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Constructional Project

LOW-COST CAPACITANCE METER

by ROBERT PENFOLD

**A simple starter project that will let you get the measure of most capacitors.
Five switched ranges: 1nF to 10uF.**

A typical multimeter can measure voltage, current and resistance over a wide range of values, and usually has a few "tricks up its sleeve" such as continuity tester and transistor checker facilities. Some multimeters have capacitance measuring ranges, but this feature remains something of a rarity. This is a pity, because anyone undertaking electronic faultfinding will soon need to check suspect capacitors and a ready-made capacitance meter is an expensive item of equipment.

The unit featured here offers a low-cost solution to the problem of testing capacitors. It is an analog capacitance meter that has five switched ranges with full-scale values of 1nF; 10nF; 100nF; 1uF; and 10uF. It cannot measure very high or low value components, but it is suitable for

testing the vast majority of capacitors used in everyday electronics.

SYSTEM OPERATION

The block diagram for the *Low-Cost Capacitance Meter* is shown in Fig.1. Like most simple capacitance meter designs, this unit is based on a monostable circuit. When triggered by an input pulse a monostable produces an output pulse having a duration that is controlled by a CR network. In this case the monostable is triggered manually using a pushbutton switch each time a reading is required.

The resistor in the timing network is one of five resistors selected via a switch, and these resistors provide the unit with its five ranges. The capacitor in the CR network is the capacitor

under test.

The duration of the output pulse is proportional to the values of both components in the CR network. If a 1nF capacitor produces an output pulse of one millisecond in duration, components having values of 2.2nF and 4.7nF would respectively produce pulse lengths of 2.2ms and 4.7ms.

Each output pulse must be converted into a voltage that is proportional to the pulse duration. A moving coil panel meter can then read this voltage, and with everything set up correctly it will provide accurate capacitance readings.

If we extend the example given previously, with a potential of one volt per millisecond being produced, a meter having a full-scale value of 10V would actually read 0 to 10nF. This time-to-voltage conversion is actually quite simple to achieve, and is provided by a constant current generator and a charge storage capacitor.

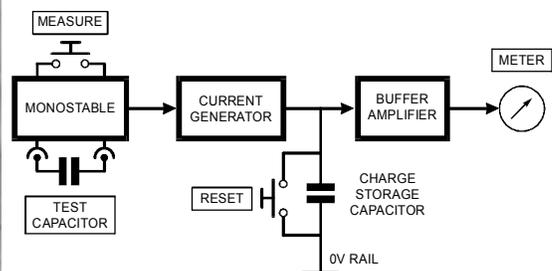


Fig.1. Schematic block diagram for the *Low-Cost Capacitance Meter*.

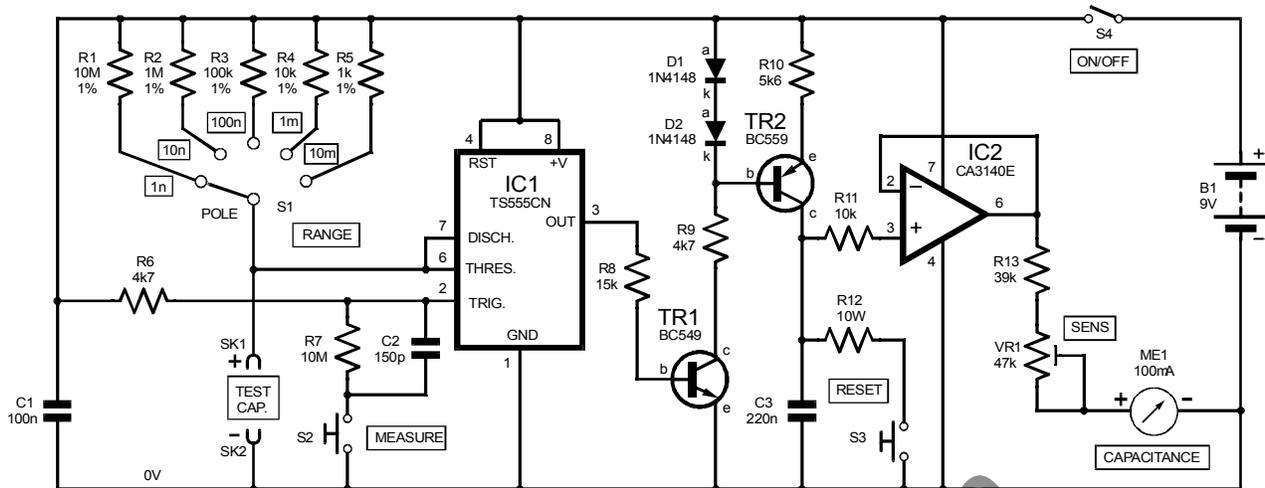


Fig.2. Complete circuit diagram for the Low-Cost Capacitance Meter.

capacitor.

When charged via a resistor the potential across the capacitor does not rise in a linear fashion. As the charge potential increases, the voltage across the resistor falls, giving a steadily reducing charge current. The voltage therefore increases at an ever-decreasing rate (inverse exponentially).

A current regulator avoids this problem by ensuring that the charge current does not vary with time, giving a linear rise in the charge voltage. The circuit therefore provides the required conversion from capacitance to voltage, but it is important that loading on the storage capacitor is kept to a minimum.

Tapping off a significant current could adversely affect the linearity of the circuit and would also result in readings rapidly decaying to zero. The meter is, therefore, driven via a buffer amplifier that has a very high input impedance. Once a reading has been taken and noted, operating the Reset switch discharges the storage capacitor and returns the reading to zero so that a new reading can be taken.

CIRCUIT OPERATION

The complete circuit diagram for the *Low-Cost Capacitance Meter* project appears in Fig.2. The monostable is based on a low-power 555 timer (IC1) used in

the standard monostable configuration.

Apart from the fact it gives much longer battery life, a low-power 555 is a better choice for this type of circuit due its lower self-capacitance. This produces much better accuracy on the 1nF range, and a standard 555 is

COMPONENTS

Resistors

- R1 10M 1% metal film
- R2 1M 1% metal film
- R3 100k 1% metal film
- R4 10k 1% metal film
- R5 1k 1% metal film
- R6, R9 4k7 (2 off)
- R7 10M
- R8 15k
- R10 5k6
- R11 10k
- R12 10 ohms
- R13 39k

All 0.25W 5% carbon film, except where otherwise specified

Potentiometer

- VR1 47k miniature enclosed or skeleton preset, horizontal

Capacitors

- C1 100n ceramic
- C2 150p ceramic plate
- C3 220n polyester

Semiconductors

- D1, D2 1N4148 signal diode (2 off)
- TR1 BC549 *npn* transistor
- TR2 BC559 *pnp* transistor
- IC1 TS555CN low power timer
- IC2 CA3140E PMOS opamp

Miscellaneous

- ME1 100uA moving coil panel meter
- SK1 2mm socket, red
- SK2 2mm socket, black
- S1 12-way single-pole rotary switch (set for 5-way operation) (see text)
- S2, S3 pushbutton switch, push-to-make (2 off)
- S4 s.p.s.t. miniature toggle switch
- B1 battery (PP3 size), with connector leads

Metal instrument case (or type to choice), size 150mm x 100mm x 75mm; stripboard 0.1-inch matrix, size 34 holes by 21 copper strips; 8-pin DIL socket (2 off); control knob; calibration capacitor (see text); test leads (see text); solder pins; multistrand connecting wire; solder, etc.

**See also the
SHOP TALK Page!**

Approx. Cost
Guidance Only (Excluding batteries, case, & meter)

\$19

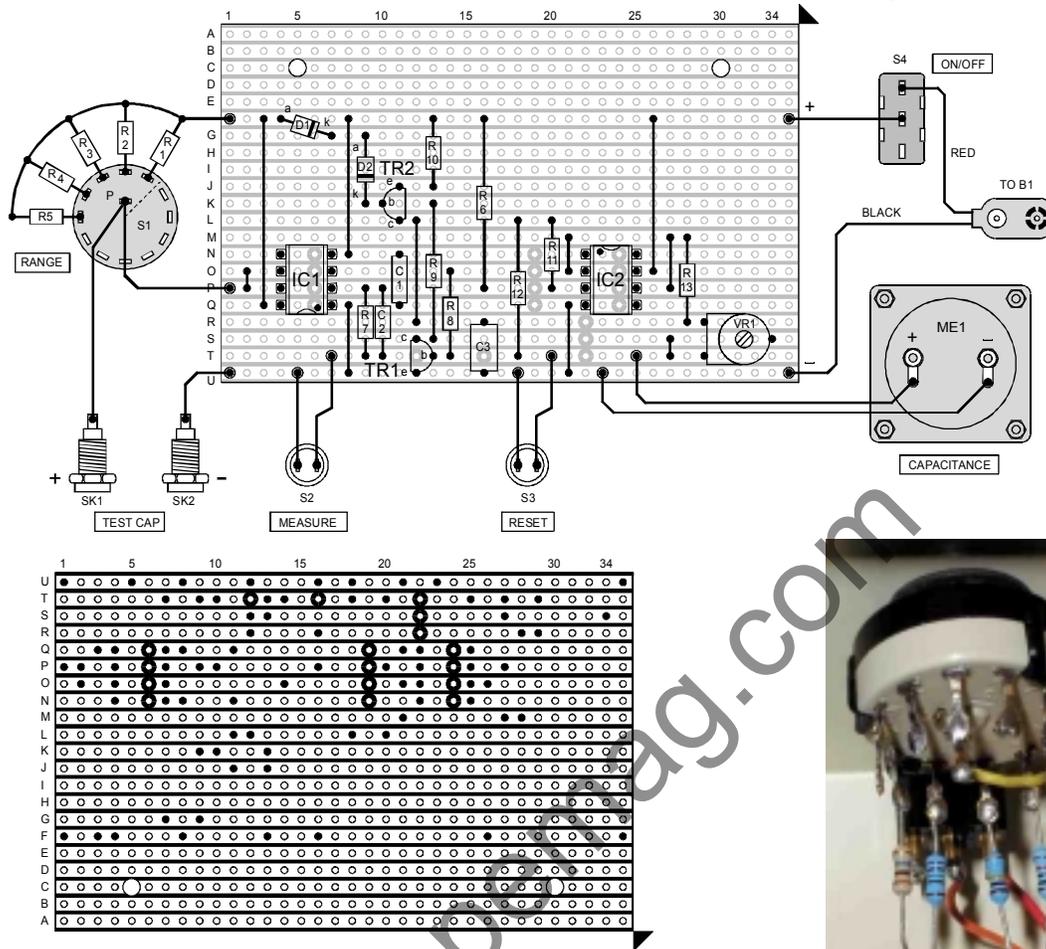


Fig.3. Stripboard component layout, interwiring, and details of breaks required in underside copper tracks.

therefore not recommended for use in this circuit.

Switch S1 sets the Range and R1 to R5 are the five timing resistors. Resistors R1 to R5 respectively provide the 1nF, 10nF, 100nF, 1uF, and 10uF ranges.

One slight flaw in the 555 for this application is that it will only act as a pulse stretcher and not as a pulse shortener. In other words, the output pulse will not end at the appropriate time if the input pulse is still present.

If it were used to directly trigger IC1, the input pulse from pushbutton switch S2 would invariably be far too long. A simple CR circuit is therefore

used to ensure that IC1 will always receive a very short trigger pulse, regardless of how long Measure switch S2 is pressed.

Resistor R6 holds the trigger input of IC1 (pin 2) high under standby conditions, but it is briefly pulsed low when S2 is operated and capacitor C2 charges via R6. When S2 is released, resistor R7 discharges C2 so that the unit is ready to trigger again the next time S2 is operated. Resistor R7 has been given a very high value so that the discharge time of C2 is long enough to prevent spurious triggering if S2 does not operate "cleanly". Most mechanical switches suffer from contact bounce, and without this debouncing it is likely that re-

Mount the Range resistors directly on the switch tags before the switch is fitted in the case.

triggering would occur practically every time S2 was released.

Under standby conditions the output at pin 3 of IC1 is low, and both transistor TR1 and TR2 are switched off. Consequently, only insignificant leakage currents flow into the charge storage capacitor C3. An output pulse from IC1 switches on TR1, which in turn activates TR2.

Transistor TR2 is connected as a conventional constant current generator, and the value of resistor R10 controls the

output current. This is around 115uA with the specified value. Transistors TR1 and TR2 switch off again at the end of the pulse from IC1, and the charge voltage on C3 is then read by the voltmeter circuit based on panel meter ME1.

METER CIRCUIT

Operational amplifier (opamp) IC2 is used as the buffer amplifier, and the PMOS input stage of this device ensures that there is no significant loading on the "charge" capacitor C3. The input resistance of IC2 is actually over one million megohms.

However, the voltage on C3 will gradually leak away through various paths, including C3's own leakage resistance. The reading should remain accurate for at least a minute or two, and in most cases it will not change noticeably for several minutes. There will certainly be plenty of time for a reading to be taken before any significant drift occurs.

Briefly operating Reset switch S3 discharges C3 and zeros the meter so that another reading can be taken. Resistor R12 limits the discharge current to a level that ensures the contacts of S3 have a long operating life. The rate of discharge is still so high that it appears to be instant.

Preset VR1 enables the sensitivity of the voltmeter ME1 to be adjusted, and in practice this is adjusted so that the required full-scale values are obtained. In order to ensure good accuracy on all five ranges it is essential for range resistors R1 to R5 to be close tolerance (one or two percent) components.

There is no overload

protection circuit for the meter, but this protection is effectively built into the design. The circuit driving the meter is only capable of producing minor overloads, and is incapable of inflicting any damage. The current consumption of the circuit is only about 3mA, and a PP3 size battery is adequate to power the unit.

CONSTRUCTION

The *Low-Cost Capacitance Meter* is built up on a small piece of stripboard having 34 holes by 21 copper strips. The topside component layout, underside details and interwiring to off-board components is shown in Fig.3.

As this board is not of a standard size, a piece will have to be cut from a large board using a small hacksaw. Cut along rows of holes rather than between them, and smooth any rough edges produced using a file. Then drill the two 3mm diameter mounting holes in the board and make the 17 breaks in the copper strips. There is a special tool for making the breaks in the copper strips, but a handheld twist drill bit of around 5mm diameter does the job very well.

The circuit board is now ready for the components, link wires, and solder pins to be added. The CA3140E used for IC2 has a PMOS input stage that is vulnerable to damage from static charges, and the appropriate handling precautions must therefore be taken when dealing with this IC.

It should be fitted to the board via a holder, but it should not be plugged into place until the unit is otherwise finished, and the board and wiring double-checked for any errors.

It should be left in its anti-static packing until then. Try to handle the device as little as possible when fitting it in its IC socket, and keep well away from any likely sources of static electricity such as television sets and computer monitors.

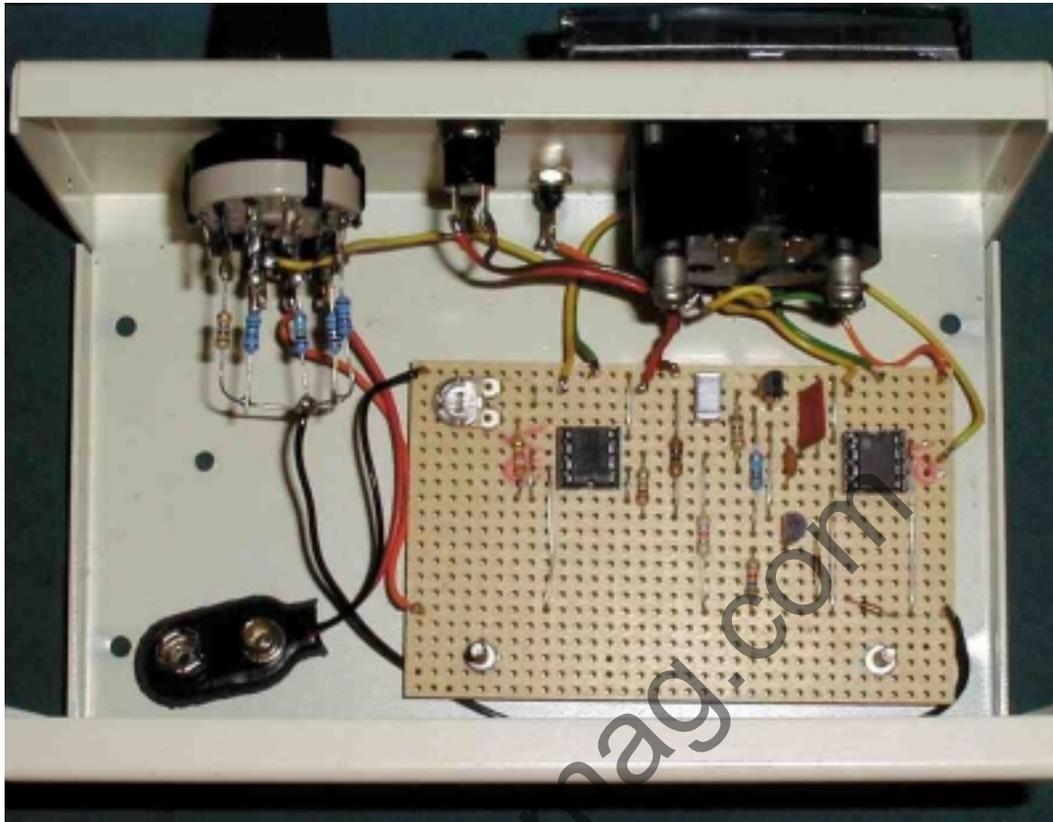
Although the TS555CN timer used for IC1 is not static-sensitive it is still a good idea to fit it in an IC socket. Be careful to fit IC1 the right way around because it has the opposite orientation to normal, with pin one at the bottom. This chip could easily be destroyed if it is fitted the wrong way around.

In all other respects construction of the board is fairly straightforward. The link wires can be made from the trimmings from resistor leadouts or 22 s.w.g. tinned copper wire. In order to fit into this layout properly capacitor C3 should be a printed circuit mounting component having 7.5mm (0.3-inch) lead spacing. Be careful to fit the diodes and transistors with the correct orientation. Note that transistors TR1 and TR2 have opposite orientations.

RANGE RESISTORS

The five range resistors (R1 to R5) are mounted directly on the Range rotary switch S1, which helps to minimize stray capacitance and pick up of electrical noise. This aids good accuracy, especially on the 1nF range. It is best to mount the resistors on S1 before this switch is fitted in the case.

Fitting the resistors is made much easier if the switch is stuck to the workbench using Plasticine, or Bostik Blu-Tack. Provided the tags and the ends of the leadouts are tinned with solder it should then be quite easy to build this sub-assembly.



Layout of components inside the metal case of the completed Low-Cost Capacitance Meter. The circuit board is mounted to one side to leave space for the battery

Try to complete the soldered joints reasonably swiftly so that the resistors do not overheat. It takes quite a lot of heat to destroy resistors, but relatively small amounts can impair their accuracy.

CASING UP

A medium size metal instrument case is probably the best choice for a project of this type, but a plastic box is also suitable. The exact layout is not critical, but mount SK1 and SK2 close together.

Many capacitors will then connect directly into the sockets without too much difficulty, but a set of test leads will also be needed to accommodate some capacitors. All that is required are two insulated leads about

100mm long. Each lead is fitted with a 2mm plug at one end and a small crocodile clip at the other.

Fitting the meter on the front panel is potentially awkward because a large round cutout is required. For most meters a cutout of 38mm diameter is required, but it is advisable to check this point by actually measuring the diameter of the meter's rear section. DIY superstores sell adjustable hole cutters that will do the job quickly and easily, or the cutout can be made using a coping saw, Abrafile, etc.

Four 3mm diameter holes are required for the meter's threaded mounting rods. Marking the positions of these is quite easy as they are usually at the corners of a square having

32mm sides, and the same center as the main cutout. Once again though, it would be prudent to check this by making measurements on the meter prior to drilling the holes.

The circuit board is mounted on the base panel of the case towards the left-hand side of the unit, leaving sufficient space for the battery to the right of the board. The component panel is mounted using either 6BA or metric M2.5 bolts, and spacers or nuts are used to ensure that the underside of the board is held well clear of the case bottom. To complete the unit the hard wiring is added. This offers nothing out of the ordinary, but be careful to connect the battery clip and meter ME1 with the correct polarity.

CALIBRATION

Preset potentiometer (wired as a "variable resistor") VR1 must be given the correct setting in order to obtain good accuracy from the unit, and a close tolerance capacitor is needed for calibration. For optimum accuracy this capacitor should have a value equal to the full-scale value of the range used during calibration.

In theory it does not matter which range is used when calibrating the unit, but in practice either the 1nF or 10nF range has to be used. Suitable capacitors for the other ranges are either unavailable or extremely expensive.

The 10nF range is the better choice as the small self-capacitance of IC1 is less

significant on this range, although this factor seems to have very little affect on accuracy. Probably the best option is to calibrate the unit on the 10nF range using a 10nF polystyrene capacitor having a tolerance of one percent.

It is possible that a large reading will be produced on the meter when the unit is first switched on, but pressing Reset switch S3 should reset the meter to zero. If it is not possible to zero the meter properly, switch off at once and recheck the entire wiring, etc.

If all is well, set preset VR1 at maximum resistance (adjusted full clockwise). Then with the unit set to the correct range and the calibration capacitor connected to SK1 and SK2, operate pushswitch S2. This should produce a strong

deflection of the meter, and VR1 is then adjusted for precisely full-scale reading on meter ME1. The unit should then provide accurate readings on all five ranges.

IN USE

The Meter is suitable for use with polarized capacitors such as electrolytic and tantalum types. However, it is essential that they are connected to SK1 and SK2 with the correct polarity. The positive (+) lead connects to SK1 and the negative lead connects to SK2.

Especially when using the 1nF and 10nF ranges, avoid touching the lead that connects to SK1 when a reading is being taken. Otherwise electrical noise might be introduced into the system producing inaccurate results.

Avoid connecting a charged capacitor to this or any other capacitance meter, since doing so could result in damage to the semiconductors in the meter circuit. If in doubt always discharge a capacitor before testing it.