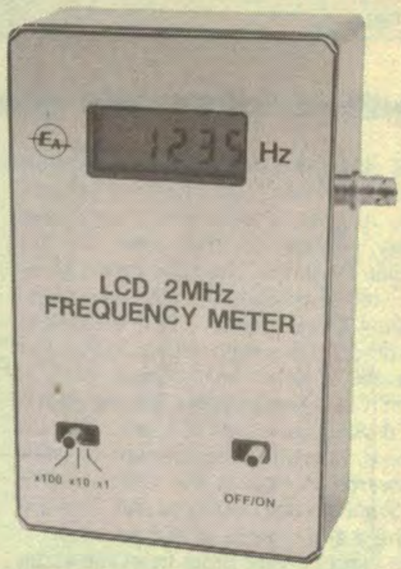
2MHz 4½-digit frequency meter



Featuring a 4½-digit LCD, this new digital frequency meter (DFM) is battery powered and can measure frequencies up to 2MHz. It uses the LCD Event Counter described last month and is easy to build and get going.

by JOHN CLARKE and GREG SWAIN

At the heart of this new design is the 4½-digit LCD Event Counter described last month. By adding the simple module described in this article, you get a compact 2MHz DFM that should set you back no more than about $60. At that price, there's no excuse for not adding a DFM to your test equipment range.

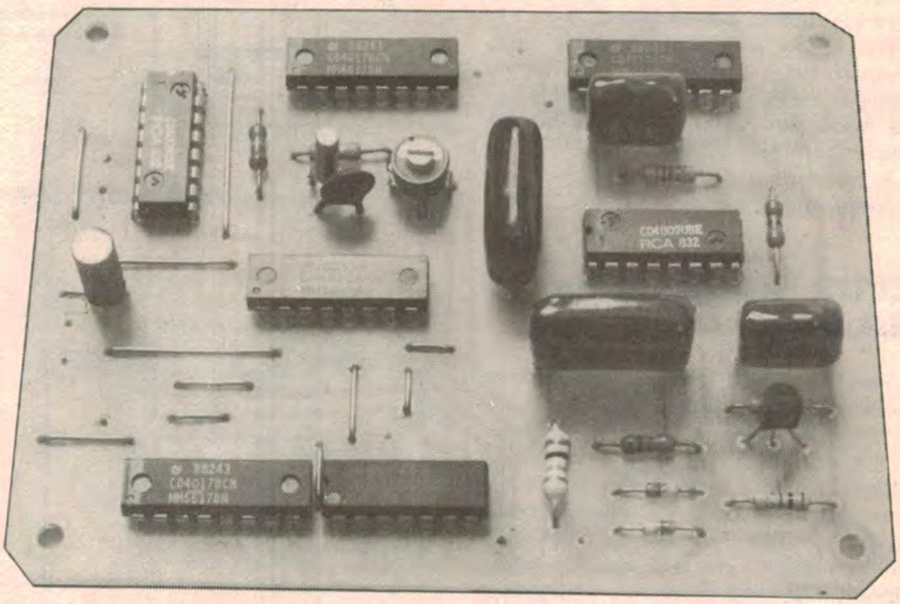
On board the add-on module is an input preamplifier and prescaler stage, a timebase, and housekeeping circuitry to provide the reset and store (latch enable) signals required by the counter module. This circuitry is all contained on a separate printed circuit board (PCB) and is housed together with the event counter module in a low-cost plastic zippy case. Power is supplied by four 1.5V penlite batteries.

As can be seen from the photograph, there are just two front panel controls: a power on/off switch and a range switch. In addition, the front panel carries the 4½-digit LCD, while the BNC input socket is mounted on one side of the case.

The range selector switch has three positions: 0-19.999kHz (x1), 0-199.99kHz (x10), and 0-1999.9kHz (x100). On the first range, measurements can be made with 1Hz resolution, while the second and third ranges have a resolution of 10Hz and 100Hz respectively. Other features include leading zero blanking, a 2s update time, and a sensitivity of around 200mV p-p from 20Hz to 2MHz.

Power consumption is fairly modest at less than 10mA. This is well within the capabilities of the battery pack (4x1.5V) and should give about 200 hours of continuous operation.

Before moving on to the circuit description, we should point out that this design in no way supersedes the 500MHz DFM described in December 1981. Its specifications are much too modest for that. Rather, it is intended as a low-cost alternative for readers who don't need to measure frequencies above 2MHz and who don't need to make period measurements.



This add-on module contains the input preamplifier and timebase circuitry.

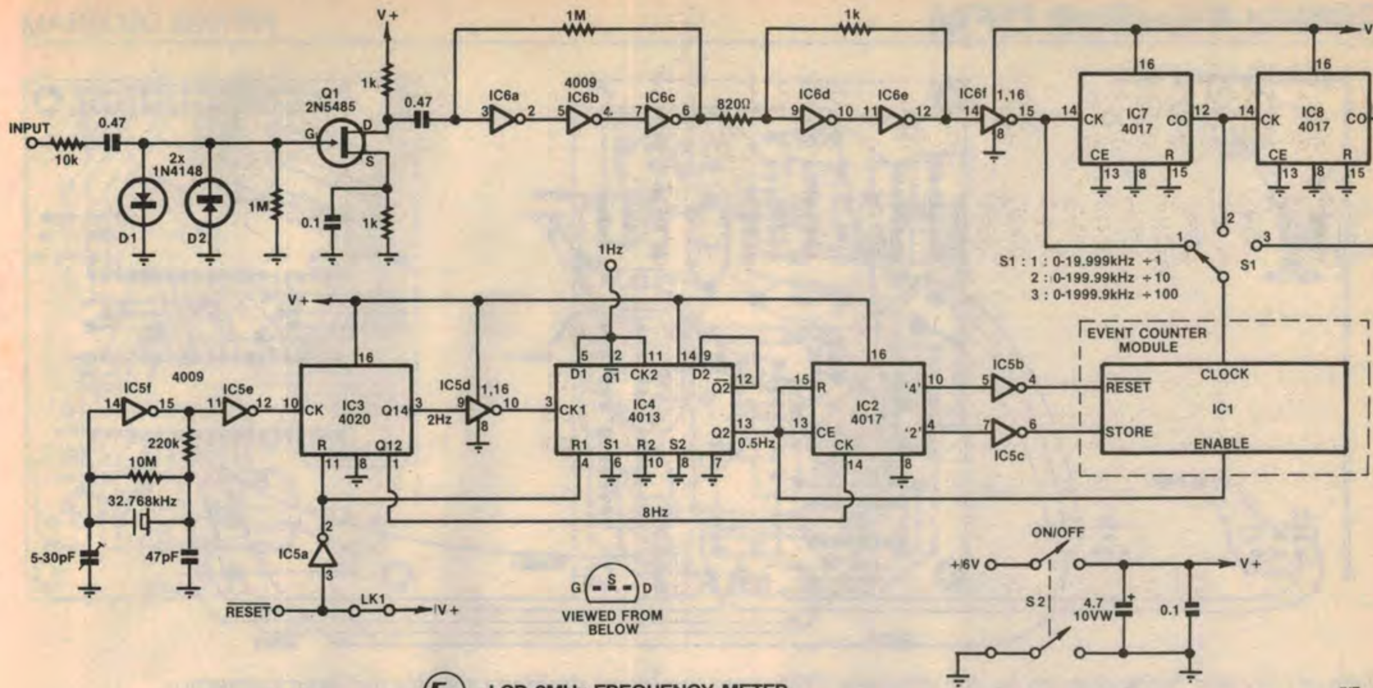
But despite its modest frequency range, the new unit will be quite adequate for many hobby applications. In particular, it will find application with audio circuitry, broadcast band AM receivers, and digital logic circuitry where frequencies of less than 2MHz are involved.

How it works

The circuit can be broadly divided into three sections: the event counter module (IC1); the input preamplifier and prescaler stage (Q1, IC6, IC7 and IC8); and the timebase and housekeeping circuitry (IC2-IC5). We dealt with the counter module in some detail last month, so we'll deal only with the additional circuitry for the add-on module.

Let's look at the input preamplifier and prescaler circuitry first. The input signal is coupled in via a 0.47μF capacitor and series 10kΩ resistor and fed to the gate of Q1, a FET buffer stage. Together with diodes D1 and D2, this input circuit clips the input waveform to 600mV amplitude to prevent damage to the preamplifier.

Q1 is a 2N5485 VHF FET arranged in common source configuration and with its gate connected to ground via a 1MΩ resistor. This resistor sets the input impedance to 1MΩ except for signals greater than 600mV p-p when the input impedance drops to 10kΩ. The 1kΩ



LCD 2MHz FREQUENCY METER

7/F

SPECIFICATIONS

RANGES: 0-19.999kHz; 0-199.99kHz; 0-1999.9kHz
SENSITIVITY: 200mV p-p from 20Hz-2MHz
INPUT IMPEDANCE: 1MΩ for signals less than 600mV p-p; 10kΩ for signals greater than 600mV p-p
RESOLUTION: 1Hz on x1 range; 10Hz on x10 range; 100Hz on x100 range
UPDATE TIME: two seconds
POWER REQUIREMENT: 6VDC, 10mA

source and drain resistors, together with the 0.1μF bypass capacitor, set the gain to around unity.

So Q1 functions merely as an input buffer stage with unity gain. Its output is taken from the drain and AC-coupled to a 4009 CMOS inverter chain (IC6). The first three gates, IC6a-IC6c, function as a gain block, while IC6d and IC6e are connected as a Schmitt trigger.

Note the 1MΩ resistor between the pin 3 input and the pin 6 output of the gain stage. This biases pins 3 and 6 to half supply – ie, to 3V – thus allowing IC6a-IC6c to operate in the linear mode. The gain of this stage is about 25 at 2MHz and is determined by the characteristics of the inverter gates.

Schmitt trigger IC6d and IC6e squares up the waveform from the gain stage and feeds it to buffer stage IC6f. Positive feedback for the Schmitt trigger is via a 1kΩ resistor which gives a hysteresis of 4.92V for a 6V supply. The value of this feedback resistor has been kept low so that the Schmitt trigger will operate satisfactorily to 2MHz.

Because the display only has 4½ digits, it is necessary to divide the input signal by 10 or 100 if we want to measure signals to 2MHz. This task is performed by a prescaler circuit consisting of two 4017 decade counters, IC7 and IC8. As can be seen from the circuit these two ICs are interconnected in a ripple clocking mode, ie. the carry output (CO) of IC7 is connected to the clock input (CK) of IC8.

IC7 thus divides the signal on its clock input by 10, while IC8 provides further division by 10 to give the divide-by-100 output. Switch S1 selects either the divide-by-one, divide-by-10 or divide-by-100 output and feeds the signal to the clock input of the counter module (IC1).

Timebase circuitry

Clock signals for the 2MHz DFM are derived from a single "pi-network" oscillator consisting of a 32.768kHz crystal and CMOS inverter IC5f. The 10MΩ feedback resistor biases the inverter in the linear mode so that it operates as a high gain amplifier, while the 220kΩ resistor presents the correct load to the crystal. A 5-30pF trimmer capacitor is provided to compensate for the frequency tolerance of the crystal.

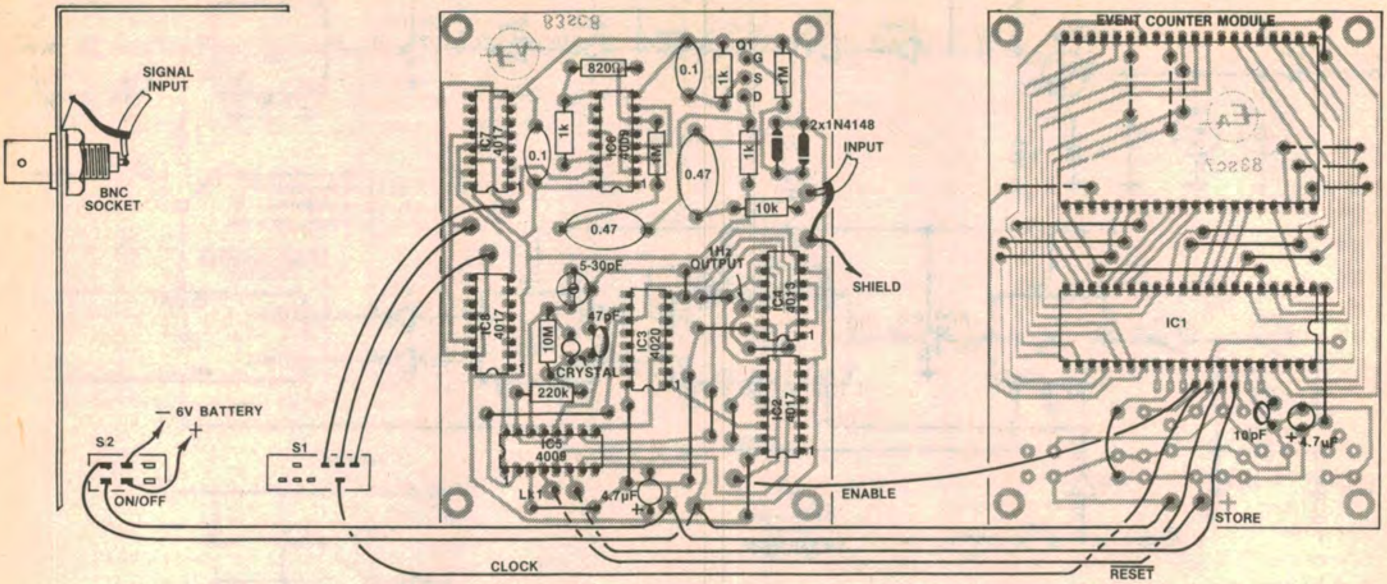
The 32.768kHz crystal is a miniature type commonly used in digital wrist watches. It was chosen because 32.768kHz is an easy frequency to divide and because the CMOS oscillator will operate at this low frequency from a 6V supply rail.

Three different pulse trains are derived from the timebase by the housekeeping circuitry to control the counter module: one second pulses for gating (enable), and 125ms pulses for store and reset. The enable pulse gates through the incoming frequency to the counters, the store pulse transfers the data from the counters to the output latches, and the reset pulse resets the counters to zero. Let's look at this in detail.

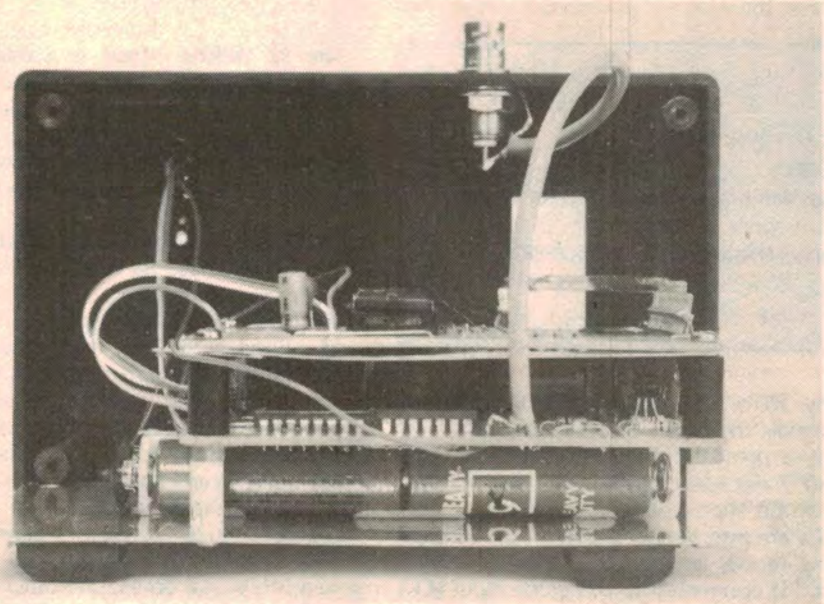
IC3 is a 4020 14-stage ripple carry binary counter that divides by 2^{14} to give a 2Hz signal on its Q14 output. This signal is buffered by inverter IC5d and fed to the clock input (CK1) of a 4013 dual D flipflop (IC4). Similarly, an 8Hz signal is derived from IC3's Q12 output and clocks IC2, a 4017 decade counter with 10 decoded outputs.

Dual D flipflop IC4 divides the 2Hz signal from IC5d by four, the resulting 0.5Hz signal appearing at its Q2 (pin 13) output. This signal is applied to the clock enable and reset pins of decade counter IC2, and to the enable input of the counter module. Gates IC5b and IC5c invert the "2" and "4" outputs of IC2 to provide the correct logic sense for IC1.

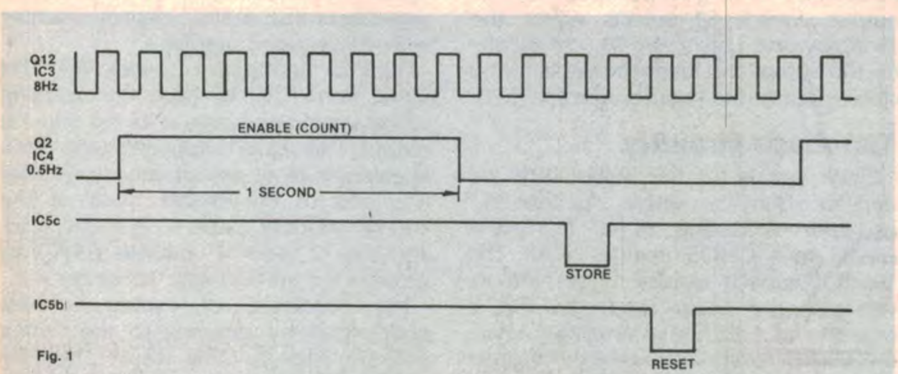
The sequence of events is best understood by referring to the timing diagram (Fig. 1). This shows the 8Hz clock waveform from Q12 of IC3, together with the three housekeeping signals; enable, store and reset. IC4



Parts overlay and wiring diagram for the complete DFM. Note the use of shielded cable for the input connection.



This view shows how the two PCBs are mounted on the lid of the case. Note the cardboard insulator and aluminium shield directly beneath the display PCB.



The complete measurement cycle takes two seconds.

generates the enable pulse, while the 8Hz waveform clocks IC2 to generate the store and reset pulses.

The basic measurement cycle takes two seconds. In the first second, the 0.5Hz output of IC4 goes high, resetting IC2 and gating through a one second burst of input signal to the counter (enable high). The output of IC4 then goes low, halting the counter operation and enabling IC2.

IC2 is now clocked by the 8Hz waveform from IC3. After a period of some 312.5ms, the "2" output (pin 4) goes high and a 125ms negative going pulse is delivered by IC5c to the store input of the counter. This pulse transfers the BCD count to the output latches to update the liquid crystal display.

Finally, 125ms later, the "4" output of IC2 goes high for 125ms and is inverted by IC5b to give the reset pulse. The measurement cycle is then repeated.

Note that it is necessary to slightly modify the event counter so that it can be used in the DFM. In particular, it is necessary to alter the circuitry associated with the clock, reset, store and enable inputs. The wiring diagram accompanying this article has the full details.

Note also that the event counter can be converted to operate as a seconds counter by connecting the 1Hz output from Q1 of IC4 directly to the clock input. In addition, link LK1 will have to be deleted and pin 3 of IC5a connected to the reset pin of the counter module to provide the reset function. The count may be stopped by using a momentary contact pushbutton switch circuit on the enable input, exactly as for the reset input (ie, switch plus 1MΩ resistor plus .027µF capacitor).

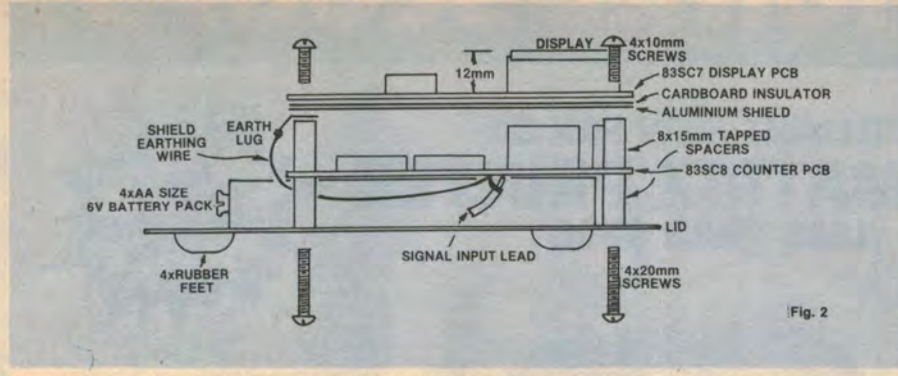


Fig. 2

Don't forget to earth the aluminium shield to the signal input earth.

Construction

The preamplifier/timebase circuitry is built on a small printed circuit board (PCB) coded 83sc8 and measuring 78x102mm. Before commencing assembly, carefully check the copper side of the PCB and repair any faults that may be evident. This done, assemble the PCB according to the parts layout diagram.

The ICs are all CMOS devices and should be left until last. Take care to ensure that the ICs are inserted the right way round, and solder the supply pins (7 and 14 or 8 and 16) first. Similarly, check that the FET, diodes and electrolytic capacitor are all mounted with the correct polarity. The crystal may be soldered in either way round.

The completed PCB may now be wired to the counter module using short lengths of rainbow cable (see wiring diagram). At this stage, you should also solder short lengths of hook-up wire to the 83sc8 module for ultimate connection to switches S1 and S2. Although not strictly necessary, some readers may prefer to use PC stakes to make the job of wiring easier.

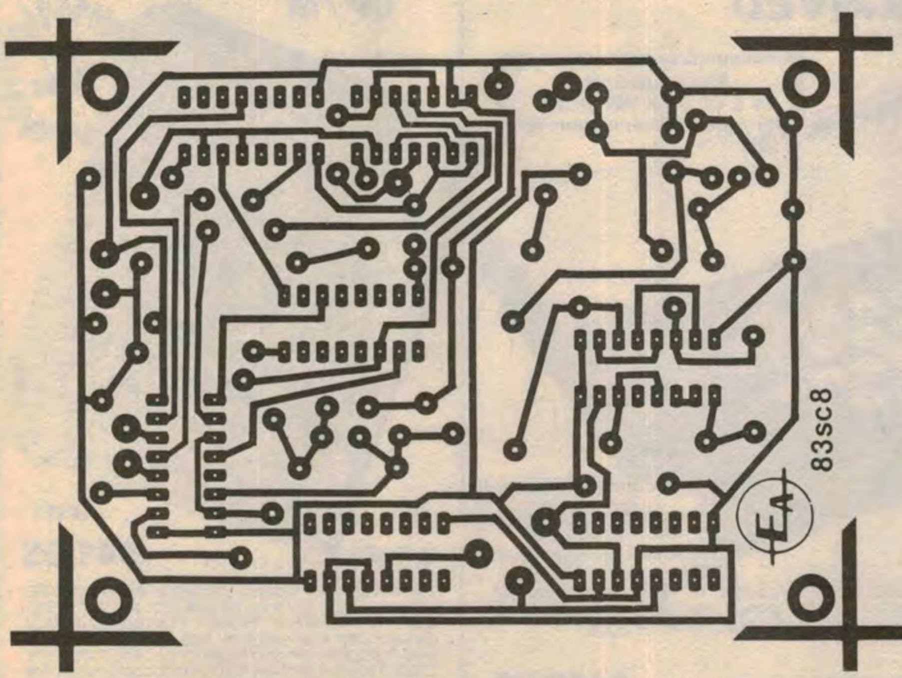
A plastic zippy case measuring 50x95x158mm is used to house the circuitry, and is fitted with a Scotchcal front panel label. Spray the label with a hard-setting lacquer (eg, Estapol), then carefully affix the label to the plastic base of the case (NOT the lid). The front-panel cutouts can now be made by drilling inside the marked lines with a small drill and then filing for a neat finish.

You will have to make three cutouts in all – one each for the range switch and the on/off switch, and one for the display. You will also have to drill mounting holes for the switches, and for the BNC input connector. The latter is mounted on the bottom right hand side of the case, as shown in the photographs.

Now for the final assembly. The two PCBs are stacked and mounted on the aluminium lid of the case using 15mm tapped spacers. Fig. 2 shows how it all goes together. Note in particular the earthed aluminium shield and the cardboard insulator directly beneath the 83sc7 display PCB.

The aluminium shield is necessary to prevent radiation from the 83sc8 module from falsely triggering the high impedance counter circuitry. Don't forget to earth the shield as shown in Fig. 2.

The PCB assembly must be accurately positioned on the lid so that, when the case is assembled, the LCD sits directly



Above is the actual-size artwork for the preamplifier/timebase PCB.

PARTS LIST

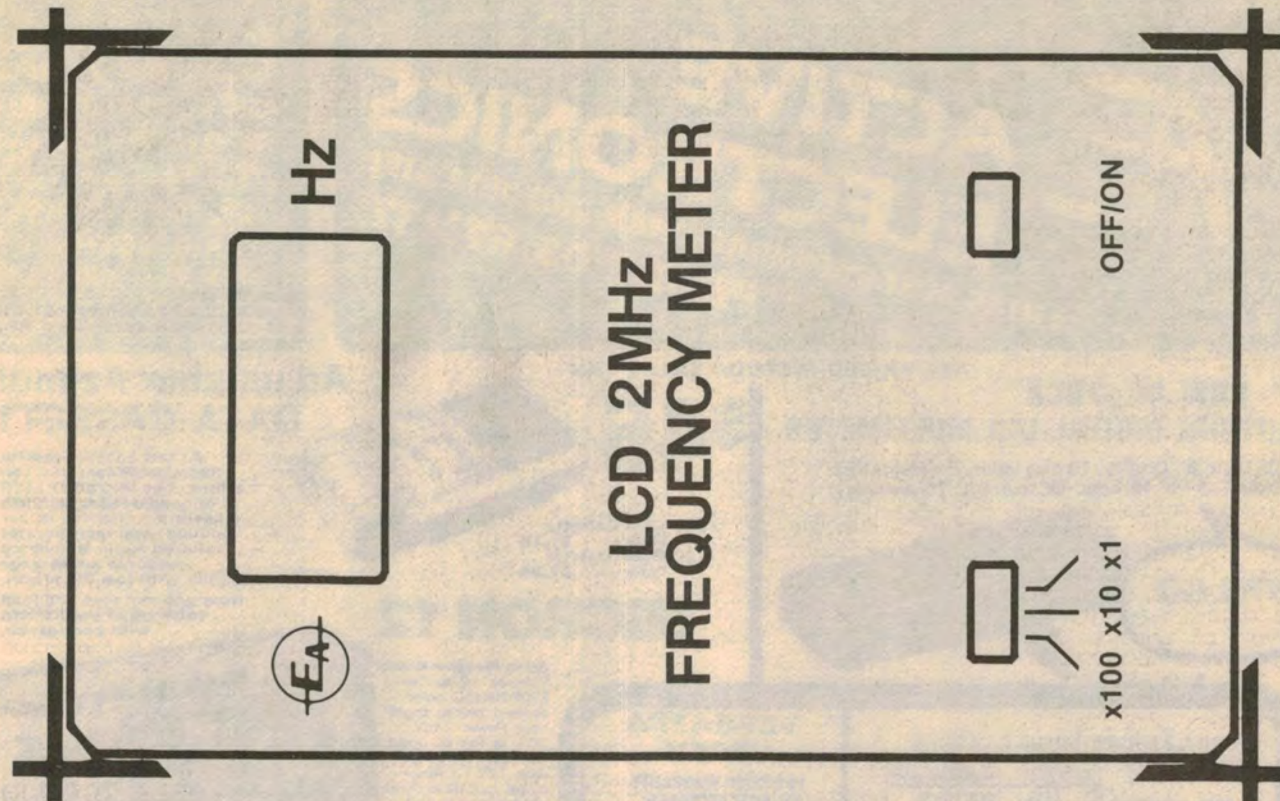
1 printed circuit board, code 83sc7, 78x102mm
1 printed circuit board, code 83sc8, 78x102mm
1 plastic utility box, 50x95x158mm
1 Scotchcal front panel label, 94x156mm
1 piece of aluminium sheet, 78x102mm
1 piece of cardboard, 78x102mm
1 battery clip
1 4-way AA battery holder
4 1.5V size AA batteries
1 DP3W slider switch (single pole used)
1 DPDT slider switch
1 watch crystal, 32.768kHz
1 BNC panel socket
1 40-pin DIL socket
1 48-pin Molex IC socket strip
1 4½-digit liquid crystal display (Dick Smith Catalog No. Z-4175 or equivalent)
4 stick-on rubber feet
8 15mm tapped brass spacers
4 20mm machine screws
4 10mm machine screws
1 earth lug

SEMICONDUCTORS
2 1N4148, 1N914 small signal diodes
1 2N5485 N-channel FET
1 74C946 or ICM7224 4½-digit counter/display driver
1 4020 14-stage ripple carry binary counter
3 4017 decade counters
1 4013 dual D-flipflop
2 4009, 4049 hex inverters

CAPACITORS
2 4.7µF/10VW PC electrolytic capacitors
2 0.47µF metallised polyester
2 0.1µF metallised polyester
1 47pF ceramic
1 10pF ceramic
1 5-30pF miniature trimmer

RESISTORS (¼W, 5%)
1 x 10MΩ, 2 x 1MΩ, 1 x 220kΩ, 1 x 10kΩ, 3 x 1kΩ, 1 x 820Ω

MISCELLANEOUS
Tinned copper wire, solder, rainbow cable and shielded cable, machine screws and nuts, etc.



Here is an actual-size reproduction of the front panel artwork.

beneath the display cutout. Drill the four mounting holes, mount the PCB assembly in position, and then complete the wiring to the switches and to the battery connector. The battery holder is a snug fit between the lid and the lower PCB.

Testing

The display should be blanked when power is first applied due to the leading zero blanking feature. To test the unit, insert a short length of tinned copper wire into the BNC input connector and select the x100 range. The display should now show a high random reading when the wire is touched, the actual reading depending upon the frequency of the noise.

> We estimate that the current cost of parts for this project is approximately
>
> **$60**
>
> This includes sales tax.

The other two ranges can be checked in similar fashion.

If you have access to a signal generator, it may be used to give the DFM a final checkout. Calibration is not necessary, since the accuracy of the unit exceeds the resolution. The trimmer capacitor has been provided to allow accurate adjustment of the 1Hz output if required.

Finally, don't get caught out by the blanked display. Make sure that you always turn the unit off after use to ensure long battery life.