Experimental Methods

PY2108

Practical Session 1

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Contents

1 Learning objectives

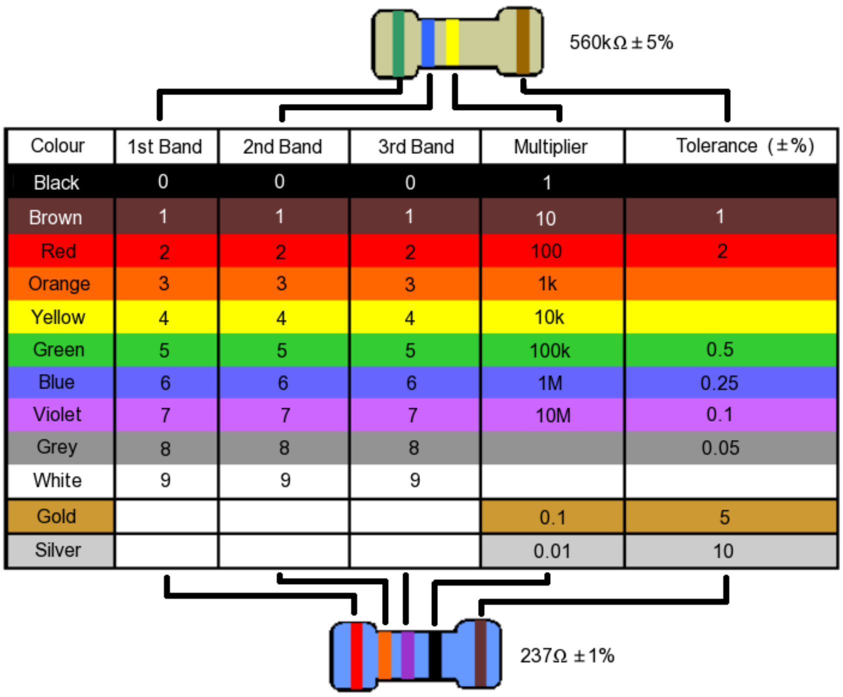
The objectives of this practical section are to

1. Use Ohm's and Kirchoff's laws to analyse resistive circuits
2. Read resistor colour codes
3. Construct resistive circuits on a breadboard
4. Use a power source
5. Use a multimeter to measure voltage and current
6. Use a multimeter to measure the actual resistance of a resistor
7. Gain familiarity with an analogue oscilloscope and signal generator

2 Lab equipment and components

2.1 Resistor colour codes

The SI unit of resistance is the Ohm (Ω). Hence, using Ohm's law, a 1 Ω resistor will pass a current of 1 A when a voltage of 1 V is dropped over it.



Colour	1st Band	2nd Band	3rd Band	Multiplier	Tolerance (±%)
Black	0	0	0	1	
Brown	1	1	1	10	1
Red	2	2	2	100	2
Orange	3	3	3	1k	
Yellow	4	4	4	10k	
Green	5	5	5	100k	0.5
Blue	6	6	6	1M	0.25
Violet	7	7	7	10M	0.1
Grey	8	8	8		0.05
White	9	9	9		
Gold				0.1	5
Silver				0.01	10

Figure 1: Resistor colour codes.

Very often the value of a resistor is marked on the component using the colour code summarised in Fig. 1. The two most common forms of code are the

4-band and 5-band code illustrated. One of the bands is slightly removed from the others and gives a measure of the tolerance of the quoted resistance (this is the only band that can be silver or gold).

The colour code of the other bands takes black to be 0, brown to be 1 then assigns the colours of the rainbow in order (excluding indigo) to the numbers 2 to 7. We might therefore use the mnemonic *R*ichard *O*f *Y*ork *G*ave *B*attle *V*ainly. White is then assigned to 9.

The first 2 bands (for the 4-band code) or 3 bands (for the 5-band code) gives a numeric value of the resistance. The last gives a power of 10 multiplying this number. For example, for a 4-band code with bands green, blue, yellow and gold, green = 5, blue = 6, yellow = 4 and, for the tolerance, gold = 5. Hence, $R = 56 \times 10^4 \Omega = 560$ k$\Omega \pm 5\%$.

2.2 Breadboard

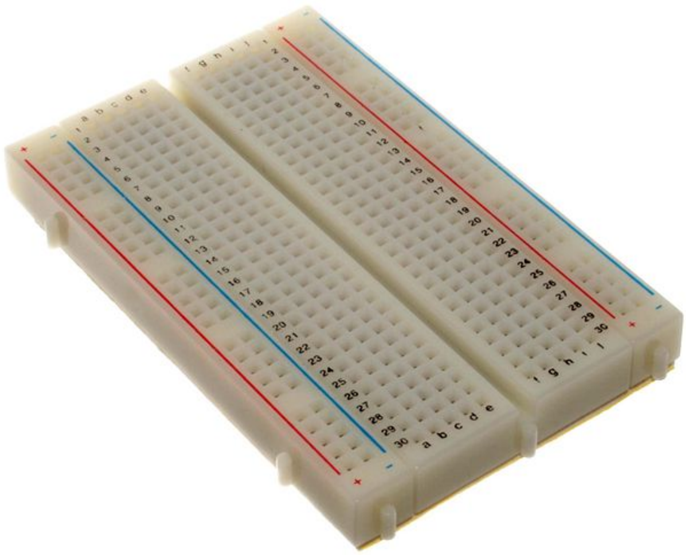


Figure 2: Example of a breadboard for prototype circuit construction (cf. Fig 3).

A breadboard provides a means of solder-less circuit construction for easy prototyping. Figure 2 shows a typical example of a breadboard. Wires and component leads may be inserted into the holes where they are held in place with springs. Note that on some poor quality boards, the springs may become deformed with use and fail to grip properly. Moreover, the leads on some components may be too thick to fit into the holes.

Figure 3 shows a typical scheme for the electrical connections inside the breadboard. The outer two rows of holes are connected along the length of the board and may be used for connecting to the power source. These must then be connected via jumper leads to the inner rows of holes, which are connected along the width of the board, with a break along the middle.

It is always good practice to test the connectivity of any new board that you are using, possibly with a multimeter.

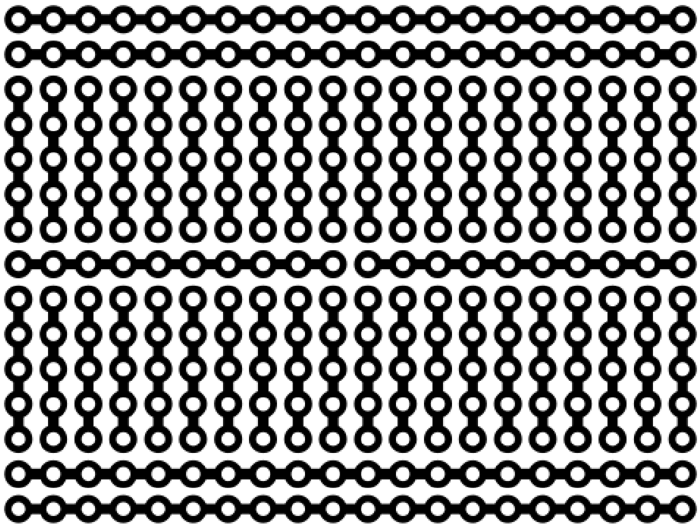


Figure 3: Typical connections on a breadboard (cf. Fig 2). Dark areas show conducting metal regions.

2.3 Power supplies

Power supplies provide a way of supplying a stable DC power source in the lab. Fig. 4 shows an example exhibiting a built-in digital voltmeter and ammeter. Note that the output voltage and current may be set from the control panel.

2.4 Multimeters

Figure 5 shows an example of a digital multimeter. Typically, a multimeter will be able to measure both DC and AC voltages and currents; measure resistance directly and sometimes may be able to measure capacitance. A multimeter may also have an electrical connection tester, linked to a buzzer.

2.5 Analogue oscilloscope

An analogue oscilloscope uses a cathode ray tube (CRT) to visualise a time varying voltage. Modern oscilloscopes provide this functionality digitally plotting the output on, say, a liquid crystal display. However, the CRT provides a more physically intuitive method for doing this. Figure 6 is a photograph of the screen of dual trace oscilloscope showing two sinusoidal output signals from a function generator.

In an oscilloscope CRT, a beam of electrons is swept horizontally by an electric field (rather than by a magnetic field) at a set rate. This provides the *time base* of the trace and should be commensurate with the period of the signal under study. The vertical deflection is provided by another electric field,

Figure 4: Picture of a Manson EP-613 power supply.

Figure 5: Example of a digital multimeter for measuring voltage and current.

which is directly proportional to the signal voltage. When the electrons hit the phosphor coated screen, light is emitted displaying the *trace* of the input signal.

A grid on the screen facilitates measurement of the signal. The vertical scale is adjusted by selecting the number of volts per division from the control panel. The time base is adjusted by setting the time unit per division.

In order to synchronise the trace, the start of the time sweep is triggered at a certain voltage or rate of change of voltage. The *source* input used to trigger the

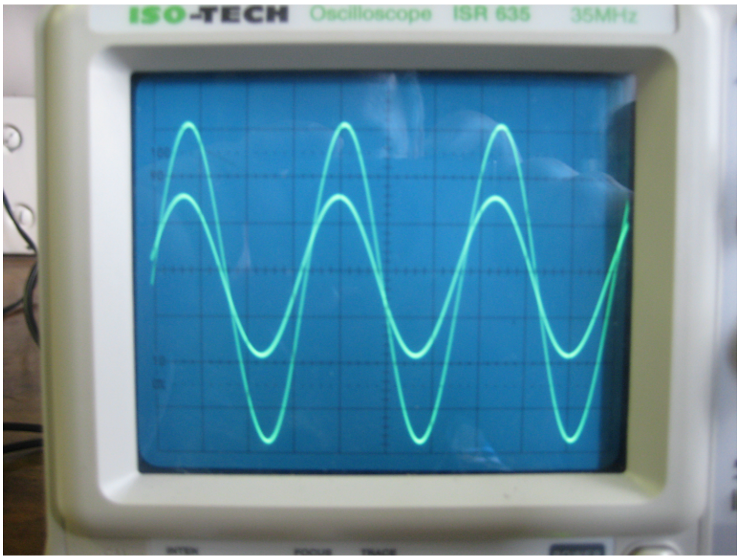


Figure 6: The screen of an analogue oscilloscope with dual trace, showing the output of a sinusoidal signal from a function generator.

sweep must also be correctly selected. Very often, one would use *AC coupling*, which filters out any DC component of the input signal.

2.6 Function generator

A function generator provides a time-varying output voltage. Typically such a unit would provide sinusoidal and square wave outputs and allow user selection of the peak-to-peak voltage and frequency. Usually, the signal is synthesised digitally. Figure 7 shows the front panel of a typical unit.

Figure 7: The front panel of a GFG-2120 synthesised function generator.

3 Pre-lab preparation

All the results to the pre-lab questions should be recorded in your lab book.

3.1 Resistors in series and in parallel

Using Ohm's and Kirchhoff's laws, you should derive expressions the effective resistance of (a) a number of resistors in series and (b) a number of resistors in parallel.

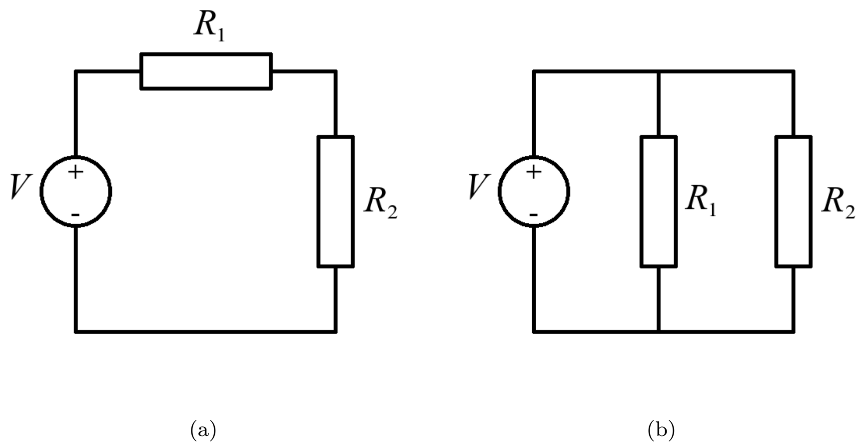


Figure 8: Resistors in (a) series and (b) parallel.

3.1.1 Resistors in series

Figure 8 (a) shows a circuit with two resistors R_1 and R_2 in series.

(a) Derive an expression for the effective resistance of these two resistors.

(b) Generalise this result for a system of N resistors in series.

3.1.2 Voltage divider

Two resistors in series may be thought of as a *voltage divider*. This is especially useful when used in conjunction with a *potentiometer*, or simply 'pot', shown in Fig. 9. This is a variable resistor with 3 terminals. The middle terminal is connected to a contact that sweeps over a resistive track, dividing the total resistance of the track into two resistances. It can therefore be used to provide a variable voltage.

(c) Using the results of the previous sub-section, find expressions for the voltages dropped over R_1 and R_2 in Fig. 8 (a) in terms of the total voltage V and the resistances.

3.1.3 Resistors in parallel

Figure 8 (b) shows a circuit with two resistors R_1 and R_2 in parallel.

(d) Derive an expression for the effective resistance of these two resistors.

(e) Generalise this result for a system of N resistors in parallel.

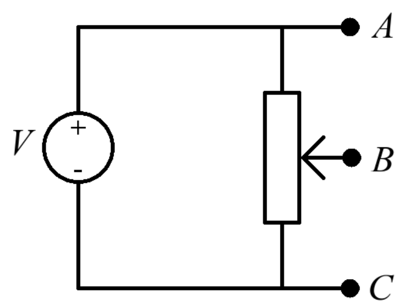


Figure 9: A potentiometer used as a voltage divider.

3.2 Analysis of a resistive circuit

(f) Analyse the circuit shown in Fig 10 and find (i) the effective resistance of the total circuit and (b) the voltage drops over each resistor.

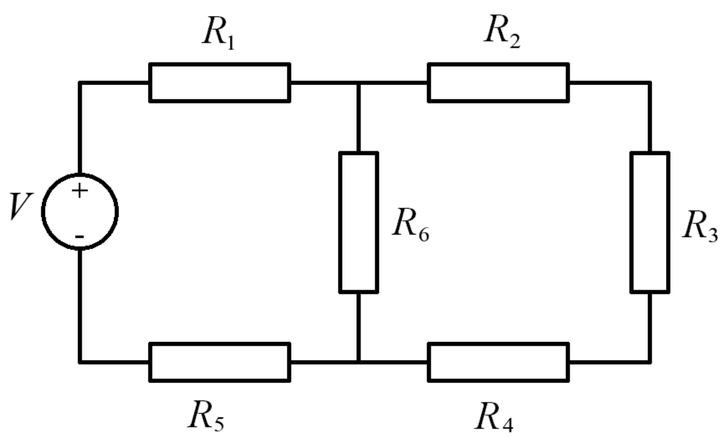


Figure 10: A resistive circuit.

4 Methods

In this session, you will first familiarise yourself with the lab equipment described above. Note that you should set voltages that yield low currents (< 100 mA) for the chosen resistors.

4.1 Resistors in series and in parallel

Select two different but comparable resistors and record their nominative values and tolerances in your lab book. Next, determine the actual resistance of component by

(a) Use of a multimeter to measure the resistance directly.

(b) Constructing a circuit on the breadboard, connecting it to a power source and measuring both voltage across the resistor and current in the circuit. Note that you will have to break the circuit to insert the ammeter in series with the resistor. Calculate the resistance using Ohm's law.

(c) Repeat (b) using an oscilloscope to measure the voltage.

(d) Repeat (c) using a signal generator to power the board with an AC source. You should select a frequency that gives a stable trace on the oscilloscope. Record the peak-to-peak voltages and divide by $2\sqrt{2}$ to obtain the root-mean-square (RMS) values. Note that for the current measurement, you should select the AC option on the multimeter. Does changing the frequency have any effect on the measured values?

4.1.1 Resistors in series

(e) Using the measured values of the resistors, calculate the effective resistance when they are wired in series as in Fig. 8 (a).

(f) Repeat (b) - (d) above for the series circuit.

4.1.2 Resistors in parallel

(g) Using the measured values of the resistors, calculate the effective resistance when they are wired in parallel as in Fig. 8 (b).

(h) Repeat (b) - (d) above for the parallel circuit.

4.2 Resistive circuit

Select four more different but comparable resistors and record their nominative values.

(g) Using the measured values of the resistors, calculate the effective resistance when they are wired as in Fig. 10.

(h) Repeat (b) - (d) above for this circuit.

4.3 Writing up the report (post-lab)

Write up your results in a report. This should have the following structure:

Title Here give the session number and some meaningful title for the experiments.

Author (Your name)

Abstract A very brief synopsis of the report content including any major conclusions.

Introduction A short introduction to the report. This is where to include any possible applications of the results / methods described.

Theory A short write-up of the theory required (this may be given in the introduction if it is very brief). Include any pre-lab results in this section.

Method A description of your experimental set-up and methods used.

Results Report your measured results in this section, together with estimates of experimental error. Compare to theory where appropriate. Plot any results that you can, otherwise tabulate. Graphs and tables should always have a caption and figure / table number. Also, clearly label graph axes, indicating the units used (or AU for arbitrary units). Also include error bars if these would be visible on the scale used.

Discussion and conclusions Discuss your results and, where possible, draw justified conclusions. If you encountered problems in the lab, this is the section to point that out in. However, avoid unjustified or sweeping comments.

References (If appropriate).