

UEECD0046

Solve problems in single path circuits

Workbook

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About this unit

This unit covers determining correct operation of single source d.c. series and providing solutions as they apply to various electrotechnology work functions. This resource encompasses working safely, problem solving procedures, including the use of voltage, current and resistance measuring devices, providing solutions derived from measurements and calculations to predictable problems in single and multiple path circuits.

This unit will cover:

- The electrotechnology industry
- Base electrical circuit
- Ohm's Law
- Electrical power
- Effects of electrical current
- EMF sources, energy sources and conversion
- Resistors
- Series circuits
- Factors affecting resistance
- Effects of meters in a circuit
- Resistance measurement

Topic 1 Electrotechnology industry

We all rely on electricity for getting things done in almost every aspect of our daily lives. For this reason, the electrotechnology industry includes a broad range of disciplines, and is constantly expanding and evolving as new technologies are developed.

This topic provides an overview of electrotechnology in Australia, including:

- Areas of employment
- Electricity generation
- Basic concepts of electricity
- Hazard identification and control measures
- Hazard reporting
- OHS/WHS records
- Safe isolation
- Materials
- Serviceability of tools and equipment

The electrotechnology industry impacts on almost every aspect of daily life. The technology ranges from traditional light and power, hardware platforms and networking automation to virtual enterprise, the internet and fibre-optics. The spread of new information processing and communication technologies means that the industry is developing rapidly.

The industry includes the installation, servicing, repair and maintenance of electrical and electronic equipment for industrial, commercial and domestic purposes. It comprises communications, distribution and transmission, electrical generation and computer data and communications cabling systems and Sustainable/Renewable Energies. The telecommunications and information technology aspects of the industry are becoming increasingly important as the knowledge economy alters the way businesses operate, as is Sustainable Energy Practices and Renewable Energies are on our environment.

1.1 Areas of employment

People employed in the electrotechnology industry can be found working in most sectors. Principal areas include:

- Construction
- Communication services
- Electrical generation, transmission, and distribution
- Manufacturing
- Mining
- Chemical
- Commercial
- Industrial
- Housing/domestic
- Resources
- Transport and logistics
- Maritime
- Health and community services
- Wholesale and retail
- Sustainable and Renewable Energies

The major occupations in the electrotechnology trades include:

- Electrician
- Electrical Fitter
- Electrical Mechanic
- Electronics Technician
- Communications Technician
- Computer System Technician
- Refrigeration and Air Conditioning Mechanic
- Information Technology Technician
- Instrumentation and Control Technician
- Data and Voice Technician
- Telecommunications Technician

These trades often encompass Licensing, Registration, Sustainable Energy certification, career paths or pathways, apprenticeships, training plans and agreements, and the completion of training and assessment processes to confirm competence by registered training organisations.

The current rate of technological change in the industry is very high and is expected to increase. The use of 'smart' technology such as home automation and the integration of systems such as data, voice and video, is becoming common in many sectors of the industry.

The electrotechnology industry is a multi-billion-dollar industry in Australia and a multi-trillion-dollar industry worldwide.

1.2 Electricity generation

The majority of electricity is currently generated by electromagnetic induction. The laws of electromagnetic induction state that electrical energy can be produced by moving a conductor with respect to a magnetic field.

A basic electromagnetic generator consists of a magnet that rotates in the centre of several stationary coils of conductive wire. In thermal power stations, high pressure steam is used to rotate a turbine which is coupled to the magnet. As the magnet is rotated, electrical energy is 'electromagnetically induced' into the stationary coils.

You will learn much more about electromagnetic induction in later units. For the purpose of this topic, it is sufficient to understand that electricity can be generated by rotating a turbine.

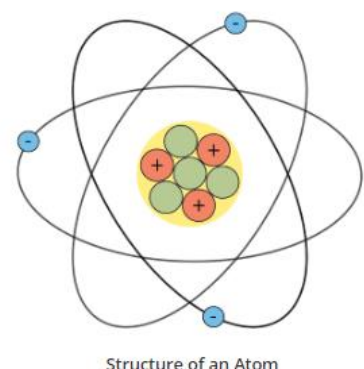
Electricity generation in Australia			
Method	Environmental impact	Approx. market share	Description
Black Coal	Non-renewable	51%	- Coal is burnt in a furnace to produce heat - The heat is used to turn water into steam - The steam is used to rotate a turbine - Primary method of power generation in Australia
Brown Coal	Non-renewable	24%	
Natural Gas	Non-renewable	15%	- Gas is burnt in a furnace to produce heat - The heat is used to turn water into steam - The steam is used to rotate a turbine
Hydro	Renewable	7%	- Water is released through a dam - The flow of water is used to rotate a turbine
Wind	Renewable	3%	Natural wind currents are utilised to rotate a turbine
Photoelectric (solar)	Renewable	<1%	Electricity is generated when light strikes the surface of a photovoltaic (PV) array
Geothermal	Renewable	<1%	- Natural heat from within the earth is used to turn water into steam - The steam is used to rotate a turbine
Tidal & Wave	Renewable	<1%	- The movement of waves/tides is used to create water pressure - The water is used to rotate a turbine
Nuclear	Non-renewable	0%	- Radioactive material is used to heat water - The water turns to steam - The steam is used to rotate a turbine - One nuclear reactor exists in Australia for research purposes

1.3 Basic concepts of electricity

1.3.1 Matter

In order to understand electrical concepts, we must understand the basic structure of matter. All matter is made up of atoms containing neutrons, protons and electrons:

- Neutrons are located in the nucleus of an atom, and have no electric charge
- Protons are located in the nucleus of an atom, and have a positive electric charge
- Electrons orbit the nucleus of an atom, and have a negative electric charge



1.3.2 Current electricity

The phenomenon of 'electricity' refers to the presence and movement of electric charge. It is the movement of electrons between materials that can result in an overall electric charge being exhibited by a material:

- If a material receives extra electrons, such that it has more than normal, then it becomes negatively charged
- If a material loses electrons, such that it has less than normal, then it becomes positively charged

Two items having the same charge will repel each other whilst two items having different charges will attract one another.

1.3.3 Static electricity

Static electricity refers to the build-up of an electric charge on the surface of objects. Rubbing together of two materials can transfer negative charges, or electrons. For example, if you rub your shoe on a carpet, your body collects extra electrons. The electrons cling to your body until they can be released. The charge is either bleed off to earth slowly or quickly discharged by grounding to earth by for example, touching a door knob and getting a shock.

1.4 Hazard identification and control measures

The risk management process involves four steps:

1. Identify hazards - find out what could cause harm.
2. Assess risks, if necessary - understand the nature of the harm that could be caused by the hazard, how serious the harm could be and the likelihood of it happening.
3. Control risks - implement the most effective control measure that is reasonably practicable in the circumstances.
4. Review control measures - to ensure they are working as planned.

Identifying hazards involves finding all of the things and situations that could potentially cause harm to people. Hazards generally arise from the following aspects of work:

- The physical work environment
- The equipment, materials and substances used at the workplace
- Work tasks and how they are performed
- Work design and management.

Methods that can be used to identify hazards in your workplace include:

- Inspecting the workplace and observing how work tasks are performed
- Consulting your workers about any health and safety problems they have encountered in doing their work
- Analysing your records of workplace incidents, near misses and worker complaints
- Reviewing any information and advice about hazards and risks relevant to your particular industry or the type of work that you do, for example, information provided by industry associations, manufacturers or suppliers.

A risk assessment should be done when:

- There is uncertainty about how a hazard may result in injury or illness
- The work activity involves a number of different hazards and there is a lack of understanding about how the Hazards may interact with each other to produce new or greater risks
- Changes at the workplace occur that may impact on the effectiveness of control measures.

The ways of controlling risks are ranked from the highest level of protection and reliability to the lowest. This is known as the hierarchy of risk control. You must work through the hierarchy of control in order and, where possible, implement risk controls high in the order as follows:

1. Eliminate - remove the hazard completely from the workplace, for example, removing trip hazards on the floor or disposing of unwanted chemicals. This is the most effective control measure and must always be considered before anything else.
2. Substitute - substitute or replace the hazard with a less hazardous work practice, for example, replace solvent-based paints with water-based paints.
3. Isolate - as much as possible, separate the hazard or hazardous work practice from people by distance or using barriers, for example, placing guards around moving parts of machinery.
4. Engineering controls - these are physical control measures, for example, use a trolley to lift heavy loads.
5. Administrative controls - these should only be considered when other higher order control measures are not practicable. These are work methods or procedures that are designed to minimise the exposure to a hazard, for example, developing a procedure on how to operate machinery safely or use signs to warn people of a hazard.
6. Personal protective equipment (PPE) - this should be the last option. PPE, such as ear muffs, hard hats, gloves and protective eyewear, relies on the proper fit and use of the PPE, but does nothing to change the hazard itself.

In some cases a combination of control measures may need to be implemented to provide the highest level of protection that is reasonably practicable. When selecting and implementing a combination of control measures it is important to consider whether any new risks might be introduced as a result. Control measures implemented must be reviewed, and if necessary, revised to make sure they work as planned. There are certain situations where you must review your control measures, including:

- When the control measure is not effective in controlling the risk e.g. when an incident occurs
- Before a change at the workplace that is likely to give rise to a new or different health and safety risk that the control measure may not effectively control
- If a new hazard or risk is identified
- If the results of consultation indicate that a review is necessary
- If a Health and Safety Representative requests a review.

Control measures may be reviewed using the same methods as the initial hazard identification step.

1.5 Hazard reporting

If you are aware of a hazard in your workplace, you should report it promptly to your supervisor, employer or health and safety representative. Once a hazard has been identified, your employer and/or supervisor has a duty to assess the problem and eliminate any hazard that could injure workers.

1.6 OHS/WHS records

A worker should always contact his/her employer immediately when a serious accident occurs at the workplace. However, workers should be encouraged to report all injury incidents to their employer, even those resulting in very minor injuries. These reports will help to identify hazards in the workplace that may need to be addressed. These incidents will be recorded on an incident register for future reference.

The model Work Health and Safety (WHS) Act sets out certain types of workplace incidents that need to be notified to regulators. Only the most serious safety incidents are intended to be notifiable and they trigger requirements to preserve the incident site pending further direction from the regulator.

Notifiable incidents are:

- The death of a person
- A 'serious injury or illness', or
- A dangerous incident arising out of work carried out by a business, undertaking or a workplace.

Notifiable incidents relate to any person—whether an employee, contractor or member of the public.

If a notifiable incident occurs the model WHS Act sets out that:

- Immediate notification of a 'notifiable incident' to the regulator, after becoming aware of it
- If the regulator asks—written notification with 48 hours of the request, and
- Preservation of the incident site until an inspector arrives or directs otherwise.

Notification is also required of any incident in relation to a workplace that exposes a worker or any other person to a serious risk resulting from an immediate or imminent exposure to:

- An uncontrolled escape, spillage or leakage of a substance
- An uncontrolled implosion, explosion or fire
- An uncontrolled escape of gas or steam
- An uncontrolled escape of a pressurised substance
- Electric shock:
- The fall or release from a height of any plant, substance or thing
- The collapse, overturning, failure or malfunction of, or damage to, any plant that is required to be design or item registered under the Work Health and Safety Regulations
- The collapse or partial collapse of a structure
- The collapse or failure of an excavation or of any shoring supporting an excavation
- The inrush of water, mud or gas in workings, in an underground excavation or tunnel, or
- The interruption of the main system of ventilation in an underground excavation or tunnel.

Any of these occurrences are reportable as a 'dangerous incident' (or 'near miss') if a person is exposed to a serious risk from immediate or imminent exposure to a hazard. For most hazards such as plant or a structure collapsing a person will need to be in the immediate vicinity to be exposed to a serious risk to their health or safety. However, some hazards such as an uncontrolled leak of a hazardous gas or a fire can travel towards a person and expose them to a serious risk to health and safety away from the original source. A dangerous incident includes both immediate serious risks to health or safety, and also a risk from an immediate exposure to a substance which is likely to create a serious risk to health or safety in the future, for example asbestos or chemicals. Only occurrences involving a 'serious risk' are notifiable taking into account the likelihood of a serious illness or injury occurring from the incident. This would include any situation which seriously endangers or threatens the health or safety of a person.

1.7 Safe isolation

1.7.1 Safe isolation procedures

Prior to carrying out work on low voltage equipment, the equipment supply should be isolated and tested to verify isolation. This is of extreme importance in order to reduce the risk of receiving an electric shock.

The only circumstances under which 'live' work is permitted, is when the risk to health and safety will be greater if the equipment is isolated.

The procedure for safe isolation of a circuit is to:

1. Perform a job safety analysis
2. Identify the isolation points
3. Notify the relevant personnel of your intent to isolate
4. Isolate, lock-off and tag isolation points
5. Test to verify isolation
6. Test your tester on a known live source to verify correct operation

Electrical Safety Tags	
Front and Back	Application
 Personal Danger Tag	A personal danger tag is used to indicate that a circuit has been isolated so that work can be carried out on the connected equipment. This means that ignoring the tag and energising the circuit is likely to result in a fatal electric shock. Only the person who affixed the tag has the authority to remove it, or they can authorise another person to do so. These types of tags are typically affixed to control and protection devices such as isolation switches, circuit breakers and fuse holders.
 Out of Service Tag	An out of service tag is used to identify equipment that is damaged, faulty, or should not be used for some other reason. It is intended to ensure that a person does not attempt to operate the equipment. The person responsible for verifying the serviceability of the equipment removes the tag after any repairs or maintenance has been completed. It may commonly be seen affixed to faulty appliances such as power tools and machinery, but can be used on any item that is not fit for service.

1.8 Materials

Materials required for any job need to be determined and well planned. Both your supervisor and you should pre-plan what you will use as tools and equipment and what materials you need to complete the job. Manufacturer apparatus dismantling and assembling guides may be a good source of information to determine tool or equipment requirements. An equipment list helps in the planning of any job and can aid you in the effectiveness of completing your task. Most standard jobs have a set amount of tools and equipment required to complete the job. Standard operating procedures (SOP) for most organisations and companies cover such detail and you need to have a good understanding of them.

1.9 Serviceability of tools and equipment

All tools and equipment need to be well organised and maintained in good working condition. They should be stored in a secure place so that they are safe and easy to find. This is usually best done in a place which is separate from the worksite. Lost tools are expensive to replace and much time can be wasted if they are not available and ready to use when needed. It is usual for those who have responsibility for looking after tools, equipment and materials to keep an inventory (list) of these things.

Using any kind of tool or equipment can be dangerous if it is used incorrectly or is not in good working order.

Before selecting and using tools and equipment always ensure that it is in serviceable condition. Ensure any faults are reported to your supervisor. Any maintenance requirements such as sharpening needs to be maintained as per manufacturer's guidelines or your companies' procedures.



Summary

By now you should have a good overview of electrotechnology in Australia, including areas of employment, electricity generation, basic concepts of electricity, hazard identification and control measures, hazard reporting, OHS/WHS records, safe isolation, materials and serviceability of tools and equipment.

Topic 2 Base electrical circuit

In this topic, you will explore the basic electrical circuit, upon which all electrical circuits are based. You will learn about:

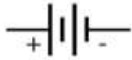
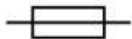
- electrical terminology
- circuit components
- the arrangement of components in a basic circuit
- basic quantities and units associated with electrical circuits

2.1 Circuit symbols and components

2.1.1 Basic circuit components

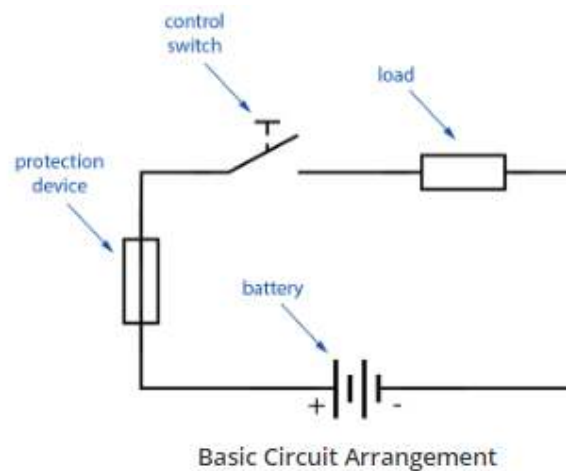
In a basic electrical circuit, these components are arranged in a specific order, as shown below

Control Switch			The purpose of the control switch is to control the flow of electrical energy in the circuit. For example, a light switch controls the flow of energy to a lamp.
Load			The purpose of the load is to convert the electrical energy into another form of energy. Example: a stove converts electrical energy into heat energy for cooking.
Connecting Wires			The purpose of the connecting wires is to connect the circuit components together into a 'circuit'.

Fundamental Circuit Components			
Component	Symbol	Illustration	Purpose
Power Source			The purpose of the power source is to supply electrical energy to the circuit.
Protection Device			The purpose of the protection device is to protect the circuit components in the event of an electrical fault. Example: a circuit breaker automatically disconnects the circuit when a fault occurs.
			

2.1.2 Basic circuit arrangements

The diagram below shows the arrangement of components in a basic circuit:



2.2 Multiple and sub-multiple units

2.2.1 SI units

The International System of Units (SI) is a standard metric system for expressing measured quantities. In Australia, SI units are used in the electrotechnology industry to express quantities of voltage, current, resistance, power, as well as many others. For this reason, it is important to understand the SI system of units, including multiples and sub-multiples.

The following table defines some of the fundamental electrical SI quantities and units.

Common SI units used in electrotechnology		
Quantity	SI unit	Basic concept
Voltage (V)	Volts (V)	Electrical pressure
Current (I)	Amperes (A)	Electrical flow
Resistance (R)	Ohms (Ω)	The opposition to electrical flow
Power (P)	Watts (W)	The rate at which electrical energy is converted into another form of energy, e.g. light, heat or mechanical

2.2.2 Multiple and sub-multiple units

In order to express very large or very small quantities, a system of multiple and sub-multiple units is incorporated into the SI system. The following table shows the multiples and sub-multiples used to represent values. It also includes an example of how they can be applied to representing different values of voltage.

Multiples and sub-multiples		
Tera (T)	$\times 10^{12}$	1 TV = 1,000,000,000,000 volts
Giga (G)	$\times 10^9$	1 GV = 1,000,000,000 volts
Mega (M)	$\times 10^6$	1 MV = 1,000,000 volts
kilo (k)	$\times 10^3$	1 kV = 1,000 volts
Base unit	$\times 10^0$	1 V = 1 volt
milli (m)	$\times 10^{-3}$	1 mV = 0.001 volts
micro (μ)	$\times 10^{-6}$	1 μ V = 0.000001 volts
nano (n)	$\times 10^{-9}$	1 nV = 0.000000001 volts
pico (p)	$\times 10^{-12}$	1 pV = 0.000000000001 volts

2.2.3 Converting multiples and sub-multiples

The only real difference between representing a number in the base unit and representing a number in a multiple or sub-multiple unit is the position of the decimal point. The following diagram illustrates the principle of converting between base and sub-multiple units by moving the decimal place.

Converting Base Units to Sub-Multiple Units	
0.0052 A ↓ 0.0052 ↓ 5.2 mA	In this example, the decimal place is moved three places to the right in order to convert a quantity of amperes (A) into a quantity of milliamperes (mA). Remember: The <i>number</i> representing a given quantity will always be larger when represented using a smaller unit (i.e. 5.2 is larger than 0.0052)

The following diagram illustrates the principle of converting between base and multiple units by moving the decimal place.

Converting Base Units to Multiple Units	
3500 W ↓ 3.500 ↓ 3.5 kW	In this example, the decimal place is moved three places to the left in order to convert a quantity of watts (W) into a quantity of kilowatts (kW). Remember: The <i>number</i> representing a given quantity will always be smaller when represented using a larger unit (i.e. 3.5 is smaller than 3500)

Summary

Now this topic is completed, you know about basic electrical circuits. Including electrical terminology, circuit components, the arrangement of components in a basic circuit and basic quantities and units associated with electrical circuits.

Topic 3 Ohm's Law

In this topic, you will learn about basic circuit operating conditions, and the relationships between circuit operating parameters, including:

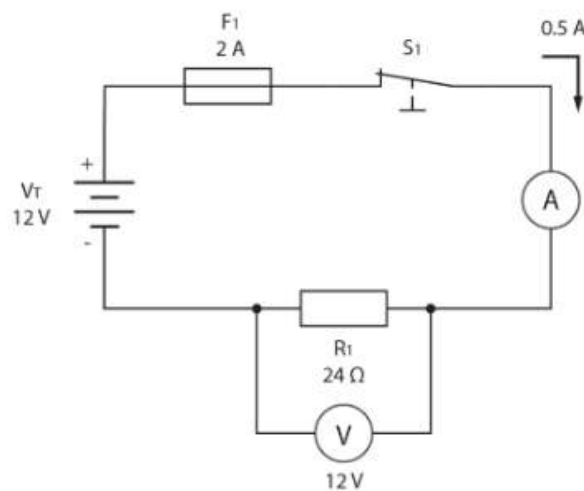
- The arrangement of circuit components
- The relationships between voltage, current and resistance
- The effect of an open-circuit
- The effect of a closed-circuit
- The effect of a short-circuit
- Ohm's Law

3.1 Basic circuit relationships

3.1.1 Single path circuit

The components of a 'single path' circuit are connected so that there is only one path through which an electric current can flow. The following diagram shows a basic single path circuit with a voltmeter and ammeter connected to measure the load voltage and current.

Note that the ammeter is connected in series with the load to measure the current flowing through the circuit, and the voltmeter is connected in parallel with the load to measure the voltage across the load.



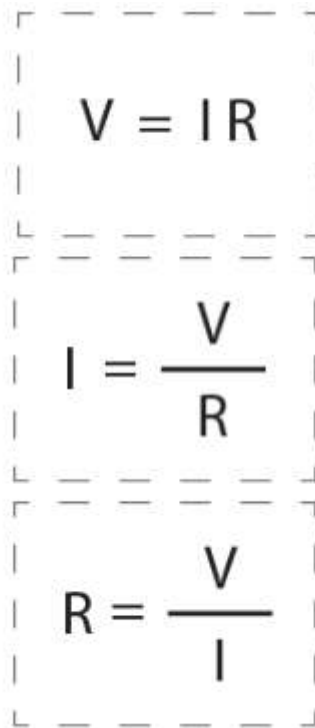
3.2 Ohm's Law

Ohm's Law shows how voltage, current and resistance will interact in a circuit. This knowledge is fundamental to all areas of electrical work. For example, it helps you to:

- Understand how electrical equipment works
- Install and connect circuits safely
- Identify when electrical equipment might be unsafe
- Figure out why electrical equipment is not working correctly
- Repair faulty electrical equipment

Ohm's Law states that the current flowing in a circuit will be directly proportional to the applied voltage, and inversely proportional to the resistance. This means that if the supply voltage is increased, the current will increase, but if the circuit resistance is increased, the current will decrease.

Ohm's Law can be expressed in three ways:



The image shows three mathematical expressions for Ohm's Law, each enclosed within a dashed rectangular border. The first expression is $V = IR$. The second expression is $I = \frac{V}{R}$. The third expression is $R = \frac{V}{I}$.

Where:

- V = voltage measured in volts (V)
- I = current measured in amperes (A)
- R = resistance measured in ohms (Ω)

One of the most common applications for Ohm's Law is to predict how much current will flow when a circuit is switched on. A circuit will usually be connected with a known resistance (the load) connected to a known voltage (the supply). By dividing the voltage (volts) by the resistance (ohms), we can calculate the current.

Worked Example 1 – Calculating Current

Calculate the current flowing in a circuit with a resistance of $24\ \Omega$ if the supply voltage is 18 volts.

$$I = V/R$$

$$I = 18 \div 24$$

$$I = 0.75\ \text{amperes}$$

Worked Example 2 – Calculating Voltage

Calculate the voltage needed to supply 2.3 amperes into a circuit with a resistance of $10\ \Omega$.

$$V = IR$$

$$V = 2.3 \times 10$$

$$V = 23\ \text{volts}$$

Worked Example 3 – Calculating Resistance

Calculate the resistance of a circuit if the current is 3.1 amperes and the voltage is 75 volts.

$$R = V/I$$

$$R = 75 \div 3.1$$

$$R = 24.19\ \text{ohms}$$

3.3 Basic circuit conditions

3.3.1 Circuit conditions

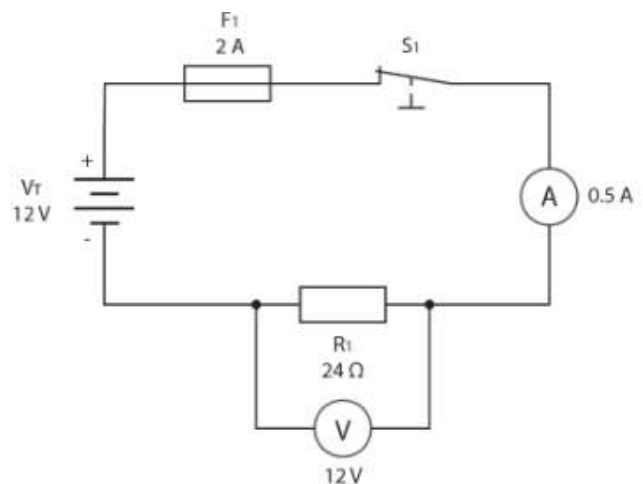
There are three basic circuit conditions that will be discussed in this topic, these are:

- Closed-circuit
- Open-circuit
- Short-circuit

We will see how each of these circuit conditions affects the parameters of a 12 V circuit supplying a $24\ \Omega$ load. The circuit is protected by a 2 A fuse, and an ammeter, voltmeter and control switch are also connected in the circuit.

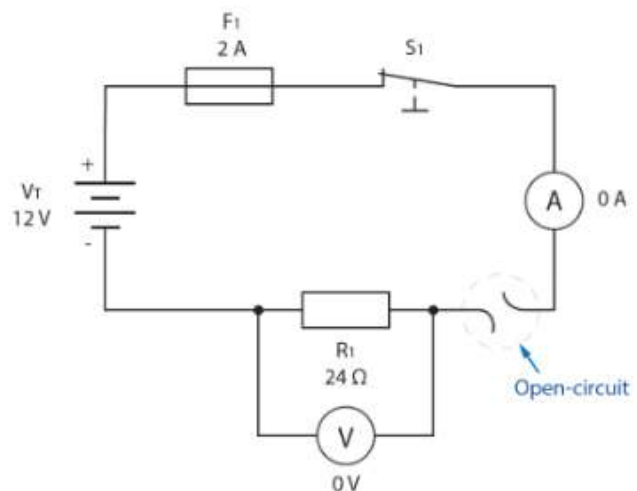
3.3.2 Closed circuits

A closed-circuit is when circuit controls are operated to energise a load. Closing the circuit switch creates a continuous conductive loop, through which electric current can flow. The following diagram shows the closed-circuit condition. Note that the circuit switch is in the closed position, and the normal load current of 0.5 amperes is flowing in the circuit.



3.3.3 Open circuits

An open-circuit is a break in a conductor or component that should normally be electrically continuous. The following diagram shows a circuit with an open-circuit in the positive wire.

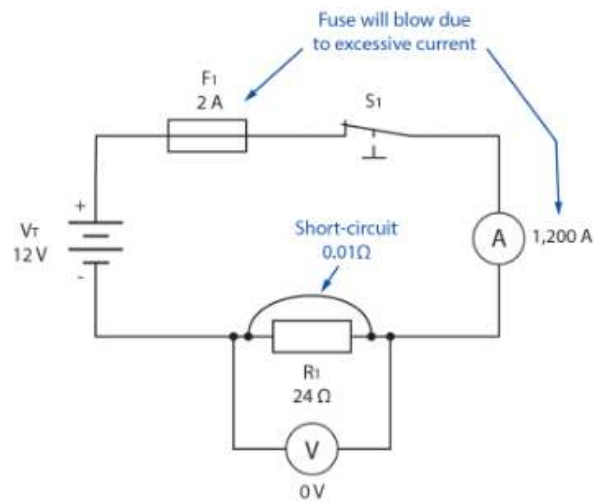


When an open-circuit occurs in a single path circuit, the total circuit resistance becomes infinite causing the load current to drop to zero.

There can be many causes of open-circuits, for example a wire falling out of a terminal, or a component 'burning out' due to high temperatures or excessive currents.

3.3.4 Short circuits

A short-circuit is a connection occurring between two conductors that should normally be insulated from one another. The following diagram shows a circuit where a short-circuit has developed across the load.



When a short-circuit occurs in a single path circuit, the total resistance is reduced, causing the total current to increase. In many cases, short-circuits increase the circuit current to dangerously high values, causing circuit protection devices to disconnect the circuit. In this case, the short-circuit current is 1,200 amperes, caused by the very low short-circuit resistance of 0.01 ohms. In practice, this would cause the 2 A fuse to operate very quickly to disconnect the circuit.

Short-circuits can be caused by the failure of insulation due to mechanical damage or some other form of stress.

Summary

After completing this topic you should now know basic circuit operating conditions, and the relationships between circuit operating parameters.

Topic 4 Electrical power

In this topic you will explore the concepts of 'acceleration', 'force', 'work', 'power' and 'energy'. You will also learn about the significance of power ratings on electrical equipment, and practice using different methods to determine power in a d.c. circuit. It is of great importance for electrotechnology workers to understand power ratings, as they indicate what will happen in the circuit when the equipment is connected to a given supply. This information is commonly used in the selection of cables and other equipment that aims to ensure circuits don't end up overheating and causing electrical fires.

4.1 Force, power, work and energy

4.1.1 Electrical power

Electrical power can be defined as the rate at which electrical energy is converted into another form of energy (e.g. light, heat, mechanical). The power equation can be expressed in a number of ways:

Where:

P = power measured in watts (W)

V = voltage measured in volts (V)

I = current measured in amperes (A)

$$P = VI$$

$$P = I^2 R$$

$$P = \frac{V^2}{R}$$

Worked Example – Calculating Power 1

Calculate the power dissipated when a current of 2 amperes flows through a 230 V resistive load.

$$P=VI$$

$$P=230 \times 2$$

$$P = 460 \text{ watts}$$

Worked Example – Calculating Power 2

Calculate the power dissipated when a current of 4 amperes flows through a load having a resistance of 32 Ω .

$$P=I^2 R$$

$$P=(4)^2 \times 32$$

$$P = 512 \text{ watts}$$

Worked Example – Calculating Power 3

Calculate the power dissipated when a 120 V supply is applied across a 50 Ω resistive load.

$$P=V^2/R$$

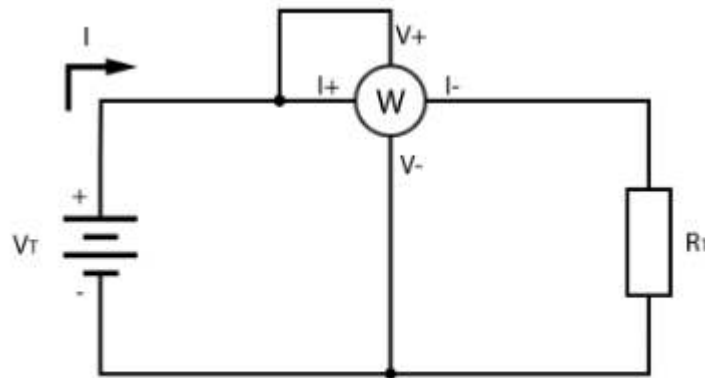
$$P=(120)^2 \div 50$$

$$P = 288 \text{ watts}$$

4.1.2 Measuring electrical power

In order to measure electrical power, a wattmeter can be connected into a circuit. Wattmeters are designed to indicate the power used in a circuit based on the circuit voltage and current values. Another method of determining power is to connect a voltmeter and ammeter into the circuit, and simply multiply the two readings ($P = VI$).

The diagram below shows how a wattmeter is connected into a basic circuit.



Wattmeter Connection

Energy

Energy can be defined as the capacity to expend power over a period of time. The equation for energy can be expressed as:

$$E = P t$$

Where:

E = energy measured in joules (J)

P = power measured in watts (W)

t = time measured in seconds (s)

Worked Example – Calculating Energy

Calculate the amount of electrical energy that has been converted into light (and heat) energy when a 60 watt lamp is left on for 200 seconds.

$$E = Pt$$

$$E = 60 \times 200$$

$$E = 12,000 \text{ joules}$$

Work

Work can be defined as a measure of force applied over a distance. The equation for work can be expressed as

Where:

W = work measured in joules (J)

F = force measured in newtons (N)

d = distance measured in meters (m)

$$W = F d$$

Worked Example – Calculating Work

Calculate the work done when a force of 120 newtons is applied to push a box 10 metres across the floor.

$$\begin{aligned} W &= Fd \\ W &= 120 \times 10 \\ W &= 1,200 \text{ joules} \end{aligned}$$

Force

Force can be defined as a measure of the degree to which a pushing or pulling action changes the motion of a mass/object. The equation for force can be expressed as:

Where:

F = force measured in newtons (N)

m = mass measured in kilograms (kg)

a = acceleration measured in meters per second per second (ms⁻²)

$$F = m a$$

Worked Example – Calculating Force

Calculate the force required to accelerate a mass of 80 kilograms at a rate of 20 metres per second per second.

$$\begin{aligned} F &= m a \\ F &= 80 \times 20 \\ F &= 1,600 \text{ newtons} \end{aligned}$$

4.2 Power ratings of devices

4.2.1 Power ratings of devices

Electrical appliances are rated in terms of voltage and output power. From these two ratings, it is possible to determine the approximate value of current that the device will draw from the supply. This is done by transposing the power equation:

Where:

P = power measured in watts (W)

V = voltage measured in volts (V)

I = current measured in amperes (A)

$$I = \frac{P}{V}$$

Worked Example – Calculating Current

Calculate the current that will be drawn by a 2.3 kilowatt kitchen appliance when connected to a 230 V supply.

$$\begin{aligned} I &= P/V \\ I &= 2300 \div 230 \\ I &= 10 \text{ amperes} \end{aligned}$$

Power ratings are of particular importance to note when connecting resistors into a circuit. The power rating of a resistor indicates the maximum amount of heat it can dissipate continuously without causing damage. In turn this indicates the maximum value of voltage that can be safely applied across the resistor. The easiest method of determining the maximum voltage for a given resistor is to use the following transposition of the power equation:

$$V = \sqrt{P R}$$

Where:

V = voltage measured in volts (V)

P = power measured in watts (W)

R = resistance measured in ohms (Ω)

Worked Example – Calculating Voltage

Calculate the maximum voltage that can safely be applied to a $45\ \Omega$ resistor that has a power rating of 5 W.

$$\begin{aligned}V &= \sqrt{PR} \\V &= \sqrt{5 \times 45} \\V &= 15\ \text{volt}\end{aligned}$$

The power ratings of electrical equipment indicate their maximum output power. If a voltage greater than 15 V is applied to the resistor in the worked example above, the heating caused by the resulting current would damage the resistor.

Summary

By now you should be familiar with the concepts of acceleration, force, work, power and energy, as well as the different power ratings on electrical equipment and methods of determining power.

Topic 5 Effects of electrical current

This topic is about the effects of electric current, including:

- physiological effects of current
- Heating magnetic and chemical effects of current
- Protection against the damaging effects of current

Electric current can be extremely hazardous to the health and safety of people and livestock. The current used to boil an electric jug for a cup of tea or coffee could easily kill if it passed through a human being. In addition, the heating effect of electric current flow has the potential to cause fires that could further endanger lives.

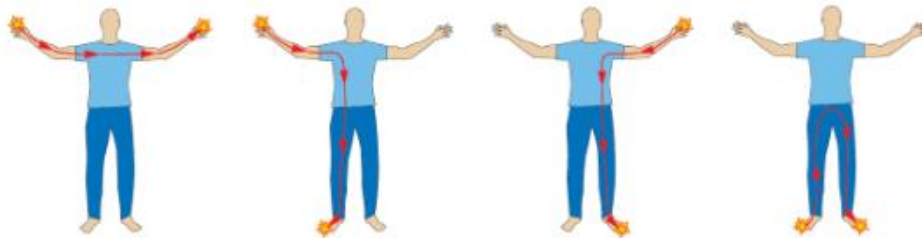
Understanding the effects of electric current flow is fundamental to ensuring your own safety, the safety of your co-workers, and for ensuring electrical installations are safe for use by members of the public.

5.1 Physiological effects of current

The physiological effects of an electric current on the human body depends on:

- The magnitude of the current
- The duration of exposure

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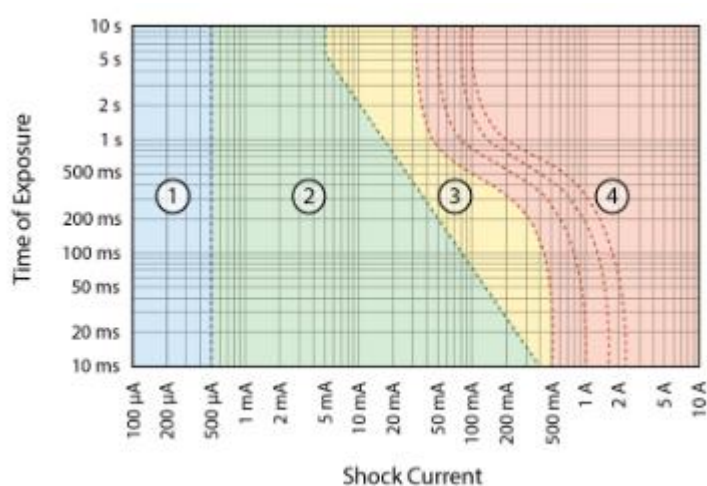


Examples of Shock Current Paths

- The path the current through body
- Whether current is alternating (a.c.) or direct (d.c.)

In general, the higher the shock current and the longer the duration of the shock, the more serious the injuries will be. An electric shock is also more likely to be fatal if the shock current passes through the heart or head.

A guide to the physiological effects of current is provided in the following chart.



Zone	Typical Physiological Effects
1 (blue)	- usually below the level of perception - no noticeable physiological effects on the body
2 (green)	- may startle a person causing them to pull away - minor discomfort - no serious physiological effects on the body
3 (yellow)	- muscular tensing and the inability to let go - increased discomfort to severe pain - difficulty breathing - disturbance to heart rhythms - burns
4 (red)	- cardiac arrest - asphyxiation - ventricular fibrillation - severe burns

5.2 Heating, magnetic and chemical effects of current

5.2.1 Magnetic effect of current

Whenever current flows in a conductor, a magnetic field is established around the conductor. The direction of the magnetic field depends on the direction of current in the conductor. Applications for the magnetic effect of current include:

- Alternators and generators
- Electric motors
- Transformers
- Relays and contactors

Heating effect of current

The heating effect of electric current occurs as a result of the work done to overcome the resistance of the conductor. Applications for the heating effect of current include:

- Heating elements
- Spot welding
- Arc welding

Chemical effect of current

The chemical effect of electric current occurs when current flows in an electrolyte that is in contact with two or more dissimilar metals. Applications for the chemical effect of current include:

- Battery charging
- Electroplating
- Refining metals

5.3 Protection against the damaging effects of current

5.3.1 Fundamental safety principle

To ensure minimum standards of safety, electrical installations in Australia are required to comply with the requirements of AS/NZS 3000, commonly known as the 'Wiring Rules'.

The three fundamental risks in an electrical installation are:

- Shock current
- Excessive temperatures
- Explosive atmospheres

Part 1 of AS/NZS 3000 states these fundamental safety risks, and specifies the types of protection required to control these risks. Part 1 also provides definitions for the terms given throughout the standard.

5.3.2 Mechanisms of corrosion

The term 'corrosion' refers to the deterioration of a metal due to a chemical reaction called 'oxidation'. There are three mechanisms by which metals can corrode:

- Galvanic corrosion
- Atmospheric corrosion
- Microbial corrosion

Galvanic corrosion occurs when an electrolyte (such as water) allows the movement of ions from one dissimilar metal to another. This causes the more reactive metal to deteriorate at an accelerated rate and the less reactive metal deteriorate at a reduced rate.

5.3.3 Atmospheric corrosion

Atmospheric corrosion occurs when a metal is exposed to an oxidizing agent in the environment (such as oxygen).

5.3.4 Microbial corrosion

Microbial corrosion occurs when certain types of microorganisms are present on a metal. The microorganisms produce oxidizing or acidic by-products that cause the metal to degrade.

Summary

Now that you have finished this topic, you should be aware of the physiological effects of current, heating, magnetic and chemical effects of current and protection against the damaging effects of current.

Topic 6 EMF sources, energy sources and conversion

This topic covers sources of EMF, primary, secondary and fuel cells and the efficiency of electrical systems and machines.

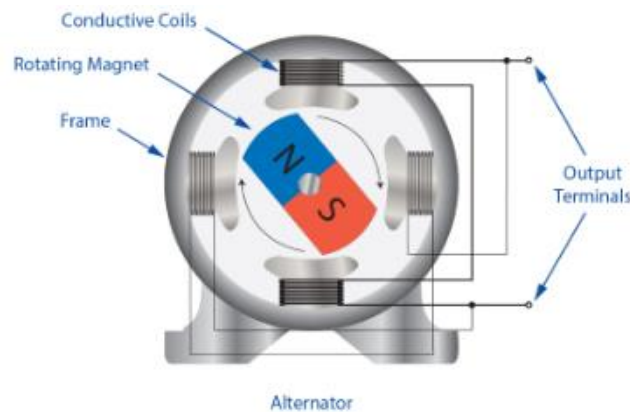
An electromotive force (EMF) can be defined as the electrical pressure, i.e. voltage, in a circuit. This topic explores the various methods of producing an E.M.F., as well as the efficiency of electrical systems, the effects of losses, and the principles of energy conservation.

6.1 Sources of EMF

6.1.1 Electromagnetic induction

An E.M.F. is produced when relative movement occurs between a magnetic field and a conductor within that magnetic field. The majority of modern generation systems operate based on this principle.

Note that you will study motors and generators in depth in later units. The diagram above is for illustration purposes only – you don't need to fully understand the operation of generators at this stage in your training.



It can be seen, however, that when the magnet is rotated, that the magnetic field will be moving with respect to the coils of conductive wire which remain stationary.

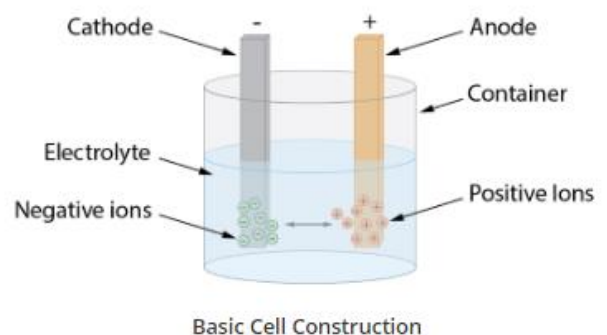
6.2 Primary, secondary and fuel cells

6.2.1 Primary and secondary cells

A basic cell consists of a two dissimilar metals (electrodes) immersed in a conductive liquid (electrolyte).

Due to the differing characteristics of the metals, positive and negative ions start to move through the electrolyte and collect at the electrodes:

- The electrode that attracts the positive ions is referred to as the 'anode'
- The electrode that attracts the negative ions is referred to as the 'cathode'



An E.M.F. develops across the electrodes due to an excess of electrons at the cathode, and a deficiency of electrons at the anode. When a circuit is completed between the anode and cathode, a current will flow.

The characteristics of a cell depend on the electrodes and electrolyte materials used in its construction.

A 'primary cell' is a cell in which the chemical reaction is irreversible – the cell becomes useless once the electrical energy has been used. An example of a primary cell is a non-rechargeable alkaline battery you might use in a TV remote.

A 'secondary cell' is a cell in which the chemical reaction can be reversed by applying an external E.M.F. across the electrodes. An example of a secondary cell is a rechargeable Li-ion battery you may find in your mobile phone.

6.2.2 Fuel cells

In order for a fuel cell to produce an E.M.F. a "fuel" must be supplied to the cell. In a hydrogen fuel cell, oxygen and hydrogen fuels react with one another to produce water (H_2O) and give off free electrons in the process.

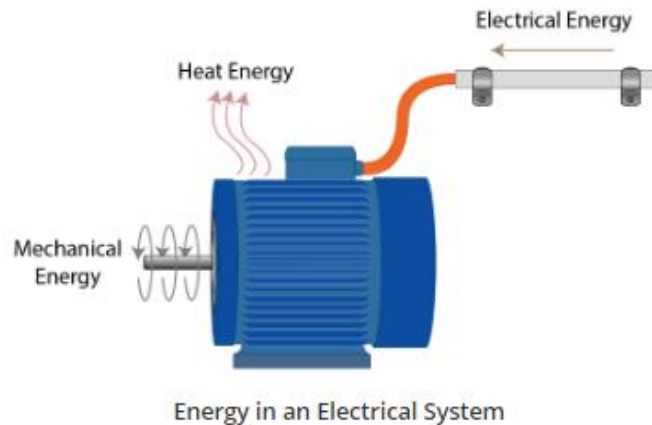
6.3 Efficiency of electrical systems and machines

6.3.1 Power in electrical systems

Every electrical system draws electrical energy in and converts it to another form of energy for a given purpose, such as heating food or lighting a room.

The power the electrical system receives is called the "input power". The useable power the electrical system gives out is called the "output power".

The amount of useable power that comes out of a system, however, is never quite as much as the power that goes in. This is because some power gets lost in the system, through the unwanted heating of the system wiring.



The difference between the input power and the output power is referred to as "losses".

In the motor diagram above, electrical power is put into the motor and mechanical power is given out, but some power is also lost in the form of heat. In reality, there would also be "magnetic losses" and "windage losses" associated with the motor.

For any electrical system, the ratio of the output power to its input power is called its "efficiency" (η).

The losses in a system can be determined from the following equation:

The efficiency of a system can be determined from the following equation:

$$\eta = \frac{P_{OUT}}{P_{IN}} \times 100$$

Where:

η = efficiency expressed as a percentage (%)

P_{OUT} = output power measured in watts (W)

P_{IN} = input power measured in watts (W)

$$\text{Losses} = P_{IN} - P_{OUT}$$

Worked Example – Calculating Efficiency and Losses

Calculate the efficiency and losses of an electric motor that draws 5 kW of power from the supply and outputs 4.5 kW of useable power to drive a mechanical load.

$$\begin{aligned}\eta &= P_{OUT}/P_{IN} \times 100 \\ \eta &= (4500/5000) \times 100 \\ \eta &= 90 \%\end{aligned}$$

$$\begin{aligned}\text{Losses} &= P_{IN} - P_{OUT} \\ \text{Losses} &= 5000 - 4500 \\ \text{Losses} &= 500 \text{ W}\end{aligned}$$

Summary

Now that you have completed this topic, you should be aware of sources of EMF, primary, secondary and fuel cells and the efficiency of electrical systems and machines.

Topic 7 Resistors

This topic explains all about resistors, including:

- Fixed resistors
- Variable resistors
- Non-linear resistors
- Selecting resistors

Resistors are electrical components that are found in most electrical and electronic devices. They serve a wide variety of purposes in different circuits, such as voltage reduction, heating and filtering. Resistors are likely to be encountered frequently when working on electrical and electronic equipment, and so it is important to be able to identify and understand the various types, as well as their functions in different circuits.

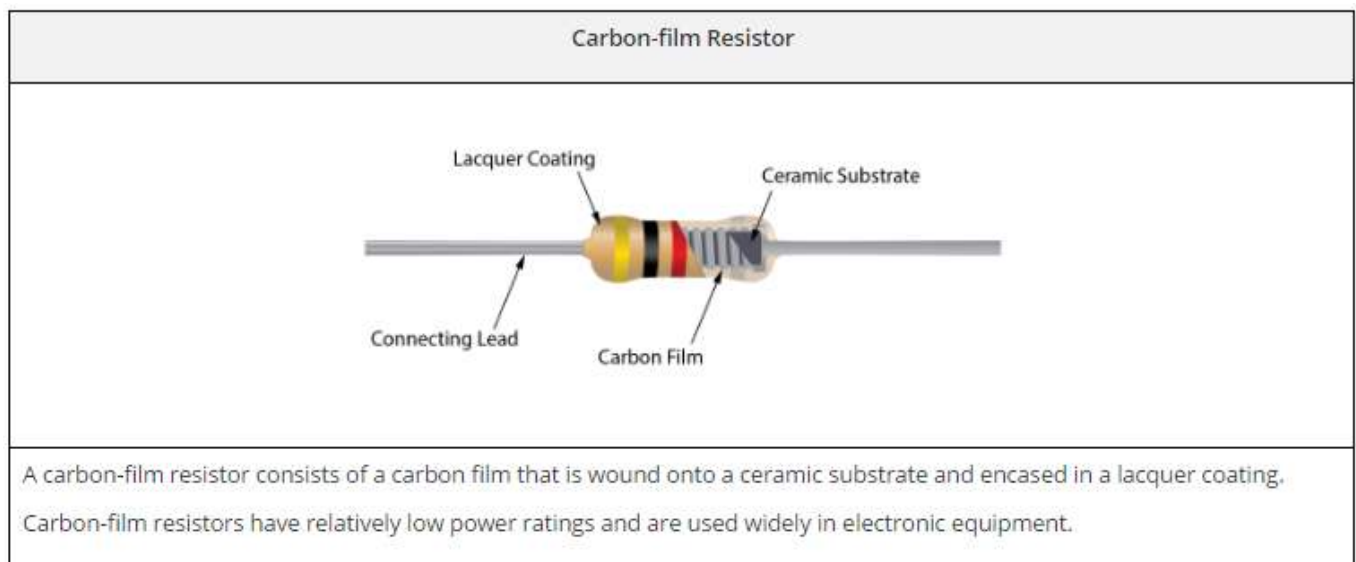
This topic explores the common types of resistors and their roles in electrotechnology equipment, plus the factors to consider when selecting resistors for different electrotechnology applications.

7.1 Fixed and variable resistors

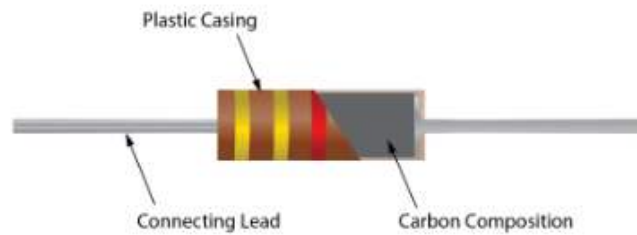
7.1.1 Fixed resistors

A fixed resistor is manufactured to have a specific resistance. Types of fixed resistors include:

- Carbon-film resistors
- Carbon composite resistors
- Wire-wound resistors
- Grid resistors

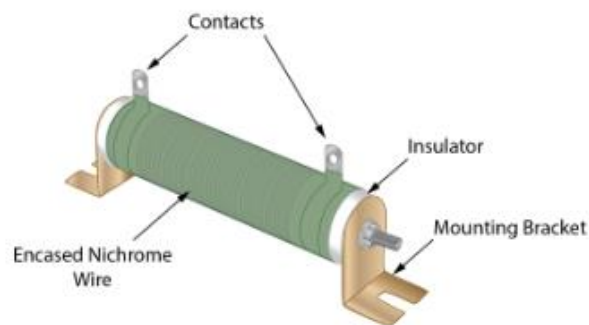


Carbon Composite Resistor

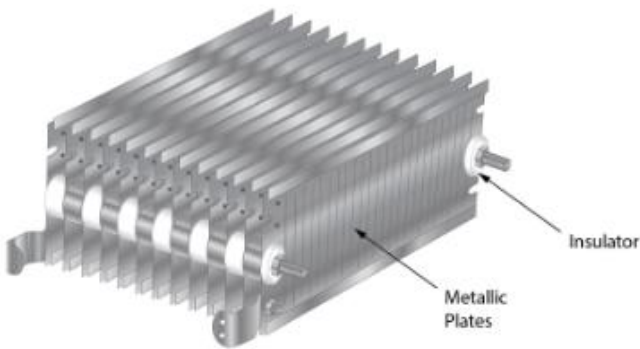


A carbon composite resistor consists of a carbon composition encased in a plastic coating. Carbon composite resistors have relatively low power ratings and are typically used in electronic equipment.

Wire-wound Resistor

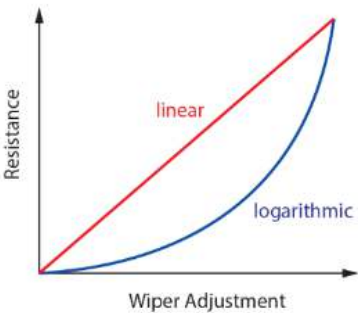


A wire-wound resistor consists of a nichrome wire that is wound onto a former and encased in an insulating material. Wire-wound resistors are available in a wide range of power ratings. Typical applications include power supplies and surge protection resistor networks.

Grid Resistor

A grid resistor consists of several stainless steel or cast iron plates arranged so that current must flow along the length of each plate. Grid resistors are commonly used for high power applications such as for motor control, load banks and harmonic filtering.

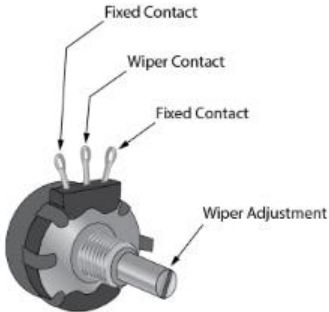
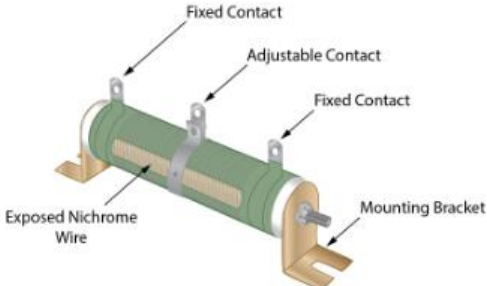
7.1.2 Variable resistors

A variable resistor is designed in such a way that the resistance can be changed manually. A variable resistor has two fixed contacts attached to the ends of a resistive strip and a 'wiper' contact that can be adjusted to vary the resistance between the fixed and wiper terminals.



The relationship between the resistance and the wiper position can be either linear or logarithmic:

- For a linear type, the change in resistance is directly proportional to physical adjustment
- For a logarithmic type, the change in resistance is not directly proportional to the physical adjustment

Common Variable Resistors	
	

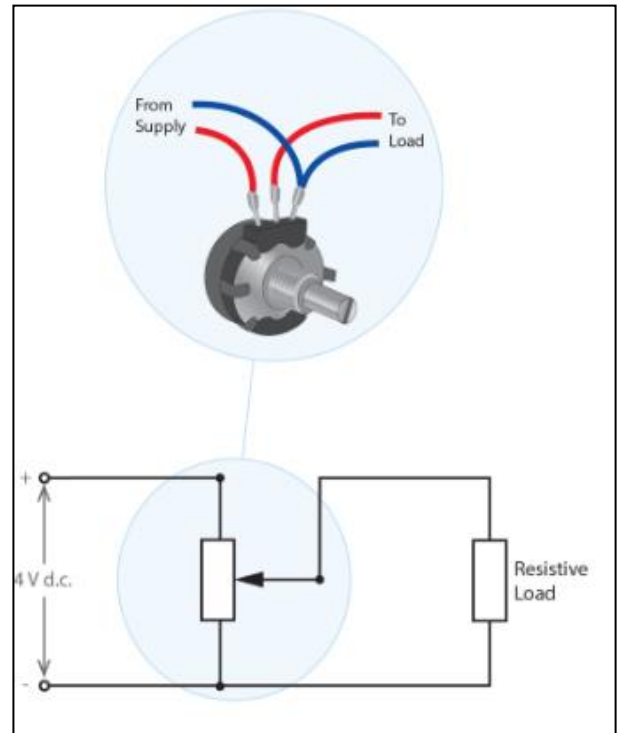
There are two primary types of variable resistors:

- Potentiometers
- Rheostats

Potentiometers and rheostats are essentially the same device; the difference between them is how they are connected and what they are used for.

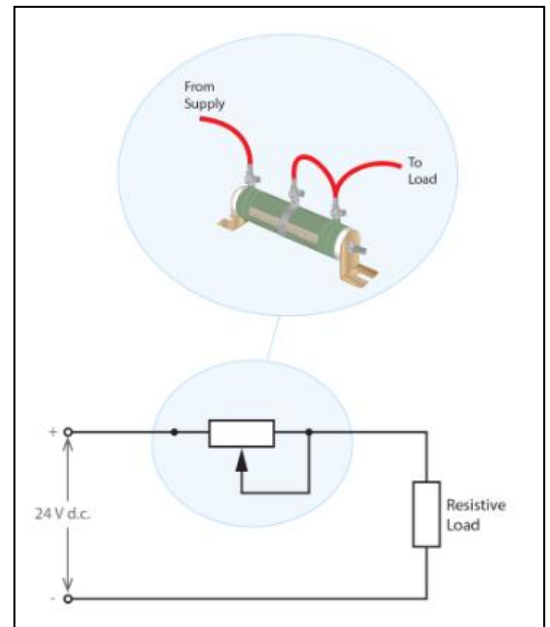
Potentiometer connection

The purpose of a potentiometer is to provide voltage adjustment. A typical application for a potentiometer is to provide volume control on audio equipment.



Rheostat connection

The purpose of a rheostat is to provide current adjustment. They come in a range of power ratings for low and high power applications, including motor control (high power), and various electronic equipment (low power).



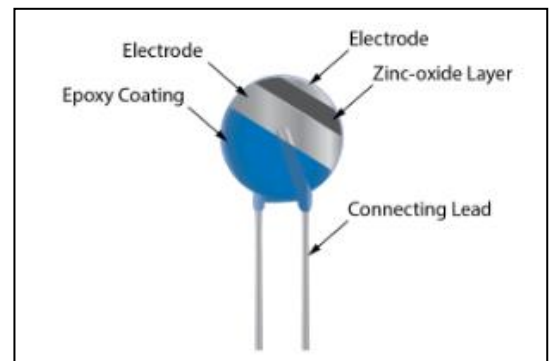
7.2 Non-linear resistors

Non-linear resistors

The resistance of a non-linear resistor varies depending on an external factor, such as temperature, voltage or illumination. The term 'non-linear' means that the relationship between the resistance and the external factor are not directly proportional.

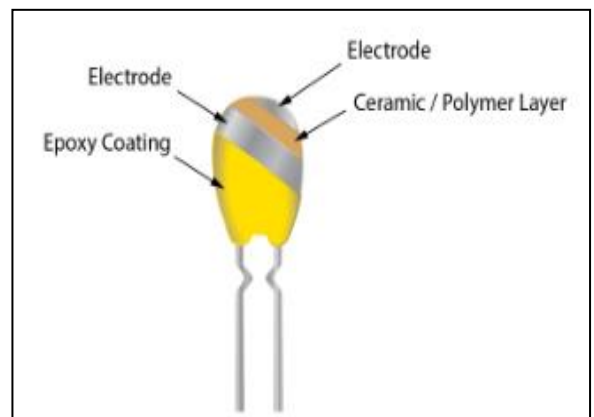
Types of non-linear resistors include:

- Varistors
- Thermistors
- Light dependent resistors (LDRs)



Varistor

A varistor consists of two electrodes separated by a metal-oxide layer. The metal-oxide offers a very high resistance until the applied voltage reaches a certain level, at which point the resistance drops sharply.

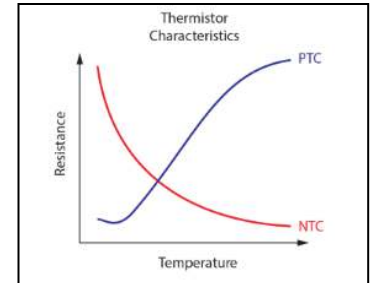


Metal-oxide varistors are commonly used as overvoltage (surge) protection devices.

Thermistor

A thermistor consists of two electrodes separated by a ceramic or polymer layer. There are two types of thermistor:

- Positive Temperature Coefficient (PTC) thermistors
- Negative Temperature Coefficient (NTC) thermistors



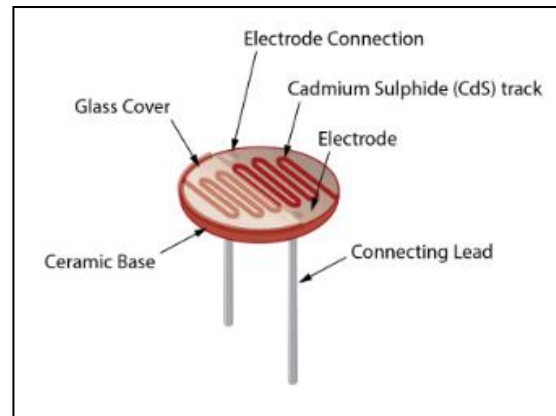
The resistance of a PTC thermistor will increase with an increase in temperature. The resistance of a NTC thermistor will decrease with an increase in temperature. In both cases, the temperature/resistance characteristics are non-linear, and depend on the characteristics of the ceramic/polymer layer.

Thermistors are commonly used for motor protection and temperature sensing.

Light dependent resistor (LDR)

A light dependent resistor (LDR) consists of two electrodes separated by a cadmium sulphide track. The cadmium sulphide track offers a very high resistance when not exposed to light, and a very low resistance when illuminated.

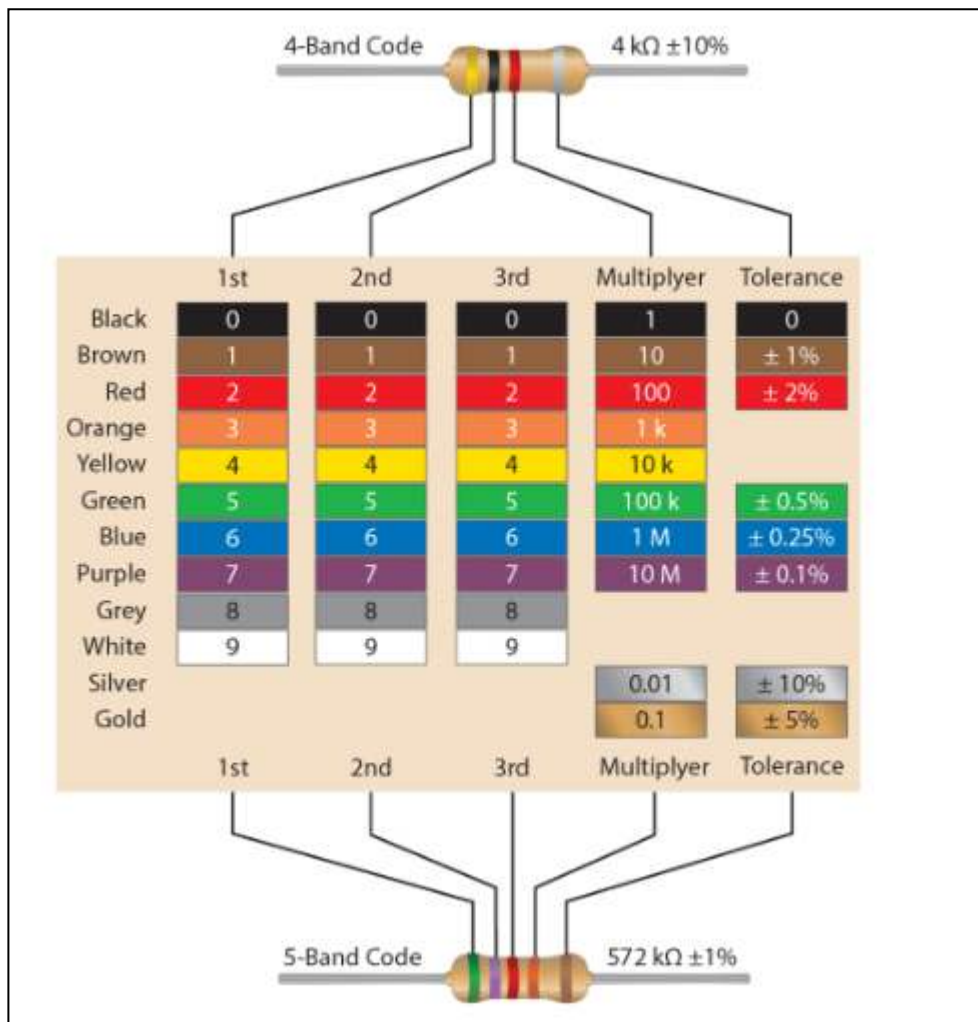
Light dependent resistors are commonly used in lighting control systems, for example to automatically switch street lighting at dawn and dusk.



7.3 Selection of resistors

7.3.1 Resistor colour code

The resistor colour code provides a simplified method of identifying the resistance values of resistors based on a series of coloured bands. The following diagram shows how to interpret the four and five band colour codes.



7.3.2 Resistor power ratings

Resistors are given power ratings based on how much heat they can dissipate continuously without sustaining damage. This rating indicates the maximum voltage that can be safely applied across the resistor. Remember – an increase in applied voltage causes an increase in current and therefore an increase in the power dissipated as heat within the resistor.

When selecting resistors, the power rating should be noted to ensure the resistor will be suitable for the circuit operating voltage.

7.3.3 Referred resistor values

A system of 'preferred resistor values' was implemented to facilitate manufacture and selection of resistors. The system involves a number of standardised series of resistor values, where each series contains resistors of a specific tolerance. There are five main series in use today:

- E12 Series (10% tolerance)
- E24 Series (5% tolerance)
- E48 Series (2% tolerance)
- E96 Series (1% tolerance)
- E192 Series (<1% tolerance)

7.3.4 Resistor notation

An important thing to understand is how the resistance values of resistors are denoted within these series. Some examples are provided in the following table.

Resistor Notation	
Resistance	Notation
8.2 Ω	8R2
22 Ω	22R
360 Ω	360R
1,800 Ω	1K8
10,000 Ω	10K
240,000 Ω	240K
1,200,000 Ω	1M2
10,000,000 Ω	10M

7.4 Summary

Now that you have completed this topic, you should be well versed in resistors, including fixed resistors, variable resistor and non-linear resistors and how to select resistors.

Topic 8 Series circuits

This topic covers an introduction to series circuits and the characteristics and operation of series circuits.

The components of a series circuit are arranged in such a way that there is only one path through which the current can flow. This single path arrangement provides unique characteristics that can be useful for certain applications such as protection and control.

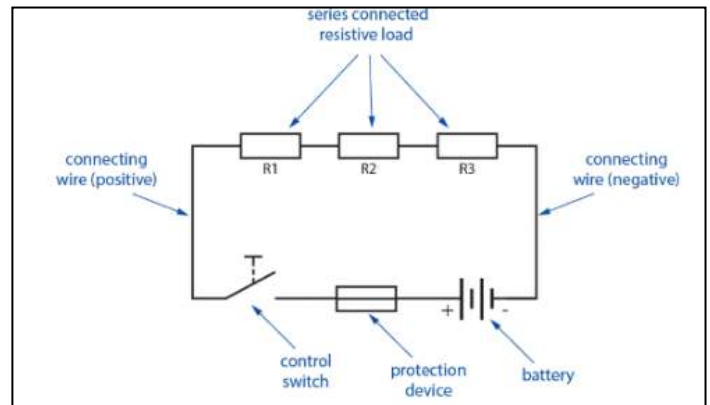
Many circuits in low voltage electrical installations have some of their components connected in series, and so it is essential for an electrotechnology worker to have a good understanding of series circuit components, applications, connections and characteristics.

8.1 Introduction to series circuits

8.1.1 Major components

The fundamental components of a series circuit are:

- A power supply
- A protection device
- A control switch
- A load
- Connecting wires



The diagram shows the arrangement of a series d.c. circuit:

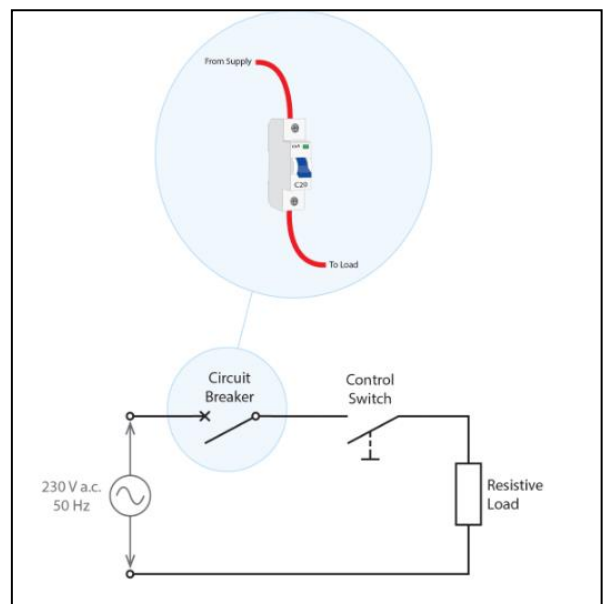
8.1.2 Applications

The unique characteristics of series circuits are useful for a variety of applications. Some common examples of series connected components and circuits include:

- Protection devices
- Control switches
- Cells and batteries
- Photovoltaic (PV) cells and modules
- Filtering circuits
- Voltage divider circuits
- Metering circuits

8.1.3 Protection devices

Overcurrent protection devices, such as fuses or circuit breakers, are provided at the origin of most low voltage circuits. There are many reasons for overcurrent in a circuit, and it is the role of the protection device to prevent danger and damage if this occurs. A protection device achieves this by automatically disconnecting the circuit when the current rating is exceeded. In order to effectively disconnect a circuit from the supply, the protection device must be connected in series with the circuit equipment.

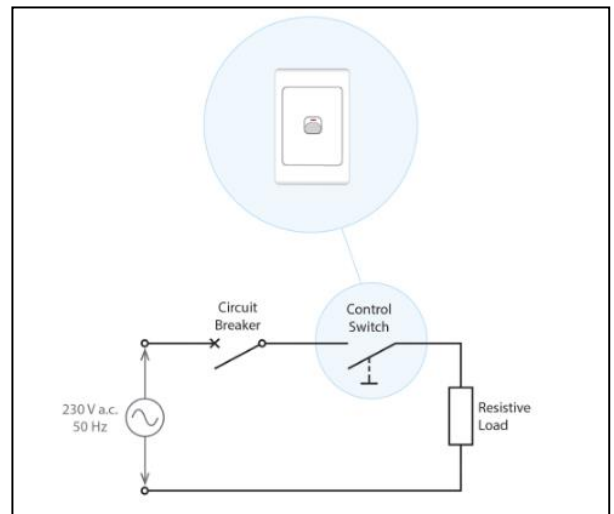


The diagram shows the arrangement of a protection device in a 230 V a.c. circuit.

8.1.4 Control switches

The purpose of a control switch is to control the flow of current in a circuit. There are many types of automatic and manual control switches available for specific applications, but the fundamental principle is generally to provide a way of making (connecting) or breaking (disconnecting) the circuit. To achieve this functionality, a basic control switch is connected in series with the component it is controlling.

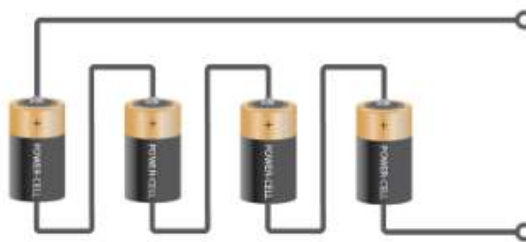
The diagram shows the arrangement of a basic ON/OFF control switch used to control the flow of current to a resistive load.



8.1.5 Cells and batteries

Cells and batteries are a common and convenient d.c. power source. The total output voltage and current provided by a group of cells or batteries can be altered by changing the way they are connected. Connecting cells or batteries in series 'strings' has the effect of increasing the total output voltage, but has no effect on the available current.

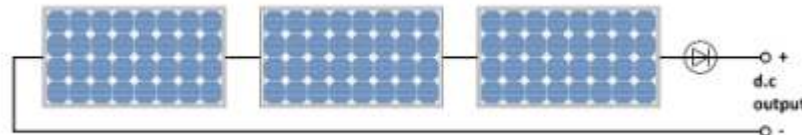
The diagram below shows the arrangement of four series connected batteries. If each battery had an individual terminal voltage of 1.5 V, then the total output voltage of the bank would be 6 V (4 batteries x 1.5 volts).



8.1.6 Photovoltaic (PV) cells and modules

Similarly to batteries, photovoltaic (PV) cells and modules are also commonly connected into series strings to achieve desired voltage parameters.

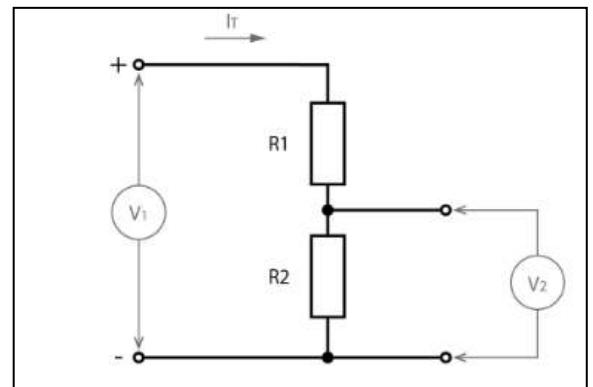
The diagram below shows the arrangement of three modules connected into a series string. In addition, a protective 'blocking diode' is also connected in series with the string.



8.1.7 Voltage divider circuits

A basic voltage divider circuit consists of two resistors in series. They are used to reduce values of voltage, and have common applications in electrical meters, sensor equipment, amplifiers, and other electronic devices.

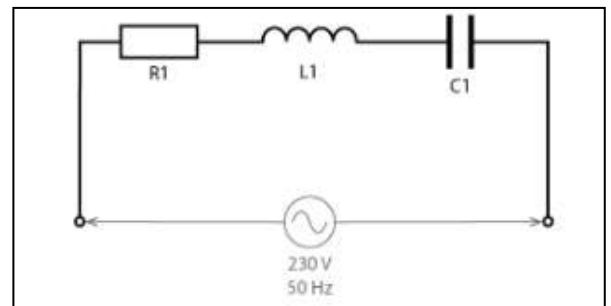
The diagram shows a basic voltage divider circuit. When an input voltage (V_1) is applied to the circuit, a reduced voltage (V_2) becomes available at the output terminals.



Filtering circuits

Filtering circuits are commonly used to improve power quality in electrical installations.

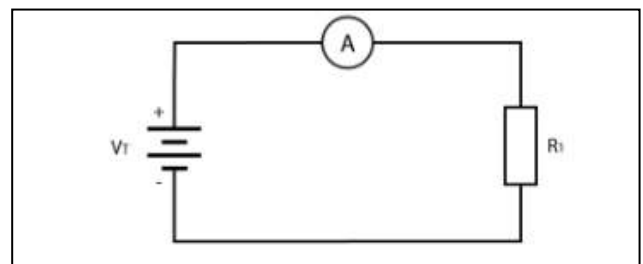
The diagram shows an a.c. filtering circuit consisting of a resistor (R_1), inductor (L_1) and capacitor (C_1) connected in series. The circuit is for illustrative purposes only – it is not important that you understand the operating principles of this circuit at this stage of your training. You will study this type of circuit in Phase 2 of the Certificate III in Electrotechnology Electrician.



Metering circuits

An ammeter must be connected in series to measure current flowing in a circuit. The series connection means that all the current flows through the meter, ensuring an accurate measurement.

The circuit diagram shows the arrangement of an ammeter to measure the current drawn by a resistor in a d.c. circuit.

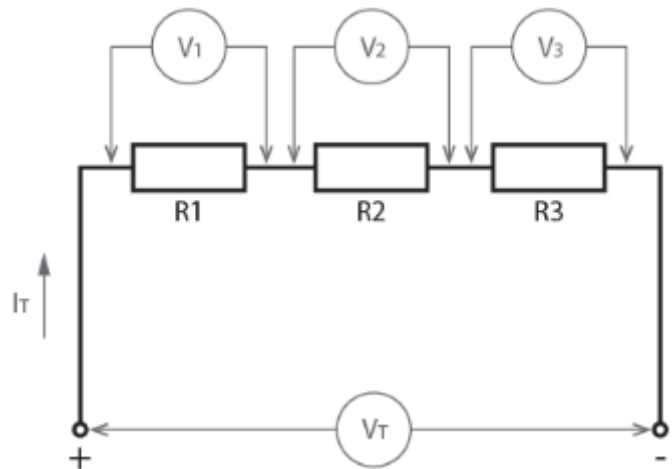


8.2 Characteristics and operation of series circuits

8.2.1 Circuit characteristics

The diagram shows three resistive loads connected in series.

By examining the circuit, it can be seen that a series circuit has only one current path. It is this feature that produces the unique current, resistance and voltage characteristics of series circuits.



8.2.2 Current in series circuits

Because there is only one current path, the value of current in any part of a series circuit will always be the same. This can be represented by the equation:

Where:

I_T = total circuit current

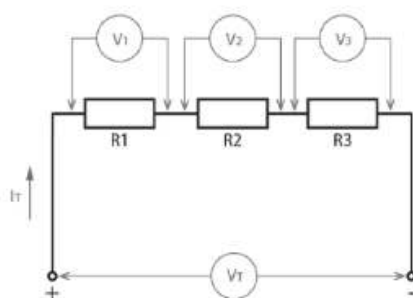
I_1 = current through R_1

I_2 = current through R_2

I_3 = current through R_3

$$I_T = I_1 = I_2 = I_3$$

Worked Example – Calculating Current



For the circuit pictured above, calculate the total current drawn from the supply, if the current flowing in R_2 is 2 amperes.

$$\begin{aligned} I_T &= I_1 = I_2 = I_3 \\ I_T &= I_1 = 2 = I_3 \\ I_T &= 2 \text{ amperes} \end{aligned}$$

In addition, it can be determined that there is 2 amperes flowing in R_1 and 2 amperes flowing in R_3 .

8.2.3 Resistance in series circuits

When resistors are connected in series, the sum of the individual resistances is equal to the total equivalent resistance. This can be represented by the equation:

$$R_T = R_1 + R_2 + R_3$$

Where:

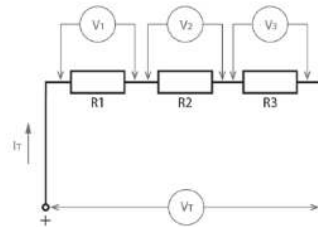
R_T = total resistance

R_1 = resistance of R_1

R_2 = resistance of R_2

R_3 = resistance of R_3

Worked Example – Calculating Resistance



For the circuit pictured above, calculate the total resistance if R_1 has a resistance of 80 ohms, R_2 has a resistance of 120 ohms, and R_3 has a resistance of 200 ohms.

$$R_T = R_1 + R_2 + R_3$$

$$R_T = 80 + 120 + 200$$

$$R_T = 400 \text{ ohms}$$

8.2.4 Voltage in series circuits

Another important characteristic of series circuits is that when a voltage is applied, a portion of the voltage drops across each resistor, such that the sum of the individual voltage drops is equal to the total voltage. This series circuit characteristic can be represented by the equation:

$$V_T = V_1 + V_2 + V_3$$

Where:

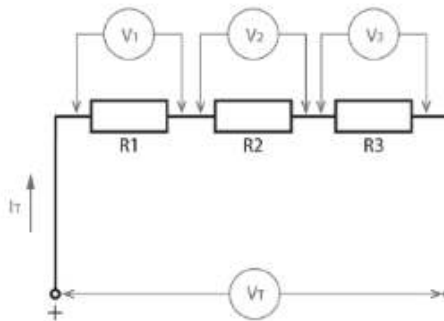
V_T = total circuit voltage

V_1 = voltage across R_1

V_2 = voltage across R_2

V_3 = voltage across R_3

Worked Example – Calculating Voltage



For the circuit pictured above, calculate the total voltage if V_1 is 8 volts, V_2 is 24 volts, and V_3 is 16 volts.

$$V_T = V_1 + V_2 + V_3$$

$$V_T = 8 + 24 + 16$$

$$V_T = 48 \text{ volts}$$

The values of voltage that drop across each series connected resistor will be proportional to the values of resistance.

For example, if three resistors with respective resistance of $80 \, \Omega$, $120 \, \Omega$ and $200 \, \Omega$, are connected in series to a 40 V supply, then:

- The voltage across the $80 \, \Omega$ resistor will be 8 V
- The voltage across the $120 \, \Omega$ resistor will be 12 V
- The voltage across the $200 \, \Omega$ resistor will be 20 V
- $8 + 12 + 20 = 40 \text{ V}$

8.2.5 Power in series circuits

The total power dissipated in a series circuit is equal to the sum of the individual powers. This can be represented by the equation:

Where:

P_T = total circuit power

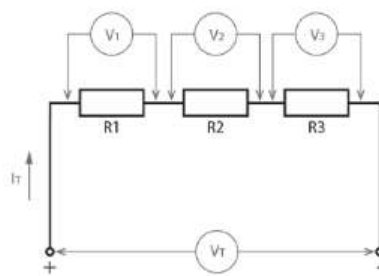
P_1 = power dissipated by R_1

P_2 = power dissipated by R_2

P_3 = power dissipated by R_3

$$P_T = P_1 + P_2 + P_3$$

Worked Example – Calculating Power



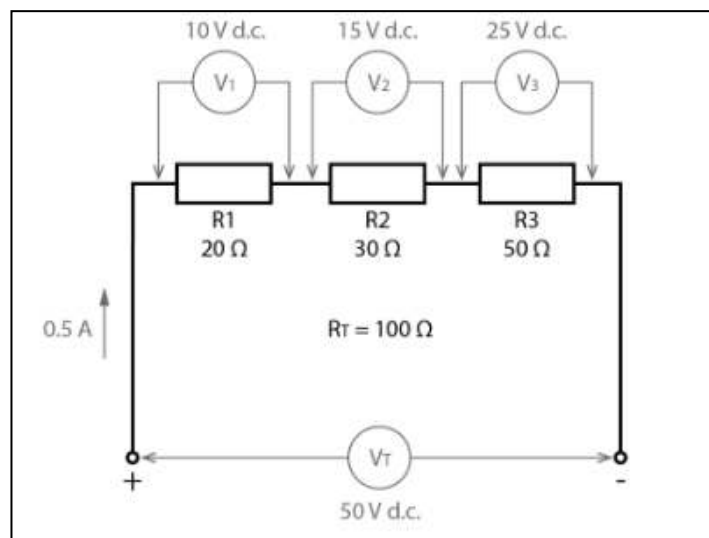
For the circuit pictured above, calculate the total power rating of the series circuit if each individual resistor has a power rating of 500 W.

$$P_T = P_1 + P_2 + P_3$$

$$P_T = 500 + 500 + 500$$

$$P_T = 1,500 \text{ watts}$$

To illustrate how all of these operating characteristics come together, consider the following series circuit:



Note that:

- The total resistance is the sum of the individual resistances
- The current flowing in each resistor will be 0.5 A
- The voltage drop across each resistor is proportional to its resistance
- The sum of the voltage drops is equal to the total supply voltage
- The current, voltage and resistance values at each point in the circuit obey Ohm's Law

8.2.6 Circuit fault conditions

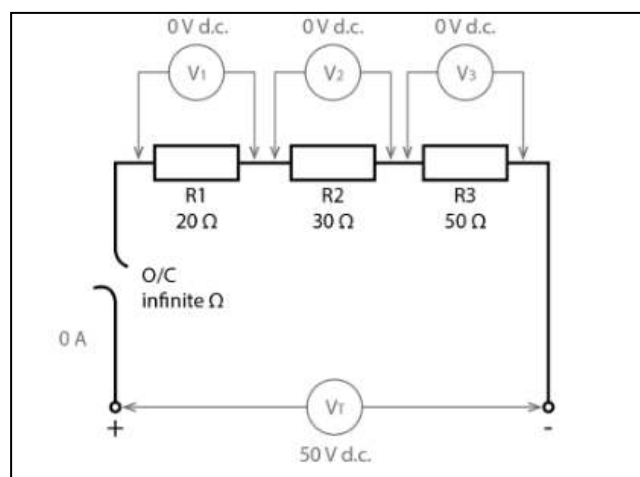
There are two basic fault conditions that will be discussed in this unit, these are:

- Open-circuits
- Short-circuits

We will see how each of these two fault conditions affects the parameters of a 50 V circuit supplying a series load with a total resistance of 100 Ω .

Open-circuits

An open-circuit is a break in a conductor or component that should normally be electrically continuous. The following diagram shows the series circuit with an open-circuit in the positive wire.



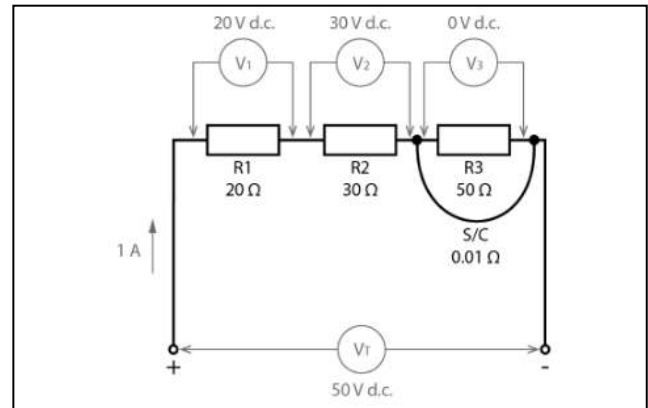
When an open-circuit occurs in a series circuit, the load current drops to zero, as the only current path has become broken, causing the total resistance to become infinite.

There can be many causes of open-circuits, for example a wire falling out of a terminal, or a component 'burning out' due to high temperatures or excessive currents.

Short-circuits

A short-circuit is a connection occurring between two conductors that should not be directly connected together in normal operation. The following diagram shows a series circuit where a short-circuit has developed across R_3 .

When a short-circuit occurs in a series circuit the total resistance is reduced, causing the total current to increase. In many cases, short-circuits increase the circuit current to dangerously high values, causing circuit protection devices to disconnect the circuit. In this case, the short-circuit current is 1 A, which is double the normal load current of 0.5 A.



Short-circuits are most commonly caused by the failure of insulation due to mechanical damage or some other form of stress.

Summary

Now that you have finished this topic, you should be aware of the different components and applications of series circuits as well as the characteristics and operation of series circuits.

Topic 9 Factors affecting resistance

This topic covers the factors that affect the resistance of conductors.

Every material has a degree of electrical resistance; termed "resistivity". Materials with a very low resistivity, such as copper, silver and aluminium, are typically used as conductors, whilst materials with a very high resistivity, such as PVC, rubber, paper and porcelain, are commonly used as insulators.

Whilst resistance in insulators is a good thing, resistance in conductors can be the cause of various problems in electrical installations. Conductor resistance limits a cable's ability to carry current safely, and causes a "voltage drop" across the cable, just like voltage would drop across a load resistor. The effect is that less voltage is available at the actual load. In addition, the correct operation of the protective earthing system relies heavily on the selection of conductors with sufficiently low resistance.

The problematic effects of cable resistance need to be minimised, and it is therefore necessary to have a good understanding of the factors that affect resistance in electrical circuits.

9.1 Factors affecting the resistance of conductors

9.1.1 Factors affecting resistance

There are four factors that affect the resistance of a conductor:

- Length
- Cross-sectional area (C.S.A.)
- Material
- Temperature
- Length

Provided all other quantities remain unchanged, the resistance of a conductor is directly proportional to its length. This means that:

- If the length is increased then the resistance will increase
- If the length is decreased then the resistance will decrease



This relationship can be expressed by the following ratio:

$$\frac{R_1}{R_2} = \frac{l_1}{l_2}$$

This ratio can be transposed to create the following equation:

$$R_2 = \frac{R_1 l_2}{l_1}$$

Where:

R1 = the resistance of a conductor 1

l1 = the length of conductor 1

R2 = the resistance of a conductor 2

l2 = the length of conductor 2

Worked Example – Calculating Resistance 1

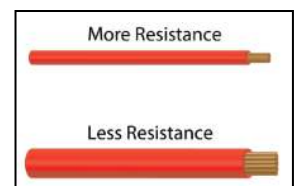
Calculate the resistance of a 60 m length of conductor, if a 30 m length of the same conductor has a resistance of 1.2 Ω.

$$R_2 = \frac{R_1 l_2}{l_1}$$
$$R_2 = (1.2 \times 60) \div 30$$
$$R_2 = 2.4 \text{ ohms}$$

9.1.2 Cross-sectional area

Provided all other quantities remain unchanged, the resistance of a conductor is inversely proportional to its C.S.A. This means that:

- If the C.S.A. is increased then the resistance will decrease
- If the C.S.A. is decreased then the resistance will increase



This relationship can be expressed by the following ratio:

This ratio can be transposed to create the following equation:

$$\frac{R_1}{R_2} = \frac{A_2}{A_1}$$

Where:

R1 = the resistance of a conductor 1

A1 = the cross-sectional area of conductor 1

R2 = the resistance of a conductor 2

A2 = the cross-sectional area of conductor 2

$$R_2 = \frac{R_1 A_1}{A_2}$$

Worked Example – Calculating Resistance 2

Calculate the resistance of a 6 mm² conductor, if a 4 mm² conductor of the same length and material has a resistance of 1.2 Ω.

$$R_2 = \frac{R_1 A_1}{A_2}$$

$$R_2 = (1.2 \times 4) \div 6$$

$$R_2 = 0.8 \text{ ohms}$$

Another way this relationship can be expressed is to say that the resistance of a conductor is inversely proportional to the square of its diameter, expressed as a ratio: And transposed into the equation:

$$\frac{R_1}{R_2} = \frac{d_2^2}{d_1^2}$$

Where:

R1 = the resistance of a conductor 1

d1 = the diameter of conductor 1

R2 = the resistance of a conductor 2

d2 = the diameter of conductor 2

$$R_2 = R_1 \left(\frac{d_1}{d_2} \right)^2$$

$$R_2 = \frac{R_1 A_1 / l_1}{A_2 / l_2}$$

All of these relationships can be combined to produce the following equation:

Where:

R1 = the resistance of a conductor 1

A1 = the cross-sectional area of conductor 1

l1 = the length of conductor 1

R2 = the resistance of a conductor 2

A2 = the cross-sectional area of conductor 2

l2 = the length of conductor 2

Worked Example – Calculating Resistance 3

Calculate the resistance of a 80 m length of 6 mm² conductor, if a 40 m length of 10 mm² conductor (of the same material) has a resistance of 0.09 Ω.

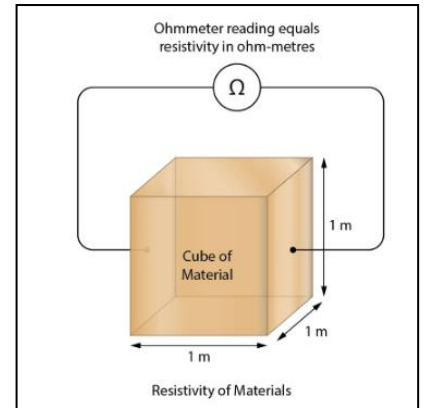
$$R_2 = \frac{R_1 A_1 l_2}{A_2 l_1}$$
$$R_2 = (0.09 \times (10 \times 10^{-6}) \times 80) \div ((6 \times 10^{-6}) \times 40)$$
$$R_2 = 0.3 \text{ ohms}$$

Conductor material

The resistance of a conductor is dependent on the chemical properties of the conductor material itself. The 'resistivity' (ρ) of a material represents the degree to which a material allows or opposes the flow of electrons. It is measured in ohmmeters (Ωm) and is expressed as a constant value for each material.

Note: the symbol for resistivity, ρ , is the Greek letter 'rho'

For example, the resistivity of copper (a conductor) is $1.72 \times 10^{-8} \Omega\text{m}$, whilst the resistivity of rubber (an insulator) is approximately $1 \times 10^{13} \Omega\text{m}$.



The relationship between resistance and resistivity can be expressed by the following equation:

$$R = \frac{\rho l}{A}$$

Where:

R = resistance in ohms (Ω)

ρ = resistivity in ohmmeters (Ωm)

l = length in meters (m)

A = cross-sectional area in square meters (m^2)

Worked Example – Calculating Resistance 4

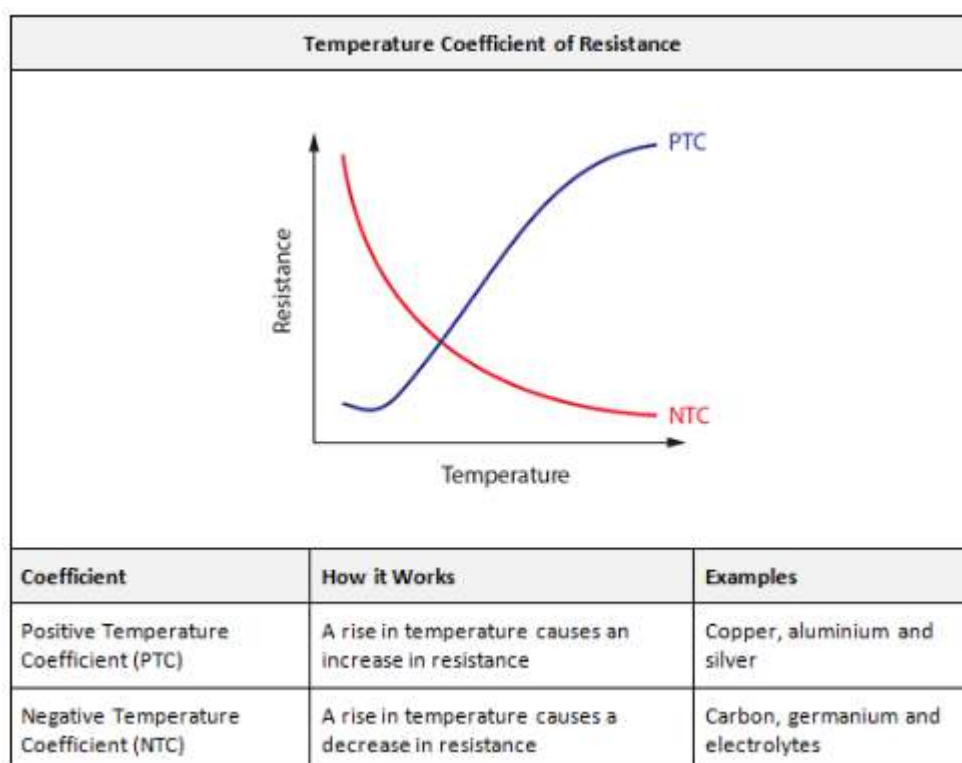
Calculate the resistance of a 2.5 mm^2 conductor that has a resistivity of $1.72 \times 10^{-8} \Omega\text{m}$ and is 50 m in length.

$$\begin{aligned} R_2 &= \frac{\rho l}{A} \\ R_2 &= \frac{(1.72 \times 10^{-8}) \times 50}{(2.5 \times 10^{-6})} \\ R_2 &= 0.344 \text{ ohms} \end{aligned}$$

Temperature

The resistance of a material changes depending on its temperature. This factor is of particular importance in relation to current carrying conductors. The temperature of a conductor is raised when it carries an electric current and therefore the resistance of the conductor is affected by the change in temperature. This effect needs to be taken into account when selecting cables in situations where there is a risk of very high short-circuit currents.

The amount of change (increase or decrease) in each ohm of the initial resistance of the material per degree of temperature is known as the temperature coefficient of resistance.



The temperature coefficient of a material can be used to determine the change in resistance that occurs for a given change in temperature:

Where:

R_h = the final (hot) resistance in ohms (Ω)

R_c = the initial (cold) resistance in ohms (Ω)

α = the temperature coefficient of resistance in ohms per degree Celsius ($\Omega/^\circ\text{C}$)

Δt = the change in temperature in degrees Celsius ($^\circ\text{C}$)

$$R_h = R_c (1 + \alpha \Delta t)$$

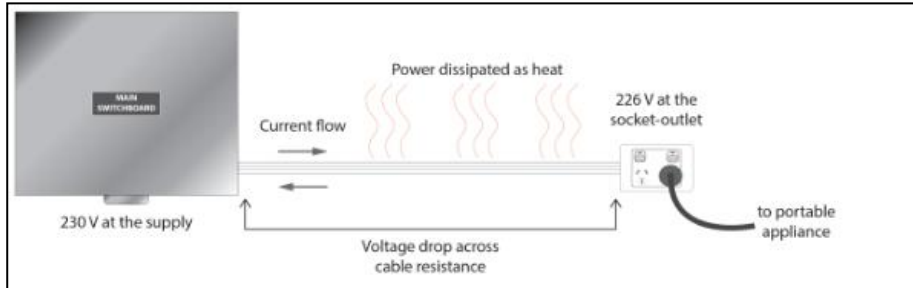
Worked Example – Calculating Resistance 5

Consider a conductive heating element that has a temperature coefficient of $0.0004 \Omega/^\circ\text{C}$ and a resistance of 16Ω at 25°C . Calculate the resistance of the element when its temperature is increased to 100°C .

$$\begin{aligned}
 R_h &= R_c (1 + \alpha \Delta t) \\
 R_h &= 16 \times (1 + (0.0004 \times (100 - 25))) \\
 R &= 16.48 \text{ ohms}
 \end{aligned}$$

Effects of conductor resistance

The purpose of a conductor is to carry current and, as discussed above, every conductor has some resistance. Ohm's Law states that when current flows through a resistance, a voltage will drop across that resistance. This 'voltage drop' is an undesirable, but unavoidable effect of conductor resistance.



Voltage drop in practice

Electrical equipment is generally designed to operate within a specific voltage range (e.g. 220-250 V a.c.). A large voltage drop in a circuit can mean that the voltage available at the load is outside the equipment's operating range, causing it to malfunction. For this reason, the Wiring Rules (AS/NZS 3000) specifies maximum limits for voltage drop in circuits.

The main variables that are within your control when addressing voltage drop in circuit conductors are the length and cross-sectional area. If the voltage drop in a circuit is excessive, the problem can generally be corrected by either:

- Reducing the route length of the circuit
- Increasing the size of the circuit wiring
- Current carrying capacity

The 'current carrying capacity' of a cable indicates the ability of the cable to dissipate heat continuously without sustaining damage. When current flows through a resistance, electrical energy is converted into heat. If this heat cannot be adequately dissipated, the cable insulation will deteriorate and a fire could be started.

There are a number of factors that affect the current carrying capacity of a cable, such as:

- How well the cable is ventilated, i.e. the installation conditions
- The temperature rating of the cable insulation
- The cable size, i.e. cross-sectional area of the conductors
- The conductor material, i.e. resistivity

Summary

Now that you have finished this topic, you should be aware of the factors that affect the resistance of conductors.

Topic 10 Effects of meters in a circuit

Using test equipment to measure the parameters of circuits and components is a fundamental skill required by those working in the electrotechnology industry. Electricity cannot be detected by sight or smell, and using touch to detect electricity could easily be fatal. It is therefore essential for the safety of electrotechnology workers to be able to use test equipment correctly, and interpret electrical measurements accurately.

This topic covers:

- Analogue and digital test equipment
- Characteristics of test equipment
- Measuring voltage and current

10.1 Analogue and digital test equipment

10.1.1 Test equipment

The following table shows a range of meters, testers and indicators commonly used in the electrotechnology industry to test for voltage and current.

Common Test Equipment – Voltage		
 Series Test Lamps	 Volt-Stick	 LED Tester
 Analogue Voltmeter	 Digital Voltmeter	 Digital Multimeter
Common Test Equipment – Current		
 Analogue Ammeter	 Digital Clamp Meter/Tong Tester	 Digital Multimeter

10.2 Characteristics of test equipment

10.2.1 Voltmeters

A voltmeter has a very high resistance so that the total value of voltage drops across the meter. Connecting a voltmeter adds a parallel resistance into the circuit, thereby drawing additional current to supply the meter and slightly reducing the total circuit resistance.

The accuracy of a voltmeter is therefore dependent on its internal resistance. The higher the resistance of a voltmeter, the less effect it will have on the circuit parameters, and the more accurate the reading will be.

The 'sensitivity' of a voltmeter indicates its internal resistance in ohms per volt (Ω/V). For example, a typical sensitivity for an analogue voltmeter is 20,000 Ω/V , this means that on the 250 V range, the internal resistance of the meter is 5 M Ω (20,000 $\times$ 250 = 5,000,000).

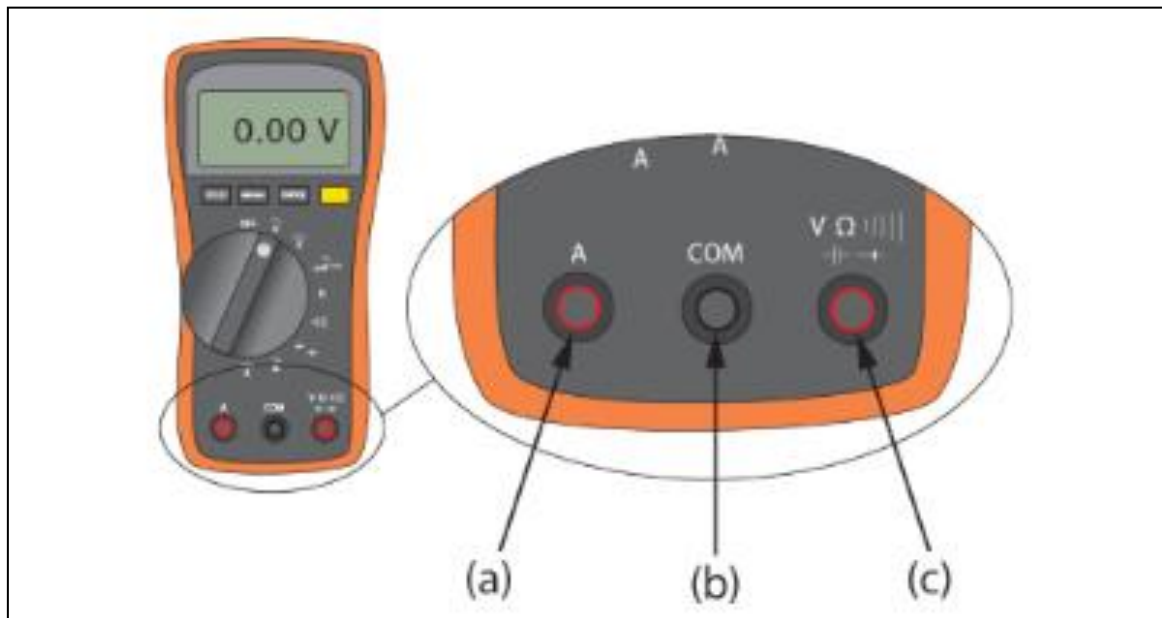
Prior to using a voltmeter, an appropriate 'range' setting should be selected, taking the following factors into account:

- Whether the voltage to be measured is a.c. or d.c.
- The approximate value of voltage expected to be measured

When measuring values of d.c. voltage, it is important to match the polarity of the meter leads to the polarity of the circuit. Remember to exercise caution when taking voltage measurements, as the circuit under test will generally be energised.

Voltmeter range and settings

The diagram below shows the terminals of a digital multimeter. When measuring voltage, the meter probes should be connected into terminals (b) and (c), and the range selector dial should be set to a.c. or d.c. volts as applicable.



Voltage Indicators	
	LED Tester <i>Operation:</i> consists of several neon indicators that light up to indicate the rough voltage level that is present across the probes <i>Advantages:</i> durable and less expensive than a digital voltmeter <i>Disadvantages:</i> does not indicate a precise value of voltage
	Series Test Lamps <i>Operation:</i> consists of one or more lamps that light up when the probes are connected across a voltage. It should be noted that these testers place a significant load on the circuit under test when compared to a voltmeter. <i>Advantages:</i> simple, durable and inexpensive <i>Disadvantages:</i> does not indicate the value of voltage
	Volt-Stick <i>Operation:</i> detects the presence of a voltage by sensing the presence of an electric field around a conductor <i>Advantages:</i> 'non-contact' type tester – does not require direct connection into a circuit <i>Disadvantages:</i> does not indicate the value of voltage, unreliable, not suitable for proving a circuit is isolated

Ammeters

An ammeter has a very low resistance in order to allow the total value of current to flow through the meter. Connecting an ammeter adds a series resistance into the circuit, thereby reducing the circuit current and slightly increasing the circuit resistance.

The accuracy of an ammeter is therefore dependent on its internal resistance. The lower the resistance of an ammeter, the less effect it will have on the circuit parameters, and the more accurate the reading will be.

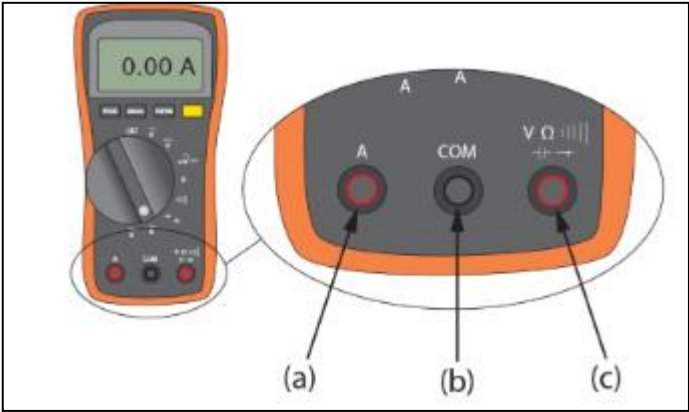
Prior to using an ammeter, an appropriate range setting should be selected, taking the following factors into account:

- Whether the current to be measured is a.c. or d.c.
- The approximate value of current expected to be measured

When connecting a d.c. ammeter into a circuit, it is important to ensure the polarity of the meter is correct. Remember to exercise caution when taking current measurements, as the circuit under test must be energised.

Ammeter range and settings

The diagram below shows the terminals of a digital multimeter. When measuring current, the meter probes should be connected into terminals (a) and (b), and the range selector dial should be set to a.c. or d.c. amperes as applicable.



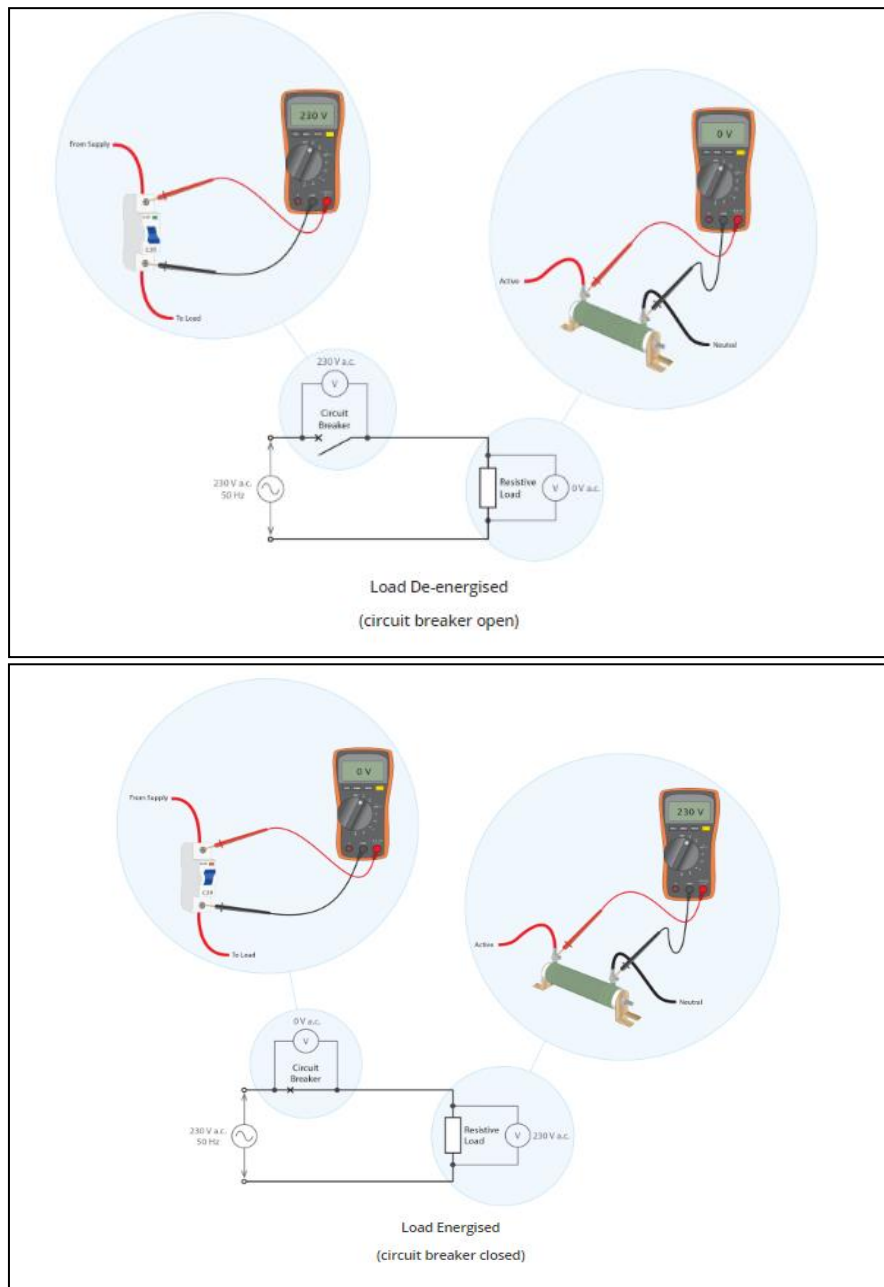
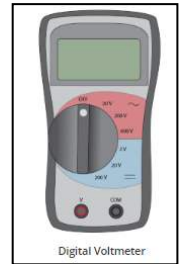
Digital Vs Analogue	
Analogue Meters	Digital Meters
• faster response time • good indication of real-time fluctuations	• greater accuracy • easier to read, no chance of parallax error • more robust • additional features • higher sensitivity

10.3 Measuring voltage and current

Measuring voltage in a circuit

To measure the voltage across a circuit or component, a voltmeter must be connected in parallel.

The diagrams below illustrate the methods of connecting a voltmeter in a circuit to measure the voltage across a protection device and a resistive load. Notice the differences in the measured values when the circuit protection device is open and closed.

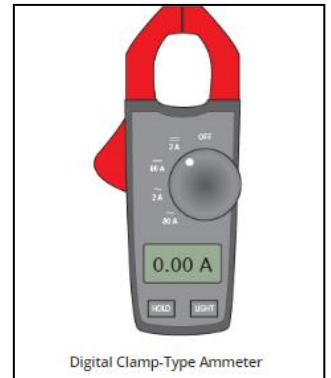


Measuring current in a circuit

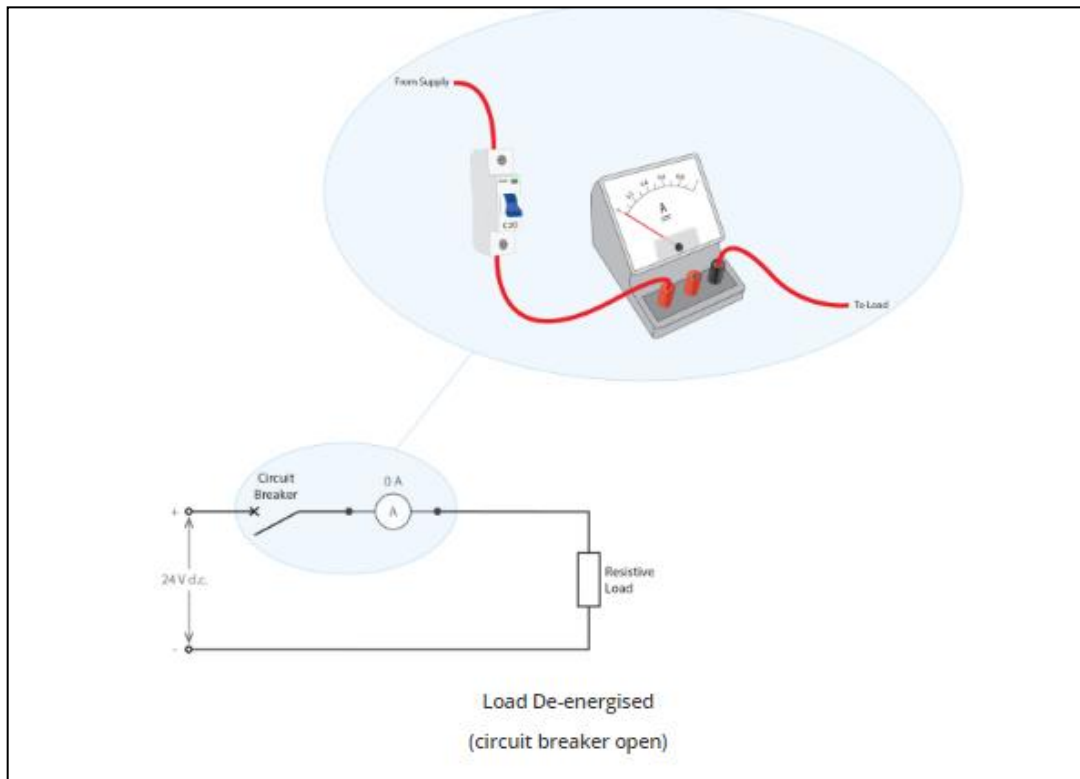
To measure the current in a circuit or component, an ammeter must be connected in series. This means that the circuit conductor under test must be broken to allow the ammeter to be connected.

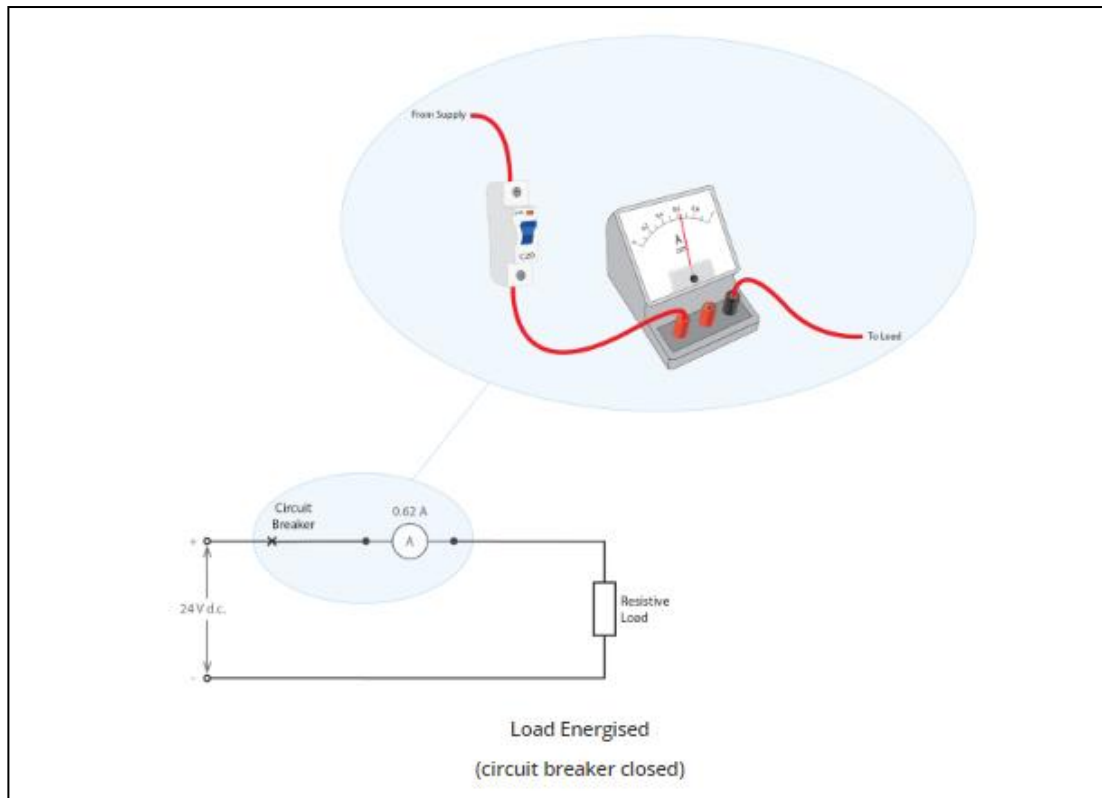
Alternatively, clamp-type ammeters are designed to measure current by sensing the electromagnetic field around a conductor. This allows current to be measured without the need for direct connection of the meter into the circuit.

The internal resistance of an ammeter must be extremely low to reduce the loading effect. It is very important not to connect an ammeter in parallel, as this will result in a hazardous current flowing through the low resistance parallel path offered by the meter.



The diagrams below illustrate the methods of connecting an analogue ammeter into a circuit to measure the line current. Notice the differences in the measured values when the circuit protection device is open and closed.



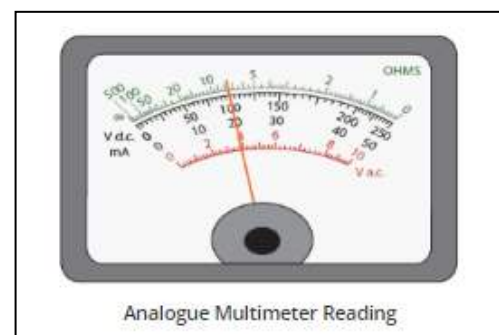


Analogue meter readings

Analogue meters often consist of more than one range, and so it's important to understand how to interpret the readings. The following diagram shows a reading taken by an analogue multimeter, consisting of of:

- An ohm's range
- A D.C. volts range
- An A.C. volts range
- A D.C. mA range

When set to ohms, the meter is calibrated to indicate resistance on the green scale. In this case the meter indicates a reading of 6.5 Ω .



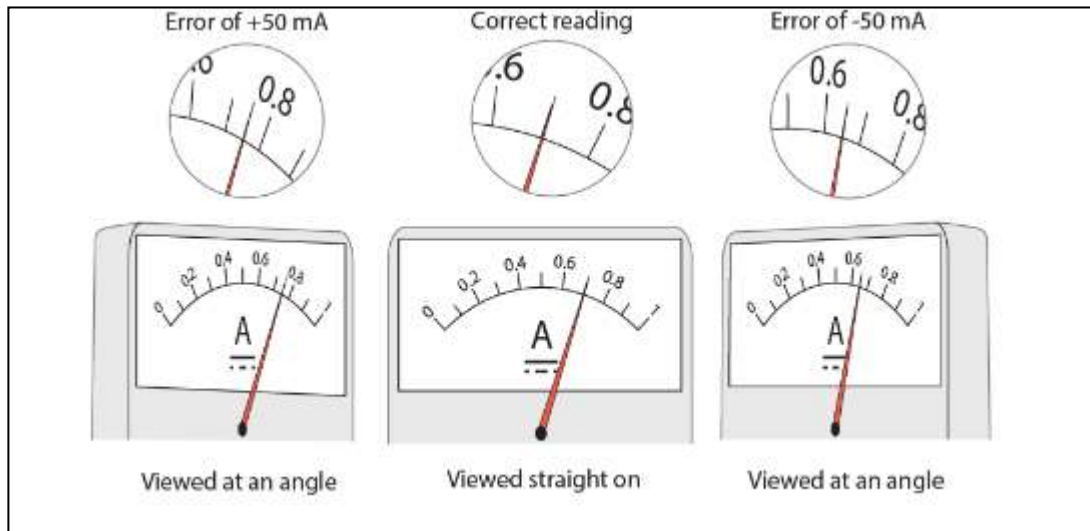
When set to d.c. volts, the meter is calibrated to indicate d.c. voltage on the uppermost black scale. In this case the meter indicates a reading of 100 V d.c.

When set to d.c. milliamperes, the meter is calibrated to indicate d.c. current on the lower black scale. In this case the meter indicates a reading of 20 mA.

When set to a.c. volts, the meter is calibrated to indicate a.c. voltage on the red scale. In this case the meter indicates a reading of 4 V a.c.

Parallax error

Parallax error can occur when an analogue scale is read at an angle other than straight on, due to the distance between the needle and the scale.



Testing hazards and safety

The primary risk associated with electrical testing is coming into contact with energised parts. This can be caused by poor understanding, incorrect meter connections or faulty test equipment. To reduce the risks associated with testing electrical circuits and equipment, a few general safety precautions should be taken:

- Only use test equipment that meets Australian Standards
- Only use test equipment of a suitable Category for the test being carried out
- Always check test equipment for damage or faulty operation prior to use
- Ensure that you have selected the correct range and settings prior to use
- Ensure correct polarity where applicable
- When using series test lamps, remember that if one probe is in contact with an energised conductor, the other probe poses a shock hazard
- Never trust a non-contact voltage indicator to prove that a circuit is de-energised

Summary

By now you will be familiar with the effects of meters in a circuit, including familiarity with analogue and digital test equipment, the characteristics of test equipment and measuring voltage and current

Topic 11 Resistance measurement

This topic covers resistance measurement instruments and how to measure resistance.

Resistance testing is a very common task in electrotechnology work. Resistance tests are commonly used to troubleshoot circuits, check that equipment has been correctly connected and verify the condition of wiring and insulation.

There are various different types of test equipment used to measure resistance in different scenarios. In this topic, you will examine the various types of test instruments and techniques used to measure resistance in electrotechnology work.

11.1 Resistance measurement instruments

The following table shows a range of meters, testers and indicators commonly used in the electrotechnology industry to test for resistance.

11.1.1 Resistance testers

Ohmmeters and multimeters indicate actual values of resistance which can be important when diagnosing problems or verifying compliance.

A continuity tester such as a neon tester is a simple and robust device that can be used to check for continuity between two points. It can indicate the presence of open and short-circuits, but has limited use based on the fact that it doesn't indicate the value of resistance.

11.1.2 Insulation resistance tester

An insulation resistance tester applies a d.c. voltage (250 V, 500 V or 1 kV) across two conductors that are insulated from one another. A low resistance reading indicates that the insulation cannot contain the test voltage, and is therefore not suitable to be placed in service. A high reading indicates that the insulation is in good working order.



Components / Features	Function / Purpose
Leads and probes	Allows connection across circuit conductors
Needle and scale	Indicates resistance reading
Zero adjustment	Manually adjusts the position of the needle
Test button	Actuates testing
Range selector	Provides selection of test voltages, resistance ranges or battery check feature
Battery check	Indicates the battery's state of charge

Verification of circuit insulation is a critical part of electrical work, and so it is important to ensure that your insulation resistance tester is operating within standard specifications. To achieve this, periodic calibration is required.

According to the Wiring Rules (AS/NZS 3000) Clause 8.3.6.1, an insulation resistance tester must be able to maintain its terminal voltage within +20% and -10% of the nominal value when measuring a resistance of 1 M Ω on the 500 V range.

11.2 Measuring resistance

11.2.1 Resistance measurement

To measure the resistance of a circuit or component, the supply must be de-energised, and the leads of the ohmmeter are connected across the circuit or component. Connecting a resistance tester across an energised component will likely result in damage to the meter, and pose a potential shock hazard to the operator.

An ohmmeter uses a battery to apply a small voltage across the circuit/component being measured. The meter then determines the resistance from the value of current that flows, and indicates this value as the meter reading.

To maintain accuracy and service prolong life, ohmmeters, multimeters and insulation resistance testers should be treated with care whilst in use, and stored in a location that is cool and dry. They will typically come with a hard or soft case that will provide some protection, and it is generally best to store them separately from heavy tools which might cause damage.

11.2.2 Why measure resistance?

Resistance testing is a fundamental part of an electrotechnology worker's role, and is commonly carried out for a number of different reasons, as indicated in the following table.

Wiring rules

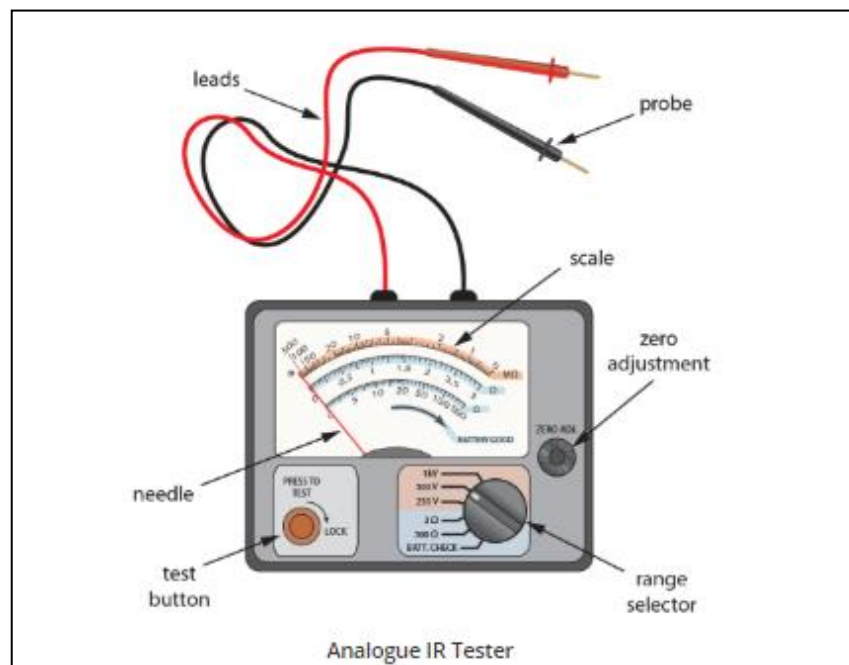
The Wiring Rules (AS/NZS 3000) requires that a number of resistance tests are carried out on installed circuits prior to connecting them to the supply. Try having a look through AS/NZS 3000 Clause 8.3, which provides details of the tests and results required to ensure safety and compliance.

Why Measure Resistance?		
Purpose of Test	Basic Description	Examples
To check the condition of components	Check that the measured value of resistance is the correct value, as determined from calculation or manufacturer's data	Test the resistance of motor windings Test the resistance of a heating element
To check the condition of conductors	Test to see if there are any open-circuits in circuit conductors	Test circuit connecting conductors Testing earthing conductors
To check the condition of insulation	Test to make sure that the insulation on circuit conductors and components has not deteriorated or been damaged	Test the insulation of circuit conductors Test the insulation of motor windings
To check that equipment is connected correctly	Check for continuity where there should be continuity, and no continuity where there should be no continuity	Test that each socket of a socket-outlet is connected to the correct circuit conductors Test that two circuits have not been accidentally connected together

Meter range and settings

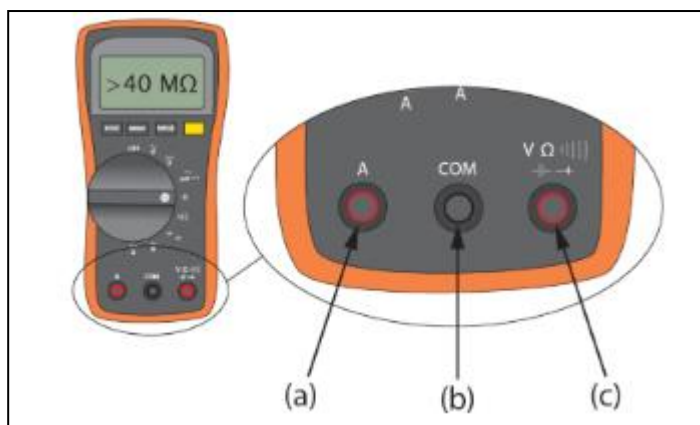
Prior to using a resistance tester, an appropriate range setting should be selected, taking into account the approximate value of resistance expected to be measured.

When testing insulation resistance, the rule of thumb is to select a test voltage that is at least double the normal operating voltage that the insulation will be exposed to. For example, a test voltage of 500 V would be suitable for testing the insulation resistance between the active and earthing conductors of a 230 V lighting circuit.



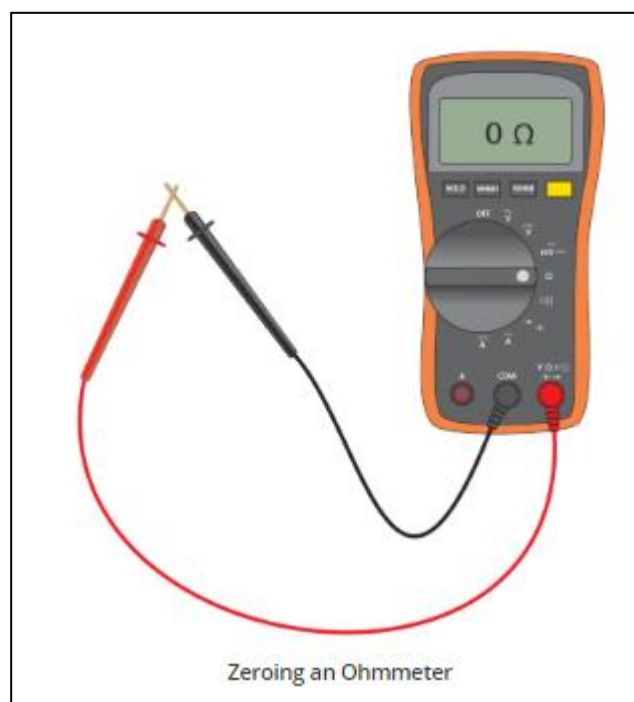
Note that it may be necessary to use a lower test voltage where surge protection devices are connected in the circuit. A high test voltage can drop the resistance of the varistor, resulting in a false reading.

The diagram below shows the terminals of a digital multimeter. When measuring resistance, the meter probes should be connected into terminals (b) and (c), and the range selector dial should be set to the ohms scale.



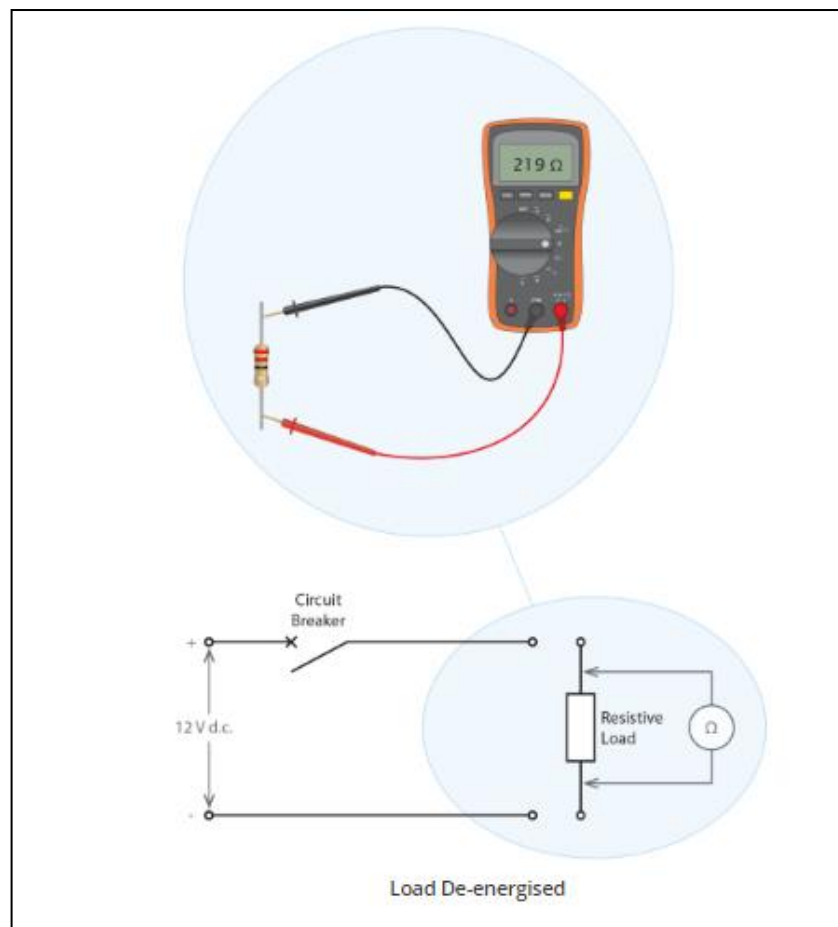
Note that this meter also has a 'continuity bell' setting directly below the ohms range, identified by five vertical lines, increasing in length slightly from left to right. When set to continuity, the meter will give an audible indication when continuity is detected across the probes.

It is also important to 'zero' an ohmmeter prior to use. This involves adjusting the meter to read zero ohms whilst the meter leads are touching, as shown.



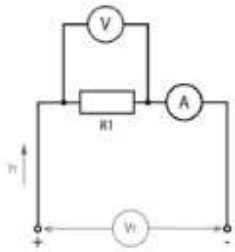
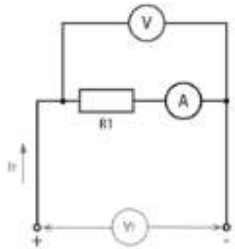
Measuring resistance in a circuit

The diagram below illustrates how to measure the resistance of a circuit component.



Volt-ammeter resistance measurement

It is also possible to measure resistance using a voltmeter and an ammeter, where the value of resistance is calculated from the meter readings using Ohm's Law.

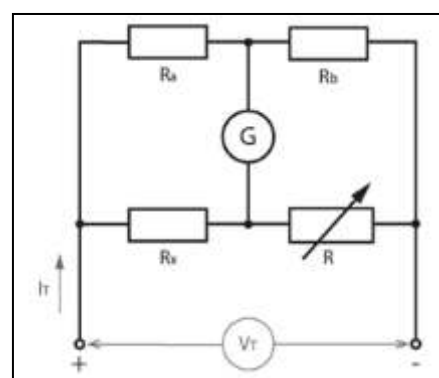
Volt-Ammeter Methods	
	Short-Shunt Method • Most suitable for measuring low resistance values (less than 10 Ω) • The voltmeter is connected only across the unknown resistance • A value slightly less than the true value is obtained using this method
	Long-Shunt Method • Most suitable for measuring high resistance values • The voltmeter is connected across both the unknown resistance and the ammeter • A value slightly higher than the true value is obtained, because it is the resistance of the unknown resistance plus that of the ammeter

Wheatstone bridge

A wheatstone bridge is a device for measuring resistance values to a high degree of accuracy. It consists of a closed loop of four resistors, bridged by a sensitive centre zero galvanometer and energised by a small d.c. supply.

The ratio of the resistance R_a to that of R_b can be set by a ratio switch and the variable resistance (R) can be varied within known limits.

To determine the unknown resistance (R_x), the variable resistance (R) is varied until the galvanometer needle indicates zero. At this time, the bridge is considered to be "balanced", such that:

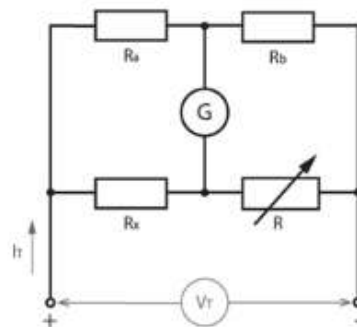


$$\frac{R_a}{R_b} = \frac{R_x}{R}$$

$$R_x = R \left(\frac{R_a}{R_b} \right)$$

The unknown resistance (R_x) can then be calculated using the following equation:

Worked Example - Using a Wheatstone Bridge



In the Wheatstone bridge pictured above, R_a is 50 k Ω and R_b is 4.8 k Ω . Calculate the unknown resistance R_x if the bridge is balanced when the variable resistor is set to 1,200 Ω .

$$R_x = R \left(\frac{R_a}{R_b} \right)$$

$$R_x = 1,200 \times (50,000 \div 4,800)$$

$$R_x = 12,500 \text{ ohms}$$

Summary

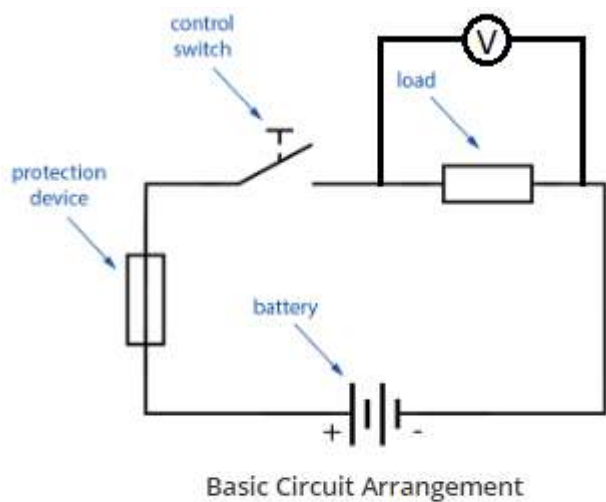
After completing this topic you should be familiar with resistance measurement.

Practical activities

Practical activity 1 – Build a simple electrical circuit

Overview

Following a basic circuit diagram, build a simple electrical circuit.



Measured Voltage (v) open	
Measured Voltage (v) closed	

Instructions

Identify all tools and materials required for practicals and obtain them under correct procedures

Build a simple electrical circuit by following the basic circuit arrangement as shown above

Apply the voltage provided to you by your trainer

Measure the circuit voltage with the switch open then record the value

Measure the circuit voltage with the switch closed and record the value

Ensure your JSA is completed and checked by the trainer prior to commencing

Ensure you follow relevant Australian standards and legislation in regard to isolation

Upon completion return all equipment and meters and present your results to your trainer.



Practical activity 2 – Build a simple electrical circuit and change voltage.

Instructions

Using the basic circuit diagram from practical assessment 2 build a simple electrical circuit with the addition of an ammeter in series with the load.

Identify all tools and materials required for practical's and obtain them under correct procedures

Apply the voltage provided to you by your trainer

Adjust this voltage and measure the voltages and currents, then record them in the table below

To complete the task, calculate the power being drawn from the supply at each setting.

Ensure your JSA is completed and checked by the trainer prior to starting

Ensure you follow relevant Australian standards and legislation in regard to isolation

Upon completion tidy your work area and return all equipment to the correct storage area.

and present your results to your trainer

Change Voltage Results					
	Voltage set	Voltage measured	Resistance measured	Current measured	Power calculated
Setting One					
Setting Two					
Setting Three					
Setting Four					

Practical activity 3 – EMF practical activity results

Instructions

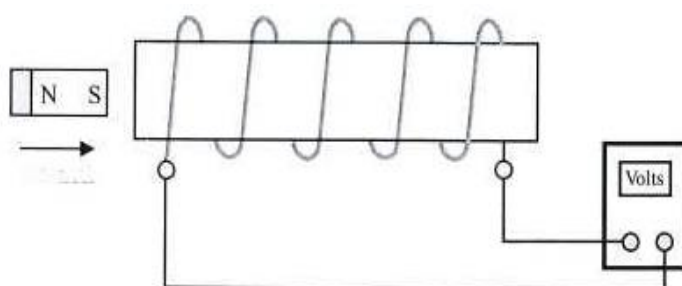
Your trainer will provide you with the equipment required to produce an EMF on a voltmeter.

Using the voltmeter, measure your circuit under the four conditions listed below, then record the deflection shown on the voltmeter, in the table

1. The magnets' north pole is inserted slowly and quickly
2. The magnets' north pole is withdrawn slowly and quickly
3. The magnets' south pole is inserted slowly and quickly
4. The magnets' south pole is withdrawn slowly and quickly.

Ensure your JSA is completed and checked by the trainer prior to starting. Your trainer will observe the generated EMF for assessment.

Upon completion tidy your work area and return all equipment to the correct storage area.



EMF practical activity results		
	Positive deflection (large/small)	Negative deflection (large/small)
North pole inserted slowly		
North pole withdrawn slowly		
North pole inserted quickly		
North pole withdrawn quickly		
South pole inserted slowly		
South pole withdrawn slowly		
South pole inserted quickly		
South pole withdrawn quickly		

Practical activity 4 – Identification of coloured resistors results

Instructions

Using the resistor colour code provided by your trainer, determine the resistance value from the range of resistors provided by your trainer.

Measure each resistor then determine if the resistance is within tolerance.

Record your results in the table below.

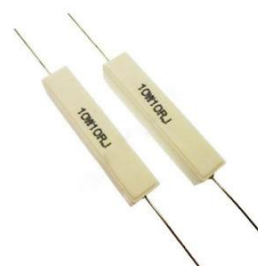
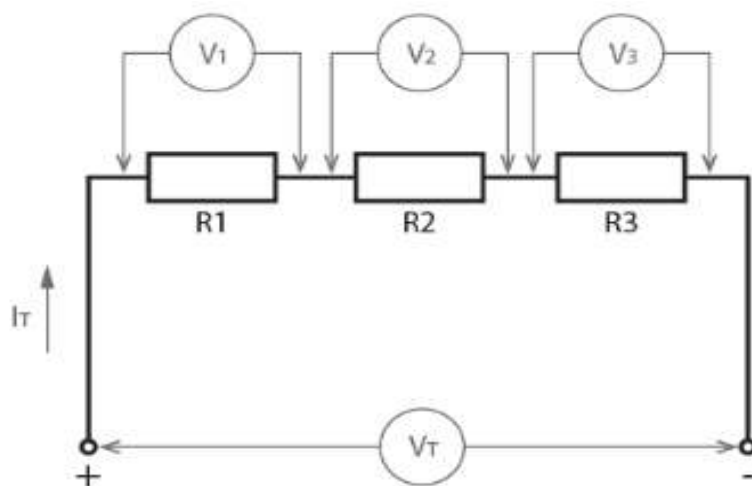
Ensure your JSA is completed and checked by the trainer prior to starting. Upon completion tidy your work area and return all equipment to the correct storage area.

Identification of coloured resistors results				
Resistors	Determined resistance	Tolerance	Measured resistance	Within tolerance Yes / No
R1				
R2				
R3				
R4				
R5				
R6				
R7				
R8				
R9				
R10				
R11				
R12				

Practical activity 5 – Build a series electrical circuit

Overview

Measure the value of resistance in three resistors then, using the resistors, build a series electrical circuit.



Instructions

This task requires you to complete 2 scenarios

Your trainer will provide you with three resistors and a range of tools.

Measure the value of resistance in each resistor and record the values in the table below.

Following the circuit above, build a series electrical circuit using the three resistors.

Apply the voltage given to you by your trainer, measure the voltage across each resistor, then total the voltage and record the values.

Safely install the ammeter into the circuit in series after each resistor and record the values. Calculate the power drawn from the supply by each resistor and the total power drawn from the supply.

Ensure your JSA is completed and checked by the trainer prior to starting. Upon completion, return all equipment then present your results to your trainer.

Build a series electrical circuit results				
	Resistance measured	Voltage measured	Current measured	Power calculated
Resistor One				
Resistor Two				
Resistor Three				
Total Circuit Measured				

Build a series electrical circuit and short out Resistor 2 (R2)				
	Resistance measured	Voltage measured	Current measured	Power calculated
Resistor One				
Resistor Two				
Resistor Three				
Total Circuit Measured				

Q1. In Scenario 2, what effect did shorting out the resistance have on the total circuit resistance and hence total circuit current?

Next steps

Congratulations on finishing this unit! Now you should be familiar with determining the correct operation of single source d.c. series and providing solutions as they apply to various electrotechnology work functions. If you have any further questions, please ask your trainer.