ADVANCED

Lesson 10

MAINS POWER and POWER SUPPLIES

ACMA Syllabus February 2024 Chapter 3.3

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Mains Power – 230v Wiring

As experimenters, homebrewers and repairers of our equipment plugged into the 230 VAC (50 Hz) mains, we need to be mindful of electric shock-hazards.

The socket outlet (General Power Outlet (GPO)) on the wall is the source of electricity and is usually rated at 10 Amps. Any hard-wired equipment (e.g., Ovens, cook tops) or anything behind that GPO can only be altered or repaired by a licenced electrician.

The work must comply with the Australian/New Zealand Wiring Rules AS/NZS 3000:2018.

Our area of focus extends from the three-pin plug, which plugs into the GPO, and lead that supplies power to our communications equipment.

Was 240v.

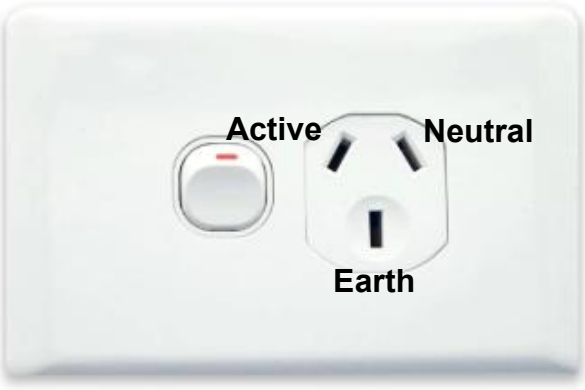
In 1994, European Commission (EC) decided to ‘harmonise’ the standard UK mains voltage of 240v and the European standard of 220 V to an agreed 230 V. However, the cost of replacing or adjusting all the electricity supply equipment across Europe to deliver 230 V was prohibitive, there being no technical advantage.

The European Commission simply altered the legal voltage limits.

Australia's official standard voltage is 230 volts AC at 50 Hz. While the standard changed from 240V to 230V to align with international standards, the supply tolerance allows it to range between 216V and 253V, meaning voltage in practice often remains closer to 240V in many areas.

The GPO

The standard three pin configuration plug and socket is used in Australia is also utilized in New Zealand, Fiji, Tonga, Solomon Islands, Cook Islands, Papua New Guinea, and several other Pacific Island countries.



Three Pin Plug.

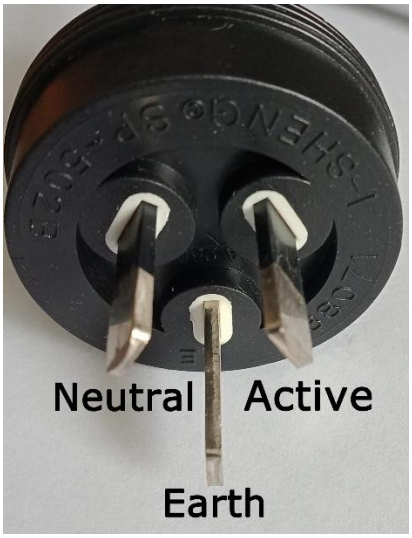


Figure 1: Three pin power plug.

Voltage Testing

Using an appropriate multimeter set to the AC 240v or higher range. The expected test results are shown below.

Active to Neutral	230v
Active to Earth	230v
Neutral to Earth	0v

Modern Wire Colours

In modern mains wiring.

- The active wire is coloured brown.
- The neutral conductor is coloured blue and is the return path for the circuit.
- The Earth conductor is coloured green with a yellow tracer.

Mains Earthing

An earth wire must be connected to the metal case of any equipment. The Earth provides protection if the equipment fails. This prevents the metal case from ever having the mains voltage on the casing.

The Earth pin is electrically connected to an Earth stake near your power box.

Deliberately disconnecting the Earth and operating the equipment is an extremely dangerous practice.

Signal Earthing

A signal earth should be connected to a separate earth stake near your radio shack.

Mains Earth V Signal Earth

Electrical earth provides a low-impedance path to the ground for faulty currents and prevents electric shock.

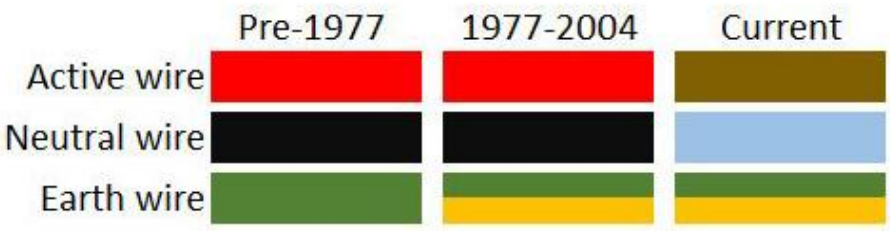
Signal earth serves as a common, zero-volt reference point for electronic circuits to ensure signal integrity and reduce noise.

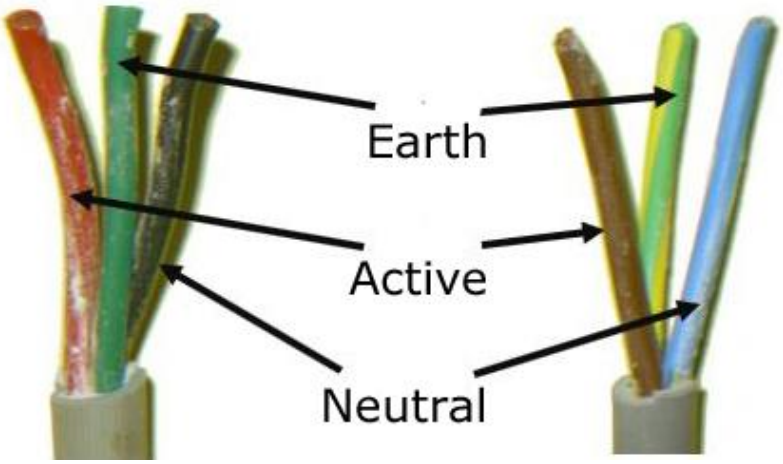
Electrical earth is for safety while signal earth is for functionality.

Older Wire Colours

Older equipment may have the older coloured wiring fitted.

- Active – Red
- Neutral – Black
- Earth - Green





15 Amp Plugs

The general three pin plug is rated at maximum of 10 Amps. A different three pin plug with a larger earth pin and is rated at 15 A. These are encountered in caravan extension leads.

Power Supplies

A power supply is a device that provides the required electric power for an electrical load. The power supply may have to convert power from a source to the correct voltage for the load. Power supplies can be separate pieces of equipment or incorporated within the equipment.

Power Supply Groups

There are several types of power supplies, but the three main groups are shown below.

- DC powered.
- Linear AC powered.
- Switch mode power supply.

DC Powered

This is usually a battery or powerpack that supplies the correct DC voltage required by the equipment.

Linear Power Supply (LPS)

A linear power supply typically uses a large transformer to drop voltage from an AC line voltage to a much lower AC voltage and then uses a rectifier and filtering process to produce a very clean DC voltage.

Advantages of LPS

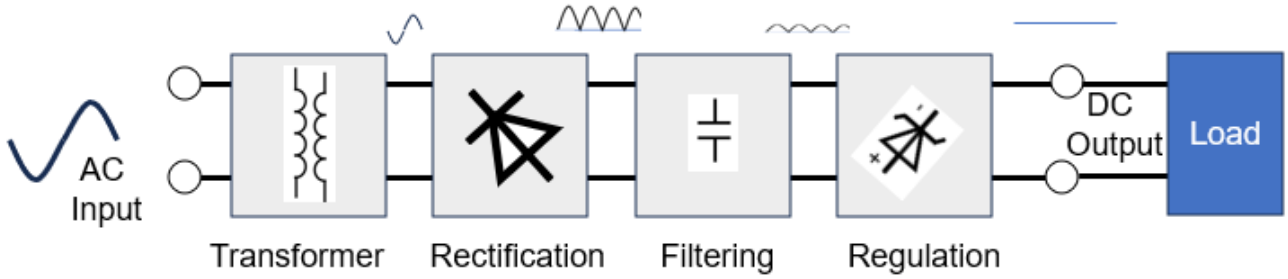
- The power supply is continuous.
- The circuitry is simple.
- These are reliable systems.
- This system dynamically responds to load changes.
- As the components operate in linear region, the noise is low.
- The ripple is very low in the output voltage.

Disadvantages of LPS

- The transformers used are heavier and large.
- The heat dissipation is high.
- The efficiency of linear power supply is 40 to 50%.
- Power is wasted in the form of heat in LPS circuits.
- Single output voltage is obtained.

Overview

A linear power supply (LPS) usually comprises of five areas.



Power source

This is the 230 V AC 50Hz mains power.

Transformation

A transformer is a passive electrical device that transfers energy between circuits through electromagnetic induction, usually to change (step-up or step-down) voltage levels while keeping frequency constant. Transformers were covered in lesson 5.

Rectification (AC to DC)

Rectification is the process of converting alternating currents (AC) into direct currents (DC).

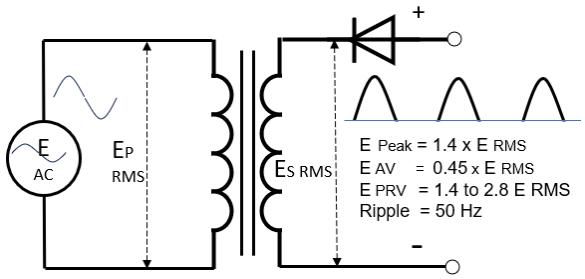
Rectification falls into three groups.

Half wave Rectifier

The current only conducts in one direct due to the diode in the circuit. The shape of the output is shown below. A DC meter will show as 0.45 times the RMS value.

The Peak Reverse Voltage (PRV) is the voltage the rectifier must withstand when the diode is not conducting. This can vary between 1.4 to 2.8 the RMS value.

The other disadvantage of a half wave rectifier is that the primary winding of the transformer must deliver approx. 40% greater rating to deliver the same DC output as other rectifiers.

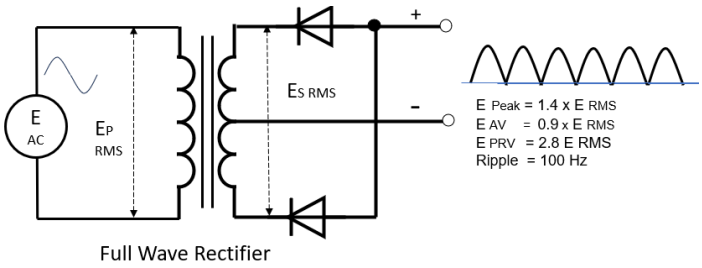


Half Wave Rectifier

Full Wave Rectifier

The full wave rectifier uses both cycles. This is the more common rectifier over the half wave rectifier.

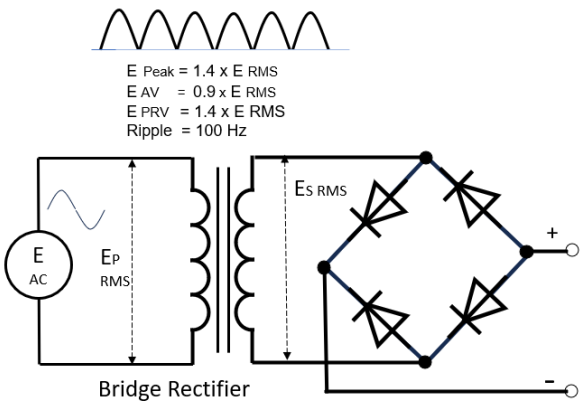
The downside is the need for a specialty centre tapped transformer.



Full Wave Rectifier

Bridge Rectifier

The Bridge rectifier has the advantage that it does not need a centre tapped transformer. The output and ratings are the same as the full wave rectifier. Also, the Peak Reverse Voltage (PRV) is halved as the transformer is not centre tapped.



Bridge Rectifier

Filtering and smoothing

Power supply filtering is the process of remove unwanted AC ripple, voltage spikes, and noise from a DC power supply, ensuring a stable, clean, and consistent voltage for electronic circuits.

Ripple Frequency

Ripple frequency is the rate of periodic voltage fluctuations in a rectified DC power supply and is measured in Hertz (Hz).

In half wave rectifiers, the ripple frequency is the line frequency.

In a full-wave or bridge rectifier, the ripple frequency is twice the line frequency.

Ripple Percentage

The ripple on the output of the rectifier can be expressed as a percentage. Depending on the application, the ripple may be as high as 5% of as low as 0.01% for a speech amplifier.

Filtering Capacitor

The size and complexity of the filtering circuit depend on the stability and reliability of the supply for the load.

A capacitor that is used to screen out frequencies from an electronic circuit is known as the filter capacitor. A filter capacitor removes the AC signals which have a low frequency near to 0Hz.

Calculating the correct filter capacitor size is important for the reduction of the ripple.

$$C = \frac{I\ x\ t}{E}$$

C = Capacitance in micro-Farads (µF)

I = Load in milliamperes (mA)

T = Time between peaks in milli seconds (mS)

E = Voltage drops on load or peak to peak of the ripple voltage. (V)

Example: I = 2000 mA E = 1 V P to P t = 7.5 mS

$$C\ \mu F = \frac{2000mA\ x\ 7.5\ mS}{1\ V\ PtoP}$$

$$C\ \mu F = \frac{1500}{1}$$

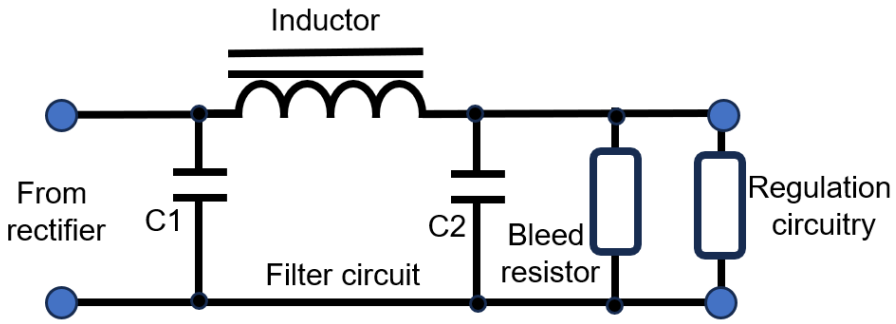
$$1500\ \mu F$$

Bleeder Resistor

The bleeder resistor is a high-resistance device connected in parallel with the filter capacitors in power supplies.

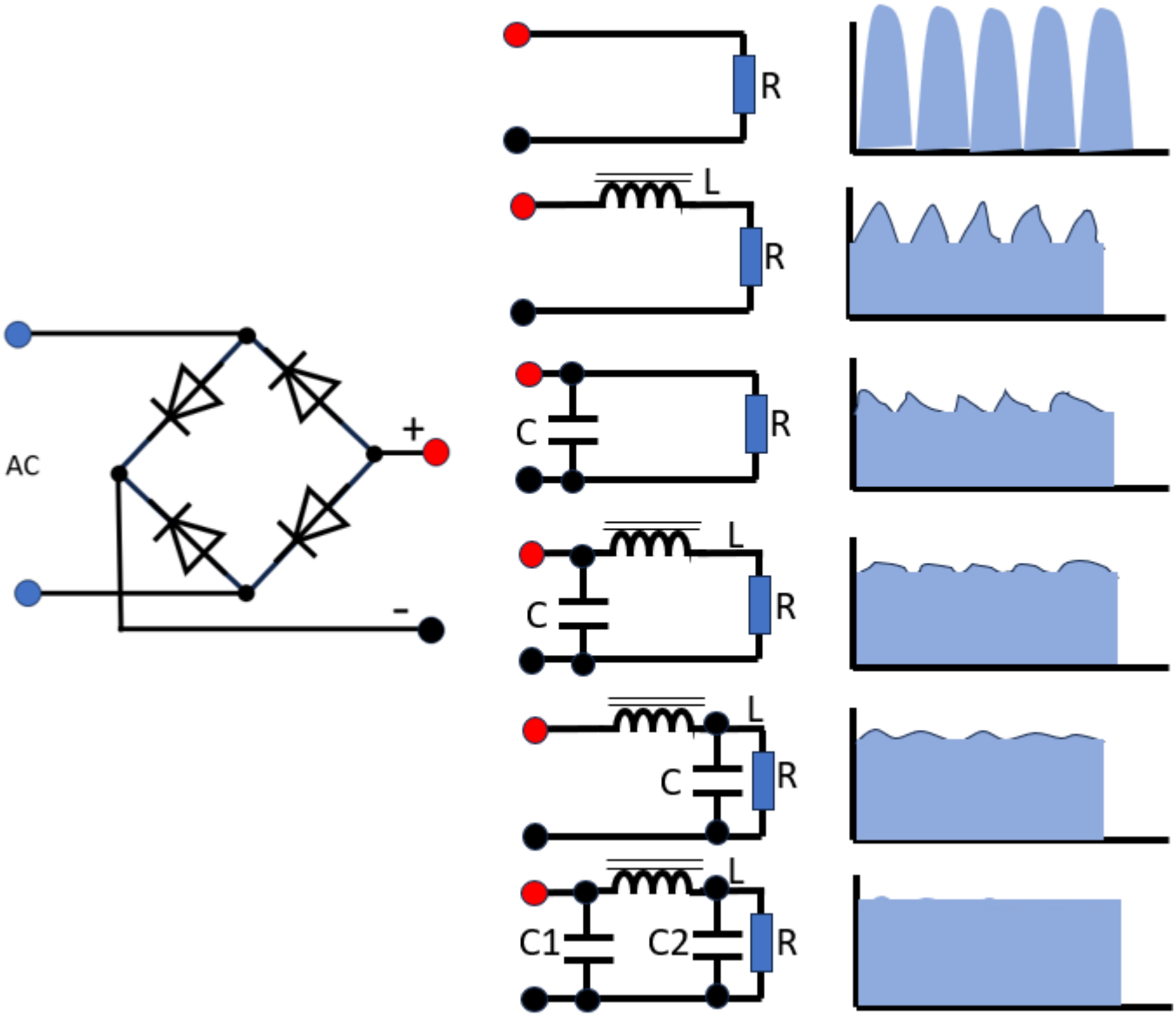
This resistor discharges the filter capacitors when the supply is off and prevents electric shocks during maintenance.

The resistor also aids in the stabilisation of the voltage by providing a minimal permanent load to the supply.



Filter Complexity

As The filter design gets more complex, the smaller and less noticeable is the ripple.



Regulation

Power supply regulation is the ability of a power supply to maintain a constant, stable output voltage (or current) despite changes to the input voltage (line regulation) or changes in the connected load (load regulation).

The output of the rectified and filtered signal may still be too unstable for some electronic equipment. Voltage regulators are added to provide the extra voltage stability.

This may range from a Zener diode to linear circuit with an op amp or a dedicated voltage regulator chip.

Chips like the LM 78XX series are common in home-brew power supplies.

The number LM78 represents the group of voltage regulators, and the second number is the output voltage.

Example:

- LM7805 is a 5-volt regulator chip.
- LM7809 is a 9-volt regulator chip.
- LM7812 is a 12-volt regulator chip.

Video: A good video to tie all the linear power supply parts together can be seen at the following link. Rectifier Filtering Examples below from

Full Wave Bridge Rectifier + Capacitor filters + half wave rectifier (youtube.com)

Switch Mode Power Supplies (SMPS)

A Switch Mode Power Supply may be used as a replacement for linear supplies when higher efficiency, smaller size or lighter weight is required. They are more complicated and switching currents can cause electrical noise problems.

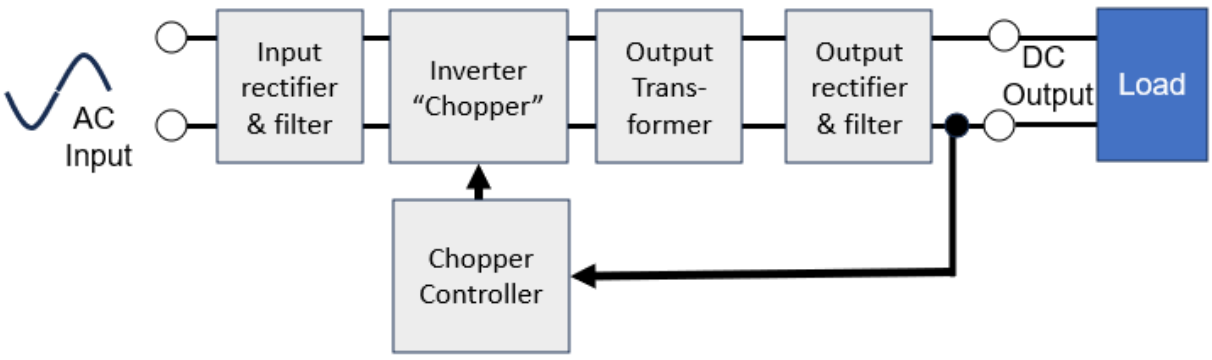
Advantages of SMPS

- Low Weight and Smaller Size
- Higher Efficiency
- Wider AC input Voltage Range
- Reduced Cost

Disadvantages of SMPS

- Noise is present due to high frequency switching.
- The circuit is complex.
- Produces electromagnetic interference.

Overview



Input

The AC input supply signal 50 Hz enters the rectifier and filter circuit combination. SMPS does not use a transformer to change the voltages at this point. The unregulated DC passes to the central switching section of SMPS.

Switching Section

A fast-switching device such as a power transistor or a MOSFET switches ON and OFF (Chops) the unregulated DC. SMPS chopper frequencies average around 50–200 kHz. High-frequency switching allows for smaller magnetic components, higher efficiency, and less power loss.

Output Transformer

The chopper output is fed to the primary of the transformer. The transformer is much smaller and lighter than the transformers used in linear supplies. Unlike those used for 50 Hz supply. These transformers are much efficient and hence the power conversion ratio is higher.

Output Rectifier

The output signal from the transformer is again rectified and filtered and delivers a regulated output DC voltage.

Control Unit

The output is monitored and fed back to the chopper. This controls the chopper frequency. The feedback ensures the final voltage output level is maintained.

A good video explaining switch mode power supplies is more detail. Go HERE

Inverters

An inverter, aka a power inverter or frequency inverter, is an electronic device designed to convert direct current (DC) into alternating current (AC) and at any frequency and voltage.

Common inverters convert 12 V DC to 230 V AC

Personnel and Equipment Protection

Crowbar protection.

Crowbar protection is a power supply circuit used to prevent an overvoltage or surge condition from damaging the load circuit connected to the power supply.

This protection operates by short circuiting the voltage output**.**

This result is the same as throwing a crowbar over exposed power supply terminals to short the output.

Fuses

The fuse protects a system or equipment from overload and short-circuit faults. If an overload of current is drawn across a fuse, the fuse melts or vaporises which breaks the conductive path of the current.

Fuses come in many shapes and sizes. Depending on the application, the is a fuse to use.

To estimate the right fuse rating, you can use the power formula (P = I x E).

Divide the power of the attached device (measured in watts) by the voltage of the power supply. If the result is a fraction, round this down. Rounding up may exceed the equipment limit. Better to be safe.

Example: A drill requiring a new fuse has a 700-watt rating, divide this by 230 V. The result is 2.91, so you will require no bigger than a 3A amp fuse for the plug.

WARNING: Never short circuit a fuse with material such as a nail or foil.

Never replace a known fuse rating with a higher rating.

Circuit Breaker

A circuit breaker is a safety device that will cut the supply in the event of over current or short circuit. Circuit breakers are made in varying current ratings.

Circuit breakers are designed to protect equipment.

Residual Current Devices

RCDs are designed to protect personnel.

RCDs immediately switch off the supply of electricity when electricity leaking to earth is detected at harmful levels. They offer high levels of personal protection from electric shock.

RCDs offer a level of personal protection that ordinary fuses and circuit-breakers cannot provide.

An RCD constantly monitors the electric current flowing through one or more circuits it is used to protect. If it detects electricity flowing down an unintended path, such as through a person who has touched a live part, the RCD will switch off the circuit very quickly, significantly reducing the risk of death or serious injury.

RCD can be grouped into three categories.

1. Fixed RCDs in the fuse box and protects all the wiring and the sockets on a circuit.

2. Socket-Outlet RCDs are built into the socket and protect only to the person in contact with equipment connected to that socket.

3. Portable RCDs provide protection only to the person in contact with the equipment, including its lead, plugged into the portable RCD.

Go to Lesson 10 Questions.