For really accurate frequency comparision . . .

Build this phase difference meter

This simple phase difference meter is designed to indicate phase changes between two frequencies over a period of time. It's also easy to build and uses readily available parts.

by IAN POGSON

There are many ways of comparing two frequencies, either those which are on the same nominal frequency or those that are harmonically related. Perhaps one of the better known procedures is that employed by the piano tuner. The instrument he uses for the purpose is his ears and he tunes by the "beat" method.

The "beat" method is also often used in the field of electronics. The two signal frequencies to be compared are mixed together (eg, in a radio receiver) to produce an audible difference frequency, or beat frequency. When the user wants the two frequencies to be exactly the same value, then usually one of them is adjusted so that they are brought into "zero beat" with each other.

However, this method is not accurate enough for many applications and so other methods must be adopted. A worthwhile step forward is to use a dual trace CRO. The two frequencies to be compared are fed into the two CRO channels.

If there is a difference between the two frequencies, then this will show up by one display moving with respect to the other. Again, one is adjusted until they appear to be stationary with respect to each other.

Even so, this is still not good enough in some situations and more sophisticated methods must be adopted. This is where our Phase Difference Meter can be put to good use. Although a relatively simple device, it can give high orders of accuracy provided it is used with care.

Inside the Phase Difference meter are two separate divider channels whose outputs are compared in a phase comparator. The phase comparator, in turn, drives a meter movement.

In practice, a reference frequency is fed to one channel while the frequency to be adjusted is fed to the other channel. By observing the meter movement, or by hooking up a chart recorder to the output, changes in phase between the two channels over a period of time can be easily observed.

Note that the Phase Difference Meter cannot be used to directly measure the absolute phase difference between the reference and signal frequencies. This is because of differences in signal propagation time through the two channels. Instead, the Phase Difference Meter is used to indicate changes in phase over a period of time.

In fact, it may be useful to think of the unit as a phase drift meter or a phase comparison meter.

Finally, it should be stressed that if absolute accuracy is required, as opposed to simply adjusting two frequencies to the same value, then a known accurate frequency reference must be available. One such source is Omega and this may be tapped using the Omega Derived Frequency Standard de-

The Phase Difference Meter circuit is housed in a standard instrument case.

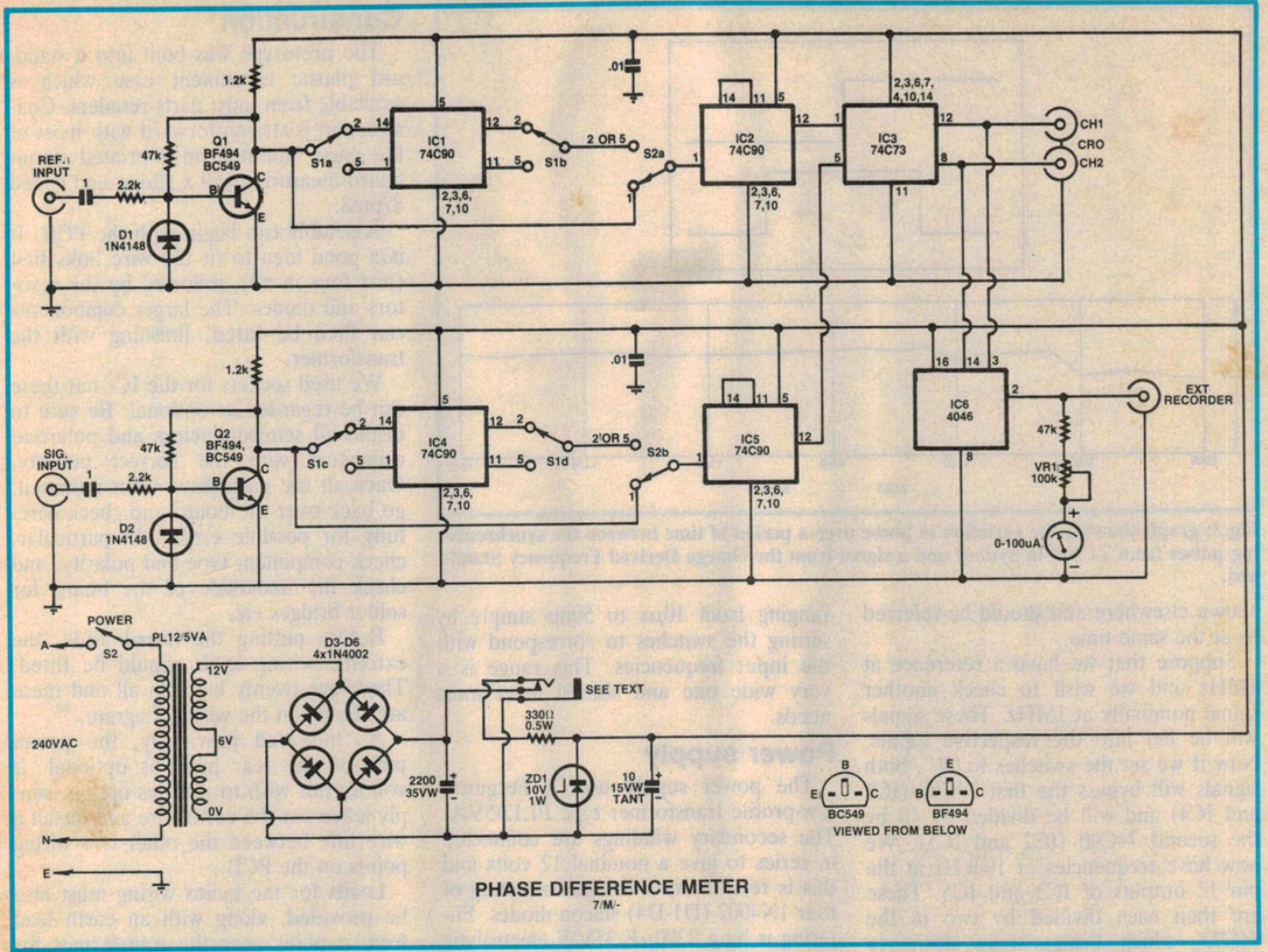


Fig.1: the circuit has two identical input channels which are fed into the X-OR phase detector of a 4046 PLL (IC6).

scribed in *Electronics Australia* for April and May 1987.

Circuit details

Let's now have a look at the circuit. Basically, it consists of two identical channels, the outputs of each being fed into the X-OR (exclusive OR) phase detector of a 4046 phase lock loop (IC6). A built-in power supply is also included.

To differentiate between channel 1 and channel 2, we have labelled them "Ref Input" and "Signal Input", respectively. It is intended that the frequency fed into the "Ref Input" will be the standard against which the frequency fed into the "Sig Input" will be compared.

Because the two channels are identical, we'll only consider the circuit associated with the Ref Input.

The input stage is based on common emitter amplifier Q1. We used a type BF494 although a number of other types may also be used. The signal at the input socket is fed to Q1 via a 1μF blocking capacitor and a 2.2kΩ current limiting resistor. A 1N4148 diode is connected across the base-emitter junction to protect the transistor against excessive reverse voltage. A 1.2kΩ resistor serves as the collector load while the 47kΩ resistor provides bias.

The input is capable of accepting a signal of between 300mV and 12V peak-to-peak. This signal may be an equal or unequal duty cycle square wave, or a sine wave. Q1 provides sufficient drive for the following digital stage circuitry.

The output of Q1 is fed to the wiper of switch S1a. When the switch is in position "2", IC1 is connected to divide by 2 and this signal is made available at pin 12. In position "5", IC1 is connected to divide by 5 and this signal appears at the pin 11 output.

S1b selects between the two divided outputs while S2a selects either the divided output from the wiper of S1b or an undivided output directly from the wiper of S1a. Thus, S1 and S2 can be set to provide division by 1, 2 or 5 as appropriate.

Following S2a, the signal is fed into pin 1 of a second 74C90 (IC2), connected to divide by 10. The divided output from pin 12 goes to the pin 1 clock input of a 74C73 dual J-K flipflop (IC3), where the signal is divided by 2. Similarly, the signal from the second channel is fed into pin 5 of the 74C73, and is also divided by 2.

The two outputs from pins 12 and 8 of the 74C73 go to the pin 3 and pin 14 inputs of the phase detector in the 4046 (IC6). The resultant output from pin 2 drives a 0-100μA meter which shows the time difference. Provision is also made at this point for driving a chart recorder, should one be available.

Switching

Let us return to the switching and explain the reasons for the arrangement. Perhaps a couple of examples may make the functions clearer. A table showing the switching functions is

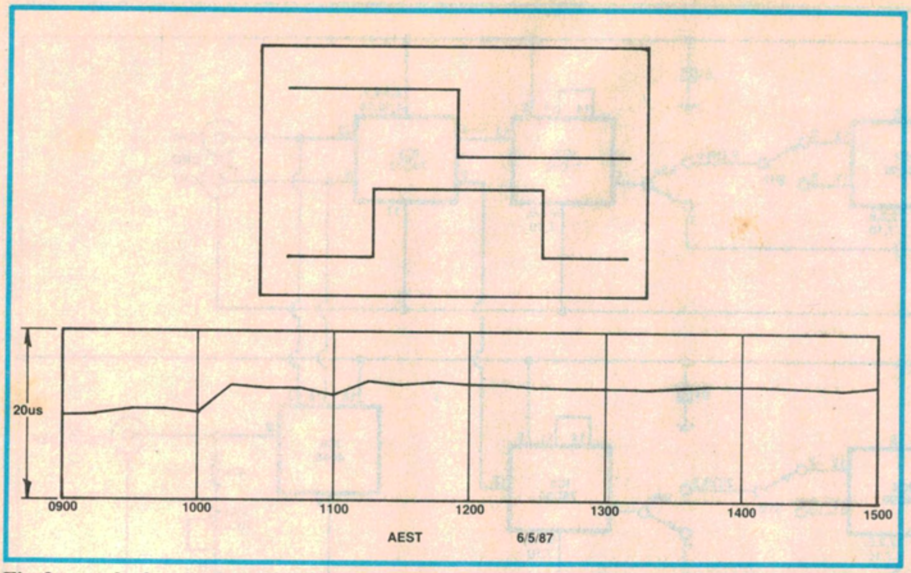


Fig.3: graph showing the variation in phase over a period of time between the synchronising pulses from TCN-9 in Sydney and a signal from the Omega Derived Frequency Standard.

shown elsewhere and should be referred to at the same time.

Suppose that we have a reference at 1MHz and we wish to check another signal nominally at 1MHz. These signals will be fed into the respective inputs. Now if we set the switches to "1", both signals will bypass the first 74C90 (IC1 and IC4) and will be divided by 10 by the second 74C90 (IC2 and IC5). We now have frequencies of 100kHz at the pin 12 outputs of IC2 and IC5. These are then each divided by two in the 74C73, which brings them down to 50kHz.

There are two important points here. First, the two signals are square waves of equal duty cycles, which is essential for our purpose. Second, we only need half a cycle to make our comparison. Half a cycle at 50kHz is equal to a period of 10μs and so the meter scale covers a range of 10μs. Check this result against the table.

If we now move the switches to "2" and refer to the table, we find that the meter scale covers a range of 20μs. Further, by moving the switches to "5" and referring to the table, we have a meter scale equal to 50μs.

Now have another look at the table, this time on the line below, where we have figures for input frequencies of 100kHz. This time, we have multiplied all the above periods and the meter full scale value by a factor of 10. This gives us meter scales of 100μs, 200μs and 500μs. Further study of the table shows that we have decades up to a maximum of 50ms (milliseconds).

Thus, we can set up our Phase Difference Meter for full scale meter readings ranging from 10μs to 50ms simply by setting the switches to correspond with the input frequencies. This range is a very wide one and should meet most needs.

Power supply

The power supply uses a Ferguson low-profile transformer type PL12/5VA. The secondary windings are connected in series to give a nominal 12 volts and this is rectified in a bridge consisting of four 1N4002 (D1-D4) silicon diodes. Filtering is by a 2200μF 35VW electrolytic capacitor.

A closed circuit jack is included in series with the supply, immediately after the filter capacitor. This was included for the writer's benefit and is obviously an optional extra.

Voltage regulation is achieved using a 10V 1W zener diode, in series with a 330Ω 0.5W resistor. A 10μF 15V tantalum bypass capacitor is connected across the output of the supply.

Construction

The prototype was built into a standard plastic instrument case which is available from most parts retailers. Construction is straightforward with most of the parts mounted on a printed circuit board measuring 169 x 93mm and coded 87pm8.

Assembly can begin with the PCB. It is a good idea to fit the wire links first (just four in all), followed by the resistors and diodes. The larger components can then be fitted, finishing with the transformer.

We used sockets for the ICs but these can be regarded as optional. Be sure to install all semiconductors and polarised capacitors with the correct polarity. Once all the parts have been mounted, go back over the board and check carefully for possible errors. In particular, check component type and polarity, and check the underside of the board for solder bridges etc.

Before putting the board aside, the external wiring leads should be fitted. There are twenty leads in all and these are shown on the wiring diagram.

As indicated previously, the power jack on the rear panel is optional. If you do not wish to use this option, simply leave out the earth wire and install a wire link between the other two wiring points on the PCB.

Leads for the mains wiring must also be provided, along with an earth lead from a point near the transformer for later connection to an earth lug on the rear panel. All these leads should be of 240V AC rating.

The PCB can now be screwed to the appropriate four mounting pillars. In order to avoid soldered joints under the board from fouling other pillars, 3mm-long spacers can be installed between each mounting pillar and the PCB. Washers or suitable oversize nuts could be pressed into service for this job.

INPUTS REF & SIG	SWITCH POSITIONS 1	2	5
	FULL SCALE		
1MHz	10us	20us	50us
100kHz	100us	200us	500us
10kHz	1000us	2000us	5000us
1kHz	10ms	20ms	50ms

This artwork shows the full-scale meter reading for various switch settings.

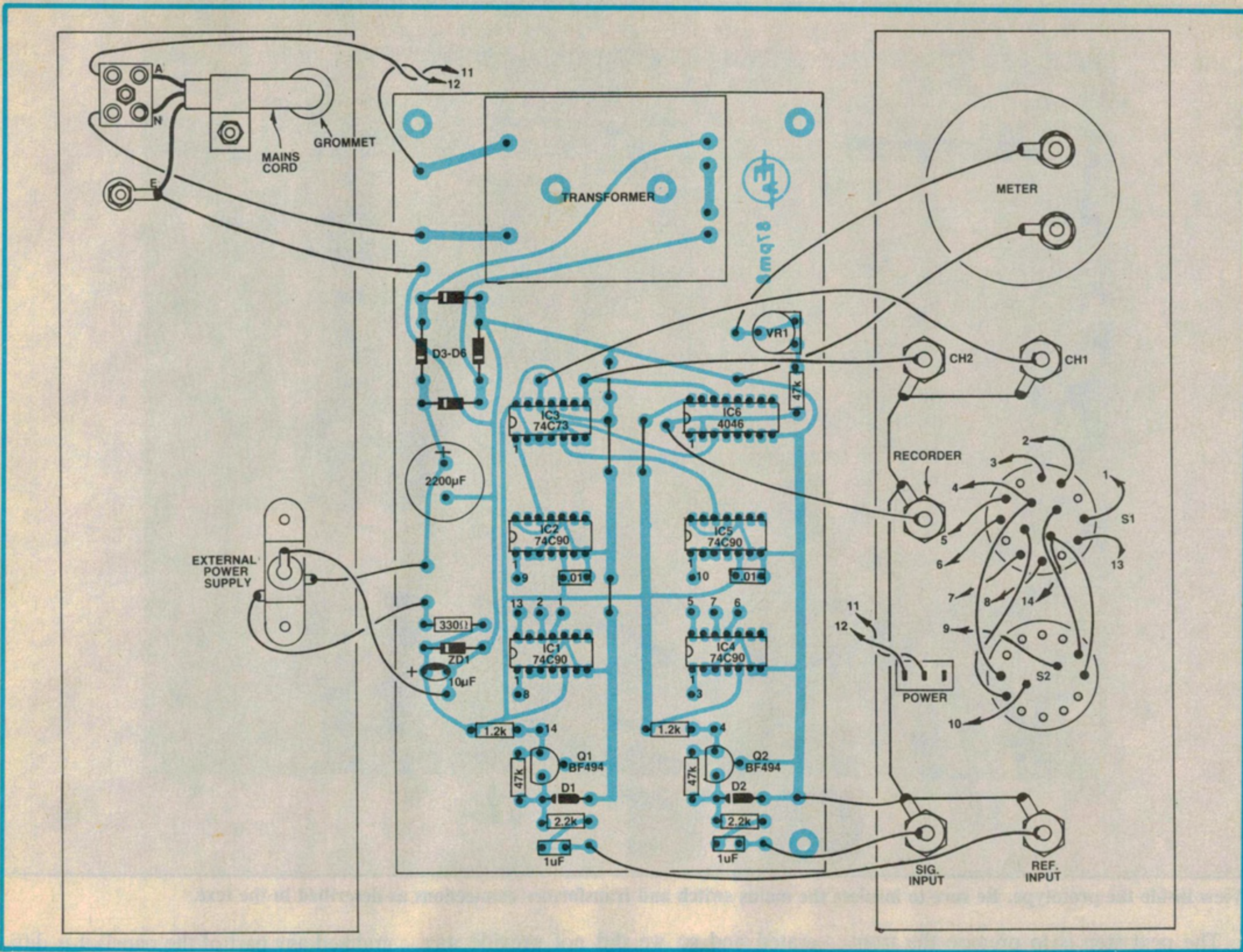
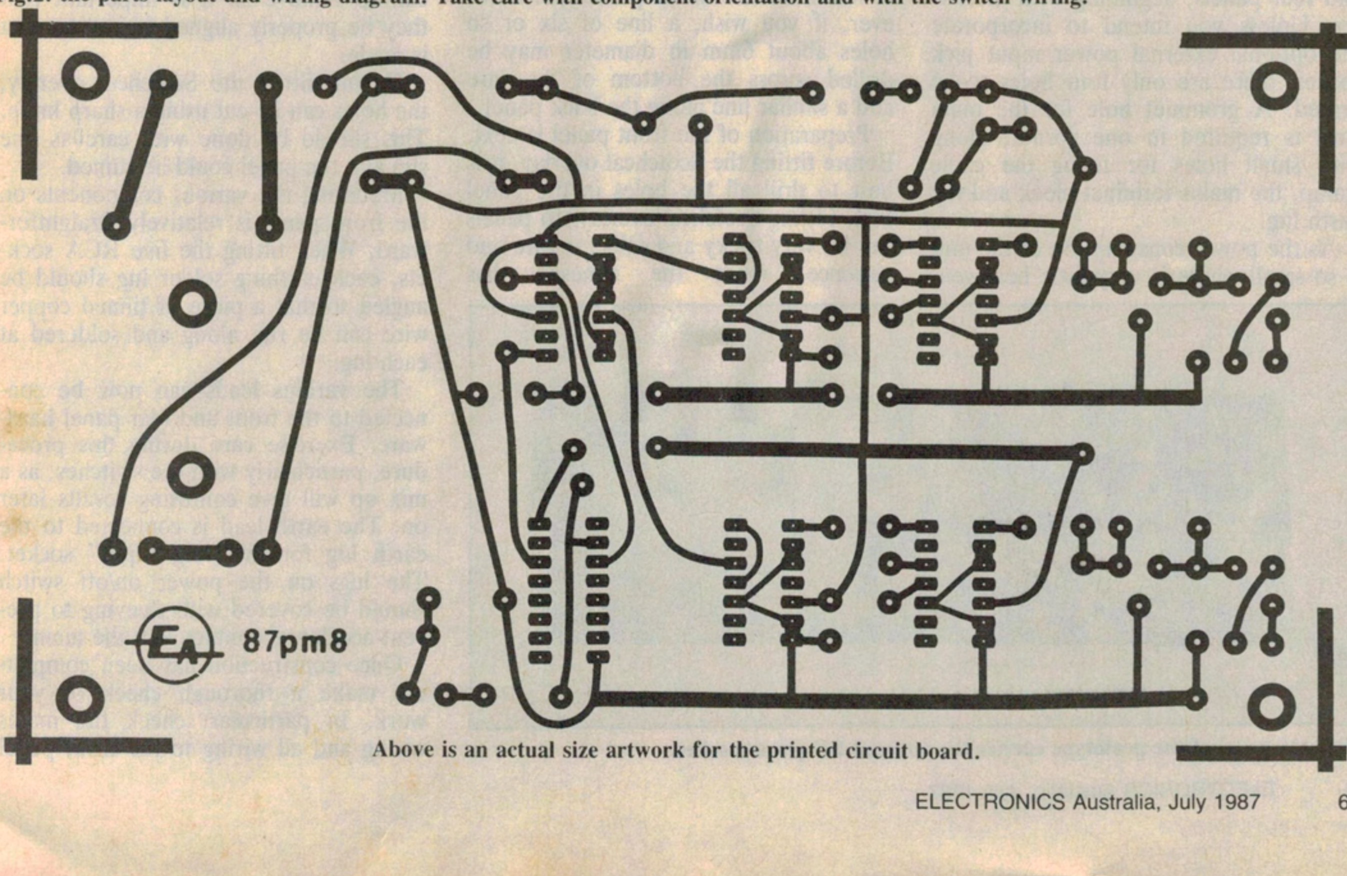
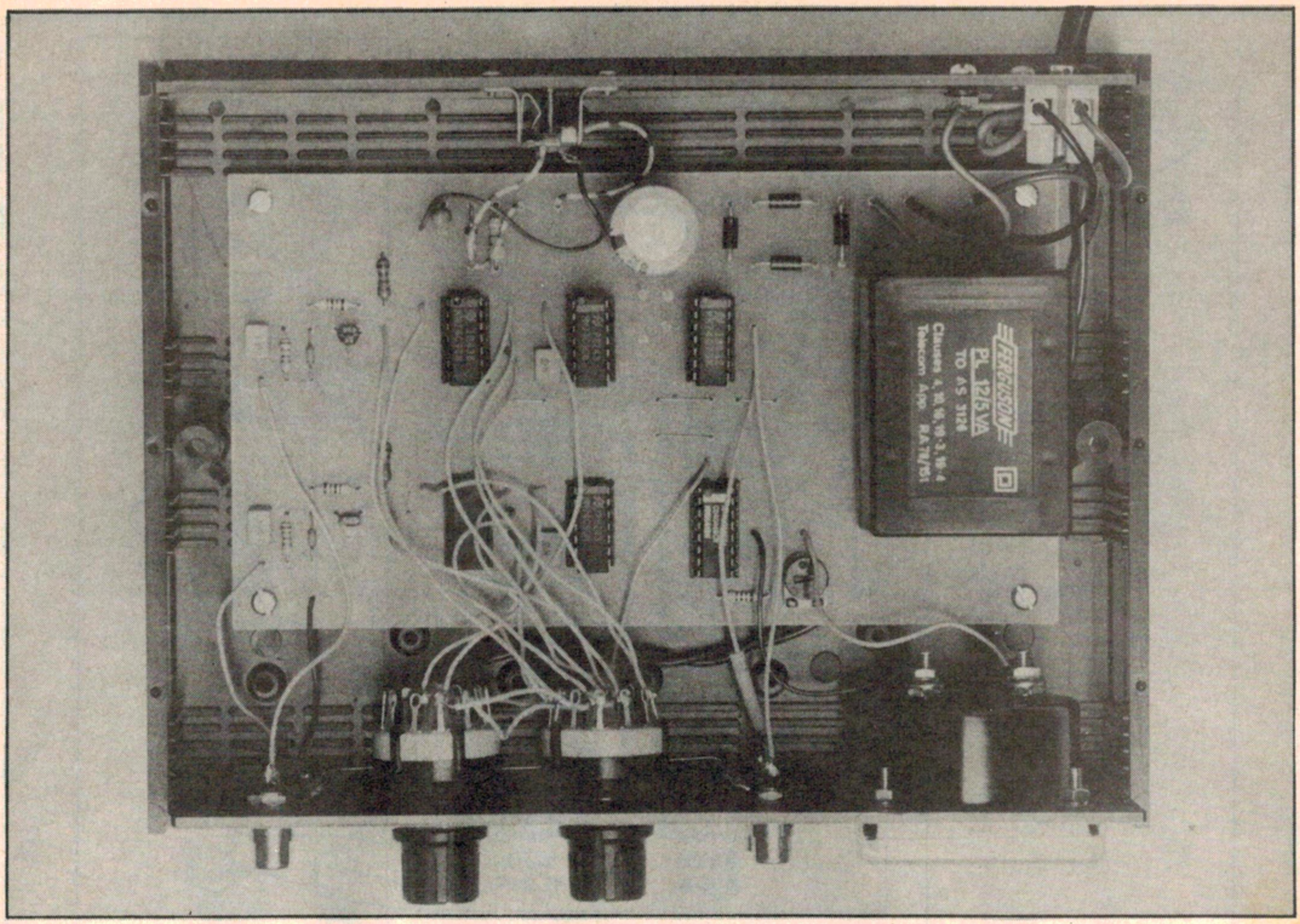


Fig.2: the parts layout and wiring diagram. Take care with component orientation and with the switch wiring.



Above is an actual size artwork for the printed circuit board.



View inside the prototype. Be sure to insulate the mains switch and transformer connections as described in the text.

The next step is to prepare the front and rear panels, beginning with the latter. Unless you intend to incorporate the optional external power input jack socket, there are only four holes to be drilled. A grommet hole for the main cord is required in one corner, along with small holes for fixing the cable clamp, the mains terminal block and the earth lug.

As the power consumption of the unit is so small, there is very little heat generated and so we did not provide any ventilation holes in the prototype. However, if you wish, a line of six or so holes about 6mm in diameter may be drilled across the bottom of the case and a similar line along the back panel.

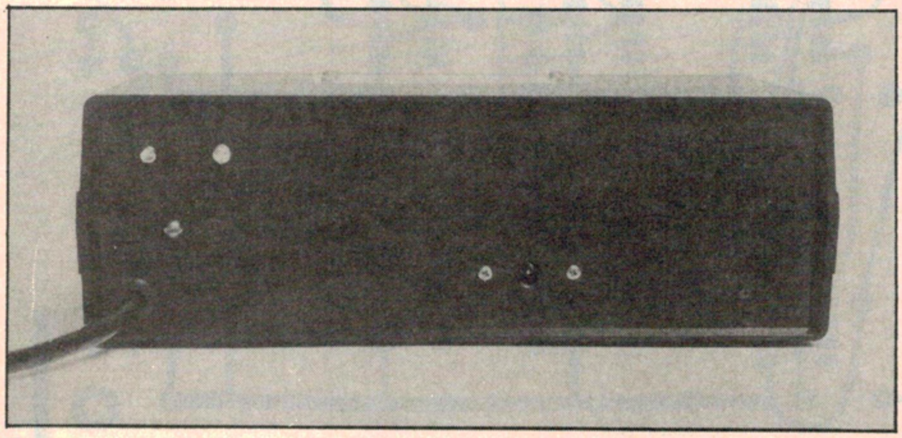
Preparation of the front panel is next. Before fitting the Scotchcal overlay, it is best to drill all the holes in the panel first. Fitting Scotchcal overlays to panels can be very tricky and calls for care and patience. Once the adhesive has grabbed any part of the panel, it is difficult to remove so it is important that they be properly aligned before contact is made.

Having fitted the Scotchcal overlay, the holes can be cut using a sharp knife. This should be done with care as one slip and the panel could be ruined.

Mounting the various components on the front panel is relatively straightforward. When fitting the five RCA sockets, each earthing solder lug should be angled so that a piece of tinned copper wire can be run along and soldered at each lug.

The various leads can now be connected to the front and rear panel hardware. Exercise care during this procedure, particularly with the switches, as a mix up will give confusing results later on. The earth lead is connected to the earth lug for the "Sig Input" socket. The lugs on the power on/off switch should be covered with sleeving to prevent accidental contact with the mains.

Once construction has been completed, make a thorough check of your work. In particular, check the mains wiring and all wiring to the front panel



The rear panel of the prototype carries the optional DC power socket.

hardware. You are now ready for the smoke test.

Setting up

The setting up procedure could hardly be simpler. First, set VR1 to the centre of its rotation, then switch on and check the meter reading. It will either read zero or read somewhere near full scale. If it reads zero, switch off and on repeatedly until you get a full-scale reading. When this happens, adjust VR1 for exactly full scale on the meter.

That's it! The instrument is now ready for use.

We'll conclude with a few pointers on how best make use of the Phase Difference Meter. First, we'll assume that you have a reference frequency at say 1MHz. This could, for example, be obtained from the Omega Derived Frequency Standard. We'll also assume that you wish to compare it with another 1MHz signal.

The procedure is as follows: set S2 to "1", then feed the reference 1MHz signal into the "Ref Input" and the frequency to be checked into the "Sig Input". The two signals will now be available at the "CRO Ch1" and the "CRO Ch2" sockets and these should be coupled to a suitable CRO. Set the CRO timebase to $2\mu s$ per division and the triggering to "CH1", corresponding to the reference signal.

This done, you should have a full cycle for the 1MHz reference as shown at the very top of Fig.3. You should also have a full cycle for the signal to be checked, but the phase relationship is likely to be anything but that shown on the diagram. With the phase relationship as shown, the meter should be at about mid-scale but will otherwise read accordingly.

If the two signals are in agreement, then there will be no movement of the bottom display. If the signal is running fast with respect to the reference, then it will be moving to the left on the screen, and vice versa. The rate of movement is a direct function of the difference between the two signals.

This last statement highlights the need for a CRO to establish which way the measured frequency is going. The meter on the instrument does not give this information but, once established, the CRO may be dispensed with, provided the readings do not overrun the meter scale. It is also obvious that readings could be taken directly from the CRO calibrations.

The foregoing illustration, while chosen for its simplicity, is only for measurements calling for the very highest stability situations. To avoid meter scale overrun and for easier initial measurments, less sensitive ranges should be chosen. In fact, if the stability and rate of the signal to be measured is unknown, it would be a good idea to select the highest range (50ms) to start with and work up from there. The procedure is similar to making unknown voltage measurements with a multimeter by selecting the highest range first.

Once the test setup is established, a graph may be drawn, after a series of meter readings have been taken. To illustrate this, I took meter readings every fifteen minutes, between 9.00am and 3.00pm one day and drew up the graph shown herewith. In this case I used the signal from the Omega Derived Frequency Standard, and compared it with the synchronising pulses from TV station TCN Channel 9 in Sydney. The variation between these two signals amounted to only $4\mu s$ over the period covered by the graph.

As mentioned earlier, provision has been made for driving a suitable chart recorder. If you are fortunate enough to have one of these units, then a recording can be made over long periods with all the advantages and benefits this system has to offer.

PARTS LIST

- 1 PCB, code 87pm8, 169 x 93mm
- 1 plastic instrument case, 200 x 160 x 70mm
- 1 Scotchcal label, 194 x 63mm
- 1 0-100μA meter, 50 x 50mm
- 1 Ferguson PL12/5VA PC-mounting transformer
- 1 mains cord and plug
- 1 cord clamp
- 1 rubber grommet
- 1 2-way mains terminal block
- 1 earth lug
- 5 RCA panel-mounting sockets
- 1 SPDT mains toggle switch
- 1 4-pole 2-position rotary switch
- 1 2-pole 2-position rotary switch
- 2 knobs (19mm)
- 5 14-pin IC sockets
- 1 16-pin IC socket
- 1 2.5mm DC power socket (optional, see text)

Semiconductors

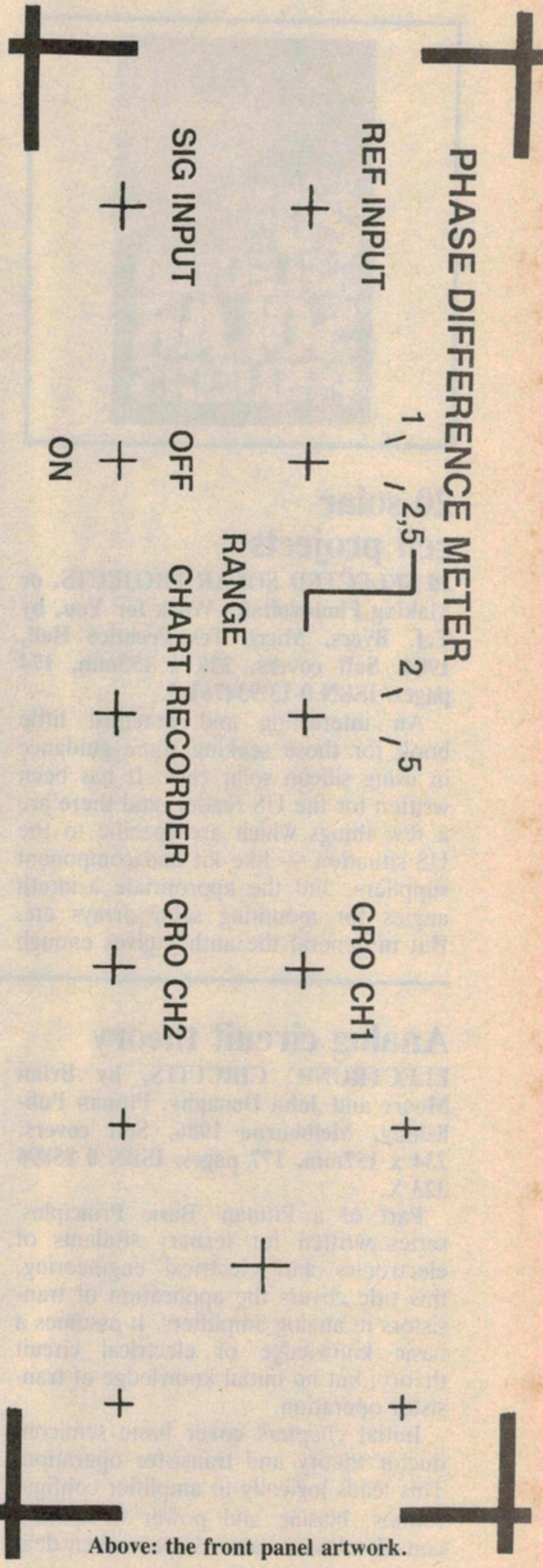
- 4 74C90 decade counters
- 1 74C73 dual J-K flipflop
- 1 4046 phase lock loop
- 2 BF494, BC549 transistors
- 2 1N4148, 1N914 diodes
- 4 1N4002 diodes
- 1 10V 1W zener diode

Capacitors

- 1 2200μF 35VW PC electrolytic
- 1 10μF 15VW tantalum
- 2 1μF metallised polyester
- 2 .01μF metallised polyester

Resistors (5%, 0.25W)

3 x 47kΩ, 2 x 2.2kΩ, 2 x 1.2kΩ, 1 x 330Ω 0.5W, 1 x 100kΩ miniature trimpot



Above: the front panel artwork.