Build this Leakage Checker for capacitors

Although leaky capacitors are often responsible for many of the fault symptoms which appear in aging electronic equipment, testing capacitors quickly is not easy. This simple transistorised unit performs a full 500V leakage test, yet is small enough to slip into a serviceman's tool-bag.

by PHILIP PIK

Leaving aside the more sophisticated laboratory measurement techniques, detection of the leakage current of a capacitor with the full rated working voltage applied is probably the simplest means of indicating its general condition. At least it tells the serviceman if there is a troublesome leakage or if he has a potentially faulty capacitor in hand — this last point being of particular importance to him.

One could add, of course, that it is helpful to know the exact capacitance as well, but equipment which applies a simultaneous leakage and capacitance test is necessarily more elaborate than we have in mind at the moment.

One testing method involves, for example, charging the capacitor to a specified voltage and measuring its charge current after a prescribed time. A good scheme no doubt, if plenty of time and patience are on hand. Another idea is to measure voltage or current in the capacitor under test with an AC signal source. Once again this brings problems, not the least of which is the need to distinguish betweer leakage and reactance.

The method of measurement we have used in our instrument consists essentially of connecting it to a DC voltage source, in series with the input of a sensitive DC amplifier. The function of the amplifier is to amplify the (often) very small leakage current of the capacitor so that a suitable indicating device can be used to show if the leakage resistance is below a critical value.

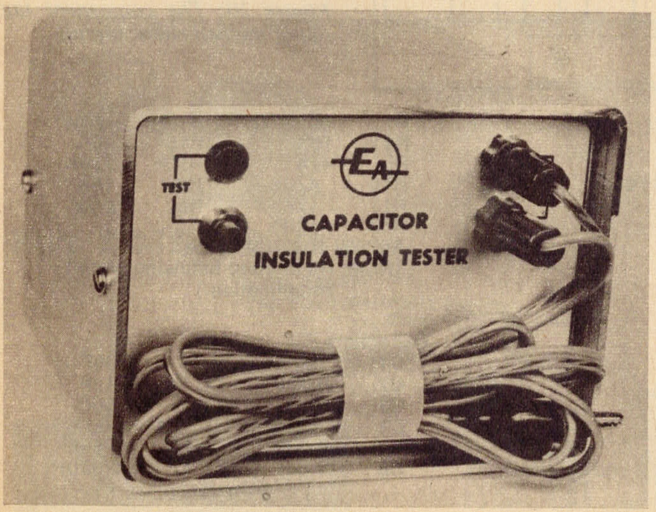
Leakage or insulation resistance is the actual DC resistance between the two "plates" of a capacitor, and is therefore a function of the insulating properties of the dielectric material used. A perfect capacitor would be one having no leakage at all, and whilst perfection in such matters is never attained, the leakage resistance of a good capacitor is very high indeed.

To quote some examples, the insulation resistance of most paper dielectric capacitors is in the range of 2000 to 5000 megohms per microfarad. This means that an 0.1uF capacitor in good condition should have an insulation resistance in the range of 20,000M to 50,000M, whilst a 2uF capacitor should lie in the range of 1000M to 2500M.

Temperature generally effects the insulation properties of paper capacitors rather adversely. In contrast with these are polyester-dielectric type capacitors, which hardly suffer at all in this regard. Their insulation resistance is generally also much higher than their paper equivalents, 50,000M or greater being quite common values. Polystyrene dielectric types rate even higher, with figures typically around the 1,000,000M mark.

Polypropylene-dielectric capacitors come next in line with 250,000M, followed by ceramic capacitors (excluding the low voltage types) at about 100,000M. Metallised polyester types are generally lowest on the list of the synthetic dielectric range, with a figure of 10,000M/uF.

These figures lead us to the conclusion that, ideally perhaps, we should be capable of measuring insulation resistance over the range of about one thousand to one million megohms.



The completed leakage checker, a little smaller than half actual size. It is fully self contained, with an internal battery supply.

However, practical limitations place a limit on the upper range that can easily and economically be achieved. Another point to consider is that whilst it may sound ideal to test every type of capacitor to its limit, in many of their applications insulation properties anywhere near their upper limits are not required. Take as an extreme example the case of a polystyrene capacitor bypassing a 1K emitter resistor. Quite clearly, an insulation resistance of only a few megohms would be more than adequate in this case.

At the other end of the scale is the case where a capacitor is used in timing circuits with long periods. Here insulation properties are of extreme importance as they directly effect the upper limit of the performance of the circuit.

With these two extreme conditions in mind, in developing the tester shown we settled for an "in between" value of 1000 megohms, this order of resistance being what we believe is a reasonable compromise between the demands of most circuits encountered in the domestic entertainment field and that which can be practically achieved in a measuring instrument without undue complexity and cost.

Admittedly, most bypass applications do not require capacitors with this order of insulation resistance, but it must be remembered that once a capacitor shows a leakage resistance below about 1000M it must be suspect. This applies particularly to paper capacitors which have a habit of deteriorating very rapidly with elevated temperatures once they exhibit some leakage.

Lastly, whilst on the subject of capacitors, mention should be made of test voltages. Although it may seem at first that capacitors with different voltage ratings would require different test voltages, this is not necessarily the case. Virtually any capacitor with a working voltage rating of 100 volts or more may be tested at the "Standard" 500 volts common to nearly all "meggers", for short periods of time. Testing capacitors at many times their rated voltage is in fact a standard procedure adopted by manufacturers. Hence, in view of this and the fact that 500 volts is the generally recognised "standard" test voltage, as mentioned before, we have provided our instrument with a single 500V test voltage facility.

Having dealt with the various basics on capacitors and the test instrument, let us now turn to the main circuit details.

From the circuit diagram it may be seen that the necessary high voltage is generated by a DC to DC converter, comprising Tr1, Tr2, and T1, the inverter transformer. Some readers may already have recognised this transformer to be the same as that used in the High Efficiency

Flasher published in the August 1971 issue. But more on this when we give the transformer details later.

Operation of the converter is conventional and will not be dealt with here. Note, however, the addition of a 0.001uF capacitor across the common lower base bias resistor (the 68 ohm resistor) to prevent high frequency crosscoupling between the two transistors. Without this capacitor self-starting of the converter can prove unreliable.

The output of the inverter transformer is fed into a ladder multiplier rectifier network which boosts the voltage to the required 500 volts DC. Filtering of the output voltage is achieved by the 0.047uF filter capacitor. The 3.9M resistor in parallel with this capacitor discharges the stored energy once the converter is switched off.

The capacitor under test is connected across terminals A and B, ie, between the 500V source and the input circuitry of the high gain DC amplifier formed by Tr3, Tr4 and Tr5.

PARTS LIST

1 Case measuring 4in x 3in x 4in (WxHxD). See text for details.
1 Front label.
1 Miniature lamp bezel 14V Red, low consumption type. Plessey type BFB or similar.
1 Miniature DPDT pushbutton switch. C&K type P8221 or similar.
2 Banana jacks (sockets), red.
2 Banana plugs, red.
4 ft miniature figure 8 flex.
2 Crocodile clips, red.
1 276P Eveready battery or equivalent.
1 Plug to suit above battery,
2 FX2240 ferrite half-cups.
1 DT2179 bobbin to suit above cups, or converter transformer (RCS part no 130).

SEMICONDUCTORS
2 TT801 or AY8139 transistors, or similar.
2 TT108 or BC108 transistors.
1 BC179 transistor
3 EM404 silicon diodes, or similar

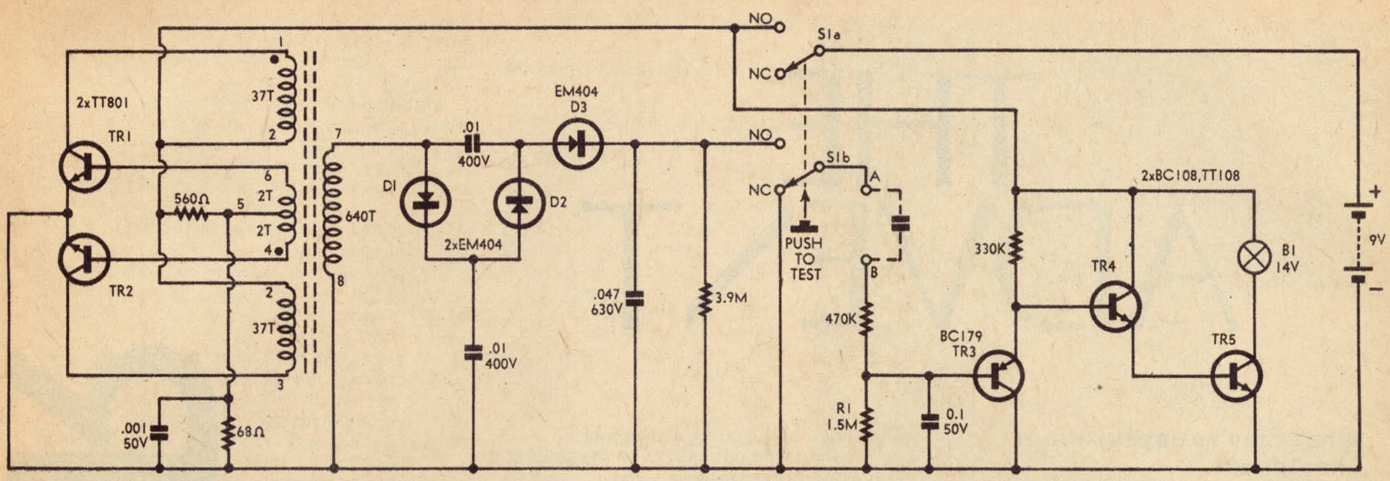
RESISTORS (½ watt)
1 3.9 meg.
1 1.5 meg.
1 470K
1 330K.
1 560 ohm.
1 68 ohm.

CAPACITORS
1 0.1uF/50VW polyester.
1 0.047uF/630VW polyester.
2 0.01uF/400VW polyester.
1 0.001uF/50VW polyester.

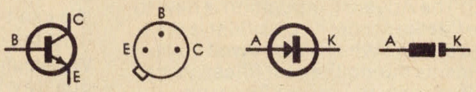
The operation of this part of the circuit is as follows. If a capacitor is connected across the terminals A and B and the TEST button pressed, the output voltage will be applied across the capacitor under test. The initial charging current will flow through the 470K current limit resistor and R1, the 1.5M bias resistor for Tr3. This transistor is connected in the "upside down" emitter-follower configuration, and is normally conducting heavily.

The initial voltage developed across R1 by the charging current turns Tr3 off. This in turn causes Tr4 and Tr5 to turn on, lighting the indicator lamp. If the capacitor under test is a good one, the charging current will steadily decrease to zero (for large capacitors this may take several seconds) finally allowing Tr3 to become forward biased once more and hence go back into conduction. Tr4 and Tr5 will then be turned off, also turning off the indicator lamp. But if the capacitor is faulty, ie, has an insulation resistance less than 1000M, Tr3 will remain off, causing the indicator to remain on.

Should the terminals A and B become



CAPACITOR INSULATION TESTER



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The circuit of the leakage checker. It uses a simple DC-DC converter to produce 500VDC, and a three-transistor lamp driver circuit to detect any leakage current drawn by a capacitor with this voltage applied.

shortcircuited either through a faulty capacitor or by accidentally short-circuiting the terminals, no harm is done as transistor Tr3 is protected by the 470K series resistor. This resistor, in conjunction with R1, also serves to discharge the capacitor at the end of the test. From the circuit it can be seen that with the TEST button in its rest position, terminal A is connected to ground. Hence, the capacitor is discharged via the 470K resistor and the base-collector junction of Tr3.

To prevent Tr3 from being unduly sensitive to hum voltage picked up externally (via the connecting leads), and also to prevent it responding to internally generated voltage spikes from the inverter, an 0.1uF capacitor has been connected across R1, effectively bypassing these unwanted voltages.

As the circuit diagram indicates, the operating voltage for the entire instrument is 9 volts. Current drain of the inverter stage is 60mA. The indicator circuitry draws an additional 20mA when the pilot light is operating, but negligible current when the light is off. To achieve this low current drain a low consumption 14V indicator lamp is used.

To adequately supply the current drain of the tester on an intermittent basis, we have selected the Eveready 276P battery. This battery presents a good compromise between physical size, power output and life expectancy. It is difficult to predict the service life that can be expected, as current is required only on an intermittent basis, but as a guide Eveready predict an expected life of some 50 hours under **continuous** operating conditions. Under intermittent operating conditions a much longer service life may be expected. These figures relate to a terminal voltage of 1 volt per cell, or 6 volts for the complete battery.

Operation of the instrument at this voltage is quite satisfactory and not effected by the rise in the battery's internal impedance. Naturally, the full 500V will not be available, but the circuit's response to leakage resistance will be much the same in spite of low operating voltages because the sensing or indicator circuitry is to a large extent self-compensating. Likely variations to be encountered are only in the order of ±10% for supply voltages between 6 and 9 volts.

The sensing circuitry is also self-compensating to a moderate degree against temperature variations. Typically, the worst likely deviation to be encountered in sensitivity to leakage resistance is about ±20% over a temperature range of 10 to 50 degrees C.

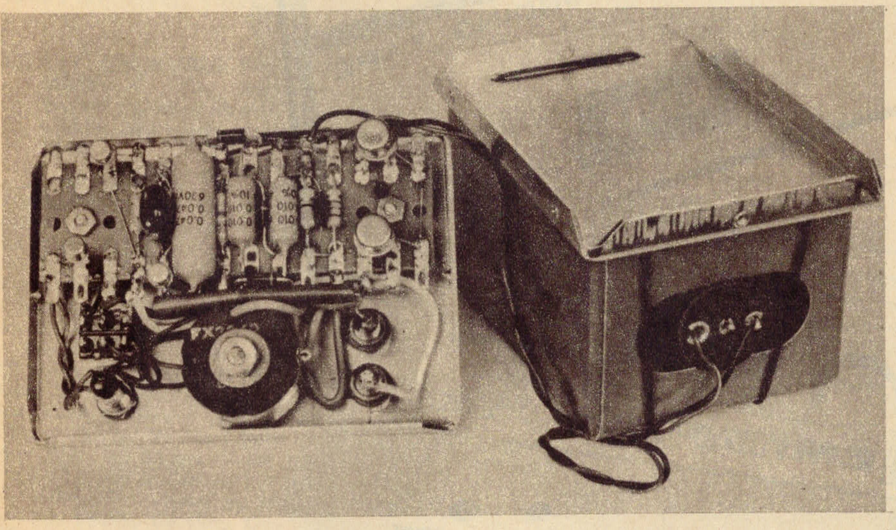
Some constructors may wish to check the

calibration of their instrument. To do this accurately a 1000M resistor is required. Resistors of this magnitude are generally not easy to come by, but if an EHT probe is on hand it can be pressed into service as these more often than not have a built-in resistor of 990M—a figure quite close enough for our purpose.

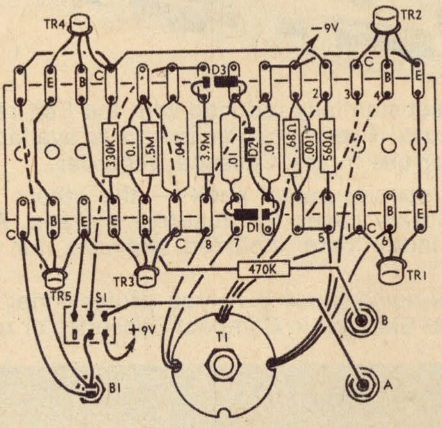
To adjust the sensitivity of the sensing circuit, connect the probe between terminals A and B and trim R1 such that the indicator light just comes on. Lowering its value results in decreased sensitivity, ie, an insulation resistance less than 1000M will be required to turn the indicator on. Conversely, increasing the value of R1 will result in an increase in sensitivity.

especially if one of the ready made transformers is employed. The complete unit is housed in a case measuring only 4in wide by 3in high by 4in deep. It consists essentially of a 4in length of 4in by 3in rectangular section extruded aluminium, available from most of the larger hardware stores. The ends consist of two pieces of 18SWG aluminium with ⅛in flanges turned over at right angles around the edges. Ready-made units of this type are available from at least one supplier in Sydney.

All components are mounted on one of the end panels, as the illustrations show. The same end panel also serves as the front panel. The transformer mounting bolt and tagboard

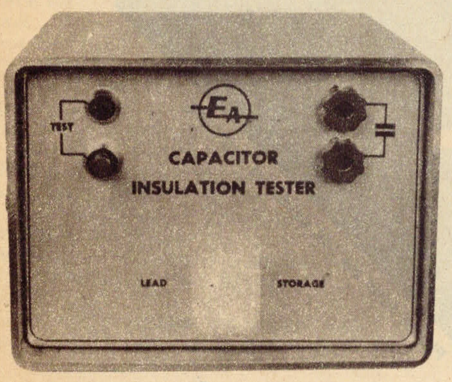


Above is a view of the interior of the checker, showing the wiring and the battery. At right is a wiring diagram to help the reader in locating the parts.



As mentioned earlier, this instrument uses the same inverter transformer as used in our High Efficiency Flasher published in the August issue last. These transformers are now available ready-made from at least one supplier, RCS Radio Pty Ltd of 651 Forest Road, Bexley, NSW. A sample was submitted by this firm and was in fact used in this project. Although identical in construction to our prototype in the August issue, the lead coding differed. We have therefore included connection details for this particular transformer in the Transformer Information panel.

Construction of the tester is straightforward.



A view of the front of the checker, showing the lead storage loop.

securing screws pass through the panel, and in view of this it is suggested that countersunk-head screws be used to give a flush surface over which the front label can be fitted.

Once the front label is in position, the banana sockets, indicator lamp and pushbutton switch may be mounted. Be sure to correctly orientate the pushbutton; the "common" lugs should face the transformer. Finally, in the way of front panel details, secure a short length of ⅛in flexible tubing, or a short length of plastic sleeving formed into a loop, to the panel in between the words "Lead Storage." This little aid will be found extremely handy to store the clip leads whilst they are not in use.

Nearly all circuit components are mounted on a short length of miniature tagboard, 14 lugs long. Wiring the board should present few problems provided the wiring diagram is followed carefully. Note the 470K resistor which runs from the lower of the two banana jacks to the base of Tr3. For safety reasons this

TRANSFORMER WINDING DETAILS

Order of windings: Secondary, Primary, Feedback.
Secondary: 640 turns, 38B&S DTE. Code start with knot.
Interleave: One wrap of electrical tape or polythene film between secondary and primary.
Primary: 37 turns, 37 turns, bifilar (two in hand). 26B&S DTE. Place two knots in one start.
Feedback: 2 turns, 2 turns, bifilar (two in hand). 26B&S DTE. Place three knots in one start.
Outer wrap: One wrap of electrical tape.

Transformers of this kind are quite simple devices to construct, partly because the number of turns is relatively small, but mainly because they are designed to use a ready-made bobbin and core.

When winding coils of this type, counting and handling can be made easier by clamping the bobbin between two large washers, using a long bolt, and rotating this assembly in the chuck of a small hand drill held in a bench vyce. This leaves one hand free to guide the wire, so that an even winding results.

Count the number of times the drill chuck rotates with one turn of the handle. Divide the number of secondary turns by this number. If your drill ratio is, say, 5:1, it will require 128 turns of the handle to place the required 640 turns on the bobbin.

Commence construction of your transformer by clamping the Delrin bobbin between two large washers as mentioned earlier. The washers prevent collapse of the side cheeks of the bobbin as the winding proceeds.

Take the 38B&S DTE (Double Tough Enamel) wire, tie a knot in it about two inches from the end, and lay the wire in the bobbin so that the end passes through a deep cheek notch for about three inches. Anchor the start with a small piece of electrical tape. Secure the free end of the wire on the drill chuck with ordinary cellulose tape or a rubber band.

Make sure that the wire passes through a deep cheek notch and not a half deep one, as the build-up of wire against this lead for about half the winding will place too high a voltage stress on the wire insulation when the converter is operated.

Proceed to wind the secondary, guiding the wire carefully to keep an even build-up. Finish off the winding with a small piece of tape so that the last turn will come out on the same side as the start. Place one wrap of polythene film or electrical tape over the completed winding.

The primary winding is of thicker gauge wire, and cannot be conveniently wound with the hand drill. A tighter, more even winding will be achieved by hand winding.

Take two 5ft lengths of 26B&S DTE wire and lay them side by side. Tie two knots in the start end of one and twist lightly with the other for about two inches. With the bobbin assembly still mounted on the bolt, but placed in the vyce instead of the drill chuck, wind on the required number of turns in the same direction as the secondary winding. Anchor the start in the same way. Avoid crossing the two wires and keep each turn as close to the previous turn as possible. Count off the winding as though the two wires were one wire. Anchor the finish with electrical tape.

The feedback winding consists of two turns, bifilar wound in the same way as the primary, using 26B&S DTE wire. One start should be designated with three knots.

Place a final wrap of electrical tape over the outside of the completed winding.

Before assembling the transformer, the following points should be observed: (1) that there are no traces of foreign matter on either of the two core faces, as the cores can be cracked on tightening if such material exists; and (2) that the secondary lead-out wires are laid in the notches provided inside the cores. Inspection of the inside of each core will reveal these lead-out notches.

Before finally placing the core halves together, place two pieces of coloured PVC sleeving on each lead of the secondary winding as close as possible to the bobbin. Use different colours for the start and finish. Suitable small diameter sleeving can be stripped from scrap pieces of thin hookup wire.

When the leads have been led out in their correct positions, press the cup-core halves together with the fingers and anchor the halves with electrical tape around the outside, or alternatively, provide a temporary clamp in the form of a 1in long x 1/8in Whitworth screw and nut through the core assembly. This screw will be removed when the transformer is finally mounted, one of the tagboard mounting screws serving as a support.

TRANSFORMER CONNECTION DETAILS

Secondary (Gn-Bk):	Start – Green sleeving (8)
	Finish – Black sleeving (7)
Primary (Bk-Rd):	Start – Black (3) On same side as Sec. Green start
	Join Red on above side to Black on other side of transformer. This pair becomes (2)
	Finish – Red (1)
Feedback (Rd-Gd):	Start – Red (6) On same side as Sec. Green start.
	Join Gold on above side to Red on other side of transformer. This pair becomes (5)
	Finish – Gold (4)

(Based on RCS Radio Pty Ltd type 130.)

resistors should be placed inside some sleeving as shown in the photograph.

The battery, Eveready type 276P or equivalent, is mounted on the other end panel, or the "bottom" of the case. We used some insulated hookup wire to secure the battery, passing it through four small holes drilled close to the edges of the shorter sides of panel. Should some constructors wish to run the instrument from the mains, there is ample room to build a small power supply in the space presently occupied by the battery. As stated before, the power requirements of the unit are 9 volts at 80mA.

This completes the description of our transistorised insulation tester or "megger". We are confident that it will prove itself one of the most popular test instruments we have described to date.

Its simplicity and low cost, combined with compactness and the ability to make rapid checks on most of the common types of capacitor should make it invaluable both for the service technician and for the home constructor. It will not check electrolytic capacitors, of course, but then these can be checked without too much difficulty using either a multimeter or the substitution method.