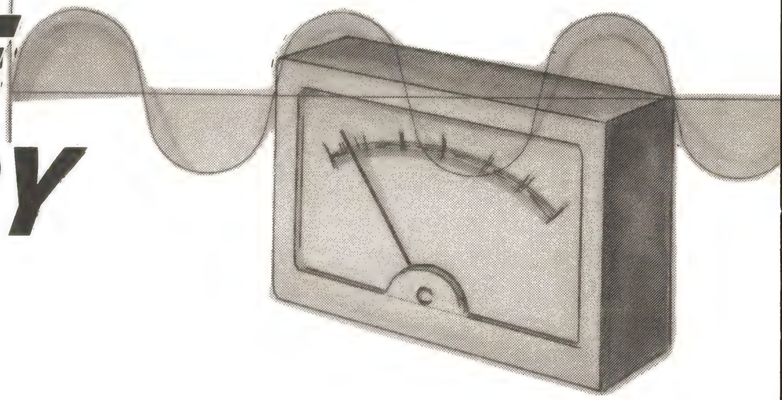
ANALOGUE FREQUENCY METER



ANDY FLIND

Switch on to the right frequency with this easy to use and construct, piece of test equipment.

AMONGST numerous items of test equipment built over the years, one of the most consistently useful has been an Analogue Frequency Meter. Despite the acquisition of a digital instrument the home-built analogue unit is still preferred in many cases because it is so quick and simple to use.

The six-place accuracy of a digital meter is often unnecessary, whilst the procedure of setting the count period, decoding the decimal position and adjusting input and filtering levels are a hassle one could do without. By contrast the analogue meter is simply connected to the circuit and a suitable range selected to obtain a reading.

Much of the time it is only necessary to know, perhaps, if the circuit is oscillating at two or ten kilohertz, or if its adjustment range is around ten to one, so reduced accuracy is perfectly acceptable whilst speed and ease of taking the reading is a distinct advantage. However, since the original analogue meter was designed over ten years ago, it seemed worthwhile to re-examine its design with a view to improvement. This article describes the construction of the new meter.

HEART OF THE MATTER

The heart of the instrument is a 0 to 100Hz frequency-to-voltage circuit. This is very simple to calibrate because all the constructor has to do is apply a 50Hz mains-derived signal and complete a single adjustment for a half-scale indication. The remaining ranges, extending to a 1MHz full scale, are simply obtained by preceding the basic movement with decade divider stages.

A suitable input circuit for converting various input waveforms to pulses with rapid and jitter-free edges completes the circuit. A block diagram of the complete system is shown in Fig. 1.

One area where worthwhile improvement has been achieved is in the frequency-to-voltage conversion. The original design simply integrated pulses from a timer. A custom i.c., the LM2917N, is now available to perform this task in a much more sophisticated manner, resulting in a simpler circuit with greater accuracy.

An internal block schematic diagram of the frequency-to-voltage converter i.c. is shown in Fig. 2. From this it can be seen that the chip contains an input amplifier which has some built-in hysteresis although this function is not important in this circuit. The input stage is followed by the heart of the chip, a "charge pump", which transfers a fixed charge to pin 3 for each input pulse. The magnitude of this charge is set by the value of the capacitor connected to pin 2.

Finally, an op.amp and transistor are provided for buffering the output. These can be used in various ways, including the linear driving of meters. As can be seen the chip requires a minimum of external components and a single adjustment is all that is necessary to calibrate its output.

SUPPLY LINES

The power supply arrangement of the LM2917N suggests that it is really intended for use in automotive rev counters. Positive supply is applied to pin 9 and negative "ground" to pin 12. Between these two pins there is an internal 7·6V Zener diode which regulates the voltage for the rest of the internal circuitry.

The manufacturer's information suggests that pin 9 should be supplied from 12V via a current-limiting resistor. Using this feature with a 9V battery supply requires ingenuity, but the feature can be put to good use.

CIRCUIT DESCRIPTION

Moving to the full circuit for the Analogue Frequency Meter, shown in Fig. 3, the power supply will be described first. To ensure an adequate voltage for the internal 7·6V Zener of IC5, bearing in mind that a 9V battery should be able to fall to at least seven volts and preferably six before it has to be discarded, the primary supply is first doubled by the 7660 converter IC4.

This is arranged as a "charge-pump" delivering current to capacitor C10. With a fresh battery, about 17·5V appears across this capacitor, falling to less than 10V as the battery ages.

To avoid current variations that would occur if the Zener in the LM2917N was supplied by a resistor, the constant current source consisting of transistors TR3 and TR4 is used instead. This supplies about 8mA to pin 9 of IC5.

The constant voltage appearing at pin 9 is then buffered by transistor TR5 and used to supply the rest of the circuit, thus avoiding

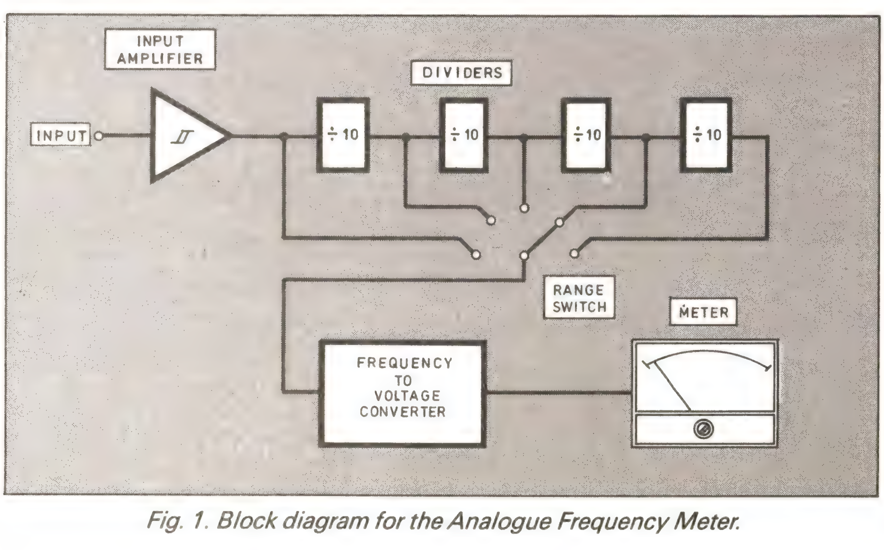


Fig. 1. Block diagram for the Analogue Frequency Meter.

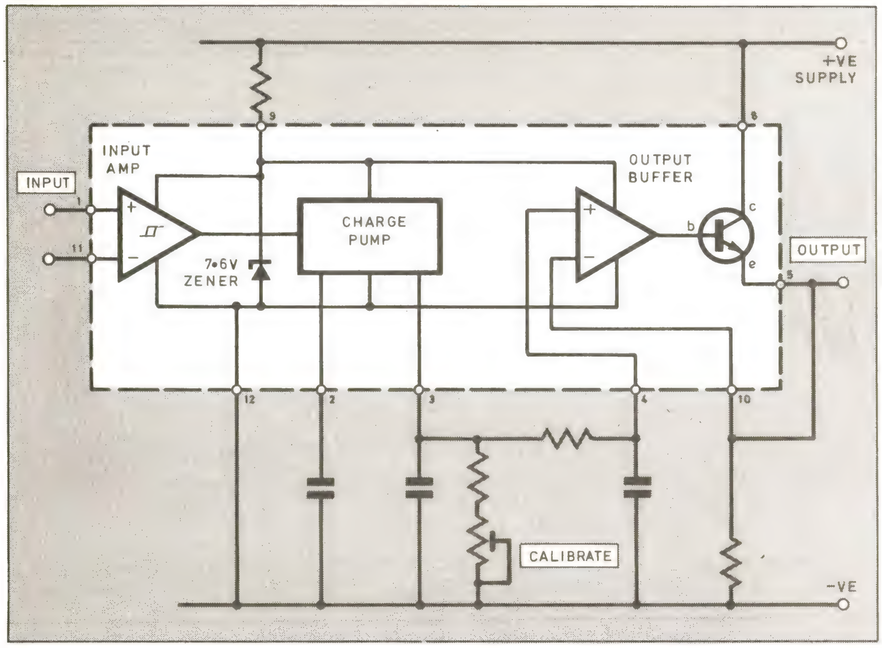


Fig. 2. Internal structure of the LM2917N frequency-to-voltage converter i.c.

the need for a separate regulator. Because of the 0·6V drop across the base-emitter junction of TR5, this supply is about 7V.

INPUT SIGNAL

Moving to the other end of the circuit, the input signal is a.c.-coupled through capacitor C1 to the gate (g) of the f.e.t. buffer TR1. The diode (D1, D2) and resistor (R1 to R3) network clamps the gate voltage of TR1 to a maximum of about 1·2V peak-to-peak, whilst capacitor C3 compensates for the capacitance of the two diodes at high frequencies.

Transistor TR2 provides a voltage gain of about ten. A *pnp* transistor is used here to maintain correct voltage polarity across the coupling capacitor C4. The output of TR2 is taken to a Schmitt trigger and buffer stage built with IC1.

The design aim was for a circuit that would operate reliably with an input of about 100mV r.m.s., and in fact this begins to respond at about 80mV, well within the objective. The upper voltage limit of the input is dependant mainly upon the voltage ratings of resistor R2 and capacitor C3, so signals up to and possibly beyond 50V r.m.s. should be acceptable without damage. This input circuit operates reliably with no loss of sensitivity to beyond 1·2MHz.

DIVIDERS

Following the input stage, the signal is taken to a group of four CMOS decade dividers contained in the two CMOS 4518B chips, IC2 and IC3. The appropriate output is selected by Range switch S1b and taken to the frequency-to-voltage converter IC5. Switch S1 is a 2-pole 6-way rotary type, with the second half (S1a) serving as the power On/Off switch. It has been arranged so that the highest range is selected first to reduce the chance of over-driving the meter when it is switched on with a high frequency present at the input.

The output from IC5's charge pump is dumped into capacitor C14 with calibration and discharge resistor R18 and preset VR1 across it. The voltage on this capacitor, nominally one volt at full scale, is taken through the low-pass filter, made up of R19 and C15, to pin 4 which is the input of the output buffering op.amp. The other input to this op.amp appears at pin 10 and is connected to ground with the one kilohm (1k) resistor R20.

Two possible options are available for

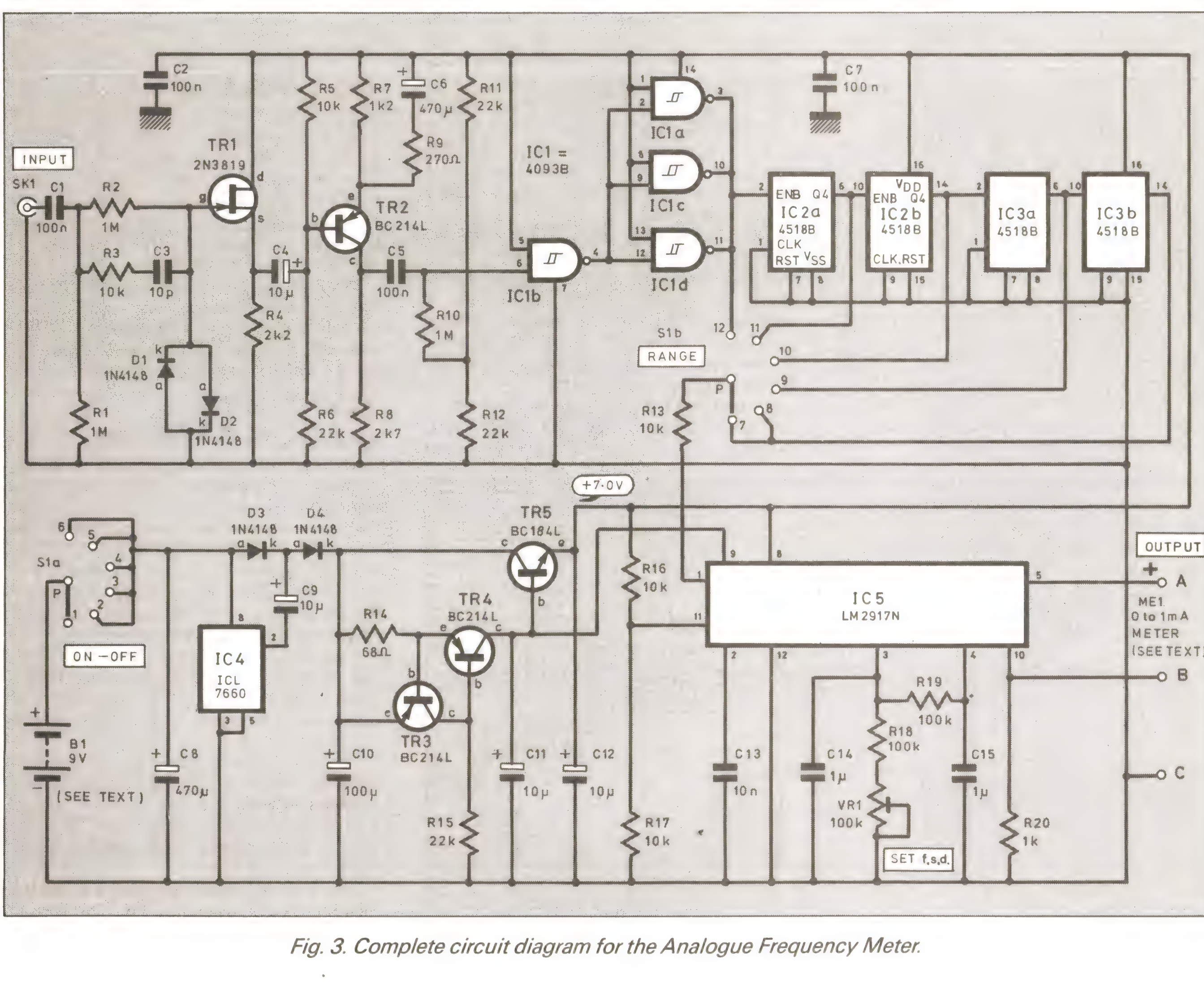
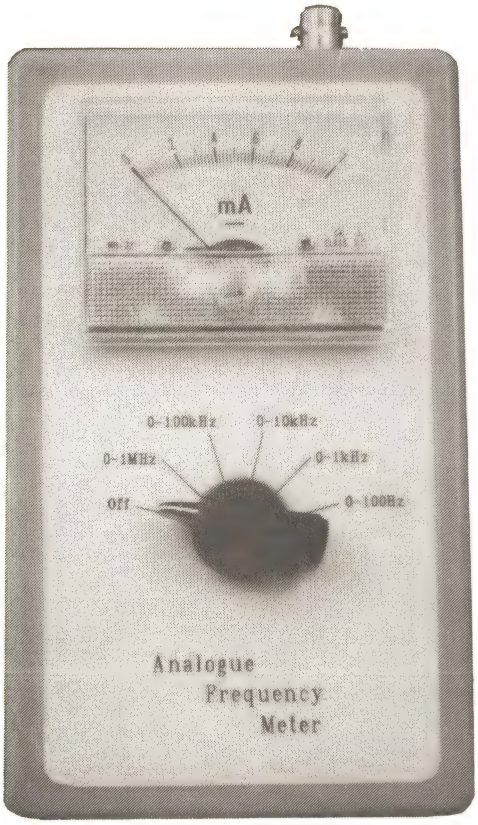


Fig. 3. Complete circuit diagram for the Analogue Frequency Meter.



connecting the meter. The internal output transistor emitter (e), from pin 5, can be shorted to pin 10 and the output will then consist of 0V to 1V at low impedance, which can be used with a one volt meter. Alternatively, where a 1mA movement is to be used as in the prototype, this can be connected between pins 5 and 10, in which case resistor R20 becomes part of a feedback network and the circuit delivers a 0 to 1mA output. This will be described in greater detail later.

CONSTRUCTION

Most of the components for this project are assembled onto a compact printed circuit board, the topside component layout and full size copper foil master is shown in Fig. 4. This board is available from the *EPE PCB Service*, code 957.

To ensure the best chance of successful construction, it is recommended that the following sequence is followed. Firstly, all the passive components should be fitted. This is everything except the transistors and i.c.s, and for ease they should be fitted in order of height.

The twenty resistors can be fitted first, followed by the four diodes, then the small ceramic capacitors, the 10n polyester capacitor C13, and the larger 1µ polyesters C14 and C15. These should be followed by the electrolytics, starting with the four 10µ components, then the 100µ C10 and finally the two 470µ capacitors C6 and C8. Note that all the electrolytics have their positive connections towards the top of the board.

The calibration cermet preset VR1, can now be fitted, noting that the adjustment screw is at the top. It will still work if it is placed the other way up, but the effect of rotation will be reversed.

FIRST TESTS

The first test can now be carried out. Power leads and the socket for IC4 should be fitted, and IC4 inserted. This, like IC1, IC2 and IC3, is a CMOS component, so precautions against static should be observed whilst handling these.

If the circuit is now powered, there will be a brief surge as the capacitors charge, following which the current drawn from the supply should settle to less than 100µA. The exact value will depend on the leakage of the electrolytics, which may take a few minutes to "form". The presence of around 17V across capacitor C10 should be checked, confirming that IC4 is operating.

Following this the socket for IC5 can be fitted along with transistors TR3, TR4, and TR5, taking care with their type and orientation. The p.c.b. should be powered up again and, using a 10mA meter with a one kilohm (1k) resistor in series to protect it, the current between pin 9 of IC5's *socket* and negative should be measured.

This should read about 8mA to 9mA. If this checks out, IC5 can be fitted and the circuit powered up again. Tests should be made for the presence of 7·6V at pin 9 of IC5 and 7V at pin 8. The overall current drain, if measured, should now be about 21mA.

Transistors TR1 and TR2 can be fitted next. Static precautions may be advisable whilst fitting the f.e.t. TR1 as a couple of these mysteriously expired during development of this project, suggesting they may be electrically fragile.

If the circuit board is now powered up, the collector (c) voltage of TR2 should be around 3·5V, an easy point to check this being the top of resistor R8. The source(s) voltage of TR1 can be checked at the top of R4. This will vary with the particular f.e.t. in use, but should be somewhere between 0·5V and 2·5V. If a fault occurs in this stage it will usually be zero or nearly full supply, 7V.

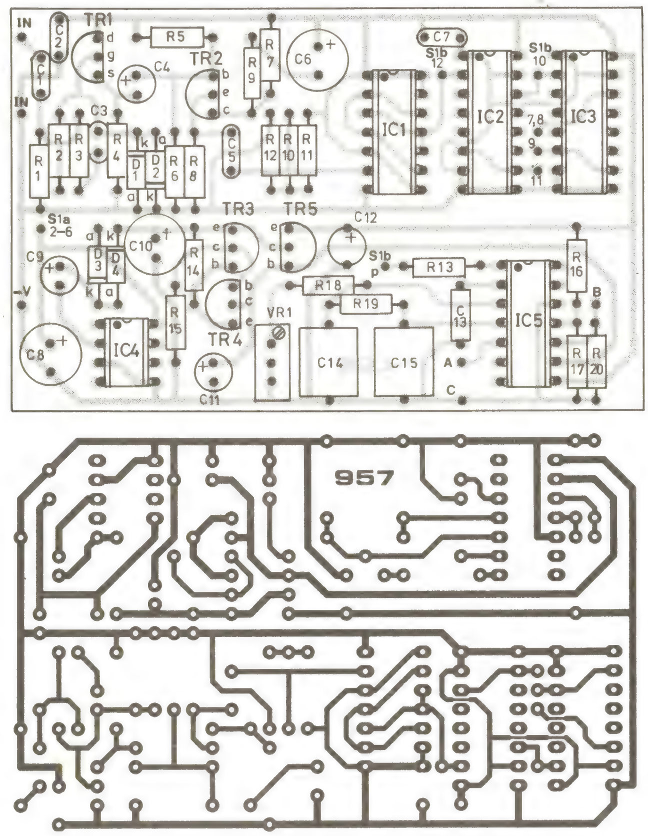
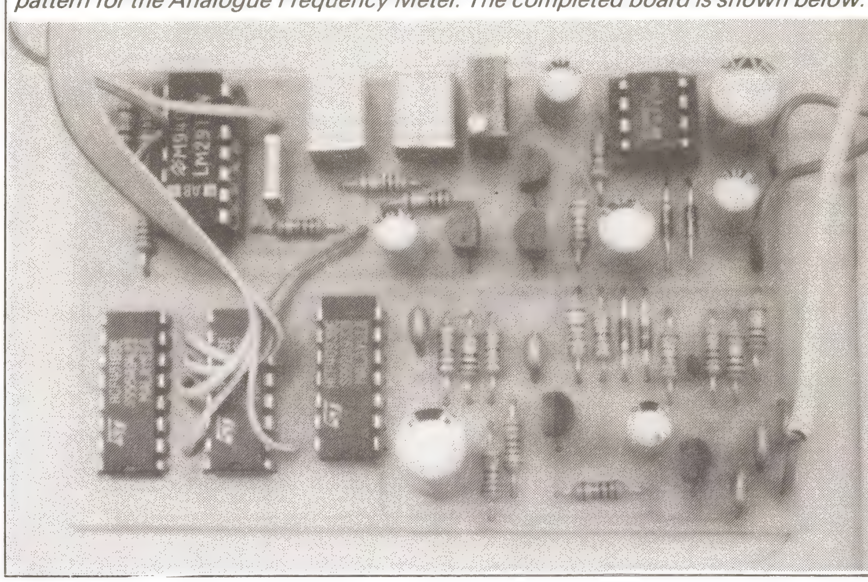


Fig. 4. Printed circuit board component layout and full size copper foil master pattern for the Analogue Frequency Meter. The completed board is shown below.



COMPONENTS

Approx cost guidance only excluding Batt. **£32**

See SHOP TALK Page

Resistors

R1, R2, R10	1M (3 off)
R3, R5, R13, R16, R17	10k (5 off)
R4	2k2
R6, R11, R12, R15	22k (4 off)
R7	1k2
R8	2k7
R9	270Ω
R14	68Ω
R18, R19	100k (2 off)
R20	1k

All 0·6W 1% carbon film

Potentiometer

VR1	100k 22-turn cermet preset, vertical

Capacitors

C1, C2, C5, C7	100n resin-dipped ceramic (4 off)
C3	10p resin-dipped ceramic
C4, C9, C11, C12	10μ radial elect. 50V (4 off)
C6, C8	470μ radial elect. 16V (2 off)
C10	100μ radial elect. 25V
C13	10n polyester layer
C14, C15	1μ polyester layer (2 off)

Semiconductors

D1, D2, D3, D4	1N4148 silicon diode (4 off)
TR1	2N3819 *n*-channel f.e.t.
TR2, TR3, TR4	BC214L *pnp* silicon transistor (3 off)
TR5	BC184L *npn* silicon transistor
IC1	4093B CMOS quad NAND gate
IC2, IC3	4518B CMOS dual decade divider (2 off)
IC4	ICL7660 voltage converter
IC5	LM2917N frequency-to-voltage converter

Miscellaneous

ME1	0-1mA f.s.d. moving coil meter (see text)
S1	2-pole 6-way rotary switch
SK1	50 ohm BNC socket
B1	9V PP3 battery (or six AA cells in holder – see text)

Printed circuit board available from *EPE PCB Service*, code 957; ABS plastic case, size 90mm × 149·5mm × 52·5mm external; 8-pin d.i.l. socket; 14-pin d.i.l. socket; pointer knob; PP3 type battery clip; multi-strand connecting wire; short piece of *screened* lead; solder pins; solder etc.

The quad NAND Schmitt trigger IC1 can be fitted next. Sockets were not used for this or the two divider i.c.s (IC2, IC3) in the prototype in order to avoid any extra capacitance they might introduce into the circuit. Where CMOS i.c.s are soldered directly into circuit, it is sometimes recommended that the *supply pins* should be soldered first, as this enables the internal static protection of these chips to operate correctly.

INPUT/OUTPUT TESTING

A lead for the input signal should be fitted, *screened* lead being preferable. The next test involves applying an input. In many cases touching the input with a finger will be sufficient as the level of "hum" voltage induced in the body is often sufficient to operate the input circuit. In the event that it isn't, a small mains transformer with a few volts output can be used, or a signal generator if one is available.

With an input applied, the output from pins 10 or 11 of IC1 should be checked either with an oscilloscope, where the "squared" waveform should be seen, or with a meter to inspect the average level. The exact voltage will depend on the waveform of the input signal, but it should not be far away from half supply, 3·5V. With the input removed, this point should stop at zero or full supply voltage.

Finally, the dividers IC2 and IC3 can be fitted. If the 50Hz input is re-applied, it will be possible to inspect the output of the first three dividers. The first, at IC2 pin 6, will show an average d.c. level of about 1·4V, and where an analogue meter is used there may be a distinct visible flicker as it is pulsing at 5Hz. The next output, from IC2 pin 14, will be a pulse every two seconds. The third output, from IC3 pin 6, pulses every 20 seconds.

Only very patient constructors will wish to test the last output with a 50Hz input as it pulses only once every 200 seconds! If a signal generator is available a higher input frequency can be used, the last output being from IC3 pin 14.

CASE DETAILS

The prototype instrument was fitted into an ABS plastic case having external dimensions of 90mm × 149·5 × 52·5mm. The layout is not critical in any way, and the general arrangement can be seen from the photographs.

A frequency meter is normally used only for relatively short periods so the prototype is fitted with a PP3 battery. However, the circuit has an overall drain of 25mA, so if extended use is envisaged it might be preferable to use a pack of six AA cells instead. There is ample room for one of these, so long as the Range/On-Off switch is not placed too close to the end of the case.

The connections between the board and other parts are shown in Fig. 5. Although not essential, ribbon cable produces a much neater assembly, particularly for the range switch S1. A BNC socket is recommended for the input, as these are far more reliable than cheaper types such as u.h.f. or phono sockets. They look more professional too.

METER OPTION

Various meter options are available. The unit could be fitted in a case without a meter, and terminals provided for connection to the workshop multimeter. It could even be used with a DVM for a digital readout.

If the points "A" and "B" are shorted together, a 0 to 1V output can be taken from between them and "C" for connection to a meter having a 1V range. If a 1mA meter is used as in the prototype, it is suggested that this is placed between points "A" (positive) and "B", leaving "C" *unused.*

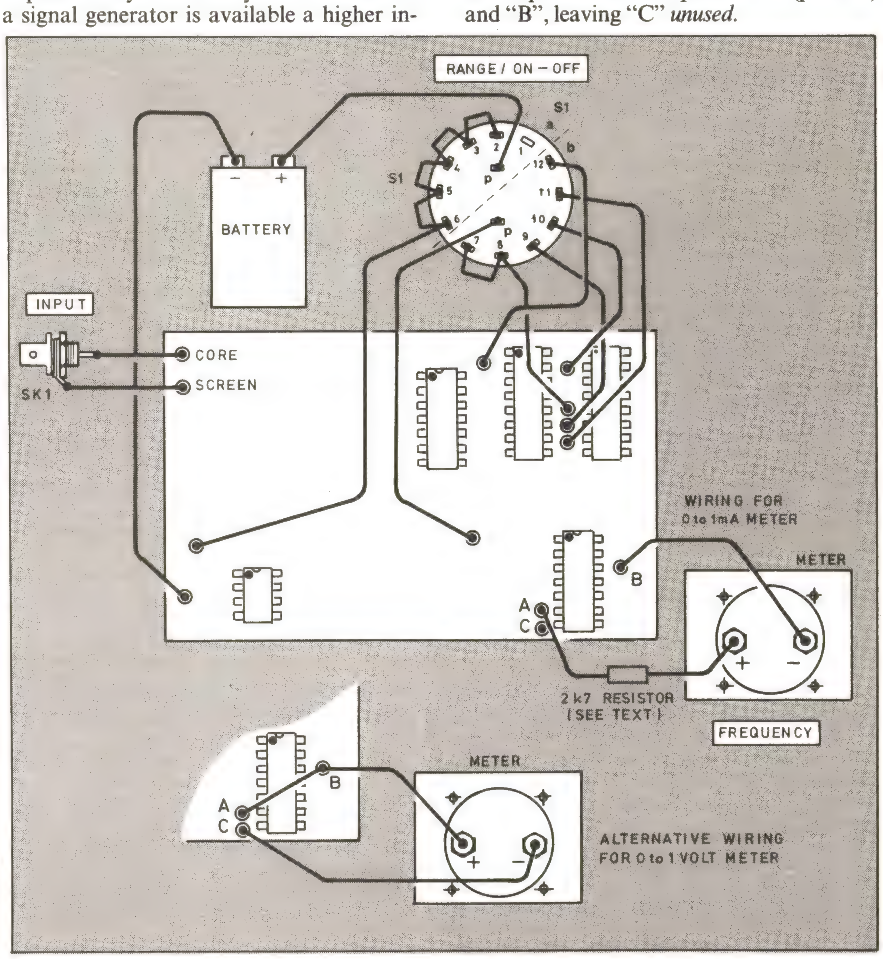
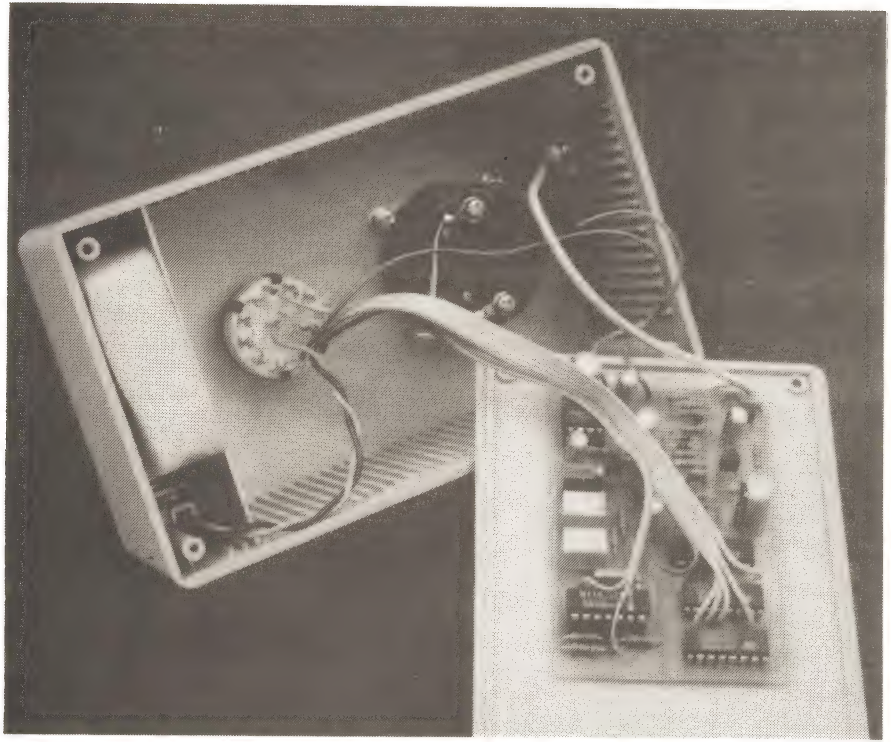


Fig. 5. Interwiring between the p.c.b. and off-board components. Also included are details for wiring to the alternative meter.



Bottom "lid" of the plastic case removed and flipped-over to reveal positioning of the p.c.b. and the layout of components in the "base" of the meter. Note the battery "compartment".

If this is done, some extra resistance can be placed in series with the meter to reduce overloading it when the circuit tries to drive it beyond full scale. This will not affect the reading because the meter is now in a feedback loop and the output op.amp will automatically compensate for the voltage appearing across this resistor. The value will depend on the meter being used, but 2·7k proved about right in the prototype.

CALIBRATION

To calibrate the instrument, it should first be switched on and, with no input, any necessary adjustment to the meter's zero should be made. A 50Hz signal should then be applied, using the basic 0Hz to 100Hz range. A wet finger may suffice, or the output from a small low-voltage transformer may be used. Preset VR1 is then adjusted as accurately as possible to a *half-scale* reading, following which the instrument is ready for use.

With its custom frequency-to-voltage output i.c. this meter is considerably more accurate and linear than its predecessor. It's less than half the size and displays less flicker at low frequencies, in fact it is perfectly readable down to about 5Hz, a twofold improvement.

Last but not least, it uses only one battery in place of two. With the present high cost of batteries, this improvement alone perhaps justifies the effort. □