Construction project:

Low cost capacitor meter

Here's a nifty little unit which turns your digital or analog multimeter into a direct-reading capacitance meter. It uses a handful of parts, and is very easy to get going.

by BARRY KAULER

The basic circuit for this project was originally described by me in the January 1985 issue of *Electronics Australia*, in the "Circuit & Design Ideas" section. Since then there has been a steady stream of letters from interested readers, asking about things like the availability of a PCB pattern, and where to get some of the components.

As a result of this interest, I thought it might be worthwhile to provide some additional information – including a PCB pattern and wiring details.

Since the circuit was first described over three years ago, there may be many readers who won't be able to refer easily to the original article. So the best idea seems to be to start all over again.

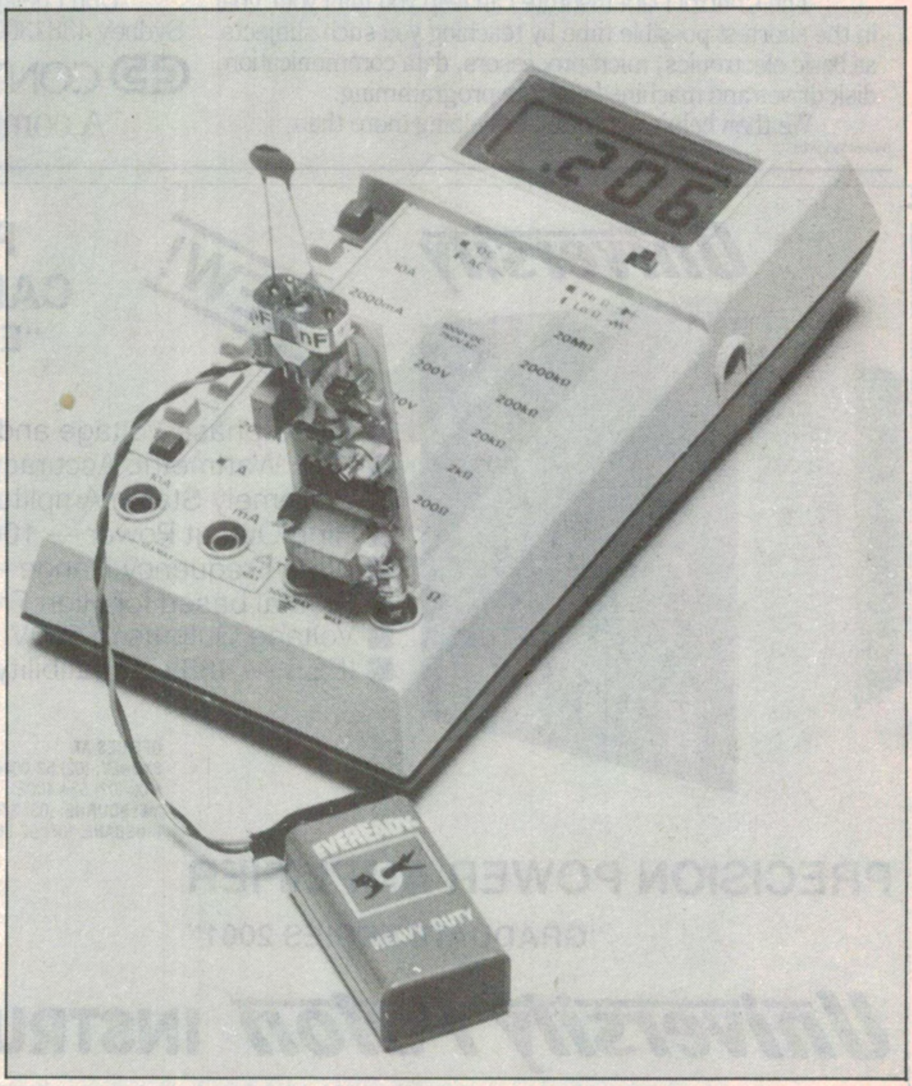
The basic idea is that the circuit is an adaptor, which plugs into any normal digital or analog multimeter to convert it into a capacitance meter. It will read any unknown capacitance in the range from 3.3pF to 2000uF, in two ranges. One range reads in picofarads, and the other in nanofarads. It can measure polarised capacitors such as aluminium and tantalum electrolytics, as well as normal non-polarised types.

The unit is very small and is made to plug directly into banana sockets which are spaced 19mm apart, as now found on the majority of multimeters.

There is only one control switch, a three-position DPDT centre-off type. There is nothing to adjust – you simply plug the pigtails of the unknown capacitor into the adaptor's socket (a modified crystal socket), switch to either the pF or nF ranges and read the capacitance value on the meter.

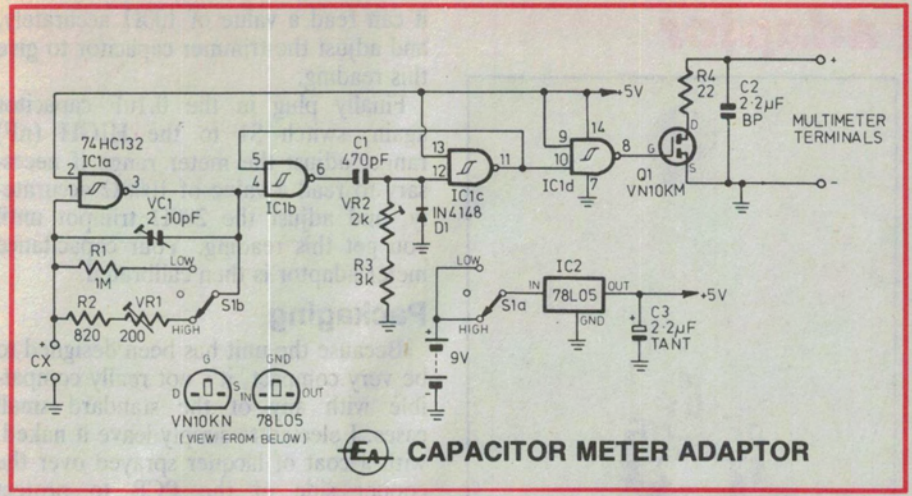
The multimeter itself is set to a standard resistance range, to measure ohms. The only minor complication is that for correct reading, the indication on the meter in ohms must be divided by 10 to give the capacitance value in pF or nF (depending on the rane selected).

So a reading of 1MΩ on the LOW range corresponds to 100,000pF, or 0.1uF. Similarly a reading of 1kΩ on the same range corresponds to 100pF, while on the HIGH range it would correspond to 100nF or 0.1uF.



The circuit

At the heart of the circuit is a 74HC132 quad Schmitt trigger chip with



The circuit for the adaptor, which uses only one IC, a small power MOSFET and a three-terminal regulator. It's very compact.

2-input NAND gates. The first of these, IC1a, is connected as a relaxation oscillator whose frequency depends on the unknown capacitor Cx connected between input pin 1 and ground.

The oscillator output is fed to IC1b, which together with IC1c forms a one-shot or monostable. This converts the oscillator output into a stream of narrow pulses, of constant width but with a duty cycle (mark/space ratio) proportional to the capacitance of Cx. These pulses are squared up and inverted by buffer IC1d, and used to switch Q1, a VN10KM enhancement-mode power MOSFET.

The multimeter, set to measure resistance, is connected between the drain and source of Q1 via a small protective resistor. Also connected across the multimeter input is a 2.2uF bipolar capacitor, which effectively forms an integrating circuit in conjunction with the meter's current source. As a result, the integrated or "average" resistance measured by the meter becomes proportional to Q1's switching duty cycle, and in turn to the value of Cx.

The effective resistance across the meter terminals varies from very close to the 22 ohms of the protective resistance, up to almost infinity – certainly many megohms, when Cx has a large value.

Although this way of measuring capacitance may seem a bit unorthodox and indirect, it has been carefully designed and is capable of very accurate results. Part of the secret is the use of a small power MOSFET for Q1, to get really fast switching and very low on-resistance.

Note that because of the way the circuit works, there is a DC voltage component across the capacitor being measured – the average value of the oscillation waveform at the input of IC1a. This has a value of around 2.5 volts, with polarity as marked. As a result polarised capacitors such as electrolytics can be measured quite accurately, providing they are connected with their negative side to the earthy terminal.

The only kind of capacitors which can cause significant reading errors are leaky high-value electrolytics, because the leakage will tend to slow down the oscillator and give false higher readings. In an extreme case, leakage can even prevent IC1a from oscillating altogether. But then very leaky capacitors are difficult to measure on any simple equipment, and are in any case best confined to the dustbin.

Switch S1b provides the two measurement ranges, by switching in two different feedback resistor values for the oscillator. The 2-10pF trimmer capacitor is to compensate for stray capacitance, which otherwise upsets accuracy at very low values of Cx.

The 2k trimpot adjusting the shunt resistance across the input of IC1c is used to calibrate the LOW capacitance range, by fine tuning the one-shot pulse width. Secondary calibration of the HIGH range is performed by the 200Ω trimpot forming part of the oscillator feedback resistance on this range.

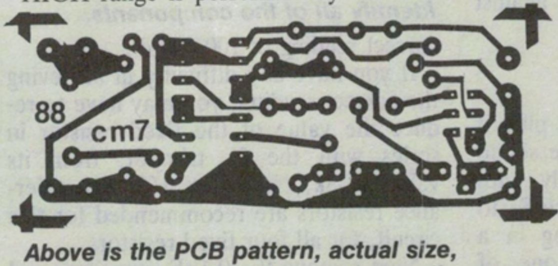
Power for the adaptor comes from a 216-type 9V battery, with a 78L05 low-power three terminal regulator (IC2) to produce the 5V rail required by IC1. On-off switching is performed by S1a, the second pole of the range switch. This not only saves a second switch, but also conserves power by reminding you to turn off the power when you're not actually making a measurement.

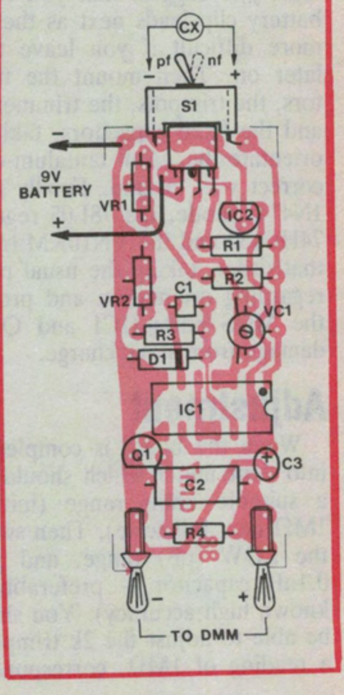
Construction

The complete circuit, apart from the 9V battery, mounts on a very compact PC board measuring only 25 x 66mm and coded 88cm7. A pair of banana plugs mount on one end, spaced 19mm apart, to plug directly into the multimeter's input jacks.

At the other end is mounted S1, a miniature toggle switch of the type which has 90° tails, for horizontal PCB mounting. Mounted concentrically with the switch is a slightly modified miniature crystal socket, to accept the leads of the capacitor to be measured. It's quite neat, and the close proximity of S1 to the socket again prompts you to switch off when the measurement is completed.

The PCB pattern has been designed to take a variety of components for the trimpots and trimmer capacitor, because there are a few different types around. I used miniature trimpots from Radiospares (Cat. No.'s 186-609 and 185-858 for the pots, 125-648 for the trimmer), but the board will also take the some-





Above is the PCB pattern, actual size, while at right is the overlay/wiring diagram. Use this in conjunction with the picture overleaf, as a guide to wiring up the project.

Capacitor meter adaptor

what larger types available from other suppliers.

Radiospares also carries the VN10KM power MOSFET (Cat. No. 295-107), which is made by Siliconix, and the 2.2uF bipolar capacitor (Cat. No. 114-446). The latter is a very compact unit – most other bipolar types of this value are rather larger physically, and won't fit on this board. But note that a 2.2uF capacitor must be used, to ensure correct operation.

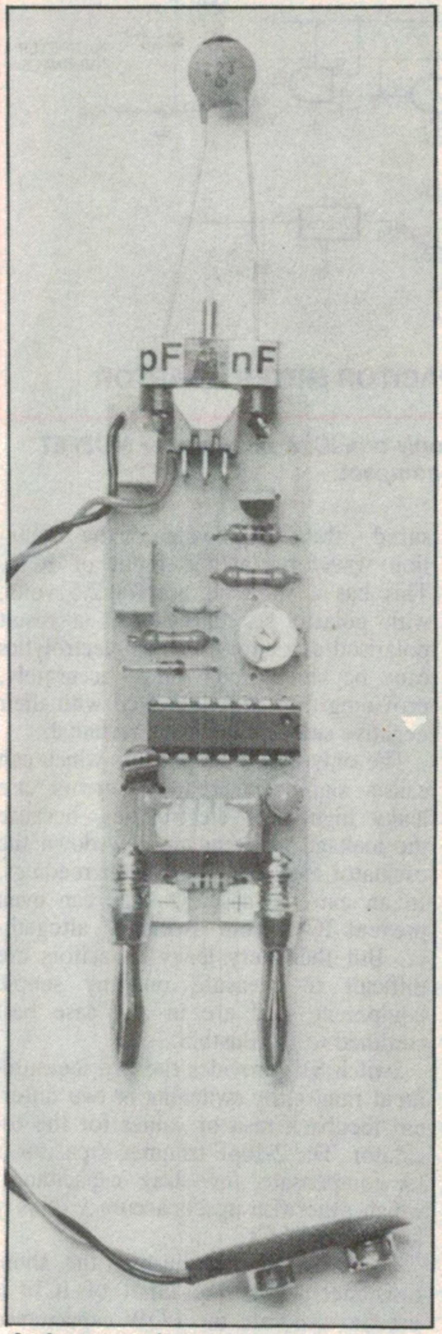
The correct positions of all of the components on the PCB should be clear from the overlay diagram. Note that the two banana plugs are "naked" (the plastic sleeves are not used), and mounted to the board via either small split pins or loops of 18G tinned copper wire.

Before mounting toggle switch S1 to the board, it is best to modify the crystal socket so that the two can be mounted together as an assembly. The socket is modified by first enlarging its centre hole carefully (using drills) until this just fits snugly over the switch sleeve. Then file flats on the inner sides of the two protrusions on the rear of the socket, to clear the sides of the switch body itself. And finally, you'll need to cut off most of the external length of the socket's two wiring tails, leaving them just long enough to crimp and solder short lengths of 18G tinned copper wire at right angles, to connect to the PCB.

After mounting the switch/socket assembly, I suggest that you connect the battery clip leads next as these become more difficult if you leave them until later on. Then mount the fixed resistors, the trimpots, the trimmer capacitor and the fixed capacitors, taking care to orientate the 2.2uF tantalum electro the correct way around. Finally mount the 1N4148 diode, the 78L05 regulator, the 74HC132 and the VN10KM transistor in that order, taking the usual precautions regarding orientation and protection of the MOS parts (IC1 and Q1) against damage from static charge.

Adjustment

When the board is complete, plug it into your meter which should be set to a suitable ohms range (initially with 1MΩ near full scale). Then switch S1 to the LOW (pF) range, and plug in a 0.1uF capacitor – preferably one of known high accuracy). You should then be able to adjust the 2k trimpot to give a reading of 1MΩ, corresponding to a



A close-up of the assembled unit, slightly larger than actual size. The overlay diagram can be used to identify all of the components.

correct reading of 100,000pF.

If you have any difficulty in achieving the correct reading, you may have to reduce the value of the fixed resistor in series with the 2k trimpot, from its value of 3k. Note that 1% high tolerance resistors are recommended for this circuit, for all four fixed resistors.

Next remove the 0.1uF capacitor, and plug in a 10pF NPO ceramic or styroseal (again of known accuracy, if possible). Then turn your meter down until it can read a value of 100Ω accurately, and adjust the trimmer capacitor to give this reading.

Finally plug in the 0.1uF capacitor again, switch S1 to the HIGH (nF) range, adjust the meter range if necessary to read a value of 1000Ω accurately, and adjust the 200Ω trimpot until you get this reading. Your capacitance meter adaptor is then calibrated.

Packaging

Because the unit has been designed to be very compact, it's not really compatible with any of the standard small cases. I elected to simply leave it naked, with a coat of lacquer sprayed over the copper side of the PCB to protect against finger grease, etc.

An alternative approach would be to enclose the whole thing in a sleeve of heat-shrink tubing, once it's all calibrated. Radiospares has suitable tubing available, as may other suppliers.

Don't forget to mark the banana plugs and the crystal socket carefully in terms of polarity, to avoid confusion and possible false measurements later on.

That's about it. I hope you find this little adaptor as useful as I have. EA

PARTS LIST

- 1 PC board, 88cm7, 25 x 66mm
- 1 Small crystal socket (see text)
- 1 DPDT centre off miniature toggle switch, horizontal PCB mounting type
- 2 Banana plugs, without plastic sleeves
- 1 9V battery (216 type)
- 1 Matching clip connector and lead
- 4 Small split pins

Semiconductors

- 1 74HC132 quad Schmitt NAND gate
- 1 78L05 three-terminal regulator
- 1 VN10KM low power MOSFET
- 1 1N4148 silicon signal diode

Resistors & trimpots

- 1 22Ω 1/4W 1%
- 1 820Ω 1/4W 1%
- 1 3k 1/4W 1%
- 1 1M 1/4W 1%
- 1 200Ω min. vertical trimpot
- 1 2k min. vertical trimpot

Capacitors

- 1 2-10pF horizontal trimmer
- 1 470pF ceramic or polystyrene
- 1 2.2uF bipolar (see text)
- 1 2.2uF tantalum electrolytic