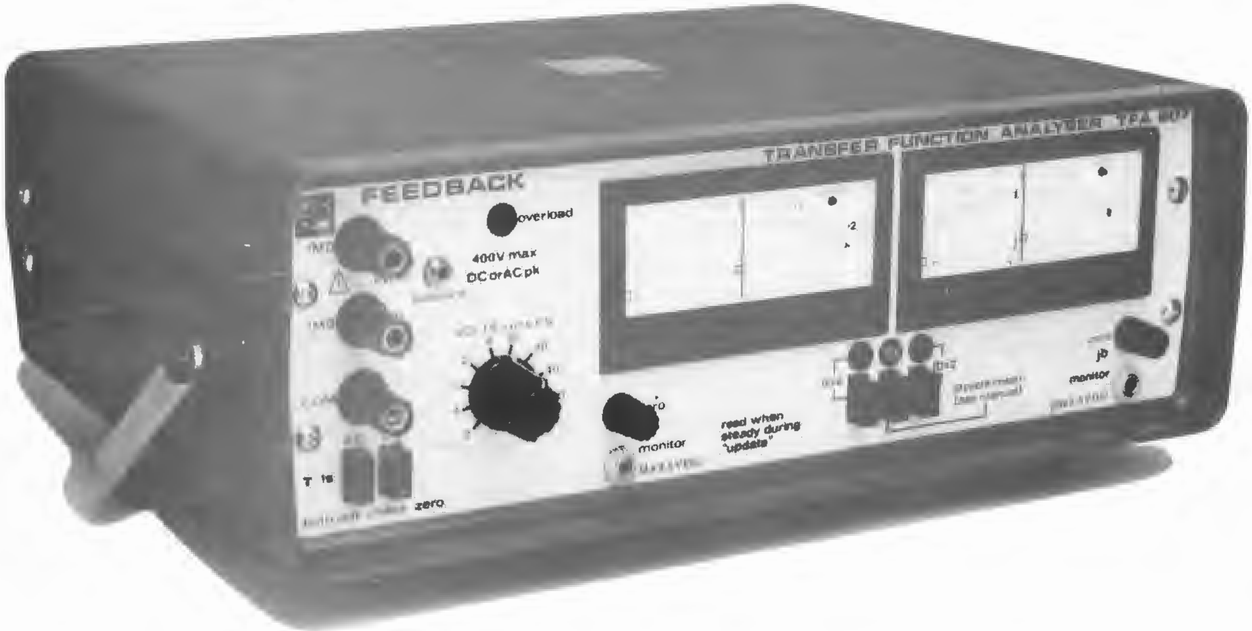
Transfer Function Analyser TFA607



FEEDBACK

TRANSFER FUNCTION ANALYSER TFA607

Contents

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Component replacement

Although this Feedback manual was believed to be correct at the time of printing, components supplied may differ slightly from those described.

We endeavour to improve our equipment continually by incorporating the latest developments and components, even up to the time of despatch. If it is practicable we include such new or revised information in the manual.

Whenever possible, replacement components should be similar to those originally supplied. These may be ordered direct from Feedback Instruments Limited or its agents by quoting the following information:

1. Equipment type
2. Equipment serial number
3. Component reference
4. Component value

Standard components can often be replaced by alternatives available locally.

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The Health and Safety at Work Act 1974

We are required under the Health and Safety at Work Act 1974, to make available to users of this equipment certain information regarding its safe use.

The equipment, when used in normal or prescribed applications within the parameters set for its mechanical and electrical performance, should not cause any danger or hazard to health and safety if normal engineering practices are observed and they are used in accordance with the instructions supplied.

If, in specific cases, circumstances exist in which a potential hazard may be brought about by careless or improper use, these will be pointed out and the necessary precautions emphasized.

While we attempt to give the fullest possible user information in our handbooks, if there is any doubt whatsoever about any aspect relating to the proper use of this equipment the user should conact the Product Safety Officer at Feedback Instruments Limited, Crowborough.

DESCRIPTION AND SPECIFICATION

SECTION 1

1.1 Introduction

The Feedback TFA607 Transfer Function Analyser is a phasor (or vector) voltmeter intended for use in conjunction with the Feedback PFG605 Power Function Generator. The TFA607 derives its power from the PFG605 by means of an interconnecting cable, through which the necessary signals to provide the phase reference are also sent.

The voltage reading is indicated on two moving-coil meters, one indicating the in-phase ('a') component and the other the quadrature ('jb') component of the fundamental-frequency content of the input signal. A high degree of rejection of unwanted signal components is provided, making the instrument especially suitable for applications such as servomechanism studies, and investigation of complex networks. This is largely due to the operating principle, based on Fourier analysis and indicated in outline in fig 1.2.

The recommended range of frequencies is 0.01Hz to 1kHz. The upper limit is determined by the range of the associated PFG605. Operation at frequencies below 0.01Hz is possible, subject to degradation of accuracy. The TFA607 obtains at low frequencies the fastest response which is, in principle, possible. This is achieved without excessive cost or complexity by a judicious blend of analogue, sampling and logic techniques, which is described more fully in Section 3.

1.2 Mechanical

The TFA607 is housed in an ABS plastic case made in two halves each secured by two screws on each side. The case provides the main structural strength of the instrument. Removal of the case (Section 4) gives access to all components. Without the case the TFA607 consists of a horizontal PWB fixed by plastic brackets to the front and rear panels, providing a structure strong enough for handling during maintenance. Power dissipation is negligibly small, so that ventilation is not required.

The two meters are mounted on the front panel (fig 1.1). So also are all of the controls, which are:

Ac/dc coupling — A pair of pushbuttons inserts and removes a d.c-blocking C–R filter from the input signal path.

Voltage range — 10-position rotary switch giving full-scale sensitivities between 0.2V and 200V inclusive.

One pushbutton switch doubles the sensitivity of the in-phase meter, and another doubles that of the quadrature meter. A lamp by each button indicates when it is in use.

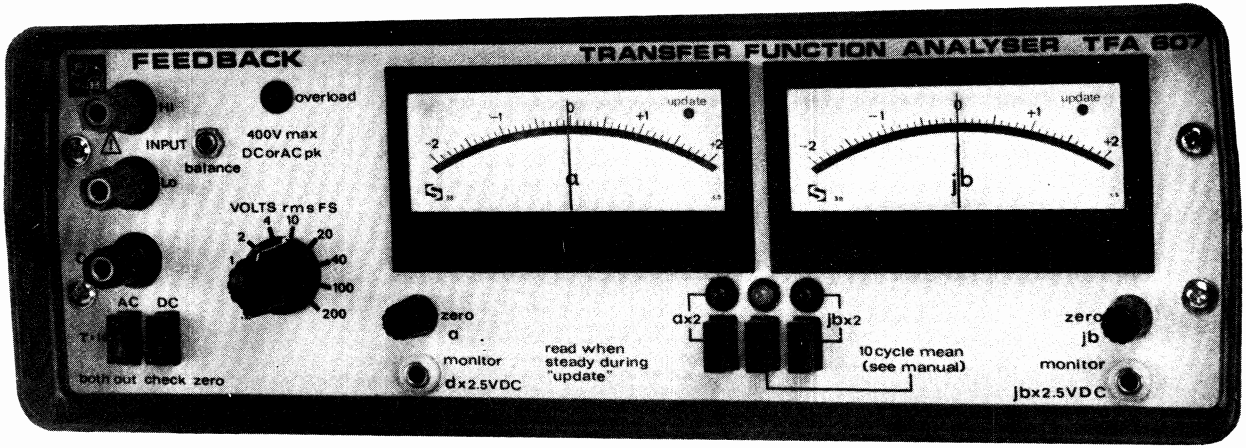

Fig 1.1

10-cycle average A pushbutton switch controls the facility for averaging the signal over up to 10 signal cycles. An associated lamp indicates when this is in use.

Zero adjust Separate rotary controls are available for fine adjustment of the zero on each meter.

Balance A screwdriver-adjustment is provided for equalising the sensitivites of the 'hi' and 'lo' inputs, so removing common-mode responses.

The front panel also carries an overload indicator and two sockets delivering output voltages proportional to the two meter readings.

The socket for the TFA607-PFG605 interconnecting cable is on the rear panel.

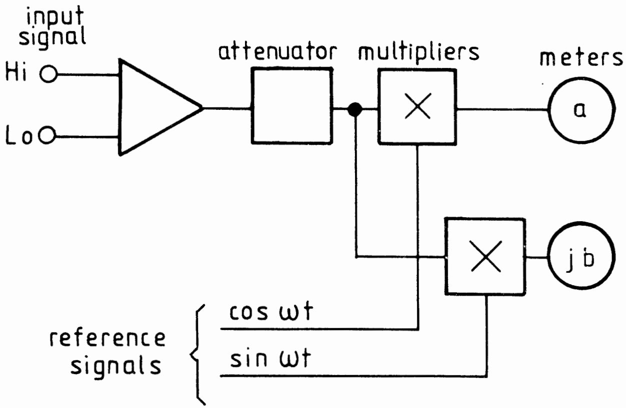

Fig 1.2

1.3 Specification

The TFA607 is a phasor voltmeter for use in conjunction with the Feedback Power Function Generator PFG605. Using the signal from the PFG605 as a reference the TFA607 measures the rms values of the in-phase (a) and quadrature (b) fundamental-frequency components of an input voltage a + jb.

Indication

Two centre-zero moving-coil meters, one with scale marked 'a' indicating the in-phase component, the other marked 'jb' indicating the quadrature component. Scale: 3" mirror scale calibrated from -2 through 0 to +2.

Zero Two uncalibrated controls allow meters to be zeroed electrically.

Expansion Separate pushbuttons with associated warning lamps provide x 2 scale expansion for a and jb deflection.

Operating mode The values of a and jb are measured during each signal input cycle. In the normal display mode the measured value at the end of each cycle is held on the appropriate meter until a new value replaces it one cycle later. The moment at which the new value is applied to the meter is signalled by the 'update' lamp indicator inside the front of each meter.

Averaging An averaging circuit is provided to reduce meter fluctuation which may be caused if irregularities are present in a low to middle-frequency signal. This is invoked by the pushbutton marked '10 cycle average', and replaces the normal display mode by the following.

With the pushbutton in the *in* position the lamp above the button shows red and an average value is displayed as follows:

After the first *complete* cycle the value for that cycle is displayed.

After the next cycle the average of that cycle and the preceding one is displayed.

After the next cycle the average of that cycle and the preceding two are displayed.

etc.

After the 10th cycle the average of 10 cycles is displayed, the lamp above the button turns green and the display follows input changes with a response time constant of 10 cycle periods.

Accuracy

Within the recommended frequency range the total error in the meter readings and in the outputs of the monitor sockets is less than ±5% full scale. The error in arctan a/b arising from error in the radio a/b is less than ±2°.

This does not include the effect of cycle-to-cycle fluctuations due to unwanted signal frequencies which may be averaged out over several cycles and are not truly errors.

Monitor outputs

Two sockets provide d.c output voltages relative to 'common' which are respectively proportional to the measured values a and b. The external load should present a resistance not less than 1kΩ between either terminal and common.

Note The zero controls operate on these outputs but the scale expansion x 2 *does not.*

Recommended Frequency Range

0.01Hz to 1kHz

Input

Differential Between Hi and Lo terminals with screwdriver 'balance' control.

CMRR Common mode rejection ratio:- 60dB.
i.e a common mode signal 10 times as large as the differential signal will not cause an error in reading greater than 1%.

Coupling Selected by two pushbutton switches giving direct coupling, AC coupling, or, with both out, inputs 'grounded' to common.

Impedance 1MΩ from Hi to common and from Lo to common.

Time constant On a.c coupling 1 second ±10%, matched for Hi and Lo inputs.

Sensitivity Selected by 10-position rotary switch giving the following full-scale sensitivity in volts rms (1):-

Input range
0.2
0.4
1
2
4
10
20
40
100
200

Overload The Hi and Lo inputs can each withstand ±400V d.c or a.c pk with respect to 'common' indefinitely on any input range a.c or d.c.

Indication A red LED indicator shows when the differential input signal amplitude exceeds the working limits of the TFA607. *Note* the overload indicator does *not* function on common mode overload and care must be taken to observe the ±400V limit.

Window 2 x the nominal input range: e.g if set to the 1V rms f.s range the TFA607 will not limit provided that the value of the signal plus noise does not exceed ±2.83 volts peak (2 x peak of 1.0V rms sine).

Noise and harmonic rejection Typically 40dB.
e.g if an unwanted signal of the same amplitude as the required signal is applied to the input it will not cause an error in average reading greater than 1%.

Power Requirements

The TFA607 is designed to be used only with the PFG 605. It is connected by means of a 1m long flexible cable which plugs into the rear of each instrument. This cable carries: +7.5V power, common, -7.5V power, reference triangular waveform, quadrature square waveform, logic information about the PFG605 frequency range and mains earth. The total power consumption is less than 2W.

The PFG605 is arranged so that the common terminal may be floated, thus enabling an external bias or mixing to be applied to the output signal. The common of the PFG605 is necessarily connected to the common of the TFA607 by the interconnecting cable. Thus should the PFG605 be floated, the common of the TFA607 will also float. This should be borne in mind while making connection to the TFA607 front panel – both to the inputs and to the monitor sockets. Generally this should cause no problem as use of a.c coupling or the differential input completely overcomes any input difficulty. When using the monitor sockets it must be remembered that their output is relative to 'common' and they should be used accordingly.

OPERATION

SECTION 2

2.1 Installation of TFA607

The TFA607 is packed in inserts of expanded polystyrene to prevent damage in transit. On opening the end of the corrugated cardboard container the inserts together with the TFA607 should be withdrawn evenly from the container, taking care that the inserts and the instrument are held together until separated from the container.

Inspect the TFA607 and if any damage is evident immediately notify the carriers.

2.2 Connection of supplies

All required supplies and reference signals are provided from the PFG605 with which the TFA607 is used. The two instruments should be connected together by means of the cable supplied with the TFA607 which plugs into the rear panel of each instrument. The cable ends are interchangeable. (The PFG605 should be set for the correct line voltage before use, in accordance with its own instruction manual).

The cable also connects the front and rear panels of the TFA607 to the ground connection of the PFG605, and the 'common' connections of the two instruments together.

2.3 Checking the meter zeros

By pressing gently on the 'a.c' pushbutton or the 'd.c' pushbutton, both of them can be released into the 'out' position. In this condition the instrument's input circuits are disconnected from the external 'hi' and 'lo' terminals, and internally shorted to 'common'. Both meters should then read zero. Each can be adjusted to zero by means of the adjacent 'zero' control.

2.4 Connection of the input signal

The input signal should normally be connected between the 'hi' and 'lo' terminals on the front panel, fig 2.1.

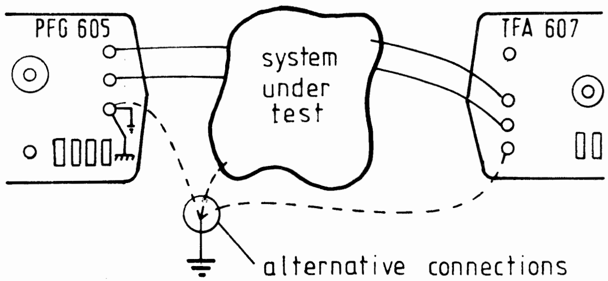

Fig 2.1

The differential input to the TFA607 may be used to examine the phase and amplitude of signals in the system which are not grounded on one side, such as the voltages across small resistances inserted into the circuit to enable in-phase and quadrature components of currents to be measured.

It is important that at least one point in the circuit is grounded. This may be in the system under test, in other instrumentation connected to it or by linking 'common' and ⏚ ⏚ on the PFG605. Only one ground point is needed, and restriction to one may be desirable when low-level signals are to be measured. The nature of the 'common' and/or ground connection may be dictated by the use of the monitor sockets on the TFA607 (paragraph 2.8) or on the PFG605.

The 'common' terminals on the TFA607 and PFG605 are linked. It may therefore be required to measure with respect to 'common'. In this case 'lo' should be linked to 'common'. A response may be obtained without this link, but (especially at the higher frequencies) errors may occur if the 'lo' terminal is left floating.

Care should be taken that neither the 'hi' nor the 'lo' input terminal differs in potential from 'common' by more than ±400V (peak or d.c).

2.5 Input coupling

If the input signal contains a large d.c component of voltage (differential mode, i.e between 'hi' and 'lo' terminals) it may be desirable to use the d.c blocking filters provided. These are brought into circuit or removed by pressing in the 'a.c' or 'd.c' pushbuttons respectively. The filter time constant is nominally one second, and is balanced between the two channels in order to avoid common-mode responses. The time constant gives rise to a leading phase shift of arccot $2\pi fT$ where f is the operating frequency and T is one second. For instance at 1Hz $2\pi fT$ is 6.28 and the phase shift is 0.16 radian = 9 degrees.

An in-phase signal (10 + j0)V would be read with this phase shift as (9.87 + j1.58)V. At lower frequencies the errors increase. However above say 10Hz the influence of the filter is negligible for most purposes.

The excellent common-mode rejection will in most cases make it possible to avoid large d.c components on signals, by the use of external backing-off potentials and/or use of the 'offset' control on the PFG605.

2.6 Checking common-mode rejection

If large common-mode signals are to be present it is desirable to check and if necessary adjust the balance between sensitivities of the 'hi' and 'lo' terminals. These terminals should be joined together and to a large signal derived from the PFG605. The 'volts' control should be set to 0.2 and the 'balance' control adjusted with a screwdriver if necessary to bring the meter deflections back to zero.

Provided that this adjustment is properly carried out the common-mode voltage is limited only by the ±400V limit of voltage between 'hi' or 'lo' and 'common'.

2.6 Selection of range

The rotary switch marked 'VOLTS rms F.S' should normally be adjusted to the least setting which exceeds the actual or expected voltage (although maladjustment will do no damage). The marked values of settings are the rms values of the in-phase (a) and quadrature (b) fundamental-frequency components of the input voltage a+jb which will give full-scale deflection of the respective meters.

If there is a very noisy or distorted input signal, or if a large d.c voltage is superimposed and cannot be filtered out because of phase-shift problems, the instrument may be overloaded. This is clearly indicated by the 'overload' indicator lamp. In this event the 'VOLTS rms' setting should be increased until the overload indication disappears. (Note that the overload indicator does *not* indicate the presence of excessive common-mode signals).

The reading of each meter may be doubled by pressing the associated pushbutton. Note that these pushbuttons do not alter the output obtained from the monitor output sockets.

2.7 Non-rms values and non-sinusoids

The fundamental-frequency components of the input signal, which the instrument measures, are by definition sinusoids. The scaling in rms volts has been chosen to suit the convenience of most users. It means that the reading on each meter is $1/\sqrt{2}$ times the peak value of the corresponding fundamental-frequency component. This is true irrespective of the nature of the complete input waveform.

If a non-sinusoidal input signal is applied, the instrument simply rejects any components of it which are not at the fundamental frequency set by the PFG605 (subject to the comments in paragraphs 2.10 and 2.11). If for instance a square wave, in-phase with the reference, of ±1V amplitude is applied as an input signal, removal of all the harmonics leaves an in-phase fundamental waveform whose peak amplitude is $4/\pi$ V = 1.27V. Its rms value will be $\sqrt{2}$ times smaller, i.e 0.9V, not 1V, which is the rms value of the square wave.

2.8 Monitor output sockets

The two 'monitor' sockets on the front panel provide signals proportional to the respective meter readings. Each signal is a voltage relative to the 'common' terminal and is scaled so that ±5V d.c corresponds to the relevant signal component having ± the value to which the 'volts' range switch is set. This corresponds to full-scale deflection of the meter when the 'X2' button is not in use, and the monitor signal is not altered by that button. The load should not have a lower resistance than 1kΩ.

Caution Bear in mind that if the 'common' terminal is at some high potential, so also will be the monitor sockets. Contact with the monitor sockets may then be dangerous both to the user and to the instrument.

2.9 Normal operating mode

The operating mode can be changed by means of the central pushbutton between the two meters. The normal mode is obtained when the button is out, and the associated lamp is unlit. In this mode the instrument measures each component of the input signal for the duration of one complete cycle of the input signal; it then transfers this measurement to the appropriate meter, which displays it for the duration of the following cycle. A green indicator lamp in each meter flashes to indicate the time at which it is updated. When operating at frequencies below 0.01Hz the reading may drift, and is best read immediately after updating.

2.10 Unwanted signal components

The input signal may contain other components beside those of the set operating frequency, such as d.c, harmonics and other frequencies. An ideal homodyne detector (to which the TFA607 approximates) would reject d.c and harmonics completely. In the presence of

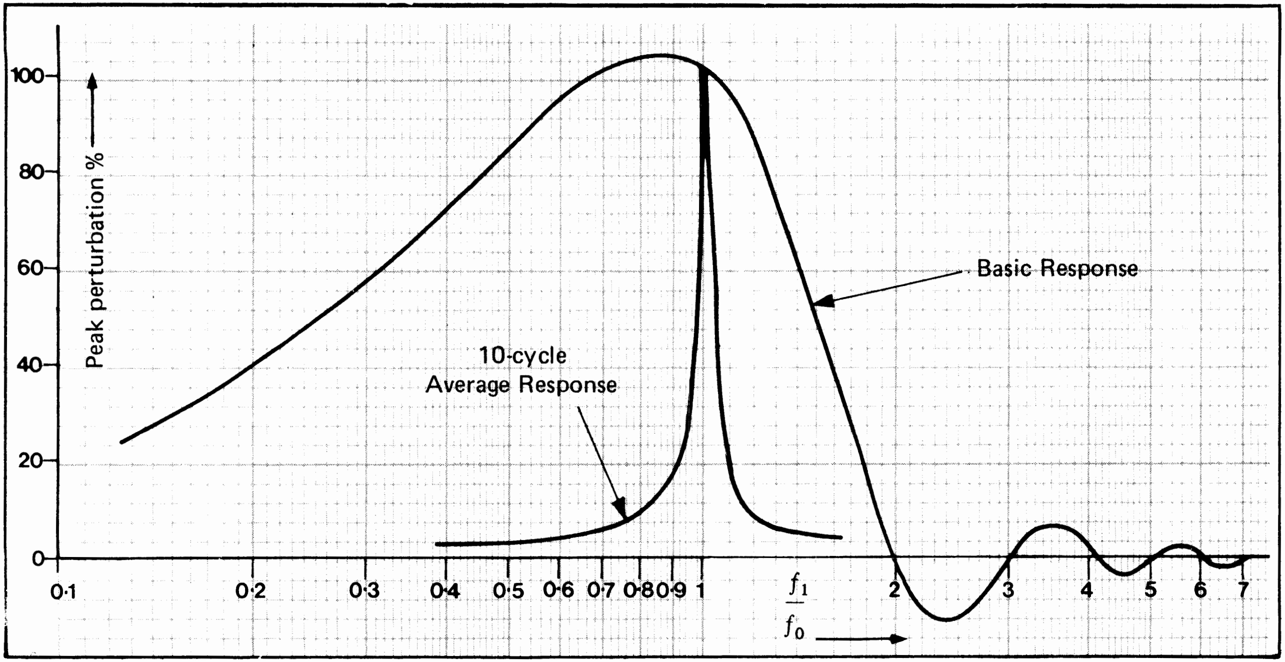

Fig 2.2

unrelated frequencies or noise the average of readings taken over a long enough period would be correct, although readings might fluctuate from one cycle to another. The TFA607 will typically produce average readings in which the error attributable to unwanted components is only 1% of the effect they would be expected to have if not rejected at all.

The cycle-to-cycle fluctuations of readings in the presence of noise depend on its amplitude and spectrum. The peak perturbation of the reading for a single-frequency unwanted signal may be expressed as a function of f_1/f_0 where f_1 is the unwanted frequency and f_0 is the reference frequency to which the instrument is set. This function expressed as a percentage of the response at f_0, is plotted in fig 2.2.

These fluctuations may in most cases be considerably reduced by use of the '10-cycle average' facility. This is clearly demonstrated by the graph for '10-cycle average' in fig 2.2. The narrowness of the response makes the use of the 10-cycle average function especially effective against random noise.

A further factor which reduces fluctuations of readings is the frequency response of each meter and the circuits which drive it. This is indicated in fig 2.3.

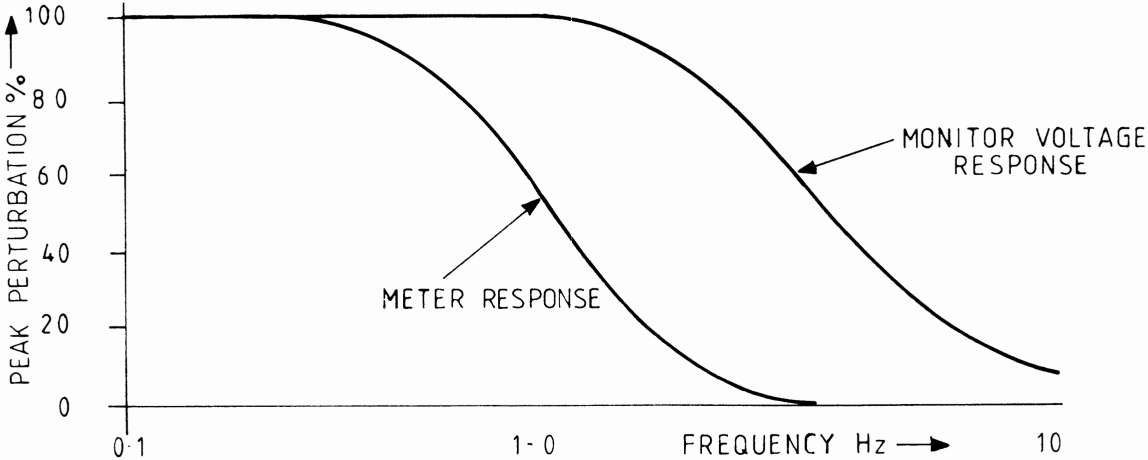

Fig 2.3

2.11 Use of the '10-cycle average' facility

The '10-cycle average' facility may be used to smooth out unwanted perturbations of readings. The penalty is an increased time of response to the desired signal, depending on its frequency. This response time can, however, be cut to the minimum theoretically possible by correct operation of the controls. The actions which follow the action of pressing the '10-cycle average' button 'in' are as follows:

The lamp above the button immediately lights up red.

At the end of the first complete measuring cycle thereafter the signal value for that cycle is displayed.

After the next cycle the average value for the two cycles is displayed.

After the next cycle the average value for the three cycles is displayed.

This sequence continues until, after the tenth complete cycle, the red light changes to green, and from then on the readings displayed follow the input with a time constant of ten cycles of the set frequency.

The effect on the speed of response is shown in fig 2.4. This plots the time required for the response of the instrument to the desired signal to come within 1% of the final value. (If signals of unrelated frequencies are present the perturbation, figs 2.2 or 2.3, may apply additionally). The response time is plotted against signal frequency for various conditions.

Considering first the broad sloping band marked 'normal response', this indicates a settling time inversely proportional to signal frequency, and variable over a 2:1 ratio. This is because although the instrument integrates over one signal cycle, the user may have to wait for most of a preceding signal cycle before the instrument reaches the time in its own cycle when the integration starts. At the higher frequencies the response time is determined by the meter, or by an internal time constant of the sample-hold circuit in the case of the monitor outputs.

If the '10-cycle average' button is now pressed, the response to the desired signal will be as fast as before. The response time shown in this case is the time for the averaging over ten cycles to take place, which will reduce the perturbations due to any spurious signals as shown in fig 2.2.

If the 10-cycle average function remains in opertion, the instrument retains always some memory of signals which were present even before the previous ten-cycle period. The response time therefore lengthens as indicated by the third graph, to 46 cycles for 1% accuracy.

For a quick response to any specific event, such as a change in frequency or amplitude of the signal, the 10-cycle average function should be cancelled momentarily. Restoring the 10-cycle average function will then once more give the most accurate possible readings with minimum delay.

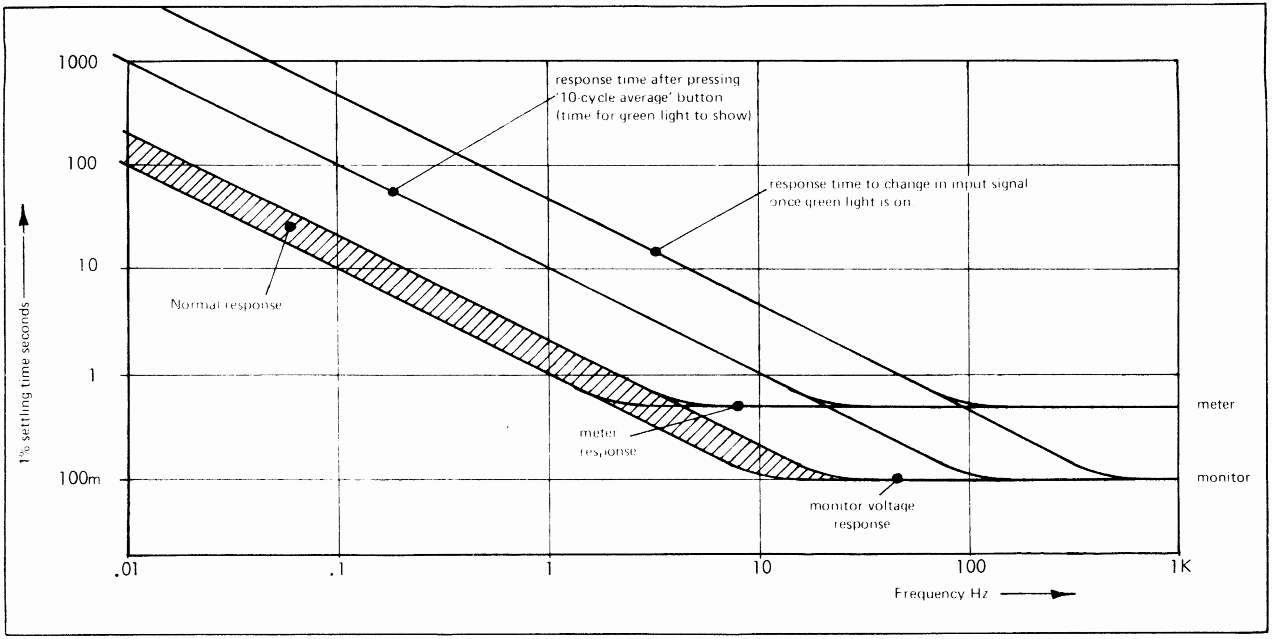

Fig 2.4 Diagram showing time taken to obtain readings within 1% of final value for various conditions, against frequency.

2.12 Effects of sampling

The sampling techniques used within the TFA607 may give rise to small fluctuations in readings. These will not normally be troublesome, but the user should be aware of what is happening.

There are two such effects.

1. When the top frequency range of the PFG605 is in use, small fluctuations may occur because the number of samples taken by the TFA607 in each cycle is small. The effect disappears at lower frequencies.

2. Aliasing can occur. That is, harmonics or other unwanted frequencies may 'beat' with the sampling frequency, producing a regular oscillation in readings at some spot frequencies. The effect is uncommon and difficult to find. In most sampling systems the input signal is filtered to remove components that could cause aliasing problems. This is not practicable in the TFA607 because of the need to preserve exact phase integrity, and because of the wide range of sampling frequencies used.

CIRCUIT DESCRIPTION

SECTION 3

The diagrams shown in this section are greatly simplified. The components referred to in the text can be found in the full circuit diagram, fig 4.5.

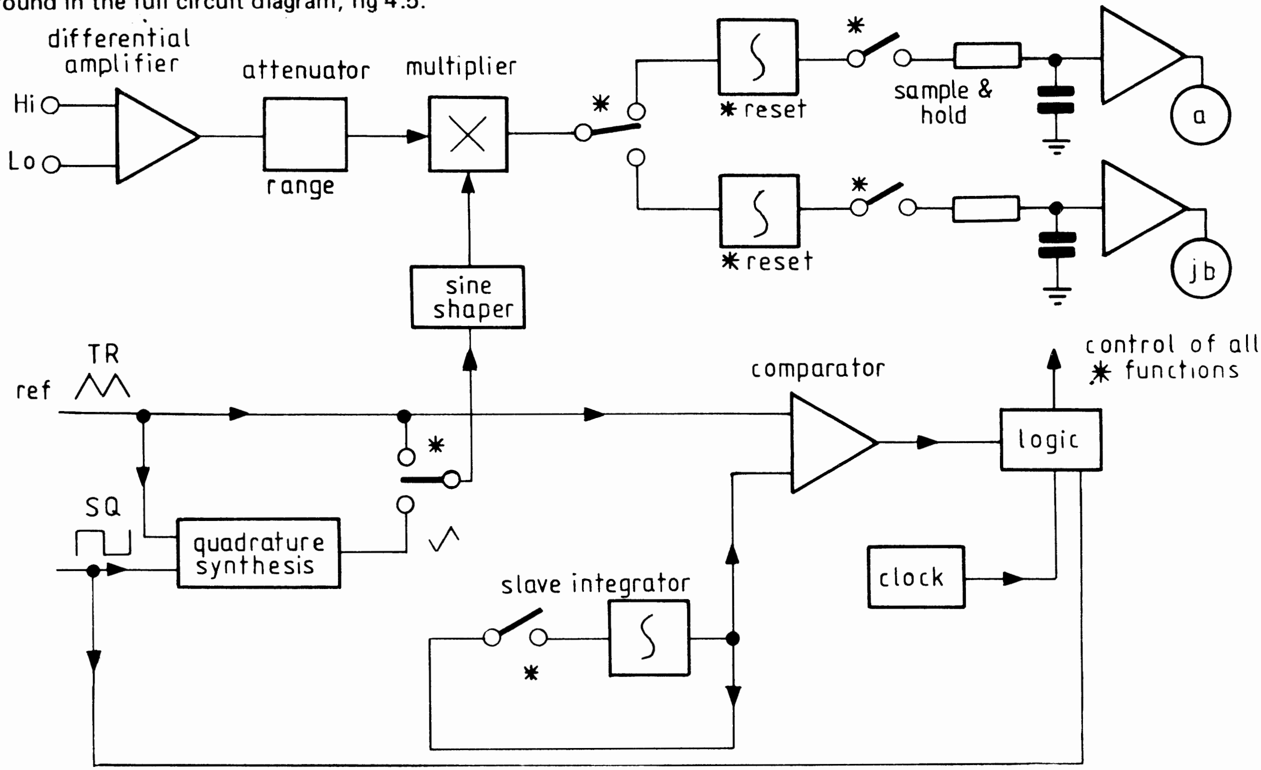

Fig 3.1

3.1 Principle of Operation

Fourier's Theorem shows that a periodic wave y(t) of period $T = 2\pi/\omega$ may be analysed into a series of sinusoidal component waves. The fundamental component is defined to be that which has a period also of T. It may be resolved into two components

$$A \cos \omega t \quad \text{and } B \sin \omega t$$

which are in phase and in quadrature respectively with a reference waveform $C \cos \omega t$.

The theorem further shows that A and B may be determined as

$$A = \frac{2}{T} \int_0^T y \cos \omega t \, dt$$

$$B = \frac{2}{T} \int_0^T y \sin \omega t \, dt$$

This determination involves integration over just one cycle of the chosen frequency ω. In the TFA607 the cosine and sine multipliers are derived by means of a non-linear sine-shaping circuit from triangle waves which in turn are derived from the output signals of the PFG605.

The sine shaper and a multiplier are multiplexed between the 'a' and 'b' channels as indicated in fig 3.1. The multiplier output is then distributed to separate integrators, each finally driving a sample-and-hold circuit.

The required multiplying factor (2/T) is introduced by allowing the integration to proceed only intermittently, the ratio between operating time and static time being adjusted to provide the correct factor.

The quantities A and B are the peak values of the in-phase and quadrature fundamental components of the signal. AC voltages are usually measured in rms terms, and since the components are by definition sinusoidal their rms values are respectively

$$a = A/\sqrt{2}, \qquad b = B/\sqrt{2}.$$

3.2 Input circuit

The 'hi' and 'lo' input terminals are connected by a resistance-capacitance network to a differential amplifier formed of two amplifier sections of the quadruple-amplifier AB. Fig 3.2 shows the half-network for one input terminal, divided into two functional elements. The series resistors feeding the amplifier and the adjacent capacitors could in principle be adjusted so that the potentials of their respective junctions were equal.

Connecting the link shown would then have no effect. However with the link joined, an alteration of the variable capacitor would produce a phase shift. In practice this phase shift is used to compensate for unwanted phase shifts arising from stray capacitances. Correct cancellation of phase shift is necessary not only for instrumental accuracy, but also because if the two input terminals are associated with different phase shifts then cancellation of common-mode signals will not occur.

The left-hand half of fig 3.2 shows the d.c blocking network. R3 enables the time constants associated with the two inputs to be equalised.

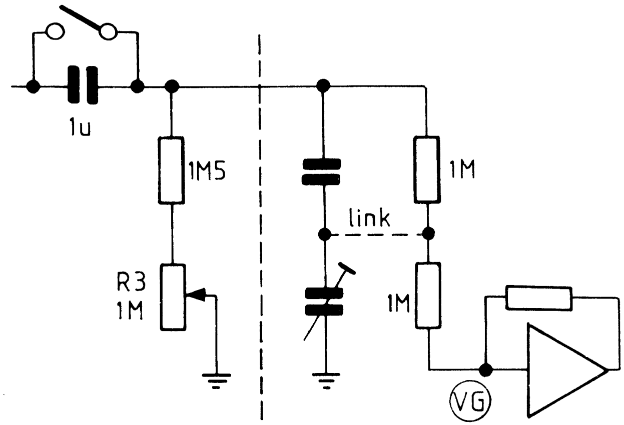

Fig 3.2

3.3 Differential amplifier

The differential amplifier is a conventional configuration of two operational amplifiers, arranged to have a gain of 0.015, thus ensuring that any input signal within the specified range will produce an output within the amplifiers' output capability. The 'balance' control R13 is adjustable by means of a screwdriver through the front panel, and adjust the relative gains from the two input terminals for equality. R8 is a preset adjustment for offset.

3.4 Range switching

The voltage range is selected by a rotary switch which places in circuit a resistance proportional to the required range. The appropriate resistor is connected between the output of the differential amplifier and the virtual ground provided by the input to the analogue multiplier.

3.5 Analogue multiplier

The multiplier is based on an array AC of matched transistors. Reliance is placed on the characteristics of each of these devices closely approximating to the form

$$i_c = I\,e^{V_{be}/V_T} \qquad \ldots\ldots (1)$$

which is equivalent to

$$V_{be} = V_T \ln i_c/I \qquad \ldots\ldots (2)$$

where i_c is the collector current, V_{be} the base-emitter voltage, and I and V_T are constants assumed to be the same for each transistor since they are matched and at the same temperature. The current gains are high, so that the base currents may be neglected.

Consider the circuit of fig 3.3. A signal current of value y and constant bias current k cause current k – y to flow in transistor AC1, whose emitter is held at a virtual ground by the operational amplifier AB. From equation 2 the base potential of transistor AC1 is

therefore

$$V_1 = V_T \ln \frac{k-y}{I}$$

The diode D5 is part of the overload indicator circuit (para 3.12). Because of it the output of its driving amplifier runs at a slightly higher potential than it would do otherwise, but this may be ignored in normal operation. Another operational amplifier holds the emitters of AC2, AC5 at a virtual ground, so that the base-emitter voltages of AC1, AC2 are the same; AC2 therefore carries the same current (k – y) as Tr28.

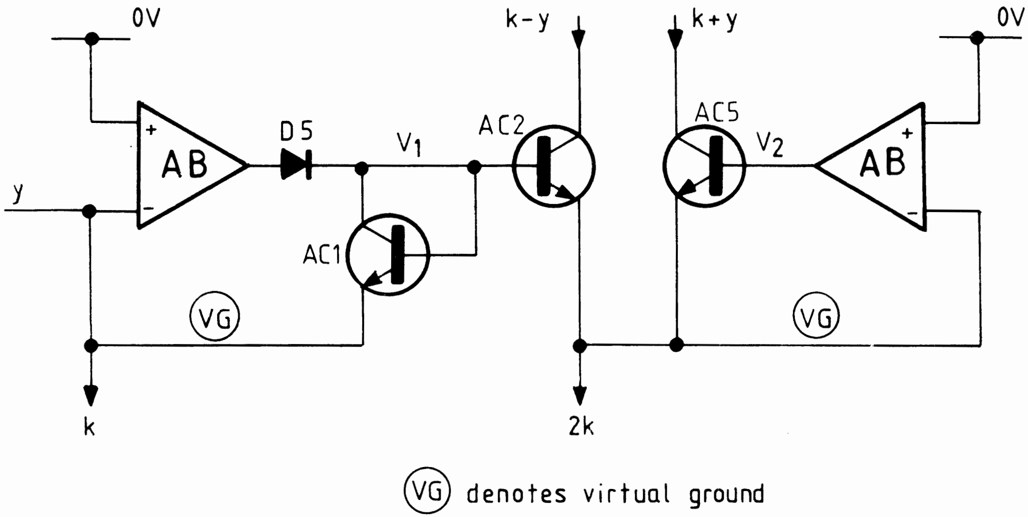

Fig 3.3

The combined emitter currents of AC2, AC5 are fixed at the value 2k. The current in AC5 is therefore k + y. The base potential of AC5 is therefore

$$V_2 = V_T \ln \frac{k+y}{I}$$

Consider next fig 3.4, in which V_1 and V_2 are the same potentials as in fig 3.3, c is the collector current of AC4 and the combined emitter current is composed of a constant bias current 2k and a signal current 2x. From equation 2 the two base-emitter voltages are

$$V_T \ln \frac{2k - 2x - c}{I}$$

and $V_T \ln c/I$.

Now the difference between these base-emitter voltages is the same as $V_1 - V_2$.

$$\therefore \quad \ln \frac{k-y}{I} - \ln \frac{k+y}{I} = \ln \frac{2k-2x-c}{I} - \ln \frac{c}{I}$$

$$\therefore \quad \frac{k-y}{k+y} = \frac{2k-2x-c}{c}$$

$$\therefore \quad c = k - b + y - \frac{yx}{k} \qquad \ldots\ldots (3)$$

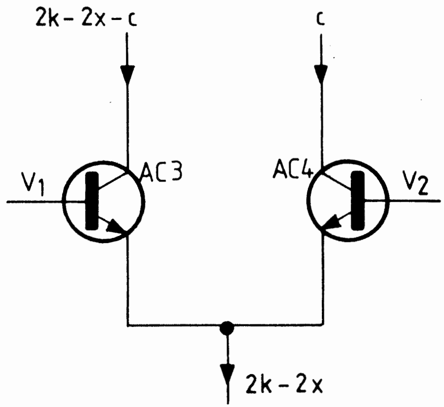

Fig 3.4

AE, AH combine to form a differential amplifier whose input is the difference between the currents

$(k - y) + c$
$- (2k - 2x - c + k + y)$

which simplifies to $2(-y + x + c - k)$.

Substituting the value of c given by equation 3, this current difference reduces to $-2xy/k$, i.e the product of the inputs to the multiplier, with a scaling factor.

A proportional output voltage is developed by AH.

The fixed potentiometer R25, R26 sets the reference potential for the summing junctions of AE,AH so that a suitable low positive potential is applied to the collectors of AC2 to AC5.

The x-input to the multiplier is the multiplexed pair of cosine and sine waves derived from the sine-shaper circuit from multiplexed triangle waves.

3.6 Supply and signals from PFG605

The TFA607 is connected to the PFG605 via a 7-way screened cable terminated in 7-pin DIN plugs.

The PFG605 supplies the following signals and voltages to TFA607.

DIN Pin No.	
6	-7.5V d.c signal when PFG605 is switched to the 100Hz to 1kHz range; o/c on all other ranges
1	-7.5V d.c signal when PFG605 is switched to the 10Hz to 100Hz range; o/c on all other ranges.
4	triangular waveform TR
2	square waveform SQ
5	+7.5V d.c 120mA
3	0V (common)
7	-7.5V d.c 120mA
chassis	mains earth and cable screen

The phase relations and amplitudes of the SQ and TR waveforms are important to the proper operation of the TFA607, and are shown in fig 3.6, related to a sine input to the 'hi' terminal which will produce a positive reading on the 'a' meter, with no 'jb' reading.

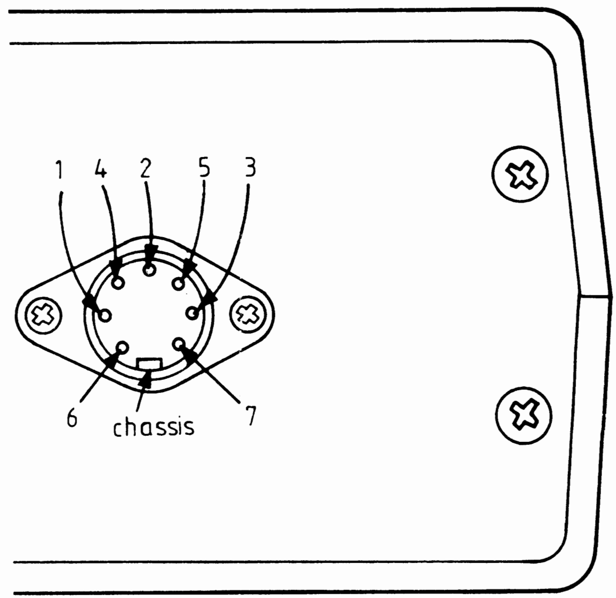

Fig 3.5 View of the socket on the rear panel as seen from behind the instrument (either PFG605 or TFA607). The numbers are moulded into the plugs and sockets.

The d.c signal voltages on pins 6 and 1 are to switch components in the TFA607 to operate at higher frequencies. With no signal supplied to either pin 6 or 1, the TFA607 operates up to 13Hz. With -7.5V d.c control signal to pin 1, the TFA607 operates to 130Hz and with -7.5V d.c control signal to pin 6, the TFA607 operates up to 1.3kHz.

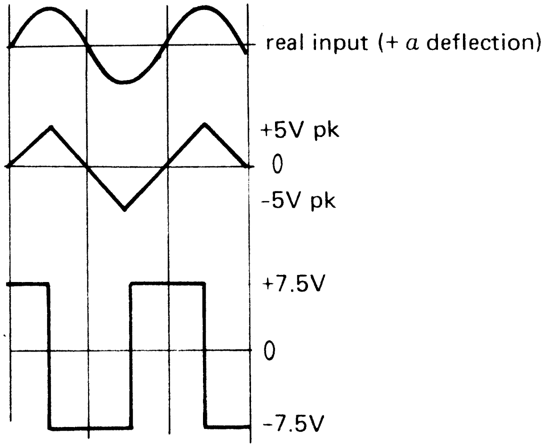

Fig 3.6

3.7 Generating the multiplexed triangles

In order to generate the multiplexed cosine and sine waves the input to the sine-shaper must be a multiplexed pair of triangle-waves in quadrature. One of these is the triangle TR supplied by the PFG605. The generation of the quadrature triangle-wave QT and the interlacing of the two is controlled by the multiplexer AG and performed by the circuits shown in fig 3.7, the waveforms being indicated in fig 3.8.

In the process an auxiliary square waveform (QS) is used, which is in quadrature with the primary square waveform SQ. QS is derived from waveform TR by the comparator AW (pin 13). Since the slow zero-crossing of TR might cause jitter on QS, positive feedback is applied to the comparator by R57, and the resulting phase lag is corrected by biassing the input with the square wave SQ fed in by R55.

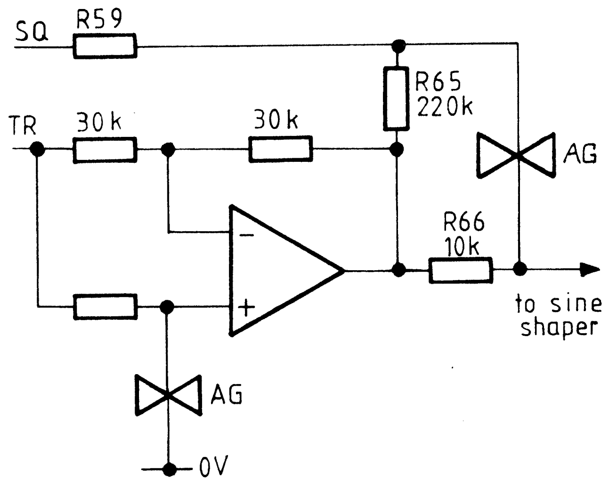

Fig 3.7

The inhibit input of AG is driven by the toggle flip-flop which switches channels. All the switches of AG are therefore off when Q of the toggle is high, corresponding to the 'a' channel in operation. In this condition AD functions as a unity-gain amplifier applying the triangle waveform TR from the PFG605 to R66 which supplies a corresponding input current to the sine-shaper circuit AA. The corresponding waveforms are those shown by broken lines in fig 3.8.

The full lines indicate the waveforms when the toggle switches to Q low, i.e when the 'b' channel is operating. Then R59 is additionally connected to the sine-shaper (by one or other of the four paralleled switches connected to pin 13 of AG), thus feeding in to the sine shaper a current corresponding to the square waveform SQ. The switch (actually two in parallel) at the non-inverting input terminal of the amplifier closes at the times indicated in fig 3.8, and when this occurs the amplifier inverts its input signal with unity gain. The current into the sine-shaper is thus the sum of the waveforms SQ and Y, making the composite waveform QT, the required quadrature triangle wave. The amplifier output in this condition is slightly attenuated by the loading of R59. The introduction of R65 corrects for this.

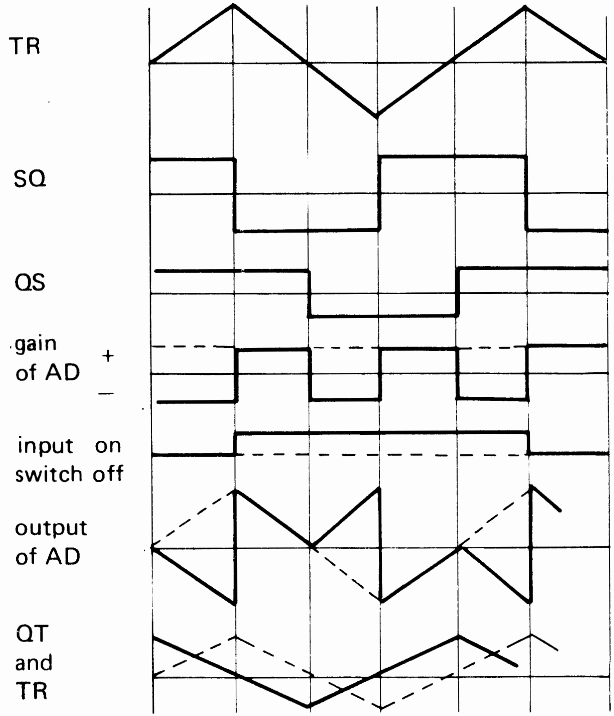

Fig 3.8

3.8 Sine shaper

The sine shaper is formed by the transistor array AA. Since it receives the two interlaced triangle waves, it produces an output which is two interlaced (or multiplexed) sine waves, the conversion being accomplished by using the non-linear characteristics of an over-driven long-tailed pair, fig 3.9. Inclusion of emitter resistors modifies the basic characteristic, fig 3.10. The complete circuit is a combination of two such circuits in parallel, modified to meet constraints on voltage levels allowable within the transistor array, and by the inclusion of R70 which improves the output waveform by subtracting from it a small proportion of the input triangle waveform. The output current is fed directly into the multiplier circuit.

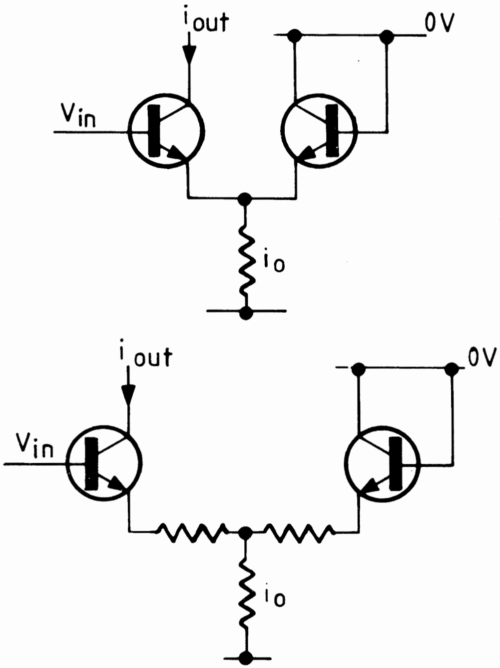

Fig 3.9

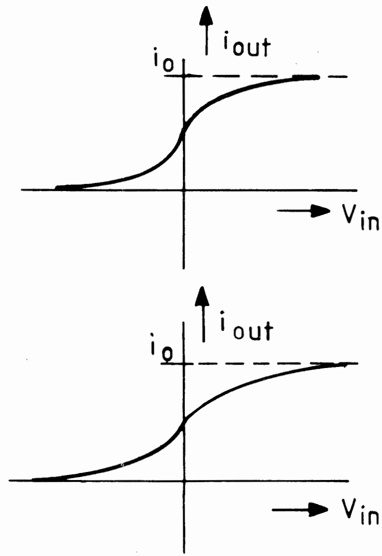

Fig 3.10

3.9 Integration and time-scaling

Three feedback integrators are based respectively on AJ for the 'a' channel, AV for the 'b' channel, and AT for a 'slave' channel. The feedback components in these three integrators are identical, and include capacitors switched by gates controlled by the frequency range switches in the PFG605. Each integrator can be 'held' by switching off an analogue gate in its input path. The input gates of the 'a' and 'b' channels are switched on alternately, in synchronism with the switching of inputs to the multiplier. When either gate is switched on, so also is the input gate of the slave integrator.

The purpose of the slave integrator is to provide the scaling implied by the factor 2/T. It does so by using a somewhat complicated feedback loop to make its output follow the PFG605's triangle-wave output, the process being controlled by varying the ratio of integrate to hold times. The same integrate and hold times then also control the 'a' and 'b' channel integrators.

The slave integrator forms part of a switch-and-integrator oscillator which, if allowed to run free would generate a rapid triangle wave at the integrator output, and square wave at the output of the trigger circuit which follows it. One of the comparators AW compares this triangle wave with the triangle-wave output TR of the PFG605, and feeds the resultant logical signal into one of three selector inputs of AP. The trigger circuit controls another selector input. The third selector input is driven by the quadrature square wave QS (paragraph 3.8). These three selector inputs determine which of the inputs, square wave, inverted square wave, 1 or 0 will appear at the output terminal of Q14, the choice being such that at every stage in the cycle the output signal changes in the same sense if the slave integrator signal runs ahead of TR, the master triangle from the PFG605.

This output signal must be converted into a decisive on/off signal. It is therefore passed through a data flip-flop clocked by the continuously running clock AU, C19, etc. The resulting output signal is used as one select input of the multiplexer Q16. The complementary signal is used to toggle a second data flip-flop which provides the second select input to the multiplexer. These select inputs select alternately the input switches to the 'a' and 'b' channel integrators. The slave integrator is always selected, since here the pair of switches is connected in parallel. The duration for which the integrators are switched on is controlled by a direct clock input to the multiplexer.

The result of this arrangement is that the slave integrator generates approximately a triangle wave synchronised with the PFG605 master wave, by integrating for the duration of one clock pulse whenever its output lags behind TR. It then waits until again overtaken by TR. Alternate slave clock pulses are associated with pulses of integration in one and then the other channel integrator. If the period T of the signal waveform is increased, the slave integrator will require a pulse of integration less frequently. The channel integrators will therefore also perform a pulse of integration less frequently, which provides the 2/T scaling.

3.10 Channel integrator and sample/hold control

Update timing is determined by the set of comparators AZ which compare various d.c levels with the TR waveform. Comparator AZ1 generates a negative-going channel-'b'-update signal BU(L) when TR is near its positive peak. Comparators AZ2 and AZ3 with their output transistors paralleled allow their output terminal to rise when TR is close to zero, but it only does so when SQ is positive, owing to the connection of R96. The fourth comparator in AZ serves as an inverter producing a negative-going channel-'a'-update signal AU(L).

These update signals operate the respective update lamp indicators through the transistor switches Tr3,4. They are used in conjunction with the SQ and QS signals and their complements in a set of gates which control the integrators.

The action of the gates may be followed in detail on the main circuit diagram, but because of the multiple inversions it may be simpler to study fig 3.11, in which a logically equivalent but simpler set of gates and signals is presented. Fig 3.12 shows corresponding waveforms.

In fig 3.11 the resistance R represents the switched network of paralleled resistors R104 to 107, whose function will be explained in due course. In normal operation

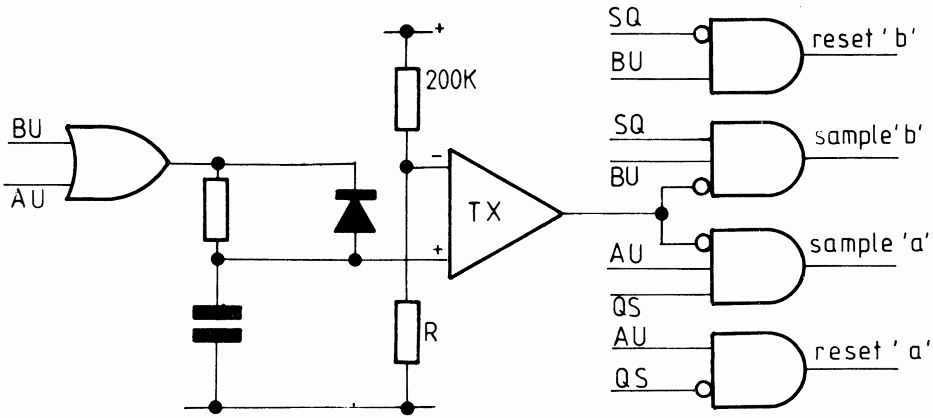

Fig 3.11 Simplified equivalent logic diagram

R is open-circuit, and the output of the comparator is permanently negative. Channel 'a' is therefore sampled when AU.QS is true, and 'b' is sampled when SQ.BU is true. These times are indicated in fig 3.12. For the sampling period the switch connecting the appropriate integrator output and the hold capacitor (C14 or C15) is switched on. The duration of the sampling pulse is long enough to exceed the charging time constant (approximately 5kΩ x 200nF = 1ms) by a large factor at any frequency at which the meter will respond. At the end of the sampling pulse the capacitor retains the signal, leakage being very small by virtue of the output amplifier having an FET input stage.

After the sampling pulse the integrator is rapidly reset in readiness for the next operating cycle by short-circuiting its feedback capacitor. This is initiated by the signal AU.$\overline{QS}$ for the 'a' channel and BU.$\overline{SQ}$ for the 'b' channel.

3.11 10-cycle averaging

Pressing the 10-cycle average pushbutton, SW4, switches the flip-flop AY, removing the reset signal and via C21, R109 temporarily applying a preset-enable signal to BE, which sets all its output bits to 1. It also lights the red indicator via a gate and Tr6. The next b-sampling pulse sets the flip-flop AY to drive the clock terminal of BE which thus counts to zero. The 'a' and 'b' channels will then each be sampled normally once. Flip-flop AY will be reset on the 'a' sampling pulse and set again on the

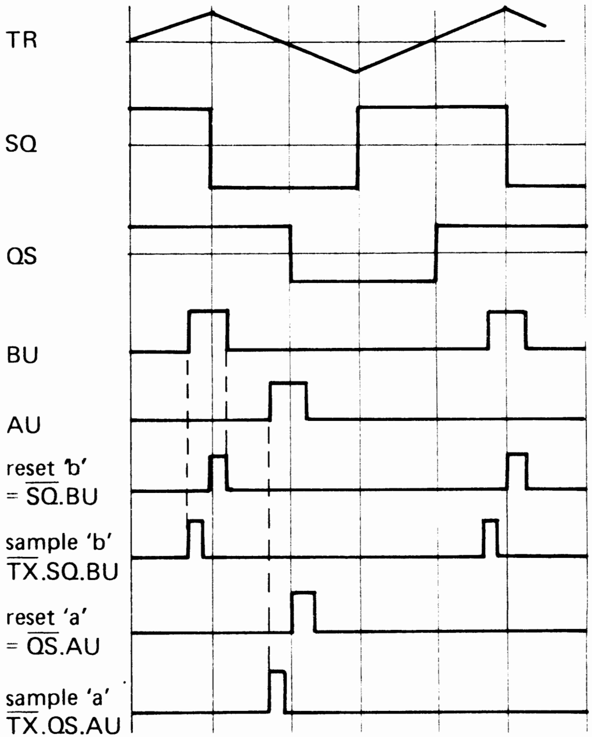

Fig 3.12

'b' pulse, thus raising the count on BE to one. Successive cycles will increase the count to a maximum of ten. This count is detected by a set of gates which prevents further counting by raising the carry in (low) terminal. The count of ten also switches the red indicator off and, via Tr5, puts the green indicator on.

For counts between 1 and 10 the resistance R of fig 3.10 takes values determined by paralleling those of resistors R104 to R107 whose corresponding bits are set to 1. Their resistance values, and therefore also their conductance values, are in a binary sequence, the conductances being 1, 2, 4, and 8 times that of R108. The combined conductance is therefore proportional to the binary number at the counter output. As the count increases the voltage dropped across R decreases.

The effect of this is that the charging of C20, initiated by either an 'a' or 'b' update pulse, switches the comparator BF progressively earlier, and this terminates the channel sampling pulse. The purpose of diode D8 is to ensure the rapid and complete discharge of C20 between one update pulse and the next.

As the channel sampling pulse becomes progressively shorter, less time is available for the integrator signal to be placed on the sample-and-hold capacitor, and also for the previously stored signal on the capacitor to escape. The timing is arranged so that the proportion of the signal transferred in successive transfers is one-half, one-third, one-quarter, and so on, of the whole, until the steady value of one-eleventh is reached.

3.12 Overload indication

When an overload occurs one half or the other (depending on the sense of the overload signal) of the multiplier tends to cut off. The operational amplifier on that side (AB, pin 8 or 7) will, as soon as cut-off is reached, produce a large negative output voltage in the vain attempt to maintain the virtual earth potential, since the cut-off removes its negative feedback. This large negative potential turns on Tr1 or Tr2 as the case may be, which lights the overload lamp.

The diode D5 serves to prevent transistor AC1 from limiting this negative excursion by avalanche conduction.

SECTION 4 MAINTENANCE

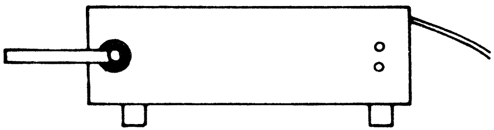

Fig 4.1

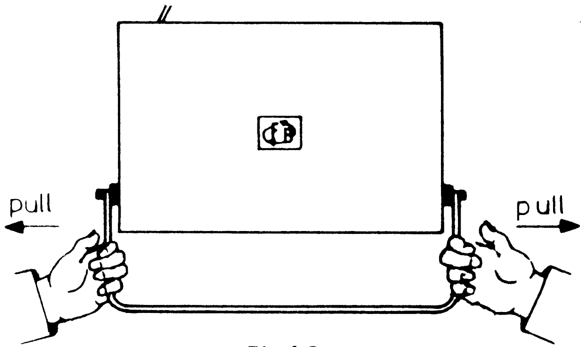

Fig 4.2

4.1 Access

Although no dangerous voltages are present within the case of the TFA607 (unless introduced through the input terminals), it is suggested that the cable from the PFG605 be unplugged while the case is removed, to avoid any possible short-circuits. All components are made accessible by removing the cover as follows.

Position the handle in the carrying position as in fig 4.1 and then use a Pozidriv screwdriver no.2 to remove the four screws on each side. Then remove the handle while pulling outwards to avoid scratching the case (see fig 4.2).

The top and bottom halves of the cover can then be lifted off. The chassis formed by the PWB and the front and rear panels is strong enough for normal handling during maintenance.

Positions of components and test points referred to in the following text can be found by reference to the component diagrams fig 4.3 and fig 4.4 and the complete circuit diagram fig 4.5. Fig 4.6 is a slightly simplified circuit diagram intended to aid understanding of the circuit operation.

4.2 Internal adjustments

Quite severe malfunctions can occur, even in a sound instrument, if the internal adjustments are incorrectly set. Before assuming a fault, check whether the following procedure will provide proper operation. This is a systematic procedure for adjusting a working TFA607 to specification, not a fault-finding procedure. Information for fault-finding is in paragraphs 4.4, 4.5.

A PFG605, an oscilloscope, an accurate d.c multimeter and a distortion meter should be available.

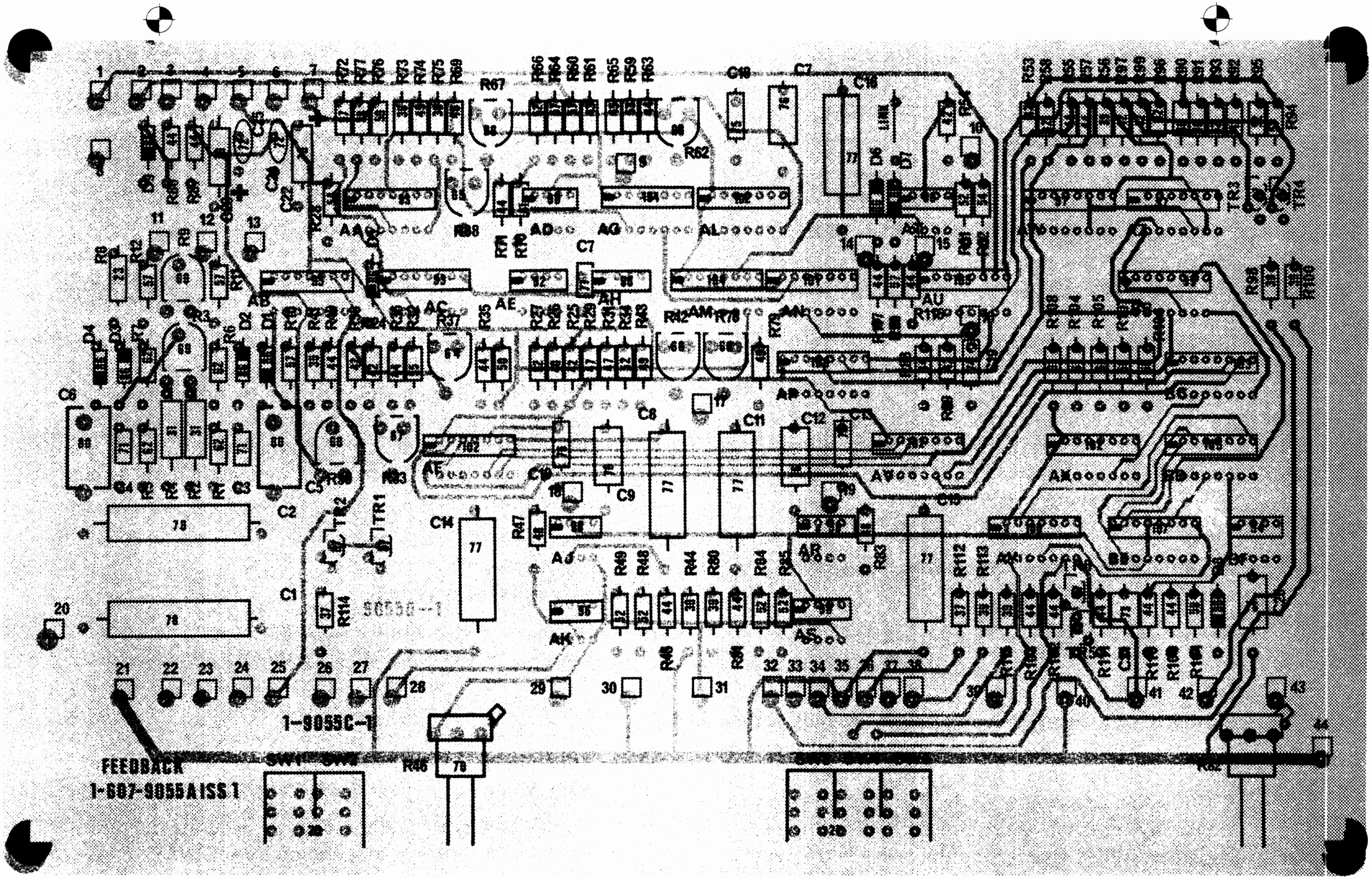

Fig 4.3 TFA607 PWB, Components side

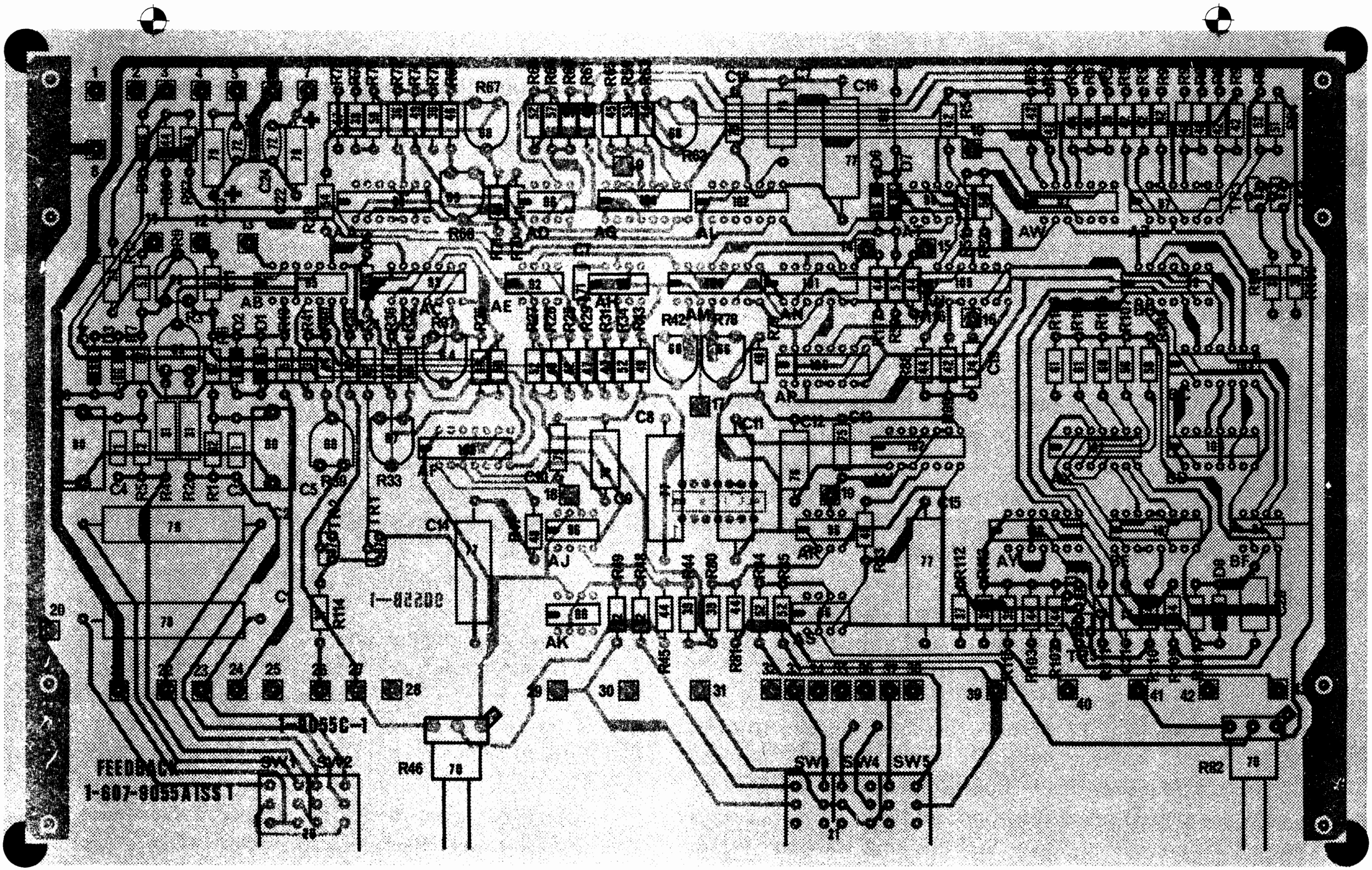

Fig 4.4 TFA607 PWB, Reverse side

Setting-up procedure
(N.B. In the following, ' [24] ' denotes test point 24.)

1. Before switching on, check that the meters on the TFA607 are mechanically at zero.

2. Switch on. Check, on the PFG605, that the power lines are at ±7.5 volts.

3. Connect the d.c oscilloscope to point [24] set to zero volts by R9.

4. Connect the oscilloscope to [16] and observe C'mos square waveform of about 70kHz and ±7.5 volts amplitude.

5. Connect the oscilloscope to [10] and observe 'staircase' triangular waveform. Display this together with the triangular auxiliary waveform of the PFG605 at 1kHz, using dual beam at identical sensitivity. The two waveforms should match, apart from the staircase 'step' structure.

6. Apply +50V d.c to Hi. Set input range to 10V rms fs, connect the oscilloscope to [17] , set the frequency of PFG605 to 80Hz, observe the multiplexed sine waves. Connect [14] to [7] to provide a single sine wave. Set this sine wave at [17] to minimum distortion, using distortion analyser, by adjusting R68 and R67.

7. With +50V d.c still connected to Hi, connect [15] to [7] and check distortion at [17] , set to minimum with R62.

8. Set the PFG605 to 800Hz, apply from an external source (e.g a Feedback VPG608) a 10V pk-to-pk sine wave at 0.5Hz to Hi terminal, set to 4V rms fs range. Set the 'a' meter to minimum fluctuation using R33 then set the 'jb' meter to minimum fluctuation using R62.

9. Connect both Hi and Lo to Common, set to 800Hz, set input range to 200V rms fs, connect oscilloscope to [17] then adjust R39 for minimum signal. Increase range sensitivity to 0.2V rms fs and adjust R9 for minimum signal.

10. Using X–Y oscilloscope, use the PFG605 auxiliary triangle output as the X deflection and connect the Y input to [17] , set the range sensitivity to 10V rms fs, connect Hi and Lo to common, set the PFG605 to about 80Hz, then adjust R37 to give a flat line display. Position the PFG607 front panel zero controls in the middle of their mechanical travel, then check that the meters 'a' and

'jb' are at zero; if not, manipulate R38 and R37 to give a flat display with the meters also at zero.

11. Apply 100V pk-to-pk from the PFG605 to the Hi input at 800Hz, connect Hi to Lo, switch progressively to 0.2V rms fs range bringing 'a' deflection to zero by adjusting the front panel 'balance' control, or alternatively bring the display on the oscilloscope connected to [17] to straight line.

12. Set the PFG605 to 1kHz, connect the auxiliary triangular waveform to Hi, connect Lo to common, set to 2V rms fs range then bring the 'jb' meter to zero by adjusting C6. Connect Lo to Hi and increase sensitivity to 0.2V rms fs then return 'jb' meter to zero by C5.

13. Set the PFG605 to 0.16Hz, 100V pk-to-pk and connect to Hi and Lo connected together, switch the TFA607 input to 'AC' coupling then switch progressively to 0.2V rms fs and bring the 'a' meter to zero by adjusting R3.
Note: This needs patience – exact zero is not important.

14. Set the PFG605 to 80Hz and adjust the output using reliable AC meter to exactly 10V rms, connect this voltage to Hi and Lo to common. Set input range to 10V rms fs then adjust 'a' meter to fsd by R42.

15. From an external source such as a Feedback VPG608, apply a signal at about 80Hz to the Hi terminal, set the input range to 2V rms fs, adjust the PFG605 to near 80Hz so that the meters oscillate slowly. Adjust the amplitude of the external source to give just ±fs deflection on the 'a' meter (5.6V pk-to-pk) then bring the 'jb' meter to just ±fs by adjusting R78.
Note: Adjust the PFG605 frequency to get slow enough measurement for accurate setting.

4.3 Removal or adjustment of knobs

Each of the rotary control knobs on the front panel is removable as follows. Prise off the cap of the knob with a thin blade, as in fig 4.7. This reveals the nut of a collet which secures the knob. Hold the knob steady and turn the nut anti-clockwise to loosen the collet, after which the knob may be turned on the shaft or removed.

Fig 4.7

4.4 Component Replacement Table

Type	*Rating*	*Tolerance*	*Fixing*	*Position*
Resistor	1/8 W or more	5% or less	PWB hole centres 0.5"	24, 25, 26, 35, 36, 38, 40, 41, 44, 45, 53, 54, 55, 56, 57, 58, 61, 63, 70, 71, 73, 75, 77, 80, 81, 86, 87, 88, 89, 90, 91, 92, 93, 96, 97, 98, 99, 100, 102, 103, 109, 110, 111, 112, 113, 114, 115, 116, 117.
		1% or less	Resistor dia. 0.15" max	1, 5, 6, 7, 10, 11, 12, 27, 29, 29, 30, 31, 32, 34, 43, 47, 48, 49, 50, 51, 52, 59, 60, 64, 65, 66, 69, 72, 74, 76, 79, 83, 84, 85, 94, 95, 101, 104, 105, 106, 107, 108.
	1/2 W or more		PWB hole centres 0.8" Resistor dia. 0.2" max	2, 4
			see rotary switch	14, 15, 16, 17, 18, 19, 20, 21, 22, 23.
		5% or less	PWB hole centres 0.6" Resistor dia. 0.2" max	8

Preset cermet potentiometer	0.1W or more	±20% or less	see fig 4.8	3, 9, 33, 37, 39, 42, 62, 67, 68, 78
Front panel preset trimmer	0.75W	±20% or less	Bush for 5mm dia hole	13
Front panel controls 4mm shaft see instrument				46, 82
Capacitor, plastic film	400V wkg	±20% or less	see PWB	1, 2
Capacitor, polystyrene	100V wkg	±1% or less	see PWB	8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21.
Capacitor, ceramic	750V	±5%	see PWB	3, 4, 7
Capacitor, ceramic disc	20V wkg	+50 -25%	PWB hole centres 0.3″	24, 25
Capacitor, Electrolytic	25V wkg	+80 -20%	see PWB	22, 23
Capacitors, compression trimmer			PWB centres 0.6″ 0.4″ wide	5, 6

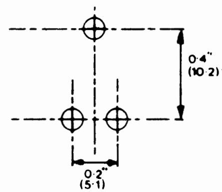

Fig 4.8

4.5 Transistors and diodes

If the Ferranti transistor types are not available the following types bearing EIA or Pro-Electron type numbers may be used. This table does not imply that the types listed are equivalent in any other situation.

Transistors & Diodes

Ferranti	*EIA*	*Pro Electron*
ZTX108C	2N930	BC108
ZTX213C	2N3251	BC178
	1N914	BAX13

Integrated circuits

The instrument is not critically dependent on integrated circuits of any particular make, and should work with corresponding types available locally.

Most types are available from RCA. The LM348 is from National and the NE531 is from Signetics.

Other components including the meters and switches are supplied to Feedback specifications and should be ordered through Feedback Instruments Ltd, Crowborough, Sussex, TN6 2QR.

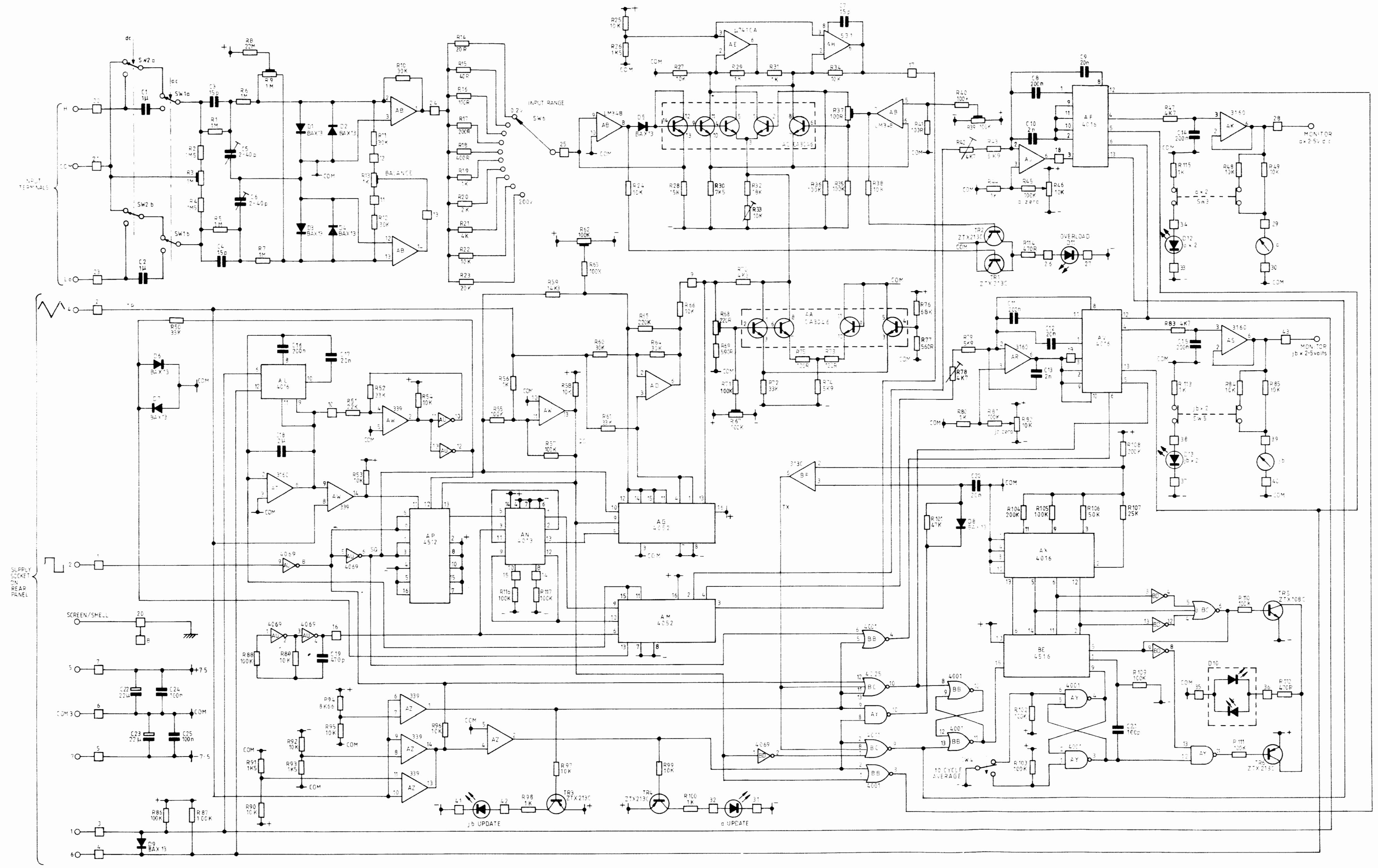

Fig 4.5 TFA607 circuit diagram (drg 1-607-9056 Iss1)

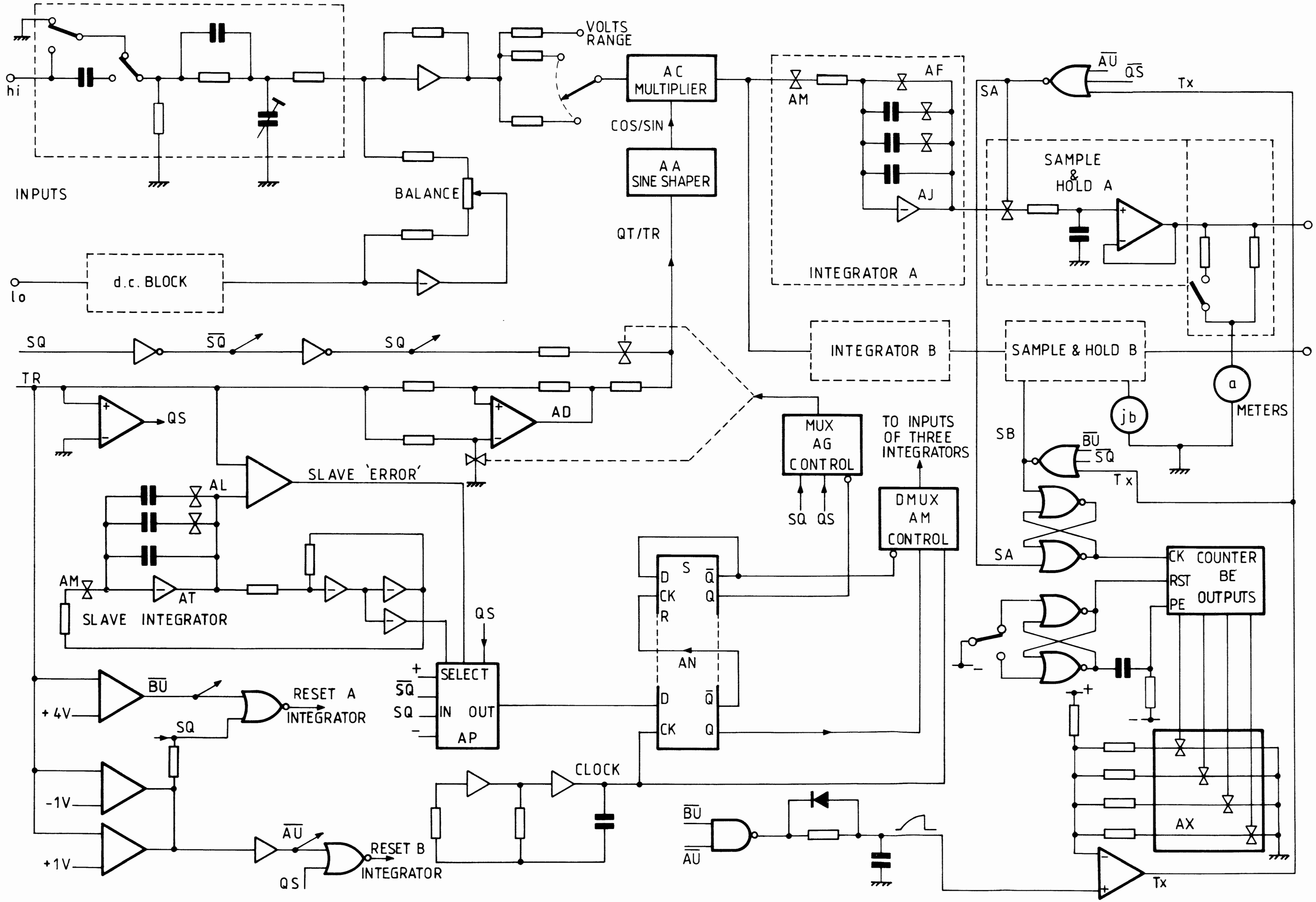

Fig 4.6 TFA607 simplified circuit diagram (drg 2-607-9359 Iss1)