1 GHz FREQUENCY METER — TIMER

Pt. 1 Circuit Details

Lab-quality instrument offers superb performance and features at low cost.

OF THE VARIOUS QUANTITIES encountered in electronics (such as charge, voltage, current, frequency), perhaps the easiest to measure accurately is frequency. Various types of frequency-measuring equipment exist, ranging up from the simple absorption wavemeter (every ham should have one) to sophisticated multi-counter instruments which use microprocessors to calculate the measured frequency.

The earliest really accurate instruments were of the heterodyne type (such as the BC221), in which finely calibrated oscillator was tuned to zero-beat with the incoming signal. Many of these devices are still in use. In the late fifties and early sixties came the first 'digital' counters appeared, based on Dekatron tubes, which are cunning decade counter and display valves.

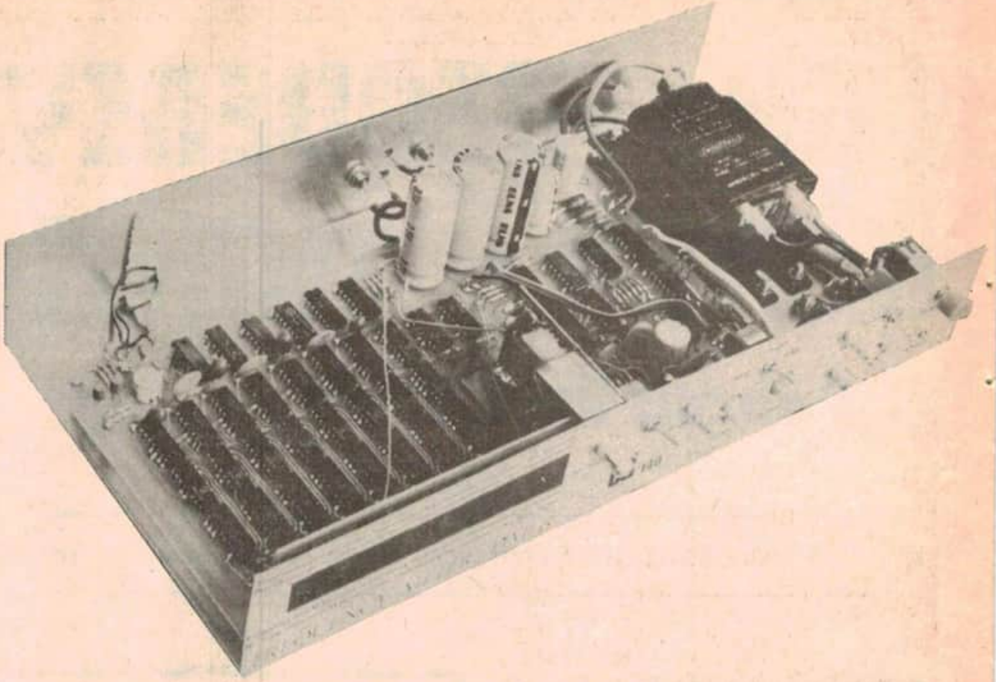
Integrated circuits and LED have now made possible compact, portable counters that can be held in the palm of the hand, and these can easily be built by the hobbyist. What we haven't seen however, is a design for use at UHF, where CB and mobile radio, are appearing, or which offered versatile measurement of time or period.

With these thoughts in mind, we set out to do a design study, and came up with a lab-quality instrument which should be very reasonably priced. The design is based mainly on TTL with some CMOS and ECL. We rejected LSI MOS and CMOS devices for various reasons. Although this increases board size and power consumption, the gain in simplicity of layout and trouble-shooting, as well as leading zero suppression, is well worth-while.

SPECIFICATIONS ETI – 140

Modes of operation	**Frequency, period and time**
Range	
Frequency	10 Hz – 50 MHz
High frequency	50 MHz – 1 GHz *
Period	0.1 μs – 10 sec.
Time	1 μs – 100 sec.
Resolution	
Frequency	1 Hz
High frequency	10 Hz
Period	0.1 μs
Time	1 μs
Display	8 digit LED, leading edge blanking
Sensitivity	
Normal input	20 mV
High frequency input	20 mV
Time inputs	0 V to +3 V level shift
Input impedance	
Normal input	1 Meg // 15 pF
High frequency input	≈ 75 ohms
Time input	> 10 k
Maximum input voltages	
Normal input	70 V ac, ∓ 100 V dc
High frequency input	200 mV ac, ∓ 50 V dc
Timing inputs	∓100 V dc
Crystal frequency	
nominal	4000 kHz
actual	3999.995 kHz
Stability and accuracy	
Frequency	Depends on crystal used and initial adjustment. Oven used keeps temperature within 2° C.
Period and time	approx –0.000125%

* The upper limit of the prescaler has not been checked due to the lack of a signal source but both the preamplifier (OM335) and the divider ICs are specified up to 1 GHz.



Design Feature

When considering this instrument initially we looked at ways to reduce both cost and component count of the unit. Our initial design of the counter section used TTL for the first two stages and CMOS for the rest. It then called for four 8 bit shift registers to take the information from the counters, latch it, and provide the multiplexing for the display. Multiplexing reduces the power consumption of the displays for the same light output and the total network would have saved 10-11 packages. However the PCB layout beat us unless a plated through board is used which would have cancelled any cost saving. The increased difficulty of fault-finding, even with fewer components, also weighed against this approach.

The counter in the LSD position has to operate at over 50 MHz. The only way to obtain this performance was to make our own divide by 10 using 74S74 dual D type flip flops as the 74LS90 is only specified to 32 MHz (although one sample we had worked at 60 MHz) and the 74S90 is no faster.

The network of 74S74's should give 60-70 MHz minimum clock rate.

Preamplifiers which can work from almost dc to 50 + MHz involving a Schmitt trigger always prove troublesome and this one was no exception. We originally dc coupled it throughout using matched FETs and a differential pair to give the correct level for the 9585 IC. This proved to have too much gain to be stable and the design shown here was the final result. Originally we used three diodes to limit the output voltage to +2v in the ECL-TTL translator but replacing it with a resistor-diode not only made it cheaper but increased the frequency response by 50% and improved stability.

Operation

The frequency and period modes are commonly known and do not require much explanation. The only extra control provided over the normal sensitivity control, is the dc shift. When measuring the frequency or period of a pulse waveform where the pulse is narrow in relation to the repetation rate, triggering problems can arise. This is due to noise pulses being counted as the average voltage is almost zero. However by using the dc shift the signal can be lifted above (or below) zero and the problem eliminated. For maximum sensitivity on normal ac signals the dc shift must be adjusted back to zero.

With the time mode intervals from 1 µs to 100 sec can be measured using pulses or level changes, into the respective sockets. A voltage change from 0V to 3V (or +3V to 0V) is all that is necessary although up to ∓ 100V can be used. For accurate timing the pulse should have a rise time of less than 1 µs. For measuring single pulses, both inputs can be paralleled and starting and finishing on opposite edges. If it is a repetitive pulse chain the unit will time the first pulse after the release of the reset button.

Calibration and Testing

To calibrate the unit a known frequency is needed so that CVI can be adjusted to give the correct reading. Alternatively a radio receiver can be used tuned to the PMG 12 MHz time transmission, VNG, and the 4 MHz crystal beat against it (take a wire from pin 11 of IC30, wrap it around the radio aerial and adjust for zero beat. This sets the crystal to exactly 4 MHz. However this is not the exact frequency needed (life wasn't meant...). Now feed the 4 MHz into the input and record the result. It should be about 3,999,995 Hz which is about 0.000125% low. Now measure the frequency of another crystal (*or extremely stable*) oscillator, record the reading and then adjust CVI to give a reading 0.000125% higher (or whatever error your unit requires). As this low reading is due to the time required for the strobe-reset pulses it is independent of the crystal frequency and adjusting CVI will not affect the reading when the counter is used to measure its own internal frequency.

Adjustment of the crystal trimmer should not be done until it is warm (allow 10 minutes) and the oven should be fixed into the chassis to prevent movement of the leads which can affect the frequency slightly. If CVI does not have enough range the parallel capacitor should be varied.

The period mode should be checked for operation. With the time mode the display can be reset by the push button and timing can be started by shorting out the start socket and stopped with the stop socket. Starting and stopping can also be performed by switching the polarity switches from negative to positive edge triggering. It should not be possible to restart the counter before the display has been reset.

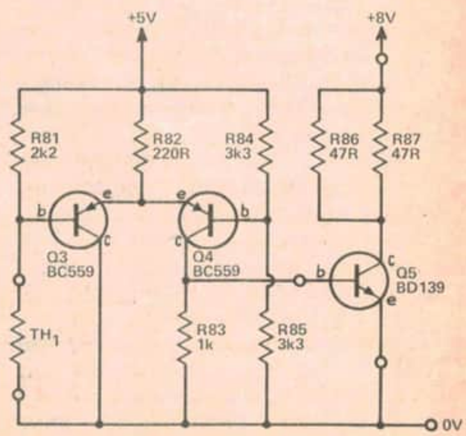


Fig. 1. The circuit diagram of the oven circuit

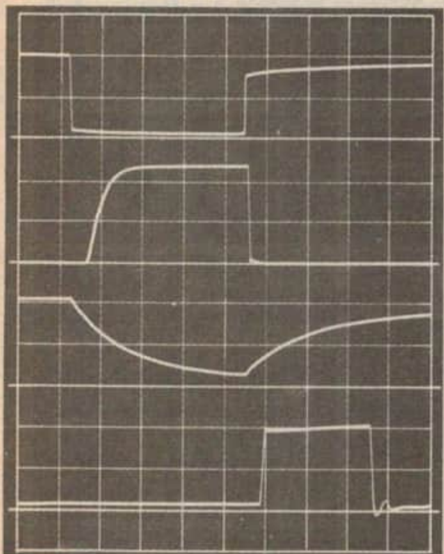


Fig. 2. Waveform diagrams showing the relationships of the strobe-reset pulses. They are, from the top down:
The output of IC37/1, pin 13
The 'strobe' pulse, i.e. the collector of Q2
The input to IC37/2, pin 10
The reset pulse on pin 5 of IC37/2
The vertical scale is 2 V/division while the horizontal is 200 ns /division. It can be seen that between the strobe pulse and the reset pulse there is a delay of about 50 ns.

The following pins are not shown on the circuit diagrams but are connected as shown below. Pins in the third * column are used as interconnections or are unused inputs terminated to some output.

	To +5V	To 0V	*
IC1	4,10,14	7	
IC2	4,10,14	7	
IC3	5	4,6,7,10	13
IC4	5	4,6,7,10	13
IC5	5	4,6,7,10	13
IC6	5	4,6,7,10	13
IC7	5	4,6,7,10	13
IC8	5	4,6,7,10	13
IC9	5	4,6,7,10	13
IC10	5	12	
IC11	5	12	
IC12	5	12	
IC13	5	12	
IC14	5	12	
IC15	5	12	
IC16	5	12	
IC17	5	12	
IC18	3,5,16	8	
IC19	3,16	8	
IC20	3,16	8	
IC21	3,16	8	
IC21	3,16	8	
IC22	3,16	8	
IC23	3,16	8	
IC24	3,16	8	
IC25	3,16	5,8	
IC26	14	7	8,9
IC27	5	2,3,6,7,10	
IC28	14	7	
IC29	14	7	
IC30	14	7	
IC31	2,4,6,7,10	11	
IC32	16	1,7,8,9,15	
IC33	16	1,8,9	1,2,3
IC34	14	7	
IC35	16	1,7,8,9	
IC36	14	7	
IC37	2,3,11,16	8	
IC38	14	7	1,2,5,6
IC39	14	7	
IC40	5,14	6,7,8	
IC41	14	7	
IC42		2,3,5,6	

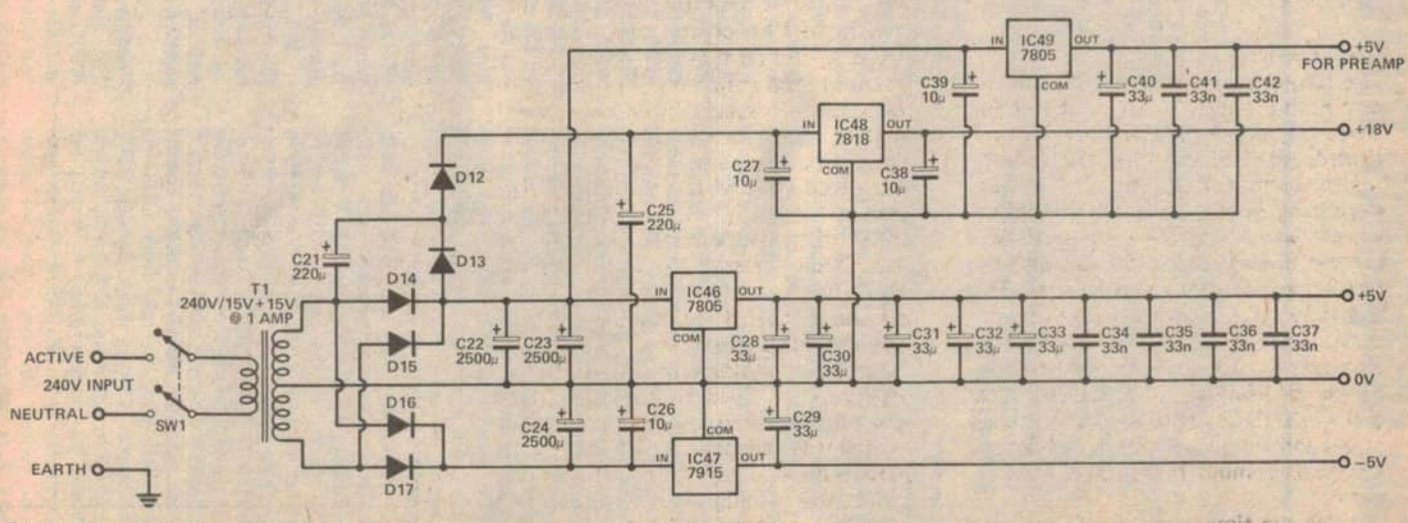


Fig. 3. The circuit diagram of the power supply

1 GHz FREQUENCY METER – TIMER

HOW IT WORKS – ETI 140

The circuit is complex but can be sparated into sections to make the explanation clearer:

A. Input preamplifier.
B. Prescaler.
C. Counter section.
D. Time base.
E. Frequency-period control logic.
F. Time measurement control logic.
G. Power supply.

Preamp

Transistors Q6, Q7 and Q8 form the high to low impedance unity gain buffer required to allow the one megohm input impedance. Diodes D5 and D6 prevent excessive input voltages damaging the unit.

Amplification is provided by IC42 which is an ECL triple differential line amplifier. Each stage has a gain of about seven giving a total voltage gain in IC42/1 and IC42/2 of around 50. The inputs of IC42/1 are biased to the internal reference voltage (pin 11) by R91 and R92 with the input signal being ac coupled via C10,11. The voltage on pin 16 can be dc shifted to allow better triggering on pulse type inputs.

The third section of IC42 is used as a Schmitt trigger to ensure that the output is square and jitter free. As the outputs of ECL move only from about +3.3 V to +4 V (on a +5V supply), a translater is needed to drive the TTL logic which follows.

Transistors Q10 and Q12 are both constant current sources with Q12 providing about 18 mA (0.6 V across 33 ohms). As the base of Q10 can be either of two levels (3.3 V or 4 V) it supplies either 33 mA (1.1 V across 33 ohms) or 9 mA (0.3 V across 33 ohms). As the two current sources are in series the differential current must go somewhere if they are to remain constant current supplies! With 33 mA from Q10, the difference (15 mA) flows through R103 and D9 to give about +2 V on the output. When the current drops to 9 mA the clamp diodes in the 74S10 which follows the preamp clip the voltage at about -0.7 V. If these limits were not used the two inputs Q9 and Q13 are used to disable one of the inputs. With both transistors off the prescaler output is disabled (it needs a pulldown resistor), leaving the normal input active. If the transistors are on the prescaler is operational but the dc shift on pin 16 of IC42 forces the output (pin 7) high, effectively disabling the input.

Counter Section

The counter section consists of eight decade counters, latches, decoders and the LED displays. Due to the symmetry of the network the centre four stages aren't shown on the circuit diagram.

Seven of the counter stages are the familiar 7490/7475/7447 combination (except that they are the LS versions) but the decade counter of the LSD (least significant digit), which has to work at over 50 MHz is made out of four D type flip-flops using a NOR gate to get the divide by ten function. Both the D type flip-flops and the NOR gate have to be 'S' series TTL to give 50 MHz + operation (our prototype went over 100 MHz!).

All the counters can be reset by a '1' on the reset line and counting is advanced on the positive transition of the count input. With the latches, if the strobe line is high ('1'), whatever data is presented to it by the counter will be transferred to the decoders. When the strobe line goes to a '0' the data present at that time will be stored and displayed with the information from the counters no longer affecting the display.

Due to the interconnection between the decoder IC's the leading zeros will be blanked, leaving only the right hand digit on with no input signal. To reduce the load on the 5V regulator the displays are supplied from the unregulated supply.

Timebase

The timebase is a 4 MHz crystal with IC30/1 and IC31/2 providing the necessary amplifier to make an oscillator. The frequency is adjustable by CV1. For critical applications an oven can be used, stop dividing (this is used in the time mode). This 1 MHz output is then divided to 10 kHz by IC32 (dual decade counter) and then to 100 Hz or 62.5 Hz by IC33. This IC is a dual divide by 16 counter with the AND gate IC34/1 resetting the first half (IC33/1) upon reaching decimal 10 and IC34/2 and IC34/3 resetting the second half to zero at ten if the control input to pin 13 of IC34 is high. If it is low the reset pulse is disabled and the counter will divide by its normal 16. This change in division ratio is necessary as the prescaler divides by 16 and not 10. A final division by 100 is done by IC37 to give the final timebase periods of 1 s and 1.6 s.

Frequency-Period control logic.

In the frequency mode the output of the preamp is coupled to the count input of the display section via IC28/1 and IC28/3. These need to be 74S10 (not LS) to handle the frequencies involved. The 1 sec (or 1.6 sec) time base is coupled to the monostable IC37/1 via IC36/1 and IC36/3 and is therefore triggered every one second generating a pulse 800ns wide. This is used for the strobe pulse (open and close the latches every one second). This output also disables counting during this period to eliminate any error due to the latch closing while a pulse is still rippling through the decade counters.

The output of this mono has to be buffered by Q2 as the input of the latches is equal to 32 LS TTL loads (about 15mA). This transistor causes a propagation delay of 100 ns on the leading edge and 50 ns on the trailing edge. After a delay at about 80 ns (which is to compensate for the 50 ns propagation delay of Q2) the second monostable IC37/2 is triggered giving a 250 ns wide pulse. This is the reset pulse. The process of frequency measurement is therefore to reset the counters, clock the counters at the input frequency, after 1 sec open and close the latches which displays the number reached by the counters, then immediately reset the counters and start the process all over again.

In the period mode the 1 MHz output totally wrong result. Because of this we use the RS slip flop IC38 which is set by the strobe pulse, stopping any further pulses, and reset by the 'C' output of IC35/2. This IC (IC35/2) is reset by the strobe pulse and the 'C' output does not occur for 400 ms giving a maximum reading rate of 2.5 per second. The reset pulse is not involved in this process and occurs every 10 clock pulses of the input.

Time Measurement

Separate inputs are used for time measurement with both start and stop inputs available. These inputs are buffered by IC39 with both true and complementary outputs available.

Timing is done by coupling the 1MHz output to the count input (via IC28/2, IC28/3 as per period mode), holding the latches open so the counter information is always displayed and controlling the divide by 4 (IC31) to stop and start the counting.

This control is performed by the D type flip flops IC40/1 and IC40/2, after being gated by IC41/3 and IC41/4. If the Q output of IC40/1 is a '1' and the $\overline{Q}$ output of IC40/2 is a '1', IC31 will be enabled. When the reset button is pressed IC40/1 is set to a '0' on Q, and IC40/2 to a '1' on $\overline{Q}$, disabling IC31. This also puts a high on the 'A' input of the reset monostable IC37/2. When the button is released this causes a reset pulse to occur resetting the counters (and display) to zero.

The D input of IC40/1 is normally connected to a '1' and this is clocked into the Q output on the positive transition of the input to pin 3. When this occurs counting will start. This also puts a '1' on the D input of IC40/2 and if a positive transition occurs on pin 11 (clock) the Q will go to a '1' and the Q to '0', which will stop the counting. Triggering the stop input before the start will have no effect as the D input is a '0' and once toggled no further action will occur until reset by the pushbutton. Either positive or negative edge triggering can be selected allowing the width of a pulse to be measured by feeding it to both inputs and selecting the transistors would saturate, reducing the response to a few MHz.

Prescaler

For frequencies above 50 MHz, a prescaler is used with an amplifier IC43 providing about 26 dB gain to frequencies up to about 1 GHz and IC44 and IC45 each dividing the signal by four to give a total division by 16. To compensate for this odd division the timebase is changed from 1 sec to 1.6 sec when the prescaler is used.

As these dividers are ECL (what else at 1GHz!) a similar translater is used (Q11). To prevent interference between and this is controlled by Q3 and Q4. These transistors compare the voltages on their bases and control the drive to Q3, which, along with R86 and R87, is mounted on the crystal body to act as a heater. Also on the crystal body is the thermistor TH1 which provides the necessary feedback to Q3 to stabilize the temperature at about 70°C. The crystal is mounted in a polystyrene box to provide the thermal insulation required.

The output of the oscillator is buffered by IC30/3 before being divided by four by the JK flip flop IC31. If the JK inputs of IC31/1 are taken low the flip flop will from IC31 is gated into the count input via IC28/2 and IC28/3. The output of the preamp, after being divided by ten in IC27 then controls the strobe-reset monostables via IC36/2 and IC36/3. The result is that we count the number of one μs pulses in the time taken for 10 cycles of the input frequency. This gives the period of one cycle to 0.1 μs accuracy. Problems with flickering occur when updating a display more often than about 1/5 sec, especially 7 segment displays, as the eye cannot follow the change. This can be shown that if the display is alternating between 100 and 99 the result could appear as 188 which is a appropriate edge.

Power Supply

Four voltages are required for the unit: +5 volt for most of the logic, +8 volts unregulated for the displays (to save power disapation in the 5 volt regulator) +18 volts for the prescaler and -5 volt for the preamplifier. A separate +5 volt regulator is used for the preamplifier and prescaler to prevent any feed back via transients in the 0V line.

The regulators are standard 3 terminal regulators with the ∓8 volt supply simply fullwave rectified. The +26V for the 18V regulator is voltage tripled.

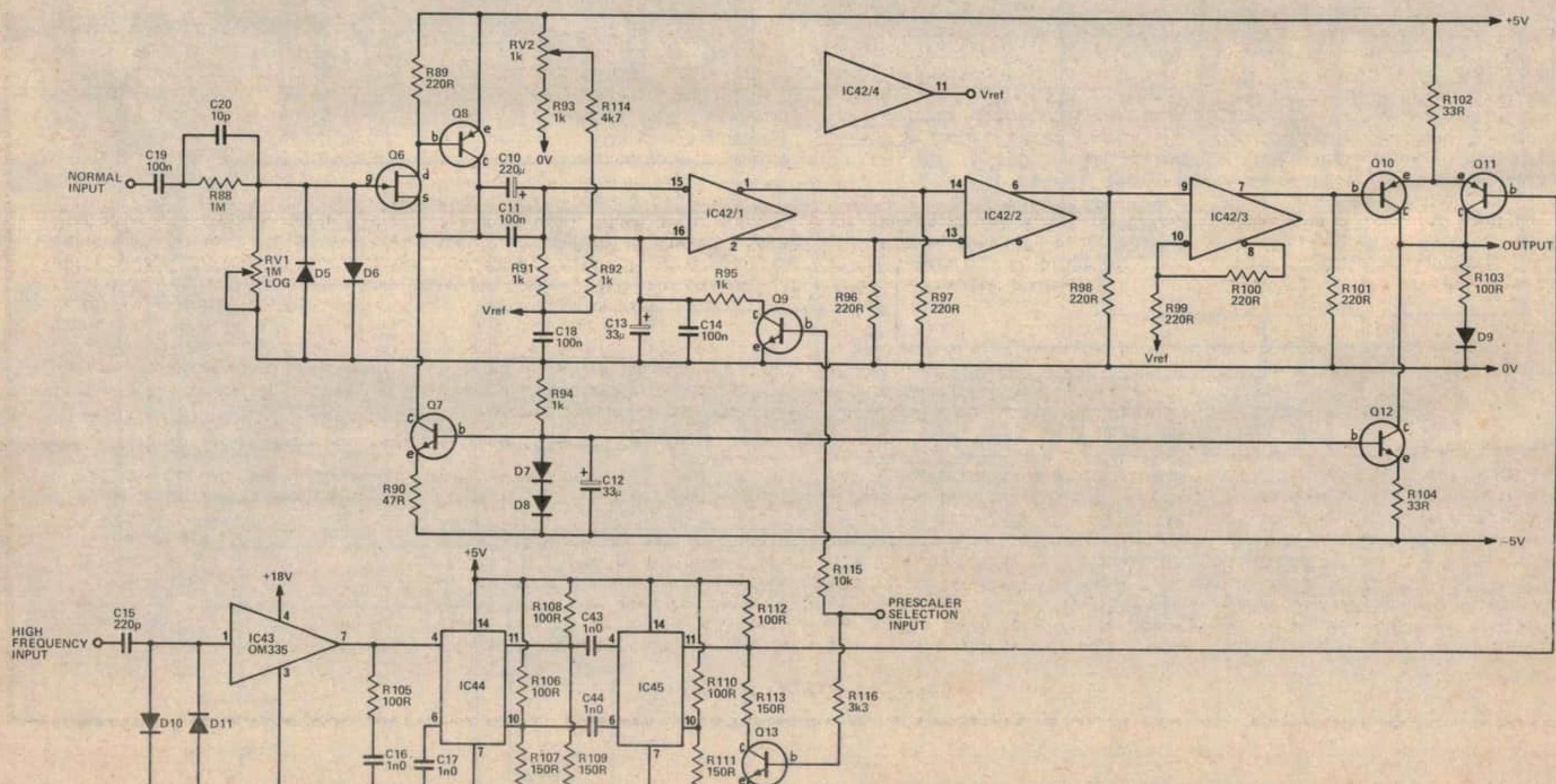


Fig. 4. The circuit diagram of the preamplifier

1 GHz FREQUENCY METER — TIMER

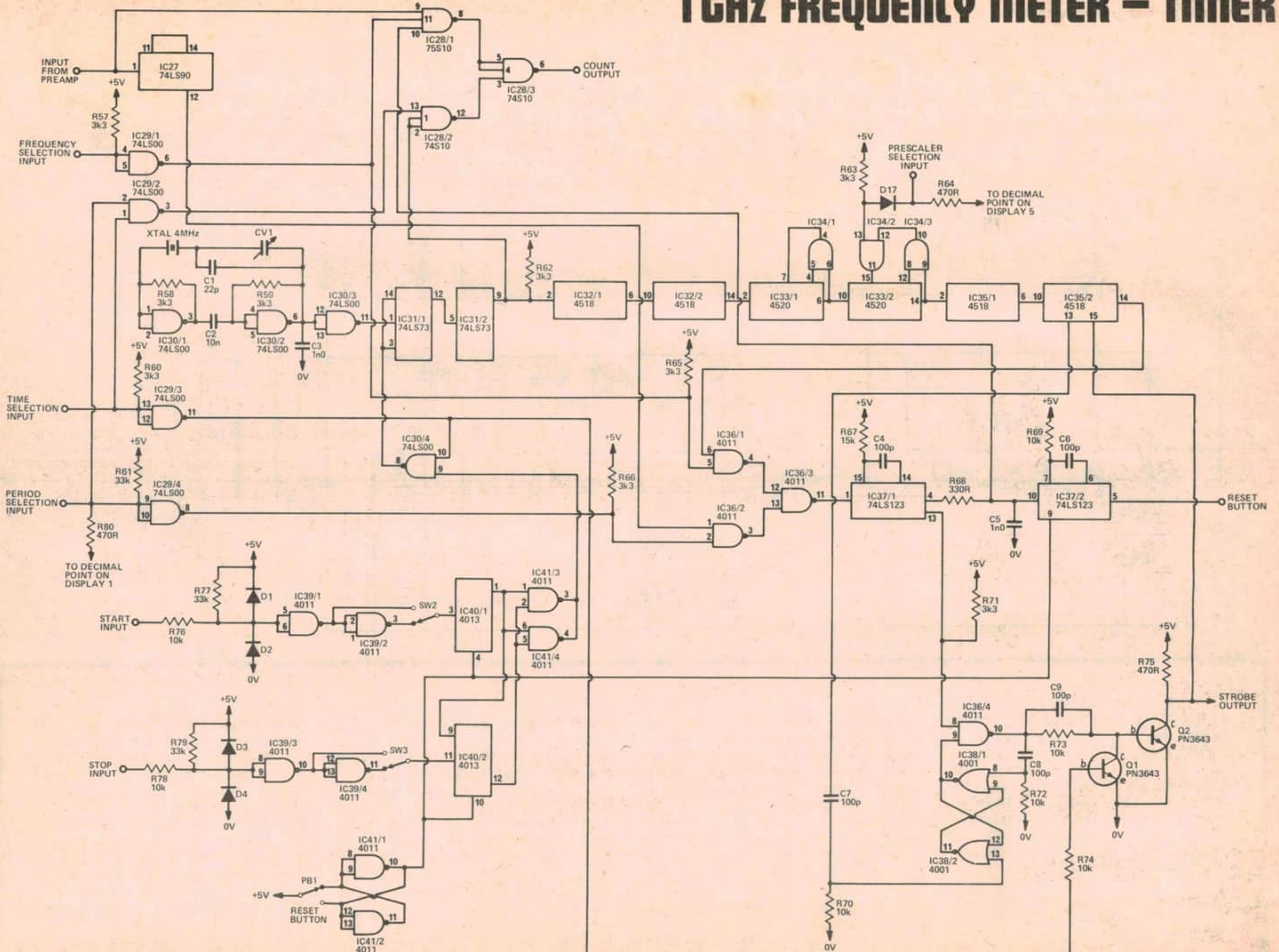
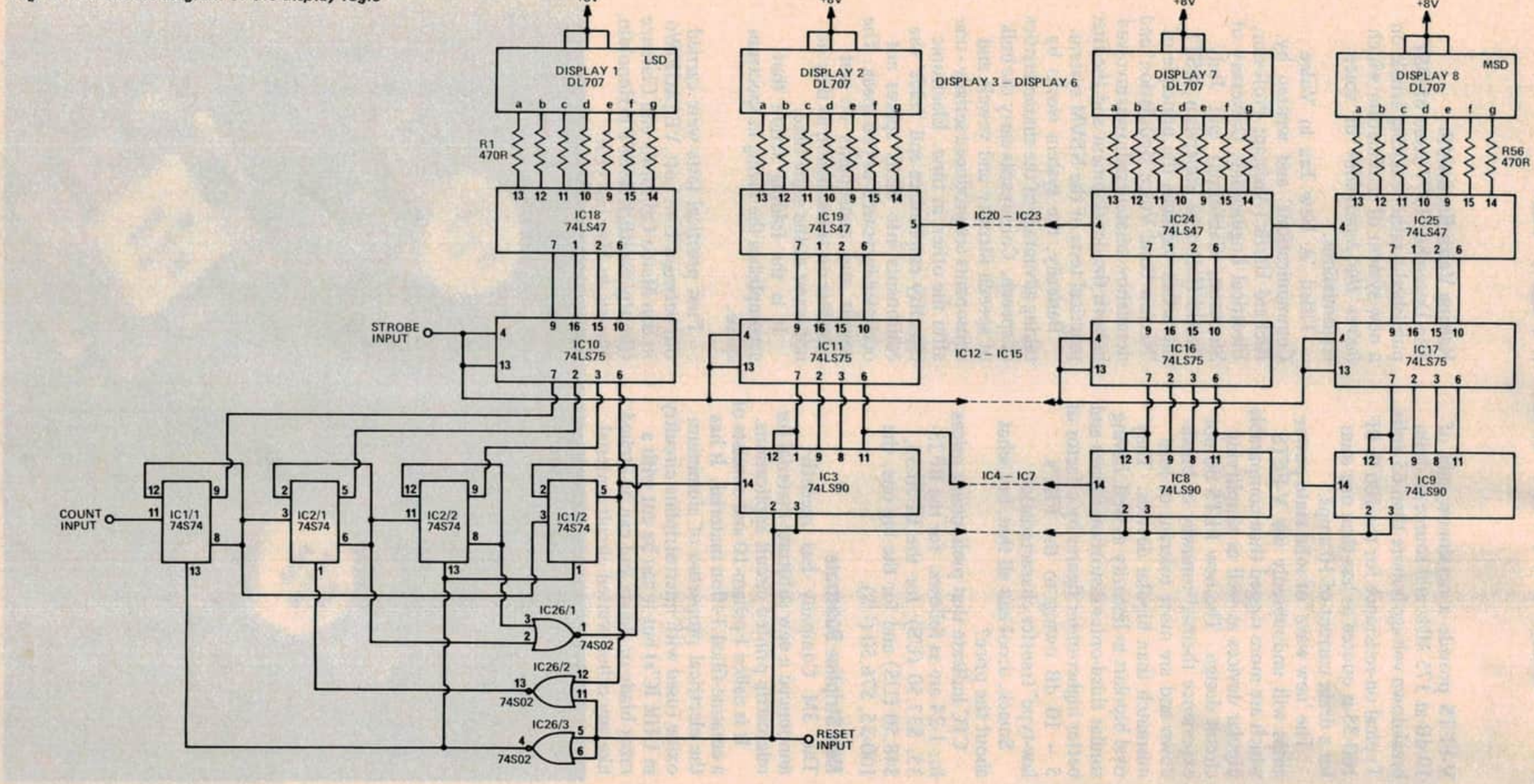


Fig. 5. The circuit diagram of the control logic

Fig. 6. The circuit diagram of the display logic



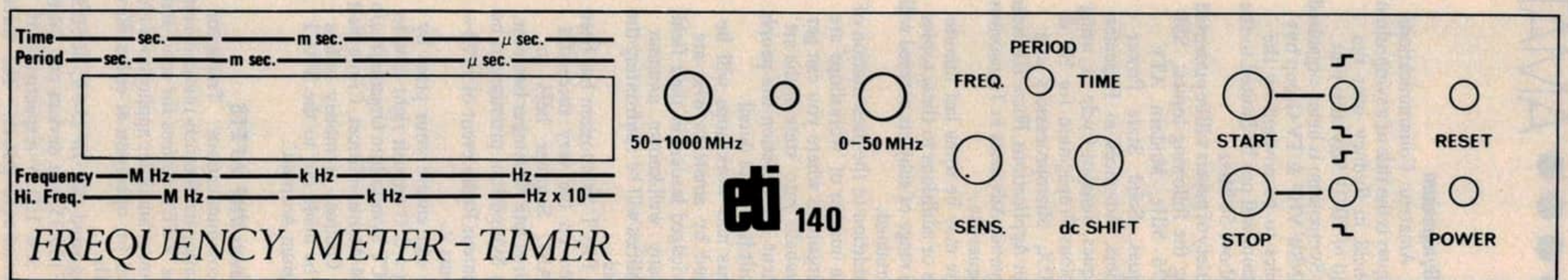


Fig. 7. The front panel artwork. Full size 320mm x 55mm

1 GHz FREQUENCY METER — TIMER

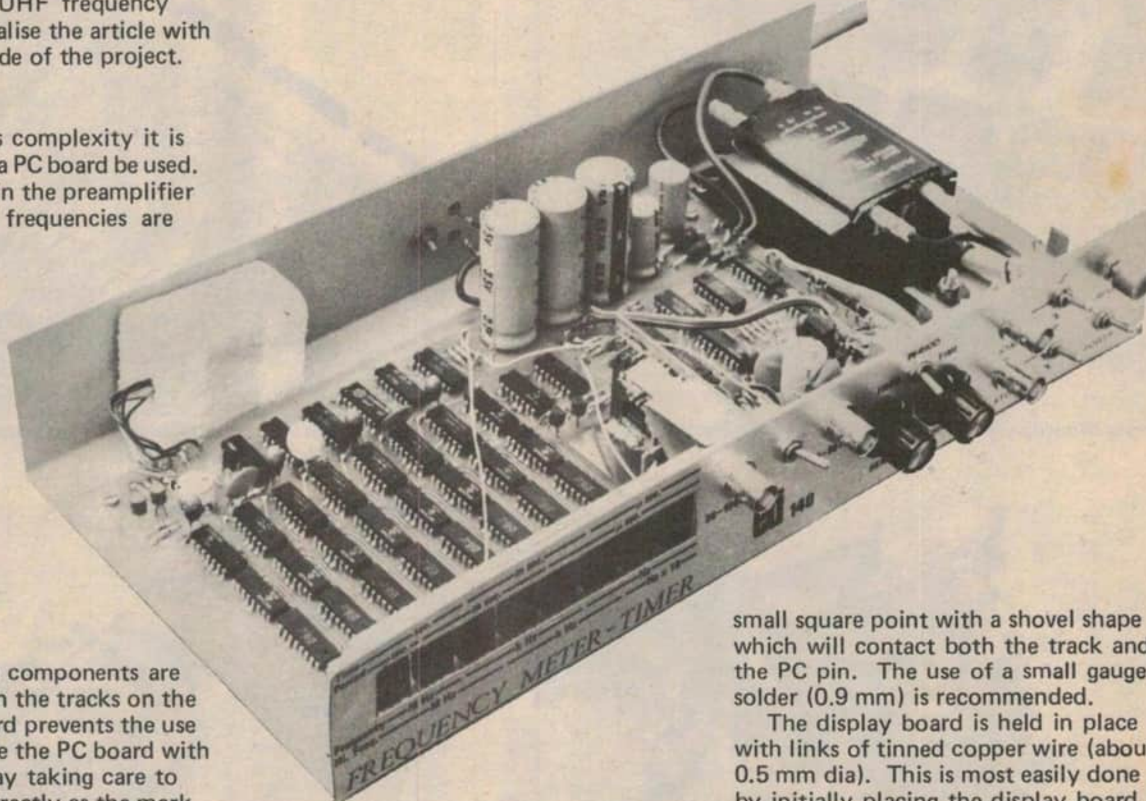
Pt.2 Construction

Lab-quality instrument offers superb performance and features at low cost.

LAST MONTH we described the circuit details of our new UHF frequency counter. We now finalise the article with the constructional side of the project.

Construction

For a project of this complexity it is almost essential that a PC board be used. This is especially so in the preamplifier section where high frequencies are involved.



The fact that the components are used as links between the tracks on the two sides of the board prevents the use of sockets. Assemble the PC board with the aid of the overlay taking care to orientate the ICs correctly as the mark is sometimes difficult to pick out. As the component leads are used as feed throughs it is not practical to build and test the unit in sections. Ensure that *all* pads on the top side of the board are soldered. Soldering the top surface is easiest if the tip of the iron is filed to a small square point with a shovel shape which will contact both the track and the PC pin. The use of a small gauge solder (0.9 mm) is recommended.

The display board is held in place with links of tinned copper wire (about 0.5 mm dia). This is most easily done by initially placing the display board horizontally on the main board and inserting loops of wire through the holes provided (see photo). When all the links are in place the board can be twisted into a vertical position and by pulling on the ends of the links the display board can be pulled down flush with the main board. It can now be soldered into place. Two additional resistors are needed per digit; the photo shows their position. The potentiometers are mounted on a small bracket (see Fig.20) before being soldered onto the main board.

The prescaler, if used, is also mounted in a similar way except that due to the small number of connections the links should be passed through the holes in the prescaler, bent flush with both sides and then mated with the main board. Solder the pads on the underside of the main board only at this stage. On the prescaler board there is a tin plate shield which should be soldered into position with a fillet of solder. Don't solder the top edge yet as capacitor C15 can only be fitted after the unit is in the chassis. Also note that the capacitors C43 and C44 are mounted on the rear of the PCB as shown in Fig. 15 along with R116.

The crystal is fitted into a polystyrene box (about 50 x 40 x 25 mm) with transistor Q5, R86, 87 and TH1 being glued onto the crystal body to act as a heater and sensor.

Before mounting the unit into the chassis assemble all the front panel components, also glueing the polarised plastic into position. Note that there is an earth lug under the prescaler input socket and the nut for the socket should be in the position shown in Fig. 8 as the board fits between the nut and the earth lug which is bent back along the surface of the board.

The unit should now be temporarily mounted into the chassis to locate the prescaler board in its correct position between the nut on the input socket and the earth lug. Fix it in this position by running a small fillet of solder between the two boards. When the unit is removed run the fillet of solder the full length (where there is copper!!) on both sides of the prescaler board.

Assemble the unit finally and wire it up as shown in the wiring diagram. The transformer can be mounted and wired along with the 5V regulator. Insulation washers should be used with this regulator even though the case is at earth potential to prevent any problem of having two earth points (the other is the lug under the prescaler input socket).

Errata

On the power supply circuit diagram last month the transformer was specified as 240V/15V+15V. It should have been 240V/9V+9V. Also the diodes D16 and D17 have been shown in reverse polarity. The regulator IC47 should have been marked as a 7905 not 7915.

On the control logic circuit diagram the diode D17 should have been D18.

The resistor R117 was omitted from the preamplifier circuit diagram and is connected between pin 6 of IC44 and 0V. This is to reduce the sensitivity at high frequency and improve stability.

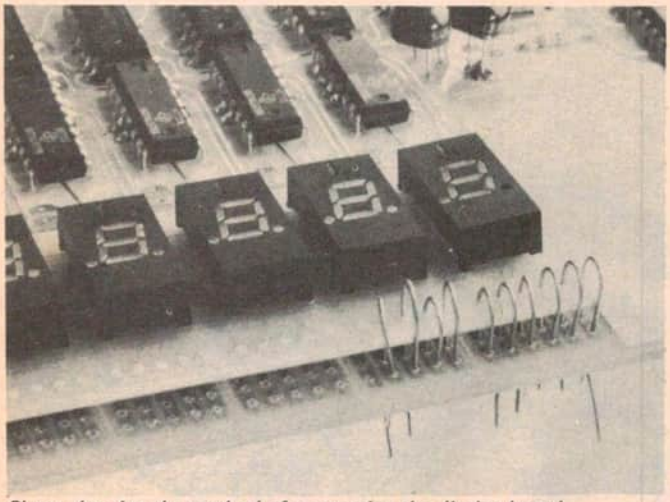
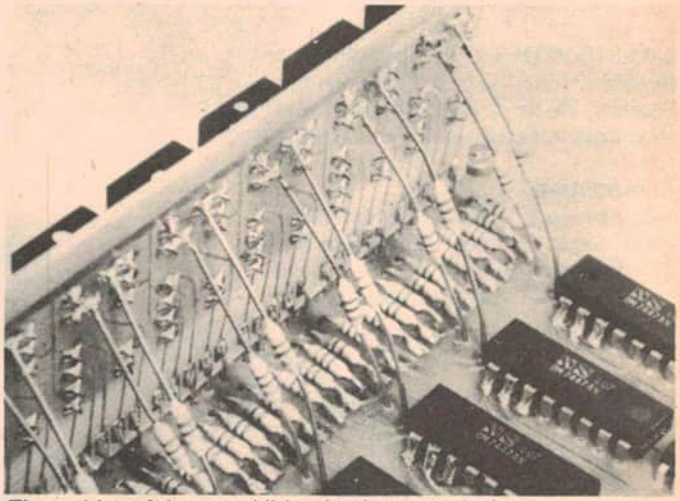
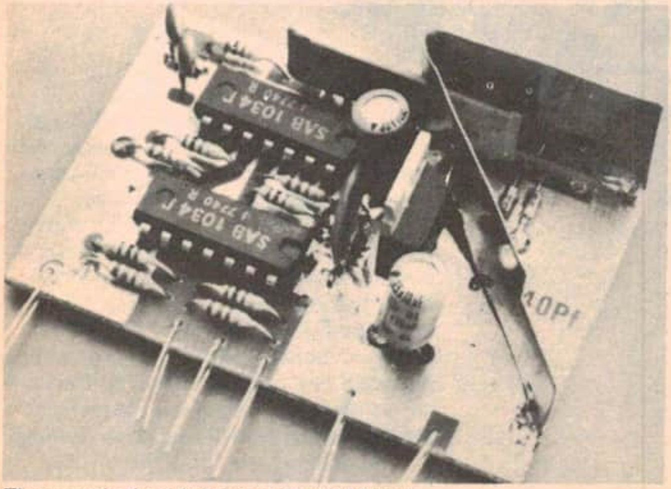


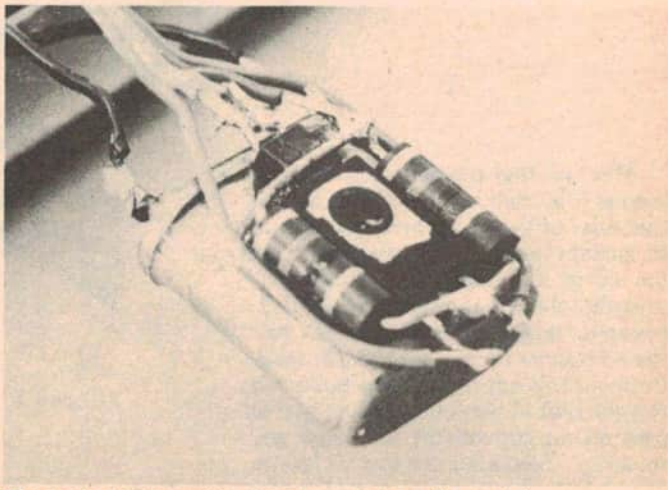
Photo showing the method of connecting the display board.



The position of the two additional resistors required per display is shown in this photograph.



The prescaler board showing the shield used.



The method of mounting the components on the crystal.

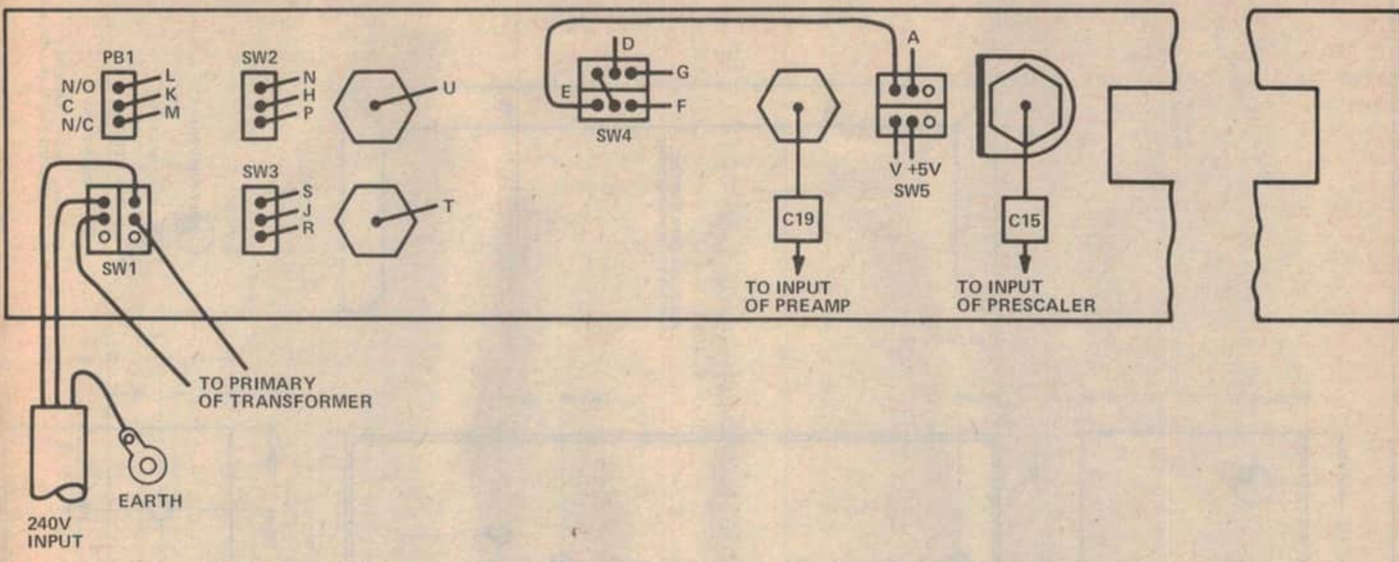


Fig. 8. Rear view of the front panel wiring.

ICs used in the prescaler.

Most of the ICs used in this project are standard TTL or CMOS and only the prescaler ICs are unusual. For this reason details of these ICs are given below.

OM335

This is a high frequency linear amplifier designed for instruments or TV amplifier.

Gain	27dB typ.
Freq. resp. ∓ 1dB	20–1000MHz
Input impedance	75ohm
Output impedance	75ohm
Power Supply	8–28V dc @ 35mA

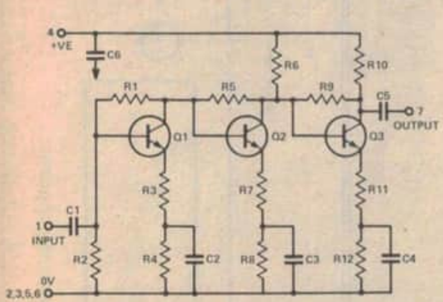


Fig. 9. Internal circuit diagram of the OM335.

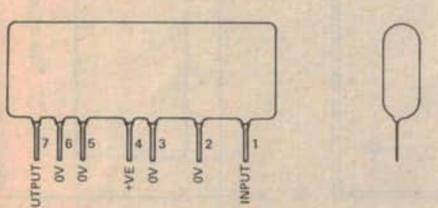


Fig. 10. Pin connections of the OM335.

SAB1048

This is a high frequency 4/1 divider (prescaler) and is designed to operate from a sinewave (50MHz min) or square wave (dc). The output is ECL compatable. The internal circuit - block diagram is given below. The differential inputs are internally biased and should be ac coupled. If only one input is used the other should be ac grounded.

Freq. range (sine wave)	50–1000MHz
Sensitivity	see graph
Power requirement	5.2V @ 53mA

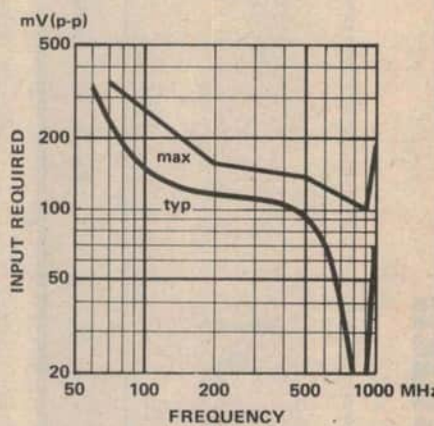


Fig. 12. Sensitivity of the SAB1048 with a sinewave input.

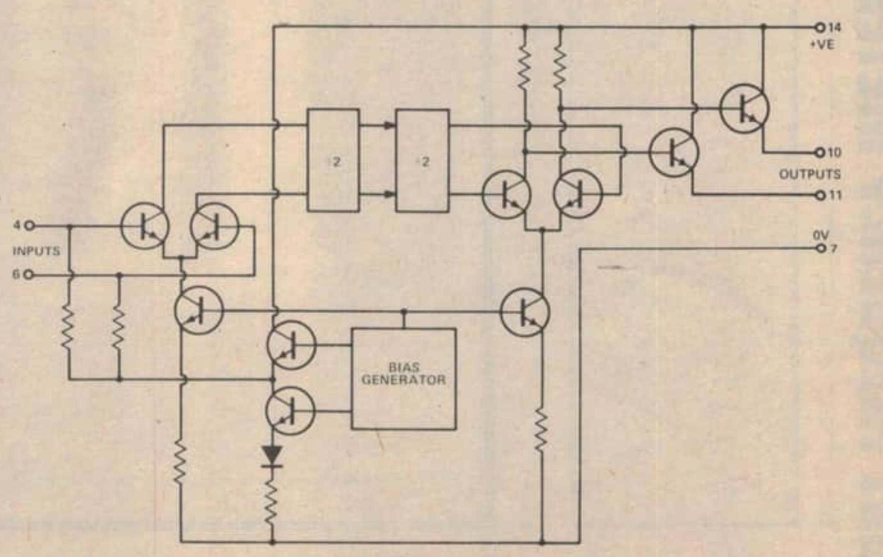


Fig. 11. Block diagram of the SAB1048.

1 GHz FREQUENCY METER – TIMER

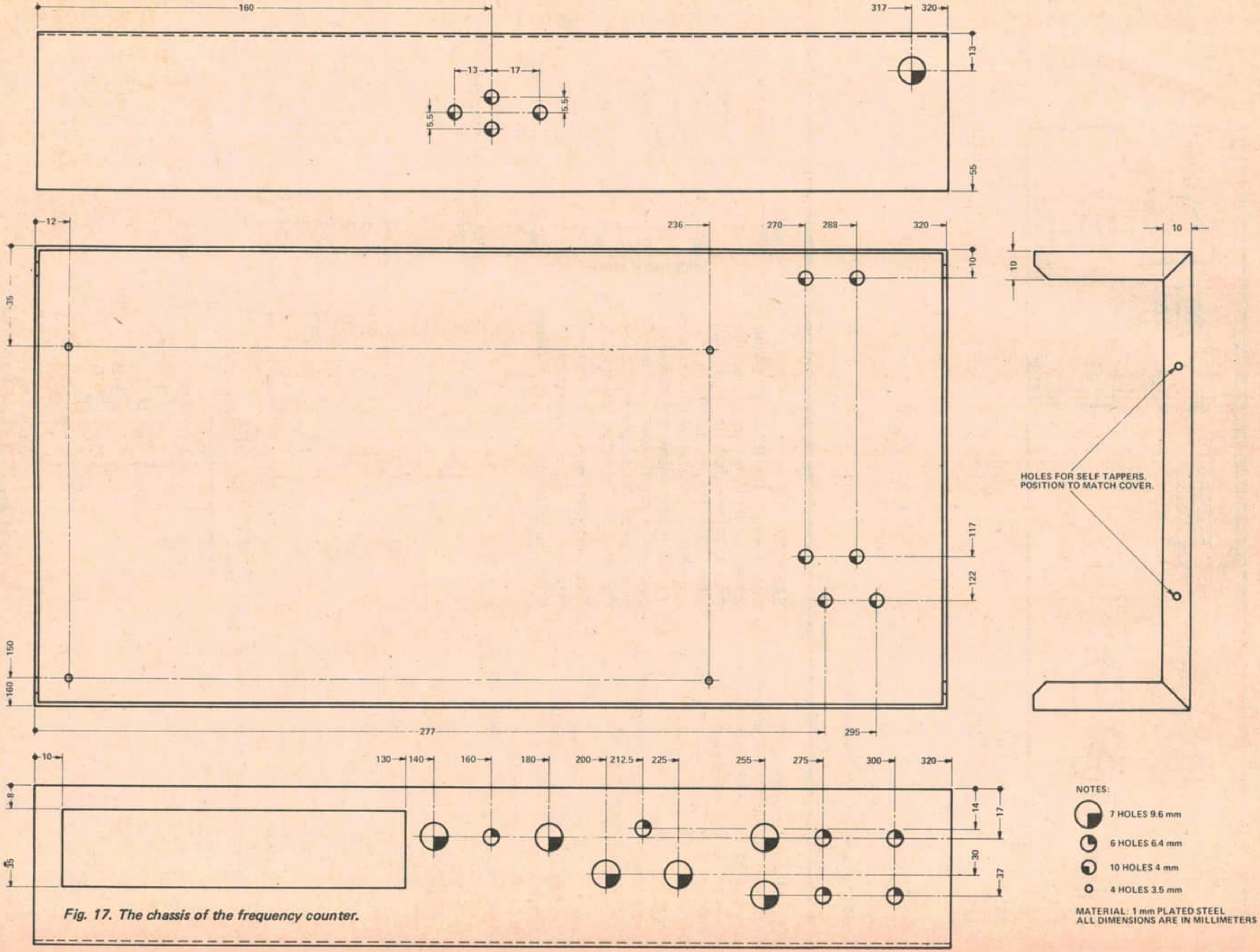


Fig. 17. The chassis of the frequency counter.

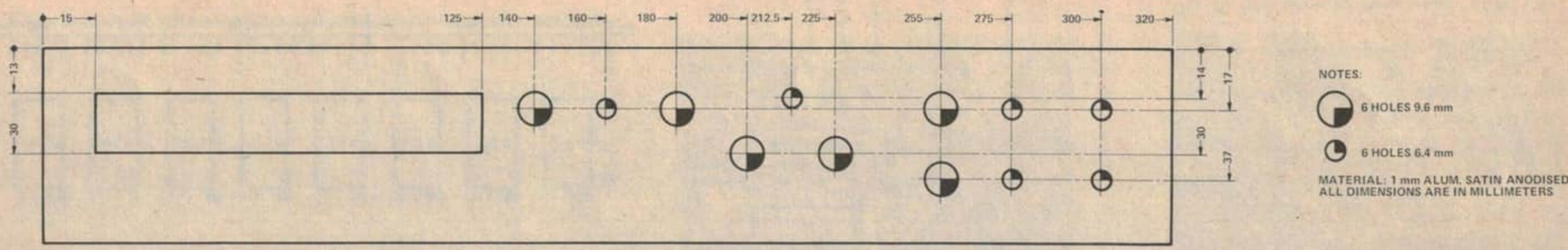


Fig. 18. The dimensions of the front panel.

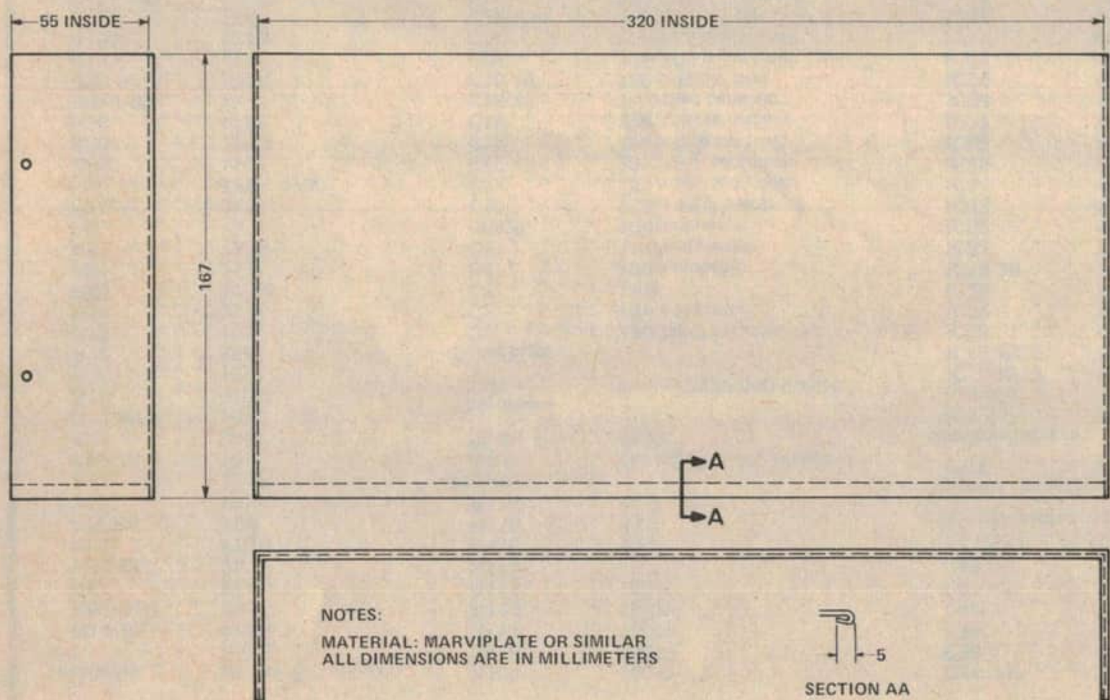


Fig. 19. The cover for the frequency counter.

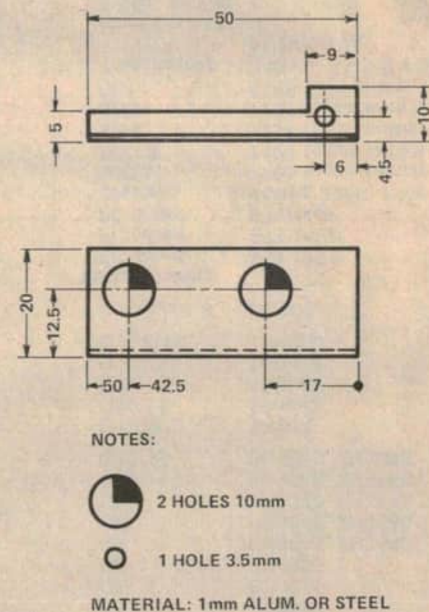


Fig. 20. The potentiometer mounting bracket.

1 GHz FREQUENCY METER – TIMER

PARTS LIST – ETI 140

Resistors all ¼W, 5% unless stated

R1-R56	470R
R57-R60	3k3
R61	33k
R62,63	3k3
R64	470R
R65,66	3k3
R67	15k
R68	330R
R69,70	10k
R71	3k3
R72-R74	10k
R75	470R
R76	10k
R77	33k
R78	10k
R79	33k
R80	470R
R81	2k2
R82	220R
R83	1k
R84,85	3k3
R86,87	47R ½W
R88	1M
R89	220R
R90	47R
R91-R95	1k
R96-R101	220R
R102	33R
R103	100R
R104	33R
R105,106	100R
R107	150R
R108	100R
R109	150R
R110	100R
R111	150R
R112	100R
R113	150R
R114	4k7
R115	10k
R116	3k3
R117	4k7

Potentiometers

RV1	1M log PR16PC (Plessey)
RV2	1k lin "

Thermistor

TH1	Philips 2322 640 90004

Capacitors

C1	22p NPO ceramic
C2	10n polyester
C3	1n0 "
C4	100p ceramic
C5	1n0 polyester
C6-C9	100p ceramic
C10	220µ 16V electro *
C11	100n disc ceramic
C12,13	33µ 10V tantalum
C14	100n disc ceramic
C15	220p silver mica
C16,17	1n0 disc ceramic
C18,19	100n 100V disc
C20	10p 100V ceramic
C21	220µ 35V electro*
C22-C24	2500µ 16V electro *
C25	220µ 35V electro *
C26	10µ 16V tantalum
C27	10µ 35V electro *
C28-C33	33µ 10V tantalum
C34-C37	33n disc ceramic
C38	10µ 35V electro *
C39	10µ 10V tantalum
C40	33µ 10V tantalum
C41,42	33n disc ceramic
C43,44	1n0 disc ceramic

* all electrolytic capacitors should be the single ended types.

Variable Capacitors

CV1	2–10p trimmer

Semiconductors

IC1,2	74S74
IC3-IC9	74LS90
IC10-IC17	74LS75
IC18-IC25	74LS47
IC26	74S02
IC27	74LS90
IC28	74S10
IC29,30	74LS00
IC31	74LS73
IC32	4518 (CMOS)
IC33	4520 (CMOS)
IC34	4081 (CMOS)
IC35	4518 (CMOS)
IC36	4011 (CMOS)
IC37	74LS123
IC38	4001 (CMOS)
IC39	4011 (CMOS)
IC40	4013 (CMOS)
IC41	4011 (CMOS)
IC42	9582 (ECL)
IC43	OM335
IC44,45	SAB1048P,SAB1034P
IC46	7805 (TO3 package)
IC47	7905 (500mA version)
IC48	7818 (500mA version)
IC49	7805 (500mA version)
Q1,2	PN3643, 2N3643
Q3,4	BC559
Q5	BD139
Q6	2N5485
Q7	PN3643, 2N3643
Q8	PN3645, 2N3645
Q9	PN3643, 2N3643
Q10,11	PN3645, 2N3645
Q12,13	PN3643, 2N3643
D1-D9	1N914
D10,11	BAW62
D12,13	1N4004
D14,15	1N5404
D16-D18	1N4004
Displays 1-8	DL707

Miscellaneous

PC board	ETI 140A
PC board	ETI 140D
PC board	ETI 140P
Crystal	4MHz, 30pF, 70°c
SW1	7201 toggle switch
SW2,3	7101 toggle switch
SW4	7211 toggle switch
SW5	7201 toggle switch
PB1	8168 push button
Transformer	240V – 9V + 9V @ 1A PL18/20VA

Metalwork to suit
4 B&C sockets
3 core flex and plug
cable clamp
Piece of polarised plastic

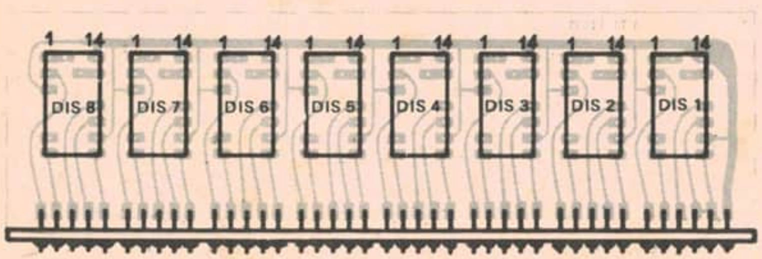


Fig. 13. Component overlay of the display board.

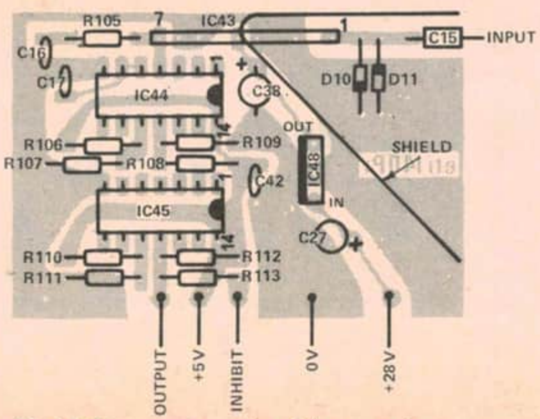


Fig. 14. Component overlay of the prescaler.

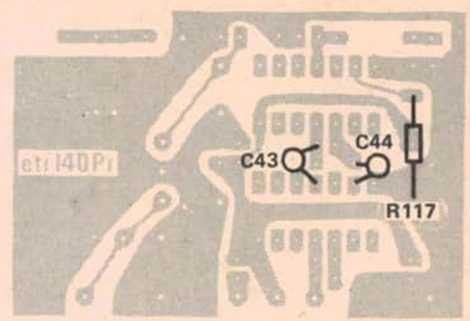


Fig. 15. View showing the position of C43, 44 and R116 on the rear of the prescaler board.

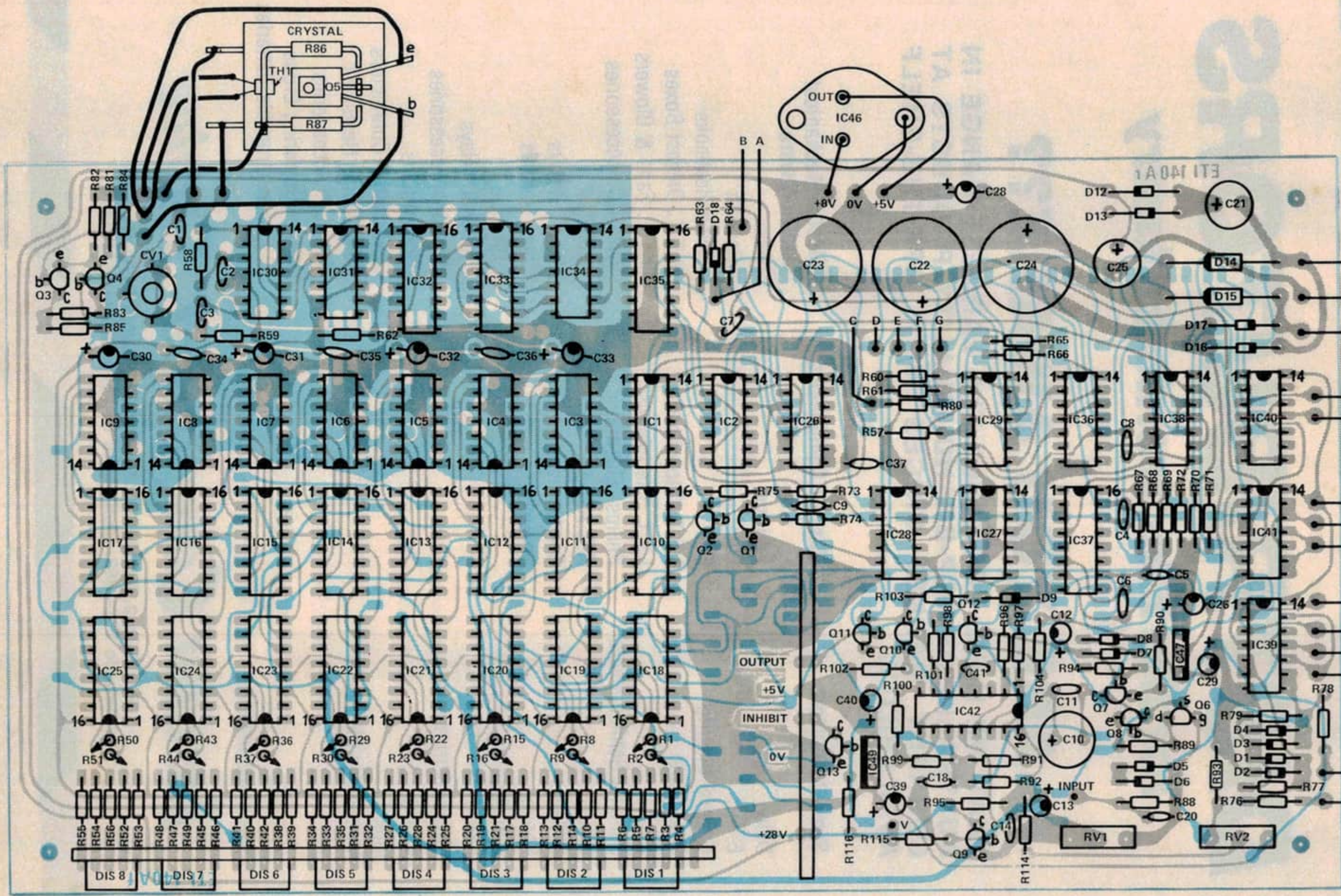
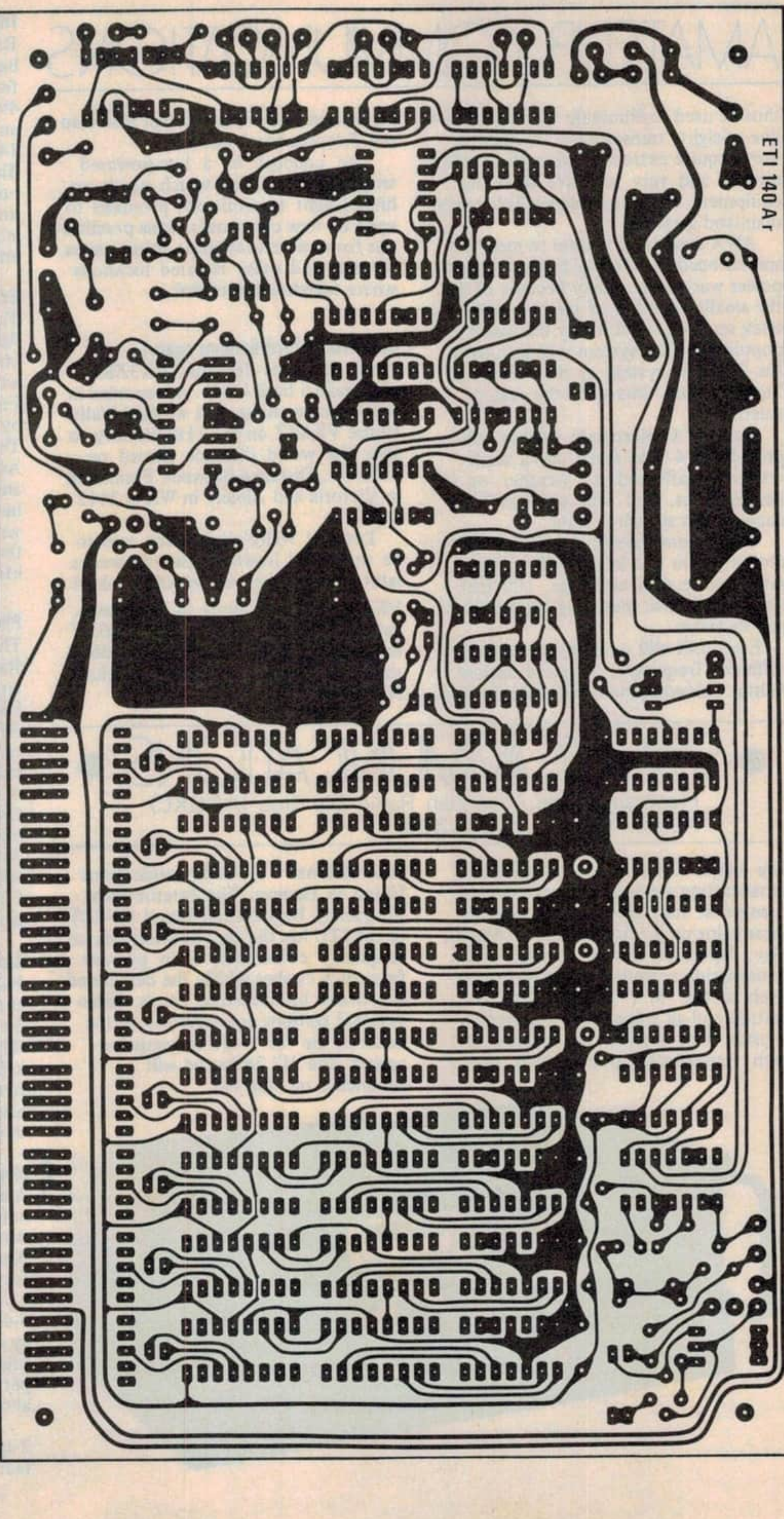
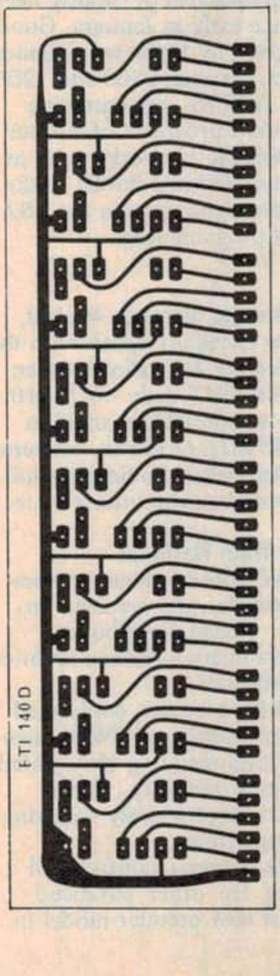
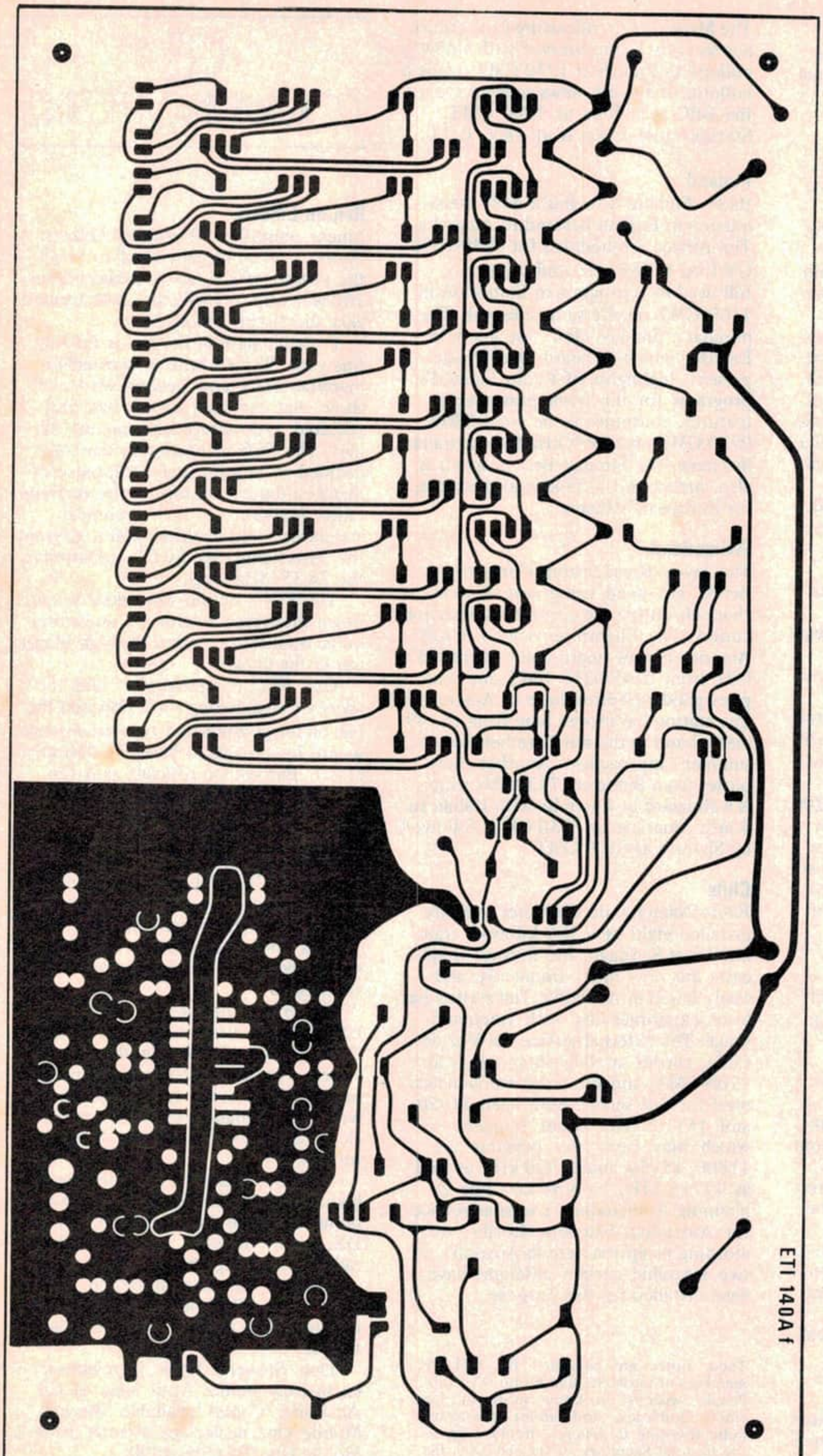


Fig. 16. The main component overlay. For the connection of wires marked A — U see Fig. 8. Wire B goes to the decimal point on DIS 5 (Pin 6) while wire C goes to the decimal point of DIS 1 (Pin 6).

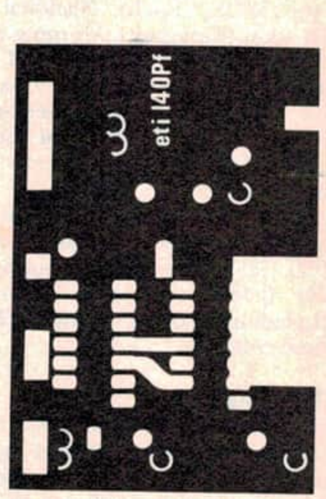
Owing to space restrictions, we have had to omit our propagation predictions this month. Normal propagation will be resumed next month.






ETI 140A f


eti 140Pr


eti 140Pf

Lab Notes

An occasional series in which we discuss interesting circuit techniques, circuits we have tried in our own laboratory but not developed as a project, practical notes on projects, measurement techniques for hobbyists etc.

Getting the best from the ETI-140 1GHz DFM

SINCE IT WAS described in the March and April 1978 issues, this project has been very popular, reportedly many hundreds have been built.

The design has proved very sound, although some constructors have reported minor problems. This is gratifying considering the complexity of the project.

Here are a number of hints and tips to help you get the best from your instrument.

Minor errata

We should get this out of the way first.

In the table on page 87 of the March 1978 issue, the connections for IC42 should show pins 4 and 5 connected to the +5V rail, while pin 12 goes to OV (zero volts).

On the circuit diagram, p. 90 of the March 1978 issue, the reset output of IC37 (pin 5) is incorrectly labelled "Reset Button". This button actually connects to IC41 (a debounce circuit). The overlay is correct.

Crystal oscillator

The oscillator stability is the main limitation on ultimate performance, as would be expected. Experience indicates that, despite the crystal oven (which works quite well), temperature changes affecting the 74LS00 oscillator/driver affect the frequency of oscillation, limiting the accuracy to a few parts per million.

This is quite satisfactory for many purposes, but, where greater accuracy is required, particularly where the full display facilities are to be used to best advantage, then an 'add-on' high stability oscillator is recommended (see following notes).

It may be found that some crystals will not 'behave' in the circuit as published. The solution lies in tailoring some of the oscillator components to suit the crystal used.

For starters, R58 and R59 may be adjusted to give the correct drive level to the crystal. Reliable starting and improved stability result from a little 'juggling' of these resistors. Not all crystals have the same characteristics.

Too high or too low a drive level may cause unreliable starting and possible harmonic or sub-harmonic oscillation. (e.g. rather than the oscillator operating on 4 MHz as intended, it may produce 8 MHz or 2 MHz). In addition, too low a drive level increases frequency drift. The correct level is best found experimentally if you experience trouble in this department.

Note that capacitor C3 is a bypass intended to suppress harmonic operation of the oscillator. However, with some crystals it may bring about sub-harmonic oscillation!

From experience, some crystals require R58 and R59 to be 470 ohms and C3 to be left out for best operation of the oscillator/driver. Still others need these resistors to be at least 1k, C3 being retained in this case.

Additionally, it has been noted that the value of C4 may need to be increased to achieve correct operation on **frequency** and **period** modes. A value of 330 pF is suggested as a starting point.

Longer gate times

The standard gating time of one second (1.6 S on prescale) is a good compromise between accuracy and reading delay, chosen to suit the majority of applications envisaged for this instrument. Longer gating times of 10 seconds, or even 100 seconds, can be provided by adding extra stages to the divider chain. This is desirable at lower frequencies where resolution is the important factor.

If the extra stages are connected at the output of IC31 (pin 9), the range of the **time** and **period** functions will be increased, but, at the same time the resolution will be reduced. Low power Shottky devices — 74LS90s — are recommended. Note that CMOS 4518s require buffering to drive the 74S10, and are therefore impractical.

Sensitivity control

If you find it disconcerting that the **sensitivity** control operates opposite to the convention; i.e. maximum sensitivity is obtained when the control is wound fully anti-clockwise, this can be reversed as follows:

On the pc board cut the track connecting the centre pin of RV1 and connect the centre pin of the pot to the opposite pin instead.

For many applications, a linear pot will provide a more 'controlled' rate of attenuation.

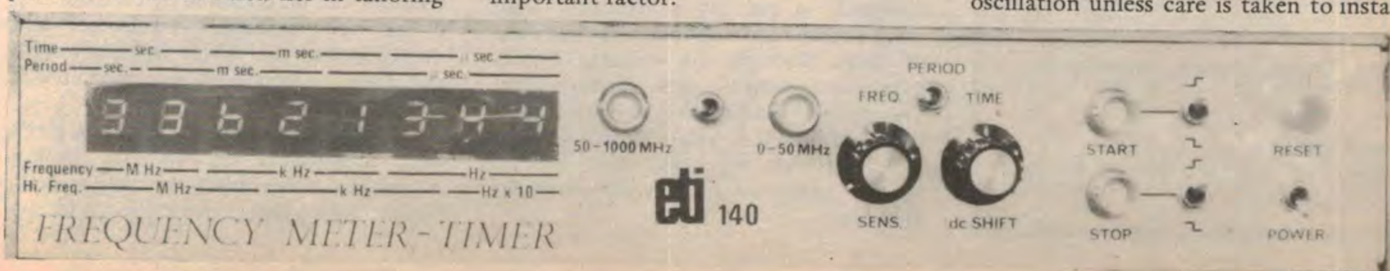
Note that the **DC shift** control is 'off' when it is centred.

Prescaler pointers

Constructers should follow stringent RF construction practices in order to avoid problems with the prescaler — particularly around the OM335.

Earth paths are critical at UHF. All components should be soldered both above and below the board where indicated, especially the earth leads of the OM335. This IC should mount right down on the pc board. Some ceramic material may need to be *carefully* scraped away from the pins at the component's body to enable successful soldering to the pins on the top side of the pc board.

As the OM335 provides a lot of gain in a small space the stage will tend to be unstable at best, breaking into oscillation unless care is taken to install ▶



Lab Notes

it correctly. If you experience instability problems, check the above points first. Then, adding an extension to the tin-plate shield running alongside the OM335 (refer to the photographs in the original article). These measures should be completely effective.

The 'Maximum input' of 200 mVac specified for the ETI 140 refers to the input impedance of 75 ohms. Above this level the input protection diodes reduce the impedance. Specified maximum input to the OM335 itself is about 2.5 V. The diodes will protect it from most overloads, but to retain system impedance during measurements and to give the maximum overload safety margin, input level should be kept well below the specified maximum.

Fortunately, the sensitivity is so high, at least 20 mV at 50 MHz and improving with increasing frequency, that for most applications direct connection to a circuit is not necessary and a small pickup loop on the end of a coax lead is all that is required to obtain an adequate measurement.

Displays

The DL707 display specified is an industry standard and can be obtained under a variety of part numbers. Some of these, for example, are:
MAN72A
745-0017
TIL312
5082-7610
5082-7650

Some constructors who used the XAN3062 display, substituted for the DL707, found them unreliable. If DL707s are unavailable, any of the above may be substituted.

Power supply

Do not be bothered (. . . my little chicken — as the fairy story goes) that the transformer specified (Ferguson PL18/20VA) gets quite hot. This is not because it is overloaded, rather it is designed to run at a relatively high temperature. It conducts a fair amount of heat through the chassis, which, naturally enough, gets quite warm. The internal temperature remains within tolerable limits. If you're worried about it, either run the unit with the lid slightly raised or put ventilation holes in the lid.

General tips

When attaching the external wiring to the pc board, a little extra length will allow the board to be pivoted forward to allow access to the underside for service. Not shown in Figure 8 (April 78 issue, p.79) is an extra connection from point 'E' to the main board. The type 8168 pushbutton switch specified for PB1 has not been available for some time, due to production problems we are told. Type 8121 may be substituted. The connections are different but, referring to figures 8 and 16 in the April 1978 issue and the markings on the switch, correct wiring is readily ascertained.

When troubleshooting

The apparent complexity of the instrument may make the task of servicing or debugging seem daunting. However, if the unit is treated in its separate sections it becomes fairly straightforward.

Firstly, it is essential that the unit not be switched on without the earth lead from the chassis to the pc board earth pattern or the 9582 (IC42) will be damaged. If a prescaler is fitted the earth should go from a lug under the prescaler input socket to the earth pattern of the prescaler board — use a short, heavy lead.

A divider probe must be used when checking operation of the ECL devices with a CRO, otherwise oscillation may result. A 'x10' probe is recommended, but should not be used on the ECL/TTL translator.

Note that it is normal of ICs 42 to 45 and 47 to 49 to run hot.

Exercise care when removing ICs from the board to avoid damage. The safest way in the absence of special equipment is to use a solder sucker or 'solder wick' to remove solder.

Add-on crystal oscillator

Improved short-term and long-term stability can be obtained by constructing a separate oscillator and buffer and incorporating the whole assembly with the oven components suggested in the article on ETI 140.

A suitable oscillator circuit is given here. Capacitors C1 and C2 should be either silver mica or polystyrene types. Exact value is not critical and one value either side of those specified may be used. The two 10n (0.01 uF) bypass capacitors should be ceramic types. The output capacitor from the collector is best chosen by experiment, depending on the buffer used. More on this later.

The 2k2 resistor marked 'Rf' determines the level of feedback, and to a certain extent, affects the ultimate stability as it isolates the crystal from the active device and the load. It should be chosen such that reliable starting is obtained, with the highest tolerable value. One standard value lower than that determined by experiment for reliable oscillator starting is the best bet. Note that it may take some seconds for the oscillator output to appear and rise to maximum level following switch on with this circuit.

The 5-60 pF trimmer is used to set the frequency exactly. A miniature Philips film trimmer or (if you have the space) a mica compression trimmer should be used.

A CMOS Schmitt trigger, to provide logic level output, is recommended as a buffer. The coupling capacitor from the oscillator collector should be chosen to be as small a value as possible, consistent with reliable operation of the Schmitt trigger. A value of 100 pF is a good place to start.

All these measures isolate the crystal from the cruel vicissitudes of the 'outside world'.

The crystal, oscillator components, buffer and oven components should all be mounted in a thermally-insulated container — polystyrene foam blocks are ideal, as mentioned previously. The crystal should be mechanically (and thus thermally) connected to the oven components as detailed in the original article. Having some thermal linkage to the other components is also a good idea, however, this is left to the individual constructor's ingenuity.

Output from the buffer can be taken direct to the divider chain.

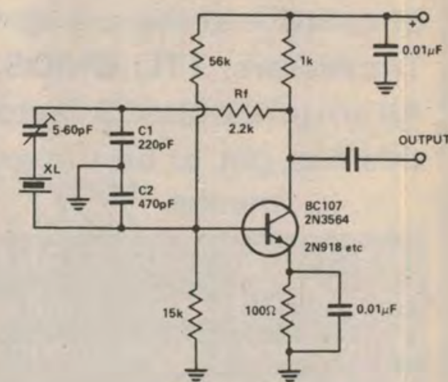
Only common and +5 V supply are the other connections necessary.

Crystal specifications

No specifications were given in the original article for the crystal. Not all crystals are the same. The following set of specifications is recommended.

Frequency:
4.0000 MHz
Manufacturing tolerance:
+/- 20 ppm
Temperature tolerance:
+/- 20 ppm,
-10 to +55°C
(or 0 to +60°C)
Load capacitance:
32 pF (or 30 pF)

The crystal can be obtained in either the HC6/U (13 mm pin spacing) or the smaller HC18/U package — the latter is preferred for space reasons. Either pins or flying leads may be ordered for the crystal connections. ●



The assistance and cooperation of John Rileagh, of JR Components, in preparing these notes on the ETI 140 DFM is greatly appreciated.