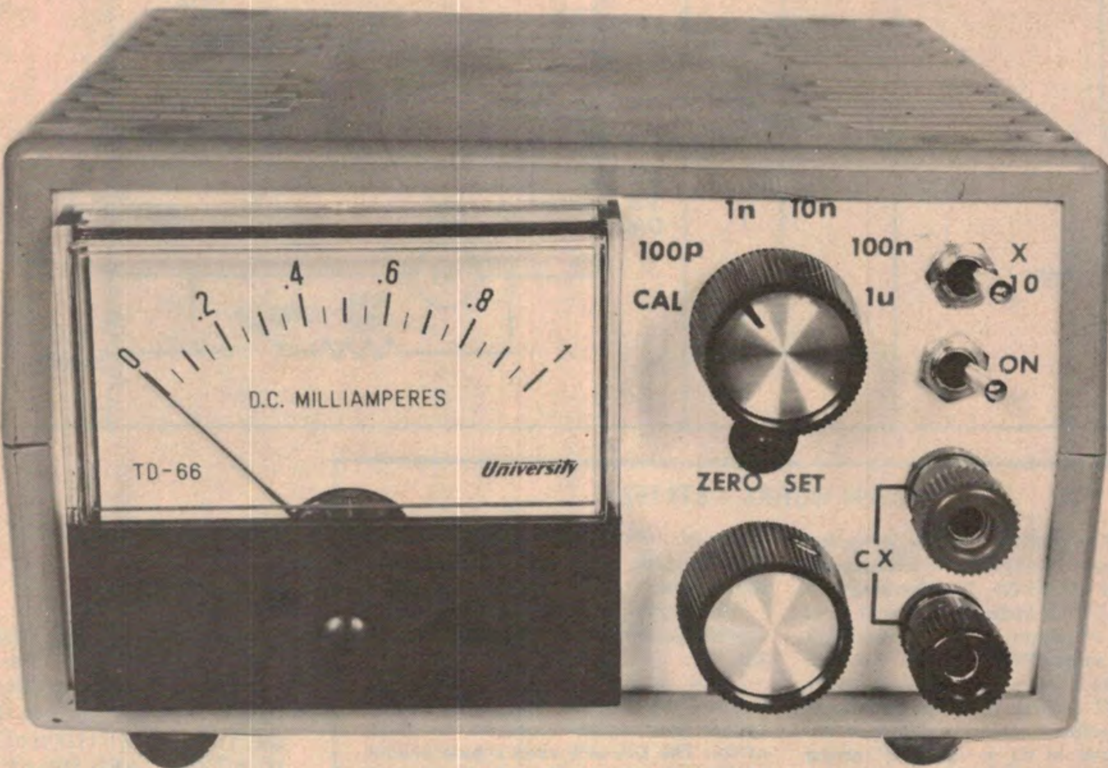
Capacitance meter features linear scale and low cost

This is the third instrument in our series of simple, inexpensive, look-alike test gear projects.

Roger Harrison



WE FIRST published a capacitance meter project almost two years ago. The Linear Scale Capacitance Meter, Project 136, (ETI, March 1978) enjoyed a certain amount of popularity at the time it was published, but ran into a few snags. Unfortunately the edgewise mounting meter became difficult to procure as did, later, the case. Also, the meter required calibration by hand. Correspondence from a number of readers also suggested extending the range of the instrument to enable capacitors up to 10 uF to be measured.

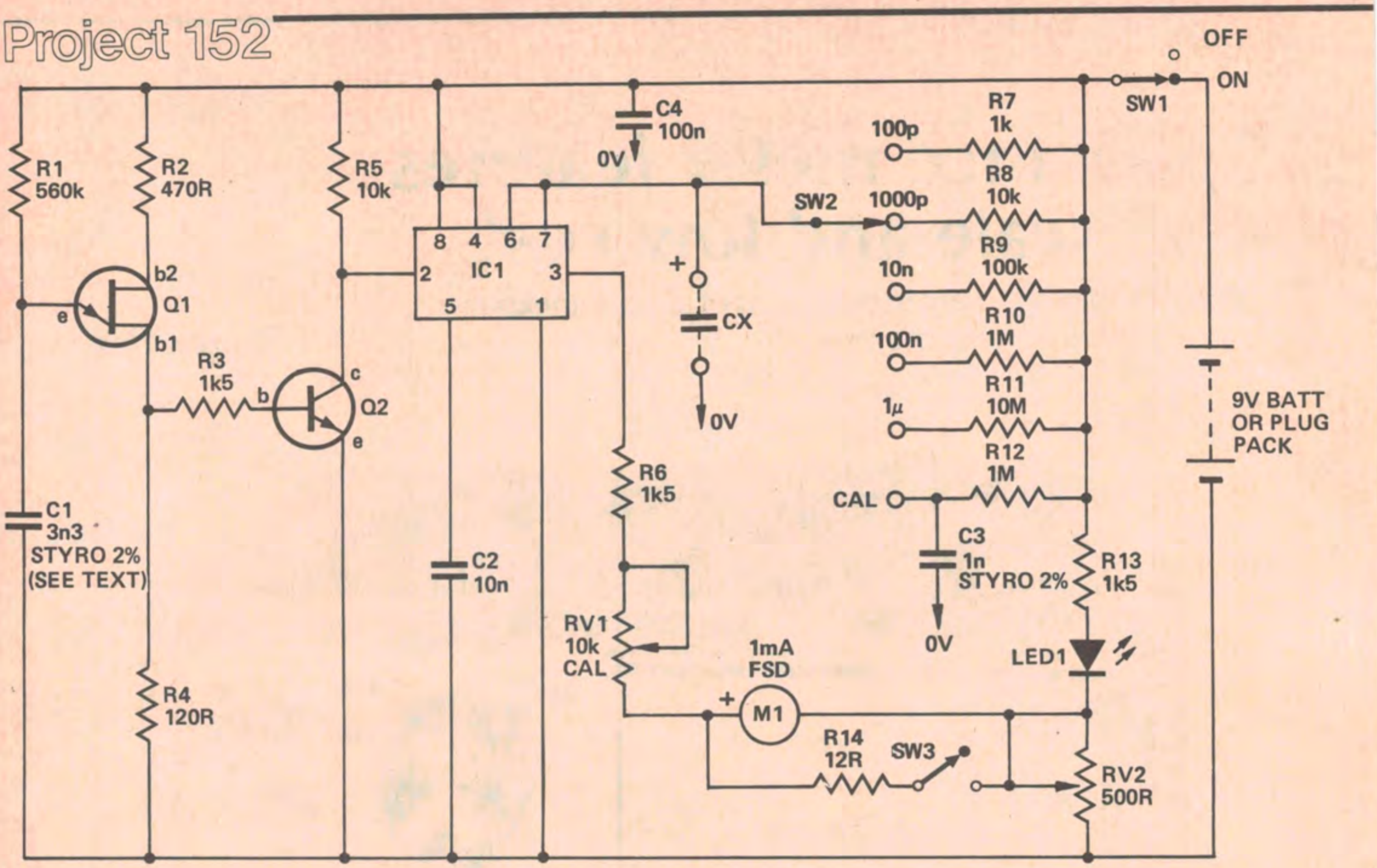
So, when we were considering our current range of simple, inexpensive test gear projects, the old linear scale capacitance meter was an obvious candidate for revamping to include in the series. Phil Wait took it in hand and here it is – the all-new, singing-dancing, lemon-fresh Linear Scale Capacitance Meter!

This unit has been constructed using the same type case, meter and range switch as the two previous projects in the series: the frequency meter, ETI-150, and linear scale ohmmeter, ETI-151. It can be powered from internal batteries or a small plugpack.

Since constructing the original project, the writer has been consistently amazed at how often it has been used. When considering the purchase or construction of test instruments, most people take resistance measurement for granted – but, in so many applications, capacitance measurement comes a good second. ▶

SPECIFICATIONS – ETI 152

Capacitance ranges (full scale)	100p, 1n, 10n, 100, 1u – to 10u on x10
Accuracy	5%, estimate to 2% on meter scale
Calibration	from internal capacitor, 2%
Supply voltage	9 Vdc from battery or plugpack



HOW IT WORKS – ETI 152

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 us 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 e-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 us, 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:

$$t = 1.1\ RrCx$$

– where 'Rr' is the range resistor, and 'Cx' the capacitor being measured.

At the end of the period, the comparator inside the 555 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 of the supply voltage and less than 1/3 of the supply in its 'high' and 'low' states respectively, the dc offset is compensated for by returning the 'load' current through an offset voltage developed across RV2 via R13 from the supply rail.

Zero-setting is accomplished by making RV2 variable. A calibration control is provided by making a portion of the 'load' resistance variable – RV1 here.

The 'X10' switch simply reduces the sensitivity of the meter, allowing measurement of a high output pulse-on to pulse-off ratio.

Ranges

The unit will measure capacitance from 5 pF up to 1 uF in five ranges with a x10 facility to extend the top range to 10 uF. Full-scale values for each range are: 100 pF; 1 nF (1000 pF or 0.001 uF); 10 nF (0.01 uF); 100 nF (0.1 uF) and 1 uF – extended to 10 uF with the x10 switch.

The x10 switch actually works on all ranges and is handy when checking capacitors that over-range when a particular range is selected, so that the appropriate range can be readily found.

Different ranges can be provided by selecting different values for the range resistors R7 to R11. For example 47 pF to 0.47 uF (in five ranges), 4.7 uF with the x10 in, could be obtained by changing R7 to 470R, R8 to 4k7 etc. However, the meter scale would need to be recalibrated. As it stands, the scale reads capacitance directly.

The meter scale provides divisions of 5% and the actual capacitance value can be estimated to about 2% or so, once the unit is calibrated. Overall accuracy will depend on the meter and the calibration capacitor accuracy.

PARTS LIST - ETI 152

Resistors all ½W, 5% (except R7—R12)

R1 . . . . 560k
R2 . . . . 470R
R3 . . . . 1k5
R4 . . . . 120R
R5 . . . . 10k
R6 . . . . 1k5
R7 . . . . 1k 2%
R8 . . . . 10k 2%
R9 . . . . 100k 2%
R10. . . . . 1M 2%
R11. . . . . 10M 2%
R12. . . . . 1M 2%
R13. . . . . 1k5
R14. . . . . 12R

Potentiometers

RV1 . . . . . . 10k min vert mounting trim pot
RV2 . . . . . . 500R lin pot

Capacitors

C1. . . . . 3n3 2% tolerance - see text
C2. . . . . 10n greencap
C3. . . . . 1n 2% tolerance - see text
C4. . . . . 100n greencap

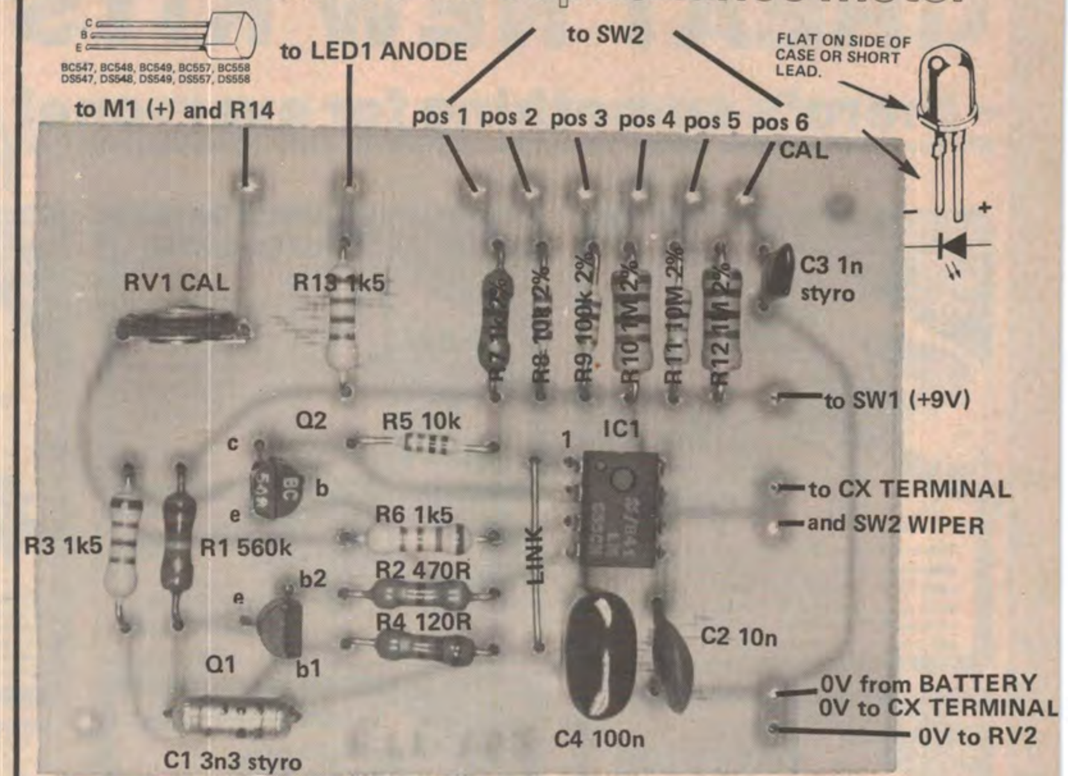
Semiconductors

LED1. . . . . . TIL220R or similar LED
Q1 . . . . 2N2646, 2N2647 uni-junction
Q2 . . . . BC548, BC108
IC1 . . . . 555 timer

Miscellaneous

M1 . . . . 1mA FSD meter 60 mm square, University TD66 or similar
SW1. . . . . . . SPST miniature toggle switch
SW2. . . . . . . one pole six pos wafer switch
SW3. . . . . . . SPST miniature toggle switch
SK1, SK2 . . . screw terminals

ETI 152 pc board, 9V battery (type 216) and battery clips, plastic case 130 mm x 130 mm x 75 mm, knobs.

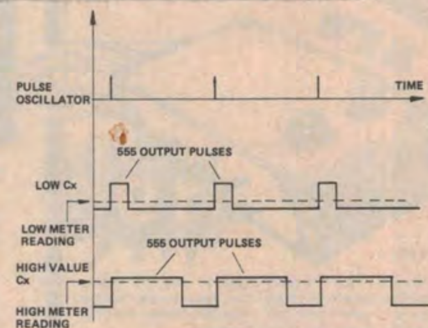


Design

A pulse oscillator, Q1, running at a pulse repetition frequency of about 1 kHz, triggers a 555 timer IC which is connected as a monostable multi-vibrator. The 555 in this configuration will produce a pulse at its output, pin 3, having a period determined by the values of the range resistor selected and the unknown capacitance. The lower the value of the unknown capacitance, the shorter the duration of the output pulse from the 555. Conversely, the higher the value of the unknown capacitance, the longer the duration of the output pulse.

The output pulse is passed through a moving-coil meter which will integrate the pulse waveform. The reading on the meter will thus be directly proportional to the ratio of the time the output pulse is on to the time it is off, resulting in a linear relationship of capacitance to meter reading. A low value of capacitance connected to the 'CX' terminals will produce a short duration pulse and thus a low meter reading; a high value of capacitance will produce a long duration pulse and a high meter reading, as illustrated on the accompanying diagram.

The output pulse of the 555 swings between values of about 2/3 of the supply voltage ('high') and 1/3 of the supply voltage ('low'). Thus, the meter needs to be returned to a voltage of about 1/3 of the supply, otherwise current would flow through it continuously. Conveniently, this voltage is set by a pot on the front panel which serves as a 'zero set' control. The meter is calibrated by varying the resistance in series with the meter, rather than having preset range resistors. This results in better accuracy and requires only one preset control. The CAL. position on the range switch is for occasional checking. Any significant variation in the calibration will generally indicate a low battery.



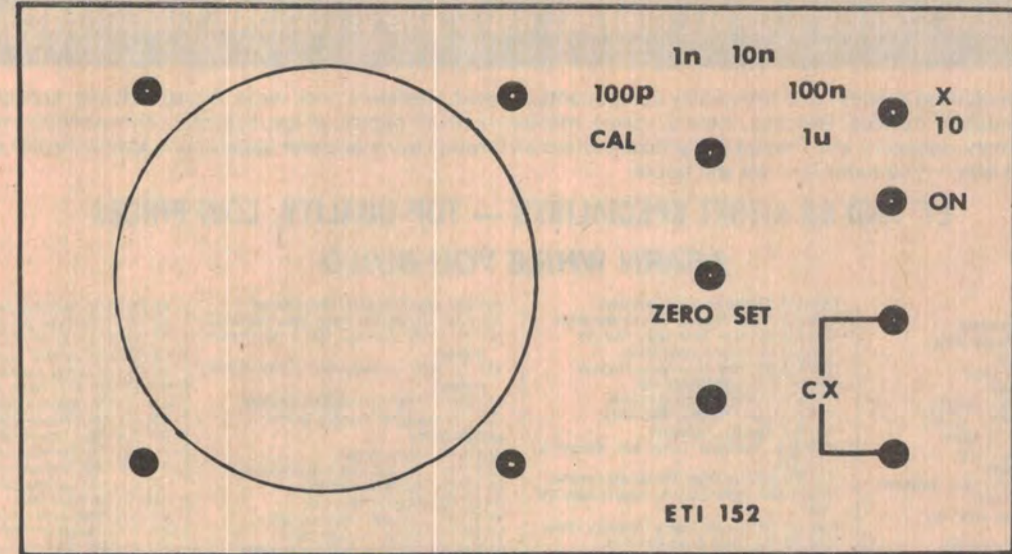
The unknown capacitance, Cx, determines the width of the output pulses from the 555 monostable. The meter integrates these pulses to produce a reading which is directly proportional to the unknown capacitor's value.

Construction

We mounted our meter in a matching case to our Linear Scale Ohm meter and Frequency Meter. The front panel layout is a little cramped but all switches and terminals are easy to use with plenty of finger room.

Start your construction with the pc board making sure that the integrated circuit is the right way around. Take care also with the transistor and UJT orientation. Capacitors C1 and C3 determine the overall accuracy of the instrument and should be close tolerance types. Some suppliers carry a range of close tolerance silver mica or styroseal capacitors. Alternatively, if you have a friend or employer with a capacitance bridge you can select one close to the required value (1n) from standard tolerance types. See Shop-around on page 93 for suppliers that stock suitable capacitors. The range resistors R7 to R12 should also be close tolerance (2%) types.

All other components, including ▶



the x10 range resistor, are mounted on the front panel. Mount the smaller switches and terminals first, followed by the potentiometers and last of all the meter. The resistor R14 is wired from the positive meter terminal to one of the contacts on the range switch, SW3.

The printed circuit must be mounted so the lead length from the Cx terminals is as short as possible to avoid stray capacitance. Mount the pc board to the bottom of the case just behind the terminals and use tinned copper wire to make the connections making sure that the wires are well spaced from each other and well away from the rest of the circuit. Wire each connection from the board to the components on the front panel carefully to avoid errors.

When the construction is complete check all the wiring but don't assemble the lid to the box yet. Switch to the 1n range and turn the instrument on. Adjust the ZERO SET pot and see that the meter pointer varies about the zero scale marking. If it doesn't, check the pc board and panel wiring. If all is well, set the control so the meter pointer is on the scale zero mark. Then, switch to the CAL position and the meter pointer should move up the scale. Adjust the CAL trimpot on the pc board, RV1, so that the meter reads '1'. Switch to any range and you're ready to go!

You will find that stray capacitance affects the meter zero reading on the 100p scale. Simply adjust the ZERO SET control so that the meter reads zero before taking a measurement on this range.You'll find that once the instrument is zeroed on the 1n range, the higher ranges will not require further adjustment of the zero set.

In use, occasionally check the calibration. If grossly in error, your battery is about to go flat. A No.216 battery should give quite a long life as the unit draws 50-60 mA. For longer life a No.2362 battery is recommended. If you operate the unit from a plug-pack, one rated at 6 Vdc output should deliver more than 8V at this low load, which is perfectly adequate.

Remember that any devices used to grip the leads of capacitors being measured will add stray capacitance and you will need to compensate for this by readjusting the zero set control. However, this will only have to be done on the 100p and 1n ranges as the added capacitance will be negligible on the higher ranges.

The 'x10' switch is primarily intended to extend the 1u range to 10u, although it is useful on the other ranges — when a capacitor being measured over-ranges you can assess whether it is just above the range selected or many ranges up in value.

Well, there you go! I hope you find this instrument as useful as I have. ●

Above is a full-size reproduction of the front panel artwork. You may cut it from the magazine if you wish and use it directly. Alternatively, Scotchcal reproductions will be available from Radio Despatch Service in Sydney.

Same-size reproduction of the pc board artwork. See Shoparound on page 93 for details on pc board suppliers.