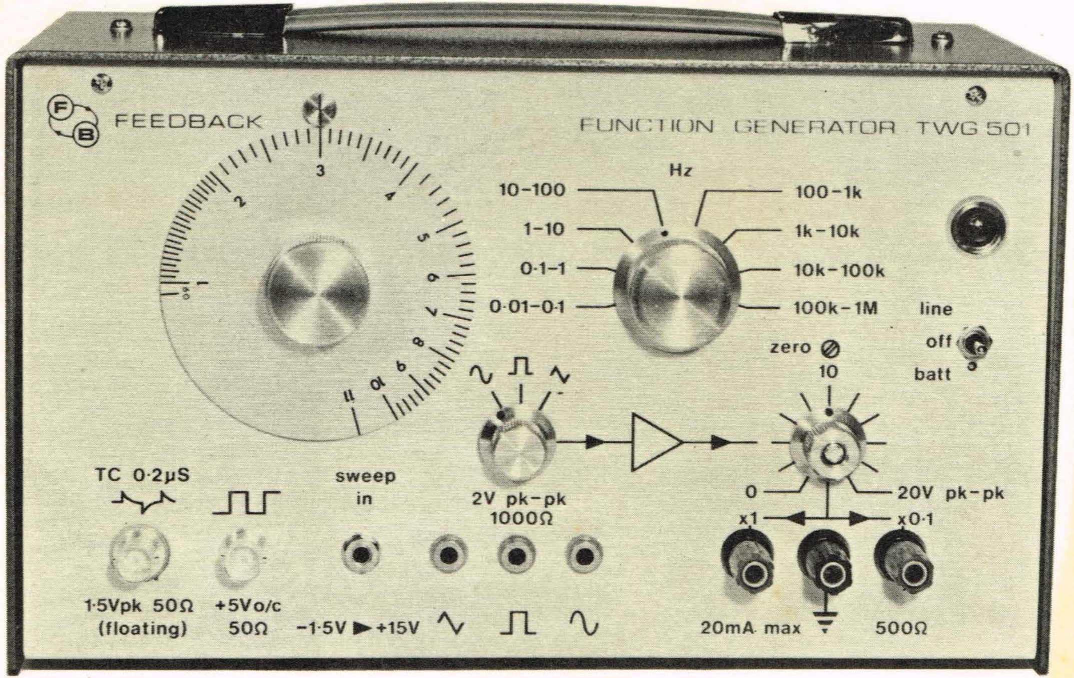
Function Generator

TWG 501



FEEDBACK

INSTRUCTION MANUAL for the Type TWG 501 FUNCTION GENERATOR

The TWG501 provides SINE, SQUARE and TRIANGLE waveforms simultaneously over the frequency range 0.01Hz to 1MHz.
High linearity, low distortion waveforms are available up to 20 volts peak-to-peak from the main output amplifier and four other outputs. Other facilities include voltage controlled frequency and dry battery operation for remote locations.

- FREQUENCY RANGE 0.01Hz to 1MHz
- SEVEN SIMULTANEOUS OUTPUTS
- FREQUENCY SWEEP FACILITIES (VCF)
- LEVEL VARIABLE UP TO 20 VOLTS P-P
- SINE DISTORTION LESS THAN 2%
- FLAT FREQUENCY RESPONSE
- SOLID STATE THROUGHOUT
- SINE-SQUARE-TRIANGLE SIMULTANEOUSLY
- FAST SQUARE-WAVE OUTPUT
- OSCILLOSCOPE TRIGGER PULSE OUTPUT

Although this Feedback manual was correct at the time of printing, components supplied may differ slightly from those described.
We endeavour continually to improve our equipment by incorporating the latest developments and components, even up to the time of despatch. Whenever possible we will include such new or revised information.

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CONTENTS

SPECIFICATION

Unless otherwise stated, this specification is given for operation at +25°C ±5°C.

Frequency

RANGE
0.01Hz to 1MHz continuously variable in eight decade ranges with calibrated fine control. A 10% range overlap at each end of the decade scale ensures continuity between ranges and effectively extends the frequency coverage from 0.009Hz to 1.1MHz, approximately.

SCALE ACCURACY
A maximum error of ±2% of nominal full scale on all decades. Also, for all ranges except the highest and lowest the frequency is within ±5% of setting.

STABILITY
Under constant line voltage, output load, and temperature conditions, after half-hour initial warm up at 10kHz.

Short term:	±0.05% over 10 minutes
Long term:	±0.1% over 6 hours (typically)

Variation with temperature (typically)
+25°C to +50°C: ±0.5%
-15°C to +25°C: ±1.0%

Variation with line voltage
±10% line voltage variation: less than ±0.1%

Variation with load on main output
At full output from no load to 500Ω load: 0.4%

JITTER
Typically less than 0.01% at 10kHz.

Waveforms

SINE, SQUARE or TRIANGLE are available by selection through the output amplifier and simultaneously at three monitor outputs:-

SINE	-	Total harmonic distortion <2% 0.01Hz to 20kHz.
SQUARE	-	Rise time <60ns via output amplifier <30ns via monitor socket into a resistive load. *
TRIANGLE	-	Linearity better than 1%.

Time symmetry of all the above waveforms within 1% except on 0.01 to 0.1Hz range where it is better than 5%.

FAST SQUARE WAVE	-	0 to +5V ±0.4V peak unloaded from 50Ω source impedance. Rise time 10% to 90%, less than 15ns. Total aberrations less than 3%. BNC socket output. *
TRIGGER OUTPUT	-	Alternate +ve and -ve going pulses 2V peak nominal into 50Ω. Time constant of exponential decay 200ns Rise time 10% to 90%, less than 20ns.

* See Note on measuring technique at end of Section.

Output facilities

MAIN OUTPUT (XI)
The main output amplifier is connected by rotary switch to any one of three waveforms - sine, square or triangle.

Level: Continuously variable from 0-20 volts peak-to-peak from source impedance of about 25Ω.

Maximum output: 20mA.
Useful dynamic range at least 35dB.
Amplifier is protected against an accidental short-circuit between output and common.

LOW LEVEL OUTPUT (X0.1)
Nominally 20dB below main output when unloaded. Source resistance 500Ω. Useful dynamic range at least 35dB, giving an overall dynamic range of at least 55dB for the instrument.

OUTPUT TERMINALS
The main output, low level output, and common terminal are all on 4mm screw-head binding posts arranged to accept standard 3/4in pitch dual plug leads (e.g General Radio Type 274-MB).

MONITOR OUTPUTS
All three generated waveforms are available simultaneously on 4mm sockets at 2 ±5% volts peak-to-peak from 1kΩ source (1 volt peak-to-peak into 1kΩ).

OUTPUT STABILITY
At the main or low level outputs at full amplitude and constant load.

Variation with frequency
±0.1dB, up to 100kHz
±0.5dB, 100kHz to 1MHz

Variation with time, typically
less than ±0.05dB over 2 hours at 10kHz

Variation with line voltage
±0.1dB for ±10% change at 10kHz

Variation with temperature, typically less than ±0.1dB from -15°C to +50°C at 10kHz, triangle or square; less than ±0.25dB from 20°C to 30°C, sine.

DC OFFSET
Mean level of any waveform at the main output may be offset by at least ±2V (±200mV at X0.1 output)

FLOATING OUTPUT
Isolated trigger pulse circuit permits ±50V flotation of entire instrument relative to ground without affecting trigger conditions.

Voltage Controlled Frequency (VCF)

The generated frequency can be controlled by an external voltage in the range -1.5V to +15V applied to the 'sweep in' jack, the dial control being rendered inactive.

Input impedance greater than 100kΩ falling to 10kΩ outside the normal operating voltage range.

Maximum input ±20V
Inputs between 0 and +15V control the frequency over the selected decade with better than ±0.1% linearity, 0V corresponding to about 0.7 and +15V to about 11 times the lower frequency of the range.

Inputs from 0 to -1.5V reduce the frequency over approximately four decades from the lower frequency of each range or to 0.01Hz, whichever is the greater frequency. Although not guaranteed, typical instruments will sweep to 0.001Hz or below on the lower ranges. The sweep characteristics are typically as shown in fig. 1.

VCF SLEW RATE
A fast step function applied to the 'sweep in' socket results in an effective frequency control voltage whose slew rate is approximately 1V per 6 nanoseconds. Thus a decade sweep can be completed in 90ns, less than 10% of one period at 1MHz.

TWG501 TYPICAL SWEEP CHARACTERISTICS

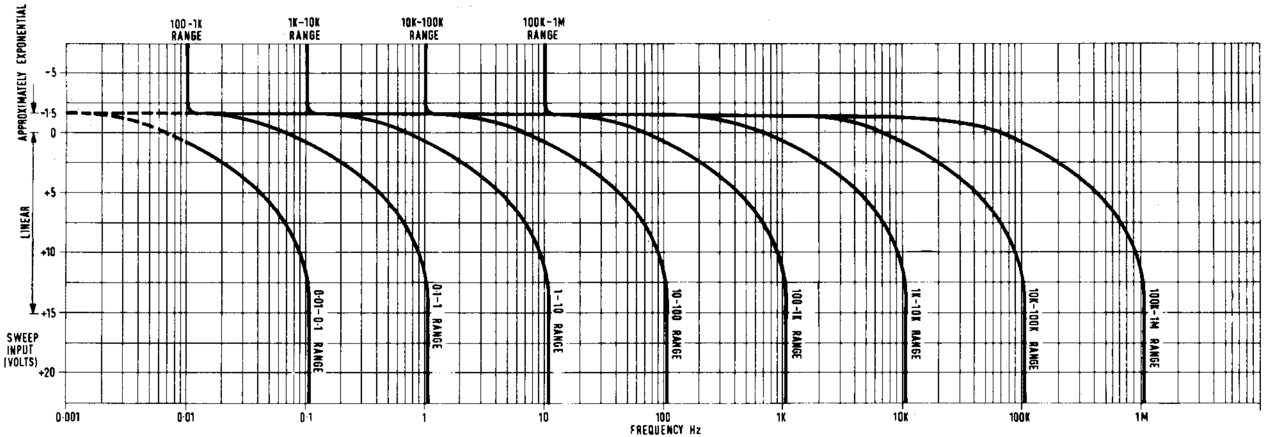

Fig 1.

Operating temperature range

-15°C to +50°C.

Power supply

Line: 100-120 volts or 200-250 volts, 50 or 60Hz
Battery: +18 to +24V and -18V to -24V each at 100mA applied to rear socket.

Weight and Dimensions

Width	Depth	Height	Weight
10.0in	4.75in	6.19in	4lb 15oz
254mm	121mm	157mm	2.2kg

Observation and use of fast waveforms

The rise times and aberrations mentioned in the specification are measured with a sampling oscilloscope and probe. For accurate observation with an ordinary oscilloscope and for accurate transmission of fast waveforms to a load, certain simple precautions are necessary according to the output in use.

1. MAIN (X1) OUTPUTS
(Source resistance about 25 ohms)

Provided the 20mA peak current limit is not exceeded, waveforms are independent of load resistance and capacitive loads up to 120pF will not deteriorate square wave edges outside specification. Open lead connections are generally satisfactory for most purposes but may cause slight ringing to occur; for optimum results a coaxial cable should be used and, if longer than about 3ft (1 metre), should be properly terminated.

2. MAIN (X0.1) and MONITOR OUTPUTS
(Source resistance 500 and 1000 ohms respectively)

Due to the higher source resistance of these outputs capacitive loads will cause deterioration of square wave edges. For example, a capacitance of 50pF at a MONITOR output gives a time constant of 50ns. In general, to make full use of fast rise and fall times, the MAIN (X0.1) or the FAST SQUARE WAVE output should be used but if the higher impedance outputs must be used, capacitive loading must be minimised. It is thus best to avoid screened cable connections and to use open leads instead.

3. FAST SQUARE WAVE OUTPUT
(Source resistance 50 ohms)

A coaxial cable connection should be used on this output and will give the most accurate transmission when properly terminated, provided the loss of amplitude is acceptable. However short, unterminated cables will cause only slight aberrations.

CIRCUIT DESCRIPTION SECTION 2

The TWG501 block diagram is shown in fig 2. The triangular waveform is generated by the integrator. The input to the integrator is switched by the diode switch to a current of either +i or -i; which are in effect opposite polarities of the same current source generated from the auxiliary dc floating supply. The magnitude of i (which determines the output voltage slope of the integrator and hence the frequency) is determinated by the value of R and the potential difference between the bases of Transistors TR1 and TR2.

The input to the integrator is a FET TR4 which has to be biased so that the gate operating potential lies within the range of the diode switch (about -7 volts). This is set using P1. Incorrect setting of P1 prevents oscillation (see 'Maintenance - Setting Up' para 4).

The output voltage of the integrator is connected to the Backlash Bistable circuit which controls the diode switch at the integrator input. This Backlash Bistable circuit switches over when the integrator output voltage reaches a preset level set by P2 and P3, (see 'Maintenance - Setting Up' para 5).

Frequency control is effected by switching C and/or R to give decade ranges. Variation of the voltage on the base of TR1 by frequency control potentiometer P11 controls the frequency within the decade range selected, whilst application of an external voltage in the range +15 to -1.5V controls the frequency within and below the selected decade.

The auxiliary floating dc supply is the rectified (voltage doubled) output of a 100kHz oscillator. DC and AC isolation is important for the proper operation of the integrator and is achieved by the use of two toroidal transformers TRAN 2 and TRAN 3, screened from each other.

The triangular waveform is connected to a special non-linear bridge circuit R46, 47, 48 D11-22 which produces a sine wave output. The output from the bridge is taken by a difference amplifier with overall negative feedback to control the gain.

The output from the Backlash Bistable circuit is a square waveform and is available at a monitor socket via an isolating emitter follower TR21. The triangular waveform at the monitor socket is also isolated by TR20 and the sine wave by the difference amplifier.

The output amplifier for the main output terminals is a straightforward linear amplifier with a fairly low gain which is reduced by X3.3 by negative feedback. The X0.1 low level output is provided by R96 and R97.

There is a separate circuit for a 50Ω fast square wave output. This consists of transistors TR14, 15 and 16. TR14 is a saturated switch controlled by the Backlash Bistable square wave. This switch in conjunction with TR15, D10 and R36 generate a square wave current of 100mA peak amplitude. This current into R38 (47Ω) provides the square wave voltage output from the coaxial socket. The current also passes through the differentiating network L_2R_{37}, and the +ve and -ve pulse waveform thus produced is transformer coupled to the trigger output coaxial socket.

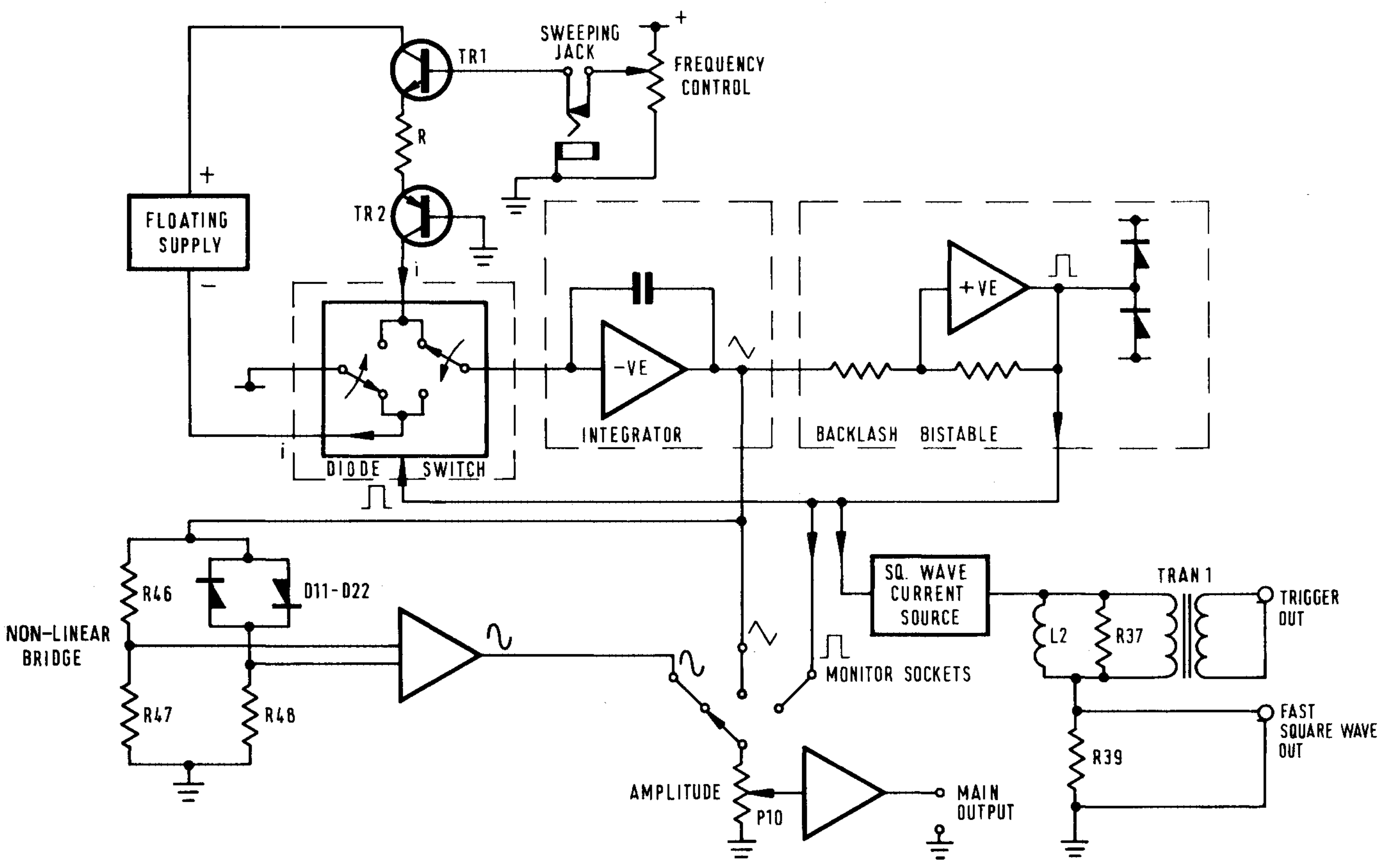

Fig 2 BLOCK DIAGRAM

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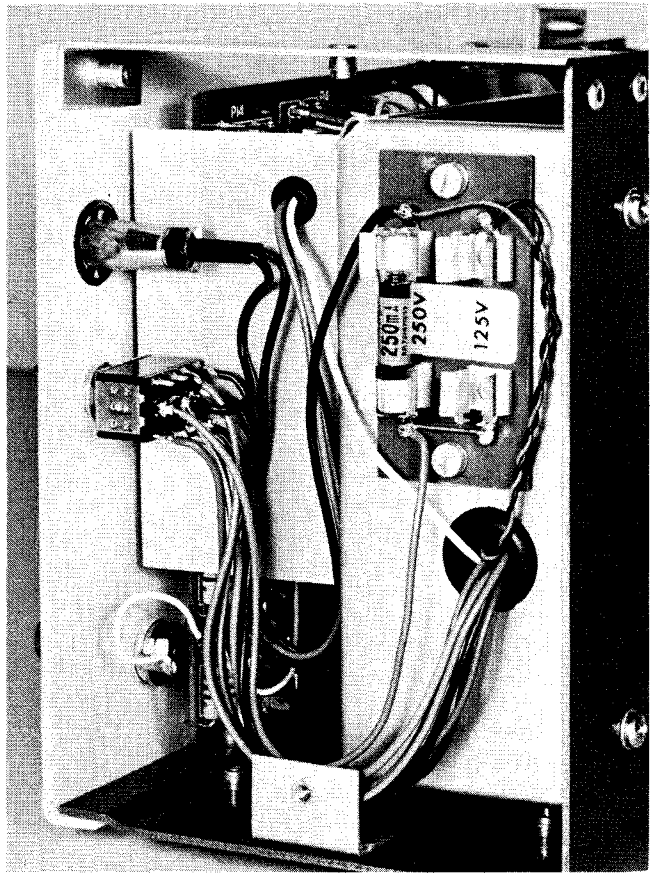
OPERATION

SECTION 3



Line voltage

On receipt of the instrument check that it is set for the correct supply voltage as follows:-

Remove the four securing screws on the wrap-around cover (two on the top and one at each side) and remove the cover. On the right of the instrument viewed from the front, a twin cartridge fuse carrier will be seen. The 250mA fuse should be positioned in the carrier appropriate to the line voltage to be used. Replace the cover and securing screws.

Switch on

The power supply switch has three positions:-

OFF

LINE - for operation from line voltage 50/60Hz, 100-250V

BATTERY - In this position the 501 may be operated from a dc supply of +18 to +24 volts and -18 to -24 volts at 100mA each.

Frequency

Selection is by means of a decade range switch and a continuous control calibrated in Hz covering the selected decade with 10% overlap at each end.

Voltage control of frequency

The insertion of the jack plug into the jack socket disconnects the normal frequency control potentiometer and enables the frequency to be controlled by a voltage applied to the jack socket centre contact.

Inputs between 0 and +15V control the frequency over the selected decade, to better than ±0.1% linearity, 0V corresponding to 0.7 and +15V to 11 times the lower frequency of each range. Inputs from 0 to -15V reduce the frequency over approximately four decades from the lower frequency of each range or to 0.01Hz, whichever is the greater frequency. Although not guaranteed, typical instruments will sweep to 0.001Hz or below on the lower ranges.
Voltages below -1.5 have no effect, no damage will be caused by voltages up to ±20V.

Outputs

Monitor

The three basic waveforms - sine, square and triangular - are simultaneously available at the 2V p-p monitor sockets.

Main (X1)

A larger output, adjustable up to 20V p-p by the amplitude control is available at the output terminals. The waveform from this output is selected by the central switch.

The source impedance is about 25Ω and peak currents up to ±20mA may be drawn before limiting occurs.

Low Level (X0.1)

The output from this socket when unloaded is nominal by 0.1 of that at the main output. The source impedance is 500Ω.

DC offset

In the centre of the amplitude control is a screwdriver adjustment allowing the mean level of the signals at both main and low level outputs to be adjusted. The range of adjustment is ±2V at the main output and ±0.2V at the low level socket. The adjustment is not dependent upon the amplitude setting. This facility is particularly useful when testing circuits (e.g integrators) which are susceptible to the mean level.

Fast square waves

Also available at 50Ω source impedance is a square wave output of 5 volts positive peak o/c. This waveform is free from significant aberrations such as overshoot, droop, change in source impedance, zero dc offset, etc. This output has a rise and fall time of less than 15ns and is intended for driving integrated circuits, etc.

Trigger pulses

The second coaxial output provides a trigger waveform for triggering oscilloscopes or driving frequency counters. The source impedance is 50Ω and, to avoid ground loops and permit the use of an external offset voltcge, the output is floating. It is thus very desirable to use a proper ground return connection from this socket when used.

Floating operation

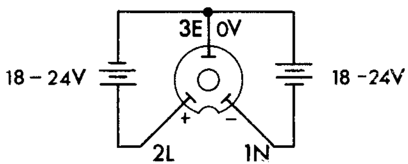
Provided that the earth core of the supply lead is removed from its terminal at the supply end the instrument may be floated relative to ground up to ±50V. The offset supply would be connected between ground and the TWG501 common (black) terminal. All outputs except the trigger output will float at the same potential (as will the instrument case) but the outer of the trigger coaxial socket may be grounded (e.g to an oscilloscope) and triggering behaviour is not affected by the degree of offset.

When using this facility care should be taken not to connect low resistance loads from any output to ground, otherwise damage may be caused.

Battery operation

The battery supplies are connected to the plug at the instrument as shown in fig 4.

Viewed from inside plug

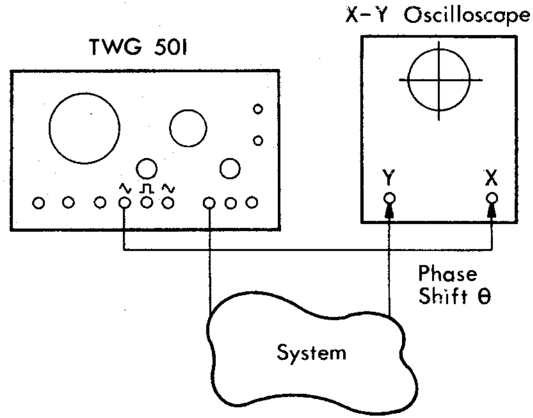


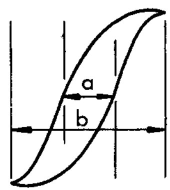
Battery plug. 3A 3-pin Bulgin type P429 Ptno 2533-112
Sweep jack. Miniature 2-pole Rendar type MJPS 600 Ptno 2533-703.

Fig 4.

Phase measurements

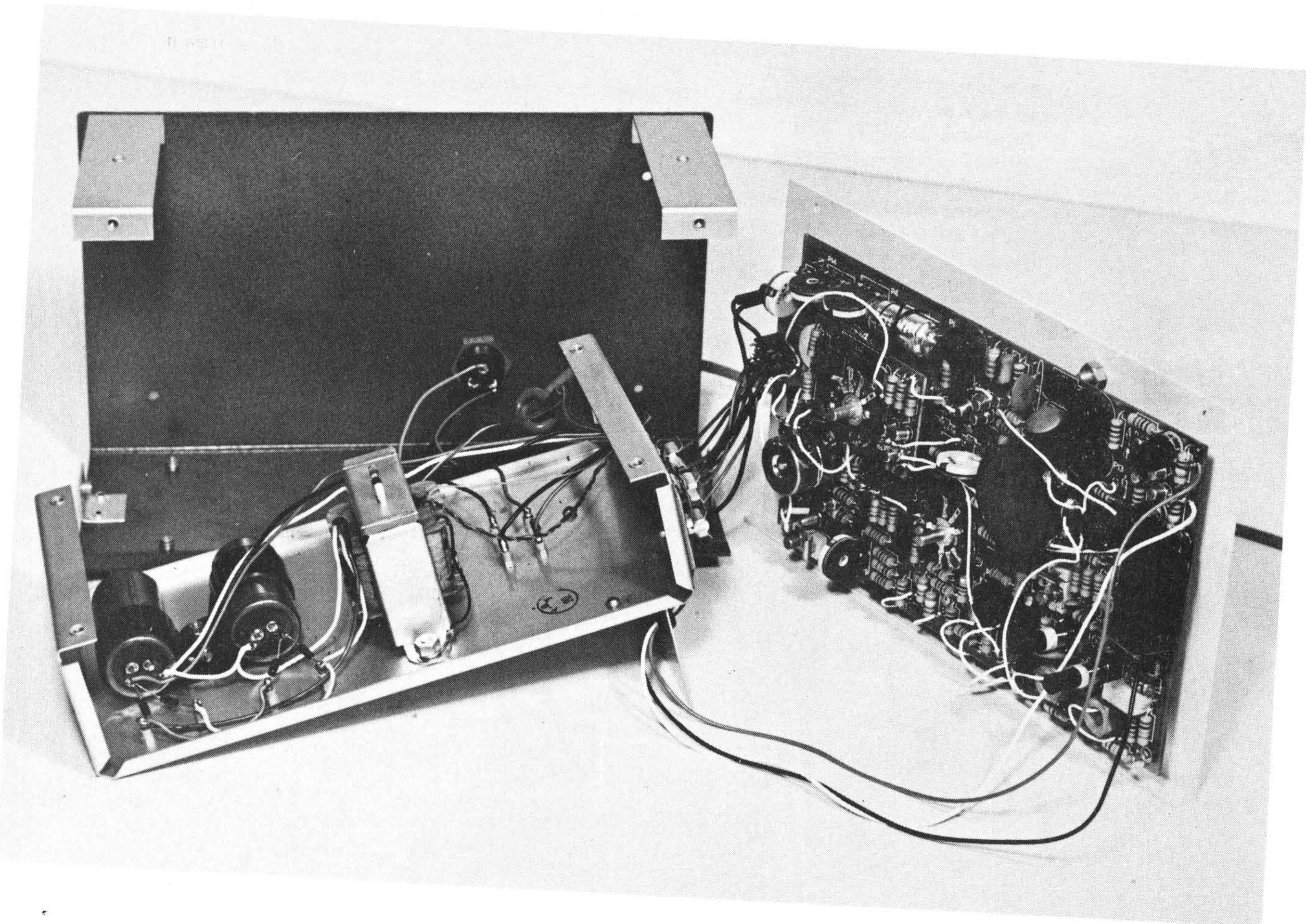
An estimation of phase angle of a signal from a system under test may be made as follows.





$$\frac{a}{b} \times 90 = \theta$$

Fig 5.



Removal of front panel

To remove the front panel remove the four fixing screws, two at the top and two underneath.

The complete circuit, with the exception only of the unregulated power supply, is mounted from the front panel and is removed with it.

Removal of printed circuit

This is not necessary for routine adjustments but if it has to be removed proceed as follows.

1. Remove all knobs and the frequency dial.

2. Disconnect the three wires from the jack socket.

3. Disconnect the wires from the two coaxial sockets.

4. Disconnect the wires from the three monitor sockets and from the X0.1 output terminal.

5. Remove the nuts from each of the four control shafts on the front panel side.

6. Remove the nuts on the printed circuit side from the two coaxial sockets and from the X1 and COMMON terminals.

The PC board may now be lifted off. In this condition it should still operate satisfactorily if a 4BA screw and nut is fitted into the hole of the ground terminal on the PC board and the two wires on main contacts of the jack socket are connected together. Components etc. may be located on the board by reference to the circuit diagrams and to the layout diagrams fig 7 and fig 8.

The board should be refitted in the reverse sequence. It will be necessary to realign the frequency dial. This is done by setting it in the correct position with the TWG501 generating 10kHz on the 1kHz to 10kHz range.

Access to power supply

To obtain access to the power supply unit proceed as follows:-

1. Remove the four securing screws on the wrap-around cover (two on the top and one each side) and remove the cover.
2. Remove front panel screws (two at the top and two underneath). Allow front panel to swing clear.
3. Unscrew the four screws on the back panel and take out the power unit.

Setting up

The following adjustments will normally be made while the printed circuit is mounted on the front panel.

1. Check the dc voltages from the power supply to the main PC board; these should be about + and -16 volts 200-volt ac supply or about + and -20 volts 240-volt ac supply, and are measured on the three pins terminating the leads from the power supply.

2. Set + and -15V lines to the correct voltage using P12 and P13 at the points shown in fig 7.

3. Check the floating integrator supply; use 20kΩ/V multimeter on 100V dc range; this should be between 27 and 33 volts with 22kΩ load, measured between the screen of the oscillator and the collector at TR1.

4. The dc input level of the integrator has to be set correctly by P1 before the TWG501 will oscillate at all.

   Set the TWG501 to 10kHz and connect an oscilloscope to the triangular monitor socket. Adjust P1 carefully to give a symmetrical triangular waveform of maximum frequency. There should be a small region of adjustment which gives proper operation. Leave P1 in the centre of this range.

5. Connect the oscilloscope to the emitter of TR20. Observe a triangular waveform. Set to exactly + and -3V peak using P3 and P2.

6. Check level of the square wave on emitter of TR21; this should be ±3V nominal.

7. Connect the oscilloscope to the junction of D23 and R55 to observe a sine wave. Connect a distortion meter to the sine monitor socket. Adjust P5 to minimise odd harmonics - symmetrical pointedness or flatness. Adjust P6 to minimise even harmonics - unsymmetrical peaks.

   Adjust P4 to give zero dc component.

   Adjust P7 to give correct amplitude, i.e. + and -3V peak. Repeat the sequence to give optimum results. Distortion should be less than 2%.

8. Set frequency to 1MHz. Use 50MHz oscilloscope on monitor square wave socket. Adjust C11 to give the best square wave free from overshoot; rise time should be better than 30ns. Care should be taken to avoid ringing in test leads.

9. Using 50Ω coaxial cable with a 50Ω termination connect the square wave socket to the 50MHz oscilloscope and observe the square wave; check that the rise and fall times are less than 15ns (10 to 90%) with no overshoot or ringing. Check amplitude; this should be 0V±0.01V to +2.5V ±0.2V.

10. Using the 50Ω coaxial cable with a 50Ω termination observe the trigger waveform. This should be between 1 and 2 volts peak and with symmetrical alternate +ve and -ve pulses with a decay period of about 160ns to half amplitude.

11. Connect the oscilloscope to the main (X1) output terminals with a load of not less than 1kΩ. Switch to square wave and adjust C14 and P9 to give optimum rise - free from overshoot and with a rise time of less than 60ns, 10% to 90%. Observe the proper amplitude and control of all waveforms - sine, triangular and square.

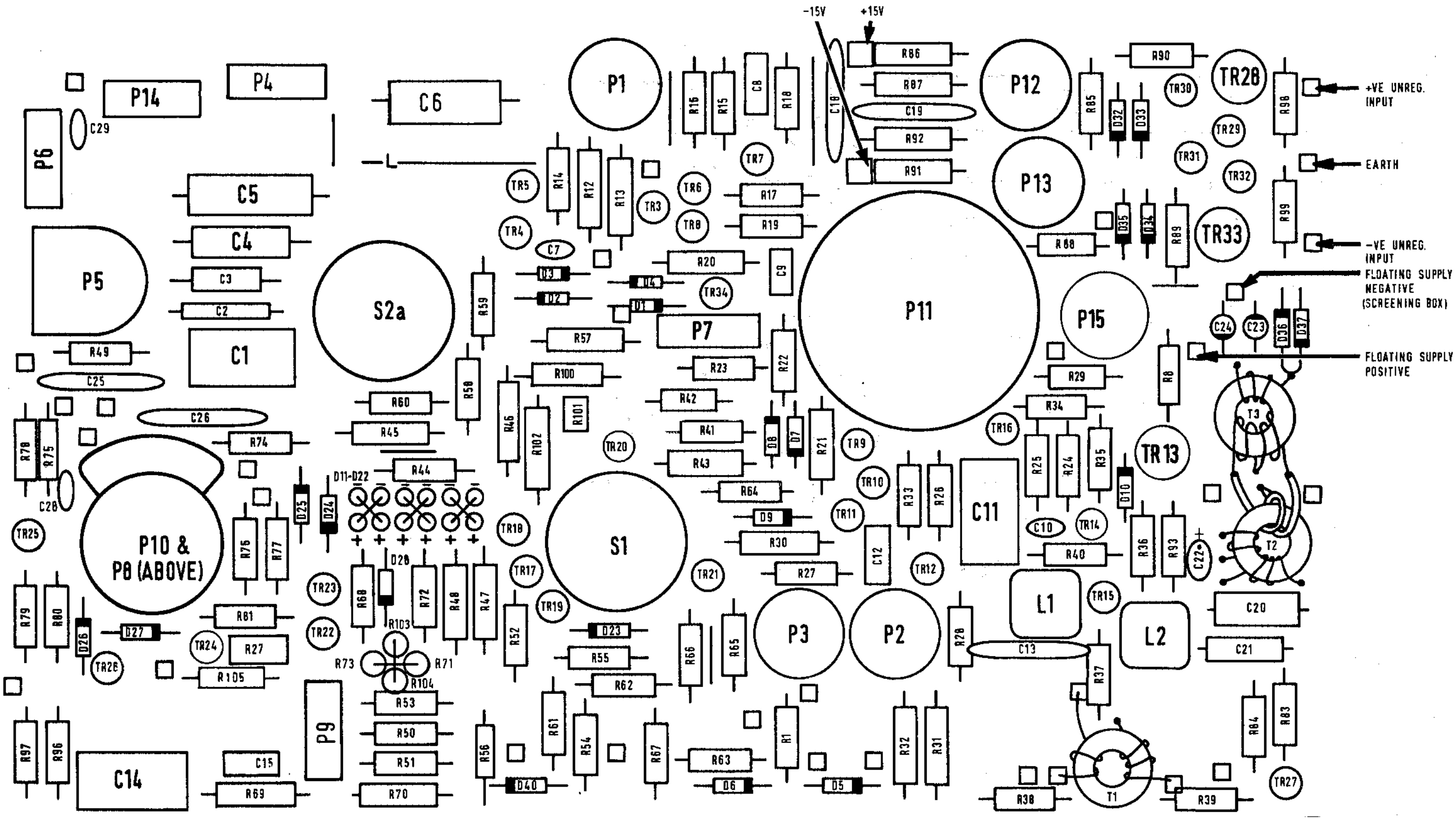


Fig 7 COMPONENT REFERENCE

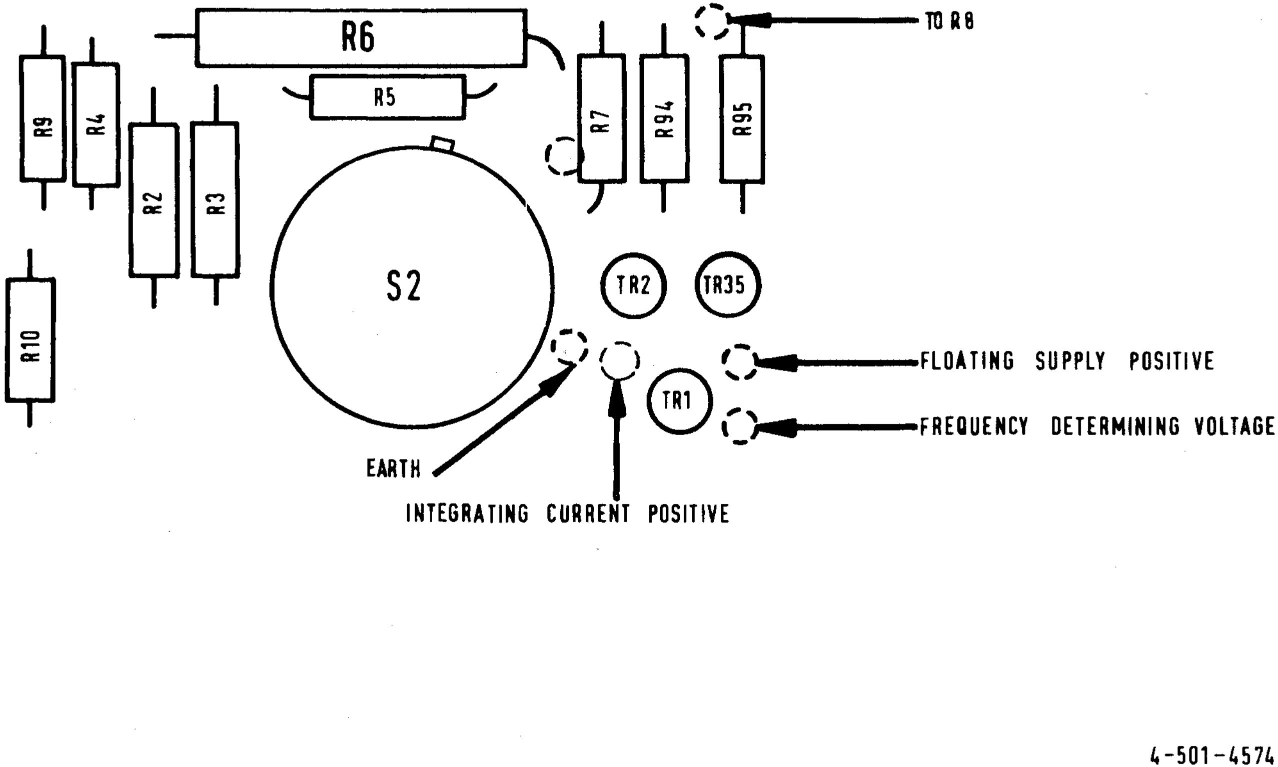


Fig 8 COMPONENT REFERENCE

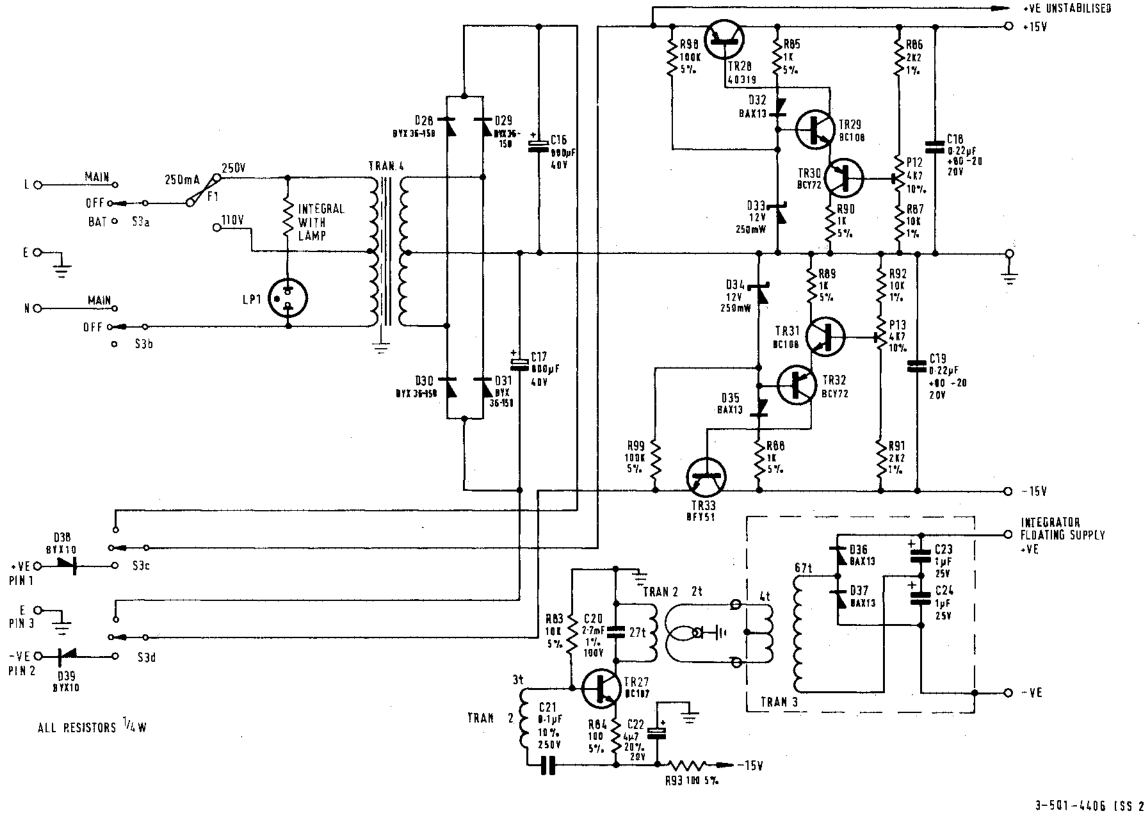


Fig 9 POWER SUPPLY

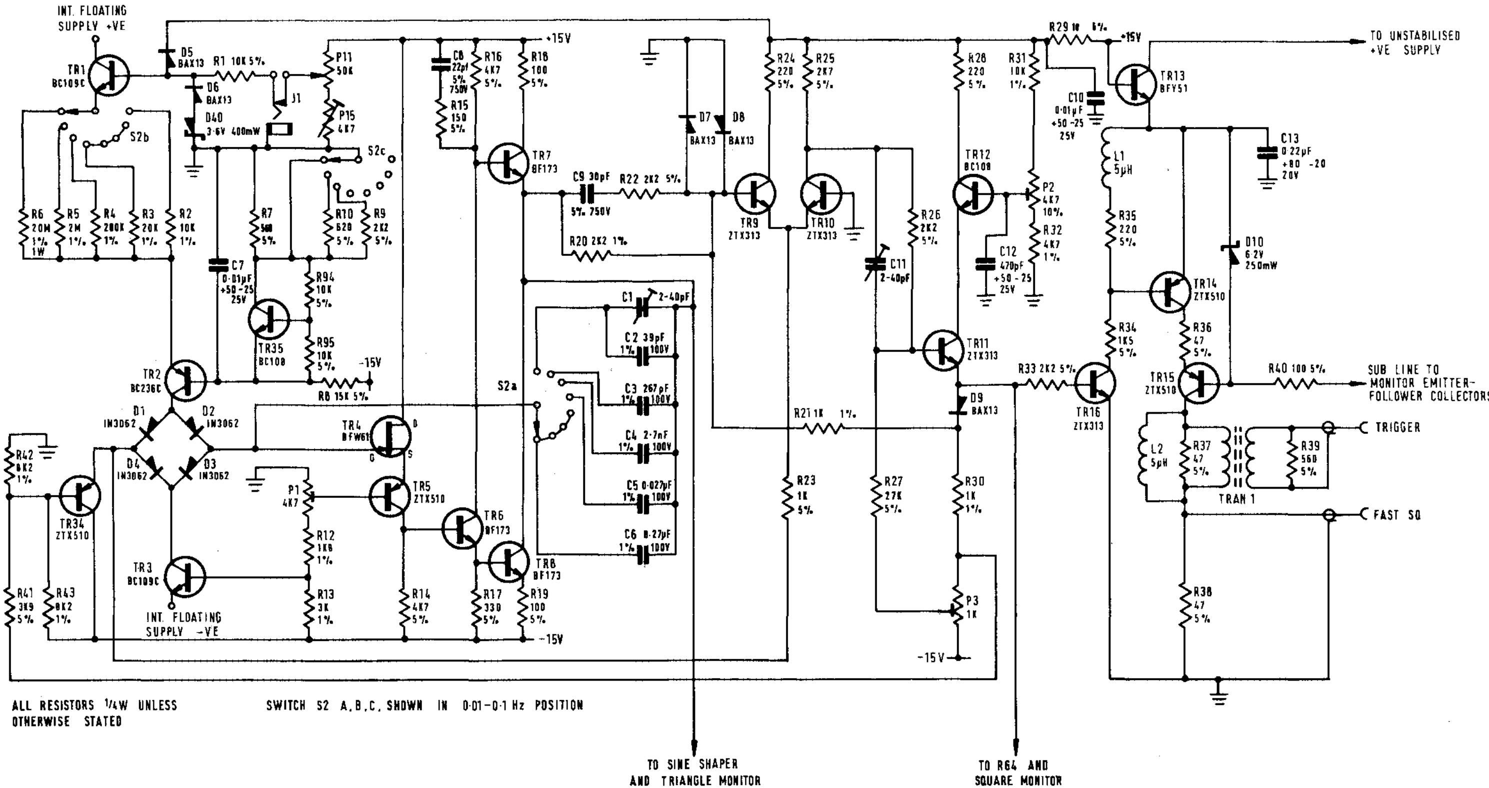


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Fig 10 CIRCUIT DIAGRAM (Part 1)

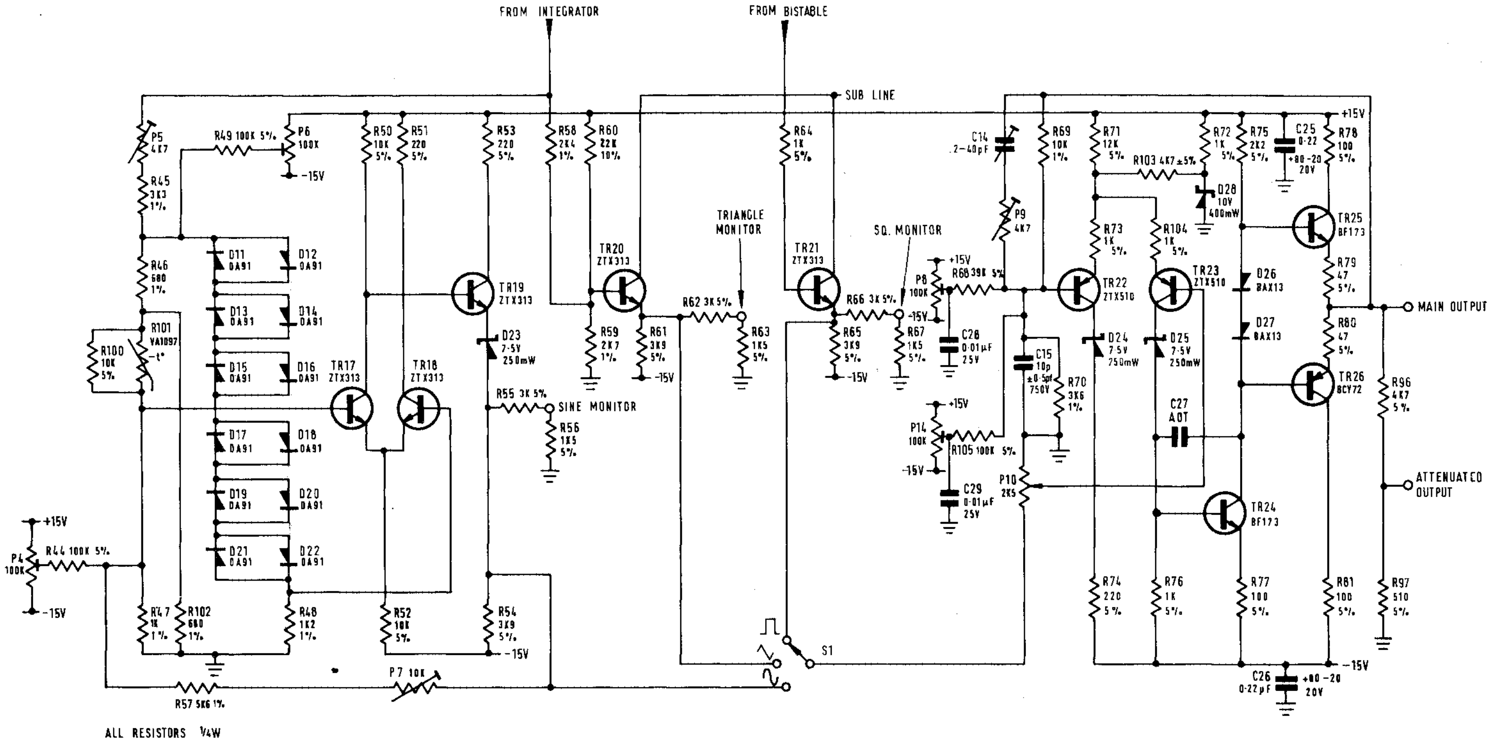

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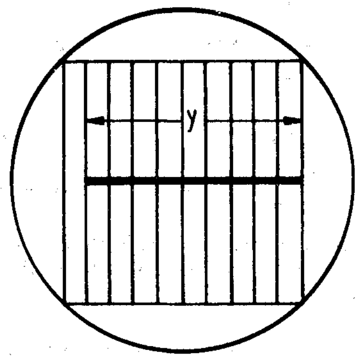
Fig 11 CIRCUIT DIAGRAM (Part 2)

PHASE MEASUREMENT

You need a dc coupled oscilloscope, preferably fitted with a long persistence cathode ray tube.

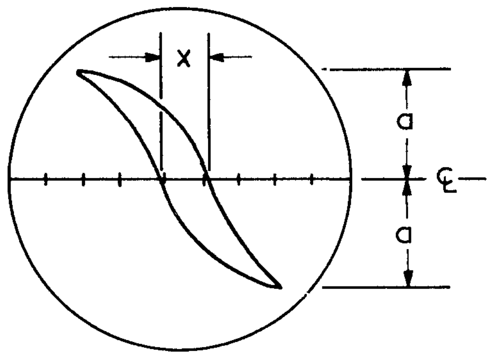
Use the triangular waveform  Feed it on to the X plates or the X plate amplifiers. Adjust the scan to cover the tube face. For convenience make it cover nine divisions on a ten division graticule, thus giving 10° per graticule division.



(On the TWG501 the  is always available)

Feed a sinewave disturbance signal into your servo system from TWG501.

Take the  signal to be measured, from the system under test, and apply it to the Y amplifiers of the oscilloscope. The trace will probably appear as in the diagram. Set the waveform symmetrically about the measured centreline of the tube, i.e a = a.



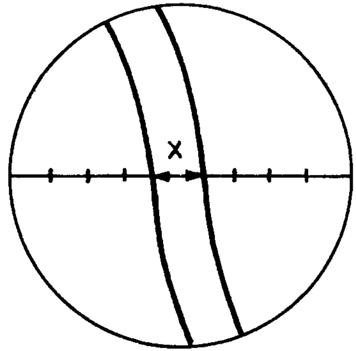
Then measure the distance 'x' horizontally where it crosses the centreline of the tube.

$$\text{Phase lag } \emptyset = \frac{x}{y} \times 90^{\circ}$$

As the frequency is increased the angle $\emptyset$ will become greater until it is 90° where x = y, thereafter the distance 'x' will decrease with increasing frequency and

$$\emptyset = 180^{\circ} - \frac{x}{y} \times 90^{\circ}$$

To obtain more accurate results where the trace crosses the horizontal at an acute angle, the Y amplification can be increased which will enable the distance 'x' to be read more easily.



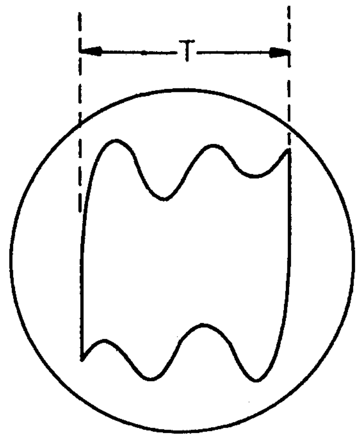
SIMILARLY WHEN MAKING MEASUREMENTS OF TRANSIENT RESPONSE

Use the  waveform as the timebase.

Feed  into the system under test.

Put the output waveform on to the Y plates. Adjust the TWG501 until the transient occupies the oscilloscope tube as shown.

The time $T = \frac{1}{2F}$ where F = the frequency setting.



NOTE : These methods may be used for measurements on all types of systems.

GUARANTEE

This equipment, Serial No. ....

was put into service on (Date) ....

We will, at our cost and discretion, repair or replace this equipment or any component parts which fail due to defective materials or faulty workmanship (fair wear and tear excepted) within a period of 12 months from the date of our invoice.

Such major items which are included in the equipment and are not of our manufacture will be covered by whatever guarantees are passed on to us by our suppliers.

In the event of failure or query please communicate with:-

Technical Sales Department
Feedback Instruments Ltd
Crowborough, Sussex
Telephone: Crowborough 3322
Cables: Feedback Crowbr Telex
Telex: 95255

The equipment covered by this guarantee is now in your possession and should give you years of satisfactory service.

Will you please complete and return the attached prepaid reply card to us, as it will assist us in improving our customer service facilities.

Please complete and return this card immediately on receipt of your equipment.

Instrument type ....

SERIAL NO .... DATE ....

The correct postal address of the Department/person responsible for the care of this equipment is:

....

....

....

If there is any damage or discrepancy on receipt, please indicate briefly below:

....

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