Digital Frequency Meter

Living by numbers? . . . do it digitally with this easy to build DFM.

WITH JUST A COUPLE of simple-to-operate controls, this project will enable you to measure and display frequencies from 20 Hz to about 2 MHz. The upper frequency limit is determined by the waveform of the input signal, the input amplifier and the performance of the particular chip used for IC3. As the CMOS chips used in this design have a better high-frequency performance with increasing supply voltage, a twelve volt supply was chosen and this can be simply provided with eight AA size cells; HP7s for example.

99999 = 1

Even a few years ago, a DFM like this unit would have been mains-powered with numerous boards and innumerable interconnections. Large scale integration, the same technology that has put microprocessors in almost everything, has changed all that and this project features a five digit readout with input amplifier, logic gating and counter all on one board. This saves you from having to worry about connecting displays and cascading discrete counter chips.

Most of the work is done by one chip which counts the input pulses and organises the display. Another chip takes the display data and drives the light-emitting-diode display while the remaining ICs provide an accurate counter "window" and gate the input signal.

The advantage of CMOS over conventional bipolar technology is low current drain and the whole unit uses less power than an ordinary torch bulb. Many more

The HE Digital Frequency Meter hooked up to our workshop signal generator and oscilloscope for calibration

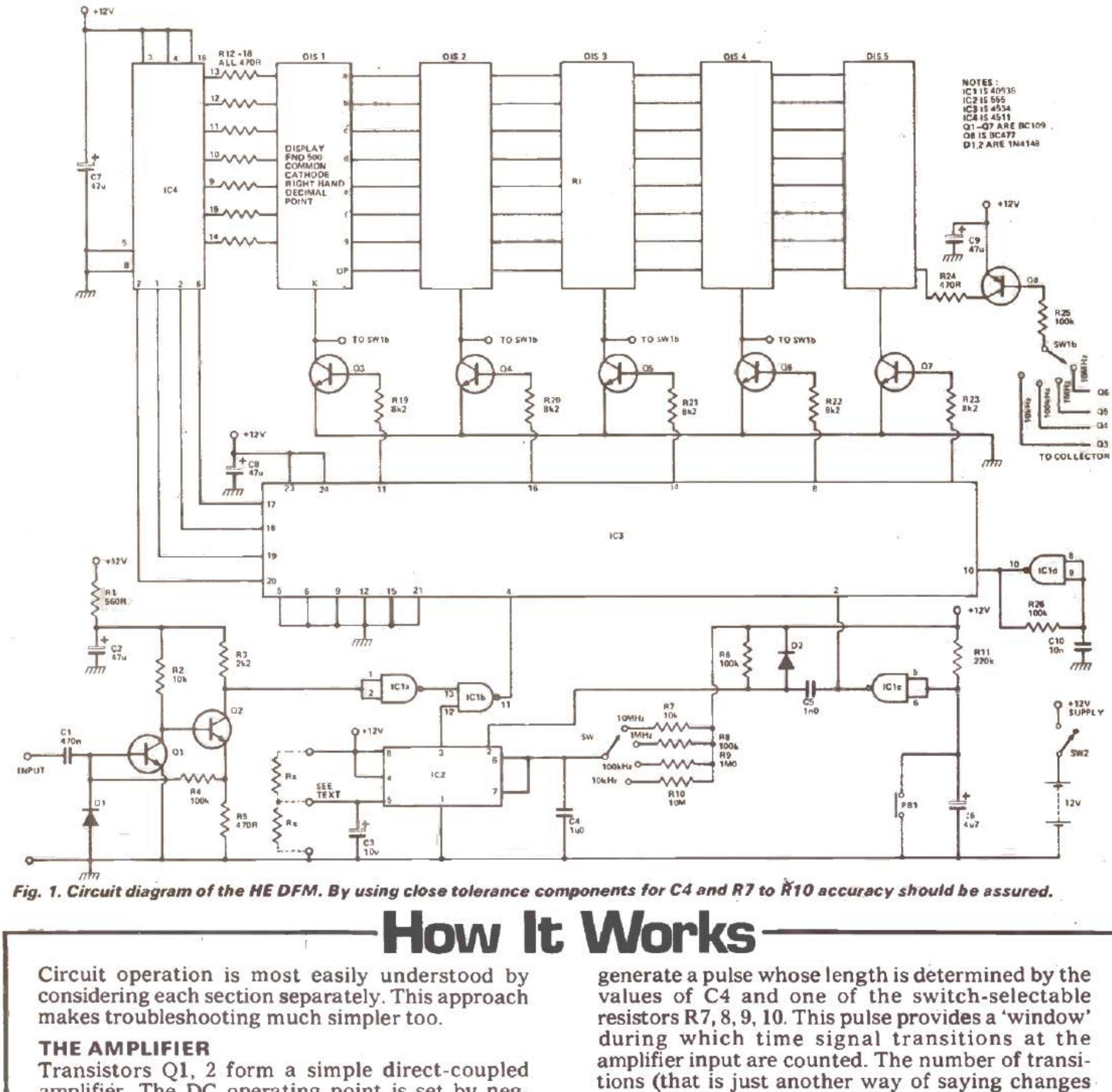


Fig. 1. Circuit diagram of the HE DFM. By using close tolerance components for C4 and R7 to R10 accuracy should be assured.

How It Works

Circuit operation is most easily understood by considering each section separately. This approach makes troubleshooting much simpler too.

THE AMPLIFIER

Transistors Q1, 2 form a simple direct-coupled amplifier. The DC operating point is set by negtive feedback via R4. Input signals are capacitively coupled via C1. The value chosen gives good results between 20 Hz and 2 MHz. The amplified signal appears at Q2 collector where it is 'squared-up' by Schmitt trigger gate IC1a whose output dirves one input of IC1b. Components R1, C2 provide a smooth 'decoupled' supply for the amplifier.

THE COUNTER WINDOW GENERATOR

Input pulses are only allowed to reach the counter (pin 4, IC3) when the other input of IC1b is 'high'; ie at about twelve volts. The input is driven from a 555 counter, IC2, connected as a monostable multivibrator. This means that upon being triggered when the voltage at pin 2 drops below about one-third of the supply voltage, the chip will generate a pulse whose length is determined by the values of C4 and one of the switch-selectable resistors R7, 8, 9, 10. This pulse provides a 'window' during which time signal transitions at the amplifier input are counted. The number of transitions (that is just another way of saying changes from one level to another) in a certain period; say a second, is expressed as the frequency of the input waveform. This means that a frequency of 50 Hz is just a way of saying that there are fifty cycles of change in one second of time. A cycle is a change from positive to negative and back again. By changing the counter window length, we can provide our frequency meter with different ranges. This circuit generates a window of ten secs., one sec., one tenth sec., or one hundredth sec. depending on the choice of resistor R10 to R7; giving a full scale measurement from 9.9999 kHz to 9.9999 MHz.

A novel feature of the 555 chip used in this design is its ability to provide a large range of output timing periods with good accuracy. Using a polyester capacitor for C4 and close tolerance resistors

How it Works

for R7 to R10, the timing intervals obtained will be very close to ten times multiples of each other. This means that if the circuit can be accurately set up on one range then the other ranges will fall into line automatically. Fortunately the 555 has another trick up its sleeve as the timing period, even with fixed values of R and C, can be varied considerably by use of the control input, pin 5.

With the unit set to the lowest range, a 50 Hz signal from the low voltage output of a transformer (say 6 or 9 volts) may be applied to the input via a resistor (about 1 MO should do). After depressing and releasing PB1, the display should flicker as the unit counts until a steady number is displayed. The mains frequency is 50 Hz but the display will probably read 55 Hz or so. A resistor 'Rx' should now be connected between 'C' and 'N' and a new reading taken. Different values of resistance should be tried until the display indicates 50 Hz (0.0500) or at least something close. Don't be surprised if a slightly different reading is obtained even with the same value of resistance for Rx. We found a value of 56 k was about right. If a value less than 10 k is required then C4 should be replaced. In the unlikely event that the display reads less than 50 Hz then the resistor should be connected between 'C' and 'P'. Any value down to 4 k7 may be used. Once one range is calibrated, the accuracy of the other ranges will depend on the tolerance of resistors R7, 8, 9, 10. Capacitor C3 prevents noise from upsetting things at the control input.

COUNTER AND TRIGGER

Depressing PB1 causes the output of IC1c to go high to a logic '1' resetting the counters in IC3. When PB1 is released, C6 charges via R11 and IC1c output goes low removing the rest signal from IC3 and triggering the monostable IC2 which enables gate IC1b to pass signals to the counter input (pin 4, IC3). IC3 contains five decade counters which means that it can count up to 99,999 before 'overflowing' and starting again from zero. The output of each stage is presented in binary-coded-decimal form on pins 17, 18, 19, 20. Each stage uses all four pins but only one stage at a time is connected to them. Simultaneously, one of the digit driver outputs goes high corresponding to the stage whose value is being output. The binary-coded-decimal signals are converted to drive a seven-segment display by IC4 and the appropriate digit is enabled by Q3 to Q7 driven from the digit driver outputs pins 11, 16, 14, 8, 7. The decimal point is driven from Q8 which is turned on at the appropriate time by controlling it from the digit driver transistors via SW1b. The technique of using a few pins to carry many signals at different times is known as multiplexing. The multiplexer circuitry inside IC3 needs to be driven by an external clock and this is provided by IC1d which, with R26 and C10, oscillates at about 700 Hz. (Try using the meter to check this after you have built it!) The exact frequency is not important. Resistors R12 to R18 and R24 serve to limit current flow in the display driver and the LED displays. Do not be surprised if the resistors feel a little warm. They dissipate about 200 mW and this is quite normal.

The 47μ capacitors dotted around the circuit help to prevent interaction between different stages and are deliberately sited close to individual chips and transistors.

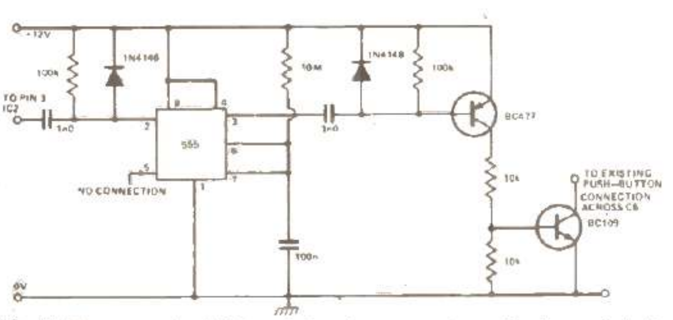
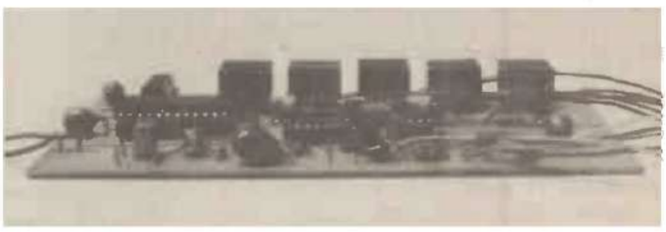


Fig. 2. Suggested additional circuitry to perform "auto update" on DFM.

sophisticated units of this type use a crystal oscillator and divider chain to provide accurate timing (just like in your digital watch). As this would have added considerably to the cost of the project an analogue technique based on the ubiquitous 555 timer chip has been used. This is not too much of a problem as the 555 is capable of providing accurate and repeatable time delays set by choice of just one resistor and capacitor and a simple technique is outlined in "how it works" for calibrating all four ranges.

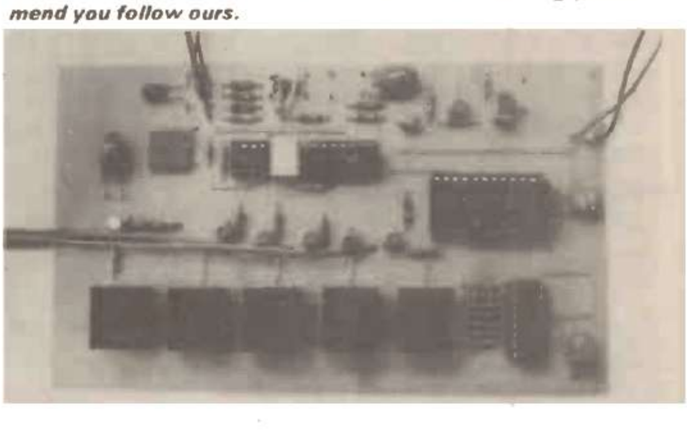
CONSTRUCTION AND USE

If you are confident of your ability to handle CMOS and make the many interconnections required then almost any constructional technique may be used. However, we



Above. Side view of the DFM. By keeping a low profile it's easier to mount the unit in its box.

Below. Although the layout is not critical we strongly recommend you follow ours.



Parts List

RESISTORS (All ½W 5%)

R1	560R
R2	10k
R3	2k2
R4, 6, 25, 26	100k
R5, 12 to 18, 24	470R
R7	10k
R8	100k
R9	1M0
R10	10M
R11	220k
R19 to 23	8k2
Rx	See text

(Resistors R7 to R10 will effect the accuracy and stability of the DFM. Use two per cent resistors if you can obtain them. Otherwise, use whatever you can get — the circuit will still work).

CAPACITORS

C1	470n ceramic
C2, 7, 8, 9	47µ tantalum
C3	10µ tantalum
C4	1µ0 polycarbonate
C5	1n0 ceramic
C6	4µ7 tantalum
C10	10n ceramic

SEMICONDUCTORS

IC1	4093B
IC2	555
IC3	4534
IC4	4511B
Q1 to Q7	BC109
Q8	BC477
D1, 2	1N4148
DIS 1 to 5	FND500

common-cathode seven-segment LED displays.

MISCELLANEOUS

PB1 push-button switch SW1 2 pole — 4 way
SW2 SPST

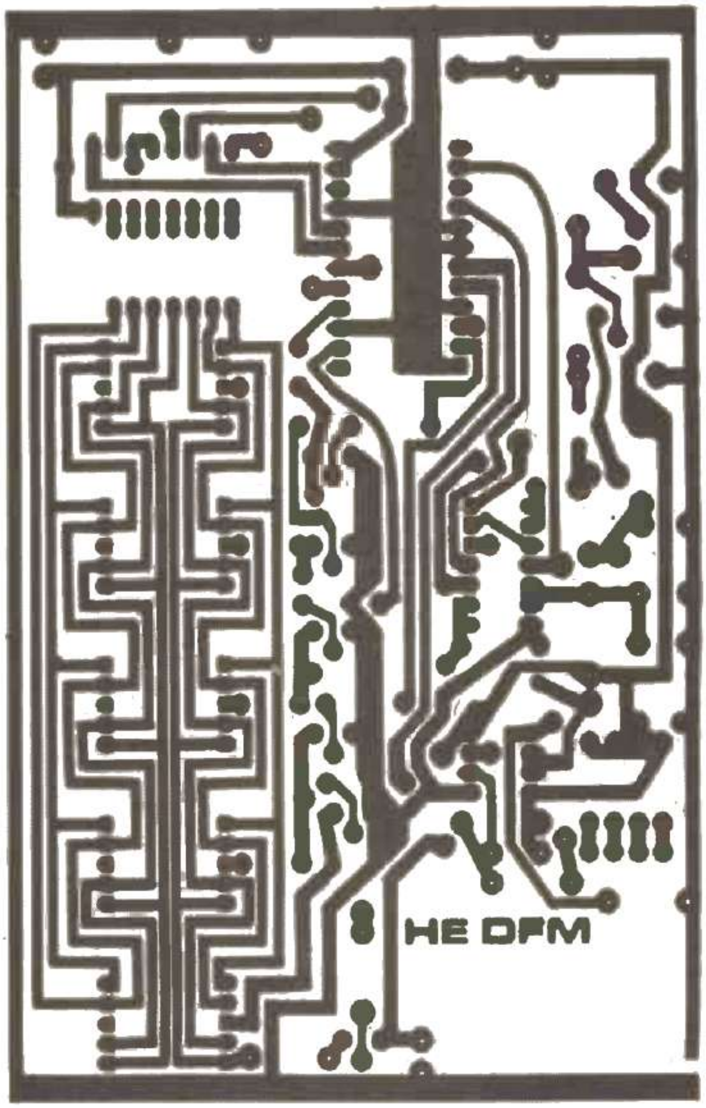


Fig. 3. PCB foil pattern for DFM.

Buylines

Most of the components are fairly ordinary and should be available from the usual mail-order suppliers. The specified LED displays and IC3 are available from Technomatic.

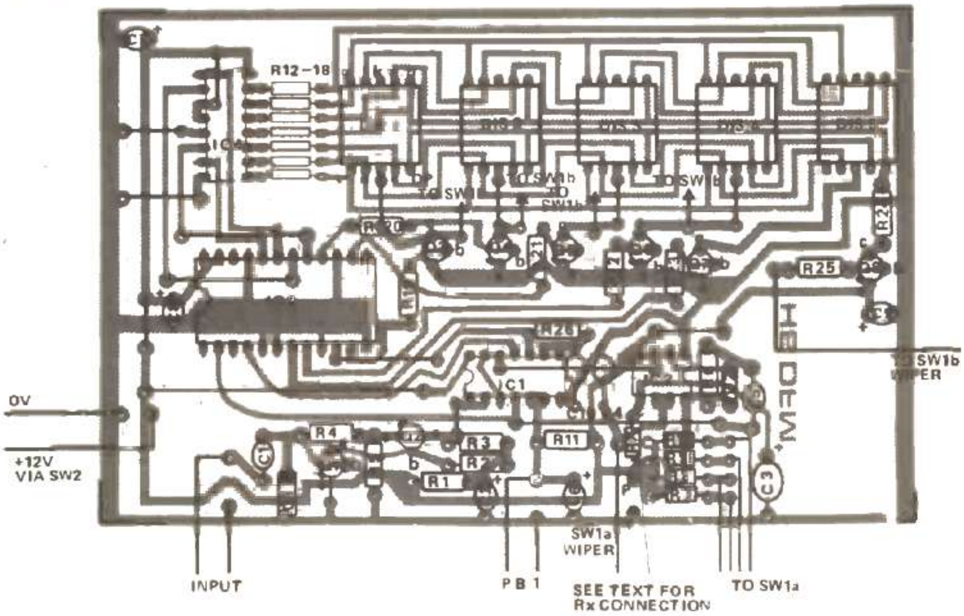
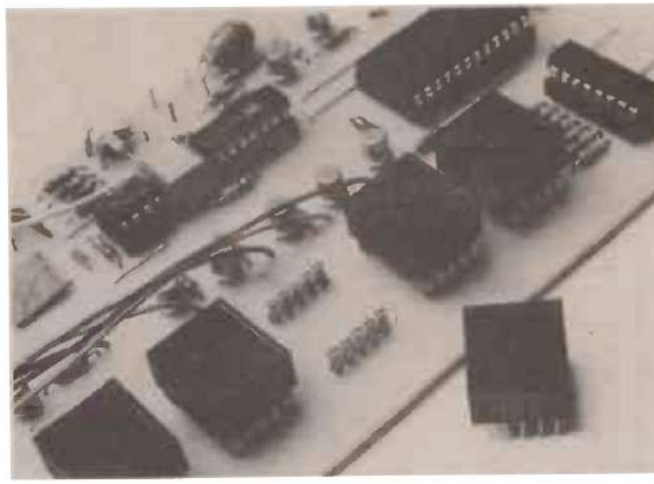


Fig. 4. Overlay diagram, we suggest you use sockets for all IC's. Note that the capacitors C2, C6, C3 are bent flush to the PCB to enable the board to fit neatly in its case.

strongly recommend that our PCB design is used as this will cut down the chance of any error creeping in.

If you do use a PCB then construction is quite straightforward. There are sixteen wire links to make and these should be inserted first as they pass beneath many of the other components. Use an insulated link for the connection between IC2, pin 3 and IC1, pin 12 to avoid a possible short circuit to C4. The other components may be inserted almost as they come to hand although it helps to have some kind of system to facilitate checking. The best course is to follow the parts list; resistors first followed by capacitors and finally the semiconductors. This technique minimises the chance of overheating the semiconductors though modern silicon devices are fairly hardy anyway. We usually use IC sockets; avoiding handling problems and enabling the chips to be re-used or replaced if they fail. The LED displays may be soldered to the PCB or "soldercon" pins can be used. These are do-it-yourself IC sockets which are supplied in strip-form. You just break off as many as you need; in this case five, solder them into the board then break off the unwanted metal carrier strip at the top of the pins by grasping it with a pair of pliers and repeatedly flexing it back and forth. The displays should be mounted so that the decimal point is facing away from the nearby edge of the board. In fact the displays will still work if you put them in back to front but you will see some pretty funny numbers!

There are few connections to make to the board and the only ones which need special care are those to SW1. These should be arranged so that when one section is connected to R7, the other section connects with the collector of Q6 and so on as the ranges are selected. This gives a display reading directly in kilo-Hertz with a moving decimal point so each range is selected and facilitates reading the display.



One of the display units removed from its socket. Note C2 and C6 are mounted flush to the board.

In use, the highest range should be used first and then lower ranges selected as required. This avoids false readings as the counter overflows. The unit is quite sensitive and will tolerate many waveforms though it becomes fussier on the highest range, preferring a sinusoidal waveform. The basic design will only update the display following a depression of PB1. Included here is a simple update circuit which you can add if you like. It works by imitating the action of depressing PB1 electronically about one second after the display has settled. Any method of construction may be used for this little circuit and there shouldn't be much difficulty in making the required connections to the main board.

Whichever way you build it, this project will provide you with an economical piece of test gear — off the shelf and made to measure. **HE**