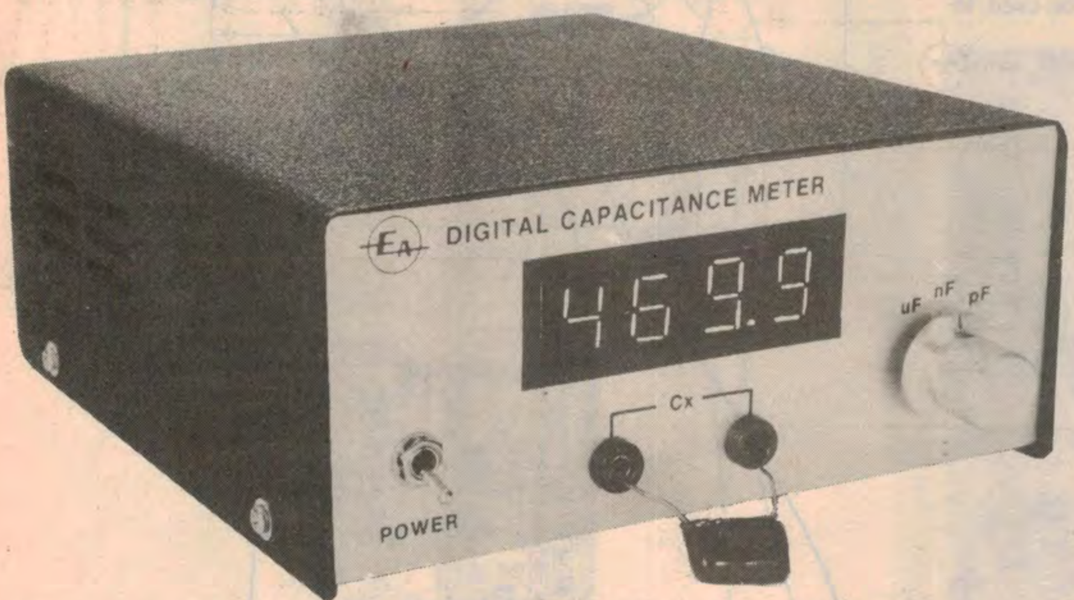
Build this digital capacitance meter



- ☆ Easy to build
- ☆ 4 digits
- ☆ LED display
- ☆ Measures 1pF-99.99uF

Here is an inexpensive digital capacitance meter which measures from 1pF to 99.99uF in just three ranges. It's simple to use and features a big bright four-digit display with automatic updating and decimal points.

by RON DE JONG

We have described quite a few capacitance meters in the past, the last one published in January 1979 proving to be quite popular. It was a simple analog meter and gave good performance at low cost. Considering the success of that project, we have taken the next "logical" step and developed an up-to-the-minute digital capacitance meter.

Our new capacitance meter uses only five ICs and has a large four-digit LED display. There are three ranges with full scale readings of 9999pF, 999.9nF and 99.99uF with over-range available on each. This means that capacitance measurements can be made over the range from one picofarad to beyond 100 microfarads. No adjustments are necessary to make a reading: just connect the capacitor, select the range and there is the reading — bright and clear.

It is certainly simpler to operate than a conventional impedance bridge but also has the advantage over both bridges and conventional analog meters in that it will accurately measure capacitance down to one picofarad directly. This is possible because of the internal "nulling" circuitry which cancels the effect of any stray capacitance between the test terminals or test leads, so when you measure a 5pF capacitor it will display 5pF! In this respect it also has the advantages of the more complex "probe" type capacitance meters used for in-circuit capacitance measurements.

With features like these our digital capacitance meter should be invaluable to experimenters and even professionals. It is a simple matter to sort capacitors even if they have no markings or the markings are difficult to decipher. This can be the case with capacitors which use colour codes, etc, or tuning and trimmer capacitors which usually have no markings at all.

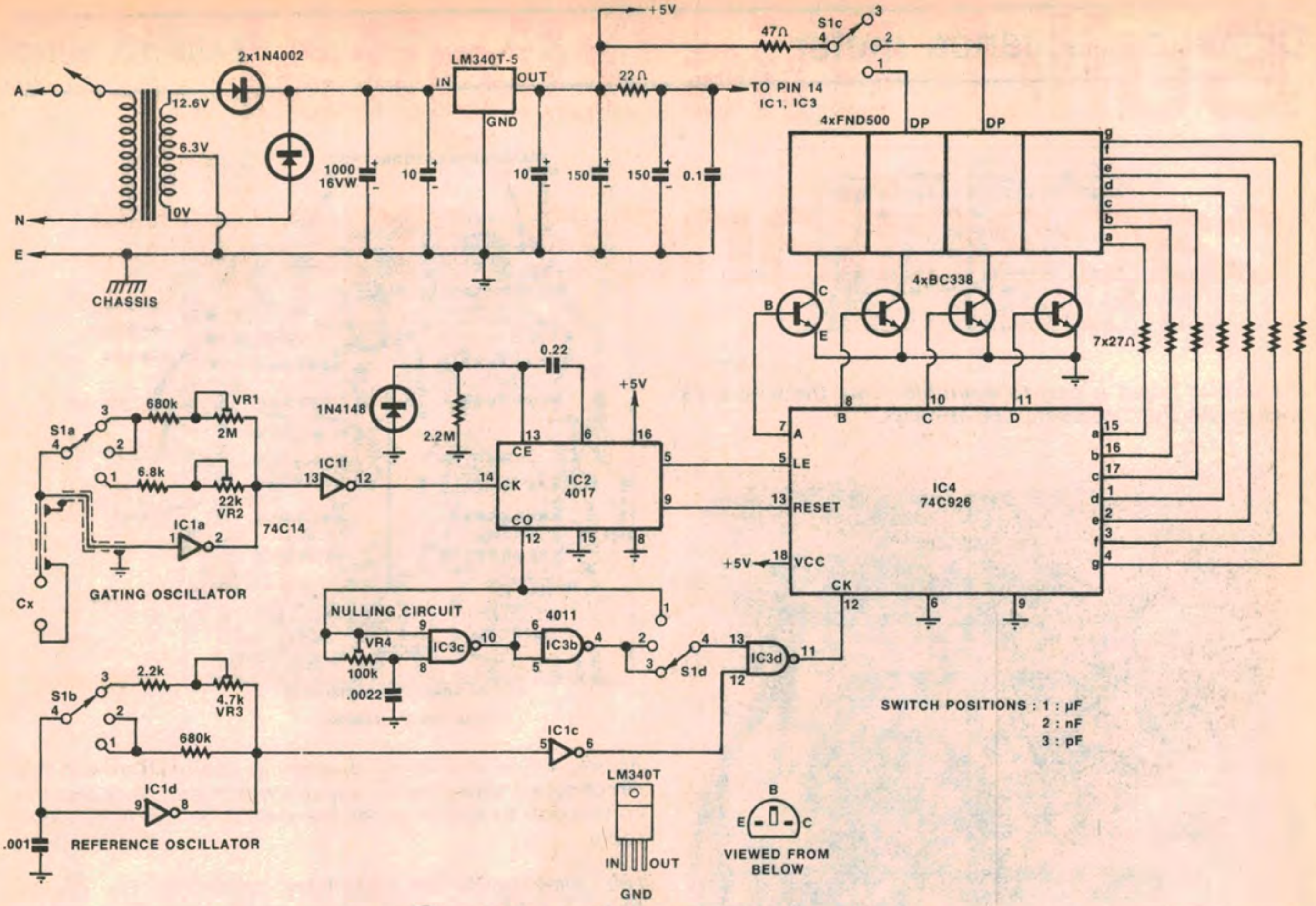
The capacitance of wiring and cables can also be readily measured. For example, it is often desirable to know the capacitance of shielded audio cable when connecting cartridges, since most cartridges usually have an optimum capacitive load.

Unlike conventional meters a digital meter offers high resolution; in this case, four digits. This means it is possible to select close-tolerance capacitors from a batch of low-tolerance units or to match capacitors for use in filters.

Last but not least our "DCM" also measures electrolytic and tantalum capacitors. The test terminals are actually polarised with a potential difference of about 3 volts between them, so electrolytics with voltage ratings of more than 3 volts can be readily measured.

To see how it all works, refer to Fig. 1. The heart of the whole meter is the "gating" oscillator which is actually a simple RC oscillator. The capacitor to be measured forms the "C" part of the oscillator so the period of oscillation will be proportional to the value of the capacitor. For example, a small capacitor will result in a relatively short period of oscillation while a larger capacitor will cause a correspondingly longer period.

The output pulses from the "gating" oscillator gate through a series of pulses from a reference oscillator which operates at a fixed frequency. With this arrangement, the number of pulses gated through to the following counter is proportional to the pulse length of the "gating" oscillator and hence the value of the capacitor being measured.



DIGITAL CAPACITANCE METER 7/CM/-

Just 5 ICs and 4 LED displays make up this accurate digital capacitance meter. Note that, for the sake of clarity, the components associated with S1a and S1b are not shown in the order that they appear on the PCB.

If the reference oscillator is set to an appropriate frequency then, the counter will actually display the capacitance value directly.

There is a little more to it than that, as reference to the circuit diagram will indicate. The two oscillators we've mentioned are IC1a, which is the "gating" oscillator and IC1d, which is the reference oscillator. Both are Schmitt oscillators in which switches S1a and S1b provide for appropriate range selection. The "gate" referred to in Fig. 1 is actually IC3d which is a 4011 NAND gate while the counter is IC4, a 74C926 CMOS IC.

The 74C926 is a four-decade counter which we have used before in other projects such as our digital frequency meter. As well as a four-decade counter, the 74C926 has latches, decoder drivers and internal multiplexing circuitry which drives a four digit LED display directly using four transistors. If conventional ICs were used in place of the 74C926, as many as 12 extra ICs would be required.

To make the 74C926 counter function properly, certain "housekeeping" signals are necessary, namely the "reset" and "latch enable" signals. The contents of the latches are used to drive the display so that the decade counters remain free to count up without affecting the display. When the count has to be displayed the "latch enable" signal goes high, transferring the contents of the counter to the latches. The purpose of the "reset" signal is to clear the counters, so that a new count cycle can begin.

These "housekeeping" signals must be generated in a particular sequence, together with the signal from the "gating" oscillator, IC1a. To do this, we have used a 4017 decade counter IC which has 10 decoded outputs as well as a "carry" output. Only one of the decoded outputs is on (high) at any given time. The "clock" signal for the 4017 is obtained from the "gating" oscillator, IC1a, so that the length of the pulses from each of the 10 decoded outputs is equal to the period of the clock signal.

The sequence of the housekeeping signals is as follows: First the gating signal arrives and the output from the

Fig. 1 (right): how the circuit works. Pulses from the reference oscillator are gated by the gating oscillator and fed to the counter circuit.

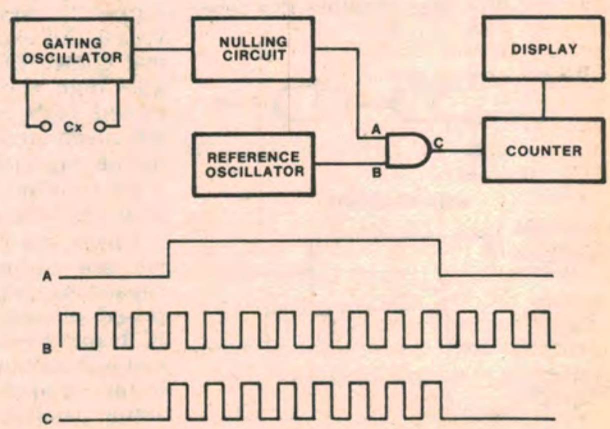
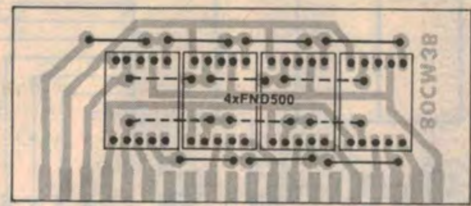
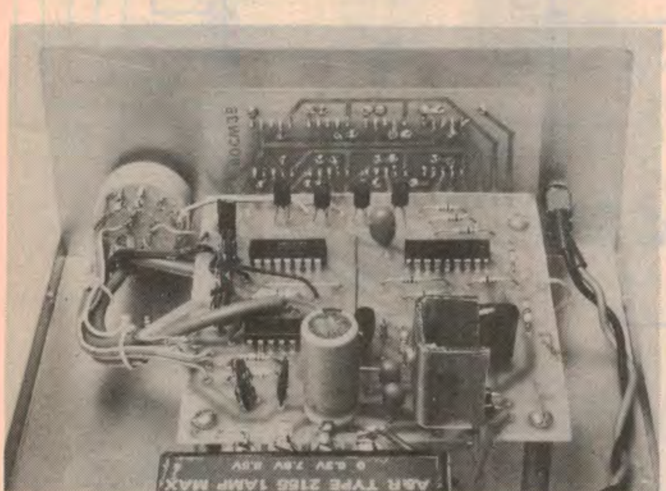
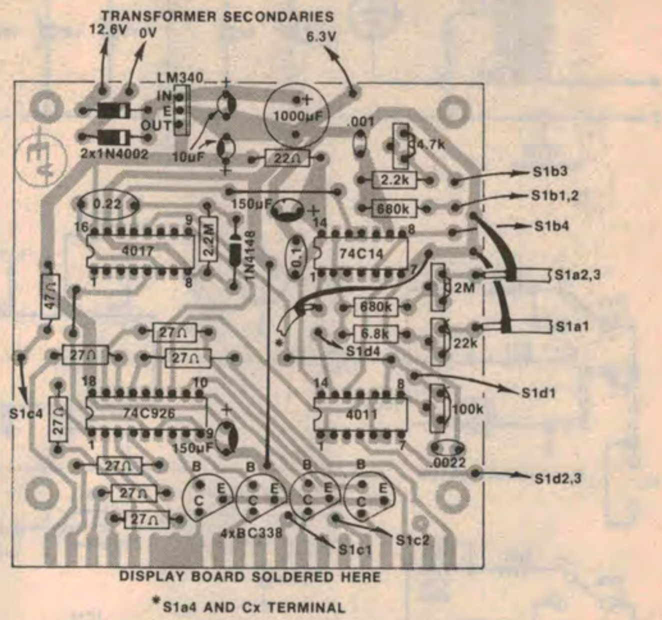


FIG. 1



The display board is easy to assemble. Note the wire links underneath the 7-segment LED displays.





Above: follow this wiring diagram in conjunction with the circuit when wiring up the capacitance meter. Note that the connection to switch wiper S1a should be run in shielded cable.

Left: view inside the completed prototype. The display board is soldered at right angles to the main PC board.

reference oscillator, IC1d, clocks up the 74C926 counter; as soon as the gating signal is finished the latch enable goes high and the contents of the counter are displayed (ie, the reading is updated); finally, the reset goes high, clearing the counter for the next cycle.

In practice, we have used the "carry" signal from the 4017 as the gating signal instead of using the output of the gating oscillator direct. However, this does not alter the principle of operation. The "carry" signal from the 4017 is high during the time the decoded outputs 0 to 4 are high, so the 74C926 is clocked during this period. The latch enable signal is the decoded "6" output from the 4017 (pin 5) while the reset signal is the decoded "8" output (pin 9).

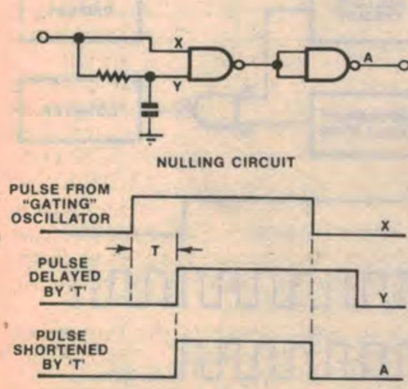


FIG. 2

Note that with this system there is a discrete clock period (ie, period of the gating oscillator IC1a) between each housekeeping signal, so that the circuit operates reliably and without "glitches".

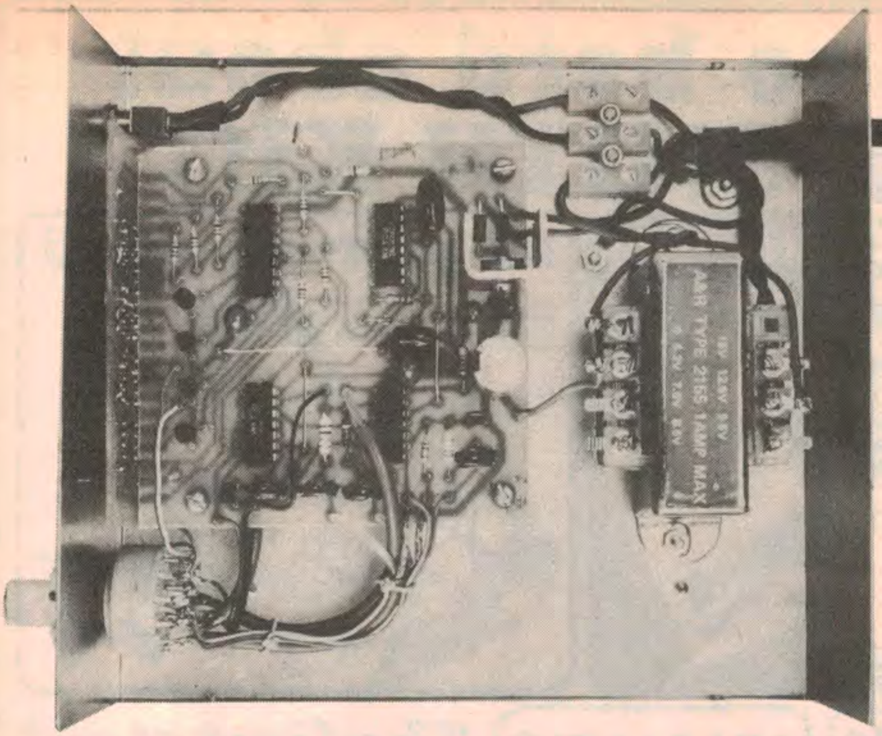
One point that emerges from the foregoing description is that the display will be updated at a rate given by the "gating" oscillator which can be quite rapid when small capacitors are being measured. To prevent the display from flickering as a result of this rapid updating, a half second delay is introduced by connecting the decoded output "7" to the clock enable (pin 13) via a 0.22uF capacitor. When in the normal course of events the "7" output goes high, the "clock enable" will be forced high, disabling the 4017 and effectively freezing the display. The 0.22uF capacitor is discharged via the 2.2M resistor. So about half a second later clocking commences again.

Finally, we can describe the feature we are quite proud of: the stray capacitance nulling circuit. It is comprised of two NAND gates, IC3c and IC3b and the basic operation of the circuit is shown in Fig. 2. Stray capacitance in the internal wiring or the test leads acts in parallel with the capacitance being measured and is added to it. Thus, stray capacitance has the effect of lengthening the pulses from the gating oscillator by a fixed amount.

The function of the nulling circuit is simply to shorten the gating pulses, effectively removing the additional time due to the stray capacitance. Fig. 2 shows the timing diagram of the nulling circuit. The gating pulse is fed to one input of NAND gate IC3c and to the other input via a delay network with time-constant "T", consisting of a variable resistor VR4 and a .0022uF capacitor. When the delayed version of the gating pulse is "ANDed" with the original, the resultant output pulse is shortened by the corresponding amount.

Range selection is provided by a four-pole three-position switch S1: switch poles S1a and S1b select appropriate resistors for the two oscillators as already discussed while switch S1d switches the nulling circuit out for the high range; S1c turns on the appropriate display decimal point for the range selected.

The power supply consists of a 12.6 volt centre-tapped transformer feeding a full-wave rectifier and 1000uF filter circuit. An LM340 three-terminal regulator at the output of the filter provides the regulated 5-volt supply for the CMOS circuitry. The 10uF tantalum capacitors ensure stability of the reg-



This view of the prototype shows the simplicity of construction. The PCB assembly is mounted using 25mm brass spacers.

ulator. An additional 150uF capacitor on the output of the regulator is mounted close to the 74C926 so as to decouple the display multiplex "hash".

The oscillator circuits (IC1) are separately decoupled from the regulator via a 22 ohm resistor and 0.1uF and 150uF capacitors. This is necessary to prevent the oscillators locking onto any "hash" signals superimposed on the supply.

The seven-segment readouts used for the display are Fairchild FND500s which have 15mm high digits and integral red plastic filters, eliminating the need for a separate red filter in front of the display.

Construction of the digital capacitance meter is fairly straightforward. Most of the components are mounted on the main PC board while the seven-segment displays are mounted on a display PC board which is soldered at right angles to the main board. The two connector strips on the edge of each PCB make all the necessary connections, keeping wiring to a minimum.

Dimensions of the main PCB, coded 80cm3a, are 92mm x 89mm. The display PCB is coded 80cm3b and measures 89mm x 37mm. The actual size artwork for both PCBs appears elsewhere in this article.

The FND500 displays are mounted on the display PCB after the links have been installed. Some links pass underneath the displays so care should be taken to ensure the displays are flush and in line with each other. This can be done by soldering only two of each of the display leads, checking alignment and adjusting where necessary and then finally soldering the remaining leads.

Mount the components on the main PCB next, leaving the CMOS ICs till last. The LM340 regulator requires a heatsink which can be made from a small piece of aluminium bent in a U-shape. Take the usual precautions when soldering the CMOS ICs: avoid handling the pins; use an earthed soldering iron and solder the supply pins first. Make sure the orientation of the electrolytic and tantalum capacitors is correct as well as for the ICs or damage may result.

With the main PCB and display PCB complete, the two can be soldered together. Let the lower edge of the display PCB overlap the lower surface of the main PCB board by about 2mm and make sure the two are exactly at right angles to each other. First, solder "tack" one strip at either end of the boards together and manipulate them until the orientation is correct; then solder the remaining connectors.

The circuitry is housed in a metal case measuring 184mm x 70mm x 160mm (D x H x W). Drill the mounting holes for the transformer, cable clamps and terminating block as shown in the photographs of the internal layout. The mains earth lead should be slightly longer than the other mains leads and should be terminated to a solder lug screwed down to the chassis.

Use the front panel artwork, shown actual size elsewhere in this article, to obtain drill centres for the on/off switch, range selector and banana plug test sockets as well as the dimensions of the cutout for the display. With the cutout complete mount the main board using 25mm washers. Then mount the switches and complete the wiring.

Keep all the leads as short as possible and use shielded cable for all the connections to the gating oscillator. The connection to the input of IC1a continues on from the wiper of S1a and to the test sockets. Make sure the cable is shielded every bit of the way, otherwise multiplex hash may influence readings, causing a slight "sticking" or bouncing of the display.

An attractive finish to the meter can be provided by using a "Scotchcal" photosensitive aluminium front panel. Use the artwork provided to make the

PARTS LIST

1 PC board, 92mm x 89mm, coded 80CM3A
1 PC board, 89mm x 37mm, coded 80CM3B
1 metal case
1 transformer, A&R2155 or similar
1 4-pole 3-position rotary switch
1 SPST miniature toggle switch
1 red banana plug socket
1 black banana plug socket
1 mains cord and plug
½ metre of shielded audio cable
1 2M mini vertical trimpot
1 100k mini vertical trimpot
1 22k mini vertical trimpot
1 4.7k mini vertical trimpot

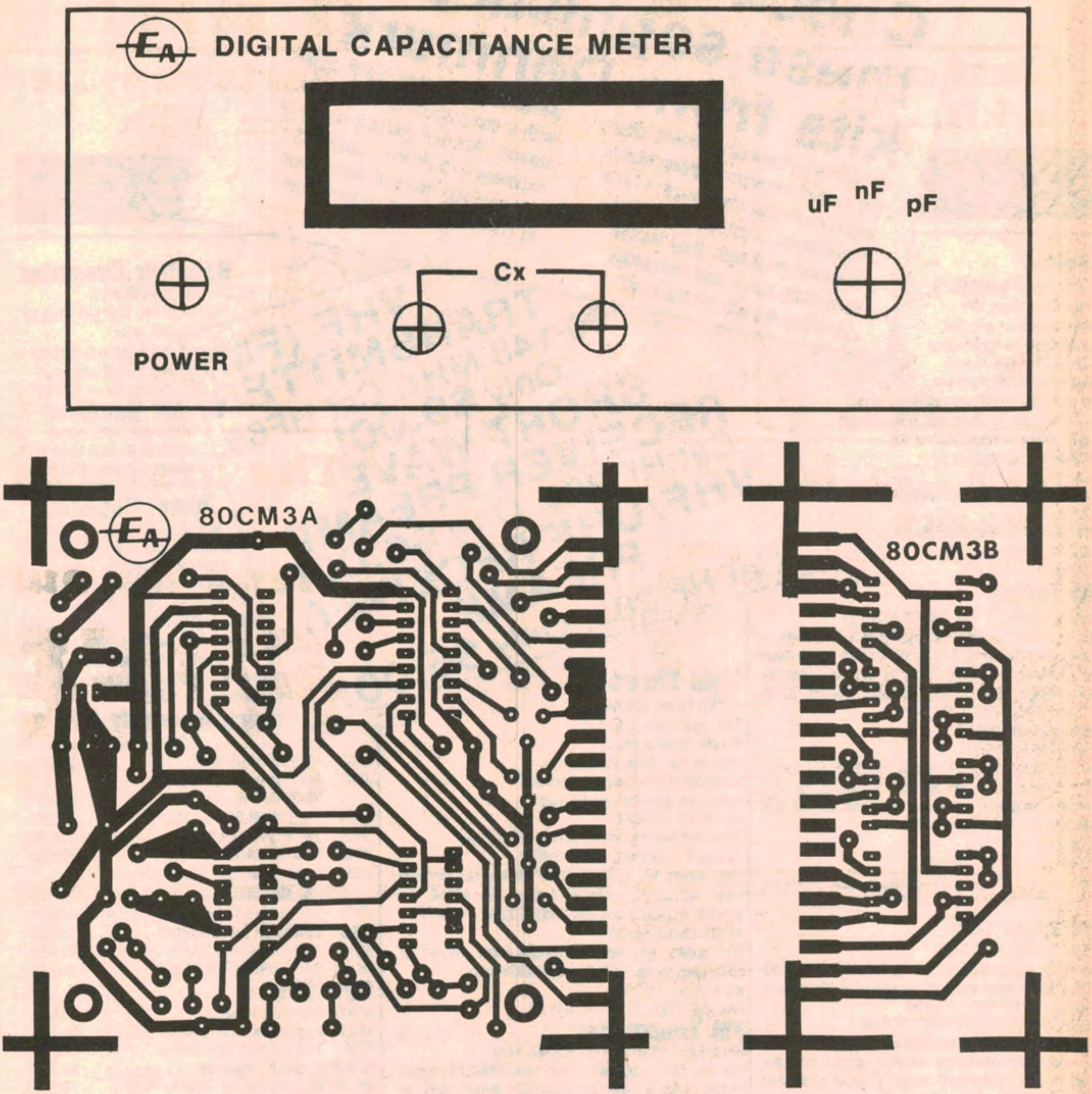
MISCELLANEOUS
3-way terminal block, cord clamp, grommet, knob, rainbow cable, 4 x 25mm brass standoffs, nuts & screws

SEMICONDUCTORS
1 74C926 CMOS IC
1 74C14, CD40106 or MC14584 CMOS IC
1 4017 CMOS IC
1 4011 CMOS IC
4 BC338 transistors
2 1N4002 diodes
1 LM340T-5 regulator
1 1N4148 signal diode
4 FND500 seven-segment LED displays

CAPACITORS:
1 1000uF/16VW PC electrolytic
2 150uF/6.3VW tantalum electrolytic
2 10uF 35VW tantalum electrolytics
1 0.22uF greencap (metallised polyester)
1 0.1uF greencap
1 .0022uF greencap
1 .001uF greencap

RESISTORS: (all ¼ watt 5%)
1 x 2.2M, 2 x 680k, 1 x 6.8k, 1 x 2.2k, 1 x 47 ohm, 7 x 27 ohm, 1 x 22 ohm

NOTE: Ratings are those used on the prototype. Components with higher ratings may generally be used providing they are physically compatible.



Above are actual size artworks for the front panel and the two PC boards.

panel or you can purchase a finished panel from Radio Despatch Service, 869 George Street, Sydney.

Now you can "fire up" the meter and proceed with the calibration. Ideally a capacitor standard for each range would be desirable. Lacking these or access to an accurate capacitance bridge you can purchase 2% capacitors for the purpose.

Calibrate the "nF" range first using a capacitor of about 0.47uF and adjusting VR1 for the appropriate reading (eg, 470.0nF). Next, switch over to the "pF" range and without any capacitor connected to test terminals or leads, adjust the NULL control VR4 until the display shows "0001" and then just touch it so the display reads "0000". Using, say, a 4700pF capacitor, calibrate the "pF" range using trimpot VR3. Finally, switch over the "uF" scale and calibrate it using trimpot VR2 and an appropriate capacitor.

We estimate that the current cost of parts for this project is approximately

$50.00

This includes sales tax.