Here's one for the workbench or toolbox!

This instrument can perform a leakage current test on almost any type of capacitor in current use, including ceramic, mica, monolithic, metallised polyester or paper, polystyrene, solid tantalum and aluminium electrolytics. There are seven different standard test voltages from 10V to 100V, so most capacitors can be checked at or close to their rated voltage. Leakage currents can also be measured, from almost 10mA down to less than 100nA.

DIGITAL CAPACITOR LEAKAGE METER

by JIM ROWE

In theory, capacitors are not supposed to conduct direct current – apart from a small amount when a DC voltage is first applied to them and they need to 'charge up'.

And with most practical capacitors using materials like ceramic, polyester or polystyrene or even waxed paper as their insulating dielectric, the only time they do conduct any DC is during charging.

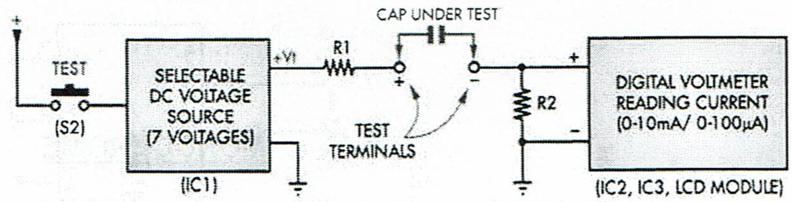
That's assuming they haven't been damaged, either physically or electrically, or that their dielectric has not deteriorated with the passage of time. In that case they may well have a significant DC "leakage current" and need to be replaced.

But as many SILICON CHIP readers will be aware, things are not this clear cut with electrolytic capacitors, whether they be aluminium or tantalum.

Even brand new electrolytic capacitors conduct a small but measurable DC current, even after they have been connected to a DC source for sufficient time to allow their dielectric oxide layer to "form". In other words, all electrolytic capacitors have a significant leakage current even when they are "good".

The range of acceptable leakage current tends to be proportional to both the capacitance and the capacitor's rated voltage. Have a look at the figures

Fig.1: block diagram of the Digital Capacitor Leakage Meter. It consists of two sections, a selectable DC voltage source based on IC1 and a digital current meter (it's actually a voltmeter set up to read current), based on IC2, IC3 and the LCD module.



in the Leakage Current Guide (Table 1). The current levels listed there are the maximum allowable before the capacitor would be regarded as faulty.

Commercially available capacitor leakage current meters are expensive (well over $1000), making this SILICON CHIP Capacitor Leakage Meter an attractive proposition since it will cost a *great* deal less.

It's easy to build and provides seven different standard test voltages: 10V, 16V, 25V, 35V, 50V, 63V and 100V which will cover the majority of capacitors that most readers will be using. Built into a compact jiffy box, it's battery powered (6 x 1.5V AA alkaline cells) and therefore fully portable. This makes it suitable not only for the workbench but also for the service technician's toolbag.

The Capacitor Leakage Meter has a simple presentation in its plastic case. The lid carries the 2-line x 16-character backlit LCD module, as well as the test terminals, power and test switches, as well as the 7-position rotary selector switch.

How it works

The Capacitor Leakage Meter's operation is quite straightforward, as you can see from the block diagram of Fig.1 above. There are two circuit sections, one being a selectable DC voltage source which generates preset test voltages when the TEST button is pressed.

The other circuit section is a digital voltmeter which is used to measure any direct current passed by the capacitor under test. We use a voltmeter to make the measurement because any current passed by the capacitor flows via resistor R2. The voltmeter measures the voltage drop across R2 and is arranged to read directly in terms of current.

So that's the basic arrangement. The reason for resistor R1 being in series with the output from the test voltage source is to limit the maximum current that can be drawn, in any circumstances. This prevents damage to either the voltage source or the digital voltmeter sections in the event of the capacitor under test having an internal short circuit. It also protects R2 and the digital voltmeter section from overload when a capacitor (especially one of high value) is initially charging up to one of the higher test voltages.

R1 has a value of 10kΩ which was chosen to limit the maximum charging and/or short circuit current to 9.9mA even on the highest test voltage range (100V).

The digital voltmeter is configured as an auto-ranging current meter, with two current ranges selected by switching the value of shunt resistor R2. When TEST button S2 is first pressed the voltmeter switches the value of R2 to 100Ω, to provide a 0-10mA range for the capacitor's charging phase. Only when (and if) the measured current level falls below 100µA does it switch the value of R2 to 10kΩ, to provide a 0-100µA range for more accurate measurement of leakage current.

Circuit description

Now have a look at the full circuit of Fig.2, overleaf.

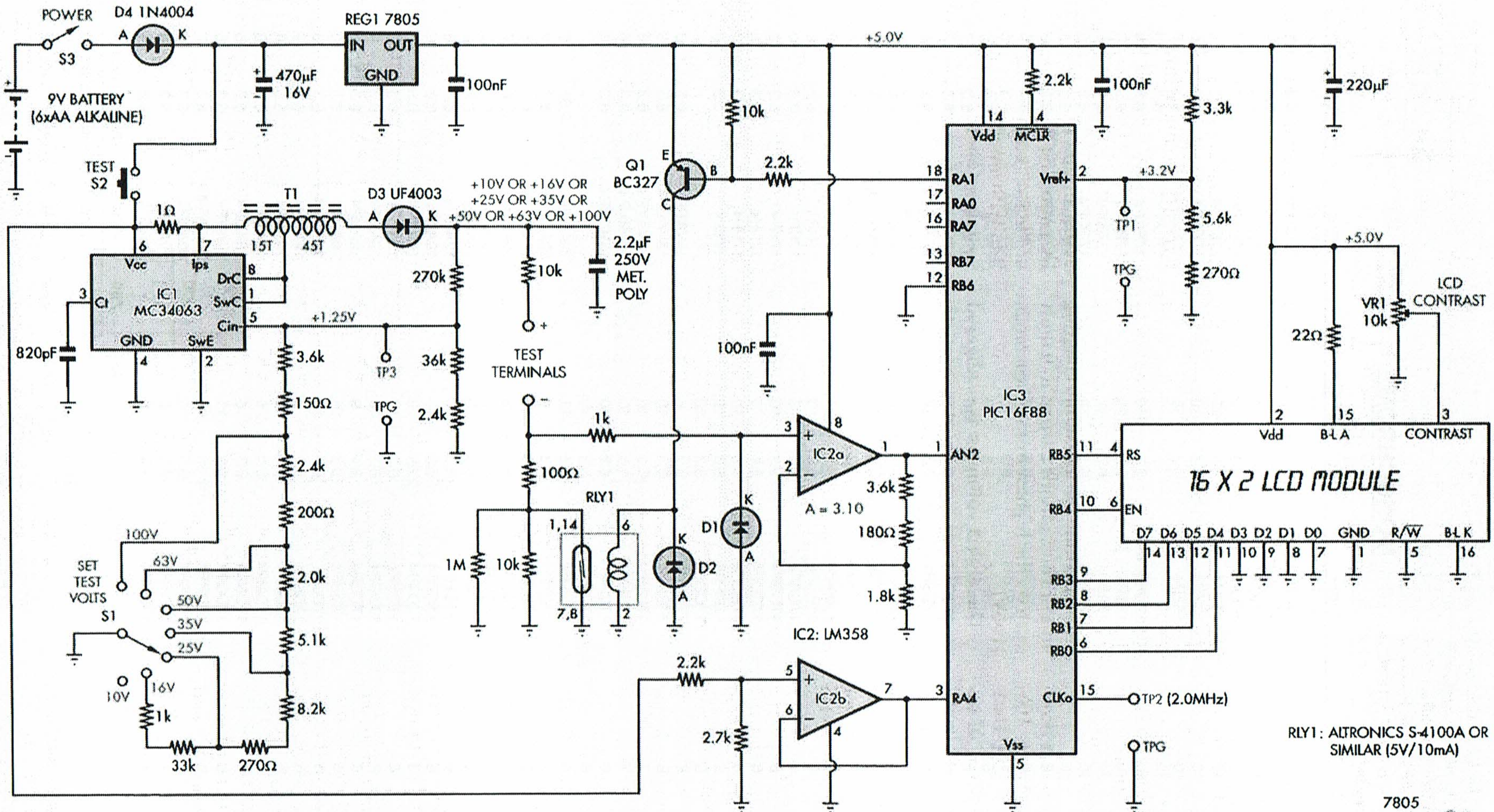
The selectable DC voltage source is based around IC1, an MC34063 DC/DC controller IC. It is used in a step-up or "boost" configuration in conjunction with autotransformer T1 and fast switching diode D3. T1 is based on a ferrite pot core and has 15 turns on its primary and 45 turns on its secondary, effectively giving a three-times boost to the input voltage.

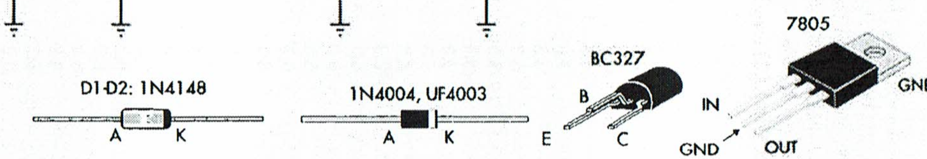
However, we set the circuit's actual DC output voltage by varying the ratio of the voltage divider in the converter's feedback loop, connecting from the

CAPACITOR LEAKAGE CURRENT GUIDE

TYPE OF CAPACITOR	Maximum leakage current in microamps (µA) at rated working voltage						
	10V	16V	25V	35V	50V	63V	100V
Ceramic, Polystyrene, Metallised Film (MKT, Greencap etc.), Paper, Mica	LEAKAGE SHOULD BE ZERO FOR ALL OF THESE TYPES						
Solid Tantalum* < 4.7µF	1.0	1.5	2.5	3.0	3.5	5.0	7.5
6.8µF ⋮ 47µF	1.5 ⋮ 10	2.0 ⋮ 10	3.0 ⋮ 15	4.0 ⋮ 16	6.5 ⋮ 17	7.0 ⋮ 19	9.0 ⋮ 24
Standard Aluminium Electrolytic# <3.3µF	5.0	5.0	5.0	6.0	8.0	10	17
4.7µF ⋮ 10µF	5.0	5.0 ⋮ 8.0	6.0 ⋮ 13	8.0 ⋮ 18	12 ⋮ 25	15 ⋮ 35	23 ⋮ 50
15µF ⋮ 100µF	8.0 ⋮ 50	11 ⋮ 230	19 ⋮ 300	25 ⋮ 330	38 ⋮ 420	100 ⋮ 500	230 ⋮ 600
150µF ⋮ 680µF	230 ⋮ 500	280 ⋮ 600	370 ⋮ 780	430 ⋮ 950	520 ⋮ 1100	600 ⋮ 1300	730 ⋮ 1560
1000µF ⋮ 4700µF	600 ⋮ 1300	730 ⋮ 1590	950 ⋮ 2060	1130 ⋮ 2450	1340 ⋮ 2900	1500 ⋮ 3300	1900 ⋮ 4110

* Figures for Solid Tantalum capacitors are after a charging period of one minute.
# Figures for Aluminium Electrolytics are after a charging/reforming period of three minutes.





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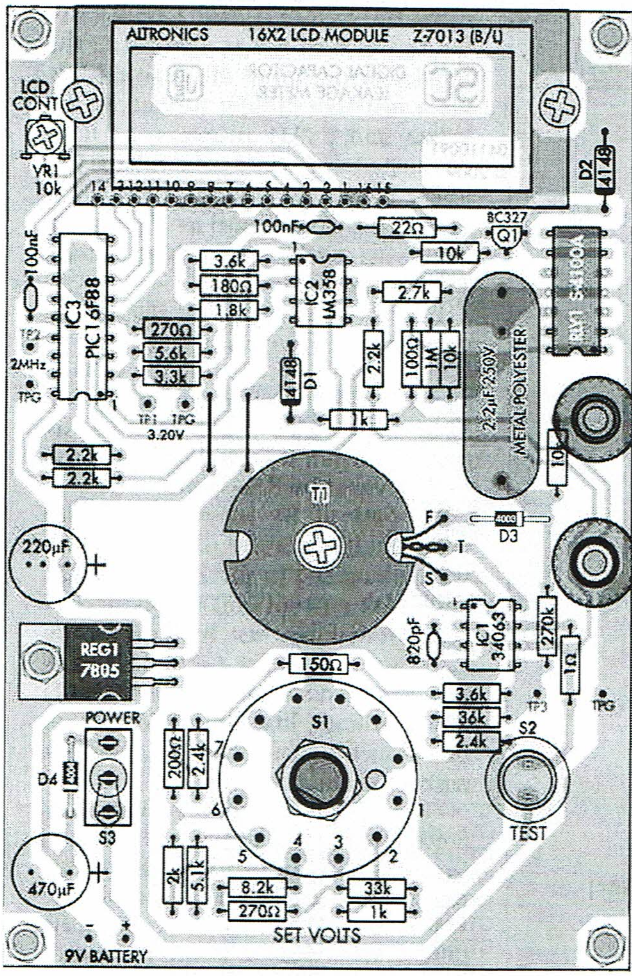
CAPACITOR LEAKAGE METER

Fig.2: the circuit diagram of the capacitor leakage meter . Some of the resistors, especially in the string attached to S1, are not values you see every day – but it's important that the correct resistors are used to achieve the correct voltage steps.



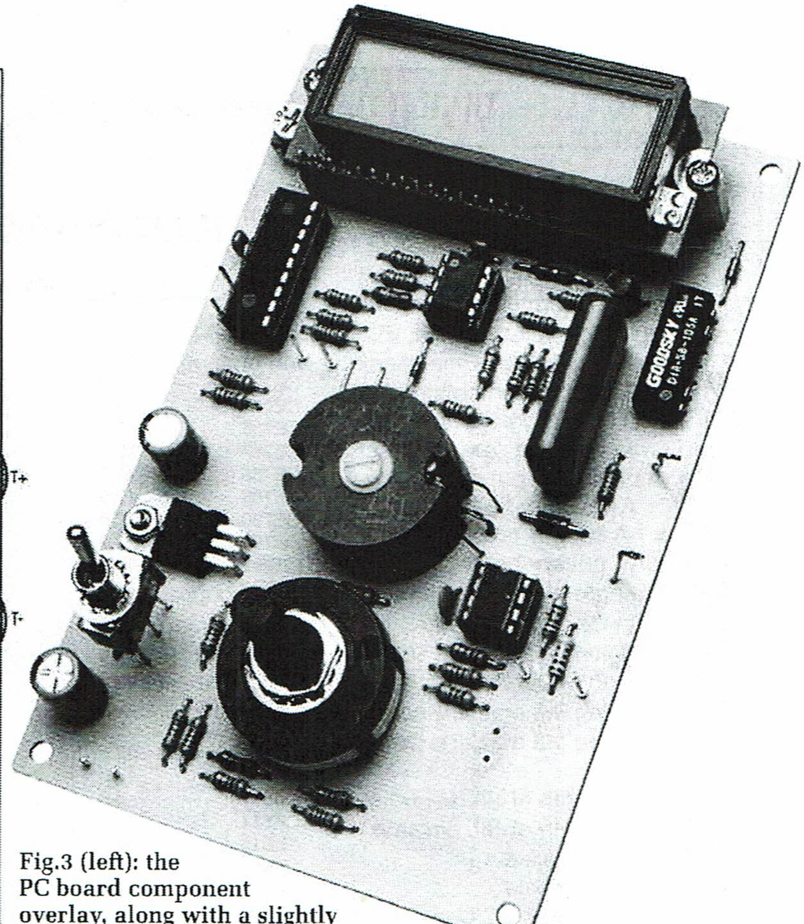


Fig.3 (left): the PC board component overlay, along with a slightly reduced photo at right. The two vacant holes (lower right of pic) are for the "Test" button, S2, while the bare leads at the right edge connect to the two terminals (T+ and T–).

cathode of D3 back to IC's pin 5. Here the feedback voltage is compared with an internal 1.25V reference.

A 270kΩ resistor forms the top arm of the feedback divider, while the 36kΩ and 2.4kΩ resistors from pin 5 to ground form the fixed component of the lower arm. These give an initial division ratio of 308.4kΩ/38.4kΩ or 8.031:1, to produce a regulated output voltage of 10.04V.

This is the converter's output voltage when switch S1 is in the 10V position.

When S1 is switched to any of the other positions, additional resistors are connected in parallel with the lower arm of the feedback divider, to increase its division ratio and hence increase the converter's output voltage.

For example, when S1 is in the 25V position, it connects the 270Ω, 8.2kΩ, 5.1kΩ, 2.0kΩ, 200Ω, 2.4kΩ, 150Ω and 3.6kΩ resistors (all in series) in parallel with the divider's lower arm, changing the division ratio to 283.954kΩ/13.954kΩ or 20.35:1. This produces a regulated output voltage of 25.44V. The same kind of change occurs in the other positions of S1, producing the various preset output voltages shown.

Although the test voltages shown are nominal, if you use the specified 1% tolerance resistors for all of the divider resistors they should all be within +/-4% of the nominal values because the 1.25V reference inside the MC34063 is accurate to within 2%.

IC1 doesn't generate the desired test voltage all the time – only when test pushbutton S2 is pressed and held down. This is because IC1 only receives power from the battery when S2 is closed.

When the converter circuit operates it generates the desired test voltage across the 2.2µF/250V metallised polyester reservoir capacitor. It is connected to the positive test terminal via the 10kΩ current limiting resistor (R1 in Fig.1).

Digital voltmeter

The digital voltmeter is based on an LM358 dual op amp (IC2) and a PIC16F88 microcontroller (IC3). The micro provides the "smarts" to calculate the leakage current and display the value on the LCD module.

The 100Ω, 1MΩ and 10kΩ resistors connected between the negative test terminal and ground correspond to the current shunt labelled R2 in Fig.1, with the contacts of reed relay RLY1 used to change the effective shunt resistance for the meter's two ranges.

For the 10mA 'charging phase' range the reed relay connects a short circuit across the parallel 1MΩ/10kΩ combination, making the effective shunt resistance 100Ω. For the more sensitive 100µA range RLY1 is turned off, connecting the parallel 1MΩ/10kΩ resistors in series with the 100Ω resistor to produce an effective shunt resistance of 10kΩ.

The voltage drop developed across the shunt resistance (as a result of any current passed by the capacitor under test) is passed to the non-inverting input of op amp IC2a, half of the LM358. IC2a is configured as a DC amplifier

Parts List – Digital Capacitor Leakage Meter

1 Jiffy box, 157 x 95 x 53mm ("UB1" size)
1 PC board, code 04112091, 127 x 84mm
2 Binding post/banana jacks (1 red, 1 black)
1 16x2 LCD module, compact with LED backlighting (Altronics Z-7013)
1 Mini DIL reed relay, SPST with 5V coil
1 Single pole rotary switch, PC board mtg (S1)
1 Instrument knob, 16mm diameter with grub screw fixing
1 SPST pushbutton switch (S2)
1 SPDT mini toggle switch (S3)
1 Ferrite pot core pair, 26mm OD
1 Bobbin to suit pot core
1 10x AA battery holder (flat) OR
1 4 x AA battery holder, flat and
1 2 x AA battery holder, side by side (see text)
1 3m length of 0.5mm diameter enamelled copper wire
2 12mm long M3 tapped Nylon spacers
4 25mm long M3 tapped spacers
1 25mm long M3 Nylon screw with nut and flat washer
9 6mm long M3 machine screws, pan head
4 6mm long M3 machine screws, csk head
1 M3 nut
1 16-pin length of SIL socket strip
1 16-pin length of SIL pin strip
1 18-pin IC socket
2 8-pin IC sockets
8 1mm diameter PC board terminal pins
1 0.5m length 0.7mm tinned copper wire (for mounting switches etc)

Semiconductors
1 MC34063 DC/DC converter controller (IC1)
1 LM358 dual op amp (IC2)
1 PIC16F88 microcontroller (IC3, programmed with 0411209A firmware)
1 7805 +5V regulator (REG1)
1 BC327 PNP transistor (Q1)
2 1N4148 100mA diodes (D1,D2)
1 UF4003 ultrafast 200V/1A diode (D3)
1 1N4004 400V/1A diode (D4)

Capacitors
1 470µF 16V RB electrolytic
1 220µF 10V RB electrolytic
1 2.2µF 250V metallised polyester
2 100nF multilayer monolithic ceramic
1 820pF disc ceramic

Resistors (0.25W 1% metal film unless specified)

1 1MΩ	1 270kΩ	1 36kΩ	1 33kΩ	3 10kΩ	1 8.2kΩ	1 5.6kΩ
1 5.1kΩ	2 3.6kΩ	1 3.3kΩ	1 2.7kΩ	2 2.4kΩ	3 2.2kΩ	1 2.0kΩ
1 1.8kΩ	2 1kΩ	2 270Ω	1 200Ω	1 180Ω	1 150Ω	1 100Ω

1 22Ω 0.5W carbon
1 1.0Ω 0.5W carbon
1 10kΩ mini horizontal trimpot (VR1)

with a voltage gain of 3.10 times, feeding the AN2 analog input of IC3, the PIC16F88 micro.

IC3 compares the voltage from IC2a with a reference voltage of 3.2V fed into its pin 2. This reference is derived from the regulated +5V supply line via the voltage divider formed by the 3.3kΩ, 5.6kΩ & 270Ω resistors. After mathematical scaling inside IC3, the readings are then displayed on the 16x2 LCD module.

IC3 can sense when the testing of a capacitor begins because it monitors the supply voltage fed to IC1, when test switch S2 is pressed. This is because the supply voltage (about 8.4V) fed to pin 6 of IC1 is also fed to the non-inverting input of op amp IC2b, via a resistive divider formed by the 2.2kΩ and 2.7kΩ resistors. As IC2b connected as a unity gain voltage follower, so a logic 'high' is fed to pin 3 of IC3 (the RA4 input) as soon as S2 is pressed, and remains there as long as S2 is held down.

When S2 is released, the 2.7kΩ resistor pulls the voltage at pin 5 of IC2b down to 0V, causing the voltage at pin 3 of IC3 to fall to the same level. So IC3 can sense when a test begins and also when it ends, because of the logic level at its RA4 input.

As part of its internal firmware program, IC3 ensures that RLY1 is always energised to short out the 1MΩ and 10kΩ current sensing resistors at the start of a new test, to allow for the capacitor's charging current. It does this by pulling its output pin 18 (RA1) down to logic low level (0V), which turns on transistor Q1 and supplies current to the coil of RLY1.

Once the capacitor's current falls below 100µA. IC3 pulls its pin 18 low, turning off Q1 and the reed relay. This removes the short circuit across the 1MΩ and 10kΩ resistors, changing the effective current shunt resistance to 10kΩ and hence switching the meter down to its more sensitive range.

Protection diodes

Diode D1 is included in the metering circuit to protect pin 3 of IC2a from damage due to accidental application of a negative voltage to the negative test terminal (from a previously charged capacitor, for example).

Diode D2 is there to protect transistor Q1 from damage due to any back EMF 'spike' from the coil of RLY1 when it is de-energised.

Trimpot VR1 adjusts the contrast of the LCD module for optimum visibility. The 22Ω resistor connecting from the +5V supply rail to pin 15 of the LCD module provides the module's LED backlighting current. The resistor's value of 22Ω is a compromise between maximising display brightness and keeping battery drain to no higher than is necessary, to promote battery life.

As you can see, although the voltage source section of the circuit operates directly from the 9V battery (via polarity protection diode D4 and S2), the rest of the circuit operates from a

Winding the transformer

The step-up autotransformer T1 has 60 turns of wire in all, wound in four 15-turn layers. As shown in the coil assembly diagram (Fig.4, right), all four layers are wound on a small Nylon bobbin using 0.5mm diameter enamelled copper wire. Use this diagram to help you wind the transformer correctly.

Here's the procedure: first you wind on 15 turns, which will neatly take up the width of the bobbin providing you wind them closely and evenly. Then to hold it down, cover this first layer with a 9mm-wide strip of plastic insulating tape or 'gaffer' tape.

Next take the wire at the end of this first layer outside of the bobbin (via one of the 'slots'), and bend it around by 180° at a point about 50mm from the end of the last turn. This doubled-up lead will be the transformer's 'tap' connection.

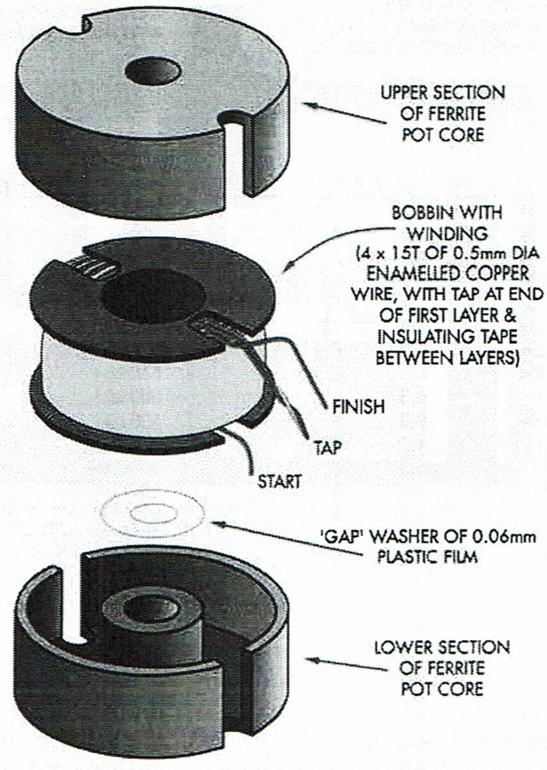
The remaining wire can then be used to wind the three further 15-turn layers, making sure that you wind them in the same direction as you wound the first layer. Each of these three further layers should be covered with another 9mm-wide strip of plastic insulating tape just as you did with the first layer, so that when all four layers have been wound and covered everything will be nicely held in place.

The 'finish' end of the wire can then be brought out of the bobbin via one of the slots (on the same side as the start and tap leads) and your wound transformer bobbin should fit inside the two halves of the ferrite pot core.

Just before you fit the bobbin inside the bottom half of the pot core, though, there's a small plastic washer to prepare. This washer provides a thin magnetic 'gap' in the pot core when it's assembled, to prevent the pot core from saturating when it's operating.

The washer is very easy to cut from a piece of the thin clear plastic that's used for packaging electronic components, like resistors and capacitors. This plastic is very close to 0.06mm thick, which is just what we need here. So the idea is to punch a 3-4mm diameter hole in a piece of this plastic using a leather punch or similar, and then use a small pair of scissors to cut around the hole in a circle, with a diameter of 10mm. Your 'gap' washer will then be ready to place inside the lower half of the pot core, over the centre hole.

Once the gap washer is in position, lower the wound bobbin into the pot core around it, and then fit the top half of the pot core. The transformer is now ready for mounting on the main PC board. To begin this step, place a Nylon flat washer on the 25mm-long M3 Nylon screw that will be used to hold it down on the board. Then pass the screw down through the centre hole in the pot core halves, holding them (and the bobbin and gap washer inside) together with your fingers. Then lower the complete assembly down in the centre of the board with the 'leads' towards the right, using the bottom end of the centre Nylon screw to locate it in the correct position.



(ASSEMBLY HELD TOGETHER & SECURED TO PC BOARD USING 25mm x M3 NYLON SCREW & NUT)

When you are aware that the end of the screw has passed through the hole in the PC board, keep holding it all together but up-end everything so you can apply the second M3 Nylon flat washer and M3 nut to the end of the screw, tightening the nut so that the pot core is not only held together but also secured to the top of the PC board.

Once this has been done, all that remains as far as the transformer is concerned is to cut the start, tap and finish leads to a suitable length, scrape the enamel off their ends so they can be tinned, and then pass the ends down through their matching holes in the board so they can be soldered to the appropriate pads.

Don't forget to scrape, tin and solder both wires which form the 'tap' lead - if this isn't done, the transformer won't produce any output.

regulated 5V rail which is derived from the battery via REG1, a 7805 3-terminal regulator.

The only other point which should be mentioned is that the PIC16F88 micro (IC3) operates from its internal RC clock, at close to 8MHz. A clock signal of one quarter this frequency (2MHz) is made available at pin 15 of IC3 and then at test point TP2, to allow you to check that IC3 is operating correctly.

Construction

Virtually all of the circuitry and components used in the Capacitor Leakage Meter are mounted on a single PC board measuring 127 x 84mm and coded 04112091.

This is supported behind the lid of the jiffy box (size UB1: 157 x 95 x 53mm) which houses the meter, with the six 1.5V AA alkaline cells used to provide power mounted in one or two battery holders inside the main part of the box.

The main board is suspended from the lid of the box (which becomes the instrument's front panel) via four 25mm long M3 tapped spacers, while the LCD module mounts at the top end of the main board on two 12mm long M3 tapped Nylon spacers. The DC/DC converter's pot core transformer T1 mounts on the main board near the centre, using a 25mm long M3 Nylon screw and nut, while voltage selector switch S1 also mounts directly on the board just below T1.

The only components not mounted directly on the main board are power switch S3, test switch pushbutton S2 and the two test terminals.

These are all mounted on the box front panel, with their rear connection lugs extended down via short lengths

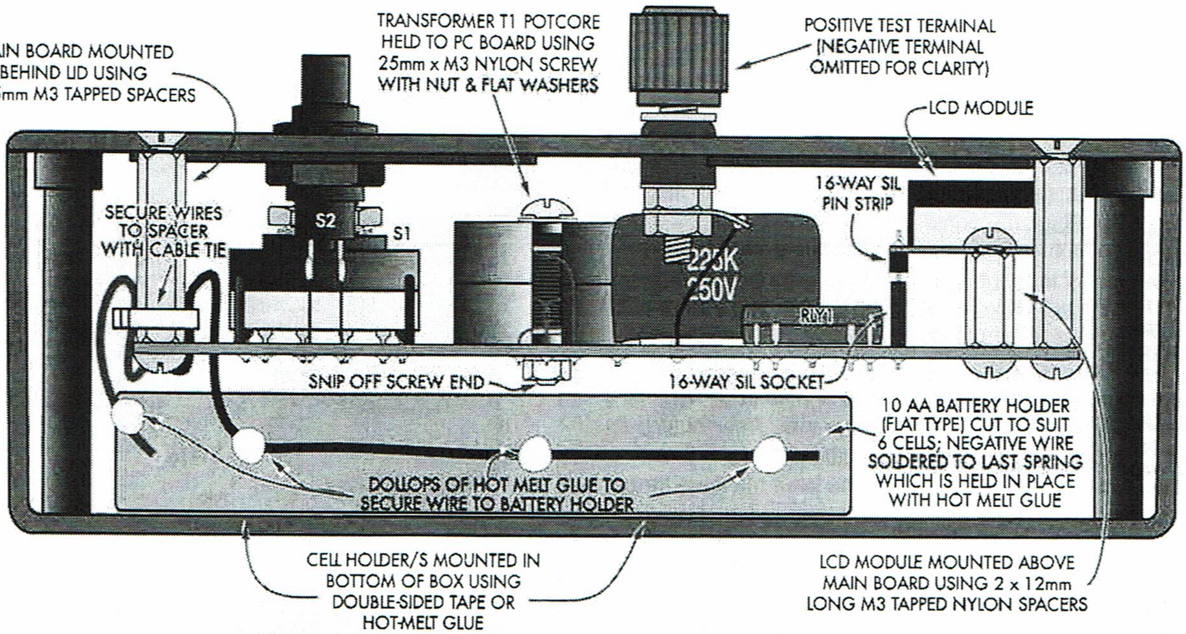


Fig.5: detailed assembly diagram of the completed project

of tinned copper wire to make their connections to the board.

All of these assembly details are shown in the diagrams and photos. The component overlay diagram for the PC board is shown in Fig.3 while the cross-sectional diagram, showing the PC board and batteries mounted inside the plastic case, is depicted in Fig.5.

To begin assembly of the PC main board, fit the two wire links, both located just to the upper left of the position for transformer T1. They are both 0.4mm long above the board, so they're easily fashioned from resistor lead offcuts or tinned copper wire.

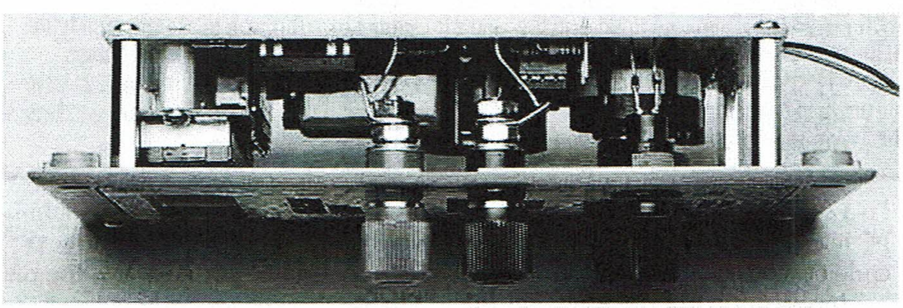
Next, fit the eight 1mm PC pins to the board – two for each of the three test point locations and the final pair at lower left for the battery clip lead connections. Follow these with the sockets for IC1 and IC2 (both 8-pin sockets) and IC3 (an 18-pin socket).

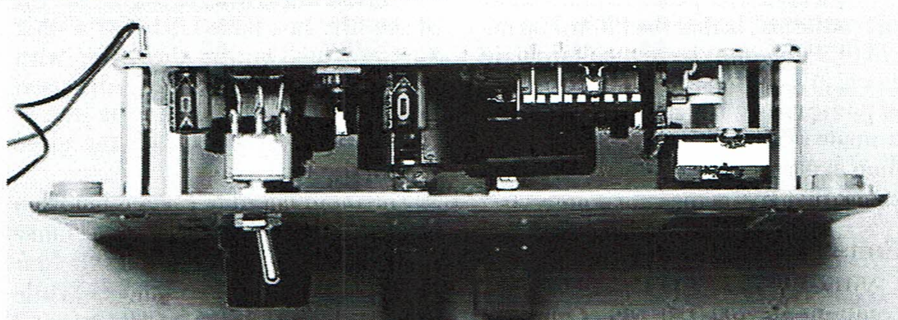
Now you can fit all of the fixed resistors. These are all 1% tolerance metal film components, apart from the 1Ω resistor just to the right of IC1 and the 22Ω resistor at the top, just below the LCD module position. These latter components should be of the 0.5W carbon composition type. When you are fitting all of the resistors make sure you place each value in its correct position, as any mixups may have a serious effect on the meter's accuracy. Check each resistor's value with a DMM before soldering it into place.

With the fixed resistors in place, you can fit trimpot VR1, which goes up near the top left-hand corner of the board. Next fit the small low-value capacitors, followed by the large 2.2μF metallised polyester unit and finally the two (polarised) electrolytics.

When fitting the mini DIL relay, make sure its locating spigot is at the bottom end. Then you can fit voltage selector switch S1, which has its indexing spigot at 3-o'clock. Just before you fit it you should cut its spindle to a length of about 12mm and file off any burrs, so it is ready to accept the knob later on.

After S1 has been fitted to the board, remove its nut/lockwasher/position stopwasher combination and turn the spindle by hand to make sure it's at the fully anticlockwise limit. Then refit the position stopwasher, making sure that its stop pin goes down into the





These two photos of the assembled Capacitor Leakage Meter (one from each side) show the construction detail mirrored in the diagram above. It wouldn't hurt to secure the thin battery wires (red and black) to the nearby mounting pillar with a cable tie to prevent flexing breaking the solder join at the PC stakes. We've shown this in the diagram above but it not in these prototype photos.

hole between the moulded '7' and '8' digits. After this refit the lockwasher and nut to hold it down securely, allowing you to check that the switch is now 'programmed' for the correct seven positions - simply by clicking it around through them by hand.

The final components

With the transformer wound and fitted to the board, you'll be ready to fit diodes D1-D4. These are all polarised, so make sure you orientate each one correctly as shown in Fig.3. Also ensure that the UF4003 diode is used for D3, the 1N4004 diode for D4 and the two 1N4148 'signal' diodes for D1 and D2.

After the diodes fit transistor Q1, a BC327 PNP device. Then fit REG1, which is in a TO-220 package and lies flat on the top of the board with its lead bent down by 90 degrees at a point about 6mm away from the body. The device is held in position on the board using a 6mm long M3 machine screw and nut which should be tightened before the leads are soldered to the pads underneath.

The final component to be mounted directly on the board is the 16-way length of SIL (single inline) socket strip used for the 'socket' for the LCD module connections. Once this has been fitted and its pins soldered to the pads underneath, you'll be almost ready to mount the LCD module itself. All that will remain before this can be done is to fasten two 12mm long M3 tapped Nylon spacers to the board in the module mounting positions (one at each end) using a 6mm M3 screw passing up through the board from underneath, and then 'plugging' a 16-way length of SIL pin strip into the socket strip you have just fitted to the board. Make sure the longer ends of the pin strip pins are mating with the socket, leaving the shorter ends uppermost to mate with the holes in the module.

Now remove the LCD module from its protective bag, taking care to hold it between the two ends so you don't touch the board copper. Then lower it carefully onto the main board so the holes along its lower front edge mate with the pins of the pin strip, allowing the module to rest on the tops of the two 12mm long nylon spacers. Then you can fit another 6mm M3 screw to each end of the module, passing down through the slots in the module and mating with the spacers. When the screws are tightened (but not OVER tightened!) the module should be securely mounted in position.

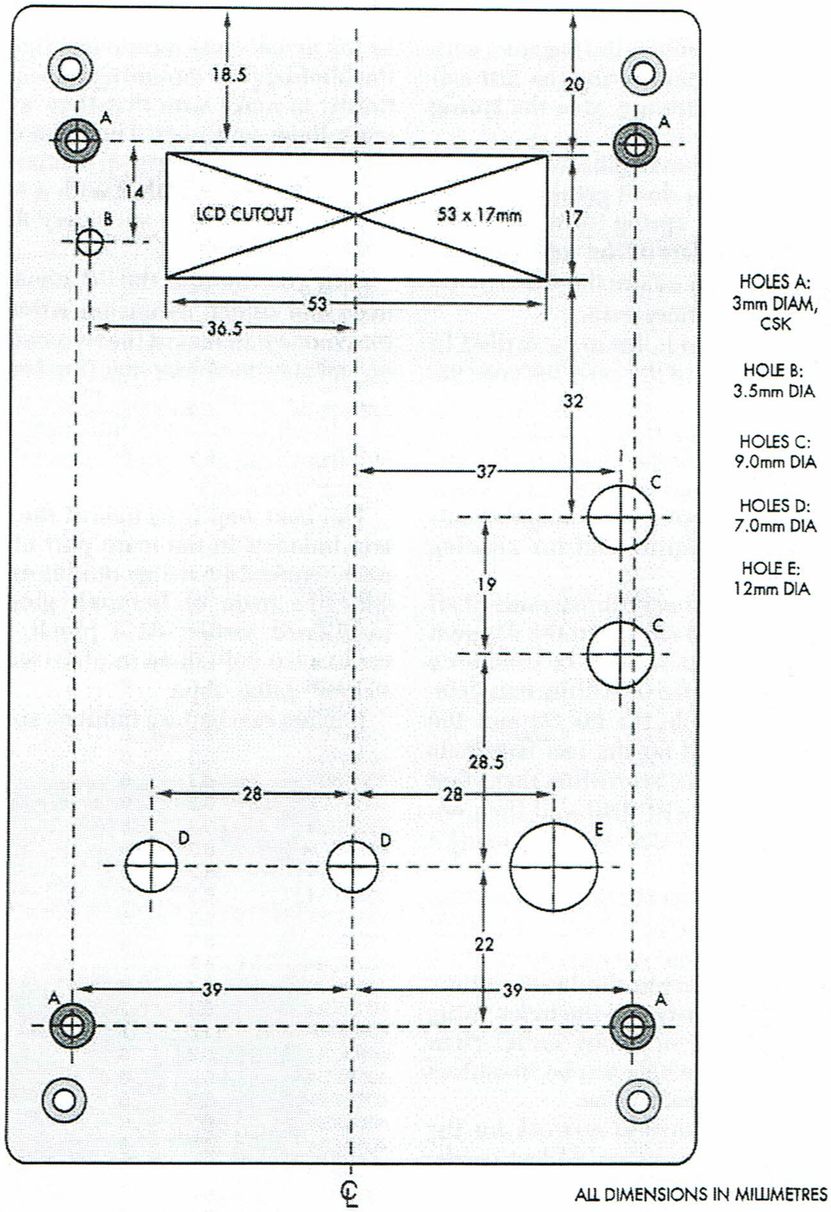


Fig.6: drilling and cutout detail for the lid of the UB-1 Jiffy Box, from which hangs the PC board containing everything but the battery holder.

The final step is then to use a fine-tipped soldering iron to carefully solder each of the 16 pins of the pin strip to the pads on the module, to complete its interconnections.

After this is done you can plug the three ICs into their respective sockets, making sure to orientate them all as shown in Fig.3.

At this stage your PC board assembly should be nearly complete. All that remains is to attach one of the 25mm long mounting spacers to the top of the board in each corner, using 6mm long M3 screws. Then the board assembly can be placed aside while you prepare the case and its lid.

Preparing the case

As the circuit requires 9V DC (and because a 9V DC battery won't last very long) we require six AA cells. Unfortunately, we couldn't find any 6xAA flat battery holders – they're only available in 1, 2, 4 and 10 cells.

You have a choice here – fit a 4-cell and a 2-cell holder and connect them in series, or cut down a 10-cell to accommodate six cells. We tried both but chose the latter because arguably it looks neater.

If you cut down a 10-cell holder, you'll need to solder the negative wire to the spring connecting the last cell and almost certainly, glue the spring in place.

We used hot-melt glue for this – just make sure you don't get any glue on the end of the spring itself and inadvertently insulate it! Hot-melt glue can also be used to secure the wires to the edge of the battery case.

There are no holes to be drilled in the lower part of the case, because the battery holder/s can be held securely in place using strips of double-sided adhesive foam tape or hot-melt glue. But the lid does need to have some holes drilled, plus a rectangular cut-out near the upper end for viewing the LCD.

The location and dimensions of all these holes are shown in the diagram of Fig.6, which can also be used (or a photocopy of it) as a drilling template. The 12mm hole (E) for S2 and the 9mm holes (C) for the test terminals are easily made by drilling them first with a 7mm twist drill and then enlarging them to size carefully using a tapered reamer.

The easiest way to make the rectangular LCD viewing window is to drill a series of closely-spaced 3mm holes around just inside the hole outline, and then cut between the holes using a sharp chisel or hobby knife. Then the sides of the hole can be smoothed using small needle files.

We have prepared artwork for the front panel if you would like to make it look neat and professional. This can be either photocopied from the magazine (Fig.7) or downloaded as a PDF or EPS file from our website and then printed out. Either way the resulting copy can be attached to the front of the lid and then covered with self-adhesive clear film for protection against finger grease, etc. An alternative is to laminate the label using a heat laminator.

You might also like to attach a 60 x 30mm rectangle of 1-2mm thick clear plastic behind the LCD viewing window, to protect the LCD from dirt and physical damage. The 'window pane' can be attached to the rear of the lid using either adhesive tape or epoxy cement.

Once your lid/front panel is finished, you can mount switches S2 and S3 on it using the nuts and washers supplied with them. These can be followed by the binding posts used as the meter's test terminals. Tighten the binding post mounting nuts quite firmly, to make sure that they won't work loose with use. Then use each post's second nut to attach a 4mm solder lug to each, together with a 4mm lockwasher to make sure they don't work loose either.

Now you can turn the lid assembly over, and solder 'extension wires' to the connection lugs of the two switches, and also the solder lugs fitted to the rear of the binding posts. These wires should all be about 30mm long and cut from tinned copper wire (about 0.7mm diameter).

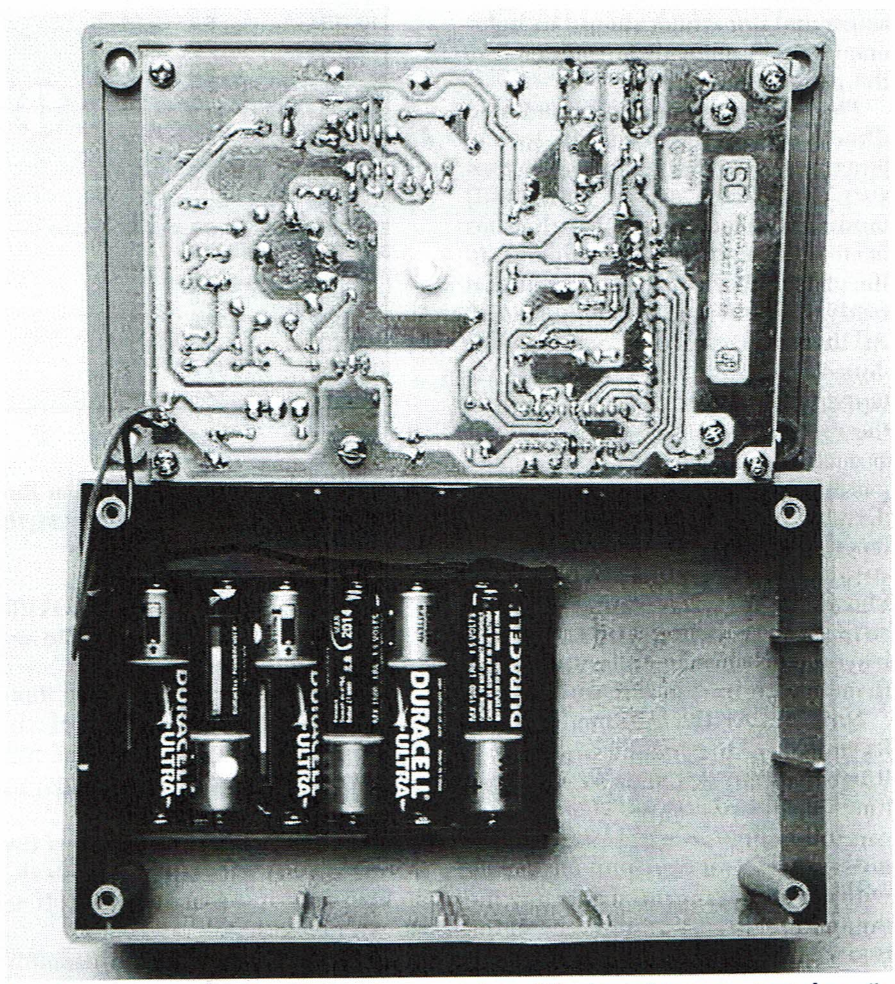
The next step is to mount the battery holder/s in the main part of the case, preferably using double-sided adhesive foam or hot-melt glue as mentioned earlier. At a pinch, you could even hold them in place with a strip of 'gaffer' tape.

If using two battery holders, solder the bared end of the red wire from one battery clip lead to the black wire from the other clip lead, and carefully wrap this joint with insulating tape (or heatshrink sleeving) so that it can't accidentally come into contact with anything.

Then solder the remaining wire of each cliplead to their appropriate terminal pins at bottom left of the PC board, directly below the position for power switch S3. The red wire should go to the positive terminal pin, of course, and the black wire to the negative pin. The alternative cut-down 10-cell holder simply solders to the supply pins on the PC board.

You should now be ready for the only slightly fiddly part of the assembly operation: attaching the PC board assembly to the rear of the lid/front panel.

This is only fiddly because you have to line up all of the extension wires from switches S2 and S3 and the two



Inside the box, just before the lid is screwed on. We elected to use a "cut down" 10xAA battery holder to make a six-cell holder. Ideally it should be cut slightly longer so that the last spring is still held in position. We used hot-melt glue to hold this spring in place and secure the wires to the battery case.

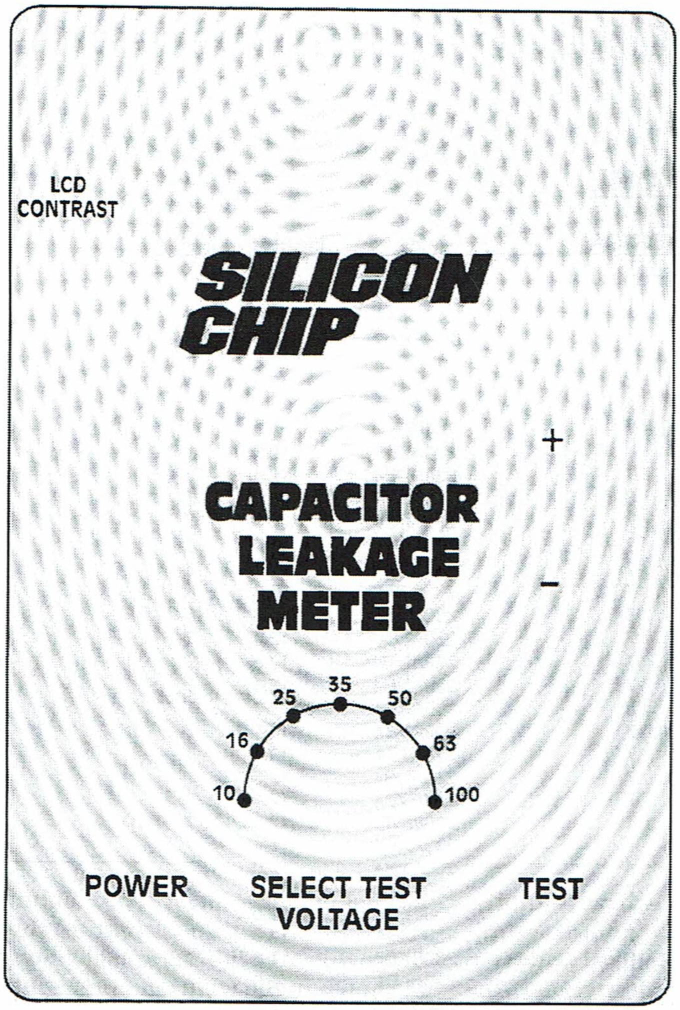


Fig.7: this front panel artwork is full size so can be either photocopied (you won't be breaching copyright!) or can be downloaded from siliconchip.com.au and printed out in glorious living colour. We'd cover it to protect the surface, either with self-adhesive clear film or with a heatset laminator (the latter is tougher!). If you choose the latter, you might remove the LCD cutout first, thus providing a clear "window" protecting the LCD.

test terminals with their matching holes in the PC board, as you bring the lid and board together and also line up the spindle of switch S1 with its matching hole in the front panel. This is actually easier to do than you'd expect though, so just take your time and the lid will soon be resting on the tops of the board mounting spacers. Then you can secure the two together using four 6mm long countersink head machine screws.

Now it's a matter of turning the complete assembly over and soldering each of the switch and terminal extension wires to their board pads. Once they are all soldered you can clip off the excess wires with sidecutters.

By the way, if you find this description a bit confusing, refer to the assembly diagram in Fig.5. This will hopefully make everything clear.

You can now fit six AA-size alkaline cells into the battery holder/s and your new Capacitor Leakage Meter should be ready for its initial checkout.

Initial checkout

When you switch on the power using S3, a reassuring glow should appear from the LCD display window – from the LCD module's backlighting. You should also be able to see the Meter's initial greeting 'screen', as shown in the first of the display grab images below. If not, you'll need to use a small screwdriver to adjust contrast trimpot VR1, through the small hole just to the left of the LCD window, until you get a clear and easily visible display.

After a few seconds, the display should change to the Meter's measurement direction 'screen', where it tells you to set the appropriate test voltage (using S1) and then press the button (S2) to make the test.

If you set the voltage and press the button at this stage, without any capacitor connected to the test terminals, you'll get a leakage current reading of '00.00μA'. This reading will remain on the display when you release the button, and it will stay on the display until you either turn off the Meter's power using S3, or else connect a capacitor to the test terminals and press the test button again.

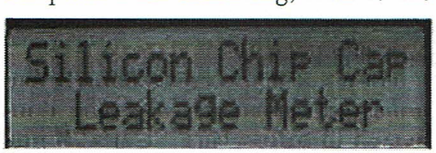
Assuming all has gone well at this point, your Meter is probably working correctly. However if you want to make sure, try shorting between the two test terminals using a short length of hookup wire. Then set S1 to the '100V' position, and press Test button S2. The meter reading should change to a value around 9.9mA, representing the current drawn from the nominal 100V source by the 10kΩ current limiting resistor and the 100Ω current shunt resistor inside the Meter.

Don't worry if the current reading is a bit above or below the 9.9mA figure, by the way. As long as it's between about 9.2mA and 10.6mA (i.e., ±0.7mA or ±7%), things are OK.

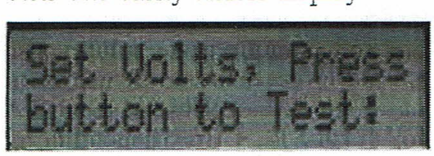
With the terminals still shorted together, you can try repeating the same test for each of the other six test voltage ranges of switch S1. You should get a reading of approximately 6.25mA on the 63V range, 4.95mA on the 50V range, 3.46mA on the 35V range, 2.48mA on the 25V range, 1.58mA on the 16V range and 99μA on the 10V range.

If the readings you get are close to these, your Capacitor Leakage Meter is working correctly.

This being the case, switch off the power again via S3 and then complete the final assembly by lowering the lid/PC board assembly into the case and securing the two together using the four small self-tapping screws supplied.



When you first turn the unit on, this welcome screen should greet you and tell you it's working . . .



. . . before it immediately switches over the the operational screen, telling you what to do . . .

. . . whereupon the leakage current is displayed. Either this is an outstanding capacitor or none is connected!

Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	1MΩ	brown black green brown	brown black black yellow brown
❑	1	270kΩ	red violet yellow brown	red violet black orange brown
❑	1	36kΩ	orange blue orange brown	orange blue black red brown
❑	1	33kΩ	orange orange orange brown	orange orange black red brown
❑	3	10kΩ	brown black orange brown	brown black black red brown
❑	1	8.2kΩ	grey red brown	grey red black brown brown
❑	1	5.6kΩ	green blue red brown	green blue black brown brown
❑	1	5.1kΩ	green brown red brown	green brown black brown brown
❑	2	3.6kΩ	orange blue red brown	orange blue black brown brown
❑	1	3.3kΩ	orange orange red brown	orange orange black brown brown
❑	1	2.7kΩ	red violet red brown	red violet black brown brown
❑	2	2.4kΩ	red yellow red brown	red yellow black brown brown
❑	3	2.2kΩ	red red red brown	red red black brown brown
❑	1	2.0kΩ	red black red brown	red black black brown brown
❑	1	1.8kΩ	brown grey red brown	brown grey black brown brown
❑	2	1kΩ	brown black red brown	brown black black brown brown
❑	2	270Ω	red violet brown brown	red violet black black brown
❑	1	200Ω	red black brown brown	red black black black brown
❑	1	180Ω	brown grey brown brown	brown grey black black brown
❑	1	150Ω	brown green brown brown	brown green black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown
❑	1	22Ω (0.5W)	red red black brown	red red black gold brown
❑	1	1Ω (0.5W)	brown black gold brown	brown black black silver brown

If you get readings which are significantly different to those above, there is obviously an error somewhere to be corrected. It is quite likely that one or more resistors in the "string" from IC1 pin 5 to S1 is/are misplaced.

Using it

The Capacitor Leakage Meter is very easy to use, because literally all that you have to do is connect the capacitor you want to test across the test terminals (with the correct polarity in the case of solid tantalums and electrolytics: + to +, - to -), set selector switch S1 for the correct test voltage, then turn on the power (S3).

When the initial greeting message on the LCD changes into the 'Set Volts, press button to Test:' message, press and hold down test button S2.

What you'll see first off may be a reading the capacitor's charging current, which can be as much as 9.9mA at first (with high value caps) but will then drop back as charging continues.

How quickly it drops back will depend on the capacitor's value. With capacitors below about 4.7µF, the charging may be so fast that the first reading will often be less than 100µA, with the meter having immediately downranged.

If the capacitor you're testing is of the type having a 'no leakage' dielectric (such as metallised polyester, glass, ceramic or polystyrene), the current should quickly drop down to less than a microamp and then to zero. That's if the capacitor is in good condition, of course.

On the other hand if the capacitor is one with a tantalum or aluminium oxide dielectric with inevitable leakage, the current reading will drop more slowly as you keep holding down the Test button.

In fact it will probably take up to a minute to stabilise at a reasonably steady value in the case of a solid tantalum capacitor and as long as three minutes in the case of an aluminium electrolytic.

(That's because these capacitors generally take a few minutes to 're-form' and reach their rated capacitance level.)

As you can see from the guide table earlier the leakage currents for tantalum and aluminium electrolytics also never drop down to zero but instead to a level somewhere between about 1µA and 4110µA (ie, 4.1mA) depending on both their capacitance value and their rated working voltage.

So with these capacitors, you should hold down the Meter's test button to see if the leakage current reading drops down to the 'acceptable' level as shown in the table (and preferably even lower). If this happens the capacitor can be judged 'OK' but if the current never drops to anywhere near this level it should definitely be replaced.

What about low leakage (LL) electrolytics? Well, the current levels shown in the table are basically those for standard electrolytics rather than for those rated as low leakage.

So when you're testing one which is rated as low leakage, you'll need to make sure that its leakage current drops well below the maximum values shown in the guide table. Ideally it should drop down to less than 25% of these current values.

A final tip: when you're testing non-polarised (NP) or 'bipolar' electrolytics, these should be tested twice – once with them connected to the terminals one way around, and then again with them connected with the opposite polarity.

These capacitors are essentially two polarised capacitors internally connected in series, back-to-back. If one of the dielectric layers is leaky but the other is OK, this will show up in one of the two tests. **SC**