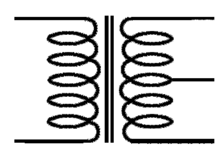
Chapter 3
Power Supplies

3.1 THE NEED FOR POWER SUPPLIES

We have already seen very basic power supply circuits, and even regulator circuits that are used in power supplies. Now we will look more closely at the power supply. Though the decision was very hard fought in the early days of electricity, AC won out as the format to deliver electricity to homes and businesses. Except for items which run off of batteries, all electrical equipment runs off of that AC delivered by the power companies. In the United States that AC arrives at between 110 and 130 volts at a 60Hz frequency. In Europe it is 220 volts and 50Hz. AC is a much easier way to deliver electricity, but for most equipment DC is necessary. The common exceptions are motors and lights, they use the AC just as it arrives. For the equipment that does need DC, a **Power Supply** is used to convert the AC into one or more DC voltages.

3.2 TRANSFORMERS

The first component that the AC reaches is typically a fuse, this is used to prevent more expensive components from being overloaded (and subsequently ruined) with too much current. The next component is the transformer. The transformer serves two important functions. First it converts the voltage from the outlet into something more useful to the circuit. Most modern semiconductor circuits require from 5-50 volts, much less than the 117 delivered by the power company. Vacuum tube circuits, however, require from 250 to 500 volts. The transformer converts to these voltages. Voltages for transformers are given in V_{RMS}. Remember that whatever voltage the transformer converts to, the power on both sides of the transformer must be equal. One advantage to having a transformer is that you can utilize multiple secondaries to have any number of different voltages coming from one transformer. This is very common. The second important function of the transformer is to isolate the circuit from the AC line. This prevents most problems with the circuit from affecting anything before the power supply. It also helps to protect anyone using the equipment.



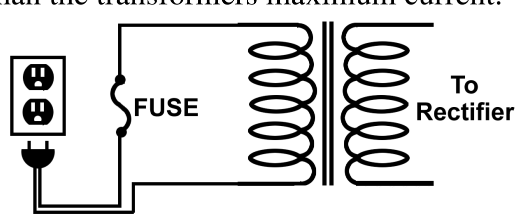
Power transformers are used to covert AC delivered by the power company to a useable voltage.

They are chosen based on: Input (primary) voltage, output (secondary) voltage, and secondary current.

Transformer voltages are given in V_{RMS}

3.3 FUSES

It is important that the fuse (which comes before the transformer) be rated at less than the transformers maximum current. A transformer will cost $20 to $100, but a fuse costs a few cents. Obviously it would be preferred that the fuse blow before the transformer is in danger of being damaged. In commercial designed products the fuse and transformer are as close in rating as possible. The more current a transformer can handle,



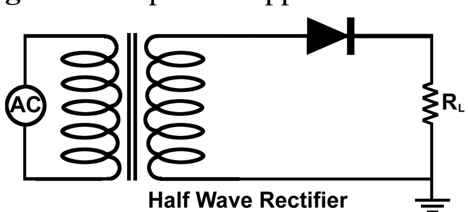
the larger it is and more it costs. Because of this manufacturers will use the lowest current rating transformer they can for the demands of the circuit. The fuse must be able to handle all the current that the circuit needs without blowing. This can mean that a manufactured product can have a fuse that is rated just a few percent below the transformer. For most designs I recommend that the fuse be rated 10-20% below the transformer rating.

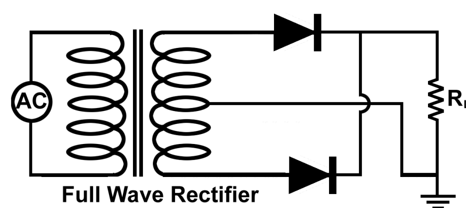
3.4 AC INTO DC

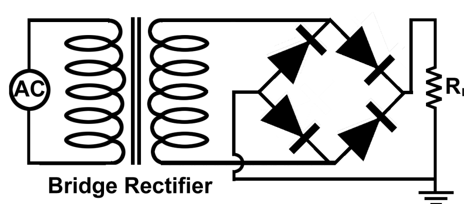
In chapter one we talked about the ways to describe AC voltage and how to convert between them:

Peak voltage (V_{pk}) is the maximum (peak) voltage that the AC signal attains. Peak to Peak ($V_{pk\text{-}pk}$) is the voltage measured from the maximum (peak) positive voltage to the maximum (peak) negative voltage. With most AC signals the numeric value of the positive and negative peaks are the same, only the polarity is different, so the $V_{pk\text{-}pk}$ is typically twice the V_{pk}. The most useful way to describe the potential of an AC signal is to use V_{rms}. V_{rms} measures AC signals in a way that gives a voltage value that is equal to what the voltage would be if it were converted to a DC signal. Most VOMs (volt-ohm meters) will read AC signals in V_{rms}. To convert to V_{rms} multiply V_{pk} by 0.707. To convert back to V_{pk} multiply V_{rms} by 1.414.

We have also seen ways to convert AC into DC using half, full, and bridge rectifiers. Because they all put out only one voltage these power supplies are all examples of **Single Ended** power supplies.







With the half-wave rectifier the transformer voltage, expressed in V_{rms}, only forward biases the diode on half of its cycle. The load will receive voltage only at the positive half of the AC signal. Because of this the V_{rms} must be converted to V_{avg}. ($V_{avg}=V_{rms} * 0.45$) If the transformer has $10V_{rms}$ what would the voltage across the load be? The voltage across the load would be $4.5V_{DC}$ minus the voltage drop of the diode (0.7V) or $3.8V_{DC}$. What about the case of the full wave rectifier? The two diode type of full wave rectifier shown above requires a center-tapped transformer. The secondary voltage of a center tapped transformer is given as "20 volts center-tapped" This means that there is $10V_{RMS}$ on each of the diodes. On other words a 20 volt center-tapped transformer will only give you $10V_{DC}$ output. In the case of a two diode full wave rectifier, only one of the two diodes is passing current at a time. With a Bridge rectifier there are two diodes passing current at any time. This has two effects on the output voltage. First you must subtract the voltage drop of two diodes (1.4V). Second, and much more important, the output voltage from a transformer with a $10V_{rms}$ secondary would be the full $10V_{rms}$. During each half of the wave cycle there current flow from both ends of the transformer secondary. V_{rms} is an average of the V_{pk}, with a bridge rectifier you get the average voltage of $V_{pk\text{-}pk}$, which is twice that of V_{pk}. You can build bridge rectifiers out of individual diodes, but they are also sold as a single component.

Recitifer Output Voltages

half wave: $V_{out}=V_{avg} - 0.7V$
($V_{avg}=V_{rms} * 0.45$)

full wave: (2 diode): $V_{out}=V_{rms} - 0.7V$
(use V_{rms} between center tap and either side of secondary)

bridge full wave: $V_{out}=V_{rms} - 1.4V$
(use full secondary voltage)

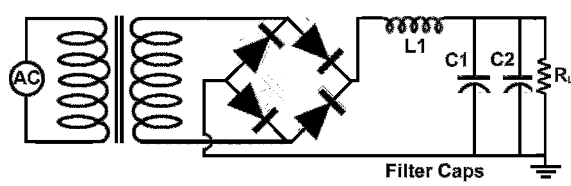
bridge dual rail: $V_{out}=V_{rms} - 0.7V$
(use V_{rms} between center tap and either side of secondary, output voltages are opposite polarity)

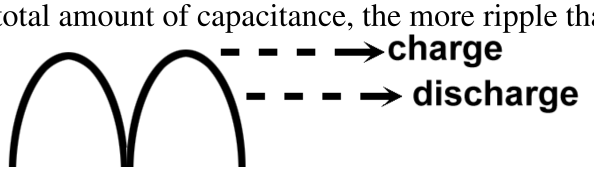
3.5 DUAL RAIL SUPPLIES

Most modern electronics require both a positive and a negative voltage power supply. These are called **Dual Rail** power supplies. The most efficient way to design the supply, and the best way to make them precisely matched, is to use one center-tapped transformer to provide both the positive and the negative voltages. A bridge rectifier is used with the center-tapped transformer. In the single ended supplies the negative corner of the bridge was connected to ground. In a Dual Rail supply it is used as the **Negative Rail** or negative voltage supply. In this configuration, a 20 volt center-tapped transformer would give you $+10V_{DC}$ and $-10V_{DC}$.

3.6 RIPPLE and FILTERING

The output of a full wave or bridge rectifier is a pulsating DC signal. The pulsating is called **Ripple**. One job of a power supply is to flatten this ripple and output a flat, stable DC voltage. Capacitors are typically used for this and are called **Filter Capacitors**. These are most often large value capacitors, often 10,000µF or larger placed from the output of the rectifier to ground. Most power supplies will utilize multiple filter capacitors. Electrolytic capacitors are used for this and correct polarity of the capacitor must be observed. As the pulsating DC moves up to its high voltage peak, the capacitors charge. When the voltage drops, the capacitors discharge. Different equipment will need differing amounts of filtering. The larger the total amount of capacitance, the more ripple that is filtered out.

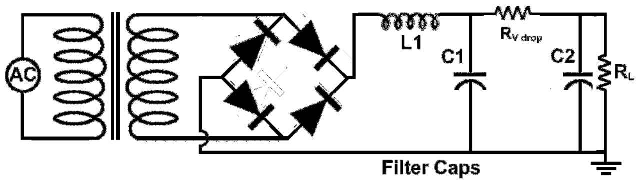




Inductors can also be used to filter out ripple. Because they are far more expensive than capacitors they are much less common. You may find one inductor with a number of capacitors to make up the filter circuit. Inductors are placed in series with the output of the rectifier. There is no polarity on an inductor.

3.7 VOLTAGE REGULATION

Because of factors such as the variations in AC line voltage, the voltage after ripple filtering is rarely the desired voltage for the circuit. It is best to design the power supply (at that stage) to deliver slightly more voltage than is necessary for the circuit. This allows the AC line voltage to drop without the power supply output voltage dropping below the desired voltage. A series resistance is required to lower this voltage. However, as the current requirements of the load change, so will the voltage drop of the resistor. This will cause the output voltage to change.



In chapter 2 we saw that a reverse biased Zener diode forms a simple voltage regulator. If we add the Zener to the above circuit we can maintain a constant output voltage regardless of the current draw of the load. This is the most basic form of **Voltage Regulation**. More commonly a Zener diode is used to control a transistor that regulated the voltage. This has a number of benefits and will be discussed later in the text. There are "voltage regulators" that are packaged into one component that are very common and are made up of the Zener, transistor and other necessary components.