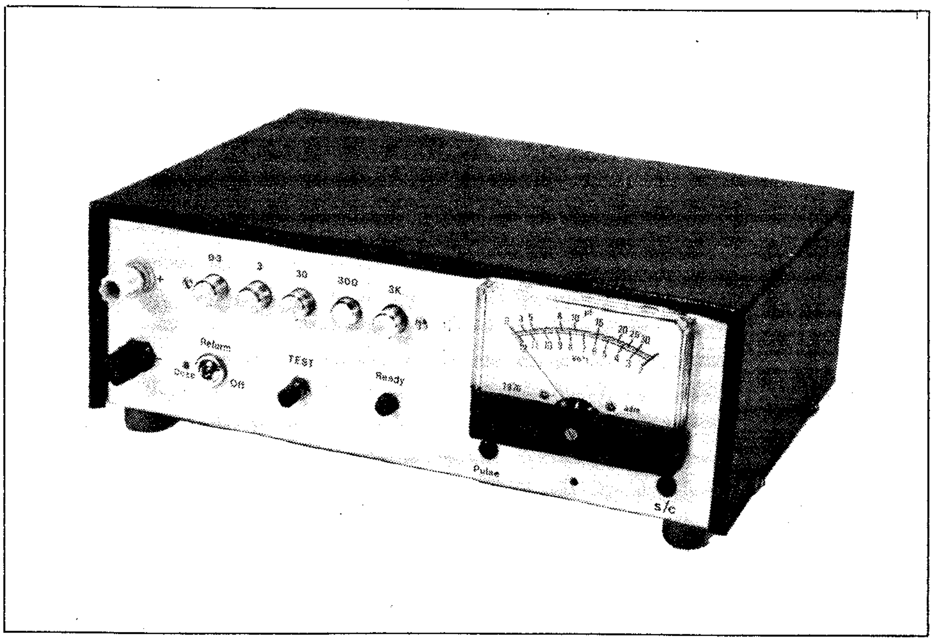
Electrolytic capacitor tester

Automatic instrument offers a reform facility and meter display

by A. Drummond-Murray

This instrument uses a charge injection technique to develop a voltage across the capacitor under test. The voltage is measured on a calibrated meter and no balancing or adjusting is required except for range selection. A reform facility allows an old or unused capacitor to have a voltage applied for about 15s which re-polarizes the dielectric before a measurement is made. An indication of leakage is also provided by the meter movement which is buffered by a f.e.t.-input amplifier.



Electrolytic capacitors depend on a dielectric formed on a aluminium or tantalum electrode by a thin layer of oxide. This dielectric requires polarizing to maintain its insulating properties and long periods of rest can result in de-polarization, a high leakage current and even total breakdown. Fortunately, the dielectric layer can be restored by applying a polarizing potential to the capacitor for at least five minutes via a current limiting resistor. This process is known as reforming. If a capacitor is to be tested and has started to de-polarize, a reforming period is necessary before any meaningful results can be obtained. The tester is provided with a reform facility which charges the capacitor to +12V via a 1200Ω resistor for about 15 seconds prior to the capacitance measurement. Although this period is too short for complete reforming, it is sufficient for most capacitors to recover enough for testing. The main property to suffer from incomplete reforming is leakage current. If, on test, a capacitor exhibits a high leakage current, a second reform period will often suffice. If no such improvement is apparent, the capacitor is fauly and unlikely to benefit from a prolonged reform. A short tone from the instrument indicates that the reform period is complete. Three l.e.ds indicate the state of the circuit during the test process. A green l.e.d. indicates that the reform process is ready to start and a red type indicates than an excessive current is flowing during the polarizing period. This facility is useful for detecting short circuit capacitors. During the measuring cycle, a further l.e.d. flashes when the test capacitor is being charged.

An equivalent circuit is shown in Fig. 1. The charge period on any range is the same for any unknown capacitance, and the voltage developed across the capacitor is proportional to its capacitance. If this voltage is measured from 0V instead of 12V, the capacitance increase is indicated as an increased voltage. This voltage rises exponentially. Fig. 2 shows the sequence of events following a start pulse. After a polarizing potential is applied, the capacitor is completely discharged through a circuit which limits the peak current to 100mA. A finite charge is then injected into the capacitor and the voltage is measured on a calibrated meter. The rate of decay is taken as a measure of internal leakage. A complete circuit of the tester is shown in Fig. 3.

Input impedance of the measuring circuit is important because of the shunting effect which occurs. Fortunately, modern operational amplifiers are ideally suited for producing high input

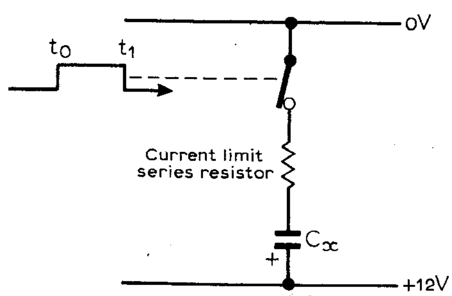
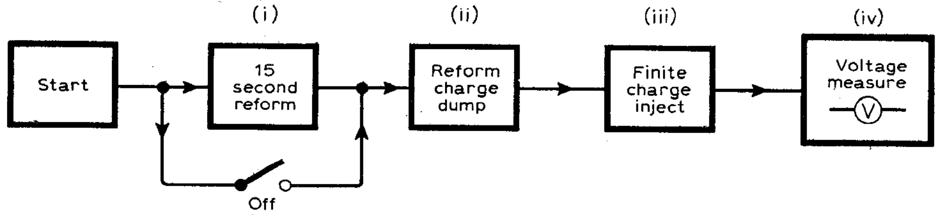


Fig.1. Simplified circuit of the tester

Fig.2. Block diagram of circuit operation.



impedances. Simple devices like the 741 can be made to have a high input impedance, but the bias current taken by the input transistors can still cause the capacitor voltage to vary. F.e.t.-input op-amps do not suffer from this problem, and the input resistance is greater than 1000MΩ. Using a f.e.t.-input amplifier the meter reading obtained with a 1μF polyester capacitor had no change after 20 minutes. Leakage current through any conventional electrolytic capacitor is certain to be many times higher than this, so the meter-drive loading may be disregarded.

In general the range of the instrument is altered by varying the charge current period. Because each range is ten times larger than the previous one, the charge injected increases by the same proportion, so the scale calibration is correct for all ranges. Calibration of the instrument is achieved by using known values of capacitance and marking the scale accordingly. Mullard 10% 100V polyester types with values 0.33μF, 0.47μF and 1.0μF ×3, were used and checked on a capacitance bridge and found to be within ±5%. These are quite adequate for calibration in view of the wide tolerance of electrolytic types (up to +100% −50%). On the 3000μF range a ten-fold increase in charge current is used to avoid a 47μF non-electrolytic capacitor, which is both large and expensive. The charging current is determined by the series resistance in the circuit and by the exponential rise in voltage across the capacitor. On the 3000μF range the initial current is a little under 100mA, so a well regulated supply is required to prevent a momentary fall in voltage as the 100mA demand is met.

The timing sequences are controlled by three monostable multivibrators. The initial forming period is determined by the 1000μF electrolytic capacitor on IC_{1a} and will vary with the component used. If it is not desired to reform a capacitor before testing, the 1000μF capacitor is switched out of circuit, and the period reduces to a few nanoseconds. At the completion of this period the test capacitor is fully discharged. The duration of the discharge cycle is 0.25s on all except the 3000μF range which is increased to 2s. Capacitor C_5 is switched in parallel with the existing timing capacitor, C_4 for this purpose.

As discussed earlier, the accuracy of the instrument depends on each range having a ten-fold change in the amount of charge injected during the test period. Stable capacitors are therefore required on the timing multivibrator, IC_3. Polycarbonate and polystyrene capacitors are particularly suitable but mylar, paper or ceramic devices are not recommended.

On all but the 3000μF range, the test capacitors are charged through a series 1.2kΩ resistor and consequently the accuracy with which the periods change directly affects the meter calibration from range to range. On the 3000μF range the test capacitor is charged through 120Ω, formed by the addition of 135Ω in parallel with R_{12}. Two extra resistors are used to prevent aging due to the relatively high peak current of 100mA.

A monostable is used to drive the precision charge circuit because this device is recommended by the manufacturer for stability and repeatability.

Operation of the circuit is indicated by the pulsing of LED_2. During the reform period, current passing through R_{12} is monitored by Tr_4. If the V_{be} exceeds 0.7V then Tr_4 turns on LED_3. Resistor R_{14} limits the base current and prevents Tr_4 from shunting R_{12}. The l.e.d. is illuminated fully when the capacitor current exceeds about 5mA. During the discharge sequence, Tr_2 is turned on by Tr_3 and Tr_1 remains cut off. When Tr_2 turns on, the discharge path is completed via R_{12} and R_{13} in series. Because R_{12} is in parallel with a diode which will be forward biased, the maximum potential across R_{12} is limited to 0.7V so the remainder of the voltage drop will be across R_{13} which is a low resistance. Diode D_3 removes R_{12} from the discharge path during the initial current flow, and until the capacitor voltage falls below 0.7V. Schmitt trigger IC_{4a} is connected as a simple oscillator producing a continous rectangular waveform. The second Schmitt trigger IC_{4b} isolates the oscillator from the loudspeaker. The trailing edge of the reform cycle pulse at Pin 13 of IC_{1a} has a positive-going edge which is differentiated by C_2, R_5 and used to switch the oscillator output to the loudspeaker. It

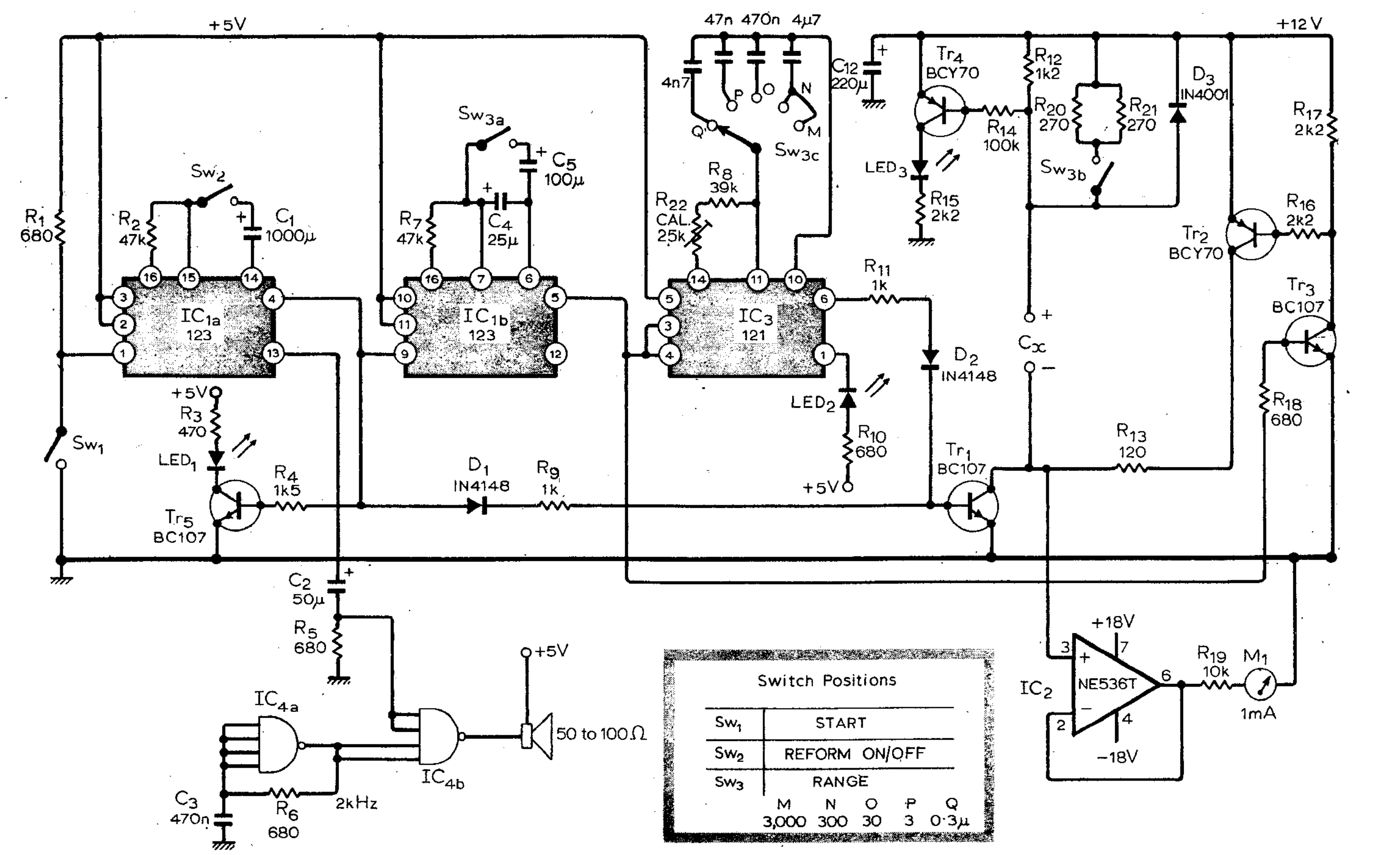


Fig.3. Complete circuit of the capacitor tester. Switches 3_a and 3_b only close on range M of switch 3_c

Components list

R_1	680Ω
R_2	47k
R_3	470Ω
R_4	1.5k
R_5	680Ω
R_6	680Ω
R_7	47k
R_8	39k
R_9	1k
R_{10}	680Ω
R_{11}	1k
R_{12}	1.2k
R_{13}	120Ω ¼W
R_{14}	100k
$R_{15,16,17}$	2.2k
R_{18}	680Ω
R_{19}	10k
$R_{20,21}$	270Ω
R_{22}	25k preset
C_1	1000μF 10V
C_2	50μF 10V
C_3	0.47μF 10V
C_4	25μF 10V
C_5	100μF 10V
C_6	4700pF polystyrene
C_7	47nF
C_8	0.47μF polycarbonate
C_9	4.7μF polycarbonate
C_{10}	2000μF 25V
C_{11}	100μF 25V
C_{12}	220μF 25V
$C_{13,14}$	0.1μF disc ceramic
$D_{1,2}$	1N4148
D_3	1N4001
$Tr_{1,3,5}$	BC107
$Tr_{2,4}$	BCY70
LED_1	Green
$LED_{2,3}$	Red
IC_1	SN74123N
IC_2	NE536 (or RS Components 'FET MOPA')
IC_3	SN74121N
IC_4	SN7413N
IC_5	MC7812CP
IC_6	MC7805CP
Bridge rectifier	100V p.i.v., 1A

Miscellaneous

Loudspeaker	50-100Ω min
Panel meter	1mA
Transformer	240/15.0.15 1A
Sw_1	SPSM
Sw_2	SPSM
Sw_3	3P5W
Fuse	250mA

Prototype scale calibration

Capacitance/terminal voltage	*meter scaled 0-1*
0μF	0
0.33μF	0.08
0.5μF	0.12
0.8μF	0.34
1.0μF	0.44
1.5μF	0.59
2.0μF	0.75
3.0μF	0.90
12V	0
10V	0.2
8V	0.4
6V	0.6
4V	0.8
2V	1.0
0V	20% greater than f.s.d.

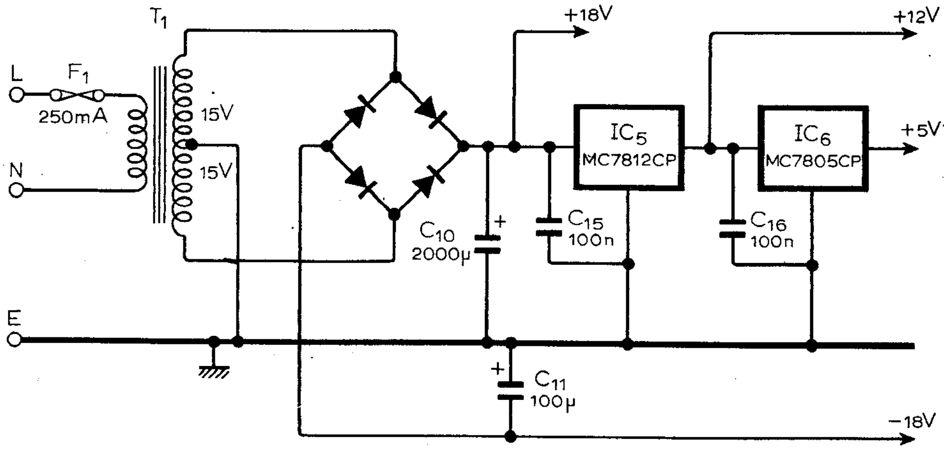


Fig.4. Power supply.

is important that this spike is applied only to a Schmitt trigger input to prevent oscillation when the input voltage lies between logic 1 and 0.

The operational amplifier requires positive and negative supplies in order to operate on inputs that are very close to 0 or +12V. Current consumption of the amplifier is low, and the inherent ripple rejection is high so a simple power supply as shown in Fig. 4 is adequate.

Construction & calibration

Leads should be kept short and wherever possible separate. This is particularly important in the relatively high impedance wiring associated with the timing circuits of IC_1 and IC_3. An efficient ground plane should be provided on the circuit board to keep the earth impedance as low as possible. Disc ceramic capacitors should be used to decouple the circuits at h.f. If the power supply leads are more than 25cm long sufficient l.f. decoupling must also be provided. The best solution is to mount the power supply regulators on the circuit board. If monolithic voltage regulators are used, it is advisable to decouple the input lead with a disc ceramic capacitor to ensure stability.

Calibration of the meter movement is achieved by adjusting the preset potentiometer on IC_3 with a capacitor of known value on test. Calibration for other values and ranges should then be correct. Resistor R_{19} is used for scaling the voltmeter circuit. The prototype uses a 1mA meter movement and consequently a 10kΩ resistor is required to provide a 10V f.s.d. range. The tester is not really suitable for capacitors with voltage ratings of less than 10V. Lower voltage components may be tested provided that no attempt is made to reform them from the internal 12V current-limited supply, and the range selected for testing ensures that the terminal voltage is less than the capacitor peak voltage rating. The meter scale can be marked with the capacitor terminal voltage corresponding to the capacitance value of this purpose. The table shows the prototype meter calibration figures.

Electroytic capacitors vary in value according to the applied voltage, and when a capacitor is severely under-rated, the nominal capacitance is reduced. This must be borne in mind when relatively high voltage capacitors are tested. Because the tester measures voltage from 0V, the capacitor voltage will decay upwards. Some capacitors, always faulty, exhibit a fall of meter reading. This effect is similar to a c.r.t. regaining the e.h.t. potential, after switch-off, due to the physical properties of the glass dielectric.

P.C.Bs

A glass fibre printed circuit board which accommodates board mounted switches will be available for £3.50 inclusive from M. R. Sagin at 23 Keyes Road, London NW2.

We understand that Circuit Services, 36 Hallows Crescent, S. Oxhey, Herts, will be offering a set of components for this design.

Correction

In the article "Metal detector," published in the April issue, the values of R_3 and R_7 were printed incorrectly in the parts list. The correct values are 4.7kΩ as shown in the circuit diagram.

Readers of the April issue may have been fooled by Part 2 of the article entitled Power Semiconductors — so were we; it should have read Part 1.