Lesson 10

POWER SUPPLIS AND RECTIFIERS

ACMA Syllabus February 2024 Chapter 3.3

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Power Supplies

Mains Power- 240V Wiring

As experimenters, homebrewers and repairers of our equipment plugged into the 240 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.

The Three Pin Plug.

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

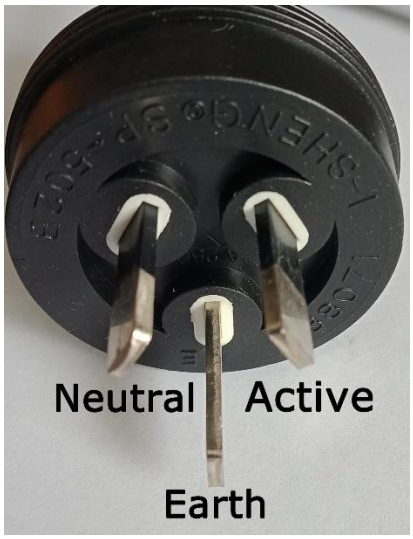


Figure 1: Three pin power plug.

Wire Colours

- The active wire is coloured brown.
- The neutral conductor is normally coloured blue and is the return path for the circuit.
- The Earth conductor is coloured green with a yellow tracer. This wire must be connected to the metal case of any equipment. The Earth provides protection if the equipment fails. 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.

Older equipment may have the older coloured wiring fitted.

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

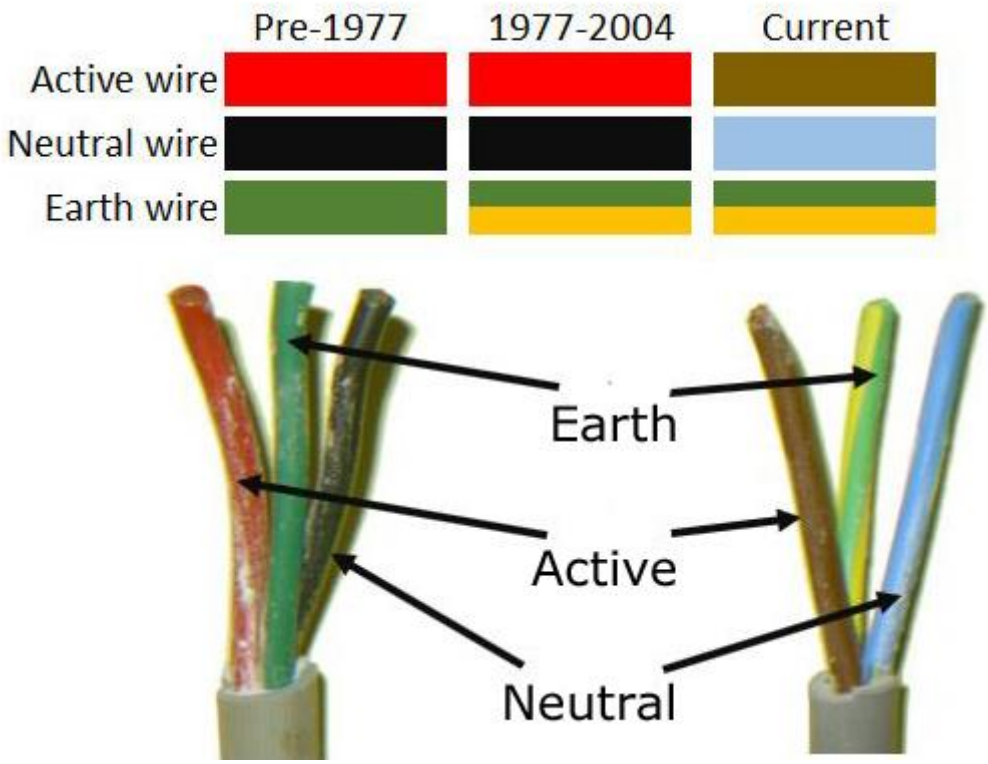


Figure 2: Wiring colours.

Current

The general three pin plug is rated at maximum of 10 A.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 converts power from a source to the correct voltage for the load. Power supplies can be separate pieces of equipment or incorporated with the equipment it supplies.

Types

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

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

The focus of this lesson will be on the linear and 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.

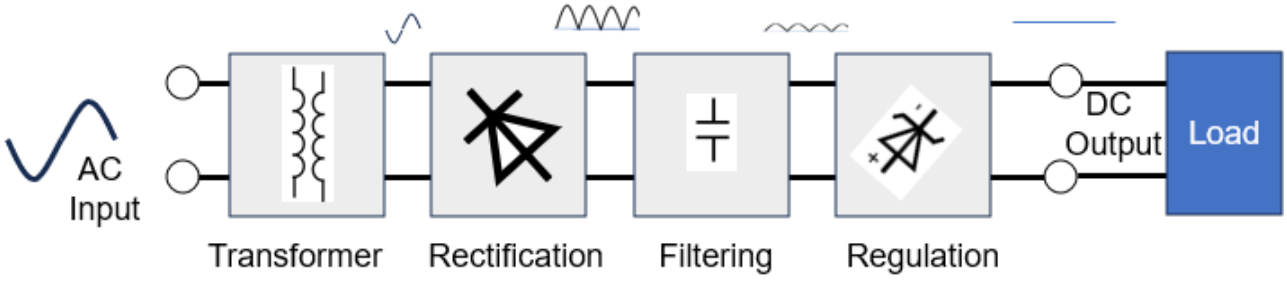
Disadvantages of LPS

- 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 usually comprises of five areas.

1. The original power source.
2. A conversion (transformation) from the source voltage to a required voltage
3. Rectification (AC to DC)
4. Filtering and smoothing
5. Regulation of the DC voltage



Power source

The usual power source is the 240 V AC 50Hz mains power as covered earlier.

Conversion (Transformer)

The conversion of AC voltages is usually performed by a transformer as covered in Lesson 5.

Rectification

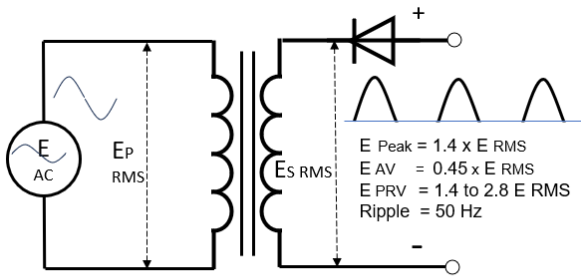
Rectification falls into three groups.

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. His can vary between 1.4 to 2.8 the RMS value.

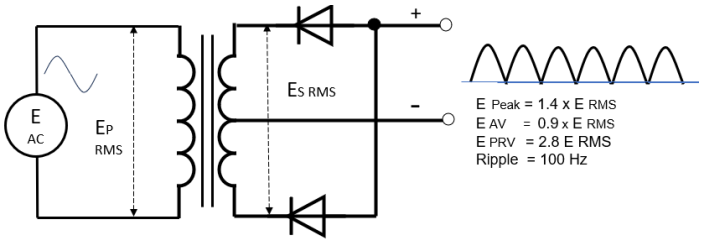
The other disadvantage of a half wave rectifier is that the primary winding of the transformer must deliver approx. 40% greater rating to deliver the same DC output as other rectifiers.



Half Wave Rectifier

Full Wave Rectifier

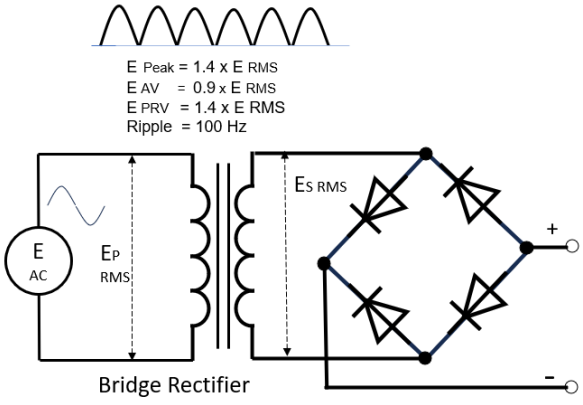
The full wave rectifier uses both cycles. This is the more common rectifier over the half wave rectifier.



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

Ripple Frequency

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 depends 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.

The 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

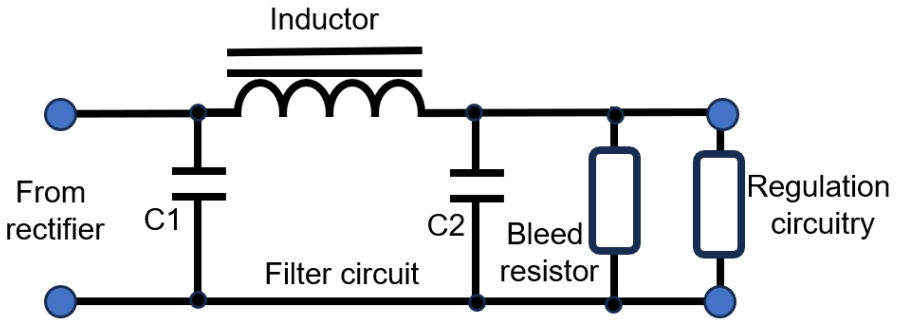
$$C\ \mu F = \frac{2000mA\ x\ 7.5\ mS}{1\ V\ PtoP}$$

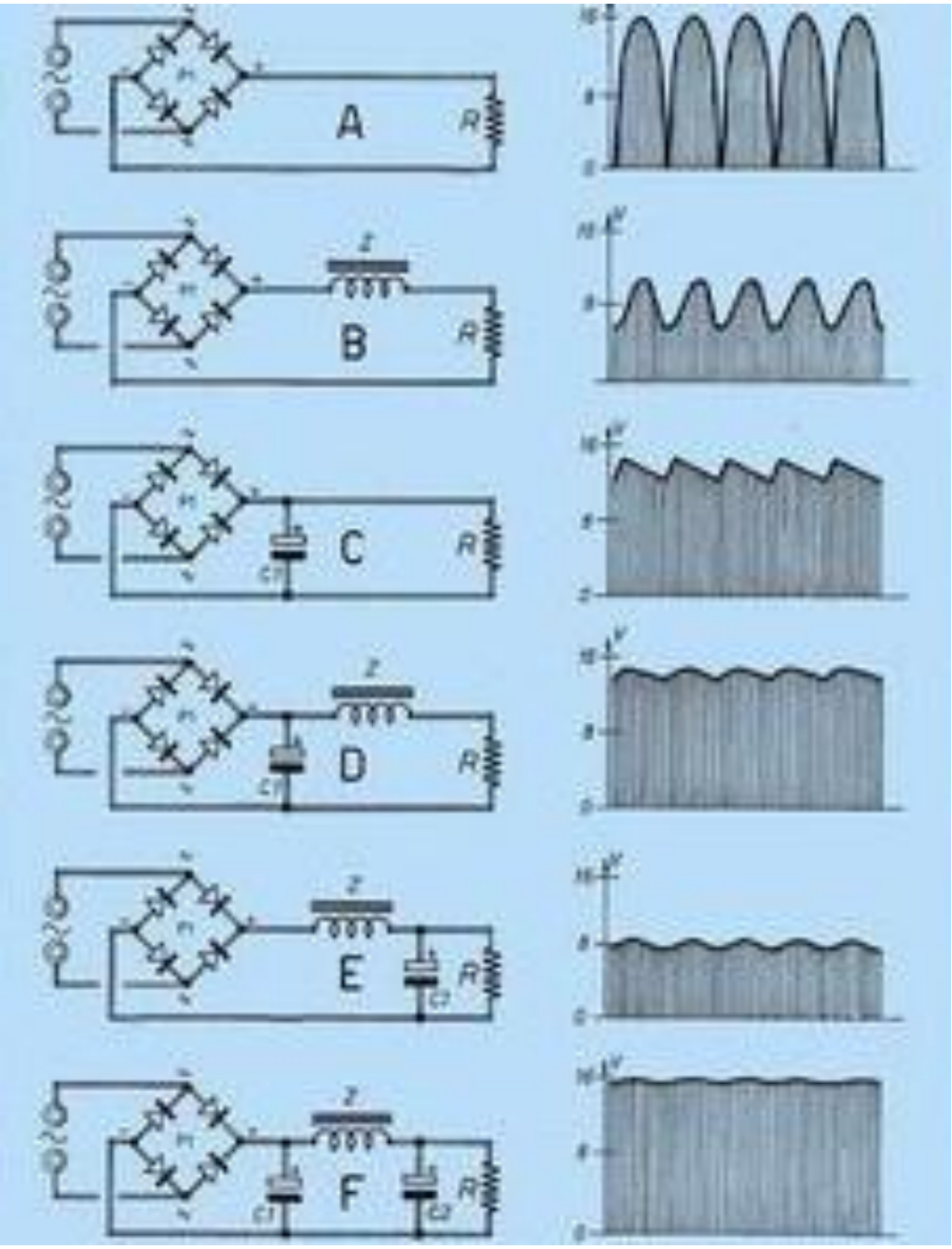
$$C\ \mu F = \frac{1500}{1}$$

$$1500\ \mu F$$

Bleeder Resistor

The filtering capacitors, C1 and C2, can hold a charge. A bleeder resistor across the output terminal discharges the filter capacitors when the supply is off.





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 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.

Crowbar protection.

A crowbar circuit in a power supply is a protection for the load. In the event of an overvoltage, to protect the load, the supply output will short and blow the power supply fuses.

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.

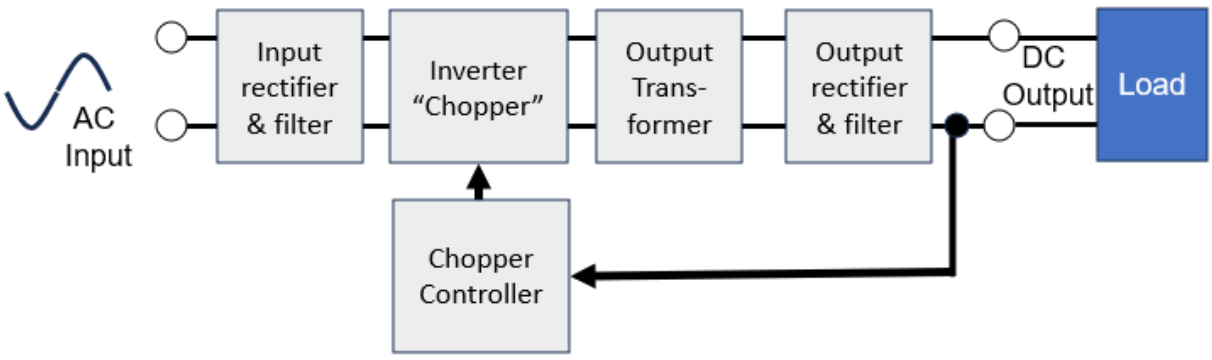
Advantages of SMPS

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

Disadvantages of SMPS

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

Overview



Input

The AC input supply signal 50 Hz is passed to the rectifier and filter circuit combination without using a transformer. This unregulated dc is given 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 according to the variations. The chopper output is fed to the primary of the transformer. The transformer is much smaller and lighter ones unlike the ones used for 50 Hz supply. These are much efficient and hence the power conversion ratio is higher.

Output Stage

The output signal from the transformer is again rectified and filtered delivering a regulated output DC voltage. The output is a fed back to the chopper controller.

Control Unit

The feedback controlling the chopping frequency ensures the final voltage 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 240 V AC

PROTECTION

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 calculate the right fuse rating, you can use Ohm's Law. 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 up or down.

Example: A drill requiring a new fuse has a 700-watt rating, divide this by 240 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 (e.g. use a nail instead of a fuse) or 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.

Residual Current Devices

RCDs are designed to 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.