Mains Power Supplies

Introduction.

Power supplies are necessary to supply the voltage and current to operate all radio equipment. The power supplies can be divided into two general categories:
1.fixed power supplies;
Fixed power supplies are those that operate using the electricity authority supply of 240 volts, single phase AC, operating at a frequency of 50 Hz.

2. portable power supplies.
Portable power supplies are those that can be carried, such as batteries, portable generators etc.

240 volt AC supplies.

Most radio and electronic equipment requires access to a 240 volt 50 Hz single phase supply to operate base station equipment. The supplying authority generates the power which contains three separate phases of 240 volt RMS, each phase 120° apart. In most cases in Australia only one of these phases is fed to homes for domestic use. This is fed from the street distribution point to the metering point on your premises. Fuses or circuit breakers are provided at the street distribution and the metering point.

In Australia the 240 volt single phase system is multiple earth neutral system (MEN) where the neutral conductor is connected to the earth. This means that the voltage between the active and neutral or ground on a single phase system will be 240v AC. RMS.

At the metering point the supply is divided and wired throughout your home. The power in your home is made available for use via a general power outlet (GPO). Domestic wiring should not be added to or modified unless by a qualified electrician. Failure to comply with these regulations can result in loss of life due to exposed wiring, damage to your home which may not be covered by insurance, or costly rewiring to restore your installation to normal.

From a safety point of view, it is necessary that amateur operators have knowledge of the requirements as far as operating equipment from the 240 volt AC supply.
The supply is 240 volts RMS. This is a peak voltage of 1.414 x 240 = 339.36 volts. The general power outlet in the home is capable of supplying 10 or in some instances 15 amps. In terms of power this is approximately 2400 watts. The power is supplied at a frequency of 50 Hz which is extremely accurate over a 24-hour period. The supply wired throughout your home has three wires - active, neutral and earth.
When looking at the front of a GPO, the wiring should be connected as shown in Figure 1.

The active supplies the power to the circuit. The active wire in our equipment should always be switched and fused or have a circuit breaker. This will open the circuit if a fault condition occurs. The earth provides a low impedance path for fault current.
The neutral is the return circuit for the active. This in conjunction with the active can also be switched, i.e. double-pole switching. This provides additional safety as, if the incoming lead is reversed, the active is still removed when the equipment is turned off.

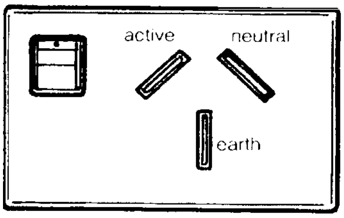


Figure 1.

The plug that is inserted into the socket must be wired correctly, as shown in Figure 2. Incorrect wiring of the plug or socket on an extension lead can lead to electric shock, which may be fatal. The three-core flex for mains leads are colour coded:

1. active - brown;
2. neutral -blue;
3. earth ___ yellow/green.

Some older cable is still in use where:

1. active ___ red;
2. neutral ____ black;
3. earth ____green;

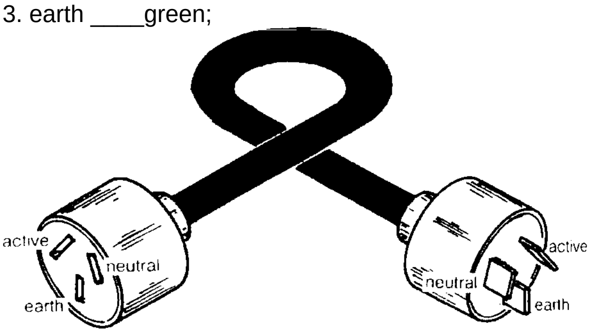


Figure 2.

Power wiring in Australia should be carried out to Australian standard AS/NZS 3000:2000. All wiring back from the general power outlet must be carried out and inspected by a suitably qualified licensed electrician. A detailed knowledge of this wiring is not necessary. However, we as amateurs will construct power supplies, make extension leads, etc., which we shall connect to the mains. Therefore, it is necessary for us to know the regulations and requirements for the safe connection of this equipment.

Extension leads are often responsible for electric shock due to their being in poor condition or having incorrectly terminated wires. Reversal of the wires in an extension lead can cause the equipment to which it is connected to become live and an electric shock can result from touching the equipment.

Frayed or damaged leads are potential sources of electric shock and should be replaced. If repaired the repairs should be completed by an appropriately qualified person.

Circuit breakers and fuses.

A fuse is included in the circuit to protect the wiring. Fuse rating should always be observed and heavier fuses should never be placed in the circuit under any circumstances. Incorrectly rated fuses can cause fire as well as damage to equipment. The neutral is often at earth potential; however, this is not always the case.

The earth is connected to a local earth stake to provide a low impedance path to cause the equipment to blow a fuse if a short or low resistance path occurs between the active and the earth. The earth connection is vital to the equipment and must always be short and of very low resistance.

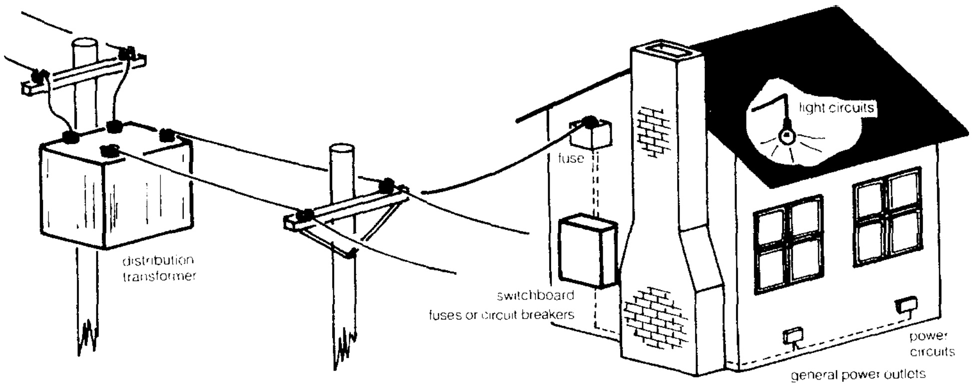
Circuit breakers are available in two general types: thermal and magnetic. The thermal circuit breaker is used for current overload. A temperature sensitive circuit within the breaker causes it to open the circuit if the overload causes the temperature to rise significantly. The temperature must return to normal before the circuit breaker is reset.

The magnetic circuit breaker has a small coil included, the magnetic field of which will trip the breaker when excess current is passed through it. This principle is not unlike a solenoid. This breaker cannot be reset until the excessive load causing the current is removed.

The advantage of the circuit breaker over the fuse is that the fuse, if it blows, must be replaced by a new fuse or fuse wire, whereas the circuit breaker is reset restore it to its normal operating condition.

Fuse and circuit breaker rating.

Fuses and circuit breakers should be rated so that they do not operate under normal circuit conditions. To work out the rating of a fuse, the following information is required:



Calculate all the maximum currents that are going to occur in the circuit and add these values together.

Add 20% to 50% to the calculated value.

3. Never exceed fuse ratings that are specified

Figure 3.

Figure 3 is a diagram showing the location of the fuses in a typical home. Each fuse has a lower operating value than the one preceding. The highest fuse rating will be at the power distribution point at the pole, the lowest at the equipment. All fuses must be the type and value as specified by the supply authority or equipment manufacturer. Earth leakage or core balance circuit breakers, often termed safety switches, are being used for circuit protection and personal safety. Magnetic or thermal circuit breakers, as well as fuses, require high current to be present for some time before the protection comes into operation. In addition, conventional circuit protection does not protect against a voltage rise in the earth system. Earth leakage circuit breakers have a voltage-sensing circuit in the earth lead and will trip if the voltage of the earthing system rises 20 volts above earth potential. Core balance circuit breakers continuously monitor leakage current to earth and will trip if the earth current is in excess of 20 mA for a predetermined time. The earth current is passed through a balanced magnetic circuit in the core and will trip as soon as the balanced condition is upset. It is advisable to be conversant with the manufacturer's specifications prior to using these devices. The installation of these devices on your premises by a qualified electrician is advisable.

A highly visible mains isolating switch should be located in an obvious location adjacent to the radio and electronic equipment being operated. This is a safety precaution to disconnect the power in case of an electric shock

The domestic 240 volt supply in its supplied state is not suitable to operate radio equipment. Inside an item of electronic equipment is a power supply which converts the AC fed into it to DC at the required operating voltage.

Power Supply Basics.

Half Wave Rectifier:

Fig 4 shows a simple half-wave rectifier circuit. A rectifier (in this case a semiconductor diode) conducts current in one direction but not the other. During one half of the ac cycle, the rectifier conducts and there is current through the rectifier to the load . During the other half cycle, the rectifier is reverse biased and there is no current to the load. As shown, the output is in the form of pulsed dc, and current always flows in the same direction. A filter can be used to smooth out these variations and provide a higher average dc voltage from the circuit. This idea will be covered in the section on filters.

The average output voltage - the voltage read by a dc voltmeter-with this circuit (no filter connected) is 0.45 x $_{ERMS}$ of the ac voltage delivered by the transformer secondary. Because the frequency of the pulses is low (one pulse per cycle), considerable filtering is required to provide adequately smooth dc output. For this reason the circuit is usually limited to applications where the required current is small, as in a transmitter bias supply.

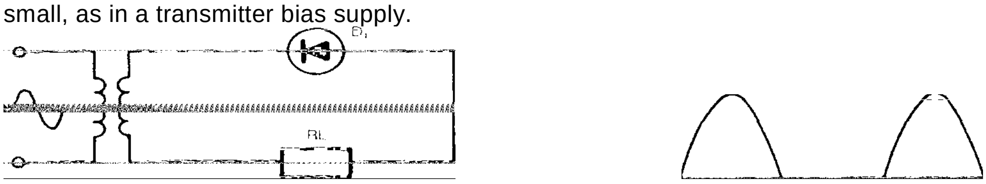


Figure 4.

FULL-WAVE CENTER-TAP RECTIFIER.

A commonly-used rectifier circuit is shown in Fig 5. Essentially an arrangement in which the outputs of two half-wave rectifiers are combined, it makes use of both halves of the ac cycle. A trans former with a center-tapped secondary is required in the circuit.

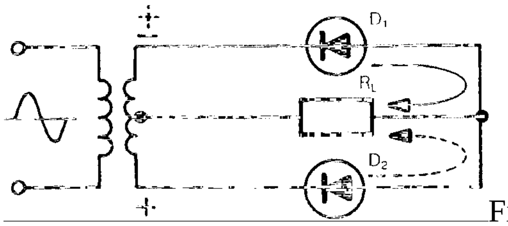
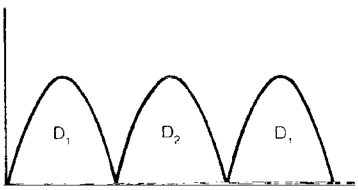


Figure 5

To reduce the amount of ripple in the output, a full-wave rectifier is used. With full-wave rectification, both halves of the input AC are converted to pulses of DC. The ripple is reduced to 48% when full-wave rectification is used.

With the first half-cycle of input signal, as shown with solid lines, diode D, conducts, which produces a pulse of DC in the load. Diode D2 is reverse biased and plays no part while D, conducts. The next halfcycle of input signal, as shown dotted, causes diode D2 to conduct. D, is reverse biased. Another pulse of DC appears in the load. The full-wave rectifier has a ripple frequency of 100 Hz when the input frequency is 50 Hz.

This rectifier has the disadvantage of having a centre tap transformer and each side of the centre tap must have a voltage equal to the voltage across the load. Therefore, the reverse biased diode must withstand twice the peak voltage of the voltage across the load.



Bridge Rectifier.

Figure 6 is the circuit diagram of a full-wave bridge rectifier. The bridge rectifier produces a ripple frequency of 100 Hz and a ripple content of 48%.

The voltage at the secondary of the transformer, shown in solid lines, will cause current to flow from negative through D_I, load, D2 to positive. Diodes D_3 and D_4 are reverse biased and therefore no current passes through them.

On the next half input cycle, the voltage at the secondary is as shown in dotted lines. Current will flow from negative D_3 load in the same direction as the previous half-cycle, D4 to positive. Pulsating DC is caused to flow through the load.

The advantage of the bridge rectifier is that the peak inverse voltage rating of the diodes need only be the secondary voltage of the transformer. The disadvantage of the bridge is that there are forward bias voltage drops across two diodes which means that the secondary voltage must be sufficiently high to overcome these voltage drops, i.e. 0.7 V + 0.7 V = 1.4 V, in addition to the voltage required at the load.

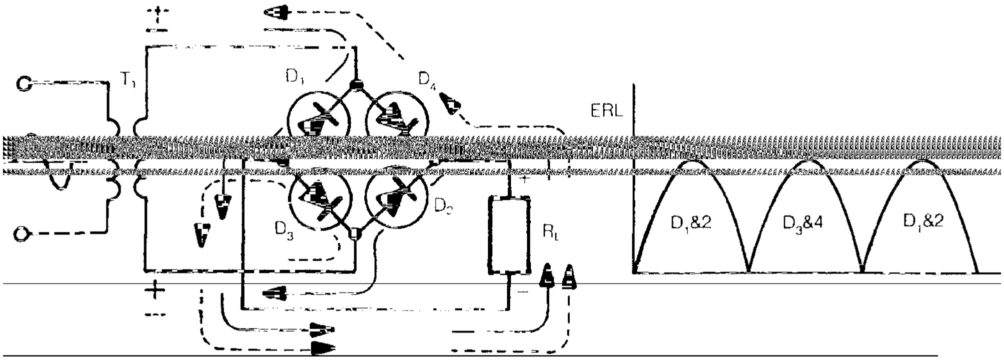


Figure 6

A note on Peak Inverse Voltage. You should always aim to have a diode PIV rating of sufficient rating to withstand the reverse voltage that is coming back. In a Full wave rectifier it should be DOUBLE the secondary voltage MINIMUM. For a safe overhead you should allow 20 % onto that figure or higher.

For a simple half wave and a Bridge rectifier you should aim for the secondary voltage value plus a 20 % overhead or higher to get a safe PIV rating.

Example:

I am designing a power supply and the secondary RMS value of the transformer is 16 volts. If I am using a full wave rectifier design then I would need TWICE the secondary voltage (32) plus 20 % safety margin that gives 36 volts. So any diode with a PIV greater than this would suffice. The PIV can be found on the diode Specifications sheets.

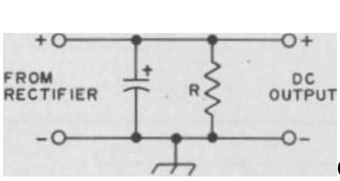
In the above example, if I was to change to Bridge rectifier, I would need a diode with 16 volts plus 20 % overhead would give me about 20 volts. So any PIV voltage rating greater than this value should suffice.

Silicon Diodes generally used for low voltage rectification will have a very high PIV value and be able to withstand the voltage that is coming in the reverse direction.
If the PIV is exceeded then the diode junction can be damaged or destroyed.

Filters for power supplies.

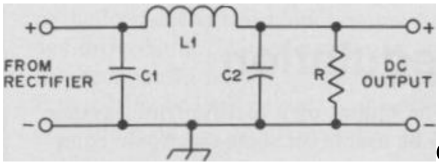
The ripple produced by rectification is too large to operate most radio equipment. To make the current suitable, a filter circuit follows the rectifier.

The type of filter is a low-pass filter, that is, one which will pass only the low frequencies and block all others. In the power supply, the frequency that the filter must pass is the lowest frequency or no frequency at all to provide DC at the output of the filter.
The simplest of these filters is a capacitor across the output of the full wave rectifier.
The capacitor will charge to the peak of the ripple and will tend to remain charged and provide current to the load while the ripple falls to zero.

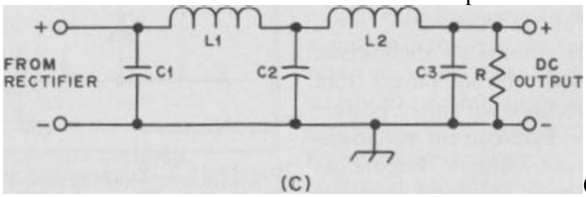


Capacitor input filter.

Note the resistor in the above diagram. It is called the ***BLEED RESISTOR***. It has a very important function in that it discharges the voltage off the filter capacitors when the power supply is switched off. This ensures that any electric shocks will be avoided. Capacitors of a large capacity can store an electric charge of a lethal potential for an extended period if no bleeders are used to reduce them to earth potential. The value of bleeders can be up to 150K Ohms or larger.
If a string of filter capacitors are used (which is common in large current capacity supplies) several bleeders can be used. One on each cap is common. Thus if one bleeder fails there are still others there for protection.



Capacitor filter with inductance choke.



Capacitor filter with double inductance choke.

The addition of the inductive chokes will reduce the output ripple of the supply greatly giving a smoother output and greater voltage stability over varying loads, but the disadvantage is they are bulky and heavy, and the output voltage is reduced to half of what the capacitor input can provide.

Be aware that there are additional elements to a power supply such as regulator circuits, over voltage and over current protection circuits and switch mode power supplies which have not been covered here as they are not covered in the official standard syllabus, but feel free to read up about these to get a better understanding of them.