Electrolytic capacitor reformer and tester

Got a bunch of old electrolytic capacitors you'd like to use . . . but don't know if they are any good? Or do you need to reform the electrolytics in an old valve amplifier or vintage radio set?

This Electrolytic Capacitor Reformer and Tester will do the job for you, at any of 11 different standard voltages from 10V to 630V.

Part 1: by JIM ROWE

IN ADDITION, it provides the ability to apply the selected test voltage for any of seven periods, ranging from 10 seconds to 60 minutes.

Thus you can use it for 'reforming' electrolytic capacitors that have developed high leakage and high impedance due to years of inactivity. Also, it can be used to test the leakage of virtually all capacitors at or near their rated voltage.

Of course, we have to state that not all old electrolytics can be restored – they can't. Some will have very high leakage due to contamination of the can seal or breakdown of the electrolyte, some will have just dried out. In those cases, you cannot do anything to resurrect them, but in many cases you will be able to restore and reuse capacitors that have not been used for many years, if not decades.

Some very old caps (1960s vintage) we had took several hours to come good, while others, made in more recent years, were good within a few minutes.

Most high voltage (ie, 250V and above) capacitors should be capable of being reformed to the extent that their leakage current drops to around 3mA or less.

Damage limitation

The *Reformer* circuit is designed so that no damage can occur if the capacitor connected to it is short circuit or has very high leakage, or is even connected back-to-front (ie, with reverse polarity). Furthermore, even if the capacitor leakage is very high, the output current is limited so that the maximum dissipation in the capacitor is no more than 2W.

This means that some capacitors might get warm while they are being reformed, but none will get so hot that they are in danger of swelling up and 'letting the smoke out'.

That's a good thing, because electrolytic capacitor smoke is particularly foul-smelling! And as any serviceman will tell you, the gunk (electrolyte) inside is particularly nasty if it escapes with the smoke.

The *Electrolytic Capacitor Reformer and Tester* is housed not in a traditional instrument case or box, but in a standard plastic storage organiser case, which, together with a microswitch interlock, provides a safe compartment for the capacitor when it has high voltage applied. Another compartment provides handy storage for the switchmode 12V plugpack.

Opening the lid of the case means that no voltage is applied to the capacitor – until the lid is closed – but perhaps even more importantly, opening the lid safely and quickly discharges the capacitor so there is no chance of a

WARNING: SHOCK HAZARD!

Because the voltage source in this instrument can be set to provide quite high DC voltages (up to 630V) and can also supply significant current (tens of milliamps), it does represent a potential hazard in terms of electric shock. We have taken a great deal of care to ensure that this hazard is virtually zero if the instrument is used in the correct way – ie, with the lid closed and secured – even to the extent of quickly discharging any capacitor when the lid is opened.

However, if the safety switching is bypassed, especially when the unit is set to one of the higher test voltages, it is capable of giving you a very nasty 'bite' should you become connected across the test clips or a charged high voltage capacitor. There are some situations where such a shock could potentially be lethal.

Do NOT bypass the safety features included in this design. We don't want to lose any readers to electrocution.

Most hobbyists would have collected many old electros over the years (maybe not as old as some of these!) – but are they any good, and can they be resurrected?

nasty electric shock – for you or anyone else. A charged 630V capacitor with its leads exposed is not something to be trifled with!

With the lid closed, you can select the test voltage and the period of reform/testing, and view the 2-line LCD which shows the capacitor voltage, leakage current and the time elapsed.

Circuit design

Electrolytic Capacitor Reformer and Tester is based on the simpler unit described in the November 2011 issue of *EPE,* but with a much bigger selection of test voltages, plus the in-built test timer, which allows the test voltage to be applied for as long as 60 minutes.

Commercial capacitor leakage current meters/reformers are available, but they tend to be fairly expensive (well over £650) and we don't believe any of them incorporate a safety interlock to avoid the possibility of electric shock. With ours, you have a choice of eleven different standard test voltages: 10V, 16V, 25V, 35V, 50V, 63V, 100V, 250V, 400V, 450V and 630V. These correspond with the rated voltages of most electrolytic capacitors which have been available for the last 30 years or so.

If you have an 'oddball' capacitor with a different working voltage, simply select the next voltage down. (In fact, in the vast majority of cases selecting the next voltage up won't do the capacitor any harm either, because most capacitors, especially electrolytics, can stand a short-term higher peak voltage than their working voltage, hence the labelling – eg, 400VW, 500VP).

With any of these test voltages applied to a 'test capacitor', you can read its leakage current on the 2-line × 16-character backlit LCD screen, with two automatically selected current ranges: 0 to 200μA or 0 to 20mA. You can also read the voltage which

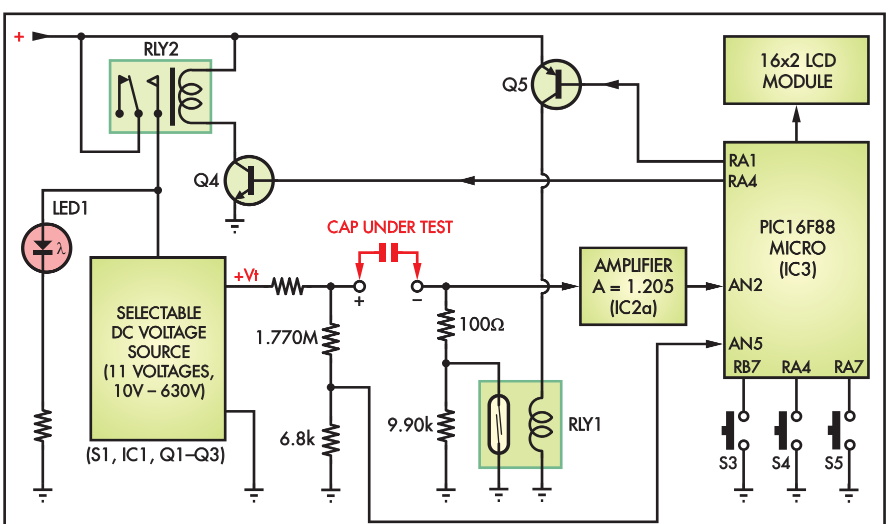


Fig.1: block diagram of the Electrolytic Capacitor Reformer and Tester. Not shown here is the safety interlock microswitch and discharge resistors.

appears across the capacitor at any time in the procedure.

Also important, is that for reforming capacitors you have the choice of ten test periods: 10 seconds, 30 seconds, 1 minute, 3 minutes, 10 minutes, 30 minutes or 60 minutes.

How it works

Essentially, the *Reformer's* operation is quite straightforward, as you can see from the block diagram of Fig.1. This is broadly very similar to the design in our November 2011 issue.

There are only two functional circuit sections, one being a selectable DC voltage source (on the left) which generates one of 11 different preset test voltages when power is applied to the voltage source (actually a DC-to-DC converter) via relay RLY2, controlled by the PIC micro (IC3) via transistor Q4. This test voltage is applied to the positive terminal of the capacitor via a protective current-limiting resistor and a microswitch, whose purpose we will look at shortly.

The second functional circuit section is on the right in Fig.1, and combines a digital meter, which is used to measure any direct current passed by the capacitor under test, and the voltage appearing across the capacitor. There is also a digital timer which controls the DC test voltage source via Q4 and RLY2. The PIC micro (IC3) forms the 'brains' of this section.

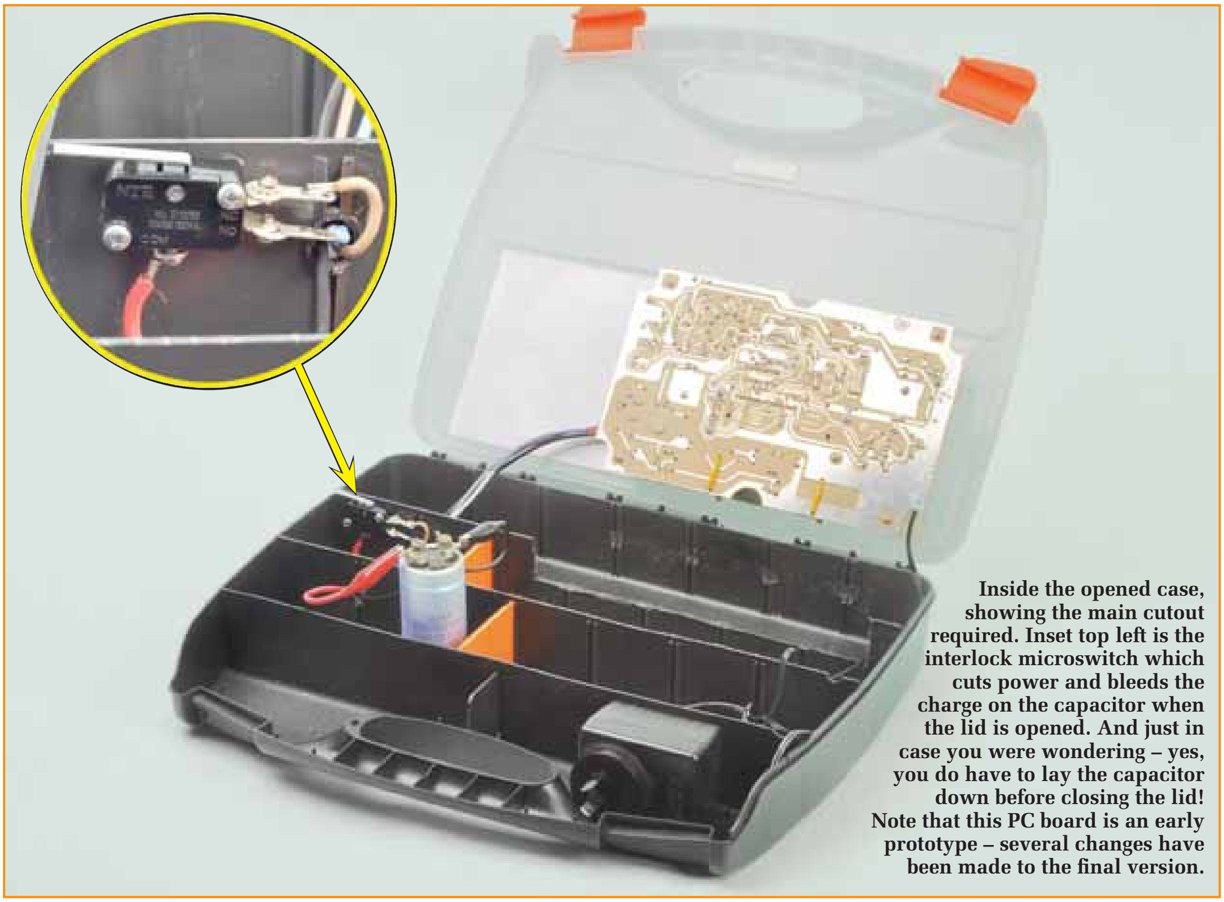
Voltmeter

We use IC3 as a voltmeter to make the current measurement because any current passed by the capacitor flows down to ground via the 100Ω resistor, either alone or with the 9.90kΩ resistor in series. The resistor(s) therefore act as a current shunt, and its voltage drop is directly proportional to the current flowing through the capacitor. The meter measures the voltage across the resistor(s) and is arranged to read directly in terms of current.

We also use IC3 to measure the voltage across the capacitor for the duration of the leakage test or reforming period. That way, you can keep track of the leakage current and the voltage at any time. For a good capacitor, the voltage across it will rise while the leakage current steadily reduces.

The reason for relay RLY1 and the 9.90kΩ resistor, which it effectively switches in series with the 100Ω resistor, is that this gives the digital current meter two ranges. This allows it to read leakage currents down to less than 100nA (0.1μA), while also coping with charging and/or leakage currents of up to 20mA or thereabouts.

Before the micro (IC3) begins a test by turning on transistor Q4 and relay RLY2 to apply power to the test voltage source, it first turns on transistor Q5 and relay RLY1 to short out the 9.90kΩ resistor, giving the effective current shunt



Inside the opened case, showing the main cutout required. Inset top left is the interlock microswitch which cuts power and bleeds the charge on the capacitor when the lid is opened. And just in case you were wondering – yes, you do have to lay the capacitor down before closing the lid! Note that this PC board is an early prototype – several changes have been made to the final version.

resistance a value of 100Ω, which gives a 0 to 20mA range for the capacitor's charging phase.

Only when (and if) the measured current level falls below 200µA does it switch off Q5 and RLY1, increasing the total shunt resistance to 10kΩ and thus providing a 0 to 200µA range for more accurate measurement of any residual leakage current.

So that's the basic arrangement. Pushbutton switches S3 to S5 are used to select the test time period and also to begin a test, or end it prematurely. LED1 is used to indicate when RLY2 has applied power to the DC voltage source, and when the test voltage is present across the capacitor test terminals.

The reason for the resistor in series with the output from 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 digital metering sections in the event of the capacitor under test having an internal short circuit. It also protects the 9.90kΩ shunt resistor 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.

In the full circuit you'll find that this series resistance has a total value of 10.4kΩ, which was chosen to limit the maximum voltage which can ever appear at the input of the voltmeter's input amplifier (IC2a) to just over 6V, even under short-circuit conditions and with the highest test voltage of 630V.

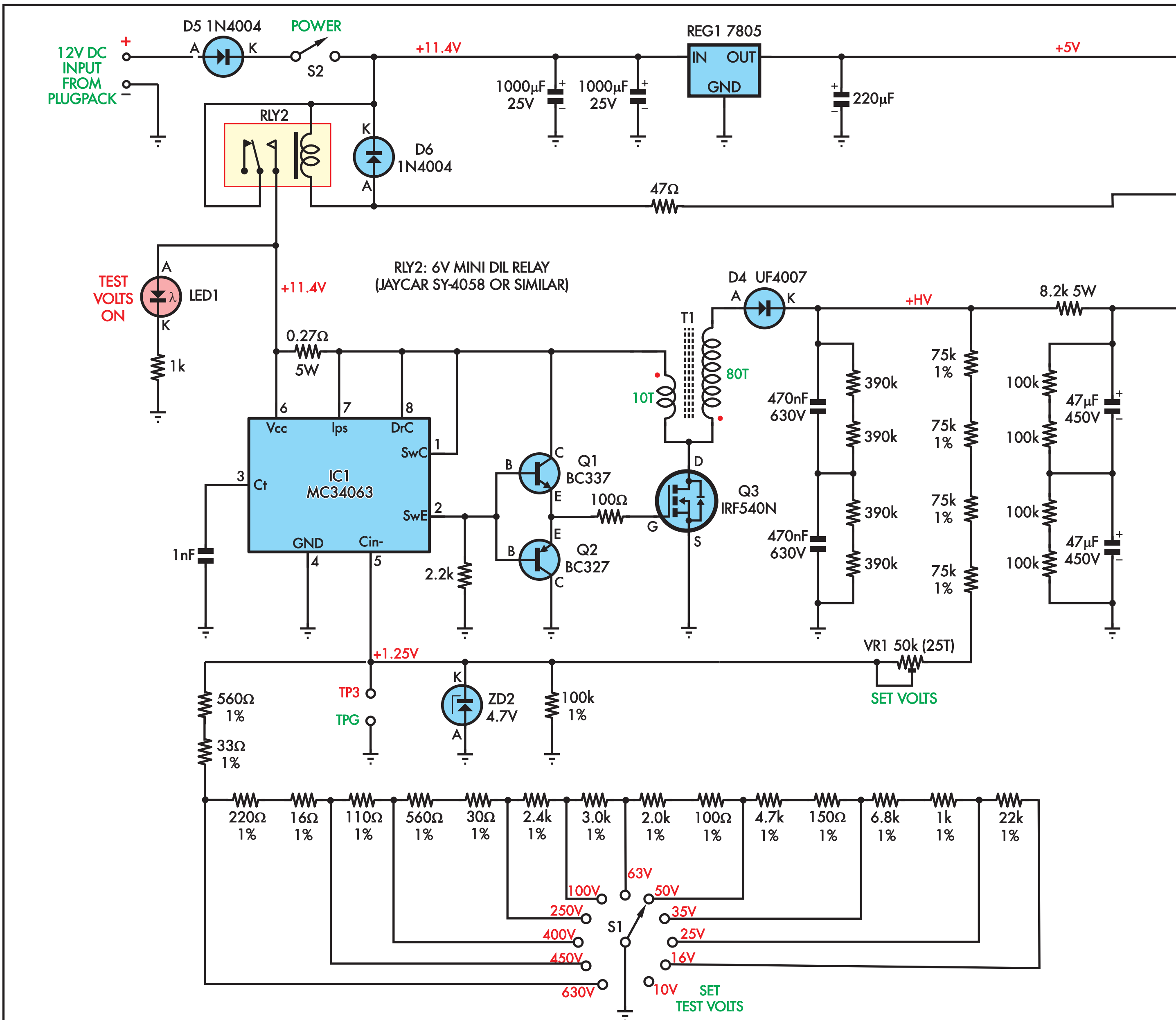
It is also used to limit the current when the instrument is being used for reforming electrolytics.

Circuit description

Now let's have a look at the full circuit diagram of the *Electrolytic Capacitor Reformer and Tester* (Fig.2). The selectable DC voltage source is again on the left, based around IC1 – an MC34063 DC/DC conversion controller IC.

It is used here in a step-up or 'boost' configuration in conjunction with driver transistors Q1 and Q2, switching transistor Q3, autotransformer T1 and fast switching diode D4. 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 D4 back to IC1's pin 5 (where the voltage is compared with an internal 1.25V reference).

The four series-connected 75kΩ resistors, together with trimpot VR1, form the top arm of the feedback divider, while the 100kΩ resistor from pin 5 to ground forms the fixed component of the lower arm. These give the voltage source its lowest output voltage of close to 10.5V, which is the converter's output voltage when selector switch S1 is in the '10V' position.



ELECTROLYTIC CAPACITOR REFORMER AND TESTER

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 '16V' position, all of the series-connected resistors in the string between the various positions of S1 are in parallel with the 100kΩ resistor, increasing the division ratio to increase the converter's regulated output voltage to 16.25V.

The same kind of change occurs in all of 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 operates only when the 11.4V supply rail is connected to it via relay RLY2, under the control of micro IC3. The converter circuit then operates and generates the desired test voltage across the two 470nF/630V metallised polyester reservoir capacitors, connected in series, with their voltage-sharing resistors in parallel. At the same time, LED1 is illuminated, to warn you that the test voltage will be present at the test terminals.

Note that the test voltage present at the top of the feedback divider is not fed directly to the positive test connector, but is first fed through a low-pass RC filter formed by the 8.2kΩ 5W resistor and the series-connected 47µF/450V capacitors (which again have voltage-sharing resistors in parallel).

This filter is to smooth out any ripple present in the output of the voltage source/converter. The filtered test voltage is then made available at the positive test terminal via a 2.2kΩ 5W

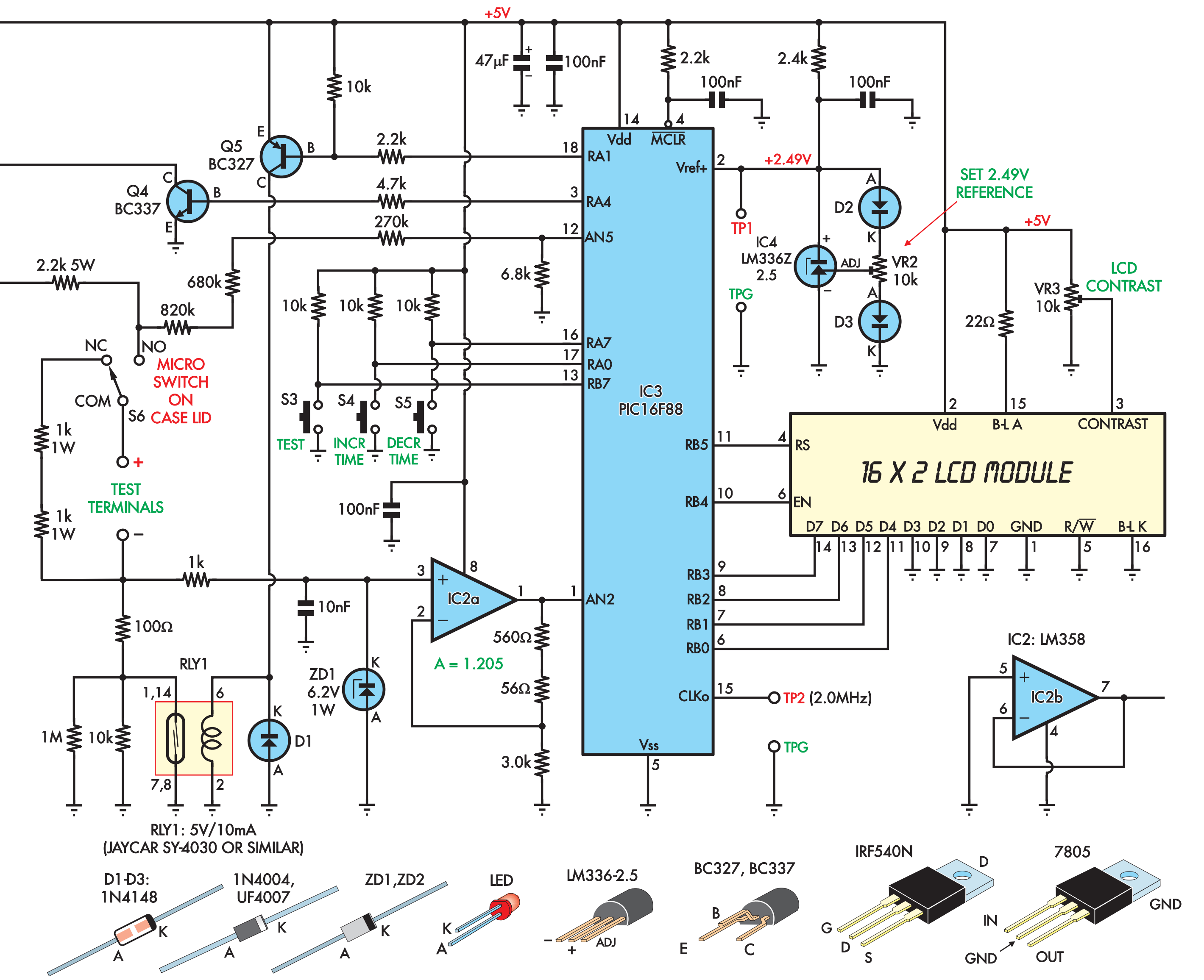


Fig.2: similar to the block diagram, the circuit is divided into two distinct sections – the high voltage generation on the left side and the reforming/reading/metering section on the right, which itself is under the control of a PIC microcontroller. Don't depart from this circuit diagram – a lot of effort has gone into making it safe!

series resistor, which together with the 8.2kΩ 5W series resistance of the filter forms the protective current-limiting resistance shown in Fig.1.

Charged electros can be lethal!

Before the test voltage is fed to the capacitor's positive test connector, it first has to pass through microswitch S6, which is attached to the case so that it switches when the case lid is opened. Normally, (ie, with the lid closed) the test voltage is connected, but when the lid is opened, the test capacitor's positive terminal is connected to its negative terminal via two 1kΩ, 1W resistors, which will discharge even the largest high voltage capacitors normally encountered in less than a second. Two 1W resistors are used to obtain a sufficiently high voltage rating for the highest value test setting.

Of course, very high value lower-voltage capacitors will take much longer to discharge (as much as a few seconds or so) but these are not considered as dangerous to life and limb.

It is important for your safety (and more importantly, the safety of others) that the microswitch is not left out nor bypassed or worse, the circuit is built into a case which does not have a hinged lid allowing this form of protection. The circuit is perfectly safe as described.

Wiring external to the PC board (ie, the high voltage wiring) ***MUST*** be made with 250V AC-rated cable. The easiest place to get such cable is from a surplus flexible mains lead. In fact, you might be lucky enough to find that you have some with red and black insulated wires (which are needed for the test capacitor connections) and newer ones with brown and blue insulated wires (ideal for the connections between PC board and microswitch). We wouldn't use the green or green/yellow wiring for ANY purpose except earth wiring.

Parts List – Electrolytic Reformer and Tester

1 PC board, code 861, available from the *EPE PCB Service,* 224mm × 120mm
1 Trojan TJW0510 38cm Storage Organiser
1 Front panel label, 320mm × 120mm, laminated
1 16×2 LCD module with backlighting (**Jaycar QP-5516)**
1 Mini DIL reed relay, SPST with 5V coil
1 Mini DIL relay, SPDT with 6V coil
1 SPDT 250V 10A microswitch **(Jaycar SM-1040 or equivalent)**
2 19mm square TO-220 finned heatsinks
1 Ferrite pot core pair, 26mm OD with bobbin to suit
1 25mm long M3 nylon screw with nut and flat washer
1 1m length of 0.8mm diameter enamelled copper wire
1 10m length of 0.25mm diameter enamelled copper wire
1 Single pole 12-position rotary switch (S1)
1 Instrument knob, 16mm with grub screw fixing
1 SPDT mini toggle switch, panel mtg (S2)
3 SP Momentary pushbutton switches, panel mounting (S3-5)
18 6mm long M3 machine screws, pan head
4 25mm long M3 tapped spacers
4 12mm long M3 tapped nylon spacers (or two – see text)
3 nylon flat washers (only for QP-5516 module – see text)
2 M3 nuts
1 7×2 length DIL socket strip, OR 16-way length SIL socket strip (see text)
1 7×2 length DIL pin strip, OR 16-way length SIL pin strip (see text)
1 18-pin IC socket
2 8-pin IC sockets
10 PC board terminal pins, 1mm diameter
2 100mm long nylon cable ties

Semiconductors
1 MC34063 DC/DC converter controller (IC1)
1 LM358 dual op amp (IC2)
1 PIC16F88 programmed microcontroller (IC3)
1 LM336Z 2.5V reference (IC4)
1 7805 +5V regulator (REG1)
2 BC337 *NPN* transistor (Q1,Q4)
2 BC327 *PNP* transistor (Q2,Q5)
1 IRF540N 100V/33A MOSFET (Q3)
1 6.2V Zener diode (ZD1)
1 4.7V Zener diode (ZD2)
1 5mm red LED (LED1)
3 1N4148 100mA signal diode (D1,D2,D3)
1 UF4007 ultrafast 1000V/1A diode (D4)
2 1N4004 400V/1A rect. diode (D5,D6)

Capacitors
2 1000µF 25V radial elect.
1 220µF 16V radial elect.
1 47µF 16V radial elect.
2 47µF 450V radial elect.
2 470nF 630V metallised polyester
2 100nF MKT metallised polester
2 100nF multilayer monolithic ceramic
1 10nF MKT metallised polyester
1 1nF disc ceramic

Resistors (0.25W 1% metal film unless specified)

1 1MΩ	1 820kΩ	1 680kΩ	4 390kΩ	1 270kΩ
5 100kΩ	4 75kΩ	1 22kΩ	1 8.2kΩ 5W	5 10kΩ
2 6.8kΩ	2 4.7kΩ	2 3.0kΩ	1 2.2kΩ 5W	2 2.4kΩ
3 2.2kΩ	1 2.0kΩ	2 1kΩ 1W	3 1kΩ	3 560Ω
1 220Ω	1 150Ω	1 110Ω	2 100Ω	1 56Ω
1 47Ω	1 33Ω	1 30Ω	1 22Ω	1 16Ω

1 0.27Ω 5W
1 50kΩ 25T vertical trimpot (VR1)
2 10kΩ mini horizontal trimpot (VR2,VR3)

Software

All software program files will be available from the *EPE* website at **www.epemag.com**.

Although we do not supply pre-programmed microcontrollers, you can purchase the programmed micro featured in this project from: **parts@siliconchip.com.au**

Voltage and current metering

Now let us look at the digital metering and control section, which is virtually all of the circuitry below and to the right of the negative test terminal. The 100Ω resistor and paralleled 1MΩ and 10kΩ resistors connected between the negative test terminal and ground correspond to the current shunts shown 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 20mA 'charging phase' range, RLY1 is energised via Q5 and connects a short circuit across the parallel 1MΩ/10kΩ combination resistors, making the effective shunt resistance 100Ω. But for the more sensitive 200µA 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.

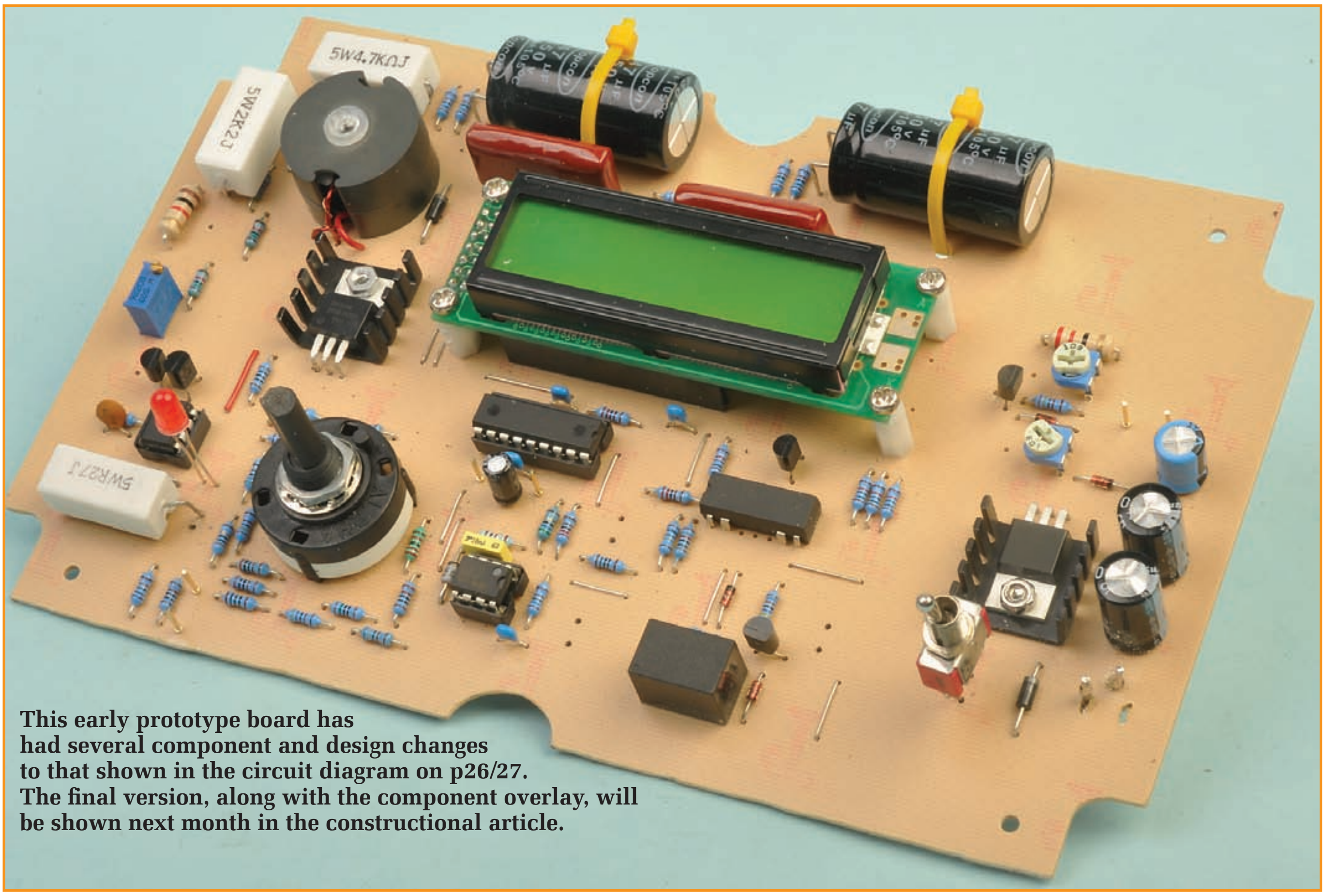
As you can see, the voltage drop across the shunt resistance (as a result of any current passed by the capacitor under test) is passed to the non-inverting input of IC2a, one half of an LM358 dual op amp. IC2a is configured as a DC amplifier with a voltage gain of 1.205 times, feeding the AN2 analogue input of IC3, the PIC16F88 microcontroller, which forms the 'heart' of the metering/control section.

Reference voltage

IC3 takes its measurements of the amplified current shunt voltage from IC2a by comparing this voltage with a reference voltage of 2.490V fed into pin 2 of IC3. The reference voltage is derived from the regulated +5V supply line via voltage reference IC4, an LM336Z device, which is provided with a voltage trim circuit using diodes D2, D3 and trimpot VR2. These are used to set its voltage drop to exactly 2.490V, where it displays a near-zero temperature coefficient.

In fact, IC3 takes a sequence of 10 measurements at a time and calculates the average of the 10 readings to reduce 'jitter' caused by noise transients. It then does mathematical scaling to arrive at the equivalent current readings, which it displays on the 16x2 LCD module.

IC3 also monitors the voltage across the capacitor via a voltage divider feeding its AN5 input, pin 12.



This early prototype board has had several component and design changes to that shown in the circuit diagram on p26/27. The final version, along with the component overlay, will be shown next month in the constructional article.

Timer function

As mentioned earlier, pushbutton switches S3 to S5 are used to select the test time period to be used, and also to begin testing a capacitor. Switch S4 is used to increase the test period time, while S5 is used to decrease it. Then, when the user has set S1 for the correct test voltage and has selected the test time period using S4 and S5, testing is begun by pressing switch S3.

IC3 then turns on transistor Q5 and relay RLY1 to set the metering circuit for the 10mA range, after which it turns on Q4 and RLY2 to feed power to the test voltage converter (and LED1). It also starts a software timer to control how long the test voltage is to be applied.

While the test is being carried out, the metering section takes voltage and current readings and displays these on the LCD module, changing down to the 0 to 200μA range automatically if the measurements drop below 0.2mA. When the selected test time period ends or the user presses S3 again to end the test prematurely, IC3 switches off the test voltage source. The voltage and current measurements continue however, so you can monitor the current decay as the test voltage drops to zero.

Zener diode ZD1 is included in the metering circuit to protect pin 3 input of IC2a from damage, due to accidental application of a negative or high positive voltage to the negative test terminal (from a previously charged capacitor, for example). On the other hand, diode D1 is included to protect transistor Q5 from damage due to any back EMF ‘spike’ from the coil of RLY1 when it is de-energised.

Trimpot VR3 allows the contrast of the LCD module to be adjusted for optimum visibility. The 22Ω resistor connecting from the +5V supply rail to pin 15 of the LCD module is to provide current for the module’s LED back-lighting.

IC1 and the selectable DC voltage source operate directly from the 12V DC supply line (via polarity protection diode D5 and, of course, power switch S2), while the rest of the circuit operates from a regulated 5V rail which is derived from the battery/plugpack via REG1, a 7805 3-terminal regulator.

That’s basically it. The only other point which should perhaps be mentioned is that the PIC16F88 micro (IC3) operates here from its internal RC clock, at a frequency very close to 8MHz. A clock signal of one quarter this frequency (ie, 2MHz) is made available at pin 15 of IC3, and is brought out to test point TP2, to allow you to check that IC3 is operating correctly.

Construction

Now that we have the design and operation under our belts, we’re ready to move onto the construction.

Unfortunately, though, space has beaten us this month, so the complete constructional details, including the mounting of the project within the special case, will be presented next month.

In the meantime, the parts list is shown opposite, so you can start collecting the bits required. Firmware for the PIC micro will also be on the *EPE* website (**www.epemag.com**) next month.

Electrolytic capacitor reformer and tester

Last month, we introduced our electrolytic reformer/tester circuit. We now show how to construct, test, and use the tester to breathe (usually) new life into your collection of vintage/suspect electrolytics.

Part 2: by JIM ROWE

WITH the exception of the power supply, microswitch (S6) and, of course, the capacitor under test/reforming, virtually all of the circuitry and components used in the *Electrolytic Capacitor Reformer and Tester* are mounted on a single PC board measuring 222mm × 120mm and coded 861. This board is available from the *EPE PCB Service*.

The board is supported behind the transparent lid of the case – in fact, a modified storage organiser – which houses the instrument.

As you can see from the photos and assembly diagrams, the board is suspended from the lid of the enclosure and label (which becomes the instrument's front panel) via four 25mm long M3 tapped spacers.

The LCD display module mounts just above the centre of the board on four 12mm-long M3 tapped nylon spacers (or two such spacers if you use the Altronics LCD module).

The DC-to-DC converter's step-up transformer T1 (wound on a 26mm ferrite pot core) mounts on the board at upper left using a 25mm-long M3 nylon screw and nut, while voltage selector switch S1 also mounts directly on the board at lower left.

The only components not mounted directly on the board are power switch S2, pushbutton switches S3 to S5, the two test leads (fitted with alligator clips) and, as mentioned earlier, the microswitch. All switches are mounted on the 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

To fit the components on the main board we suggest you start with the fixed resistors. These are all 1% tolerance metal film components, apart from the 0.27Ω, 2.2kΩ and 8.2kΩ 5W resistors and the 2 × 1kΩ 1W resistors.

When you are fitting all of the resistors, make sure you place each value in its correct position(s), as any mix ups may have a serious effect on the meter's operation and/or accuracy. Check each resistor's value with a DMM (digital multimeter) if you want to be sure of no mistakes.

It's also a good idea to fit the 1W and 5W resistors with their bodies about 2mm above the top of the board, rather than resting on it. That's because these resistors can become quite warm during an extended 'electro reforming' test run.

It's logical to follow with the wire links, most of which are 0.4mm long, so they're easily fashioned from resistor lead offcuts. There are quite a few of these links – five are located underneath the position where the LCD module is fitted later – see Fig.3.

Next, place the eleven 1mm terminal pins in the board – two for each of the three test point locations, two for the DC input connection and three for the high voltage output (to the microswitch and capacitor). Follow these with the sockets for IC1 and IC2 (both 8-pin sockets) and IC3 (an 18-pin socket).

After these are in place you can fit 25-turn trimpot VR1 at centre left and trimpots VR2 and VR3 at upper right. Next are the small low-value capacitors, followed by the two larger 470nF/630V metallised polyester units and finally the two high voltage electrolytics, which lie on their side at the top of the board with their leads bent down by 90°. They are each held down using

WARNING: SHOCK HAZARD!

Because the voltage source in this instrument can be set to provide quite high DC voltages (up to 630V) and can also supply significant current (tens of milliamps), it does represent a potential hazard in terms of electric shock. We have taken a great deal of care to ensure that this hazard is virtually zero if the instrument is used in the correct way – ie, with the lid closed and secured – even to the extent of quickly discharging any capacitor when the lid is opened.

However, if the safety switching is bypassed, especially when the unit is set to one of the higher test voltages, it is capable of giving you a very nasty 'bite' should you become connected across the test clips or a charged high voltage capacitor. There are some situations where such a shock could potentially be lethal.

Do NOT bypass the safety features included in this design. We don't want to lose any readers to electrocution.

The completed reformer and tester built into its modified 'storage organiser' case. The circuit, including the test clips, is completely isolated when the lid is closed and any charge on the capacitor under test/reforming is bled away safely when the lid is opened. There is plenty of room inside the case for the 12V DC power supply and in this case its IEC lead, which in use emerges from a hole cut in the side of the case alongside the supply.

a nylon cable tie which goes through the hole in the PC board and around the edge. Once the high voltage electros are in place you can mount the low voltage electros, three of which go at far right and the remaining 47μF unit at lower centre just near TP2.

Don't forget to fit all of the electros with the orientation shown in the PC board overlay diagram (Fig.3), as they are all polarised.

Selector switch

Next fit the two relays, making sure that they too are oriented as shown in Fig.3. Then you can solder in voltage selector switch S1, which as you can see mounts with its indexing spigot in the '1:30' position. Before you fit the switch you should cut its spindle to a length of about 12mm and file off any burrs, so it's ready to accept its knob.

After switch S1 has been fitted to the board, remove its main nut/lockwasher/position stopwasher combination and turn the spindle by hand to make sure it's at the fully anti-clockwise limit. Then refit the position stopwasher, making sure that its stop pin goes down into the hole after the moulded '11' digits.

Next, refit the lockwasher and nut to hold it down securely, allowing you to check that the switch is now 'programmed' for the correct eleven positions – simply by clicking it around through them by hand. You'll probably need to temporarily attach the knob first to get enough grip to turn it. If all is OK, remove the knob for now.

The next step is to wind the step-up autotransformer T1. This might sound a bit daunting, but it's not. You can find step-by-step instructions in the panel titled 'Winding Transformer T1', which also explains how to fit the completed transformer to the PC board.

Final components

With the transformer wound and fitted to the board, you'll be ready to install diodes D1 to D6. These are all polarised, so make sure you position each one correctly, as shown in Fig.3. Also ensure that D1 to D3 are the three 1N4148 diodes, D4 is the UF4007 and the two 1N4004 diodes for D5 and D6. When fitting the two Zener diodes ZD1 and ZD2, note that they are NOT the same voltage – they too are polarised.

After the diodes, install transistors Q1, Q2, Q4 and Q5, which are all TO-92 devices. Make sure that you fit the two BC337 (*NPN*) devices as Q1 and Q4, with the BC327 (*PNP*) devices as Q2 and Q5. You can follow these with voltage reference IC4, which is also in a TO-92 package. If in any doubt, use a magnifying glass to confirm the device's type numbers.

Next come regulator REG1 and Q3, which are both in TO-220 packages. In this project, they each lie flat on the top of the board with a 19mm-square (6073B type) heatsink underneath, and with their leads bent down by 90° at a point about 6mm away from the body. Each device is then held in position on the board using a 6mm-long M3 machine screw and nut. These should be tightened before the leads are soldered to the pads underneath to prevent stress on the pads.

Next, fit LED1 to the board. It is located just to the right of the socket for IC1, with its cathode 'flat' side towards rotary switch S1. Note that it is fitted vertically, with its leads left almost at their full length – so that the bottom of the LED's body is about 22mm above the top of the board. This should mean that the top of the LED's body will just protrude from the matching hole in the case lid, after final assembly.

LCD mounting

The final component to be mounted directly on the board is the connector for whichever LCD module you are going to use. In the case of the Jaycar QP-5516 module, this will be a 14-way (7x2) length of DIL (dual inline) socket strip, fitted vertically at the left-hand end of the module position. Whereas, if you are using the Altronics Z-7013 module, you will need to fit a 16-way length of SIL socket strip horizontally, along the lower long side.

Once this connector 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 attach to the board either four or two 12mm-long M3 tapped *nylon* spacers, in the module mounting positions. This will mean two at each end in the case of the QP-5516 module,

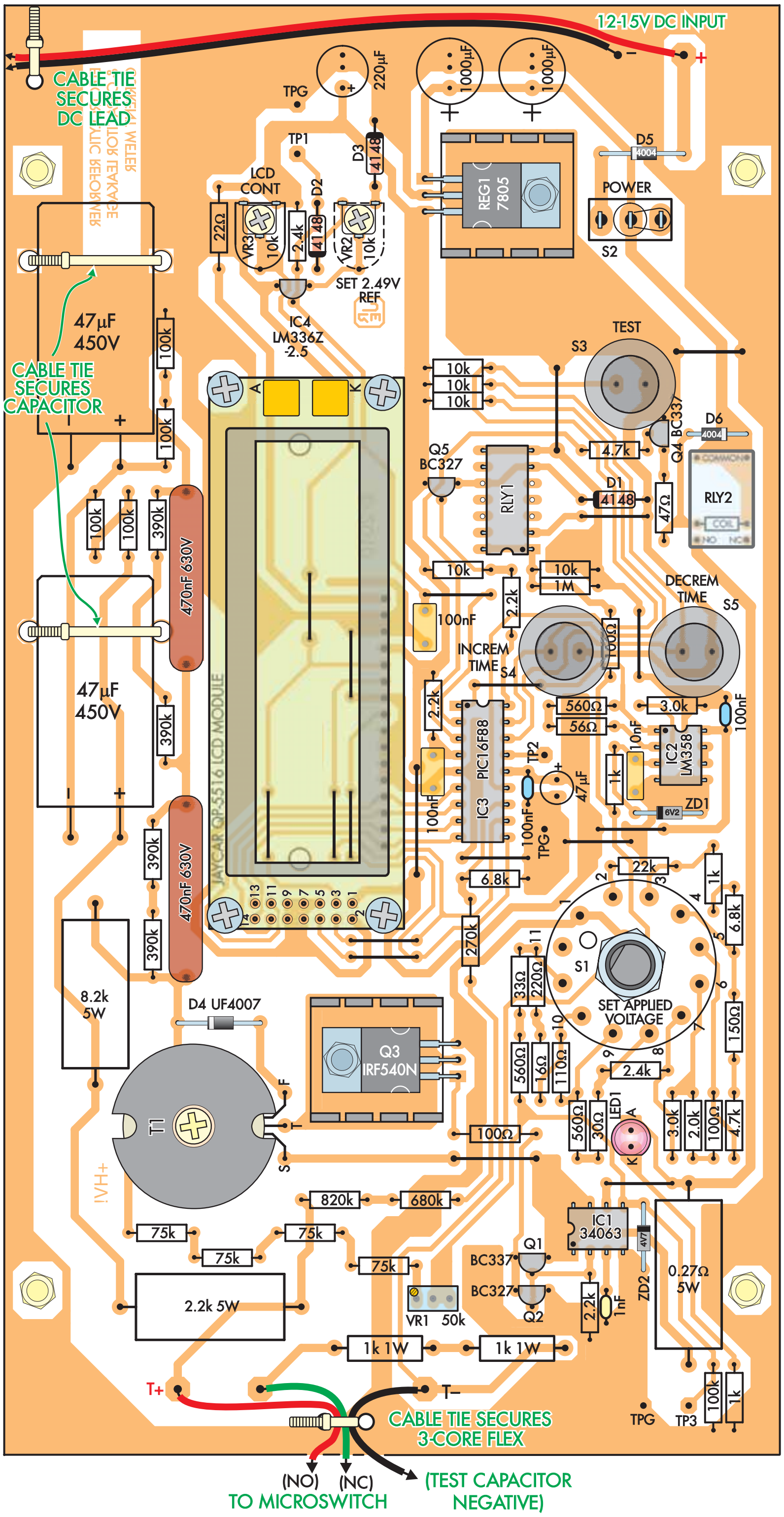


Fig.3: Apart from the 12V plugpack, interlock microswitch and test leads/clips, everything mounts on or is attached to the one large PC board, as shown here. The cable ties reduce the flexing on the soldered joints as the case is opened.

or only one at each end in the case of the Z-7013 module.

In each case, attach the spacers using a 6mm M3 screw passing up through the board from underneath – but in the case of three of the four screws for the QP-5516 module, you'll need to fit an M3 nylon flat washer under each screw head as these screws are unavoidably close to copper tracks under the board.

Next 'plug' a 7×2 length of DIL pin strip into the socket strip you have just fitted to the board for the QP-5516 module, or a 16-way length of SIL pin strip into the socket strip for the Z-7015 module. Make sure the longer ends of the pin strip pins are mating with the socket contacts, 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. Lower it carefully onto the main board so the holes along its left-hand end (QP-5516), or along its lower front edge (Z-7015), mate with the pins of the pin strip, allowing the module to rest on the tops of the 12mm-long nylon spacers.

Then you can fit either one or two more 6mm M3 screws 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.

The final step is to use a fine-tipped soldering iron to carefully solder each of the 14 or 16 pins of the pin strip to the pads on the LCD module, to complete its interconnections.

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

Your PC board assembly should now be just about complete. Before finishing it off (ie, putting it in the case), we will run a few checks on it to make sure everything is OK.

Checkout and setup

NOTE: the following checks MUST be done with selector switch S1 on a LOW voltage setting (say 35V or less). NEVER, never apply power to the unit with S1 on a higher voltage setting without the PC board fitted to the case and the safety interlock in place.

Winding transformer T1

Many constructors are put off projects which involve winding a transformer, but in most cases, it's not too difficult a job and requires just a little care and attention to detail.

In the case of the *Electrolytic Capacitor Reformer and Tester*, step-up autotransformer T1 has only 90 turns of wire in all, with an initial primary winding of 10 turns of 0.8mm diameter enamelled copper wire followed by four 20-turn layers of 0.25mm diameter enamelled copper wire to form the secondary.

And as you can see from the coil assembly diagram (Fig.4, below), all five layers are wound on a small nylon bobbin which fits inside a standard ferrite pot core (bobbins are sold to match the cores).

Coil winding

Here's the procedure: first you wind on the primary using 10 turns of 0.8mm diameter enamelled copper wire, which you'll find will neatly take up the width of the bobbin providing you wind them closely and evenly. Cover this first layer with a 9mm-wide strip of plastic insulating tape or 'gaffer' tape, to hold it down.

Now twist the start of the 0.25mm wire around the 'finish' end of the primary winding and proceed to wind on the first layer of the secondary – winding in the same direction as you wound the primary, of course.

In this case, you should find that 20 turns will neatly take up the width of the bobbin, providing you again wind them closely and evenly.

After winding this first layer of the secondary, cover it with another layer of insulating tape. Then wind on another layer, again of 20 turns and cover it with a layer of insulating tape as before.

Exactly the same procedure is then followed to wind on the third and fourth layers of the secondary.

Each of these extra 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 five 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 primary start and primary finish/secondary start leads) and your wound transformer bobbin should be ready to fit inside the two halves of the ferrite pot core.

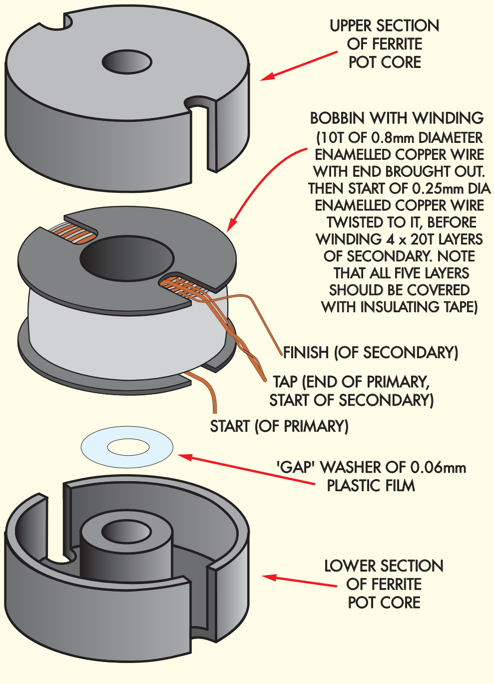


Fig.4. Ferrite pot core assembly

Just before you fit the bobbin inside the bottom half of the pot core, though, 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, 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. Your autotransformer should now be ready for mounting on the PC board.

Mounting on the PCB

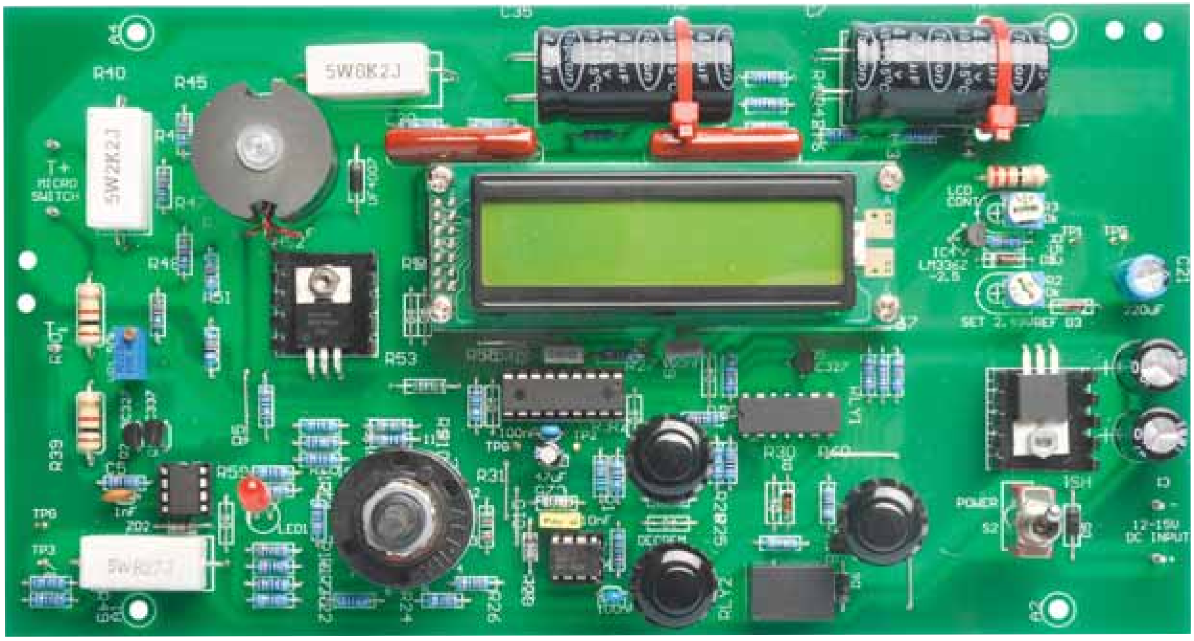
To begin this step, place a nylon flat washer on the 25mm-long M3 nylon screw that will be used to hold it down on the board. Then pass the screw down through the centre hole in the pot core halves, holding them (and the bobbin and gap washer inside) together with your fingers.

Then lower the complete assembly down on the upper left of the board with the 'leads' towards the bottom, 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 top of the PC board.

Once this has been done, all that remains as far as the transformer is concerned is to cut the primary start, 'tap' (primary finish/secondary start) and secondary finish leads to a suitable length, scrape the enamel off their ends so they can be solder '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.



The finished PC board, ready for mounting in the case. While pushbutton switches S3, S4 and S5 are shown in position here for the photograph, they are normally not soldered in until the board is mounted on the front panel – they have to pass through the panel from above and are connected to the PC board via lengths of tinned copper wire.

If you connect the 12V DC plugpack to the mains and then switch on the power using S2, a reassuring glow should appear from the LCD display window – from the LCD module's backlighting. You may also be able to see the meter's initial greeting 'screen'. If not, you'll need to use a small screwdriver to adjust contrast trimpot VR3 until you get a clear and easily visible display. (VR3 is adjusted through the upper small hole just to the right of the LCD window.)

Test voltage

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 also the test time period (using S4 and/or S5), before pressing the Start/Stop Voltage Application button (S3) to begin the test.

Note that if you make no adjustments to the test time period using S4 or S5, the default time period will be 10 seconds.

If you just set the test voltage and press S3 at this stage, without any capacitor connected to the alligator clips (make sure the alligator clips cannot short), LED1 should begin glowing to indicate that the test voltage is being presented to the test terminals, and the LCD display should change to read:

Vtest=ON 0m09s
Cap Lkg= 0.00mA

where the time displayed on the right end of the upper line will be decrementing to show the ON time remaining. Then, when the remaining time falls to zero, you'll hear a soft 'click' and LED1 will go dark to indicate that the test voltage has been removed. At the same time, the top line of the display will change to read:

Vtest=OFF 0m 0s

while the lower line will remain unchanged.

Assuming all has gone well at this point, your unit is probably working correctly. However, if you want to set its calibration to ensure maximum accuracy of the readings, try connecting your DMM between the terminal pins TP1 and TPG (at upper right on the board, accessible via the gap between the board and front panel). You should get a reading close to 2.5V, and assuming this is the case, try adjusting trimpot VR2 with a small screwdriver until you get a reading as close as possible to 2.490V.

Now set your DMM to a range where it can read a voltage of 63V accurately and connect its probes between the meter's test terminals. Then turn S1 to the '63V' position and press S3 to turn on the test voltage source. The DMM reading should quickly rise to read very close to 63.0 volts and if so, there's no need to go further.

If the reading is not within the range of 62.5V to 63.5V, you'll need to bring it inside this range (and ideally to 63.0V) using a small screwdriver or insulated alignment tool passed down through the hole in the front panel midway between the test terminals, to adjust the setting of VR1. Once you set the test voltage on the 63V range in this way, all of the other voltage settings will be correct as well.

Note that if you haven't set the meter's timer to increase the testing time period from its default 10 seconds, the timer will turn off the test voltage after this time. So, if you want to take your time to adjust the voltage to 63V using VR1, you might want to crank up the time period using S4, to keep the test voltage present for as long as you need.

Once the 2.49V reference voltage and the 63V test voltage have been set in this way, your *Electrolytic Capacitor Reformer/Tester* has been set up correctly and will be ready to be fitted into the case.

Preparing the 'case'

As mentioned earlier, the case we have used is a little unusual. It's sold as a 'storage organiser' and is made by Trojan. Ours came from Bunnings Hardware (**www.Bunnings.co.au**), and is listed as the Trojan TJW0510 38cm type. You could try checking out your local B&Q or Wickes for something similar – it must be plastic/nylon though. It has a transparent hinged lid and in the 'body' it has three rows of fixed dividers plus quite a number of movable dividers which fit into slots moulded into the fixed dividers.

First determine where your PC board will lie inside the case. Use an enlarged photocopy of the front panel (see Fig.7) or a same-size copy of the PC board layout and use it on the outside of the case as a template for drilling.

The left-to-right position is fairly unimportant (just make sure you leave enough room for the leakage current guide if you use the PC board layout diagram). However, you need to make sure that the PC board lies exactly in the space between the vertical dividers so that when the lid is closed, it fits!

There are four holes to be drilled to mount the PC board and nine for controls/indicators. You don't need to cut a slot for the LCD readout because the lid is transparent enough to read through it. (Yeah, we know, our photos show a cutout – we did that before we realised it was transparent enough, D'oh!) You will, however, need a cutout in the front panel label.

We modified the case to accommodate the PC board by removing a 30mm deep by 215mm long section from one of the fixed dividers, then cut notches along the moulded slots about 10mm wide and about 25mm down from the top. The photo of our modified case gives a better idea.

The PC board sits down in the removed divider section and along the slot notches each side. 25mm threaded standoffs then mount the PC board to the underside of the lid, on to which we had previously glued the front panel and drilled the required holes.

You'll also need to mount the microswitch so that it is actuated when the lid is closed. The microswitch has two mounting holes through the body which make this fairly simple. It doesn't have to be horizontal when mounted, in fact a little bit of an angle makes the action on the actuator arm more certain.

Holes also need to be drilled through the divider walls to allow the HV wires (from PC board to microswitch/negative capacitor terminal) to pass through, along with the wires from the plugpack to the PC board.

Power supply

While we have built the prototype with a switch-mode 12V, 2A plugpack, that's not the only option. The supply can be virtually any 12V to 15V DC type with a minimum of about 1.5A output – just so long as it fits inside the case.

If you use a plugpack, it obviously needs to be outside the unit when in operation. Therefore, a small slot can be cut in the outside vertical wall of the case, just deep enough to allow the figure-8 cable to pass through when the lid is closed and locked.

An alternative is to use a switch-mode adaptor supply – one we had on hand was a 12V, 4A type. At 60mm wide, this particular supply fits nicely into the case, as our photo shows.

Yet another, often much cheaper alternative, is to use what is commonly sold as a 'hard disk drive' supply – they're usually about the same size as the above model (or a little less), and have a 12V, 2A DC ouput (along with a 5V 2A ouput which can be ignored).

The latter supply is often sold with, or is available for, external hard disk drives and we've seen them advertised for less than £5 each.

Both of these supplies generally have an IEC socket, so a standard IEC power cable can be used. To do this, a 30mm hole could be cut in the case side to allow the supply's IEC plug to fit through, which would then allow the supply to remain inside the case when in use.

There's even room to store an IEC cable inside the case in the area you would normally connect the capacitor under test/reforming.

We used the front third of the case for the capacitor under re-forming or test, and storage for the supply. One of the supplied orange dividers makes neat separate compartments for both the capacitor and the supply.

Fitting the front panel

Before proceeding to final assembly, tinned copper extension wires need to be soldered to the three pushbutton switches (S3 to S5) which will go through the front panel from above and soldered to the underside of the PC board when it is in position.

A tip here is to make all of the S3 to S5 extension wires slightly different lengths and longer than you'd think necessary (say from 30mm to 50mm) so that when one goes in, it doesn't pop out doing the next one.

Unfortunately, the front panel is longer than a page, so we haven't been able to provide a same-size artwork as normal. You will need access to an enlarging colour photocopier, and you will need to be able to print A3 paper.

To provide a little more protection and rigidity, we laminated ours (again, an A3 laminator is required), cut out all the holes (including the LCD hole) then glue it, face-side up, inside the lid of the case using spray adhesive.

Hopefully, all the holes you previously drilled in the panel will line up with those you drilled earlier.

Allow the glue to dry and 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 to S5 with their matching holes in the PC board, while you bring the lid and board together and at the same time line up the body of LED1 along with switches S1 and S2 with their matching holes in the front panel.

Just take your time and the lid will soon be resting on the tops of the board mounting spacers. Make sure LED1 is poking through its hole, then you can secure the two together using the four remaining 6mm-long M3 machine screws, with washers underneath the heads to protect the relatively soft plastic of the case lid.

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

Place the power switch washer and nut on the thread and tighten (adjust the underside nut up or down as necessary so you don't bow the plastic) and finally make sure the LED is poking through its front panel hole (Fig.5).

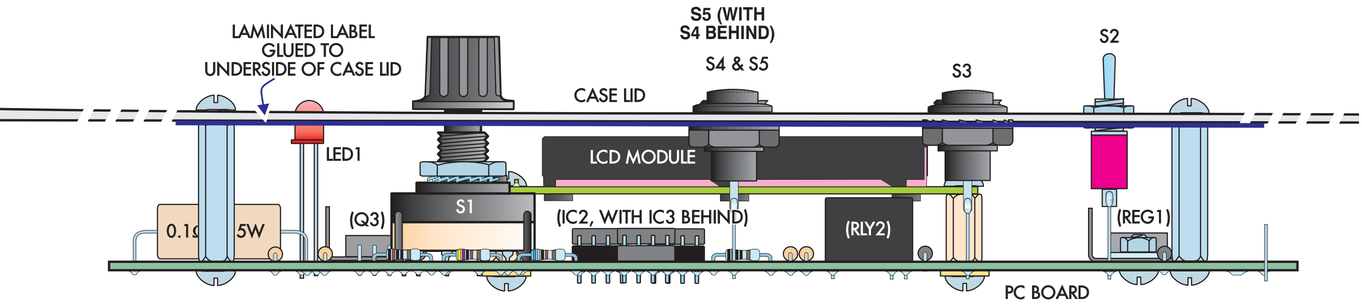


Fig.5: the PC board 'hangs' from the case lid, which becomes the front panel. The label is on the inside of the lid.

Final wiring

Power wiring (from the 12V power supply/plugpack) and high voltage wiring (to the microswitch and capacitor negative) can be attached to the PC stakes, even with the board in position. It's a bit fiddly and you have to be careful not to damage the plastic lid, but the stakes are close enough to the outer edges of the PC board to make this possible.

To protect the soldered joints, as much as possible, as the lid is opened and closed, we secured both the power supply and output cables to the PC board using small cable ties (Fig.3).

Remember to run the various wires through the holes you have drilled in the divider walls before soldering to the PC board. The power supply connections are straightforward (remember their polarity), but the high voltage wiring is just a bit more difficult. Note our comments earlier about the type of cable used for the high voltage cable: it must be rated at 250V or higher.

- *The wire from the HV+ terminal goes to the microswitch 'NO' terminal.*
- *The wire which connects to the 2 × 1kΩ 1W bleed resistors on the PC board goes to the microswitch 'NC' terminal.*
- *The wire from the microswitch 'COM' terminal goes direct to the capacitor positive (red) alligator clip.*
- *The wire from the T- terminal goes direct to the capacitor negative (black) alligator clip.*

By the way, if you find this description a bit confusing, refer to the diagrams of Fig.3 and Fig.5, and also the inside photos shown last month. These will hopefully make everything clear.

Using it

The new *Electrolytic Capacitor Reformer* is very easy to use, because all that you have to do is connect the capacitor you want to test between the alligator clips (with the correct polarity in the case of solid tantalums and electrolytics), *close* the lid, set selector switch S1 for the correct test voltage and then turn on the power using S2 (assuming you have already plugged in your plugpack supply).

When the initial greeting message on the LCD changes into the 'Set Volts and Test Time, Press Strt' message, press S4 and/or S5 to set the time period to whatever you need. Then it's simply a matter of pressing the Start/Stop Voltage Application button (S3) to start the test.

What you'll see first off may be a reading of the capacitor's charging current, which can be almost 20mA at first (with high value caps), but should 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 you see may 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 right down 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 the test proceeds.

In fact, it may 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 a 'good' aluminium electrolytic. (That's because these capacitors generally take a few minutes to 'reform'.)

As you can see from the guide table attached to the front panel, the leakage currents for tantalum and aluminium electrolytics also never drop down to zero, but instead fall to a level of somewhere between about 1µA and 9200µA (ie, 9.2mA), depending on both their capacitance value and their rated working voltage.

So, with these capacitors, you will need to set the meter's testing time period to at least three minutes to see if the leakage current reading drops down to the 'acceptable' level (as shown in the front panel 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, then this indicates that it is in need of either reforming or replacement.

Low leakage (LL) electrolytics

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 no more than about 25% of these current values.

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

That's because 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 only show up in one of the two tests.

Reforming old electros

While reading the preceding paragraphs about testing capacitors, you've perhaps

All you need to know about... electrolytics!

Most readers will be aware that all capacitors consist of two electrodes separated by an insulating dielectric.

It's the dielectric which allows the capacitor to store energy (ie, a 'charge') in an electric field between the two electrodes. The capacitance is directly proportional to the surface area of the electrodes on either side of the dielectric, and inversely proportional to the thickness of the dielectric itself. To achieve a high capacitance, the electrode area must be as large as possible, while the dielectric must be as thin as possible.

There's also another factor which determines the capacitance: the dielectric constant 'k' of the dielectric material. The capacitance is again directly proportional to this property, so to achieve a high capacitance you need to use a dielectric material with as high a k value as possible. Examples are polyester/Mylar with a k of 3.0 and mica with a k value of 6.0.

Electrolytic capacitors were developed about 90 years ago in an effort to produce high value capacitors which were at the same time much more compact than other types. Over the years they have been greatly improved, but they are still not quite as reliable and they don't have the very low leakage of other capacitors such as mica, ceramic or polyester.

As you can see from the diagram of Fig.6 (above), both electrodes in an electrolytic capacitor are made from thin aluminium foil and between them is sandwiched a sheet of paper soaked in a conducting liquid or 'electrolyte' (often sodium borate in aqueous solution, with additives to retard evaporation).

So, superficially, it would seem that we have a pair of conducting electrodes separated not by an insulating dielectric but by a sheet of paper soaked in conductive electrolyte.

But before the capacitor is assembled, the aluminium foil, which is to become the anode (positive electrode), has its surface etched in a caustic soda solution to greatly increase its surface area. This process covers the surface with an array of microscopic pits, which can have a total effective surface area of up to 60 times greater than the original unetched area for high voltage electrolytics and even higher for low voltage electros.

The etched aluminium foil is then subjected to an anodising process, whereby a very thin aluminium oxide layer covers the surfaces of all of the microscopic pits. This aluminium oxide is not only an insulating dielectric, but it also has a relatively high k value of 8.5. So electrolytics have large capacitance because of these three factors, the very high surface area of the anode, the very thin aluminium oxide dielectric and the relatively high dielectric constant of around 8.5.

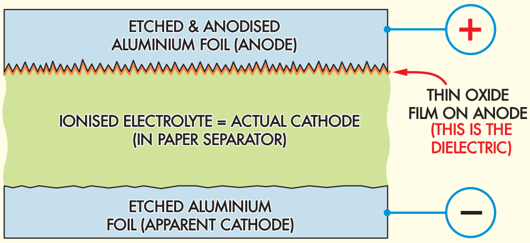


Fig.6. Typical electrolytic capacitor 'sandwich'

The anodising process was originally referred to as 'forming', as in forming the oxide layer.

The capacitor is wound with the etched/anodised foil, a paper separator and the non-anodised aluminium foil, which becomes the negative electrode. The capacitor windings are usually then immersed in a bath of electrolyte and connected to a power supply to 're-form' the anodised layer on the positive foil, which is inevitably damaged during the winding process.

After that, the windings have their terminations connected to an aluminium can in the case of the negative electrode and to the positive terminal for the anode. The can is sealed with a rubber bung, and then it is reconnected to a power supply for a final re-form and leakage current test.

It should be noted that the electrolyte layer is critical to the performance of the capacitor. Because it is a liquid, it can fill the etched pits in the oxide layer. This means that the actual cathode is in intimate contact with the dielectric layer, minimising dielectric thickness and therefore maximising capacitance.

New electrolytic capacitors typically have a shelf life of many years, but the older they get, the higher their leakage current becomes as the oxide layer on the aluminium anode gradually deteriorates, due to the lack of a polarising DC voltage. In most cases, though, such capacitors can be rejuvenated by a re-forming process, whereby they are connected to a DC supply via a suitable current-limiting resistor.

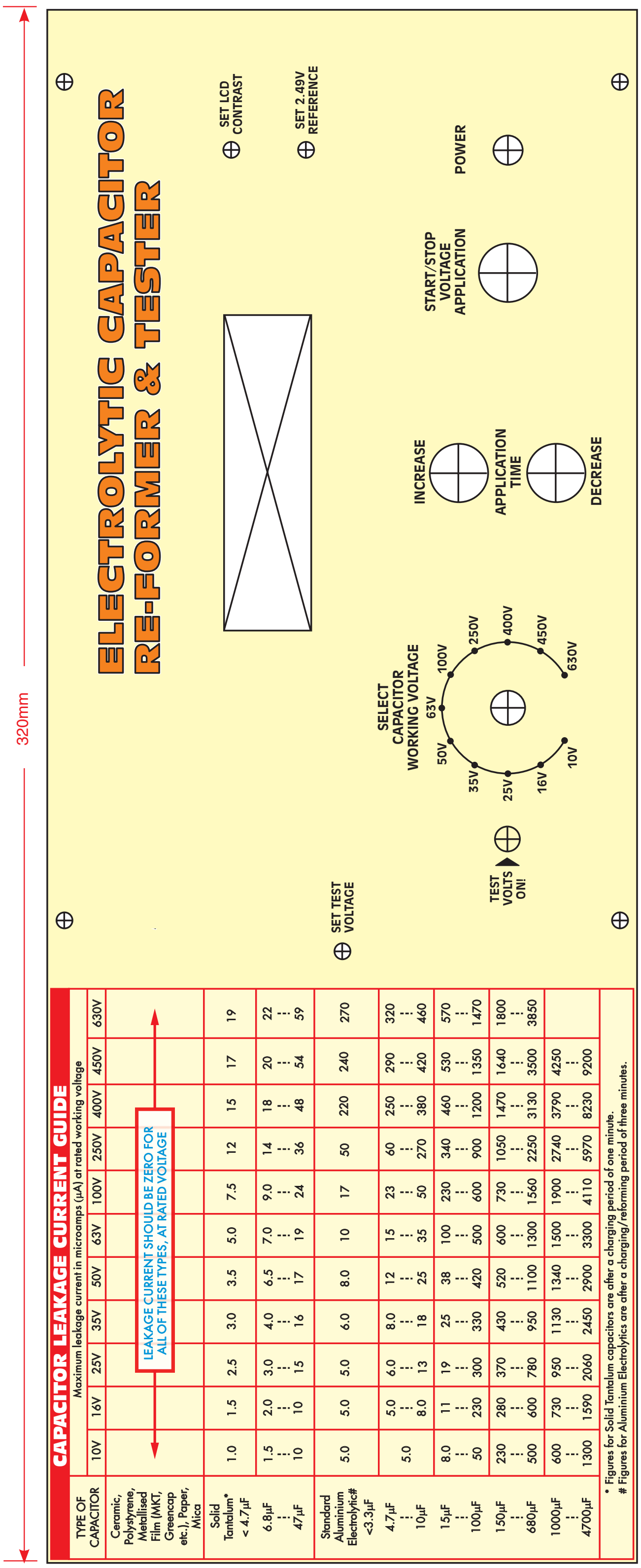
Initially, when the DC voltage is applied, the leakage current will be quite high, but it should come down within a minute or so to a value which is less than the capacitor's specified leakage current at the rated voltage. This project makes that process easy and safe for electrolytic capacitors with a wide range of voltage ratings, in addition to measuring the capacitor's leakage current.

So that's what is inside an electrolytic capacitor and that is why it is able to provide a very high capacitance in a surprisingly small package. The main drawback of electrolytics is that they always exhibit at least a small leakage current – as shown in the front panel table. So they are really only suitable for use in circuits where this small leakage current does not upset circuit operation. Luckily, this still gives them a great many applications.

been wondering about the *Reformer's* main function: reforming electrolytics that may have high leakage currents due to a long period of inactivity.

How do you use it for this function? In exactly the same way as you use it for testing capacitors, except that for reforming you set the timer for a much longer testing time period.

The idea here is that you still set S1 for the capacitor's rated voltage, but simply crank up the testing time period using S4 until it's set for either 30 or 60 minutes. Then connect the capacitor to the alligator clips (making sure of the polarity), and finally press the Start/Stop Voltage Application button (S3) to start the test/reforming operation.



CAPACITOR LEAKAGE CURRENT GUIDE

Maximum leakage current in microamps (µA) at rated working voltage

TYPE OF CAPACITOR	10V	16V	25V	35V	50V	63V	100V	250V	400V	450V	630V
Ceramic, Polystyrene, Metallised Film (MKT, Greencap etc.), Paper, Mica	LEAKAGE CURRENT SHOULD BE ZERO FOR ALL OF THESE TYPES, AT RATED VOLTAGE										
Solid Tantalum* < 4.7µF	1.0	1.5	2.5	3.0	3.5	5.0	7.5	12	15	17	19
6.8µF ... 47µF	1.5 ... 10	2.0 ... 10	3.0 ... 15	4.0 ... 16	6.5 ... 17	7.0 ... 19	9.0 ... 24	14 ... 36	18 ... 48	20 ... 54	22 ... 59
Standard Aluminium Electrolytic# <3.3µF	5.0	5.0	5.0	6.0	8.0	10	17	50	220	240	270
4.7µF ... 10µF	5.0	5.0 ... 8.0	6.0 ... 13	8.0 ... 18	12 ... 25	15 ... 35	23 ... 50	60 ... 270	250 ... 380	290 ... 420	320 ... 460
15µF ... 100µF	8.0 ... 50	11 ... 230	19 ... 300	25 ... 330	38 ... 420	100 ... 500	230 ... 600	340 ... 900	460 ... 1200	530 ... 1350	570 ... 1470
150µF ... 680µF	230 ... 500	280 ... 600	370 ... 780	430 ... 950	520 ... 1100	600 ... 1300	730 ... 1560	1050 ... 2250	1470 ... 3130	1640 ... 3500	1800 ... 3850
1000µF ... 4700µF	600 ... 1300	730 ... 1590	950 ... 2060	1130 ... 2450	1340 ... 2900	1500 ... 3300	1900 ... 4110	2740 ... 5970	3790 ... 8230	4250 ... 9200	

* 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.7: the front panel, which incorporates the leakage table, is too big to fit on the page, so is reproduced at exactly 75%. If you photocopy this at 133% (which in this case you can do without infringing copyright) it will come out right size. Obviously, you'll need a copier that can handle A3 paper.

Because the metering part of the instrument will continue to make measurements during the reforming period, this allows you to keep track of the leakage current as it slowly falls from its initial high figure (which may well be up in the region of 20mA). This is due to the oxide dielectric inside the electro slowly regrowing (reforming) as a result of the current passing through it.

Needless to say, if the current readings don't fall, even slowly, the electro concerned is beyond being reformed and should be scrapped.

On the other hand, if the current readings do fall significantly, but still don't come down to an acceptable level, this indicates that the electro will probably benefit from another reforming operation.

There's no problem about giving a capacitor repeated reforming operations, provided that it doesn't get overheated. In fact, significant heating is really a sign that the electro is beyond reforming and is not worth any further rescue efforts.

So this is the basic procedure, when dealing with electrolytics:

1 First give it a standard three-minute test run at rated voltage and see if the leakage current tapers down to an acceptable level during this time. If it does, the capacitor is OK.

2 If the current doesn't taper down significantly and/or the capacitor becomes overheated, it is beyond help and should be discarded.

3 If the current does taper down significantly but doesn't reach an acceptably low level, it can be regarded as a candidate for reforming. Give it a test/reforming run of 30 or 60 minutes.

4 At the end of the reforming run, test it again with a standard three-minute test period. If the leakage current is now in the acceptable range (according to the guide on the front panel), the capacitor has successfully reformed and is now OK. But if it hasn't quite finished reforming, it would be worth giving it another 30 or 60-minute session to see if this will 'do the trick'. *EPE*

Reproduced by arrangement
with SILICON CHIP
magazine 2012.
www.siliconchip.com.au

Note: power supply and case

In the parts list published last month, no mention was made of the mains power adaptor. As discussed in this month's text, you'll need a 12V to 15V DC supply at a minimum of about 1.5A. A more robust supply (ie, higher current output) won't hurt, but it does need to be able to fit into the case!

Also, six (not two) small cable ties are needed, the extras to secure the cables from the PC board to the microswitch/test leads and 11, not 10 PC pins are required.

We rather like the case chosen for this project, but you could choose an alternative – the main point is that it should be plastic/nylon and you ***must*** still include the microswitch interlock safety aspect of the design.