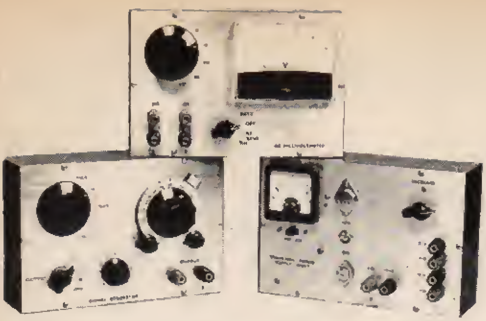
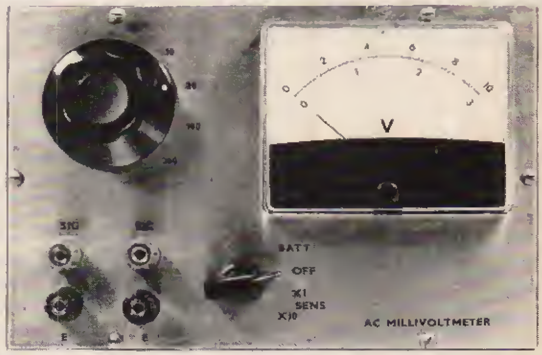


1. A.C. MILLIVOLTMETER

2. SIGNAL GENERATOR

3. STABILISED TRANSISTOR POWER UNIT

TEST GEAR 1 TRIO



SPECIFICATION

A.C. RANGES
Sensitivity switch ×10:
0–300µV, 0–1mV, 0–3mV,
0–10mV, 0–30mV, 0–100mV
Sensitivity switch ×1:
0–3mV, 0–10mV, 0–30mV,
0–100mV, 0–300mV, 0–1V*
*External probe circuit extending highest range to 100V.

ACCURACY Better than ±2% full scale deflection
INPUT IMPEDANCE Better than 5 megohms at 25°C
(External probe) better than 2·5 MΩ at 25°C
NOISE Better than 1µV on the 1mV range from 100 kilohm source
FREQUENCY RESPONSE
20c/s—250kc/s ±0·5dB

THE term "a.c. millivoltmeter" is possibly one of the most contrary phrases in the sphere of electronic test equipment: In itself, a millivolt is one thousandth part of a volt, so an instrument measuring from 1 millivolt to 1 volt is indeed a true millivoltmeter and from 1 volt upwards, a voltmeter.

The majority of instruments however, classified in the original term, have a range in the order of 1 millivolt to 300 volts, and more often than not, the higher voltage ranges are included as an integral part of the equipment. This usually leads to a compromise with respect to the frequency response and noise characteristics due to the high impedance, large signal attenuators that are, by necessity, introduced into the front-end circuitry. This poses the further problem of accurately and consistently, setting up and maintaining the effective control of stray capacity.

This constructional article sets out an instrument that is bereft of these major drawbacks, on the higher ranges mentioned above. The basic instrument

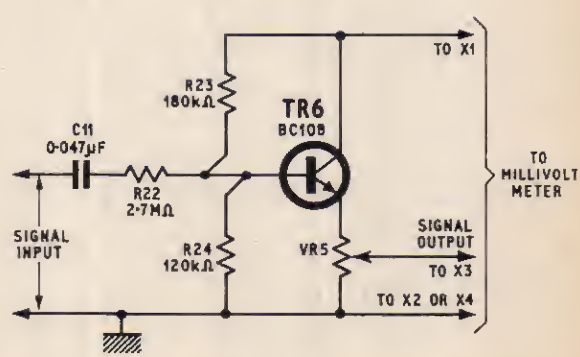


Fig. 1a. Circuit diagram of the probe unit which is connected to the terminals on the main instrument. VR5 is 10 kilohms

For experimental work, especially where audio frequency equipment is being built, the amateur often lacks facilities for testing and measuring its characteristics. At a relatively modest outlay he can set up a test bench with three basic items of test gear that will prove useful for a wide variety of applications.

measure . . .
FREQUENCY RESPONSE
DYNAMIC RANGE
SIGNAL/NOISE RATIO
OVERALL GAIN
SENSITIVITY

R. HIRST

A.C. MILLIVOLTMETER

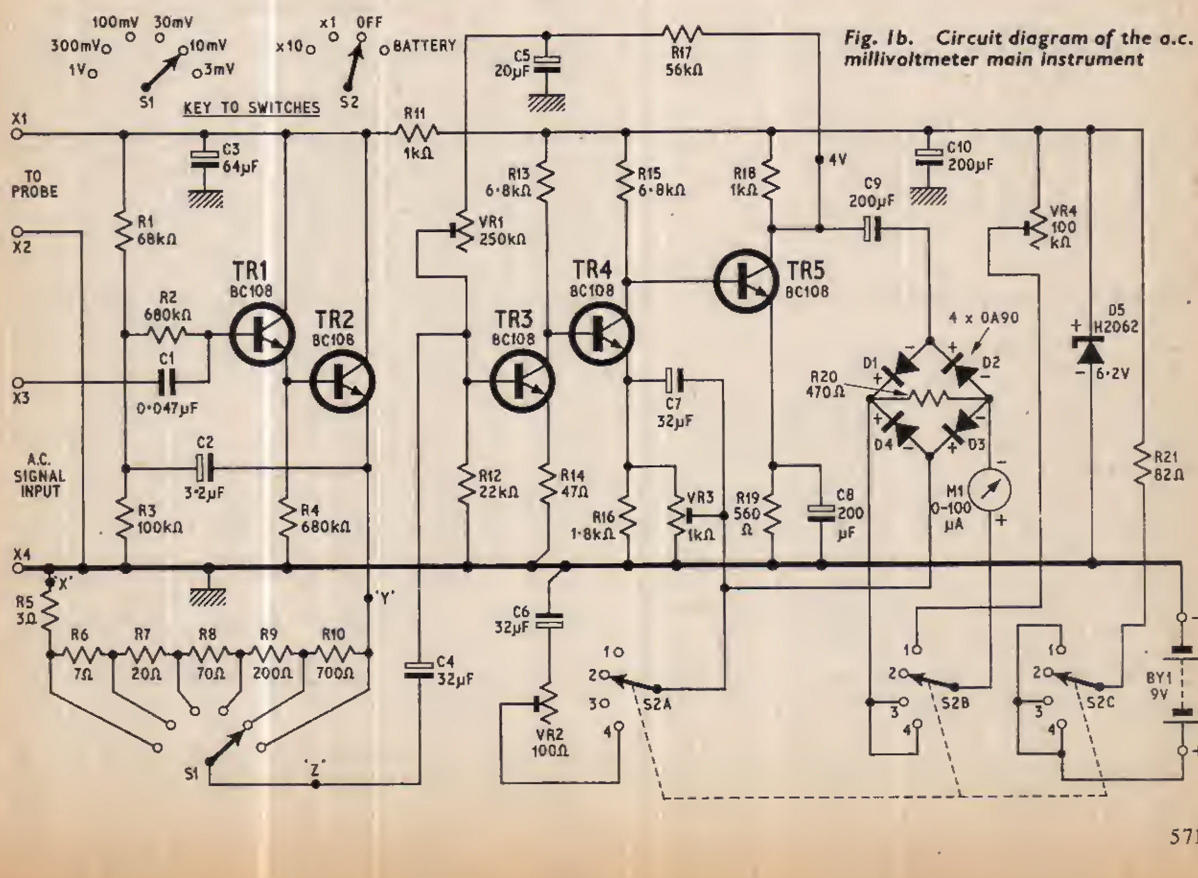


Fig. 1b. Circuit diagram of the a.c. millivoltmeter main instrument

measures from 1 millivolt to 1 volt in eight ranges with a 0·3 millivolt range introduced to facilitate noise measurements.

Internally generated noise is held to a very low level, being in the order of 1μV on the 1mV range. As an optional feature the instrument may be used as an a.c. voltmeter by the connection of an external probe (Fig. 1a), bringing the full scale deflection, on the uppermost range, to 100 volts.

This external probe circuit has the conventional high input impedance and, what is possibly more essential, a relatively low capacitance loading upon the measured circuitry. We may now use a reasonable length of connecting lead to the instrument proper, without the attendant problem of hum pick-up or capacitive losses. This advantage is gained by the output impedance of the probe being comparatively low, i.e. in the order of 100 ohms.

We can best show this advantage, by stating that the high frequency loss in the input configuration with 3ft of coaxial cable, at 20pF per foot across a 200 kilohm load, will be 3dB down at approximately 13kc/s, thus rendering any measurements inaccurate when made at or around this frequency.

With the external probe, however, the loss would occur at approximately 26Mc/s—well outside the range of the instrument. It must be clearly pointed out that all leads have to be kept as short as possible when measuring high frequencies on the millivolt ranges, with care taken to avoid any extraneous hum pick-up, should unscreened leads be used.

CIRCUIT DESCRIPTION

The input circuitry is of a well proven nature taking advantage of the "boot-strapped Darlington pair", the only relatively new feature being the employment of epitaxial silicon transistors (Fig. 1b). This configuration enables a reasonably high input impedance in the order of 5 megohms to be obtained. The input impedance is theoretically approximately equal to $\beta_{TR1} \times \beta_{TR2} \times R_e$.

The attenuator in the emitter of TR2 is possibly the greatest controlling feature in the accuracy of the instrument and care in selection of close tolerance resistors will be well rewarded in the final application.

TR3, TR4 and TR5 form a "d.c. coupled trio" which gives an excellent temperature stability factor, as any change in the working point of TR3 is immediately inverted and fed back to the input of TR3 in the following manner.

As the temperature increases, the collector current through TR3 increases resulting in a fall in TR3

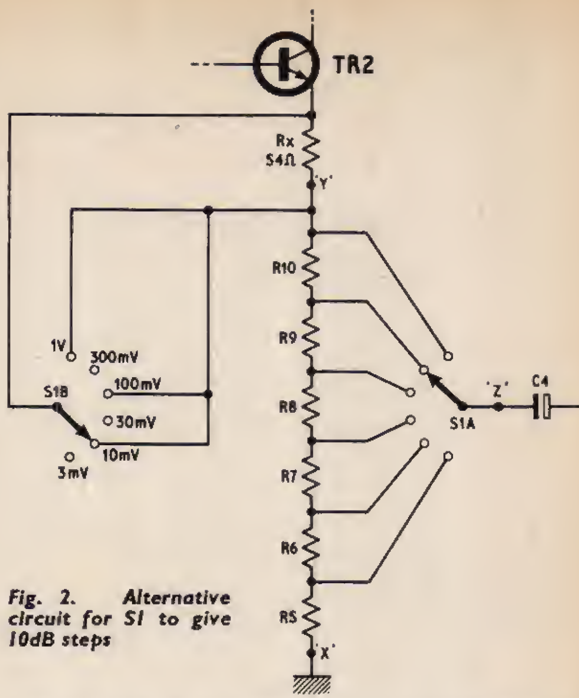


Fig. 2. Alternative circuit for S1 to give 10dB steps

collector voltage and consequently a fall in TR4 base voltage. As TR4 cuts off, the collector voltage of TR4 and the base voltage of TR5 rise, causing the collector voltage of TR5 to fall. This reduction in voltage at TR5 collector is fed back to TR3 base via R17, thus causing the collector current of TR3 to fall and restore the circuit to its original d.c. condition.

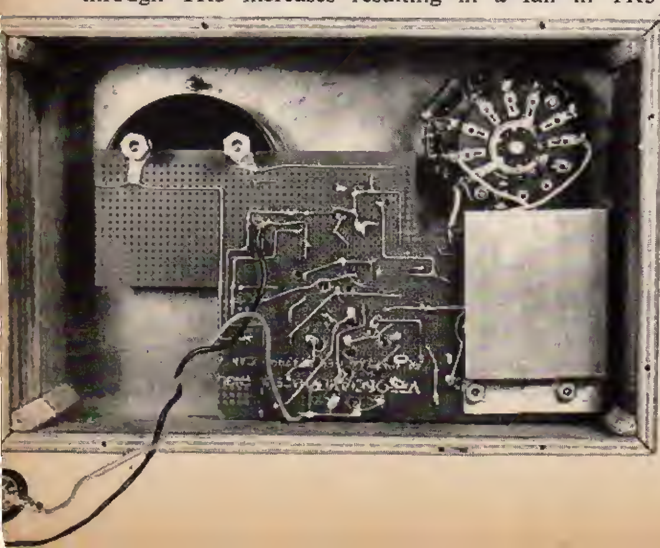
In order to clamp the d.c. conditions even further, a relatively high collector current is present in TR3, TR4 and TR5 with d.c. feedback over all the emitters, giving stability over the temperature range of -5 degrees C to 70 degrees C. A potentiometer VR1 is included for the final setting up operation.

As an a.c. amplifier, TR3 has an undecoupled emitter resistor giving a reasonably high input impedance in the order of 10 kilohms (approximately $\beta \times R_{14}$), to obviate any heavy loading of the attenuation network thus preserving accuracy. The output is directly coupled into TR4 which in turn is directly coupled to TR5. This lack of coupling capacitors helps to maintain a.c. stability at the very low frequencies.

The meter is heavily damped and fed from a bridge network of diodes connected to TR4 emitter and TR5 collector via C7 and C9. This ensures a very wide and consistent response, occasioned by the large degree of negative feedback via C7.

VR3 is adjusted in the final setting up procedure for the precise gain setting required. An increase in sensitivity of ten times is introduced by S2A in conjunction with C6 and VR2, in order to measure directly the low outputs from tape heads and other similar low signal transducers. This feature also facilitates the measurement of noise.

A stabilised line check has been incorporated, the meter reading full scale deflection for correct working conditions when S2 is switched to "BATTERY". The battery should be replaced when the reading has fallen below 0·95 of full scale. BY1 is a 9V battery giving an approximate life of 150 hours. The line voltage is stabilised at 6·2 volts by the Zener diode D5 in con-



junction with R21. The inclusion of this arrangement ensures very consistent results for considerable changes in battery voltage.

For constructors wishing to use a meter calibrated in 10dB steps the range switch modifications required are shown in Fig. 2. S1 in the case has two banks and an additional resistor Rx inserted in the emitter circuit of TR2.

CONSTRUCTIONAL NOTES

The entire instrument is of a very simple constructional nature. The components can be mounted on a perforated board with an 0·15in hole matrix, or a printed circuit board may be made. It is essential that the small metal screen is included around the input circuit or hum pick-up could give inaccurate readings on the lower ranges.

The diagrams in Figs. 3, 4, and 5 show clearly all the necessary details for constructing this instrument. The external probe can be made up in any appropriate metal casing ensuring that the input leads are not more than 12in long. The three output leads are connected to the instrument as shown in Fig. 5c.

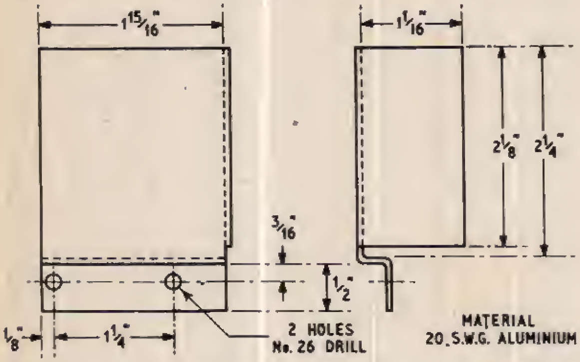


Fig. 3. Front and side elevations of the screen fitted over the first two stages

SETTING UP PROCEDURE

After very carefully checking the wiring a battery may be connected and the instrument switched to the 1 volt range with S2 in the ×1 position. VR1 should now be adjusted so that the voltage between the negative rail and TR5 collector is 4V d.c., measured with a 20,000 ohms per volt multi-range meter switched to the 10 volt range.

The next step is to apply an input signal of 1kc/s to the input terminals, X3 and X4, measuring exactly 100mV r.m.s. The switch S2 should be set to the ×1 range and S1 to the 100mV range. VR3 should be adjusted so that the meter reads full scale deflection. Finally, set the range switch S1 to 1V and S2 to ×10 and adjust VR2 for full scale deflection.

Some difficulty may be encountered in obtaining a 1kc/s signal source so a simple circuit that will give quite satisfactory results, providing one has an a.c. voltmeter,

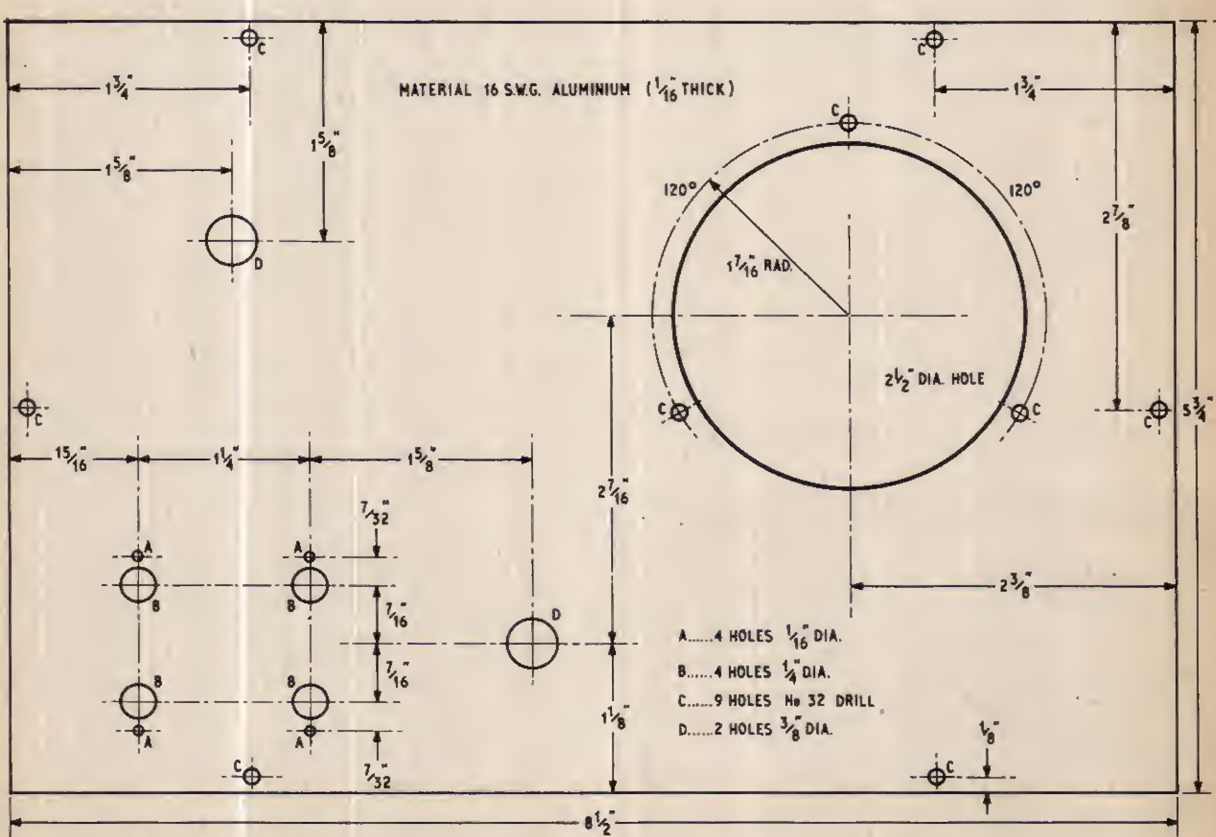
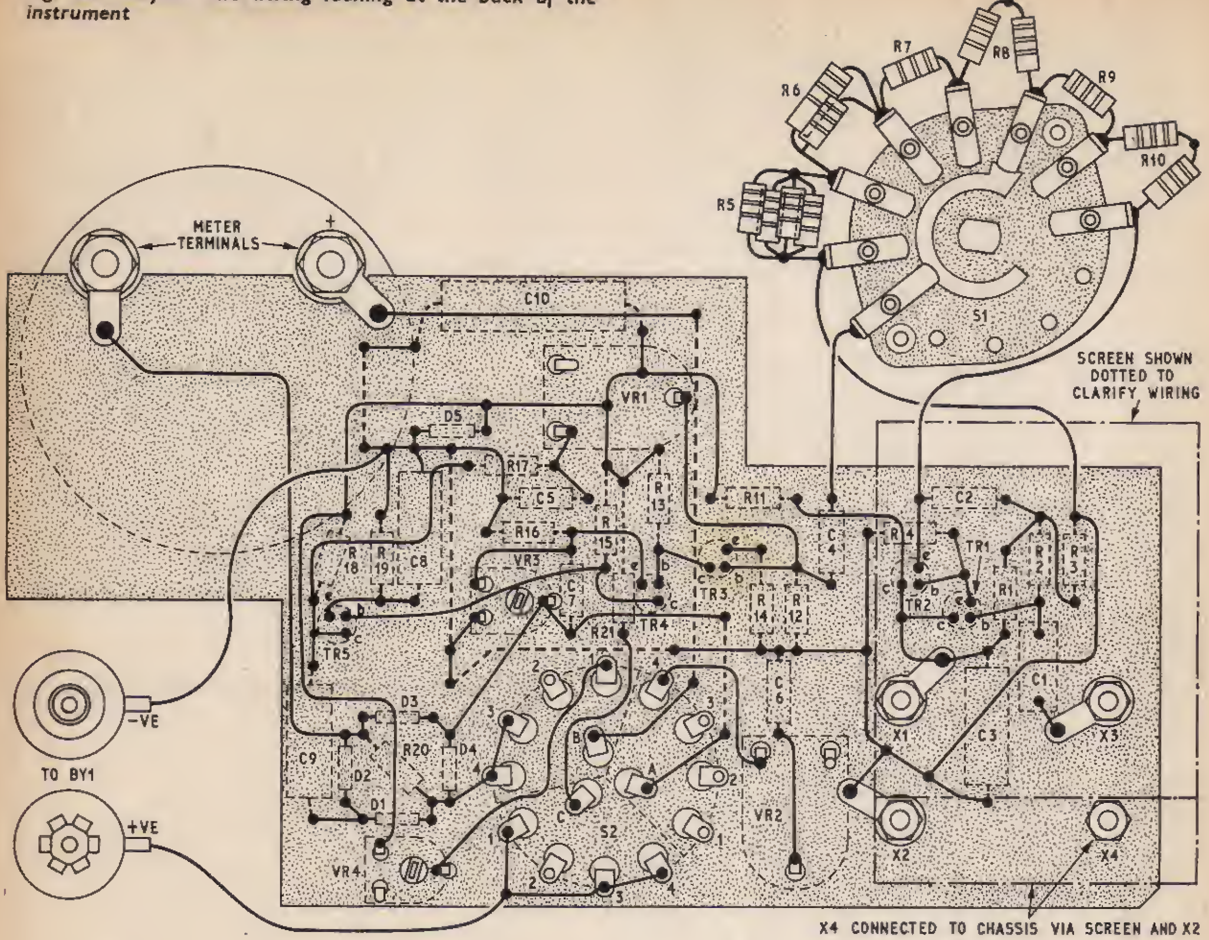


Fig. 4. Front panel drilling details

Fig. 5a. Layout and wiring looking at the back of the instrument



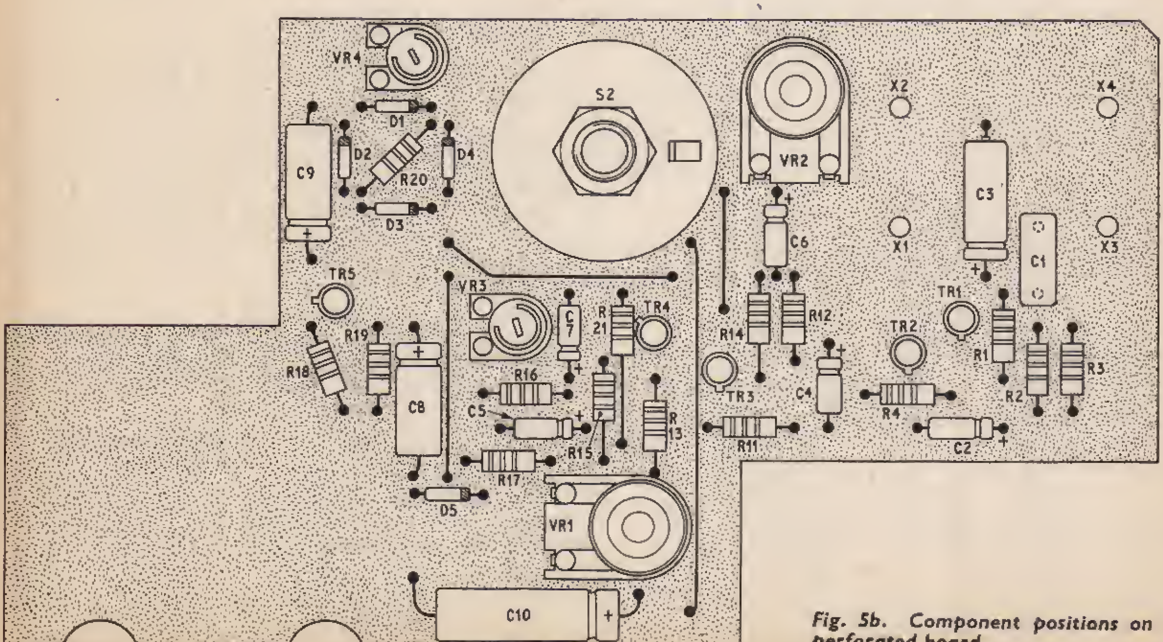


Fig. 5b. Component positions on the perforated board

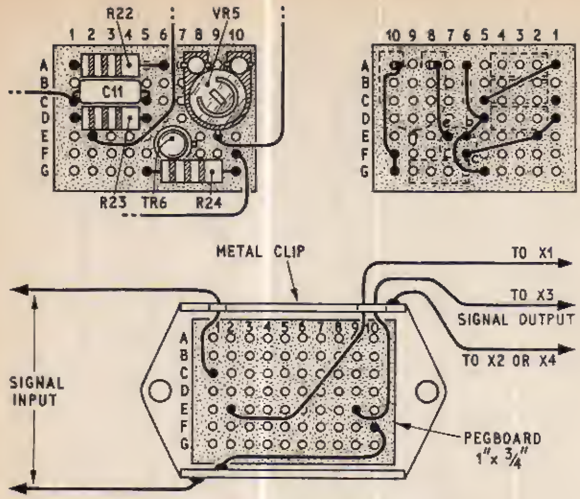
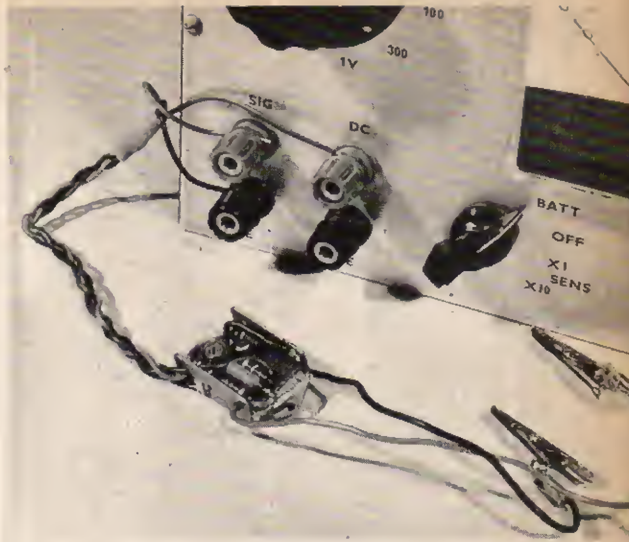


Fig. 5c. The layout and wiring of the probe unit



COMPONENTS . . .

Resistors
- *R1 68kΩ
- *R2 680kΩ
- *R3 100kΩ
- R4 680kΩ
- *R5 3Ω (four 12Ω resistors in parallel)
- *R6 7Ω (10Ω and 18Ω in parallel)
- *R7 20Ω
- *R8 70Ω (27Ω and 43Ω in series)
- *R9 200Ω
- *R10 700Ω (20Ω and 680Ω in series)
- R11 1kΩ
- R12 22kΩ
- R13 6·8kΩ
- R14 47Ω
- R15 6·8kΩ
- R16 1·8kΩ
- R17 56kΩ
- R18 1kΩ
- R19 560Ω
- R20 470Ω
- R21 82Ω
- *Rx 54Ω (two 27Ω resistors in series)

* Resistors marked with an asterisk are 5% high stab. $\frac{1}{2}$ watt carbon; all other resistors are 10% $\frac{1}{2}$ watt carbon. R5 and R6 may be wirewound (see text)

Potentiometers
- VR1 250kΩ carbon linear preset skeleton
- VR2 100Ω
- VR3 1kΩ
- VR4 100kΩ carbon linear preset skeleton

(Waycom)

Capacitors

C1	0·047μF polyester	C6	32μF elect. 2·5V
C2	3·2μF elect. 6·4V	C7	32μF elect. 2·5V
C3	64μF elect. 10V	C8	200μF elect. 6·4V
C4	32μF elect. 2·5V	C9	200μF elect. 6·4V
C5	20μF elect. 6·4V	C10	200μF elect. 6·4V

All capacitors except C1 are Mullard miniature electrolytics

Transistors
- TR1–5 BC108 (5 off) (Newmarket)

Diodes
- D1–4 OA90 (4 off) (Mullard)
- D5 6·2V Zener H2062 (Hughes) *or* OAZ243 (Mullard) *or* 1S7062 (Texas)

Meter
- M1 0–100μA f.s.d., 10kΩ/volt, moving coil type

Battery
- BY1 9 volts to fit in case

Switches
- S1 1 pole 6-way rotary wafer switch (see text)
- S2 3 poles 4-way rotary wafer switch (see Fig. 6 for style to fit component board)

Terminals
- X1–4 Screw type 4mm (4 off) (Radiospares)

Miscellaneous
- Wooden box made up 8·5in × 5·75in × 2·5in
- Aluminium panel 16 s.w.g. 8·5in × 5·75in
- Perforated s.r.b.p. 0·15in hole matrix 8in × 4·5in
- Battery connectors

PROBE UNIT

Resistors
- R22 2·7MΩ
- R23 180kΩ
- R24 120kΩ

All 10% $\frac{1}{4}$ watt carbon

Potentiometer
- VR5 10KΩ linear skeleton preset midget (Waycom)

Capacitor
- C11 0·047μF polyester 125V

Transistor
- TR6 BC108 (Newmarket)

Miscellaneous
- Perforated board (offcut from main panel)
- Suitable metal housing

is shown in Fig. 6. In order to arrange a signal source of 100mV a.c. any mains transformer capable of giving 6–9V at 30mA may be used.

Before switching on, the 500 ohm potentiometer should be turned to its maximum resistance. An a.c. voltmeter should be connected across the 3 ohm resistor and set to 1V a.c. range (after switching on). The 500Ω potentiometer should be very carefully adjusted so that 0·1V is indicated on the meter. Now inject this 50c/s signal across X3 and X4.

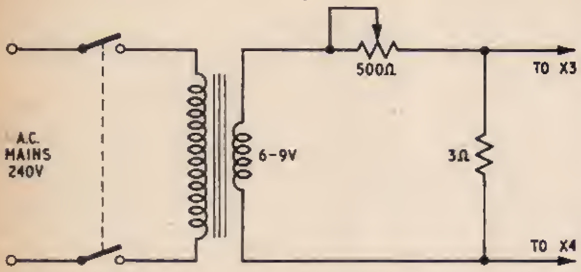


Fig. 6. Suggested circuit for providing a 50c/s calibration signal

In the prototype unit high stability 5 per cent resistors were used in the attenuator with great success but the 7 ohm and 3 ohm resistors were wound from eureka wire around a 1 megohm ½ watt resistor and then varnished over. Closer tolerance resistors will definitely ensure a high degree of accuracy.

To set up the probe, the 100mV test signal as previously used can be connected across the probe input and the a.c. millivoltmeter switched to the 10mV range, with the function switch to ×10 (i.e. to read up to 1mV) then VR5 is set for full scale deflection. This setting up should be done only after the instrument has been set up as in the earlier paragraphs. When setting up on the "battery check" position, the voltage of the battery should not be less than 8V. After ascertaining this, VR4 should be adjusted so that the meter reads full scale deflection. This is not a reading of battery voltage but a measurement of the stabilised rail voltage and any reduction in the full scale reading, once having been preset, should be regarded as detrimental to the performance. As previously mentioned, any fall indicates the necessity for battery replacement.

Note: Potentiometers quoted are made by Piher and are available from Waycom Limited, Wokingham Road, Bracknell, Berkshire.

NEXT MONTH SIGNAL GENERATOR