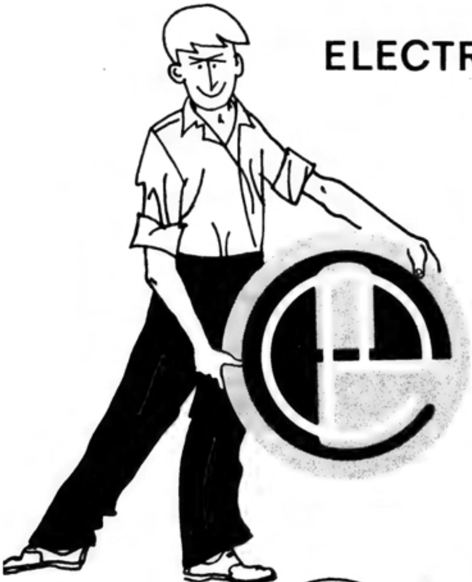


ELECTRONIC CIRCUITS–
.....IN THEORY and PRACTICE

TEACH-IN ...FOR BEGINNERS

By Mike Hughes M.A.

4 POWER

LAST month when we connected the 10 kilohm resistor in series with a 1mA meter, the reading in milliamps had the same numerical value as the voltage that was driving the current. Go back to using the single 10 kilohm in series with the meter and change the voltage of the battery to 4·5 volts. The current will be 0·45mA. Thus by changing the scale of the meter, we have a simple voltmeter which can measure up to 10 volts full scale. By putting two 10 kilohm resistors in series we have a voltmeter with a full scale reading of 20 volts. A two range voltmeter is shown in Fig. 1.

Make yourself a simple voltmeter using these principles. Initially it can be made up on the Demo Deck but if desired a separate meter could be bought and a separate instrument made.

A voltmeter of this type will usefully measure voltages in many electronic circuits but it suffers from a problem. This problem is that it has a resistance that in itself can "shunt" the circuit which is providing the voltage to be measured.

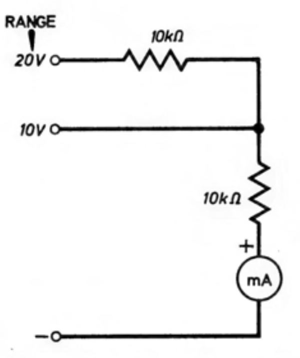


Fig. 1. A two range voltmeter. The numerical value of the current (in milliamps) gives the voltage value being measured.

This upsets the balance within the circuit and an erroneous voltage will be measured which will always read lower than actual. This means that the meter lacks sensitivity.

SENSITIVITY

The sensitivity of a meter is rated as the number of ohms the meter presents for every volt it measures. The unit we have just made is 1,000 ohms per volt and is fairly poor; more typically one requires a meter having a sensitivity of at least 10,000 ohms per volt. To make this we would have to use a basic movement having a sensitivity of 100 microamps (a microamp is one millionth of an ampere) and all our resistors would have to be scaled up in value by a factor of 10.

Test the effect of poor voltmeter sensitivity by connecting two 22 kilohm resistors in series across a 9V battery, and then use our 1,000 ohms per volt meter to measure the voltage between one end of the resistors and the common junction of the two (Fig. 2), then do the same with two 1 kilohm resistors. The reading should be 4·5V.

Justify in your own minds exactly what is happening and why the actual reading is less. The reason for this is that the 10 kilohm resistance of the meter has more shunting effect on the circuit using 22 kilohm resistors than with that using 1 kilohm resistors.

POTENTIAL DIVIDERS

The circuit of Fig. 2 is sometimes called a potential divider because the midpoint of two resistors has a potential which is based on the

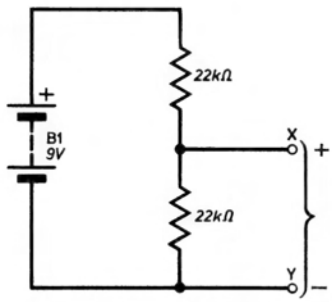


Fig. 2. Circuit for demonstrating voltmeter sensitivity.

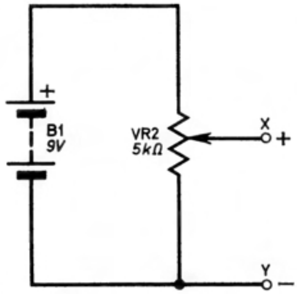


Fig. 3. The circuit diagram to be wired up on the Demo Deck to illustrate the function of a "potential divider."

potential difference across both resistors and the ratio of their values.

Substitute VR2 for the two resistors and use the wiper as the midpoint which can be varied in position to alter the ratio of the resistances either side of the wiper (Fig. 3). Measure the voltage between one end and the wiper as the knob is turned. You should get a smooth change from zero to 9V. Now try the same experiment with VR3 and VR4.

There is a great deal one can say about the principles of resistor networks, but in this beginners guide we have covered just sufficient to be of use later.

POWER

We are all familiar with the term POWER when applied to electricity. In any context it is the ability to do work whether it be manpower, horsepower or electrical power. In the latter case it is usually associated with the ability to heat something, light something or move something—the cone of a loudspeaker for example.

Driving voltage itself is not sufficient to do work—we must have current flow as well. Power is a function of both voltage and current and is measured in units of or fractions of a "watt".

Power measured in watts, $P = V \times I$

where V is the potential difference in volts and I is current flow in amperes. We can use this expression to calculate any one of the terms if the other two are known.

The current drawn by an electric fire of power 1·5 kilowatt (1·5kW) running from 250V mains

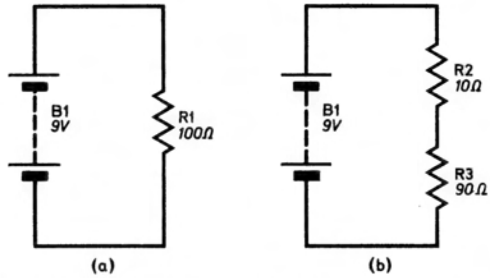


Fig. 4. The power dissipated in R1 is greater than in each of R2 and R3, but the total power dissipated in each circuit is identical.

will be given by

$$I = \frac{P}{V} = \frac{1500}{250} = 6 \text{ amperes}$$

Most frequently we are concerned with calculating the amount of power required by or dissipated in a circuit. The power dissipated in a resistor shows itself as heat, and is calculated from the current flowing through the resistance and the potential difference across it. The "potential drop" is equal to the value of the resistor multiplied by the current flowing through it (Ohm's Law)—$V = I \times R$. We can substitute $I \times R$ for V in the expression for power and obtain

$P = I \times I \times R$ this is usually written $P = I^2 \times R$

This means that we can calculate the power dissipated in any resistor purely from knowing the current flowing in the resistor and the ohmic value of the resistor.

Look at Fig. 4a. We have a 100 ohm resistor connected across a 9V battery. What is the power dissipation in it? First of all calculate the current:

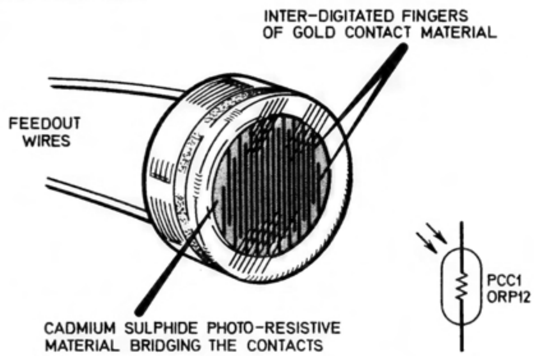
$$I = \frac{V}{R} = \frac{9}{100} = 0{\cdot}09 \text{ ampere}$$

The power dissipated is therefore,

$$0{\cdot}09 \times 0{\cdot}09 \times 100 = 0{\cdot}81 \text{ watt.}$$

Resistor R1 would have to be capable of dis-

Fig. 5. The ORP12, a typical photo conductive cell, shown in diagramatic form together with the circuit symbol and designation, PCC, for these devices.



sipating this amount of heat without undue rise in its temperature and the nearest commercially available type is a one watt device.

Fig. 4b shows two resistors in series across a 9 volt battery. Try calculating the dissipation in each resistor. First of all calculate the current flowing through the circuit as a whole then use this value of current in conjunction with the ohmic value of each of the resistors in turn. The answers are 0·08W for R2 and 0·73W for R3. Note that, although they are in the same circuit there is considerable difference in their respective dissipation. To prevent overheating the nearest commercial grades that we would use are $\frac{1}{8}$ and 1 watt devices respectively.

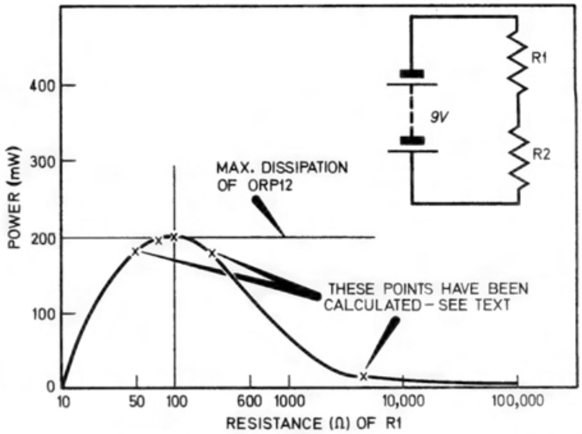


Fig. 7. Graph showing the power dissipation in R1 for various values of resistance with R2 held constant at 100 ohms. This is a maximum when R1 = R2.

LIGHT DEPENDENT RESISTOR

Some electronic components have their maximum rating specified in terms of power as opposed to current. This is usual when overheating is likely to cause irreparable damage to the component. A typical example of this is the photo conductive cell or light dependent resistor. This is a very interesting and useful component because it enables us to make a whole range of simple but fascinating circuits that are actuated by light.

As its name implies it is a resistor whose ohmic value varies as light falls on it. The one we shall be talking about is readily available and comparatively cheap—the ORP12. The appearance of the device is shown together with its symbol in Fig. 5; you can see that, like a resistor, there are two leads from it and the polarity of connection is not important.

There are several different types of this device (the ORP12 is perhaps the most common) but they can all be recognised by the distinctive interlocking fingers making contact with the photosensitive material—cadmium sulphide (CdS). Photographers will no doubt be familiar with the device because it is used as the sensor in CdS exposure meters.

The manufacturer of the ORP12 states that the resistance will typically vary from 10 Meg ohm in absolute dark conditions to approximately 75 ohm in conditions of extreme brightness. They also state that at no time may one dissipate more than 200mW in the device nor may one operate it with a potential difference greater than 110V across it.

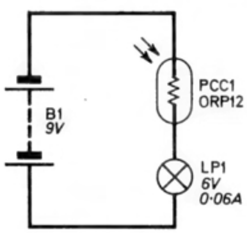
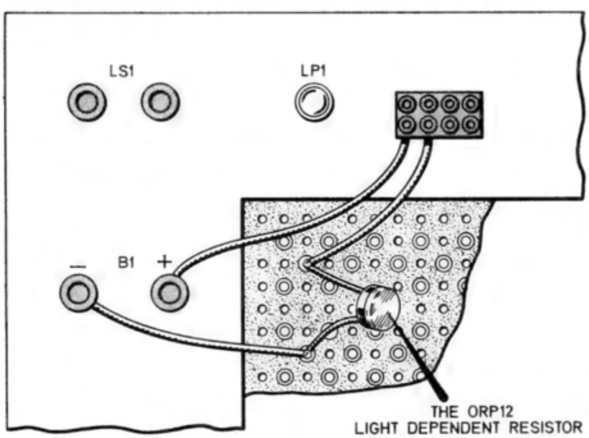


Fig. 6. (above) The circuit to demonstrate the action of a photocell. When bright light is incident on the cell, the lamp LP1 will light. (below) The wiring of this circuit on the Demo Deck.



EXPERIMENT

Use the Demo Deck to wire up the simple circuit of Fig. 6. Under normal room lighting conditions the resistance of the cell will be in excess of 500 ohm and this will prevent sufficient current to light the lamp. If you shine a very bright torch at the cell from close range you can make its resistance fall to approximately 75 ohm and the lamp will light up. You will probably be aware that the sensitivity of this circuit is poor because all the control is effected with extreme levels of light. This is because we are requiring the cell to pass quite a high current (60mA) to light the lamp and it is rather difficult to make its resistance fall sufficiently to do this.

Try working out the power dissipation in the photo cell for various light levels and see if we are exceeding the manufacturer's rating. The resistance of the photo cell varies typically from 5 kilohm down to 75 ohm for the range of lighting we are considering. Because the current

Table 1: REFERENCE DATA AND CHARACTERISTICS OF THE ORP12

Maximum power dissipation (ambient temp 25 degrees centigrade)	200mW
Absolute maximum cell voltage	110V
Cell resistance at 50 lux	2·4 kilohm
Sensitive area	0·6 cm^2
Typical resistance at 1000 lux with lamp colour temperature 2700 degrees Kelvin	75–300 ohm
Ultimate dark resistance at 110V	10 Megohm
Nominal rise time of resistance	75mS
Nominal fall time of resistance	350mS

through the cell will change as its resistance changes we cannot say that the power dissipation will be the same for every condition, in fact it is quite definitely *not* the same.

Try calculating the power dissipation in the photo cell when it has the following resistance values: 5 kilohm, 200 ohm, 100 ohm, 75 ohm and 50 ohm. To help you, assume that the bulb is simply a 100 ohm resistor.

You should find that when the photo cell resistance is 100 ohm the power dissipated is 202mW and at either side of this resistance value the dissipation is less. This is very important to appreciate because it tells us that the power dissipated is a maximum when the resistance of the cell equals the resistance of the load (the bulb). Strictly speaking, we are overstretching the capabilities of the photo cell by about 1 per cent when its resistance is exactly 100 ohm. In practice, however, this condition is unlikely to be maintained for any considerable period of time and besides, the dissipation limitation has a safety factor on its side and a momentary stress in excess of the rating can be permitted.

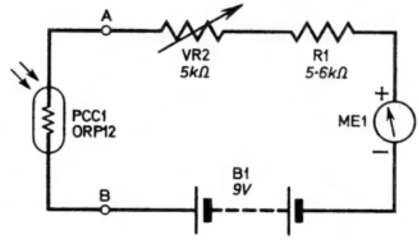
SPECIFICATIONS

Sooner or later one will need to refer to the manufacturer's specifications regarding components. Through this series we shall give you the most important specifications of the components we are using. The ORP12 is quite easily specified—see Table 1.

The parameter "Lux" is a measurement of light intensity; 50 lux is that equivalent to a dimly lit room while 1,000 lux is an exceptionally bright light—the intensity to be obtained a few inches away from a 100 watt bulb. The only parameter which you might not understand at this stage is the rise and fall time. These indicate that it takes a period of time for the cell to respond to changes in light level—the times shown for the ORP12 are quite long by electronic standards and are due to the fact that the reaction within the cell is almost a photochemical effect. Some other types of photoelectric devices can respond to millions of changes of light per second!

EXPOSURE METER EXPERIMENT

We have already said that the light dependent resistor is used in cadmium sulphide exposure



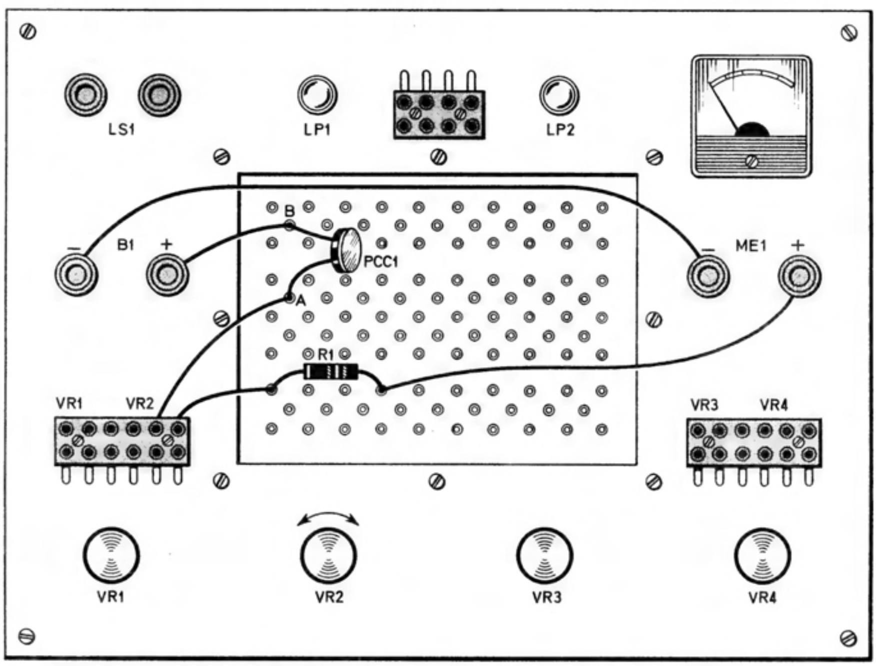
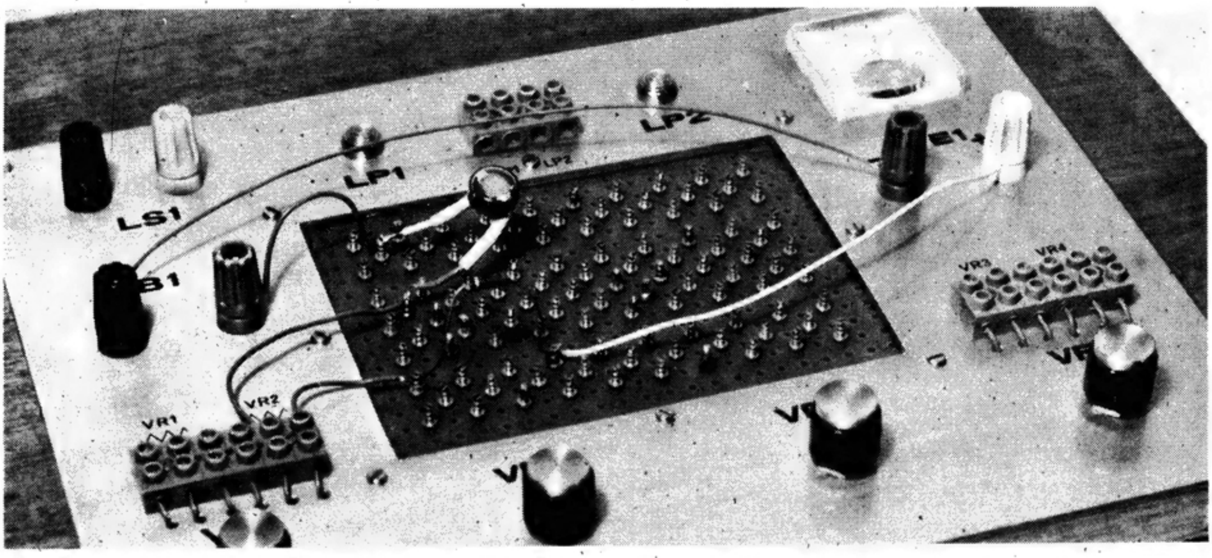


Fig. 8. (above right) The circuit diagram for a simple ohm meter which can be calibrated for use as an exposure meter. (right) This circuit wired up on the Demo Deck.



meters so now we will use the Demo Deck to make a simple version of this. Fig. 8 shows the circuit. It is a simple ohm meter where the ORP12 is a resistor whose ohmic value we shall be constantly observing.

It is usual with ohm meters to have zero ohm reading full scale on the meter. We are using a 1 mA (f.s.d.) meter, so must arrange that when we short circuit the input to the meter (across points A and B) exactly 1 mA is permitted to flow. As we are using a 9 volt battery we must incorporate a limiting resistor.

This is calculated using Ohm's Law,

$$\text{i.e. } R = \frac{V}{I} = \frac{9}{0{\cdot}001} \text{ ohm}$$
$$= 9 \text{ kilohm}$$

Because the battery voltage will vary a little with time we must make this resistor variable so that we can always set a zero ohm reading of full scale.

We could use a 10 kilohm potentiometer to do this but there is a danger that while adjusting it one might inadvertently reduce the resistance value to zero and pass excessive current through the sensitive meter. To prevent this happening we shall use a fixed resistor of 5·6 kilohm in series with VR2 (5 kilohm) on the Demo Deck. The combined effect of these two resistors will give us a variable range from 5·6 to 10·6 kilohm—ample to allow for battery variations but at the same time it will be impossible to pass more than about 2 mA through the meter (this would not cause any serious damage to the meter). With new batteries we should get our full scale zero ohms reading with VR2 set to almost maximum resistance.

METHOD

When set for zero ohm at full scale, disconnect the short circuit between points A and B and allow the ORP12 to come into circuit. We are now introducing extra resistance, thus the current through the meter will fall. If a lot of light is falling on the cell its resistance will be low (say 100 ohm) and this will have very little effect on the total circuit resistance, hence the meter will still read fairly high up the scale. If you prevent light falling on the cell, its resistance increases rapidly and the current displayed on the meter falls dramatically. Different levels of light between these extremes will give graded readings on the meter. For a given film speed one could carry out some trial exposures and experimentally produce a scale (or graph) which will convert the meter current reading into photographic light value numbers.

Next month : Capacitors