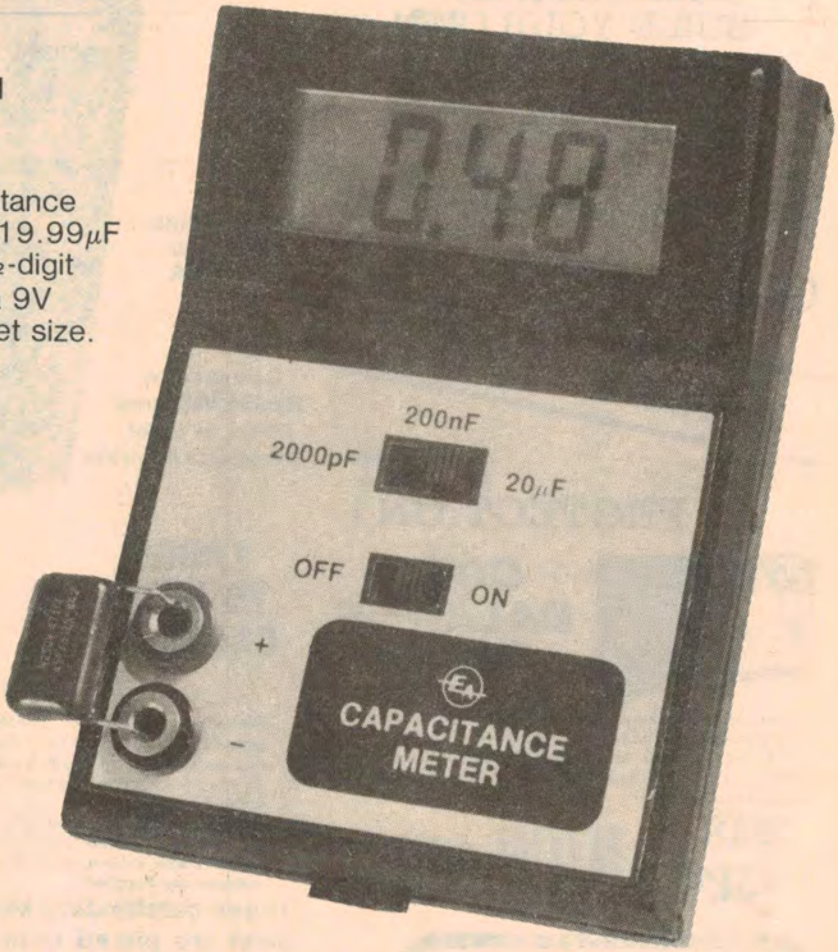
Measures 1pF to 19.99uF on 3 ranges

3½-digit LCD capacitance meter

by JEFF SKEEN and GREG SWAIN

Here is an inexpensive digital capacitance meter which measures from 1pF to 19.99μF in just three ranges. It features a 3½-digit display with decimal point, runs off a 9V battery, and comes in a handy pocket size.



This LCD Capacitance Meter is the second in our series of projects using the DPM-200 LCD module. Apart from the module itself, it uses just one IC, two transistors and a handful of other components. No adjustments are necessary when taking measurements: you simply connect a capacitor to the test leads, select the range and there is the reading. What could be easier?

The unit is certainly easier to operate than an impedance bridge and has the advantage over both bridges and conventional analog meters in that it will measure down to 1pF. There are three ranges: 0-2000pF, 0-200nF, and 0-20μF. You must remember to subtract the stray capacitance from the reading on the 0-2000pF range though (typically around 30pF).

In addition to non-polarised capacitors, both tantalum and electrolytic capacitors can be measured. The test terminals are actually polarised and, during the test procedure, the capacitor is charged to 2/3 of the supply voltage.

In addition, our new LCD Capacitance Meter has big 15mm-high digits for easy display legibility, provides low battery warning (LOW BAT) at about 7V, and features over-range indication. The latter, by the way, is indicated by a leading "1", with the three least significant digits supressed.

With features like these, the LCD Capacitance Meter will be invaluable to hobbyists and professionals alike. 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 numeric or colour codes, or tuning and trimmer capacitors which usually have no marking at all.

Now, with the flick of a switch, those previously unfathomable values become instantly apparent.

Unlike conventional meters, a digital meter offers high resolution; in this case 3½ digits. Resolution is 1pF on the 2000pF range, 0.1nF on the 200nF range, and 0.01μF on the 20μF range.

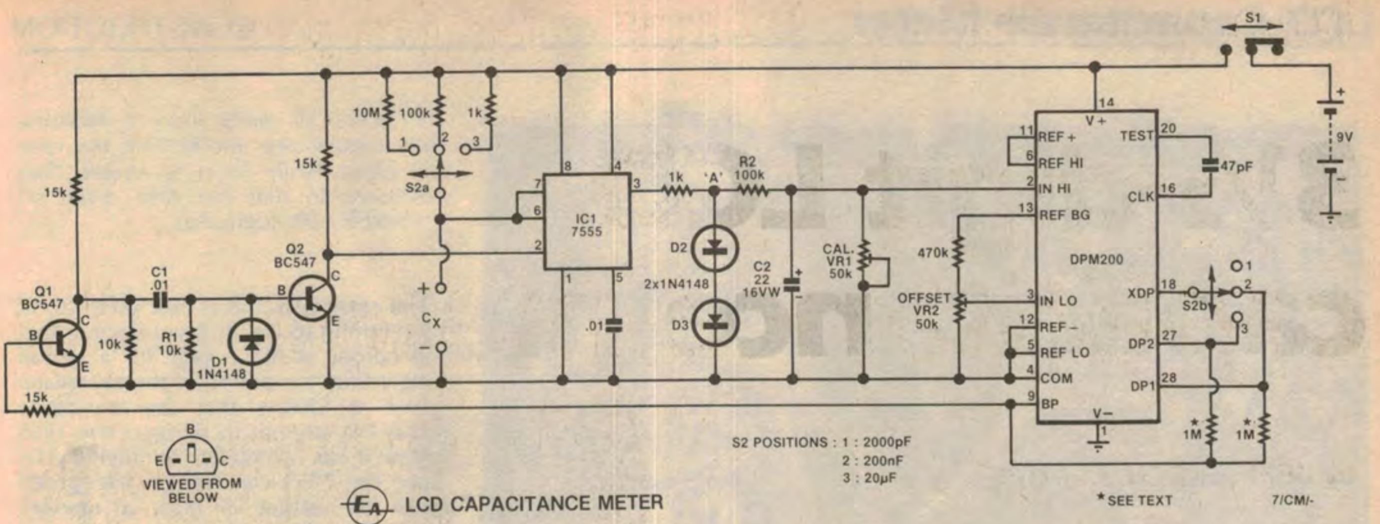
Finally, our new LCD Capacitance Meter will prove a handy test instrument for servicemen. Its compact size and battery power supply mean that suspect capacitors can be quickly checked both at the work bench and in the field.

How it works

In this circuit, a capacitor is measured by connecting it in the charging circuit of a 7555 monostable which is triggered continuously at around 35Hz. The monostable thus produces a train of pulses with a repetition rate of 35Hz and with pulse length proportional to the capacitance.

This pulse train is clipped to a constant amplitude which means that the average DC value of the pulse train waveform is directly proportional to the capacitance. By feeding this averaged value to the LCD module, a direct readout of the capacitance can be obtained in either pF, nF or, μF, depending upon the range selected.

By basing the design of the capacitance meter around the DPM-200 LCD module, the external parts count has been kept to a minimum. The operation of the DPM-200 module has been described before (see EA February, 1982)



The circuit consists of a trigger circuit (Q1 and Q2), a monostable pulse generator, an integrator and the LCD module.

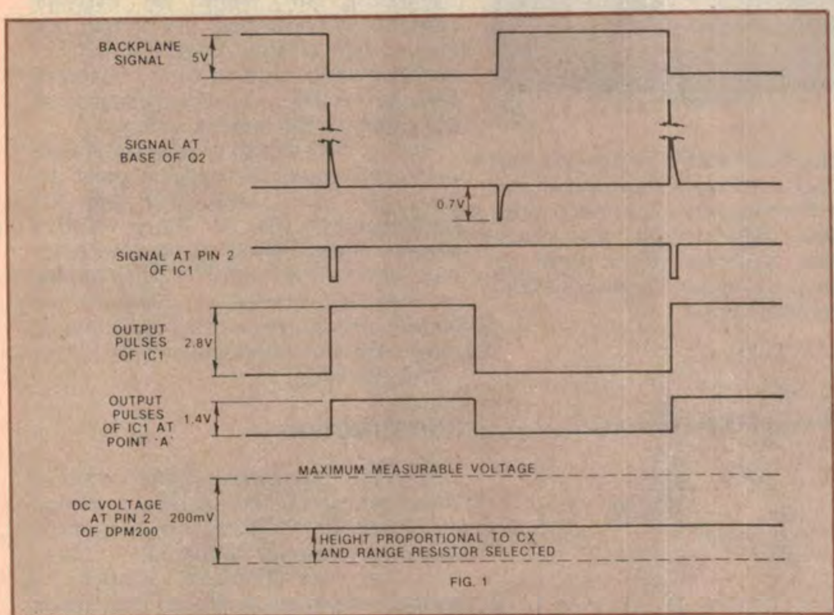


Fig. 1: Timing waveform diagram. Output pulses from the 7555 are clipped and averaged to produce a constant DC voltage at the input to the DPM-200.

but for the sake of clarity we will briefly review some of the functions once more.

The DPM-200 is essentially a high input impedance voltmeter with a full-scale reading of 199.9mV. Heart of the circuit is an analog to digital converter chip which drives the liquid crystal display, while additional circuitry drives various display annunciators.

Stable reference voltages of 1.2V and 100mV are provided on the module, with the latter voltage used as the reference against which the input voltage is compared. The reading displayed by the liquid crystal display when 100mV is used as the reference voltage is 1000 Vin/Vref.

Annunciators are supplied on the LCD and include all the commonly used electrical abbreviations such as mV,mA,Ω,+,–, etc. Decimal points are also included and may be switched on and off as required. To enable an annunciator, a connection is made from the annunciator pin on the module to the XDP pin.

The common (COM, pin 4) is maintained by the module at Vcc – 2.8V and may be used as the "earth" return for an external circuit. If a zero display reading is required when the actual input is not 0V, then an offset voltage may be applied between the COM and IN LO pins.

Clock signals are provided by an internal 48kHz oscillator which is also divided down to give the 60Hz backplane signal necessary to drive the display. This backplane signal is made available at the BP pin (pin 9), and is a square wave with an amplitude of ±2.5V with respect to the common rail. The oscillator frequency can be reduced by connecting a low-value capacitor between the TEST and CLK pins.

The supply voltage for the external circuitry is derived from the difference in voltage that is maintained between the positive supply and the COM pin by the module. This means that the external circuitry has a supply voltage of about 2.8V.

Circuit description

Refer now to the circuit diagram and to the timing waveform diagram Fig. 1. The circuit is based on one that appeared in "Practical Electronics" for July, 1981 and can be broken into three parts: the LCD module itself, a 7555 CMOS timer, and a transistor trigger circuit (Q1 and Q2).

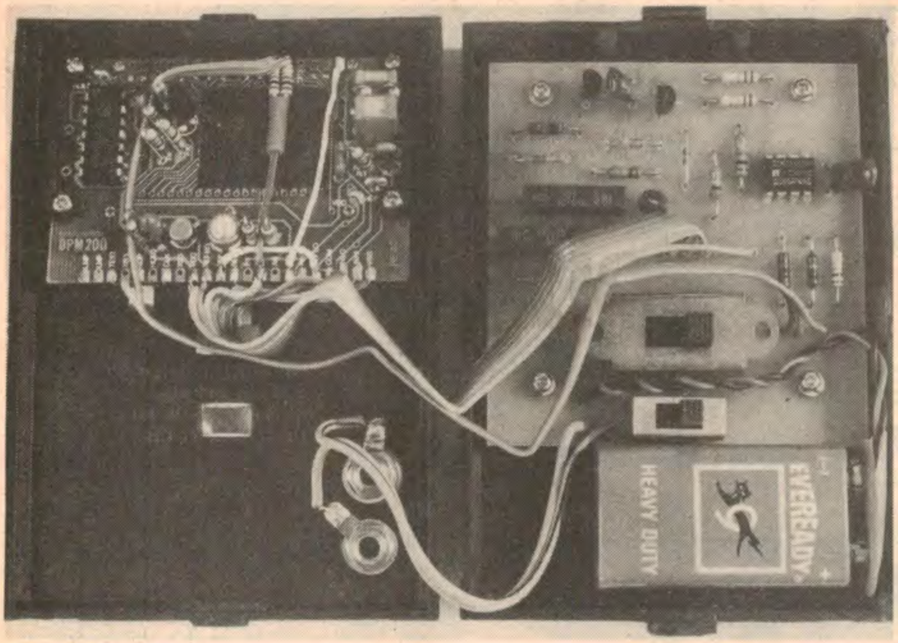
The backplane signal from the display module is fed via a 15kΩ resistor to the base of transistor Q1 which turns hard on when the backplane signal is high, and hard off when the backplane signal is low.

Thus, Q1 buffers the backplane signal and applies it to a voltage divider consisting of 15kΩ and 10kΩ resistors. From there, the signal is applied to a differentiating network (C1 and R1) which produces large positive and negative output spikes coinciding with the rising and falling edges of the input waveform. In this circuit, however, the large negative spikes are clipped by diode D1 to prevent damage to the emitter base junction of transistor Q2 (see Fig. 1).

Normally, transistor Q2 is held off by R1 and is briefly turned on each time a positive pulse is applied to its base. Q2 thus serves to invert the positive spikes, turning them into negative-going pulses with an amplitude approaching the 2.8V supply.

These negative-going pulses coincide with each negative-going edge of the backplane signal, and are used to trigger the 7555 timer IC.

The 7555 IC may seem unfamiliar to



LEFT: Keep all wiring short to minimise stray capacitance and so that the case will close easily (ours is longer than necessary so that the case could be opened for photography).

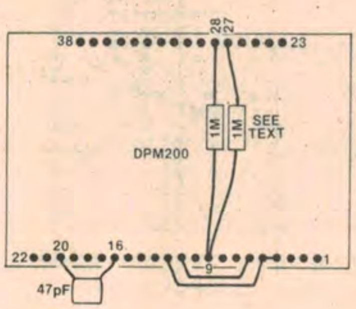
many readers at first glance, but it's really just a CMOS version of the 555. In this circuit, the 7555 has been wired as a one-shot monostable and produces a positive pulse with length proportional to the test capacitor and the range resistor selected whenever a negative pulse appears on the trigger input (pin 2).

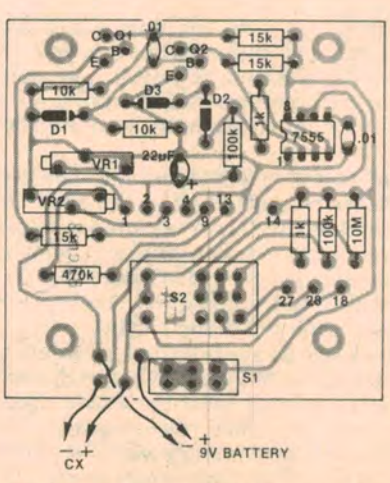
The 7555 works as follows: When pin 2 goes low, the test capacitor Cx, which is initially discharged, begins charging towards the positive supply rail. While ever it remains below 2/3 supply, the output of the 7555 (pin 3) is high. Cx charges via one of the range resistors and, when it reaches 2/3 supply, pin 3 goes low and the 7555 is reset ready for the next trigger pulse.

Switch S2a selects the appropriate range resistor, while S2b switches the decimal points. In order to maintain accuracy between ranges, the range resistors specified are all close tolerance types.

Output pulses from the 7555 pass through a 1kΩ resistor and are clipped by diodes D2 and D3 so that they are of a constant amplitude (approximately 1.4V). This is necessary otherwise small variations in the amplitude of the output pulses would give incorrect readings and cause display jitter. R2 and the CAL trimpot VR1 form a voltage divider with C2 acting as an integrator to average out the pulses and produce a constant DC voltage. The CAL trimpot is adjusted so that the full-scale DC voltage to the DPM-200 display module is 199.9mV.

A 47pF capacitor has been added to the DPM-200 display module between the CLK and TEST pins in order to slow the internal oscillator frequency slightly. This reduces the backplane frequency to around 35Hz and ensures that the maximum pulse length from the monostable (1kΩ × 20μF = 20ms) is shorter than the period of the triggering waveform. If the monostable pulse length was made longer than the period of the triggering waveform, the timing relationship of the circuit would be upset.





Don't forget the wire link between pins 4 and 5 on the DPM-200 display module.

The reason for this is best understood by referring to Fig. 1. If we assume that the output of IC1 is high for a period longer than the period of the backplane signal, it follows that the backplane signal will attempt to retrigger the 7555 before it has completed its timing cycle. Since the 7555 can not be retriggered while its output is high, a random reading would result.

An OFFSET trimpot, VR2, has been provided to null out the residual output which is produced by IC1 when it is not oscillating, ie, when no external capacitor is connected. We should add that on the 2000pF range IC1 will still oscillate when no capacitor is connected because of the residual capacitance of the wiring to the banana sockets.

Finally, 1MΩ resistors have been connected between the decimal point annunciators (DP1 and DP2) and the backplane pin (pin 9). These resistors prevent noise picked up by the leads connected to DP1 and DP2 from turning on the decimal point annunciators, yet allow normal operation of each annunciator when it is connected to XDP. More about this later.

Construction

The LCD Capacitance Meter is housed in a small plastic case specifically designed to suit the DPM-200 display module. This case measures 80 × 110 × 30mm and, like the DPM-200 module, is available from Jaycar Pty Ltd (380 Sussex St, Sydney 2000). A printed circuit board measuring 72 × 71mm and coded 82cm3 is used to hold all external components except for the 47pF capacitor and the two 1MΩ resistors.

Begin construction by assembling the PCB according to the wiring diagram. Fit the three close tolerance range resistors first (10MΩ 2%, 100kΩ 1%, 1kΩ 1%), followed by the remaining components and the 7555 timer IC. Remember that the 7555 is a CMOS device and can be destroyed by static electricity. When soldering it into circuit, connect the barrel of your soldering iron to the COM track on the PCB (use a clip lead) and solder the power supply pins (1 and 8) first to activate the static protection circuitry.

Depending upon the type of switches supplied, the holes for the switch pins may need to be enlarged slightly. Mount the switches on the PCB so that the top of each switch body is 10-12mm above the PCB. If the switches supplied have side supports, these should be trimmed with a pair of side cutters before the switches are soldered in.

Now take a sharp knife and carefully cut off the top 2mm of plastic from each mounting post in the lower case half. Do not cut off too much plastic or there will be nothing left to screw the mounting screws into. At the same time, you should also remove the same amount of plastic from the battery rib closest to the mounting posts. This is done to allow plenty of clearance between components on the PCB and components on the DPM-200 display module.

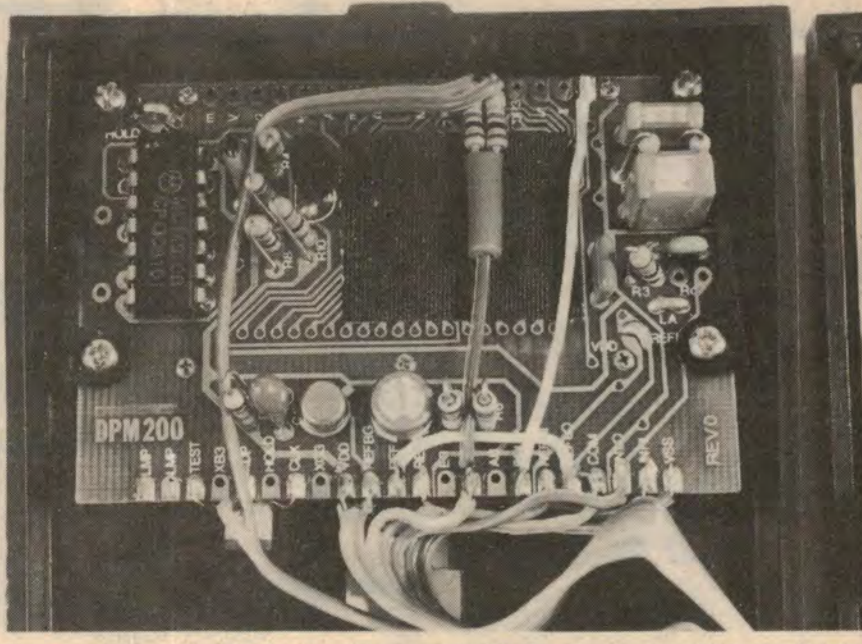
Next, use the front panel artwork to mark out hole positions for the switch actuators and banana sockets on the top of the case. Drill the banana socket holes to size, and use a small drill to remove most of the plastic from the switch actuator holes. A small, flat file can then be used to square up the actuator holes to their correct size.

The "Scotchcal" front panel can now be glued in position and holes made for the switch actuators and banana sockets by drilling and cutting with a sharp knife. This done, mount the two banana sockets in position with the red socket at the top adjacent to "+" sign. Do not mount the DPM-200 display module at this stage.

The 47pF capacitor can now be soldered in between TEST and CLK, and the wiring on the display module and between the module and the PCB completed using ribbon cable. Keep this wiring as short as practicable so that it will fit easily into the case when the case is finally assembled. Although we used a fairly long length of ribbon cable, this was done simply to allow the two case halves to be placed side-by-side for photography.

Finally, solder in the battery clip, taking care that the polarity is correct, and use a short length of figure eight wire to connect the two banana sockets to their respective inputs on the PCB. The PCB can then be screwed into place in the lower case half and a final check made to ensure that all wiring is correct.

Note: keep the wiring to the banana sockets as short as possible to minimise stray capacitance.



Close-up view of the display module mounted in the plastic case. Note the link from the POL output (pin 7) to the minus annunciator (pin 23) (optional; not shown on circuit).

PARTS LIST

1 printed circuit board, 72 x 71mm, code 82cm3
1 plastic case, 80 × 110 × 35mm
1 Scotchcal label, 72 x 60mm
1 DPM-200 liquid crystal display module
1 DPDT slide switch
1 3P3W slide switch
1 9V 216 battery
1 battery clip to suit
4 small self-tapping screws
1 20cm length of ribbon cable
1 9cm length of figure eight cable
2 4mm banana sockets, 1 red, 1 black

SEMICONDUCTORS
3 1N4148 silicon diodes
2 BC547 NPN transistors
1 7555 CMOS timer IC

CAPACITORS
1 22µF/16VW tantalum
1 0.01µF metallised polyester
1 47pF ceramic

RESISTORS (¼W, 5% unless specified)
1 x 10MΩ 2%, 2 x 1MΩ (see text), 1 x 470kΩ, 1 x 100kΩ, 1 x 100kΩ 1%, 3 x 15kΩ, 2 x 10kΩ, 1 x 1kΩ 1 x 1kΩ 1%, 2 x 50kΩ multi-turn trimpots.

Note: Components specified are those used in the prototype. Components with higher ratings may generally be used provided they are physically compatible.

Calibration

It is not necessary to mount the display module prior to calibration, as this can be done later. For the time being, sit the module display side up on an insulated work bench, clip a 9V battery into place and switch on. You should get a low reading determined by the settings of the CAL and OFFSET trimpots.

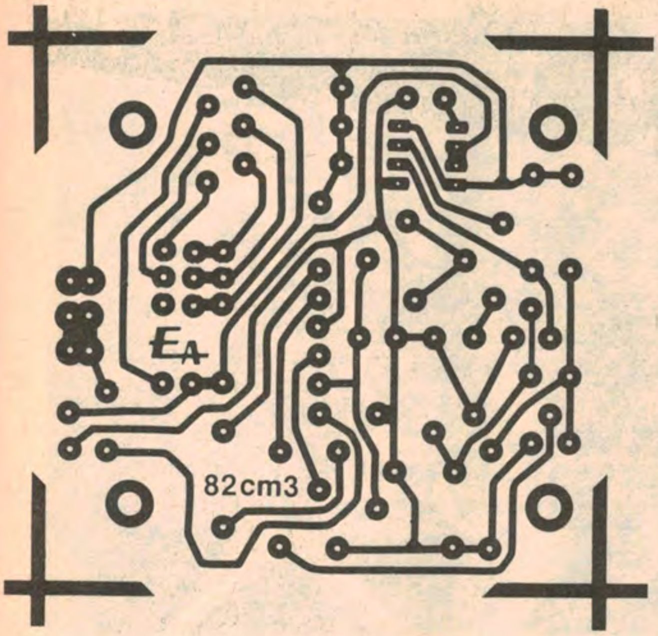
To carry out calibration, you will need a close tolerance capacitor or one with accurately known value. Calibration should be performed on the 200nF or 20µF ranges rather than on the 2000pF range where stray capacitance will be significant.

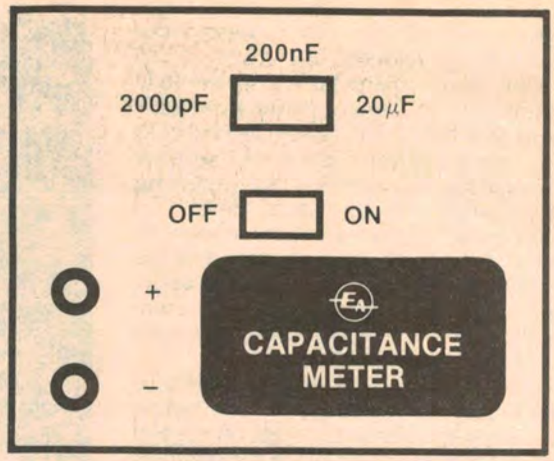
The calibration procedure is as follows:

- Turn the CAL trimpot VR1 clockwise as far as it will go (until you hear "clicks") and the OFFSET trimpot anticlockwise as far as it will go. The display should show "0.00";
- Connect the calibration capacitor to the test terminals, set the range switch to 20nF or 20µF as appropriate, and adjust the CAL trimpot until the display shows the value of the capacitor;
- Remove the calibration capacitor and adjust the OFFSET trimpot until the display reads "0.00";
- Re-connect the calibration capacitor and re-adjust the CAL trimpot for the correct value. The display should now read "0.00" with the capacitor removed.

Readers should note that both positive and negative readings may be obtained over the range of the OFFSET trimpot, but the plus and minus display annunciators are not normally shown. If you have difficulty locating the null, connect a wire from the POL output (pin 7) to the minus annunciator (pin 23) on the display module. Now, when the reading is less than zero, the minus annunciator will appear and it will be quite easy to locate the null.

You can even leave pins 7 and 23 connected if you like (we did), since this does not affect the normal operation of the meter.





Here are actual size artworks for the printed circuit board and the front panel.

That completes the calibration procedure. No adjustments are required on the other two ranges due to the close tolerance 2% range resistors used. Note, however, that if the meter is switched to the 2000pF range with no test capacitor, a reading of around 20 or 30pF will be displayed. This is quite normal and is due to stray capacitance between the PCB tracks, the hook-up wire and the banana sockets.

While this stray capacitance could be nulled out using the OFFSET trimpot, readings on the other two ranges would no longer be accurate (the meter would read low). The best procedure for measuring low-value capacitors is to measure the stray capacitance first and then subtract this from the final reading.

Provided you have kept the leads to the DP1 and DP2 pins (pins 28 and 27) reasonably short, the two 1Mμ resistors will not usually be required. While some readers may wish to fit them as a precautionary measure, they are really only necessary if the decimal points do not extinguish completely when not wanted. Check your wiring between S2b and the module if the decimal points fail to come on as required (200nF and 20μF ranges only).

The display module can now be inserted sideways through its mounting hole, slipped into position and secured by screwing down the two small plastic retaining brackets. Now screw the two halves of the plastic case together, making sure that components on the display module and the PCB do not foul each other, and the job is complete.

We estimate that the current cost of components for this project is

$60

This includes sales tax.

A final word of warning before you rush out and measure every capacitor in sight. Always make sure that any capacitor you measure is completely discharged before connecting it to the meter, otherwise the 7555 IC could be damaged.

That's it! We're sure that you will find our new LCD Capacitance Meter an invaluable test instrument.