CAPACITOR LEAKAGE ADAPTOR FOR DMMs

By JIM ROWE

Here's a cut-down version of the Digital Capacitor Leakage Meter we described in November 2011. Instead of using a PIC microcontroller and an LCD panel to display the leakage current, this version connects to your DMM to provide the readout. It provides the same range of seven different standard test voltages (from 10V to 100V) and can measure leakage currents down to 100 nanoamps!

WHY would you need to measure capacitor leakage current? In case you missed the November 2011 article, here's a summary of the introduction we provided there.

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 have to 'charge up'.

With most practical capacitors, using materials like ceramic, glass, polyester or polystyrene – 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. In that case they may well conduct DC as a steady 'leakage current', showing that they are faulty.

But as many *EPE* readers will be aware, things are not this clear cut with electrolytic capacitors, whether they are aluminium or tantalum. All 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 given in the Leakage Current Guide opposite. The current levels listed there are the maximum allowable before the capacitor is regarded as faulty.

So, an instrument capable of measuring the leakage current of capacitors can be very handy in many areas of electronics.

Commercially available capacitor leakage current meters are expensive (ie, over £500) and even the Capacitor Leakage Meter we described in the November 2011 issue will probably cost you over £50 to build. That's why we've developed a cut-down version described in this article, which lets you make all of the same measurements with your existing digital multimeter (DMM).

The Adaptor is easy to build and will have a much lower cost than the November 2011 meter, while still providing the same choice of seven different standard test voltages: 10V, 16V, 25V, 35V, 50V, 63V or 100V. It is also able to make current measurements from 10mA down to a fraction of a microamp. So it's capable of making leakage current tests on the vast majority of capacitors in current use.

It's built into a compact UB1-size jiffy box, and is battery powered (6 x AA alkaline cells). This makes it suitable for the workbench or the service technician's tool kit.

How it works

The Capacitor Leakage Adaptor's operation is straightforward, as you can see from the block diagram of Fig.1. There are two functional circuit sections, one is a selectable DC voltage source (on the left) which generates one of seven different preset voltages when the TEST button is pressed and held down.

The second section is a simple current-to-voltage converter (on the right) which is used to generate a voltage proportional to the direct current passed by the capacitor under test, so that it can be measured easily using your DMM.

Any direct current passed by the capacitor being tested flows down to ground via resistor R2, which therefore acts as a current shunt. The voltage drop across R2 is then passed through an output buffer, which feeds your DMM. The DMM is set to its 0V to 2V DC voltage range, which allows its readings to be easily converted into equivalent current levels.

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

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.

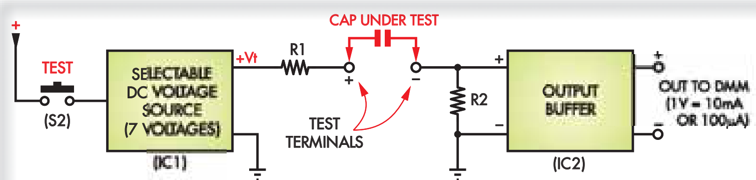


Fig.1: block diagram of the adaptor shows it has two elements: a selectable DC voltage source and a simple current-to-voltage converter.

Resistor 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).

At this stage, you may be wondering how the adaptor can allow your DMM to read leakage currents down to less than a microamp, when it also has to cope with charging currents of up to 9.9mA. The answer is that the current-to-voltage converter section of the adaptor actually has two current ranges, which are selected by switching the value of shunt resistor R2.

The default value of R2 is 100Ω, which provides a 0 to 10mA range for the capacitor's charging phase (ie, when TEST button S2 is first pressed). But when (and if) the measured current level falls below 100μA, pushbutton S4 can be pressed to switch the value of R2 to 10kΩ, providing a 0 to 100μA range for a more accurate low leakage current measurement.

Circuit description

Take a look at the full circuit diagram for the Capacitor Leakage Adaptor, see Fig.2. The selectable DC voltage source is based around IC1, an MC34063 DC/DC controller IC, used here in a 'boost' configuration in conjunction with autotransformer T1 and fast switching diode D2.

We vary the circuit's DC output voltage by varying the ratio of the voltage divider in the converter's feedback loop, connecting from the cathode (K) of D2 back to IC1's pin 5 (where the voltage is compared with an internal 1.25V reference).

The 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 the divider 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 selector 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, this 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 switch S1, producing the various preset output voltages shown.

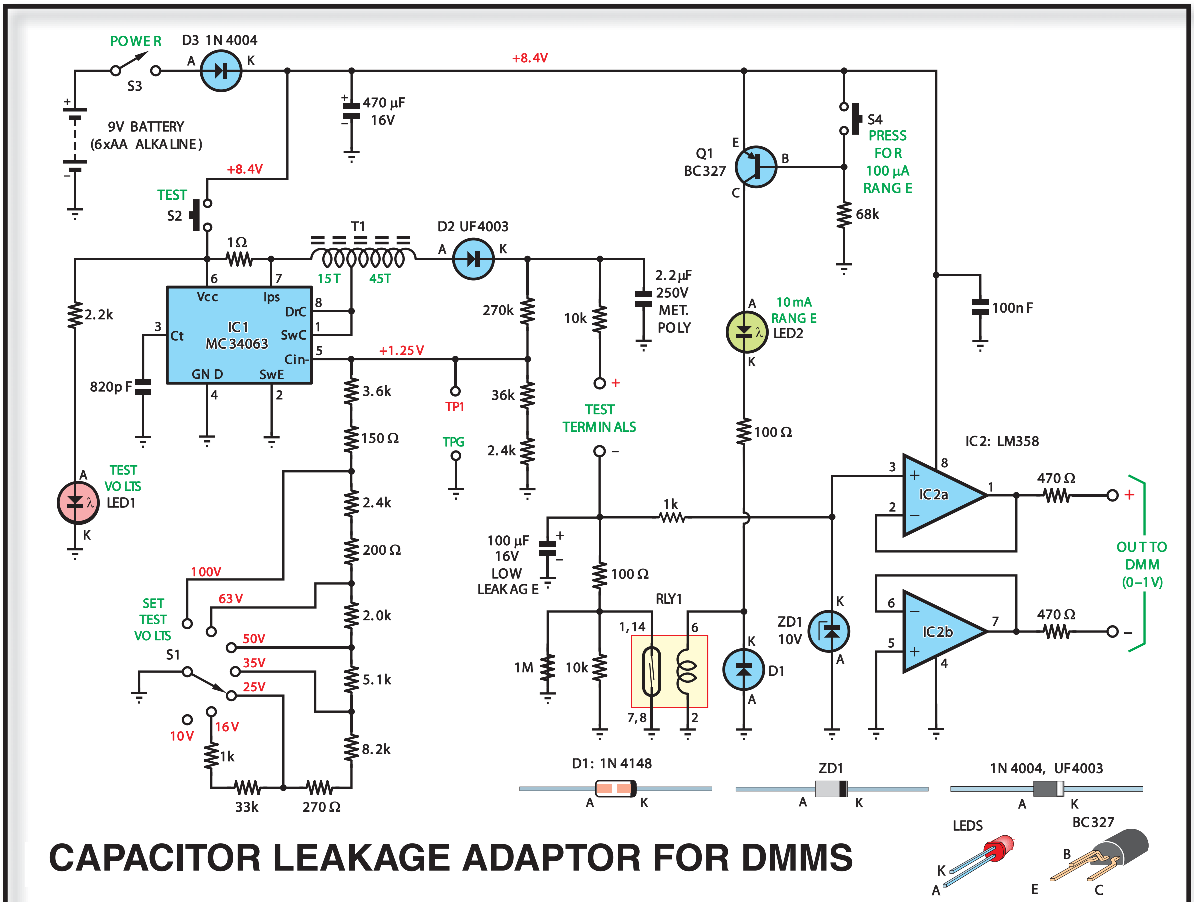


Fig.2: here's the complete circuit diagram for the Adaptor. At the beginning of each test it measures on its 10mA range, but if the current drops below 100μA it can switch to a 100μA range.

(Although the test voltages shown are nominal, with the specified 1% tolerance resistors used for the divider resistors, they should all be well within ±4% of the nominal values because the 1.25V reference inside the MC34063 is accurate to within 2%.)

Note that IC1 only generates the selected test voltage when test pushbutton switch S2 is pressed and held down. This is because IC1 only receives power from the battery when S2 is closed, allowing the converter circuit to operate and thus charge the 2.2µF/250V metallised polyester reservoir capacitor.

Specification

Test voltages .... 10V, 16V, 25V, 35V, 50V, 63V or 100V

Leakage current ..... from 10mA down to less than 100nA (0.1µA), via two ranges: 0 to 10mA (default) and 0 to 100µA (manually selected).

Both ranges convert these current values into an output voltage range of 0 to 1000mV DC, allowing all measurements to be made on the DMM's 0 to 1V or 0 to 2V range.

The adaptor's default 10mA range is current limited to provide protection from damage due to shorted capacitors, or the charging current pulse of high-value capacitors.

Power..................... Internal 9V battery (6 x AA alkaline cells).

Current drain .... Varies between 1mA and 125mA, depending on the test voltage and the current range in use.

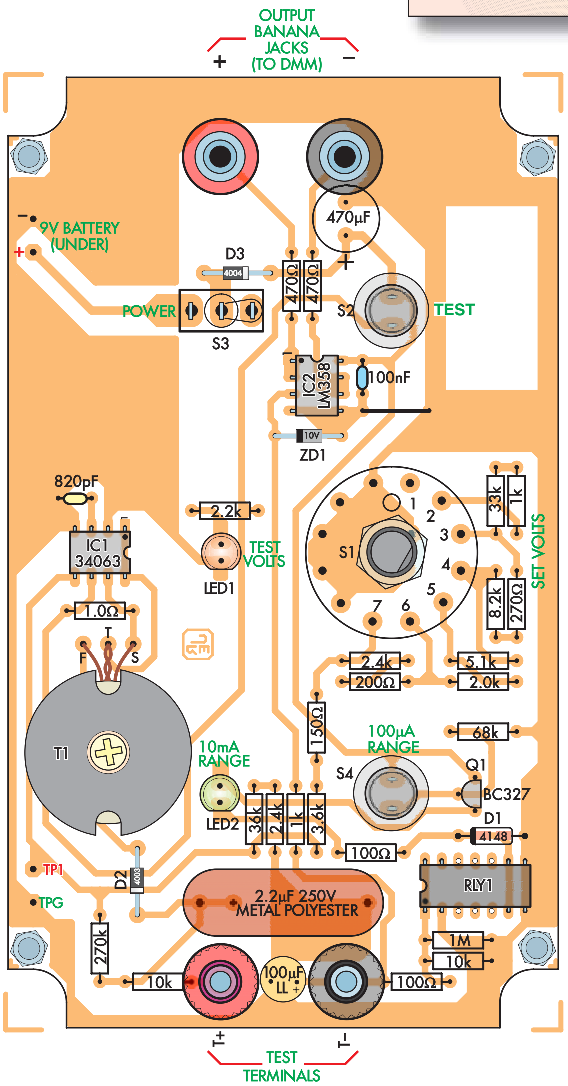
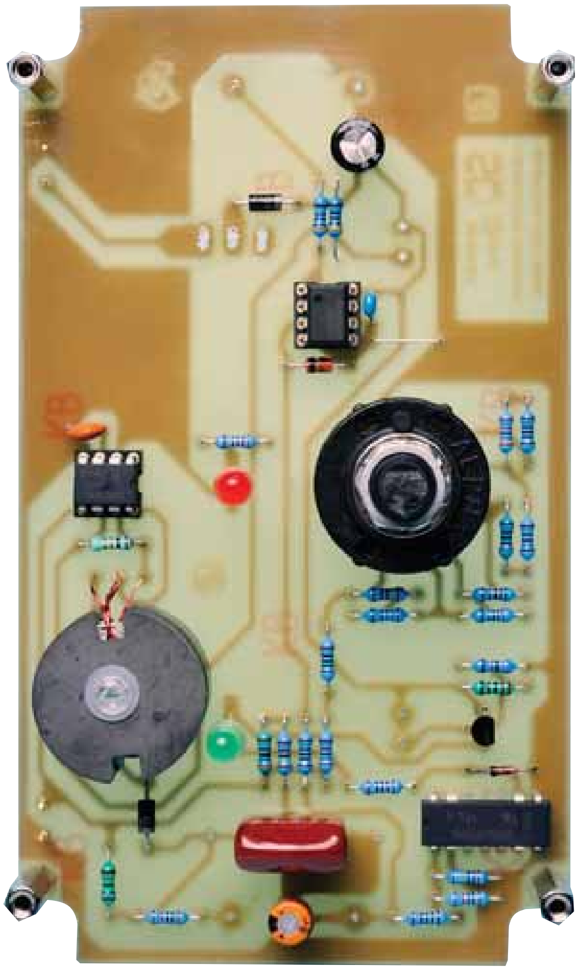


Fig.3: with the exception of the test terminals, DMM output jacks and three of the switches, all components mount on one PC board.



Here's a photograph which matches the diagram at left. In this case, the terminals and the two pushbutton switches are not shown on the board because they mount on the front panel and connect to the PC board via short lengths of tinned copper wire (one of the last steps in assembly).

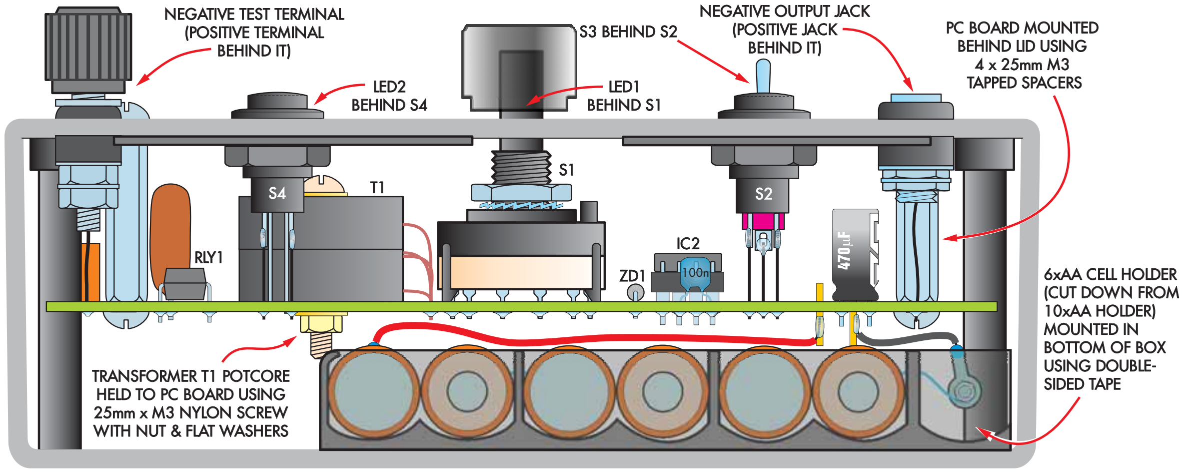


Fig.4: a side-on view 'through' the wall of the UB1-size box, showing how everything goes together. The 6xAA cell holder must be mounted at one end, as shown here, to avoid fouling the screw holding the transformer to the PC board.

The test voltage is then made available at the positive test terminal via the 10kΩ current limiting resistor, R1.

Current-to-Voltage converter

Now let us look at the current-to-voltage converter section, which is virtually all of the circuitry below and to the right of the negative test terminal.

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 adaptor's two ranges. For the default 0 to 10mA 'charging phase' range, RLY1 is energised and 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, opening its contacts and connecting the parallel 1MΩ/10kΩ resistors in series with the 100Ω resistor to produce an effective shunt resistance of 10kΩ.

Relay RLY1 is turned on or off by transistor Q1. When power is first switched on via switch S3, Q1 is switched on by forward bias current applied to its base (B) via the 68kΩ resistor to ground. It therefore conducts about 10mA of collector current, which energises RLY1 and also causes LED2 to light – indicating that the adaptor is operating in the 10mA current range. But if the capacitor's current reading (on the DMM) drops down to below 100µA, pressing pushbutton switch S4 and holding it down causes Q1 to switch off. As a result, LED2 and RLY1 both turn off as well, switching the adaptor to its 0 to 100µA range.

The 100µF low leakage capacitor, in parallel with the shunt, routes any AC signal from the capacitor being tested around the shunt. This prevents ripple from the switch-mode supply from corrupting the reading.

Regardless of which current range is in use, 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 IC2a, one half of an LM358 dual op amp. IC2a is configured as a voltage follower with a voltage gain of unity, feeding the positive output terminal of the adaptor via a 470Ω isolating resistor.

So what is the purpose of IC2b? It is connected as a voltage follower in much the same way as IC2a, except that its non-inverting (+) input is connected directly to ground, and its output is used to drive the negative output terminal. Its purpose is to balance out most of the input offset of IC2a, so that the adaptor's effective output voltage, when there is no current flowing through the test terminals, is much less than 1mV.

All of the adaptor's circuitry operates directly from the 9V battery, via polarity protection diode D3 and, of course, S3. The total current drain when in 'standby' (ie, with TEST button S2 not pressed) is about 11mA in the default 10mA current range, or 1mA if S4 is pressed to switch it into the 100µA range. The current level increases to between 25mA and 125mA when S2 is pressed and held down to generate the test voltage and perform the actual leakage current test.

Construction

Virtually all of the components used in the Capacitor Leakage Adaptor are mounted on a single PC board measuring 145mm × 84mm. This board is available from the *EPE PCB Service*, code 842. The board is mounted under the lid (which becomes the adaptor's front panel) of a UB1-size plastic box (157mm × 95mm × 53mm) via four 25mm-long M3 tapped spacers. Six AA alkaline cells provide power, mounted in a cut-down 10-cell holder secured to the bottom of the box.

Both the voltage selector switch (S1) and the DC/DC converter's step-up transformer (T1), wound on a 26mm ferrite pot core, mount on the board, the latter using a 25mm-long M3 nylon screw and nut.

The only components not mounted directly on the PC board are power switch S3, pushbutton switches S2 and S4, the two test terminals and the two output banana jacks. These are all mounted on the box front panel, with their rear connection lugs extended down via short lengths of tinned copper wire to make their connections to the board. All of these assembly details should be fairly clear from the diagrams and photos.

Board assembly

The printed circuit board component layout is shown in Fig.3, together with a board photograph. To begin fitting the components on the PC board, it is suggested you fit the wire link, located just to the right of IC2 and above the position for rotary switch S1. Next, fit the four 1mm terminal pins to the board – two for the test point at lower left and two at upper left for the battery clip lead connections. Follow these with the sockets for IC1 and IC2, which are both 8-pin devices.

Now fit the fixed resistors. These are 1% tolerance metal film components, apart from the 1.0Ω resistor just above the connecting leads of T1 and below IC1. This 1Ω resistor should be a 0.5W carbon composition type. Check each resistor's value with a digital multimeter (DMM) as you insert and solder them, to ensure they all go in the right places.

Next, you can fit the two lower-value capacitors and the large 2.2μF metallised polyester capacitor, followed by the two polarised electrolytic capacitors – see Fig.3 for their orientation. Now fit the mini DIL relay, making sure its locating groove is as shown in Fig.3.

Voltage selector switch

You can now fit voltage selector rotary switch S1, which mounts with its indexing spigot at 12 o'clock (Fig.3). Just before you fit it, you should cut its spindle to a length of about 13mm and file off any burrs, so it's ready to accept the knob during final assembly.

After it has been fitted to the board, remove its main nut/lock washer combination, and turn the spindle by hand to make sure it's at the fully anticlockwise limit. Then refit the lock washer, making sure that its stop pin goes down into the hole between the moulded '7' and '8' digits. Check that the switch is now 'programmed' for the correct seven positions, simply by clicking through them by hand.

With S1 fitted, you can add the four diodes. Don't mix them up: D1 is a low power 1N4148 'signal' diode, D2 is a UF4003 'fast' rectifier, D3 is a 1N4004 1A power diode and ZD1 is a 10V/1W Zener. Use the component layout diagram (Fig.3) as a guide to their orientation when you're fitting each one to the board.

Next, fit transistor Q1, followed by the two 5mm LEDs. The red one is used as LED1 and the green one as LED2. They are both mounted vertically with their leads left at almost full length, so that the lower surface of their bodies is about 23mm above the surface of the board. Note that the shorter lead, next to the flat on the body, is the cathode (K). This allows them to just protrude through the matching holes in the lid/front panel when the assembled board is attached behind it.

At this stage, your board assembly is very close to complete, with the main task remaining being to wind transformer T1 and fit it to the board. You'll find the full details on how to do this in the separate 'Winding' panel.

Once the transformer has been fitted to the board, you can attach the four 25mm M3 tapped spacers to it as well. These each attach very close to each corner of the board, using 6mm long M3 screws passing up from the underside – see Fig.4 and photographs.

Now all that remains to complete the board assembly is to plug IC1 and IC2 into their sockets. Place it aside while you prepare the case to receive it.

Preparing the case

There are no holes to be drilled in the lower part of the case (the battery holder can be held securely in place using strips of 'industrial' double-sided adhesive foam tape), but the lid does need to have holes drilled for the various switches, LEDs and input/output connectors.

The location and dimensions of all these holes are shown in the diagram of Fig.5, which is actual size, so it (or a photocopy) can also be used as a drilling template. The larger holes are easily made by drilling them all first with a 7mm twist drill and then carefully enlarging them to size using a tapered reamer.

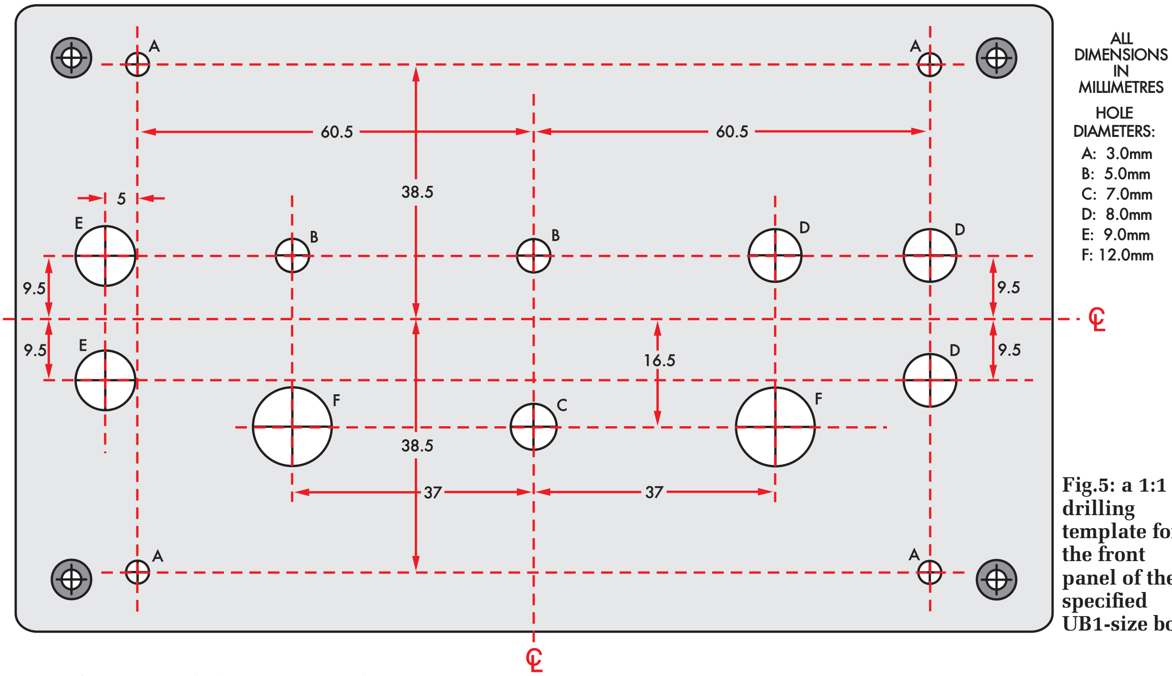


Fig.5: a 1:1 drilling template for the front panel of the specified UB1-size box.

Parts List – Capacitor Leakage DMM Adaptor

1 PC board, code 842, available from the *EPE PCB Service*, size 145mm × 84mm
1 UB1-size plastic box, 158mm × 95mm × 53mm
1 Single-pole rotary switch, PC mounting (S1)
2 SPST mini pushbutton switch (S2, S4)
1 SPDT mini toggle switch, panel mounting (S3)
1 Mini DIL reed relay, SPST with 5V coil (RLY1)
2 Premium binding posts, 1 × red and 1 × black
2 4mm banana jack sockets, 1 × red and 1 × black
1 16mm diameter fluted instrument knob
1 Ferrite pot core pair, 26mm OD
1 Bobbin to suit pot core
1 3m length of 0.5mm diameter enamelled copper wire
1 25mm M3 nylon screw and nut and two flat washers
2 8-pin DIL IC sockets
4 1mm dia. PC board terminal pins
4 25mm long M3 tapped spacers
8 6mm long M3 machine screws, pan head
1 10× AA battery holder (flat, side by side) – see text

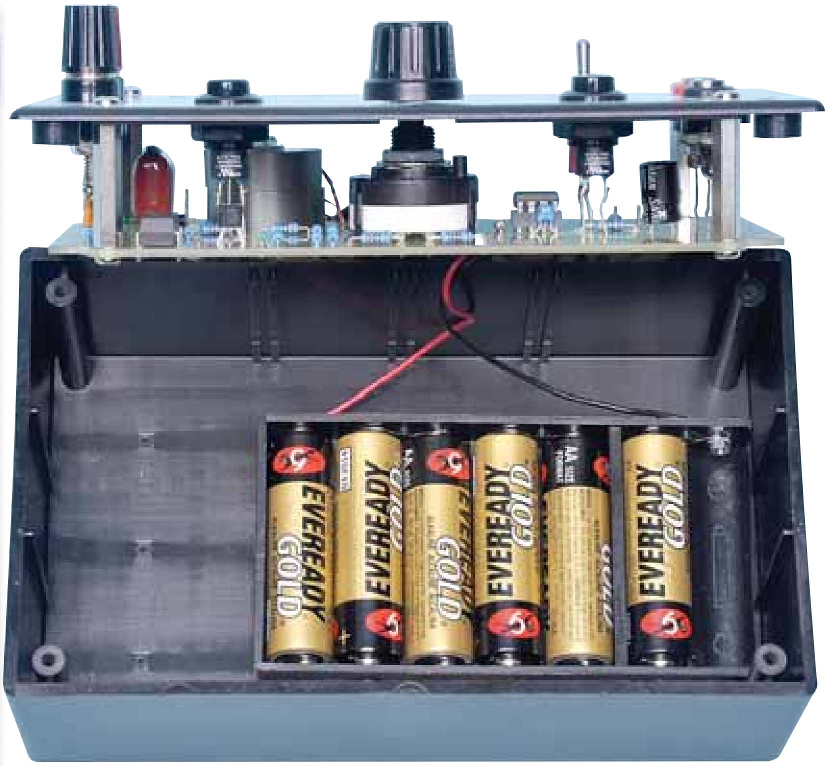
Semiconductors
1 MC34063 DC/DC converter controller (IC1)
1 LM358 dual op amp (IC2)
1 BC327 *PNP* switching transistor (Q1)
1 10V 1W Zener diode (ZD1)
1 5mm red LED (LED1)
1 5mm green LED (LED2)
1 1N4148 100mA diode (D1)
1 UF4003 fast 1A diode (D2)
1 1N4004 1A diode (D3)

Capacitors
1 470µF 16V PC elect
1 100µF 16V low leakage elect
1 2.2µF 250V (or 100V) metallised polyester
1 100nF multilayer monolithic ceramic
1 820pF disc ceramic

Resistors (0.25W 1% unless specified)

1 1MΩ	1 270kΩ	1 68kΩ
1 36kΩ	1 33kΩ	2 100Ω
2 10kΩ	1 8.2kΩ	1 5.1kΩ
1 3.6kΩ	2 2.4kΩ	1 2.2kΩ
1 2.0kΩ	2 1kΩ	2 470Ω
1 270Ω	1 200Ω	1 150Ω

1 1.0Ω 0.5Ω carbon (5%)



'Opened out' view showing the PC board 'hanging' from the front panel.

We have prepared an artwork for the front panel if you would like to make it look neat and professional. This can be photocopied (Fig.6), the resulting copy can either be covered with self-adhesive clear film or, better still, laminated, for protection against (finger) grease before it is glued to the lid/front panel.

Mount switches S2, S3 and S4 on the panel, followed by the binding posts, used as the meter's test terminals, and the banana sockets, used for the output connections to your DMM.

Tighten the binding post and banana socket mounting nuts firmly, to make sure that they cannot come loose with use. Then use the second nut of each post and socket to attach a 4mm solder tag, plus a 4mm lockwasher to make sure they don't work loose either.

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

The next step is to prepare the battery holder. Because you can't buy a six-way flat AA holder (at least we couldn't find one) we cut down a ten-way AA holder.

The last three cell positions are removed altogether (at the 'negative lead' end) and then the eyelets are drilled out and used to attach the contact spring for the sixth cell position and also the contact spring and negative lead connection lug at the end of the removed section.

This will allow you to re-attach the negative lead's connection lug to the contact spring for the sixth cell using a 6mm-long M2 machine screw and nut. The seventh cell position is still retained to support the sixth cell connection spring and the negative lead connection lug.

The converted battery holder can now be fitted inside the main section of the box at lower right, with the connection lead side uppermost. Mount it using double-sided adhesive foam as mentioned earlier, or simply a strip of 'gaffer' tape.

Final assembly

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, S3 and S4, the two test terminals and the output banana sockets with their matching holes in the PC board, as you bring the lid and board together. At the same time you have to line up the spindle of switch S1 and the two LEDs with their matching holes in the front panel.

This is actually easier to do than it sounds, 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 machine screws.

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

If you find this description a bit confusing, refer to the assembly diagram in Fig.4. This will hopefully make everything clear.

Next, solder the bared end of the red (positive) battery holder lead to the positive (+) battery terminal pin on the PC board, and the black (negative) battery holder lead to the negative pin alongside.

You can now fit six AA alkaline cells into the battery holder (make sure you fit them with the correct polarity) and your new Capacitor Leakage Adaptor should be ready for its initial checkout.

Initial checkout

You'll need to use a twin test lead to connect the adaptor's output to the input jacks of your DMM. The DMM should also be set to measure DC voltage, and to its 0V to 1V or 0V to 2V range if it's not auto-ranging.

Switch on the adaptor's power using S3 and the green Range LED2 should light – showing that the adaptor is operating, in standby mode and in the default 10mA current range. If you now press pushbutton switch S4, the range change button, LED2 should go dark. This shows that the range switching circuitry is operating. But your DMM should still be giving a 'zero' reading. At this point you can stop pressing S4.

Next, try pressing test button S2. This should cause red Test Volts LED1 to glow, indicating that power is now being applied to the test voltage generation circuitry. If there is no capacitor or other component connected across the test terminals, your DMM should still be giving a reading of zero.

DMM readings

Assuming all has gone well at this point, your adaptor is probably working correctly.

However, if you want to make sure, try shorting the two test terminals. Then set S1 to the '100V' position, and press Test button S2. The DMM reading should change to a value corresponding to 9.9mA (ie, 990mV), representing the current drawn from the nominal 100V source by the 10kΩ current-limiting resistor and the 100Ω current shunt resistor inside the adaptor.

Don't worry if the current reading is a bit above or below the 9.9mA figure. As long as it's between about 9.2mA (920mV) and 10.6mA (1.06V), things are OK.

With the terminals still shorted together, you can try repeating the same test for each of the other six test voltage positions of switch S1.

You should get a reading on the DMM corresponding to approximately:

6.25mA (625mV) on the 63V range
4.95mA (495mV) on the 50V range
3.46mA (346mV) on the 35V range
2.48mA (248mV) on the 25V range
1.58mA (158mV) on the 16V range
990μA (99mV) on the 10V range.

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

If this is 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. Make sure you also remove the shorting wire between the test terminals.

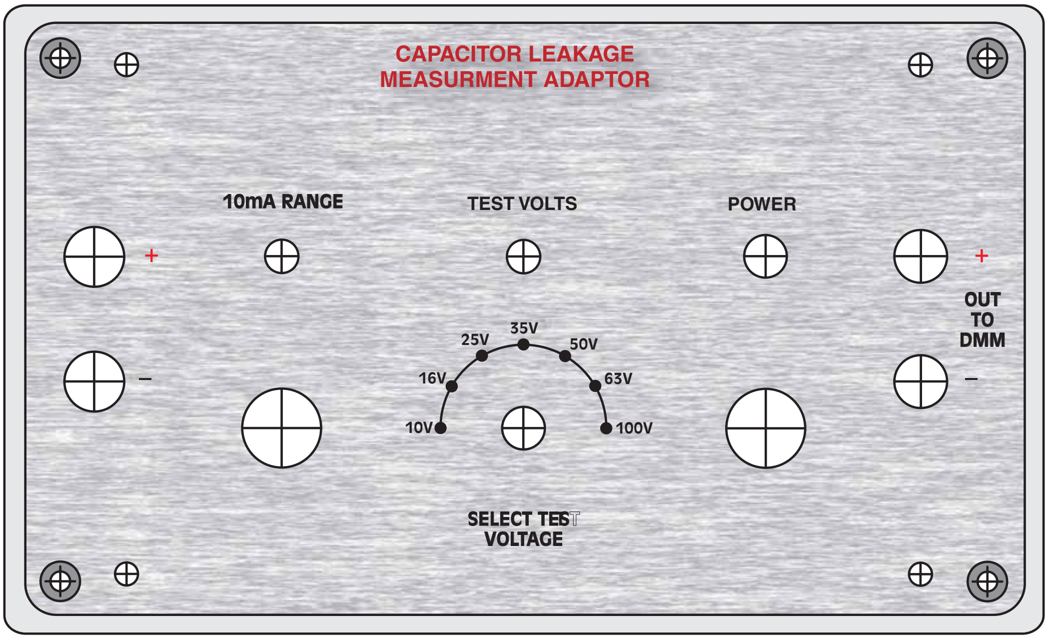


Fig.6: same-size front panel artwork.

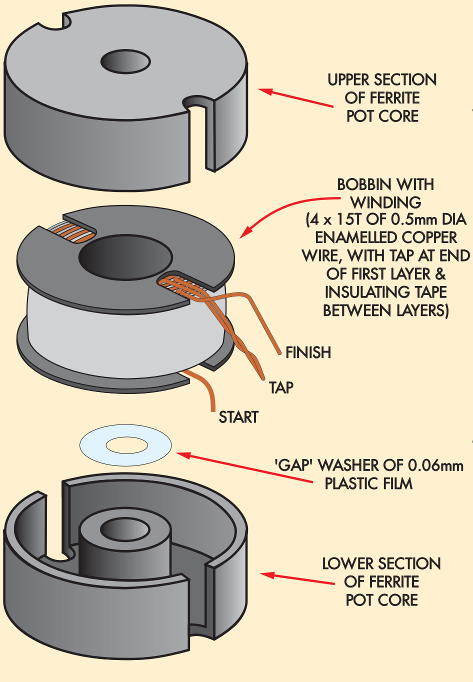
Winding autotransformer T1

The step-up autotransformer T1 has 60 turns of wire in all, wound in four 15-turn layers. As you can see from the assembly diagram at right, all four layers are wound on a small nylon bobbin using easily handled 0.5mm-diameter enamelled copper wire. Use this diagram to help you wind the transformer correctly.

Here's the procedure: first wind on 15 turns, which you'll find will neatly take up the width of the bobbin providing you wind them closely and evenly. Then to hold them 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.



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

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 be ready to fit inside the two halves of the ferrite pot core.

Just before you fit the bobbin inside the bottom half of the pot core, there's a small plastic washer to prepare. This is to provide 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 3mm to 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, you can 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.

First, 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 with gap washer inside) together with your fingers.

Then lower the complete assembly down on the board, with the 'leads' positioned as shown in Fig.3, using the bottom end of the centre nylon screw to locate it in the correct position. 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 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 that they can be soldered to the appropriate pads.

Don't forget to scrape, tin and solder BOTH wires which form the 'tap' lead – if they are not connected together, the transformer won't produce any output.

Using it

The Capacitor Leakage Adaptor is very easy to use, because all 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), after connecting the adaptor's output sockets to the input jacks of your DMM.

Then turn on the DMM and set it to measure DC volts.

Now set the adaptor's selector switch S1 for the correct test voltage and turn on the power (S3), whereupon LED2 should light. To begin the actual test, press and hold down Test button S2.

What you may see first on the DMM is a reading of the capacitor's charging current, which can be as much as 9.9mA (with high value caps), but it 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 (10mV).

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 10μA (1mV).

And if you press button S4 to switch down to the 100μA range, you should be able to see the DMM reading fall down to zero. That's if the capacitor is not faulty, 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 'reform' 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 of somewhere between about 4.1mA and 1μA, depending on both their capacitance value and their rated working voltage.

So, with these capacitors, you should hold down the test button to see if the leakage current reading drops down to the 'acceptable', level as shown in the guide table, and preferably even lower.

If this happens, then the capacitor can be judged 'OK', but if the current never drops to anywhere near this level it should definitely be replaced.

Low leakage

What about low leakage (LL) electrolytics? Well, the current levels shown in the guide 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 no more than about 25% of these current values.

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

That's because these capacitors are essentially two polarised types, internally connected in series, back-to-back. If one of the dielectric layers is leaky but the other is OK, this will only show up in one of the two tests. *EPE*

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