

Online Radio & Electronics Course

Reading 20

Ron Bertrand VK2DQ
<http://www.radioelectronicschool.com>

POWER SUPPLIES

THE RECTIFIER

A rectifier is another name for a diode. I am not going to explain the internal operation of a rectifier now as we will be covering that in full later. I will explain what a rectifier diode does and ask you to accept that on face value for now.

The schematic symbol of a rectifier is shown in figure 1. A rectifier (diode) has two terminals, a cathode and an anode as shown. If a negative voltage is applied to the cathode and a positive to the anode the diode is said to be **forward biased** and it will conduct. If it is reverse biased it will not conduct. So a diode will only conduct current in one direction ie. from cathode to anode.

A forward biased (conducting) diode:

A reverse biased (blocking) diode:

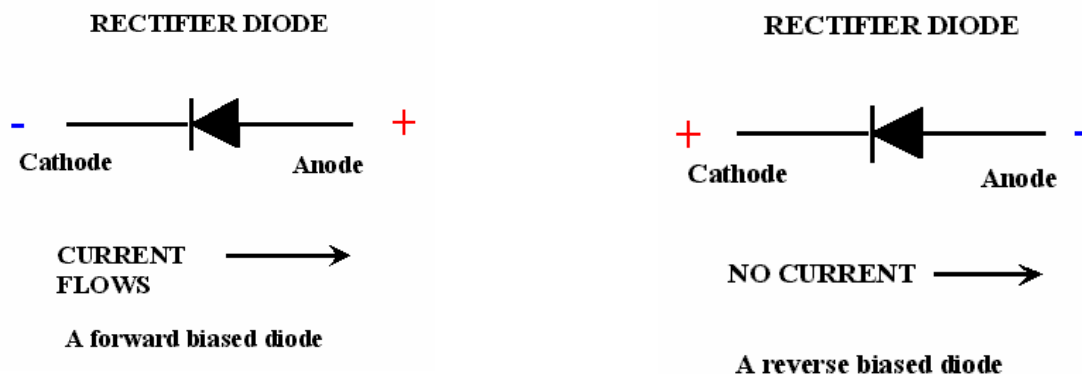


Figure 1.

PEAK INVERSE VOLTAGE (PIV)

Though we say a diode will not conduct in the reverse direction, there are limits to the reverse electrical pressure that you can apply. Manufacturers of diodes specify a peak inverse voltage for each particular diode. The PIV is the maximum reverse bias voltage that the manufacture guarantees that the diode will withstand. In practice the PIV is well below the pressure that will cause the diode to actually breakdown and conduct. However, except in special circumstances, the PIV should never be exceeded, and certainly not in power supply design.

ELECTRON FLOW VERSUS CONVENTIONAL CURRENT FLOW

Some textbooks show current flow from anode to cathode. This is called the conventional direction of current flow and is a hangover from the days when current was thought to flow from positive to negative. Electrical engineers and electricians

seem to hang on to this conventional direction of current flow. Electrons flow from negative to positive, from the cathode to the anode. In radio, electronics and communications, 'electron flow' is almost universally used. Electron flow is of course from negative to positive.

The vast majority of 'modern' references agree on the direction of current flow. Even textbooks that use conventional flow acknowledge that this direction (positive to negative) is just a convention. There is no harm in using conventional flow if this is what you prefer. However for circuit descriptions in this course, electron flow is used.

To help remember which way current flows through a diode look at the symbol - it has an arrow, and current flows against the arrow. This will help you not only with the diode but all semiconductor devices to be discussed later.

Let's have a look at the operation of a single diode rectifier if we apply an alternating voltage source to it. Since the diode will only conduct when the potential on the cathode is negative with respect to the anode, only half of the sine wave of alternating voltage will cause current to flow in the circuit of figure 2.

The current flow in the circuit of figure 2 is DC, but it is pulsating DC. The diode refuses to conduct for a complete half cycle of input voltage.

Figure 2.

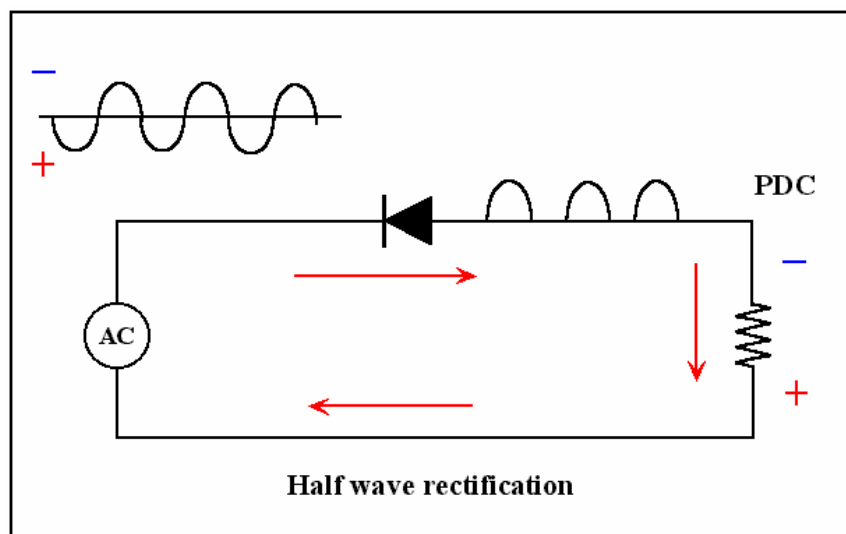
This is called half wave rectification.

This term rectification has always intrigued me a little. To rectify something means to make it right, to fix it up! This is where the term comes from. The radio pioneers considered converting AC to DC as fixing up the voltage, hence the term rectification. I often wonder if Edison had anything to do with the terminology. Edison was

strongly opposed to AC power distribution. During his feud with Tesla (who developed the AC power distribution system), Edison even electrocuted animals in public to demonstrate the dangers of AC. Tesla was right as it turns out, because for power distribution, AC is better than DC. Let me make the point that AC does not need 'fixing up', but we are left with this term 'rectification', which I find rather fascinating. In many cases we actually need to convert DC to AC so I suppose we should call this un-rectification, or perhaps stuffing it up again!

So, in trying to convert AC to DC, all we have managed to do as yet is convert AC to half wave pulsating DC (PDC).

Using diodes, it is very easy to produce full wave rectification. I am going to start with the most common method, the **bridge rectifier**. A bridge rectifier has four diodes as shown in figure 3. Rather than apply an AC voltage source, I have shown how the



bridge network will operate when two different polarities are applied to it, which in essence is simulating AC.

As you can see from figure 3, two of the bridge diodes will always conduct, because they have a negative voltage applied to their cathodes with respect to their anodes. Notice how current flows against the arrow. More importantly, notice how current always flows through the load resistor in the same direction, regardless of the polarity applied to the bridge.

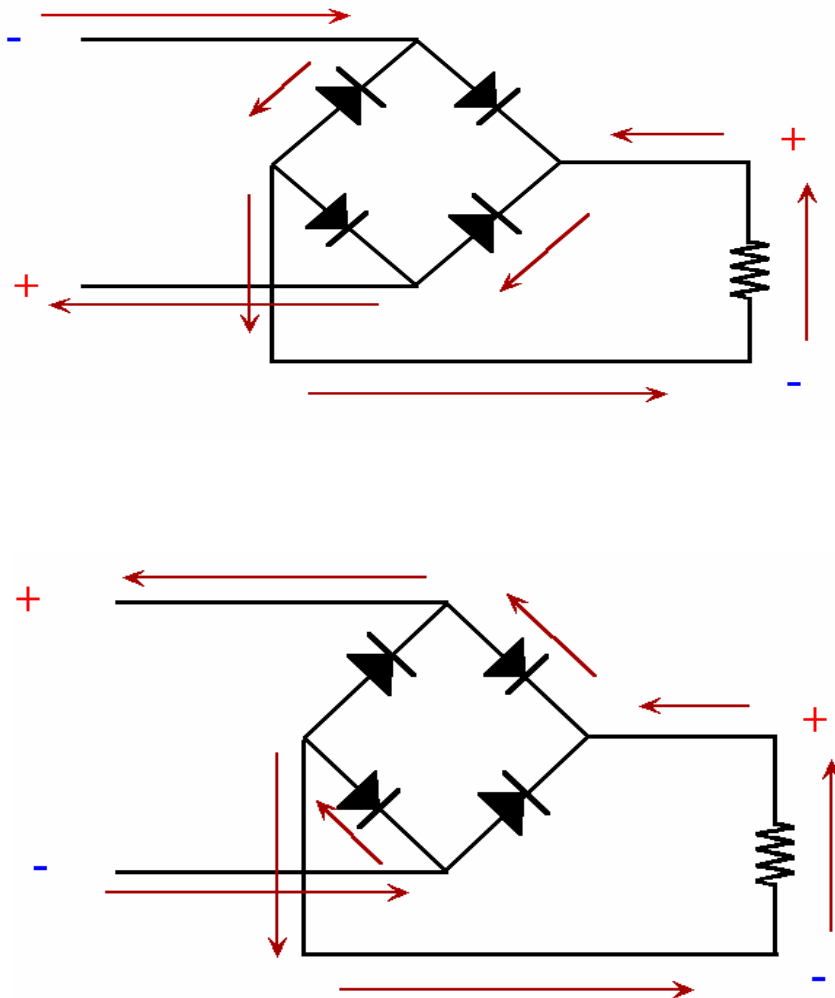


Figure 3.

WE HAVE CREATED FULL WAVE RECTIFICATION.

You simply must commit the diagram of a bridge rectifier to memory, and be careful, because opposite diodes can be reversed and you still have a working bridge, though it is just drawn differently. I like to think of the four diodes as positions on a clock face. So, we have diodes at 2, 4, 8, and 10 o'clock. The diodes at 2 and 8 o'clock can be reversed, provided the diodes at 10 and 4 o'clock are reversed. You also need to be able to determine the polarity of the output, or the direction of the current through the load. A way to do this easily is to pretend you are an electron out for a stroll. You can go wherever you want provided you go into a cathode. You can then trace out the current flow mentally or on paper, and determine if the bridge is drawn correctly. The sadistic examiner seems to get pleasure from drawing the bridge in a number of configurations and asking you to identify the correct one. The bridge I have drawn is a

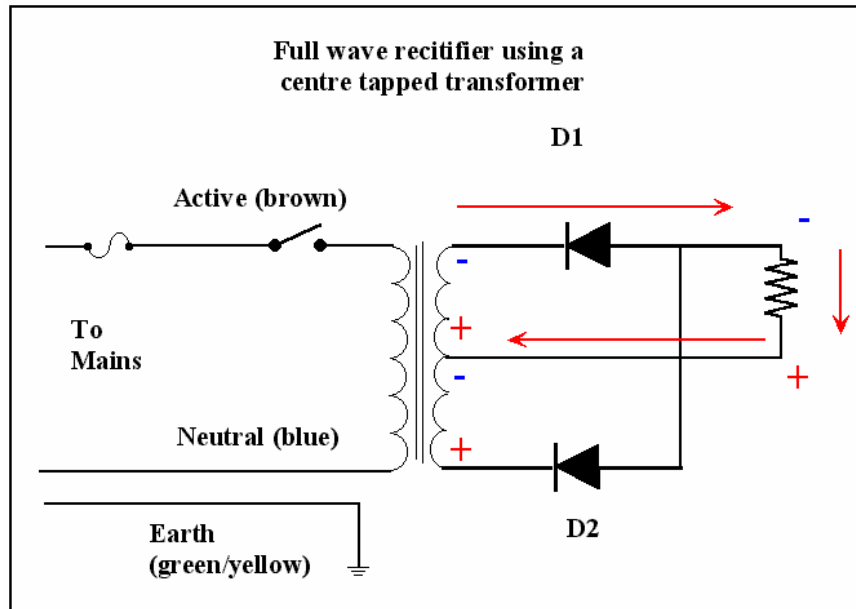
diamond or kite shape but it can also be drawn as a square. Tracing the current to determine if current will flow through the load in the same direction regardless of polarity, as I have done, is your surest way of determining if the bridge circuit is drawn correctly.

USING A CENTRE TAPPED TRANSFORMER

A less common method (today) of obtaining full wave rectification is to use a centre tapped transformer and only two diodes.

I have added some extra detail to the schematic in figure 4, which I will fully explain as we go along. A bridge rectifier would not use a centre tapped transformer as shown.

Figure 4.



I have shown the polarities on the transformer for one half cycle of AC input from the mains supply. As you can see, the top diode has a negative potential on its cathode so it will conduct with the path of the current as shown. During the next half cycle, all of the polarities will be the opposite of that shown, and the bottom diode will conduct. In either case the current will be the same through the load. So, full wave rectification is achieved again.

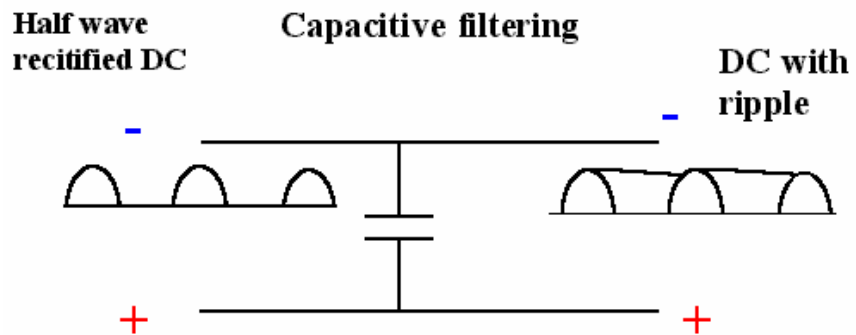
This circuit was once very popular, as it only required two diodes. This circuit is just as effective as the bridge rectifier. Which is used comes down to cost and convenience. A centre-tapped transformer is more expensive than one without a centre tap. Electron tubes (to be discussed) can also be used as diodes. Electron tubes are relatively expensive compared to semiconductor diodes. So if the power supply was using vacuum tubes, this approach would be the most cost effective, as it requires only two diodes, and this outweighs the cost of the centre tapped transformer.

Except in very high power applications, the modern trend is to use semiconductor diodes, so this circuit (figure 4) is not often used today. Still, you are expected to know it, and it does have a useful purpose when using junk box parts. Note also that the total secondary voltage is double that required for the bridge rectifier circuit, as only one half of the secondary is being used on alternate half cycles.

CAPACITIVE FILTERING - WITH A HALF WAVE RECTIFIER

Figure 5.

So far the output of the power supplies has not been smooth DC, which, perhaps with the exception of a simple car battery charger, is our requirement. Adding a capacitor to the output of the power supply will smooth the pulsating DC a great deal.



The circuit of figure 5 shows half wave rectified DC fed to a capacitor. If pulsating DC is fed to a capacitor as shown, the capacitor will charge to the peak value of the pulses. Without any load, the capacitor will charge to the peak value and stay there. I have shown the effects of a load. Between the pulses the capacitor will discharge through the load (not shown) and the voltage will drop a little. I have left the pulses under the DC output for illustration purposes only.

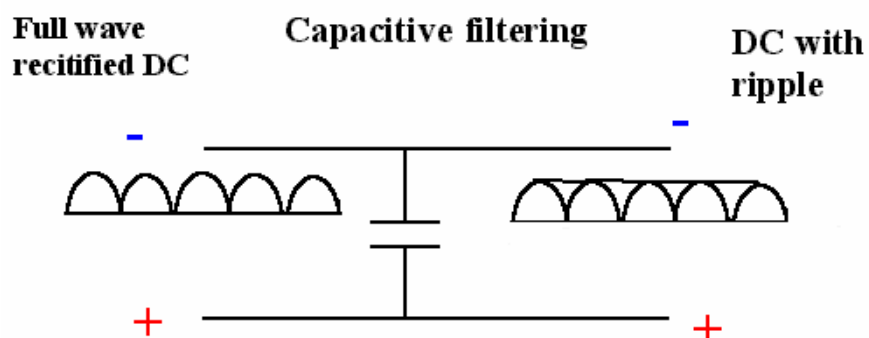
The DC output in this case is not pure. Pure DC would be a flat line indicating no voltage variation. The DC rises and falls a little, the rate of rise and fall being related to the frequency of the DC pulses. The frequency of the AC from the mains is 50Hz. For every cycle of AC rectified by a half wave rectifier we get one pulse of DC, so the pulses have a frequency of 50Hz as well. We can therefore conclude that the **ripple frequency** of a half wave rectifier is the same as the mains frequency ie. 50Hz.

Just to emphasise that a little, the DC output is not flat, it has a ripple on it, a ripple is a periodic rise and fall. The rate of rise and fall of the DC output is called the ripple frequency and is equal to the mains frequency, which in Australia is 50Hz.

CAPACITIVE FILTERING - WITH A FULL WAVE RECTIFIER

Figure 6.

It is fairly obvious that with full wave rectification the quality of the DC output is better. There are twice as many pulses of DC charging the capacitor. In fact the pulses are twice the mains frequency, or 100Hz.

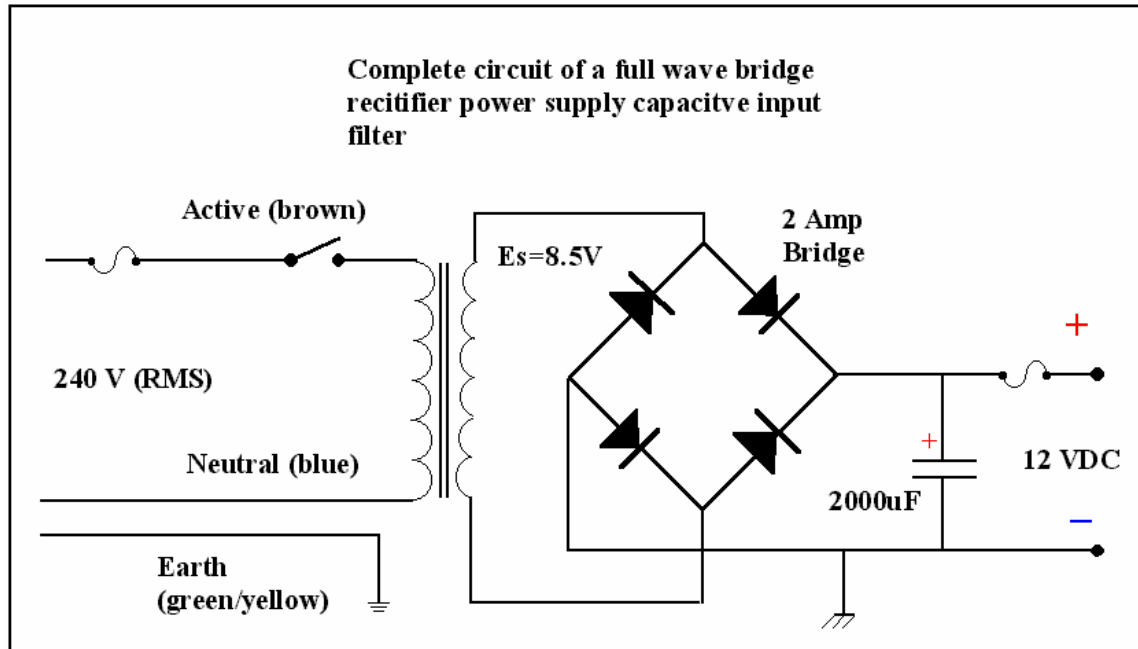


The ripple frequency of a full wave rectifier is 100Hz. Full wave rectification with filtering is much better than half wave. However, with capacitive filtering alone there is still some ripple. The frequency of the ripple will always be the same, equal to the mains frequency for half wave rectification, and twice the mains frequency for full wave rectification.

A MORE COMPLETE CIRCUIT

Figure 7 is the circuit of a full wave bridge rectifier showing the transformer, the mains connection with the colour code of the mains wires, a switch, fuse(s), and a capacitor for a filter.

Figure 7.



Most of this circuit has been explained. I will point out some important features, as such knowledge is applicable to subjects other than power supplies.

Notice how the secondary voltage E_s is shown as 8.5 volts. This is the RMS value. The output of the power supply is the peak value, $RMS \times 1.414$, or near enough to 12 volts. The negative side (also called the negative rail) of the power supply shows a chassis connection. This just means that if the power supply is in a metal box, the negative terminal is connected to the box. This is not done for safety purposes. It's for ease of construction, just in the same way that the negative terminal of a car battery is connected to the chassis (body) of the car. Of course the positive output could be connected to the chassis. This is a construction issue and will depend on the type of semiconductor devices used. However, it is more common for the negative to be connected to the chassis.

I have shown a switch in the active lead from the mains. **The switch must always be in the active lead.** The earth lead from the mains or power point is connected to the chassis of the power supply. We will have much more to do with safety issues later.

I have shown two fuses. There really only needs to be one. The important thing about fuses is to remember that a fuse operates on current. Should something go wrong in the power supply (or outside the power supply) excessive current will be drawn and the fuse will melt, opening the circuit.

What may not be obvious to you is the difference in choice of fuses - in the primary of the transformer and the output of the power supply. Remember the power in a transformer is the same in the primary and secondary, disregarding losses. However the voltage and current is not the same. Their product (the power) is the same. Fuses work on current. Say this power supply is 12 volts at 2 amps maximum. The fuse in the

secondary circuit will be around 2 amps. It will melt if more than two amps are drawn from the supply and stop the supply from being damaged further by excessive current.

Think about the fuse in the primary circuit. It would not be anything like 2 amps. If it were 2 amps then 480 watts would have to be drawn from the mains before it would melt. I will leave the calculation of the primary fuse to you. How much power can be drawn from a 12 volt 2 amp power supply?

Lets get a bit more serious about power supply filtering. What you are about to read may in some areas go beyond what is required for the examination on power supplies. Though, where concepts are required to be known, perhaps not in power supplies but in other subjects, I have included the information pertinent to power supplies knowing that this is required knowledge elsewhere.

CAPACITIVE INPUT FILTERING

Capacitance is that property of an AC circuit which opposes changes of voltage. If a large capacitor is connected across the output of the rectifier circuit, ie. in parallel with the load, the capacitor will smooth out the pulsating DC to DC with a small ripple voltage. The filter capacitor does this by taking energy from the circuit and storing this energy in its electric field. If the voltage across the load tends to fall, the capacitor will discharge some of its energy back into the circuit, which smooths out the voltage. Because a high value of capacitance is required (1000 uF to 10,000 uF or more), the capacitor has to be an electrolytic type, as this is the only type of capacitor which can provide such a high value of capacitance. Capacitive filtering alone can be used for power supplies which need to deliver only a few amperes of current.

There is an animated GIF on the web site demonstrating a water analogy of how capacitive filtering works.

One **disadvantage** of capacitive input filtering is that of surge current. When the power supply is turned off the capacitor is discharged. When the power supply is first turned on, the capacitor will charge rapidly and draw a large current from the transformer and rectifier circuit. This surge current can be so high that it may exceed the current rating of the rectifiers and damage it, or blow the fuse, whichever comes first. This is not so much an operational problem of the power supply, but a design problem.

To ensure the filter capacitor(s) in a power supply discharge when a power supply is turned off, a high value resistor is often connected across the filter capacitor. A high resistance, say 10K Ω , in parallel with the filter capacitor will have no affect on the operation of the power supply, and provide a path for the capacitor to discharge through. You may have noticed on some power supplies which have a light to indicate that the supply is turned on, that this light will slowly dim and eventually go out some time after the supply is turned off. This is the filter capacitor discharging. Sometimes the "on light" is what actually discharges the filter capacitor.

A high value resistor connected across the output of the power supply to discharge the filter capacitor(s) when switched off, is called a **bleeder resistor**.

INDUCTIVE INPUT FILTERING

Inductance is that property of an AC circuit which opposes changes of current. If we are trying to reduce ripple from a power supply, it should be no surprise then, that an inductance can be used to filter the DC output.

When an inductance is connected in series with a rectifier, a filtering or smoothing action results. An inductor used in this manner is always iron core to obtain the high level of inductance required. Inductors used in power supplies for filtering (and some other applications) are referred to as **chokes**.

Pulses of current through the choke build up a magnetic field around it, taking energy from the circuit to produce the field. As a pulse of current tries to decrease in amplitude, the magnetic field collapses and returns energy to the circuit, thereby tending to hold the current constant. If the inductance is the first component in the circuit after the rectifiers then this type of filtering circuit is called inductive input filtering. It is not practical to use inductive filtering alone in a power supply. **Inductive filtering is always used in conjunction with capacitive filtering.** A **disadvantage** of inductive filtering is that there is voltage dropped across the internal resistance of the choke (the resistance of the wire making up the choke). The voltage dropped across the choke reduces the output voltage of the power supply. In practical terms this means that the secondary voltage of the transformer has to be a little higher in voltage output to compensate for this.

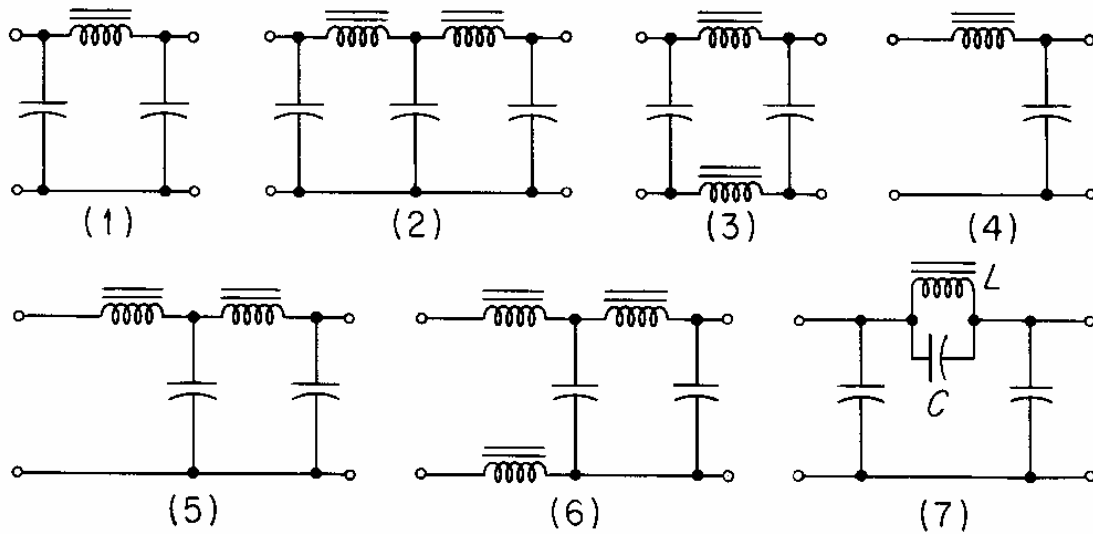
SWINGING CHOKES

You will recall from our study of inductance that the purpose of the iron core is to increase the value of the inductance. The magnetic iron core does this by concentrating the magnetic lines of force. Usually the magnetic iron core of a choke has no air gap to prevent the core from magnetically saturating. In the swing choke, the magnetic iron core has little or no air gap. This means that the magnetic iron core will begin to saturate at medium current values for the power supply. When low current flows through a swinging choke it has a high inductance and filters effectively. With high current the magnetic core saturates and it has less inductance. Thus, with a light load and little current, the swinging choke has a high reactance and develops a large voltage drop across it. When the load increases, the choke saturates and less reactance and consequently less voltage drop across it. This means the voltage output from the power supply tends to remain constant under varying loads, improving its regulation. Typically a swinging choke will vary (swing) from 5H for a heavy load (high current) to 20H for a light load.

COMBINATIONS OF CAPACITANCE AND INDUCTANCE

For better regulation, combinations of chokes and filter capacitors are used. It is not necessary for you to remember these combinations (for exam purposes). It is important to remember that whatever filter type is used, it will **get its name from the first component seen**, looking from the rectifier towards the filter. If the first component is an inductor(s) then it is an inductive input filter. Likewise if the first component is a capacitor, it is called a capacitive input filter. You may be asked the advantages and disadvantages of each type.

Figure 8.



- (1) Pi - capacitive input filter.
- (2) Capacitive input filter.
- (3) Capacitive input filter.
- (4) Inductive input filter.
- (5) Inductive input filter.
- (6) Inductive input filter.
- (7) Capacitive input filter.

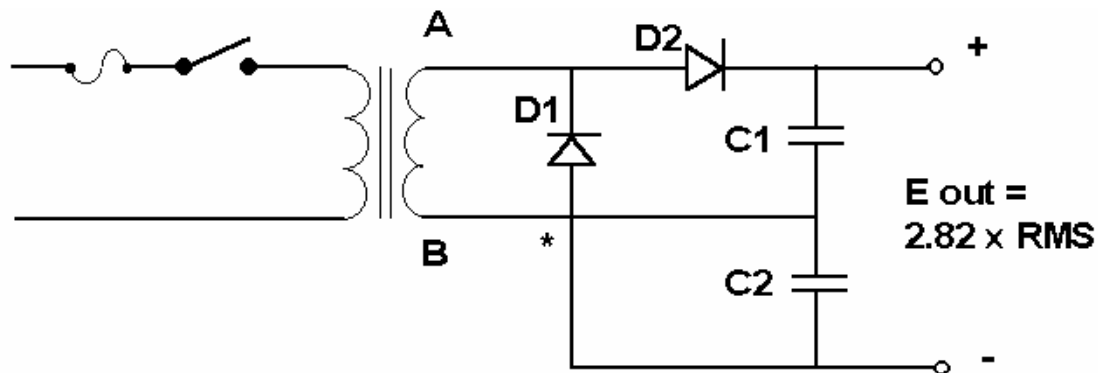
All of the power supply filter circuits shown in figure 8 use the principles we have discussed (except for circuit (7)). The purpose of a power supply is to provide smooth DC output, that is, a constant voltage with varying load conditions. In all circuits each parallel capacitor has capacitance that opposes changes in voltage, and the inductance of the inductors oppose changes of current.

Circuit (7) uses another principle, which you don't often see in power supplies, however I will discuss it, as the principle is one we need to know for other purpose. In circuit (7) the parallel inductor and capacitor is **resonant** at the ripple frequency. A parallel tuned circuit has very high impedance only at its resonant frequency. The parallel LC is resonant at the ripple frequency. Any 100Hz ripple (assuming full wave rectification) will be blocked significantly from passing through this LC combination. This is a very clever technique.

THE VOLTAGE DOUBLER (FULL WAVE)

The diagram in figure 9 is that of a full-wave voltage doubler. With a normal full-wave power supply (eg. bridge) the output voltage is approximately the peak value of the RMS secondary voltage, or $RMS \times 1.414$. For the exam you just need to know how to identify this circuit.

Figure 9.



FULL-WAVE VOLTAGE DOUBLER

* When lines are crossed as shown they are not connected.

When the AC voltage makes point 'A' negative and 'B' positive, D1 will conduct and charge C2. When the AC voltage makes 'B' negative and 'A' positive then D2 will conduct and charge C1. The capacitors C1 and C2 are in series and so the voltage at the output is the sum of the voltage on C1 and C2, or 2.82 times the RMS secondary voltage.

The voltage doubler can't deliver very high currents. However, it is an excellent method of obtaining the higher voltages required for an electron tube.

EQUALISING RESISTORS AND TRANSIENT PROTECTION CAPACITORS

In very high voltage power supply circuits, many rectifier diodes are often connected in series in order to increase the peak inverse voltage (PIV) rating. If a rectifier has a PIV of 400 volts then 'theoretically' two such rectifiers connected in series should have a PIV of 800 volts. More diodes can be added in series for even higher PIV.

However for proper series rectifier operation it is important that the PIV be divided equally amongst the individual diodes. If it is not done, one or more diodes in the string may be subjected to a greater PIV than its maximum rating and, as a result, may be destroyed. As most failures of this type result in the diode junction going short circuit, the PIV of the remaining diodes in the string is raised, making each diode subject to a greater value of PIV. Failure of a single diode in the string (stack) can therefore lead to a 'domino effect', which will destroy the remaining diodes.

Forced voltage distribution in the stack is necessary when the diodes vary appreciably in reverse resistance.

The resistors in figure 10 provide reverse PIV equalisation across the two diodes.

The reverse resistance of the diodes will be very high, in the order of megohms. Now, 470K ohms in parallel with megohms is roughly still 470K. So irrespective of the diodes reverse resistance the PIV is distributed roughly equally across each diode.

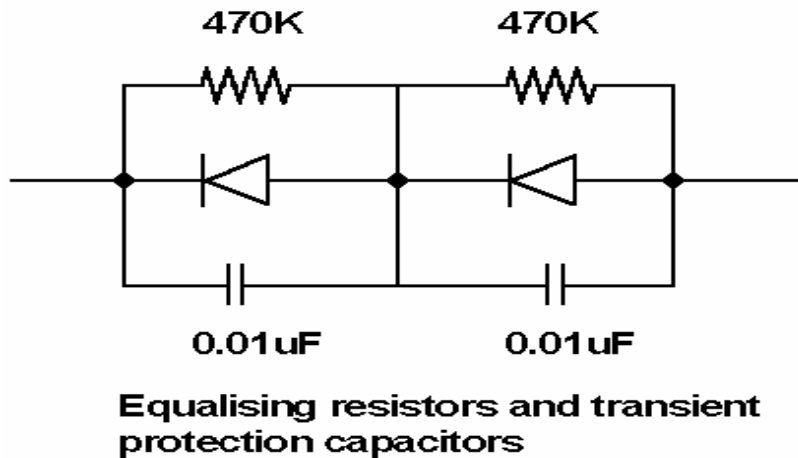


Figure 10.

TRANSIENT PROTECTION CAPACITORS

Power supplies, high voltage ones in particular, are prone to producing high voltage spikes called **transients**. These transients are caused primarily because of inductive effects of the circuit (the secondary of the transformer). These very short duration high voltage transients can destroy the rectifier diodes. The capacitors shown across the diode in figure 10 above will absorb or smooth out any transients. Recall that capacitance is that property that opposes voltage change.

You need to be able to identify the circuit of figure 10 and its purpose.

In summary, equalising resistors distribute the applied voltage almost equally across a string of diodes when they are reverse biased. This ensures that each diode, irrespective of its reverse resistance, will share the same amount of reverse voltage drop. Transient protection capacitors absorb short duration high voltage transients caused by inductive effects in the circuit.

ELECTRONIC POWER SUPPLY REGULATION

For power supplies that require extremely good regulation, **electronic regulation can be added after the filter network**. This consists of either an electronic circuit consisting of discrete components or, far more commonly these days, an integrated circuit that contains all the necessary electronics.

There are two basic types of regulation:

Series Regulation - where the regulator is in series with the current path, and

Shunt Regulation - where the regulator is placed in parallel or 'shunted' across the power supply output.

Switching regulators - These are the most efficient - that is they dissipate the least amount of wasted power.

These days series regulation is almost always used (and the type you need to know for the exam). The disadvantage with the shunt regulator is that the power dissipated by the regulator circuit is much higher. This translates to lower power supply efficiency and more heat to get rid of in the regulator circuit.

Figure 11 is a block diagram of a power supply that uses an integrated voltage regulator in series.

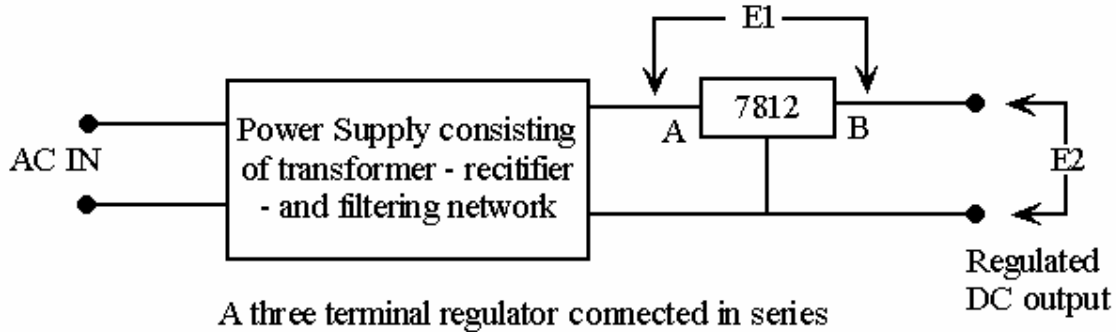
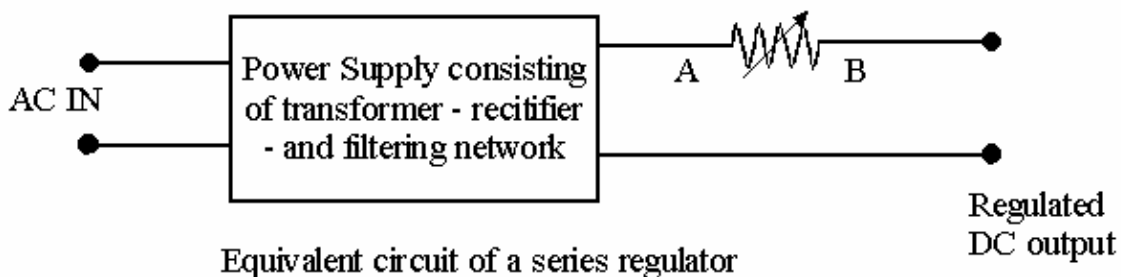


Figure 11.

The idea of voltage regulation is to provide a constant voltage output from the supply irrespective of the current drawn by the load. Under very heavy load the output of the power supply will have a tendency to fall. Under light load the output voltage of the supply will tend to rise. This rising and falling of output voltage may be unacceptable for many applications.



The voltage out from the supply mostly appears as E_2 (figure 11), however a smaller voltage is dropped across the series regulator between 'A' and 'B'. The series regulator is able to 'sense' if the output voltage changes, and if it does, it will



change its resistance between points 'A' and 'B' providing either more or less voltage to the load.

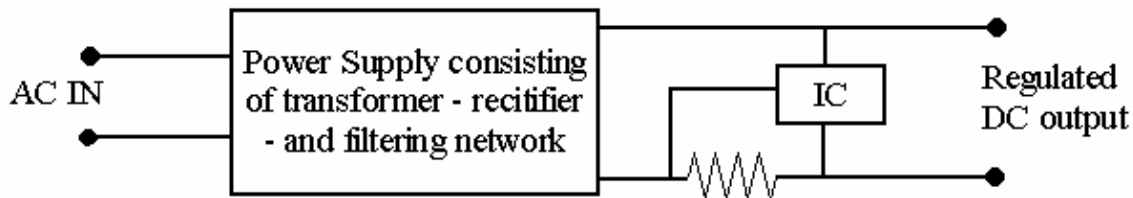
Figure 12.

If the output voltage falls then the resistance between 'A' and 'B' decreases, providing more voltage for the load, and conversely, if the output voltage rises the resistance between 'A' and 'B' increases, reducing the available voltage to the load.

This all happens so fast that the output voltage for practical purposes and, within reasonable limits, will remain constant.

The shunt regulator method shown in figure 13 is rarely used, as the power dissipated in the regulator is too high.

Shunt regulators are only used for low power applications – a good example of a shunt regulator and the only one you need to know is that of a zener diode along with its current limiting resistance.

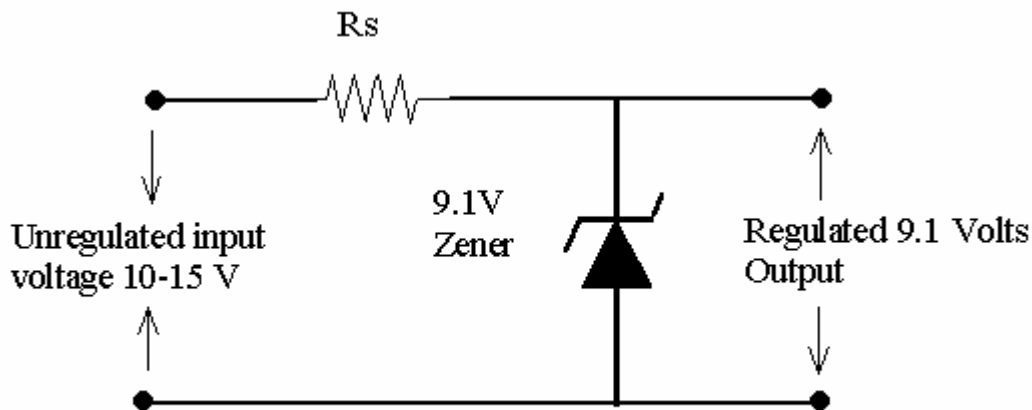


A shunt voltage regulator

Figure 13.

We have not discussed the operation of a zener diode yet – we will do so in the semiconductors reading. For now, a zener diode is one that is **meant to be operated with reverse bias**, and beyond its PIV or breakdown voltage. Normally a diode would be destroyed if operated beyond breakdown. The series resistance R_S (refer to figure 14) limits the reverse current so that the zener diode is not destroyed.

Under such conditions the zener diode will have a constant voltage drop across it – in this case 9.1 volts.



A shunt regulator using a zener diode

Figure 14.

As the unregulated input voltage varies from 10 to 15 volts, the voltage across the zener will remain (almost) constant at 9.1 volts. However the voltage across R_S will vary. The sum of the zener voltage (9.1V) and the voltage across R_S will equal the unregulated input voltage, as this is a series circuit.

This type of zener regulator circuit is very common for very low power levels, typically less than one watt. For exam purposes you need to be able to identify this circuit. Note that the polarity is reversed, as this diode operates in breakdown. Positive is connected to the cathode and negative to the anode. R_S is there to limit the reverse breakdown current to a safe value. Zener diodes are available in a range of voltages from about 5 to 18 volts.

A Shunt regulator as in figure 14 dissipates maximum (wasted) power in the zener diode with there is no load.

For higher power regulation such as the power supply for radio transceivers, the 3 terminal type regulators are used. These integrated circuits provide excellent regulating characteristics and are inexpensive.

The most common three terminal regulators are the 7800 and 7900 series. These regulators can deliver output current up to 5A, and any amount of current with some modification.

To use a three terminal regulator in the simplest way, just connect it between the filtered, unregulated DC voltage and the load, as shown in figure 15.

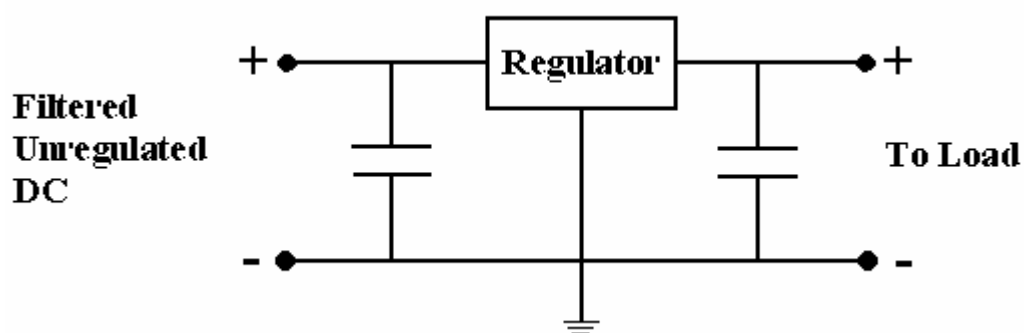


Figure 15.

A 0.22uF ceramic disc capacitor should be connected across the input terminals to maintain stability. A larger 25uF electrolytic is recommend, though not necessary, across the output.

Note: for very large currents extra 'pass transistors' can be added to the three terminal regulator.

A CONSTANT CURRENT SOURCE

This simple circuit (figure 16) is a favourite of mine, as I have found so many uses for it. First let me explain what constant current means. The purpose of most power supplies is to maintain a constant regulated DC voltage output. For example, a CB radio may require around 13 volts DC. The CB radio when in use will draw whatever current it requires from the power supply, so the current varies. The purpose of the power supply is to maintain the constant voltage output of 13 volts, regardless of the changing current demands of the CB radio.

Now, there are situations where you **don't care about the voltage output of a power supply**. What you care about is the current. This may seem a little strange because normally we apply a voltage to a load and the load determines the current. Suppose we want to force a specific current through the load irrespective of what the load wants. A classic example is charging many NICAD batteries, which are very common in portable radio communications equipment. NICAD batteries should be charged at one tenth of their amp-hour rating for 15 hours (if fully discharged). So a 500 mA hour cell or battery should be charged at $500/10 = 50\text{mA}$ for 15 hours. This cannot be done with the more usual constant voltage output power supply. We need a constant current supply. A three terminal regulator can be used

to do this for a cost of less than \$5. Commercial devices for charging NICADS (including cell phone batteries) are frankly a rip-off as most of the time they are just a plastic case with the schematic shown below in it.

I have made many of these chargers to operate from the car cigarette lighter. You need an input voltage of at least 2 volts (preferably 2.5V) higher than the battery you are charging.

The resistor is in series with the load and the three terminal regulator is producing a constant voltage across it. The resistor will therefore have a constant current through it. Since it is in series with the load, the load will have the same current as the resistor. All you need to do is buy a regulator, which will handle the current you want and calculate the value of the resistor and its minimum wattage.

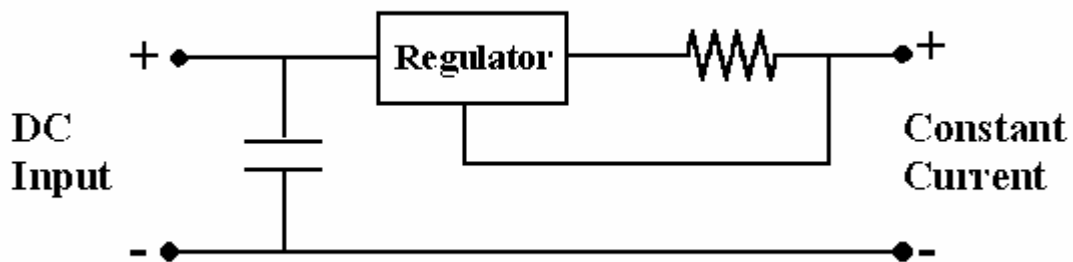


Figure 16.

Suppose we had a 7.5 V NICAD battery that has a capacity of 500 mA/hours. We need a minimum DC input voltage to the circuit in figure 16 of $7.5 + 2 = 9$ volts, say 9.5 volts. Now we need to work out the value of the resistance in ohms. Let's say we are using a 5 volt three terminal regulator. Our battery requires $500/10 = 50\text{mA}$. $R = E/I = 5/0.05 = 100 \Omega$. That's it!

Of course you need to work out the wattage of the resistor, you can do that can't you?

Well, we have had a pretty good look at power supplies. There is one area that we have neglected a bit - the mains supply. This is an examiner favourite as there are safety issues involved.

THE MAINS SUPPLY

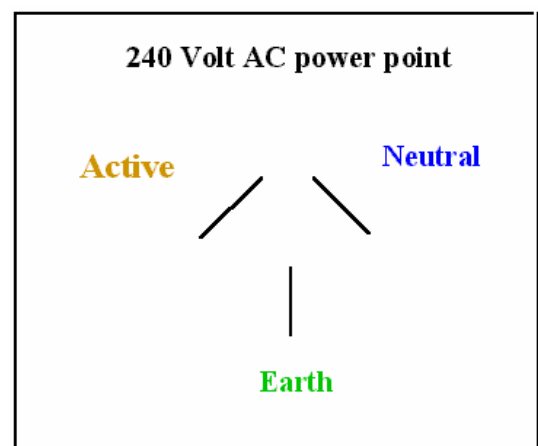
We have covered in earlier readings the frequency, voltage relationships, RMS, peak etc, and the wave shape of the mains. What we have not covered is the wiring of the mains.

Household wiring is a parallel connection. If it were not, when we switch an extra light on, all other lights would dim a bit (series circuit).

Figure 17.

The three wires in the mains circuit are:

- The Active - Colour **Brown** (old red).
- The Neutral - **Blue** Colour (old black).
- The Earth - Colour **Green/Yellow** (old green).



These names are a little confusing. First of all, active and neutral deliver the 240 volts AC throughout your home. There is 240 volts AC RMS between active and neutral.

The earth is not ground in the sense that radio operators talk about. Earth is just that, EARTH, dirt if you like. The earth connection is usually somewhere near your power box and is a copper rod going into the dirt.

Also, one side of the mains is connected to the earth as well. This is the neutral. It is usually connected to the earth near the power box.

This means that there is 240 volts AC RMS between active and earth.

The potential difference between neutral and earth SHOULD be zero volts.

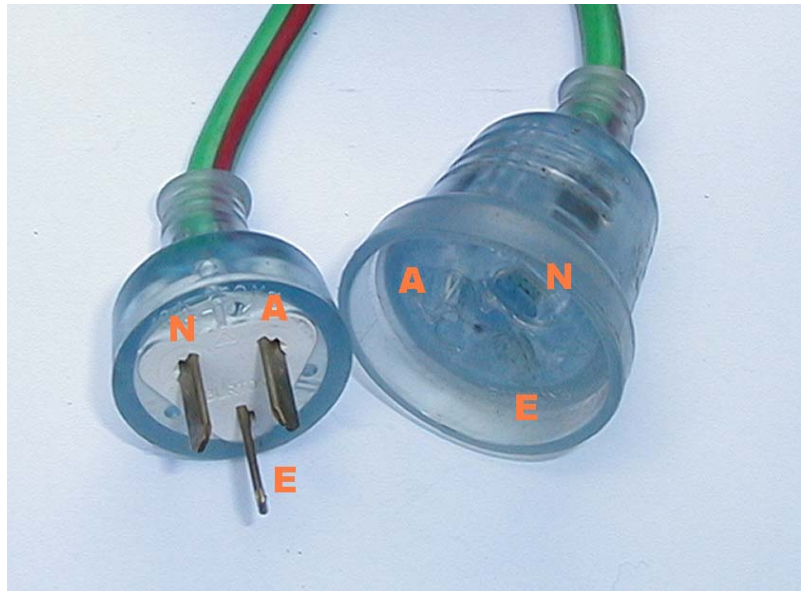
The locations of these wires are shown for a power point in figure 17. The active is on the left on a power point (socket). The active is on the right looking at a plug.

Figure 18.

The photo in figure 18 shows the connections for both a plug and a socket (extension lead).

Every switch in your house **should** be in the active wire.

The purpose of earthing one side of the mains is for safety reasons. If something goes wrong, you are most at risk if you are exposed to the active and ground. Therefore all the metal fixtures of lights, appliances etc are connected to earth. Should the active wire come adrift and contact the metal chassis of any appliance a fuse will blow. The metal (conductive) parts of appliances are connected to earth, as is the neutral. Should an active touch a metal part, and therefore potentially YOU, the active and neutral are effectively touching and a fuse will blow.



All being well, since there is no potential difference between neutral and earth you **SHOULD** be able to touch the neutral wire in your house and nothing will happen - **NEVER PUT THIS TO THE TEST**, though by all means use a voltmeter to test.

It is extremely dangerous to assume that the wiring in your home is correct. If someone has wired a switch into the neutral wire instead of the active then the appliance will still work, however the active will still be going to it when it is switched off. For example, if someone has placed the switch in the neutral wire of a light, the light will still work, as it should (as will all other appliances). If you turn the light switch off and it is wired incorrectly like this, the active is still present at the light socket. If you touch the active terminal in the light socket you will receive an electric shock that could be fatal.

How easy it is for someone to accidentally or ignorantly reverse the active and neutral on the plug or socket of an extension lead. Doing so could be fatal. In passing, electrocution is death by electric shock. You cannot be electrocuted and survive.

You need to know the potential difference between each wire in your household mains. This is not so you can work on your house mains. It is necessary for you to know this **if** you build equipment that you connect to the mains. You need to know how to test a power point with a voltmeter. This is safe provided you do not contact the metal parts of your multimeter leads. If you measure less than 240V between active to earth, and active to neutral, it may mean you have a problem. Any voltage between earth and neutral indicates a problem.

An electrician should do the testing for an adequate earth. The plug-in cheap testers do not do this adequately.

For less than \$6 you can buy a power point tester that you just plug in and read the lights. For about \$200 you can have an earth leakage detector fitted to your home, increasing your protection one hundred fold.

Only qualified electricians should work on household wiring. Being a licensed radio amateur or a professor of physics does not qualify you to tamper with household wiring. This part of the reading is not a definitive explanation of safety procedures. The best procedure is to remove equipment from the mains before working on it. However, as a licensed amateur radio operator, you are qualified to build equipment which you can connect to the mains. If you wire your switching incorrectly, safety of life is a real issue. Be aware when purchasing home brew equipment which is connected to the mains. Check it out first.

End of Reading 20.

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<http://www.radioelectronicschool.com>

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Additional material is covered on power supplies later in this course.