MEASURING INSULATION RESISTANCE

Most people involved in electronics as a hobby or career have wanted to check the insulation of capacitors at some stage or other. This note shows how to measure insulation resistance using an electronic voltmeter. Resistance values up to 50,000 megohms or more can be measured, depending on the sensitivity of the meter.

As far as capacitors are concerned, the application where insulation resistance is most critical is "signal coupling" or "DC blocking". A typical case is signal coupling from the plate of a vacuum tube stage in an amplifier to the grid of the vacuum tube in the next stage. Any leakage through the capacitor of the high voltage at the plate will upset the negative DC bias on the grid of the following stage. The degree to which the bias is likely to be upset depends upon the input resistance of the following stage. If the input resistance is high, the insulation resistance requirement of the coupling capacitor is more critical.

The insulation resistance of supply decoupling and bypass capacitors is generally less critical and for this reason electrolytic capacitors are commonly used in these applications.

To check the insulation resistance of a capacitor, a DC voltage source is needed to polarise and/or to stress the capacitor at its rated working voltage. In addition, a meter is needed to monitor the leakage current through the capacitor. The DC voltage source may be a battery of suitable voltage, a regulated DC power supply, a well filtered supply derived from the HT rail of an amplifier or TV set or even the VTVM, which will be used to make the measurements.

The insulation resistance (IR) of a good paper capacitor will be of the order of thousands of megohms. A good polyester capacitor will have an IR of 50,000 megohms and a typical polystyrene capacitor will have an IR of 1 million megohms or more. This means that the currents to be monitored are of the order of nanoamps or picoamps (10^{9} and 10^{12}). Fairly obviously, few people would have the means to monitor such small currents but it can be done by monitoring the voltage across a high value resistor.

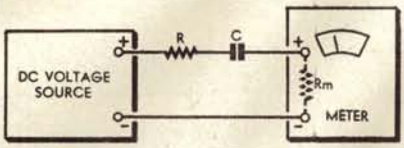

Figure 1

One of the usual characteristics of a VTVM or other electronic voltmeter is that it has a fixed high input impedance on all voltage ranges, typically 10 megohms or more. If we use this input impedance as our current monitoring resistor in conjunction with the low voltage ranges of the meter, we have the means to measure very low orders of leakage current.

The method of connection for insulation resistance measurements is shown in figure 1. The resistor R is merely to protect the DC supply against accidental short-circuit. It should be arranged to limit the short-circuit current from the supply to 1mA or less. For example if a 400-volt supply was used, a 470K resistor would be appropriate.

When first connected, the VTVM is set on a voltage range with full-scale reading greater than the supply voltage. As the capacitor charges, the meter reading should rapidly reduce so that the final reading, usually taken after one minute should be able to be taken from the lowest voltage scales on the meter.

Insulation resistance can be calculated using the following formula:

$$IR = \frac{(Vo-Vm)Rm}{Vm}$$

Where:

Vo = Supply voltage
Vm = Meter indication
Rm = Resistance of meter

If the meter indication is very small with respect to the supply voltage, the formula may be simplified:

$$IR = \frac{Vo\ Rm}{Vm}$$

As an example of a typical calculation, using the latter formula, if the supply was 400 volts, the meter reading 100mV and the meter input impedance 10 megohms, the insulation resistance of the capacitor would be 40,000 megohms. Exactly the same method can be applied to measuring the IR of transmission lines, terminal blocks, between coils of transformers and in fact any component which has high IR.

Those readers who "cut their teeth" on vacuum tube circuitry will recognise the above method of measurement as an extension of the rough and ready technique of testing blocking capacitors in situ. All that had to be done was to disconnect the grid end of the capacitor, and measure the voltage with a multimeter. If the meter gave a reading on even the lowest voltage range (typically 3V at 20,000 OPV) the capacitor was discarded.

In practical valve type circuits, the permissible insulation resistance for a coupling capacitor depends a great deal on the circuit configuration.

A typical power output valve may have a 1 megohm grid resistor coupled via a capacitor to a point 100V positive with respect to chassis; the output valve may operate at a bias level or about 10 volts. An insulation resistance of 100 megohms across the capacitor would shift the output valve grid potential by 1 volt; this may or may not be partially offset by a resulting change in cathode voltage.

If the 1-volt grid shift represented a permanent and stable condition, the effect on receiver performance might be ignored but, once the insulation resistance of a capacitor begins to fall, the process of deterioration is likely to continue to a serious and perhaps catastrophic level.

In circuits where the grid return resistor is of higher value and the valve operates with lower bias, the effect of a 1-volt potential on the grid might be quite serious in terms of linearity and distortion level. In such a case, one might think in terms of a minimum insulation resistor for a grid coupling capacitor more in the order of 1000 megohms. ■