MEASURING low resistance

Simple low-resistance measurement usually relies on high direct current to produce a voltage drop, stressing the component under test. Reducing the current and amplifying the voltage drop can result in offset problems. Frantisek Michele explains the advantages of using ac to produce the drop.

Measuring resistors with low values can be tricky. The obvious method is to measure the voltage drop across the unknown resistor using a known current and then calculate its value.

Because the drop depends on the current through the resistor, the current needs to be large enough to produce a measurable voltage. For example, the voltage drop is only 10mV if the measured resistor is 0.1Ω and current through the resistor is 100mA.

Large currents supply large voltage drops. However, in many cases, the measured components will not tolerate such large currents. Also, the heat generated by within the component due to the large current can cause measurement errors.

This problem can be solved by amplifying the voltage drop so that less current is needed. If the amplifier has a 60dB gain, the output will be 0.1V if the current is 1mA and the resistor is still 0.1Ω.

The ac alternative

Operational amplifiers however have a dc input offset voltage. This offset causes an error when the input level is very low. An ac amplifier technique circumvents this problem.

Referring to Fig. 1, IC_A, C_1, and $R_{1\text{-}4}$ form a square waveform generator operating at around 300Hz. Diode D_1 limits the square wave to 6V peak-peak. Because the values of the measured resistor R_X and additional resistor R_A are much less than R_6, current through R_X will be,

$$I_X=6/R_6=2\text{ mA}$$

Then, IC_B's input is,

$$V_{IN}=I_X\times(R_X+R_A)=0.002\times(R_X+R_A)$$

Amplifier IC_B supplies the ac gain $R_8/R_7=10$. Diode D_2 with IC_C converts the ac signal to dc with gain of $1+R_{11}/R_{10}=10$. DC amplifier

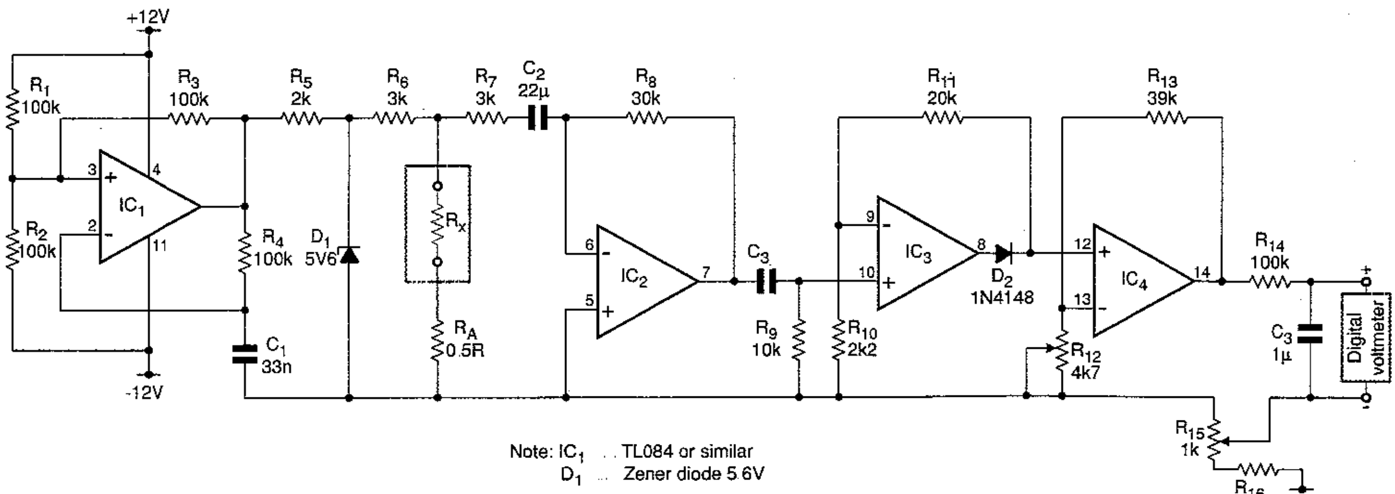

Fig. 1. Oscillator IC_A produces an ac voltage over the unknown resistor, which is then amplified, rectified and displayed. Since the stimulus is ac, high current and drift associated with dc schemes for measuring low resistance are removed.

IC_D has a gain of $1+R_{13}/R_{12}$. As a result, the output is,

$$V_O=0.5\times VIN\times 10\times 10\times (1+R_{13}/R_{12})$$
$$=0.1\times (R_X+R_A)\times (1+R_{13}/R_{12})$$

where 0.5 is the conversion efficiency for a 50% duty-cycle waveform. After the dc output is smoothed by R_{14} and C_4, a digital voltmeter can measure R_X.

Resistor R_A supplies a base signal for the amplifiers. When R_X=0, R_A sends a 1mV peak-peak signal to IC_B. If R_A=0 and R_X is very small, IC_B's noise may swamp the weak input. To compensate for the output offset due to R_A, R_{15} calibrates the digital voltmeter to zero when R_X=0. Adjusting R_{12} makes the scale 1Ω/V. Thus, a 2V digital voltmeter can measure resistances from 0.001 to 1.999Ω.

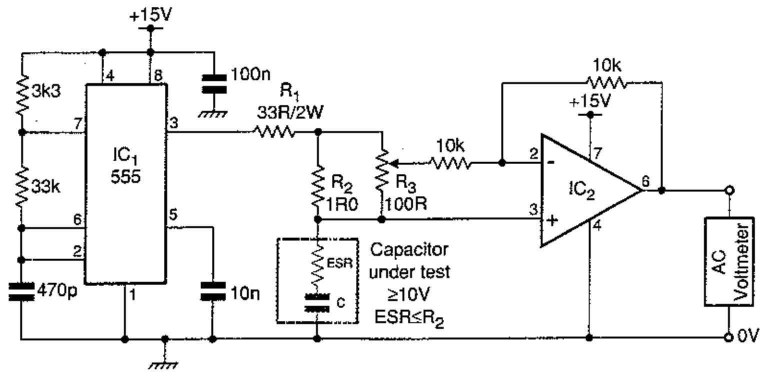

Fig. 2. Equivalent series resistance in a capacitor is particularly important in circuits such as switch-mode power supplies. Operating at 50kHz, this circuit drives about ±180mA into the capacitor and looks at the resulting ac voltage over the 1Ω resistor via an op-amp.

Measure resistance of a capacitor

The equivalent series resistance, or esr, of a capacitor can be measured using **Fig. 2**.

Oscillator IC_1 forms a 50kHz square-wave generator. It drives a current waveform of about ±180mA into the capacitor under test through R_1 and R_2.

When R_3 is adjusted to the proper value, the voltage drop across the equivalent series resistor is precisely nulled by the inverting amplifier IC_2. Thus, V_O is the pure capacitor voltage which is the minimum voltage that can be produced at V_O.

To make an ac voltage measurement, adjust R_3 until V_O is minimised. Then note the position of the potentiometer and multiply it by the value of R_2. That product equals the capacitor's esr.

The capacitor is biased about to 7.5V. Lower-voltage capacitors cannot be measured with this circuit. Changing the value of R_2 allows other ranges of esr to be measured. However, for small R_2 values, the current level should be increased to keep a reasonable voltage across R_2. This will require some sort of buffer.

The circuit is intended for capacitors greater than 100µF. Ripple voltage becomes large for smaller values and accuracy decreases. ■