	—	—	—	
		20	SQUARE	—	—	—	6029/2	DC16/20	<1·05 : 1	—	—	—	—	
8·6 –10·2	R100(WG.16)	20	ROUND	6028/5	FS16/20	1·05 : 1	—	—	—	—	—	—	—	
	R100(WG.16)	20	SQUARE	6028/6	FS16/20	1·05 : 1	—	—	—	—	—	—	—	
8·2 –12·4	R100(WG.16)	20	ROUND	—	—	—	—	—	—	6030/11	MH3/16/20	1·04 : 1	1·1 : 1	
	R100(WG.16)	20	SQUARE	—	—	—	—	—	—	6030/12	MH3/16/20	1·04 : 1	1·1 : 1	
8·5 –11·0	R100(WG.16)	30	ROUND	—	—	—	6029/3	DC16/30	<1·05 : 1	—	—	—	—	
		30	SQUARE	—	—	—	6029/4	DC16/30	<1·05 : 1	—	—	—	—	
8·5 –11·0	R100(WG.16)	40	ROUND	—	—	—	6029/5	DC16/40	<1·05 : 1	—	—	—	—	
	R100(WG.16)	40	SQUARE	—	—	—	6029/6	DC16/40	<1·05 : 1	—	—	—	—	
7·05–10·0	R84 (WG.16)	3	SQUARE	—	—	—	—	—	—	6030/13	MH3/15/3	1·1 : 1	1·1 : 1	
	R84 (WG.16)	10	SQUARE	—	—	—	—	—	—	6030/14	MH3/15/10	1·04 : 1	1·1 : 1	
7·6 – 9·4	R84 (WG.15)	10	SQUARE	6028/7	FS15/10	1·05 : 1	—	—	—	—	—	—	—	
7·5 – 9·5	R84 (WG.15)	20	SQUARE	—	—	—	6029/7	DC15/20	<1·05 : 1	—	—	—	—	
7·05–10·0	R84 (WG.15)	20	SQUARE	—	—	—	—	—	—	6030/15	MH3/15/20	1·04 : 1	1·1 : 1	
7·5 – 9·5	R84 (WG.15)	30	SQUARE	—	—	—	6029/8	DC15/30	<1·05 : 1	—	—	—	—	
5·85– 8·2	R70 (WG.14)	3	ROUND	—	—	—	—	—	—	6030/16	MH3/14/3	1·1 : 1	1·1 : 1	
	R70 (WG.14)	10	ROUND	—	—	—	—	—	—	6030/17	MH3/14/10	1·04 : 1	1·1 : 1	
5·85– 7·5	R70 (WG.14)	10	ROUND	6028/8	FS14/10	1·05 : 1	—	—	—	—	—	—	—	
5·85– 8·2	R70 (WG.14)	20	ROUND	—	—	—	—	—	—	6030/18	MH3/14/20	1·04 : 1	1·1 : 1	
5·85– 7·6	R70 (WG.14)	20	ROUND	—	—	—	6029/9	DC14/20	<1·05 : 1	—	—	—	—	
	R70 (WG.14)	30	ROUND	—	—	—	6029/10	DC14/30	<1·05 : 1	—	—	—	—	
3·95– 5·85	R48 (WG.12)	3	ROUND	—	—	—	—	—	—	6030/19	MH3/12/3	1·1 : 1	1·1 : 1	
	R48 (WG.12)	10	ROUND	—	—	—	—	—	—	6030/20	MH3/12/10	1·04 : 1	1·1 : 1	
4·35– 5·3	R48 (WG.12)	10	ROUND	6028/9	FS12/10	1·05 : 1	—	—	—	—	—	—	—	
3·95– 5·3	R48 (WG.12)	20	ROUND	—	—	—	6029/11	DC12/20	<1·05 : 1	—	—	—	—	
3·95– 5·85	R48 (WG.12)	20	ROUND	—	—	—	—	—	—	6030/21	MH3/12/20	1·04 : 1	1·1 : 1	
3·95– 5·3	R48 (WG.12)	30	ROUND	—	—	—	6029/12	DC12/80	<1·05 : 1	—	—	—	—	
2·8 – 3·6	R32 (WG.10)	20	ROUND	—	—	—	6029/13	DC10/30	<1·05 : 1	—	—	—	—	
2·6 – 3·95	R32 (WG.10)	30	ROUND	—	—	—	6029/14	DC10/30	<1·05 : 1	—	—	—	—	



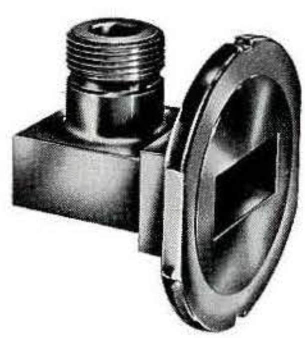
Waveguide Terminations : High Power type 6031 series *(formerly HPT series)*
Short Matched type 6032 series *(formerly MTS series)*

					TYPE 6031 SERIES			TYPE 6032 SERIES	
Frequency Range GHz	Waveguide Size	Flanges	V.S.W.R.	Mean Power Handling W	Type No.	Formerly	Peak Power kW	Type No.	Formerly
12·4–18·0	R140(WG.18)	SQUARE	1·01 :1	2	—	—	—	6032/1	MTS18
8·2–12·4	R100(WG.16)	SQUARE	1·01 :1	2	—	—	—	6032/2	MTS16/SF
		ROUND	1·01 : 1	2	—	—	—	{ 6032/3 6032/8	MTS16/RF MTS16/RF
		ROUND	1·1 :1	300	6031/1	HPT16/RF	300	—	—
		SQUARE	1·1 :1	300	6031/2	HPT16/SF	300	—	—
7·5 –10·0	R84 (WG.15)	SQUARE	1·1 :1	300	6031/3	HPT15	300	—	—
7·0 –10·0	R84 (WG.15)	SQUARE	1·01 :1	3	—	—	—	6032/4	MTS15
5·8 – 8·2	R70 (WG.14)	ROUND	1·01 :1	10	—	—	—	6032/5	MTS14
3·95– 5·85	R48 (WG.12)	ROUND	1·01 :1	10	—	—	—	6032/6	MTS12
2·6 – 3·95	R32 (WG.10)	ROUND	1·01 :1	10	—	—	—	6032/7	MTS10

Components and Accessories, *continued*

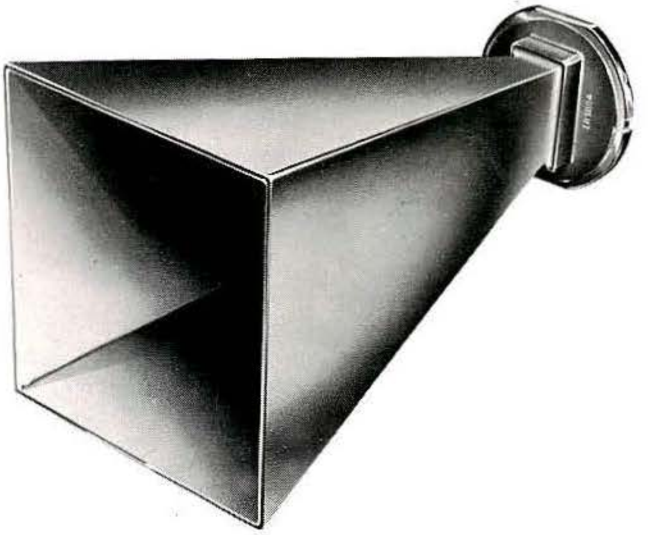
Broad Band Isolators type 6033 series *(formerly TBI series)*
Medium Power Ferrite Isolators type 6034 series *(formerly F series)*

Frequency Range GHz	Waveguide Size	Flanges Fitted	Average Power (Watts)	Isolation (Minimum)	Insertion Loss (Maximum)	TYPE 6033 SERIES V.S.W.R. 1·25 : 1 Type No.	TYPE 6033 SERIES Formerly	TYPE 6034 SERIES V.S.W.R. 1·15 : 1 Type No.	TYPE 6034 SERIES Formerly
12·4 – 18·0	R140(WG.18)	SQUARE	10	30dB	1·5dB	6033/1	TBI18/30	—	—
8·2 – 12·4	R100(WG.16)	ROUND	15	30dB	1·3dB	6033/2	TBI16/30/RF	—	—
		SQUARE	15	30dB	1·3dB	6033/3	TBI16/30/SF	—	—
8·6 – 9·6	R100(WG.16)	ROUND	100	20dB	0·8dB	—	—	6034/1	F16/20
		SQUARE	25	20dB	0·8dB	—	—	6034/2	MF16/20
5·85 – 8·2	R70 (WG.14)	ROUND	20	30dB	1·3dB	6033/4	TBI14/30	—	—
3·95 – 5·85	R48 (WG.12)	ROUND	20	25dB	1·5dB	6033/5	TBI12/25	—	—
2·6 – 3·95	R32 (WG.10)	ROUND	25	20dB	1·5dB	6033/6	TBI10/20	—	—



Coaxial-to-Waveguide Transformers type 6037 series *(formerly X series)*

FREQUENCY RANGE GHz	WAVEGUIDE SIZE	TYPE No.	FORMERLY	FLANGE FITTED	COAXIAL CONNECTOR
12·0 – 18·0	R140(WG.18)	6037/1	X18/C	SQUARE	Type N Female
8·5 – 12·0	R100(WG.16)	6037/2	X16/C/RF	ROUND	
		6037/3	X16/C/SF	SQUARE	
7·0 – 10·0	R84 (WG.15)	6037/4	X15/C	SQUARE	
5·85 – 8·2	R70 (WG.14)	6037/5	X14/C	ROUND	
3·95 – 5·85	R48 (WG.12)	6037/6	X12/C	ROUND	
2·6 – 3·95	R32 (WG.10)	6037/7	X10/C	ROUND	



Waveguide Horns type 6036 series *(formerly WH series)*

TYPE No.	FORMERLY	WAVEGUIDE SIZE	FLANGE FITTED	DESIGN FREQ. GHz	GAIN dB
6036/1	WH22/25	R320(WG.22)	Round	35·3	24·7
6036/2	WH18/25	R140(WG.18)	Square	16·0	24·7
6036/3	WH16/17/RF	R100(WG.16)	Round	9·375	17·2
6036/4	WH16/17/SF	R100(WG.16)	Square	9·375	17·2
6036/5	WH16/22/RF	R100 (WG16)	Round	9·375	22·0
6036/6	WH16/22/SF	R100 (WG16)	Square	9·375	22·0
6036/7	WH15/18	R84 (WG.15)	Square	7·6	18·0
6036/8	WH14/22	R70 (WG.14)	Round	6·3	22·0
6036/9	WH14/18	R70 (WG.14)	Round	6·3	22·0
6036/10	WH12/18	R48 (WG.12)	Round	4·5	18·0
6036/11	WH10/18	R32 (WG.10)	Round	3·0	18·0
6036/12	WH10/14	R32 (WG.10)	Round	3·3	13·7
6036/13	WH6/15	R14 (WG.6)	To order	1·3	15·5

Taper Transformers type 6038 series *(formerly XT series)*

TYPE No. 6038/1 *Formerly* XT15/16.

Transition from waveguide R84 to R100 (WG.15 to WG.16).

V.S.W.R.: Better than 1·04 : 1 over frequency band 8·5–10·0GHz when fitted with plain flanges.

FLANGES FITTED: To customer's order.

Waveguide Support Benches type 6039 series

TYPE No.	LENGTH	FEATURES AND COMPOSITION
6039/1	1 ft	Each bench consists of: 2 end plates 2 stainless steel rails Individual benches can be quickly interlocked to form desired length by using special clips, supplied separately
6039/2	2 ft	
6039/3	3 ft.	

Carriage type 6040

FOR USE WITH 6039 SERIES BENCHES

The Carriage will traverse the length of the bench and may be locked in any desired position. The vertical support position is automatically locked when the support rod is raised to the desired height, release is obtained by actuating a simple lever. The support rod can be rotated about its vertical axis and be fitted with any of the Type 6042 clips or Type 6043 table.

Free Standing Support type 6041

A specially designed base casting permits close proximity support. This casting houses the same mechanism as the type 6040 carriage and can be fitted with Type 6042 series clips and Type 6043 table.

Support Clips type 6042 series for use with type 6040 and 6041 Supports

TYPE No.	WAVEGUIDE SIZE
6042/1	R320 WG.22
6042/2	R140 WG.18
6042/3	R100 WG.16
6042/4	R84 WG.15
6042/5	R70 WG.14
6042/6	R48 WG.12
6042/7	R32 WG.10

Instrument Table type 6043 for use with type 6040 and type 6041 Supports

Suitable for supporting the larger microwave instruments.

Square-to-Round Flange Adapter type 6478

A unique device designed for coupling together waveguide 16 instruments carrying dissimilar flanges. The Adapter is suitable for either plain or choke flanges with clearance holes (enquiries for tapped hole application in reasonable quantities will be considered) and offers no greater loss in performance than the normal coupling arrangements between compatible flanges

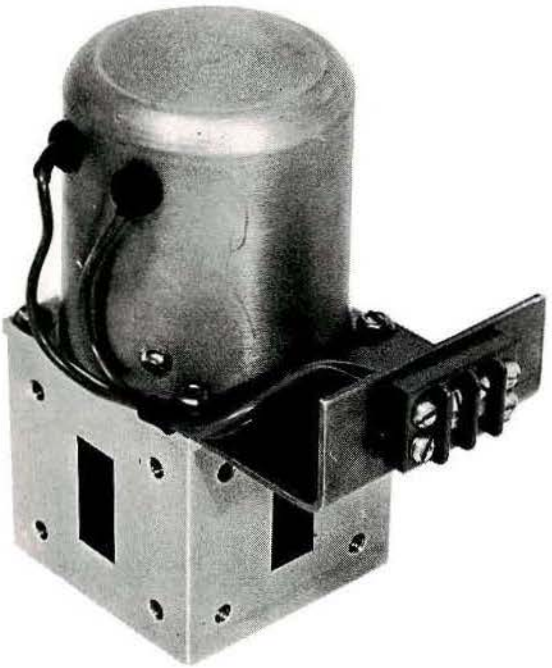
Material: Brass, nickel plated.

Square-to-Square Flange Rapid Coupler type 6478/1

Designed for coupling together X Band instruments or components having square flanges with 0·169" clearance holes. Enquiries are also invited for other clearance or tapped hole sizes when reasonable quantities are involved.

Material: Brass, nickel plated.

type 6044/3



Quick-Release Clamps type 6044 series

(formerly QRC series)

TYPE No.	FORMERLY	WAVEGUIDE SIZE	REMARKS
6044/1	QRC16/H	R100(WG.16)	'H' Plane Clamp
6044/2	QRC16/ HSH	R100(WG.16)	Short Handle Version of 6044/1
6044/3	QRC16E/H	R100(WG.16)	E/H plane Clamp
6044/4	QRC16E/H SH	R100(WG.16)	Short Handle Version of 6044/3
6044/5	QRC15/H	R84 (WG.15)	'H' Plane Bend
6044/6	QRC10	R32 (WG.10)	—
6044/7	68010	Double Ridge or WG.14	—
6044/8	64050	Double Ridge or WG.14	Short Handle Version of 6044/7

Waveguide Switches 6352, 6353, 6442, 6453 and 6473

IDENTITY	W.G. SIZE	FREQUENCY RANGE	SWITCH OPERATION	SWITCH TIME	V.S.W.R.	ISOLATION	SPECIAL FEATURES
Type 6352 4 port single pole 3-way E plane	R100 (16)	8·2–12·4GHz	Manual	—	1·05:1	80dB	
Type 6353 4 port 2 pole changeover E plane	R100 (16)	8·2—12·4GHz	Manual	—	1·05·1	80dB	Manual version of TYPE 6453
Type 6442 3 port E plane	R100 (16)	8·2 –12·4GHz	Power 28 volts	100 msec	1·10:1	35dB	Zero held current, low operate current, pair of changeover switches included for ext. equipment. Smooth motion. External indicator facility.
Type 6453 4 port E plane	R100 (16)	8·2 –12·4GHz	Power 24 volts	200 msec.	1·05:1	80dB	Different rotary solenoids may be employed to give alternative switching time and other operating voltages.
Type 6473 3 port E plane	R140 (18)	12·4–18·0GHz	Power 24 volts	30 msec.	1·10:1	40dB	Duty cycle limited to 3 secs. in 15 secs. unless transistor drive circuit (our design) is used.

Enquiries for manual or power operated switches in the waveguide range R320 (WG.22) to R32 (WG.10) are welcomed.

Waveguide Flanges

WE MANUFACTURE ALL TYPES OF FLANGES INCLUDING THE FOLLOWING WHICH ARE STOCK ITEMS

TYPE NUMBER	DESCRIPTION	W.G. SIZE
5985-99-083-0002	Locating ring	R100
5985-99-083-0003	Choke round flange	R100
5985-99-083-0004	Plain round flange	R100
5985-99-083-0005	Nut ring	R100
5985-99-083-0052 8/32"	Plain square flange	R100
5985-99-083-0051 8/32"	Choke square flange	R100
5985-99-083-0051 4BA	Choke square flange	R100
5985-99-011-0891	Choke aluminium flange	R100
5985-99-011-0148	Plain aluminium flange	R100
UG39/U	American plain flange	R100
UG40/BU	American choke flange	R100
UG136/BU	American choke square	R100
UG135/U	American plain square	R100
5985-99-083-0033	Choke flange square	R84
5985-99-083-0034	Plain flange square	R84
UG51U	American plain square flange	R84
UG52BU	American choke square flange	R84
5985-99-083-0058	Plain flange rectangular	R32
5985-99-083-0041	Choke round flange	R48
5985-99-083-0042	Plain round flange	R48
1061/B910	Square DECCA special	DECCA
1611/B1907	Square DECCA special	DECCA

Index

Measuring Equipment

NATO & Federal Catalogue Numbers

NATO

M.I. Type No.	*Military Designation*	*NATO Cat. No.*
TF 144H/4S	Signal Generator CT 452A	6625-99-924-8875
TF 144H/6S	Signal Generator CT 452A Set	6625-99-900-8337
TF 791D	Test Set Deviation	6625-99-952-2585
TF 801D/8S	Generator, Signal CT 394B	6625-99-924-8874
TF 801D/9S	Signal Generator Set CT 394B	6625-99-106-1189
TF 893A	Wattmeter Absorption Audio Frequency	6625-99-914-9811
TF 995B/2	Signal Generator CT 520A	6625-99-142-4566
TF 1066B/6	Signal Generator Set	6625-99-955-2400
TF 1066B/6S	Signal Generator Set AM/FM	6625-99-106-0902
TF 1073A/2S	Attenuator CT 421	6625-99-972-9733
OA 1094AS	Analyser Spectrum	6625-99-580-6737
OA 1094A/1S	Analyser Set Spectrum	6625-99-104-3144
TF 1099/2	Sweep Generator Set	6625-99-971-4611
TF 1099/3S	Sweep Generator Set	6625-99-104-5017
TF 1101	Signal Generator Type 16728	6625-99-999-9604
TF 1245	Panels Test Electrical (Q Meter)	6625-99-103-1083
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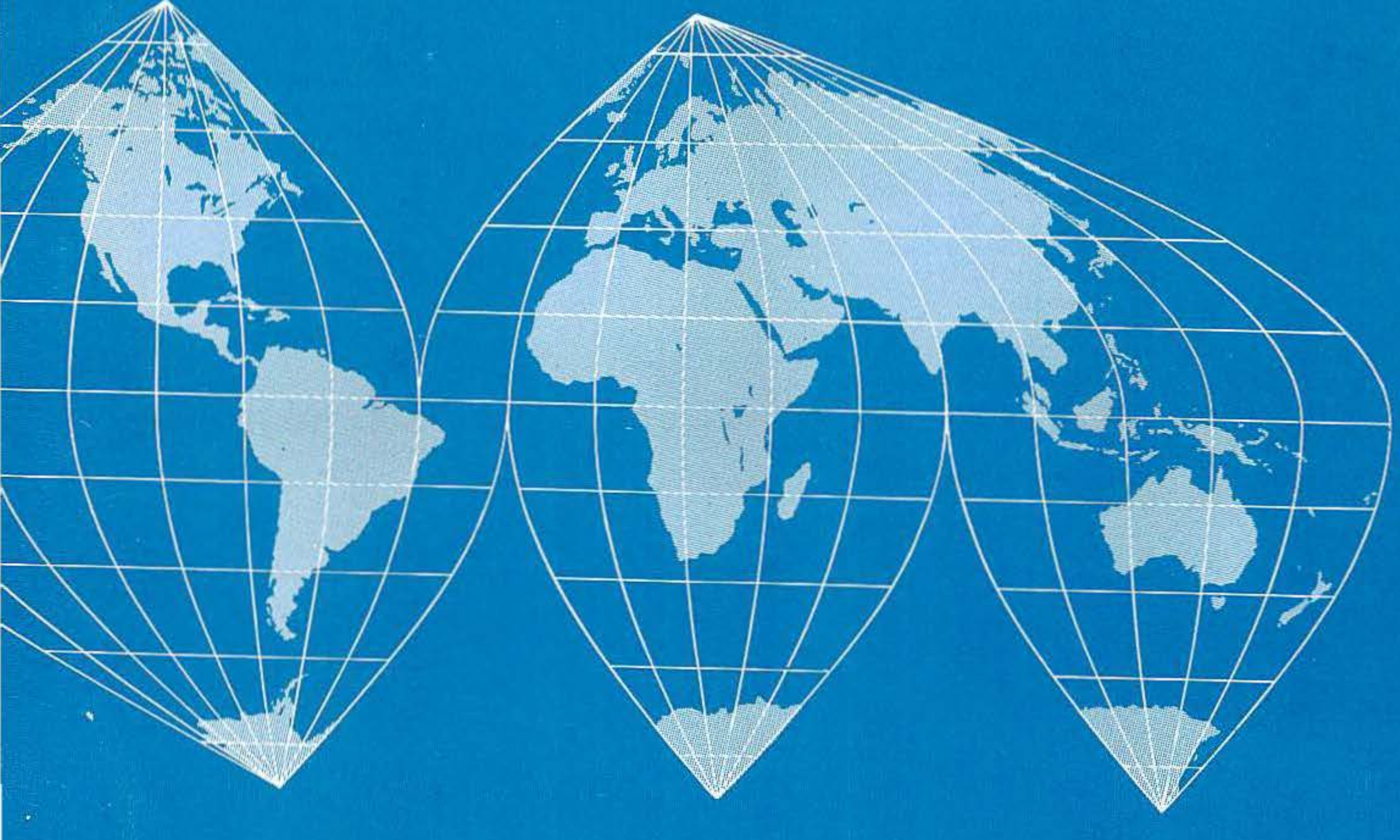

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