Project 136

Linear-Scale Capacitance Meter

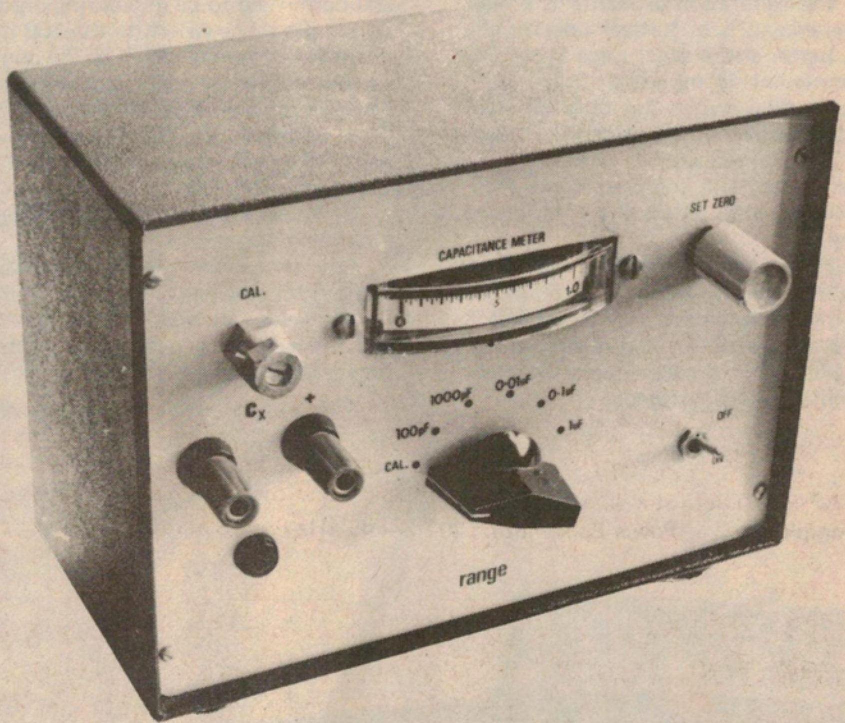
If you want to find out what values those odd capacitors are, then here's the instrument for you.

ONE OF THE HANDIEST instruments for an electronics hobbyist, or to have around an electronics workshop, is a capacitance meter. Every multimeter has a resistance scale — and it gets used quite often. But there is often a requirement for measuring capacitance, and few multimeters have a capacitance range.

For example, measuring the value of a variable capacitor used to temporarily 'trim' a filter or oscillator that is to be replaced by a set of fixed capacitors. Or a bagful of 'bargain' unmarked capacitors may have been obtained or the color code or numeral code has disappeared and the value of a component needs to be determined.

Once you have a capacitance meter, you suddenly find uses for it!

This capacitance meter provides a linear scale readout of the value of unknown capacitors generally to within 5% or as good as 2% depending on the accuracy of the meter used.



Range

The meter will measure capacitance values down to 5 pF and up to 1 μF. Scale divisions on the model shown were at 2.5% intervals.

Five ranges are provided: 100 pF, 1 nF, 10 nF, 100 nF and 1 μF.

Different ranges can be provided by selecting different values for the range resistors R7 to R11. For example, five ranges from 47 pF to 0.47 μF could be included by changing R7 to 470 ohms, R8 to 4.7k etc. The meter scale would have to be hand-calibrated in this case.

Construction

The construction is quite straightforward. The majority of the small components are mounted on the printed circuit board. The range resistors are mounted on the switch lugs as illustrated in the photographs.

All the range resistors, R7 to R11, and R12 are high tolerance 1% or 2% resistors accurately measured to be within the tolerance required. If only 5% or 10% accuracy of capacitance value is required then standard 5% or 10% tolerance resistors may be used, obviating the need for selecting them, or buying the expensive high tolerance types.

SPECIFICATION — ETI 136

Capacitance ranges	100 pF, 1 nF, 10 nF, 100 nF, 1 μF.
Accuracy	5% or better (2% possible with component selection)
Calibration	by internal calibration capacitor
Power requirements	240 V AC or 2 x 9V No. 916 batteries

The printed circuit board, meter, range switch, potentiometers, pilot light measurement terminals and on/off switch are all mounted on the front panel as illustrated.

The power supply is mounted on the back panel, as is the mains/battery switch. The batteries (if used) may be mounted inside the case. Overall case size is 180 mm wide by 95 mm deep by 128 mm high.

A small tagstrip is used to terminate the mains input and transformer leads and the rectifier components. Both the back panel and the front panel should be connected to the mains earth which is terminated on the tagstrip, the strip's earth tag being secured under one of the transformer mounting bolts.

The calibration capacitor is a high tolerance (2% or better) polystyrene or, better still a silver mica type. This component is mounted from the appropriate switch lug to a suitable ground lug mounted on the front panel.

The printed circuit board has PC stakes (or pins) soldered in all the positions marked on the component overlay.

Two of these (marked E and Cx on the PC artwork) are used to mount the PCB directly on the back of the "Cx" terminals, as illustrated in the photographs. This avoids increasing the circuit stray capacitance.

Little difficulty should be experienced if the component overlay is followed and the photographs are referred to during construction.

Note that alternative panel layout is possible if a standard type of panel meter is used rather than the edgewise meter shown in the photographs.

The front panel was hand-lettered with Letraset on the prototype. A Scotchcal type front panel could also be prepared if desired.

The CAL. potentiometer is a screw-driver-adjust type and was mounted with a fixing collet. Knob-twiddlers can cause havoc.

Using the Meter

Once the instrument has been tested and confirmed to be in working order, switch the range switch to the 100 pF position and turn the SET ZERO control so that the meter reads zero with no capacitor connected to the Cx terminals. Then switch to the CAL. position and adjust the CAL. potentiometer so that the meter reads full scale.

Now you are set to measure all those 'unknown' capacitors.

Any devices used to grip capacitors being measured, and plugged into the Cx terminals, will add stray capacitance and this will need to be compensated for by readjusting the zero set control.

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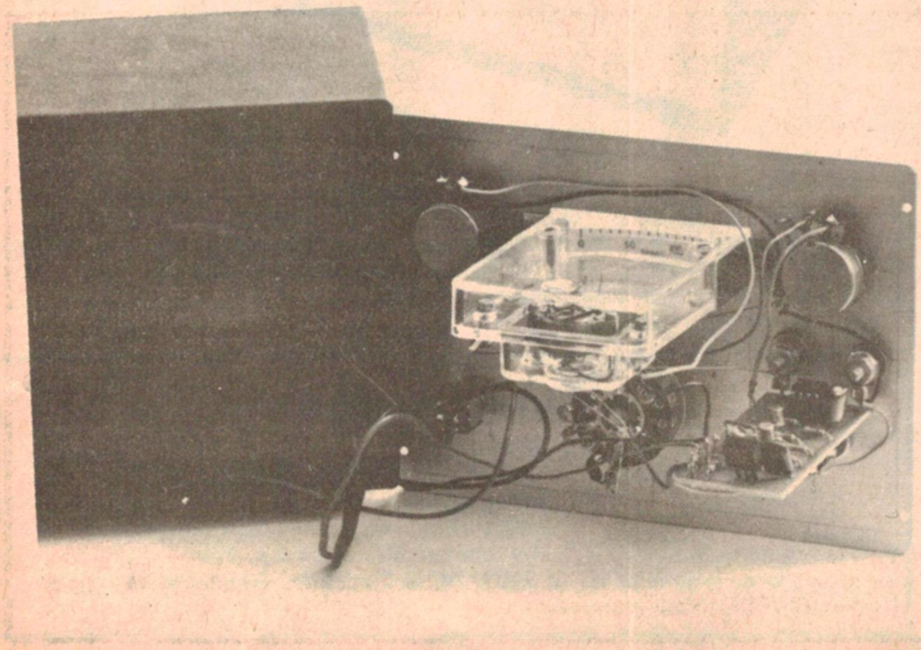
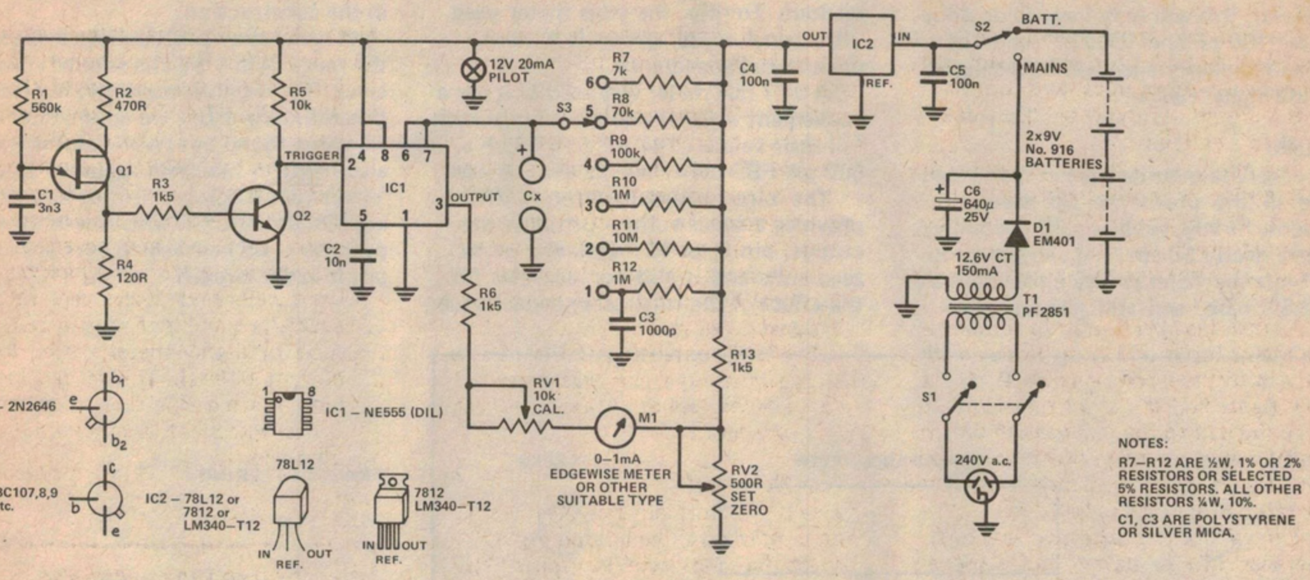
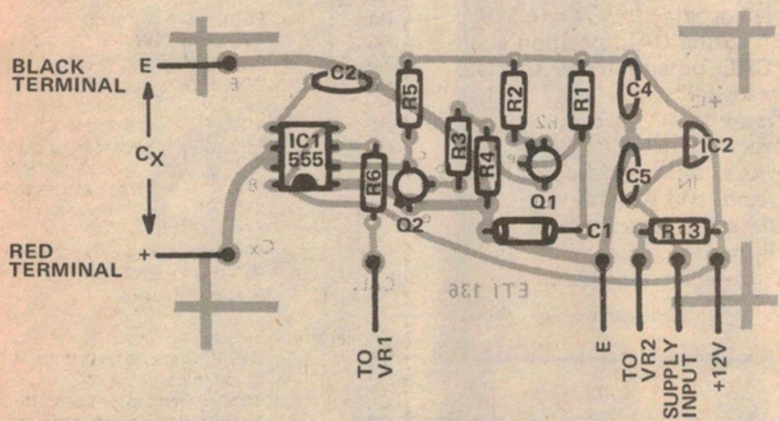


Note: A suitable edge meter is available from Ham Radio Suppliers 323 Elizabeth St, Melbourne 3000 (67-7329, 67-4286). They have been advertised at $3.00 each (plus P & P if ordered by mail). The particular meters are 0–1 mA movements calibrated 0–5 ounces. The scale is easily removed and reversed to provide a blank scale which can be hand-calibrated (use a reg. voltage supply a good pot. and a mirror scale or digital meter to set the current points). This is best done with the meter mounted on the panel. Excellent accuracy can be obtained.

PARTS LIST – ETI 136

Resistors	
R1	560k, ¼W
R2	470 ohm. ¼W
R3, 6, 13	1k5. ¼W
R5	10k, ¼W
R7	1k, ½W. 2%
R8	10k, " " either use 2% tol.
R9	100k " " resistors or selected 5% or 10% tol. see text.
R10, 12	1M " "
R11	10M " "
RV1	10k/A panel mounted, screwdriver adjusted
RV2	500 ohm/A pot.
Capacitors	
C1	3n3, Philips polystyrene or silver mica
C2	10nF greencap or ceramic
C3	1nF Philips polystyrene (selected, 2%) or silver mica, 2%
C4	100nF greencap
C5	100nF greencap
C6	640 uF, 25V electrolytic
Semiconductors	
D1	EM401 or similar
S1	DPST or DPDT, 250 V AC rated min. toggle switch
S2	SPDT or ½-DPDT min, toggle switch
S3	single pole, six-position OAK switch
Q1	2N2646
Q2	BC107 or BC108, BC109 or equivalent
IC1	LM555 or NE555 timer IC.
IC2	78L12 (preferred) or 7812 or LM340-T12
Miscellaneous	
T1	PF2851 or M2851, 12.6 V C.T. @ 150 mA
Pilot	12 V, 20 mA bayonet lamp and holder.
Case	Instrument case, Australian Transistor Co. model 754 or similar
M1	O-1 mA meter, see text
Sundries	pk screws, wire, batteries, nuts, bolts, tagstrip, etc.





R7-R12 and C3 are mounted on the rear of the range switch

● INSERT P.C. STAKE IN HOLES MARKED THUS.

HOW IT WORKS – ETI 136

A unijunction transistor, Q1, is connected as a relaxation oscillator with a frequency determined by R1-C1. The frequency of oscillation in this instance is about 1 kHz.

Pulses of about 1 μs duration are produced across R4 each time the UJT "fires". The resistance between b2 and b1 of the UJT reduces to a low value each time the emitter conducts. Much of the charge stored in C1 is "dumped" across R4 for the short duration that the c-b1 junction of Q1 conducts.

The narrow pulses across R4 drive the base of Q2 via R3, which serves as a base-current limiting resistor. The pulses cause Q2 to conduct for the same duration, that is, about 1 μs, and negative-going pulses from the collector of Q2 drive the "TRIGGER" input of the 555 timer, IC1. This is connected to operate as a monostable in this circuit.

When IC1 receives a trigger pulse at pin 2, the flip-flop is set, releasing the short circuit across Cx and driving the output, pin 3, high. The voltage across the capacitor then increases exponentially for a period that depends on the value of the unknown capacitance Cx. The period is determined according to the formula:

$$t = 1.1\, RrCx$$

At the end of the period, the comparator resets the flip-flop which in turn discharges the unknown capacitor, Cx, and drives the output to its low state.

This cycle is repeated each time a negative-going trigger pulse appears at pin 2 of IC1.

Thus as the range resistor value (Rr) is fixed, the ON/OFF ratio of the output voltage will be determined by the value of Cx. The ON/OFF ratio is independent of the relaxation oscillator frequency and trigger pulse duration.

The current measured through the 'load' resistor on the output (R6) of IC1 will thus be directly proportional to the value of the unknown capacitor Cx.

The meter, M1, measures the current through R6, the meter inertia 'averaging' the current.

As the voltage at the output pin swings between about 2/3 Vcc and less than 1/3 Vcc in its 'high' and 'low' states respectively the DC offset is compensated for by returning the 'load' current through an offset voltage developed across VR2 via R13 from the supply rail.

Zero-setting is accomplished by making VR2 variable. A calibration control is provided by making a portion of the 'load' resistance variable – VR1 here.

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However, this will only have to be done on the 100 pF and 1000 pF ranges as the added capacitance will be negligible on the higher ranges.

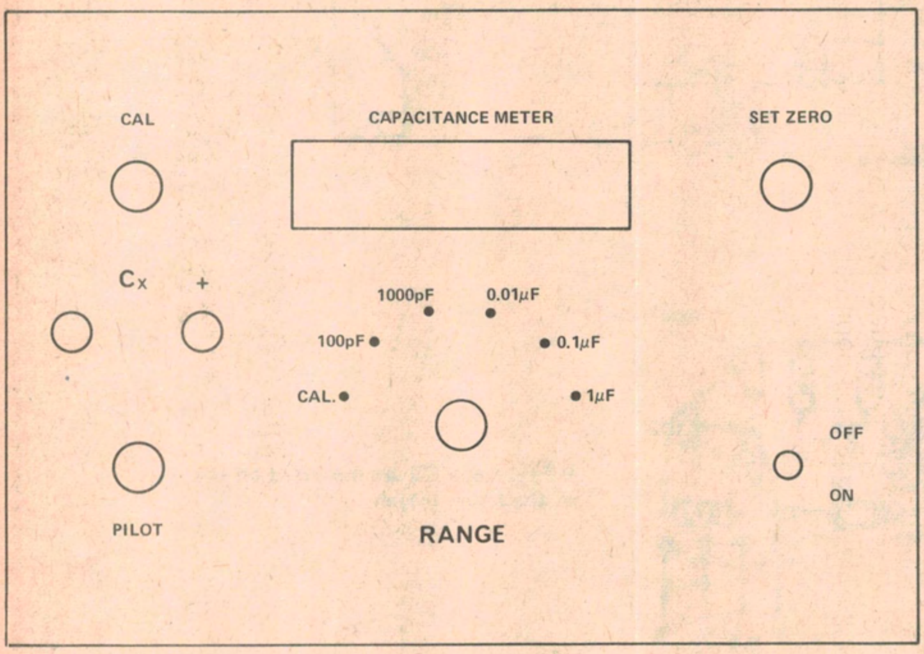
Meters

An edgewise-mounted panel meter was used in the prototype for several reasons. Firstly, we had one! Secondly, a scale nearly 50 cm long allowed us to calibrate the meter at very close intervals — 2.5% here, and still give accurate readout. Thirdly, the edge meter used little panel space, giving it a clean, uncluttered appearance.

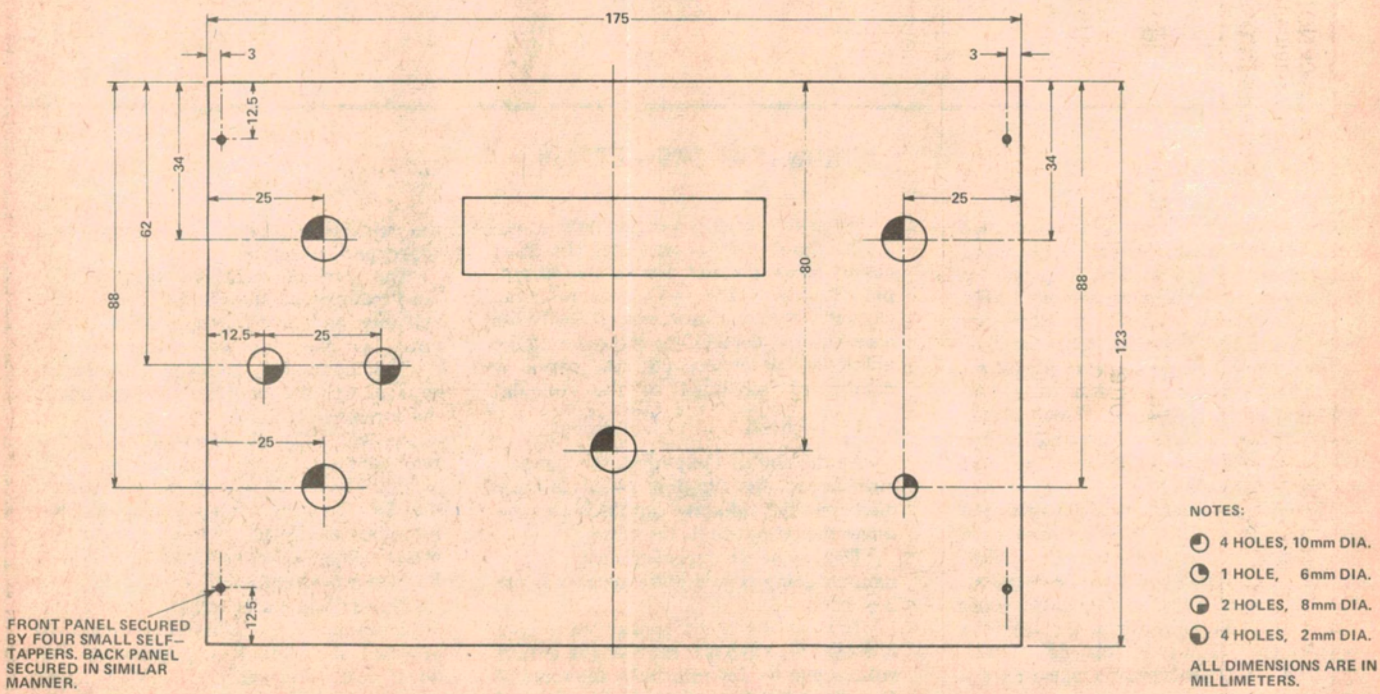
A 0–1 mA meter was used as it has a convenient scale. If you use a range with full-scale values of 47 pF to 0.47 μF a 500 μA FSD meter will have to be used.

The zero-set potentiometer, VR2, provides a small voltage offset as the output, pin 3, or IC1 does not go to zero volts and it also compensates for the effect of the small stray capacitance in the construction.

A calibration position is provided on the range switch for the sake of convenience. The original model did not have this refinement but we soon added it when we found out how useful it was! it also helps to maintain accuracy as a 'standard' capacitor does not have to be kept external to the instrument for this purpose — we kept losing ours until we put it in the circuit!



PANEL LETTERING



PROTOTYPE PANEL LAYOUT