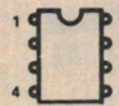
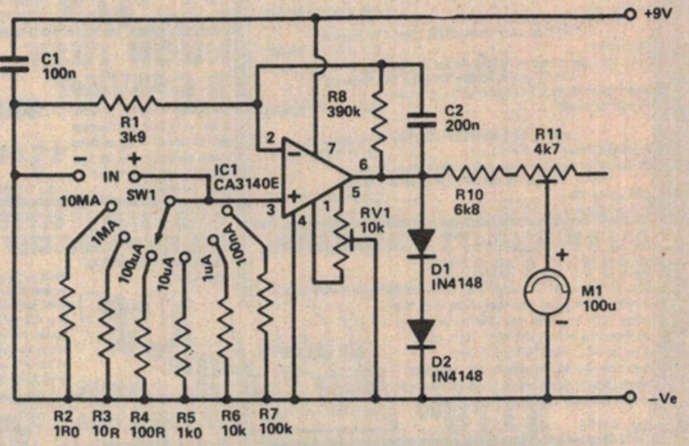
Measuring very low currents

IT IS NOT POSSIBLE to accurately measure currents of a few microamps or less using an ordinary panel meter or multimeter. In order to make such measurements it is necessary to use an active circuit such as the one shown here. It can be built as a self-contained unit or used as part of an instrument requiring a highly sensitive current range.

This instrument will measure from 100 nanoamps (10^{-7} amps) to 10 mA full scale, in six ranges. The higher ranges are included so that the instrument may be accurately calibrated and they generally overlap with the lower current ranges on many multimeters.



CA3140E TOP VIEW



R1 TO R7 ARE CLOSE TOLERANCE TYPES

The meter, M1, is a 100 μA movement connected as a voltmeter having 1 V full scale deflection. Resistors R10 and R11 (a trimpot) are the 'multiplier' resistors. The trimpot is a calibration control, adjusted to give full scale meter deflection on the 10 mA or 1 mA ranges.

IC1 is an op-amp connected in the non-inverting mode and having a dc voltage gain of about 100 times (set by the feedback network R8 and R1). C2 reduces the ac gain to about unity to improve stability and immunity to stray pick-up. The non-inverting input of IC1 is biased to the 0 V rail by whichever of the range resistors (R2-R7) is selected by SW1. In theory, this gives zero output voltage and no meter deflection, but in practice it is necessary to compensate for small offset voltages using the offset null control, RV1.

Current in the circuit being measured flows into the instrument's input terminals. A voltage will be developed across the selected input resistor, one of R2 to R7. This voltage will be amplified by IC1 and will produce a positive meter deflection. Say the 10 mA range has been selected. The input current will flow through R2. If the input current is 5 mA, say, from Ohm's law, 5 mV will be developed across R2.

$$E = I.R = 5 \times 10^{-3} \times 1 = 5\ mV$$

Now, IC1 has a gain of 100, as

$$\text{Gain} = \frac{R8}{R1} = \frac{390 \times 10^3}{3900} = 100$$

The voltage at pin 6 of IC1, with 5 mA flowing in the input, will be 500 mV, or half a volt. The meter will thus indicate half scale, giving a reading of 5 mA.

Successive ranges increase the sensitivity of the instrument by a factor of 10.

This arrangement relies on the fact that IC1 (a 3140) has a very high input impedance so that it does not 'load' the input resistor selected and affect the accuracy of the reading by drawing a significant amount of input current itself. The 3140 is a FET-input op-amp having a typical input impedance of 1.5 million megohms. Note that, to achieve reasonable accuracy, the input resistors R2 to R7 and the op-amp feedback resistors should all have a tolerance of 2 % or better.

Meter protection is provided by D1 and D2. Should the input current exceed the maximum for the range, the output of IC1 will rise higher than 1 V. If it exceeds about 1.2 V, the two diodes conduct, preventing any further rise in the output of IC1 and protecting the meter from any overload exceeding 20% of the rated input.

When adjusting the offset null control (RV1), start with its slider positioned at the end connected to pin 5 of IC1. The meter should show a strong deflection. Back off RV1 just far enough to zero the meter and no further.

The unit may be calibrated by a number of methods. A simple way is to obtain a variable power supply that will provide 10 V and a 10k 1% or 2% resistor. You will also need either a good mirror-scale multimeter or a digital multimeter.

Connect the resistor and the low current meter in series and connect across the output of the power supply. Also connect the multimeter across the output of the power supply (observe polarities). Select the 1 mA range on the low current meter and a suitable range on the multimeter. Turn the output of the power supply down and switch it on. Set the power supply to give a reading of 10 V on the multimeter. Do this carefully for best accuracy. Now, adjust R11 for full scale deflection. Your low current meter should now be calibrated. If you substitute a 1k, 1% or 2% resistor for the 10k resistor, you can check the calibration on the 10 mA range.