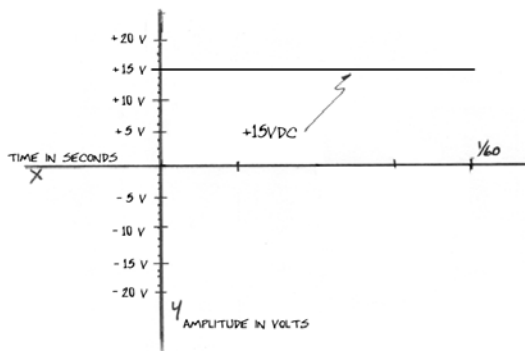


CONSTRUCTING A VARIABLE POWER SUPPLY UNIT

Building a *power supply* is a good way to put into practice many of the ideas we have been studying about electrical power so far. Most often, power supplies are used in consumer electronics to provide a source of DC power that is not dependent on batteries; which of course lose voltage and run down over time. The project associated with this chapter will be to construct a *variable power supply*, because this type contains some overtones of an analog electronic dimmer used to control lighting equipment.

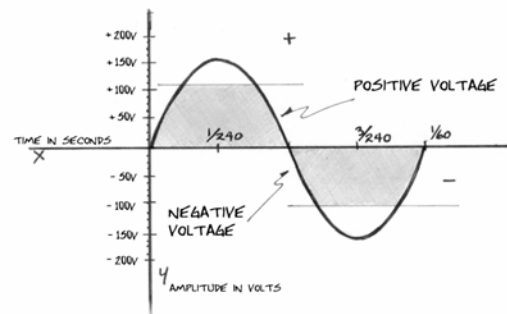
Building any sort of electronics kit teaches several basic skills such as reading a schematic, understanding the functions of basic electronic components, and learning soldering techniques, which are important to any beginning technician.

You will recall that the *waveform* of a 15 volt, DC current looks like this:



This doesn't look like much of a wave at all, because the peaks and valleys all have the same position on the y axis, or amplitude. Since the *peak voltage* and the minimum voltage each have the same value the graph is a straight line from left to right.

A 120VAC waveform looks like this:



The peak positive voltage is +141. The maximum inverse voltage is -141 volts. The RMS apparent voltage is 120VAC. The sine curve of an AC voltage is due to induction of an electrical current passing through a circular motion, such as was described in the functioning of a generator.

In order to build this type of device, which will convert 120VAC power to a 0 to 15VDC variable source, we will need to do the following things:

- 1 Use a *switch* to turn the power on and off.
- 2 Use a *transformer* to lower a 120VAC mains power supply to a much safer 12VAC.
- 3 Use a pair of *diodes* to *rectify* the AC power into a pulsating DC waveform. (diodes will allow current to flow in one direction only)

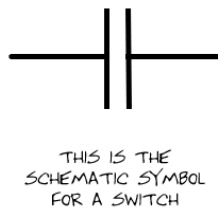
4 Use a *capacitor* to “smooth out” the pulsating DC waveform to a more linear shape.

5 Use *resistors* as a *voltage divider* to provide specific voltages to certain parts of the power supply unit.

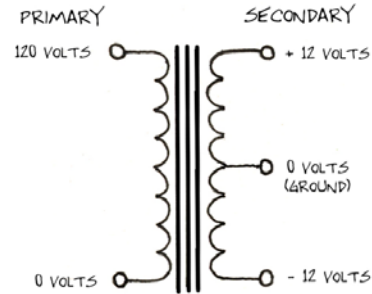
6 Use a variable resistor or *potentiometer* to create a variable voltage divider.

7 Use a *transistor* to control the DC voltage output of the variable supply unit.

Switches are used everywhere to open and close circuits. They are the start mechanism that sets an electrical process in motion. You see this everyday in turning on a wall switch so that a room light comes on. What you are really doing is completing the electrical circuit so that electrons flow through it to do their work of lighting, starting a motor, turning on a television set, and so forth. In a schematic the symbol for a *single pole* switch looks like this:

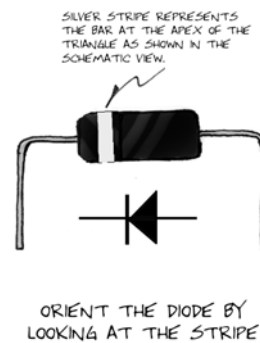


We've already spent a bit of time looking at transformers, their job is to change voltage pressure. In this instance the transformer is said to be center-tapped, meaning that the ground potential of 0 volts is in the center of the secondary coil of wire. This causes the transformer output to have both positive and negative outputs. The center tap is 0 volts, the top one is + 12 volts, and the bottom one is - 12 volts. The schematic symbol for that is:



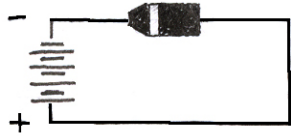
Since this transformer is manufactured with one terminal producing +12 volts, and the other - 12 volts, the voltage potential (difference) between the two is 24 volts.

A diode is an electronic component that allows current to flow in one direction, but not the other. The first diodes were made as vacuum tubes, but today's solid state version looks on the outside very much like a resistor, but electronically is very different.



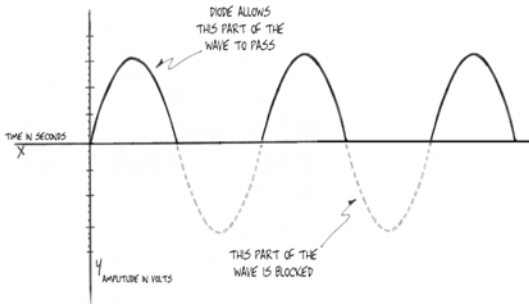
It is very important to put the diode into a circuit going the right direction so that current is resisted in one direction, but allowed freely in the other. Diodes are generally black, with a silver line around one end as seen in the drawing. The schematic symbol is a triangle with a line at one end. In order for the diode to conduct electricity, the line end of the symbol, and/or the line end of the diode should be on the side of the device which

is closest to the source of power, represented by the negative terminal. In a DC circuit this would look like:



IN ORDER TO CONDUCT THE DIODE MUST BE IN THIS POSITION

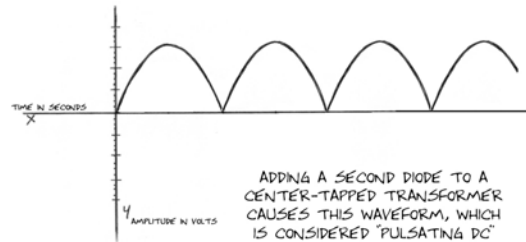
However, diodes are not often used in DC circuits. Instead they are used to rectify alternating current so that it becomes DC. Remember that AC gets its name from the fact that it alternates between negative and positive, so that electrons are flowing one direction and then the other. The diode will allow current flow in one direction and not the other, so only one-half of the waveform is permitted to pass.



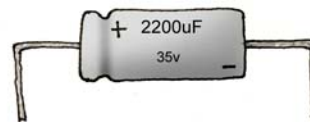
THE EFFECT OF A DIODE ON AC CURRENT IS TO ALLOW ONLY HALF THE WAVE FORM TO PASS THROUGH, THIS CREATING A DC CURRENT, SINCE THE ELECTRONS NEVER ACTUALLY MOVE IN THE OPPOSITE DIRECTION

This is, technically, a DC current because electrons flow in only one direction, but it would be helpful to create a current that is steadier than this. An unsteady DC current with this type of waveform is said

to be noisy, and can cause problems with delicate electronics. *Noise* is an apt description because it can cause sound equipment to hum very loudly. In our power supply project, the center tapped transformer allows the use of two diodes, so that both halves of the sine wave are captured. With this arrangement, the part of the wave that is on the bottom portion of the graph is flipped to the positive side of the x axis so that the output of the circuit after both the transformer and diode sections looks like this:



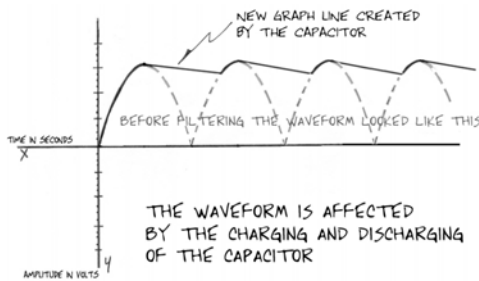
As you will recall, capacitors are used to store electrons. This electrical phenomenon was one of the first observed by early electrical pioneers like Leyden and Franklin. A *Leyden jar* has two metal plates that are forced apart because they are both charged similarly, and like charges repel one another. The two plates in a Leyden jar have a certain *capacity* for storing electrons.



2200 MICRO FARAD ELECTROLYTIC CAPACITOR RATED AT 35 VOLTS

NOTE THE + AND - DESIGNATIONS

In practical modern terms, a capacitor is used to store electrons until they are needed again. In our power supply project, the capacitor is used to smooth out the pulsating waveform coming from the diodes so that it more closely resembles a steady, battery-like current. It does this by storing electrons as the wave form ramps up on the front of the sine curve, and then discharging them as the voltage pressure falls on the back side of the wave form. A “filter” capacitor of this type needs to be quite large because it needs to store many electrons.



AS SHOWN ON THE GRAPH, THE CAPACITOR CHARGES AS THE PRESSURE OF THE VOLTAGE RISES ON THE Y AXIS. AS THE PRESSURE FROM THE INPUT TRANSFORMER FALLS, ELECTRONS BLEED OFF FROM THE CAPACITOR TO FILL THE GAP. AS THE CAPACITOR ITSELF DISCHARGES, THE VOLTAGE PRESSURE DROPS SOME, BUT NOT AS MUCH AS IT WOULD HAVE BEFORE.

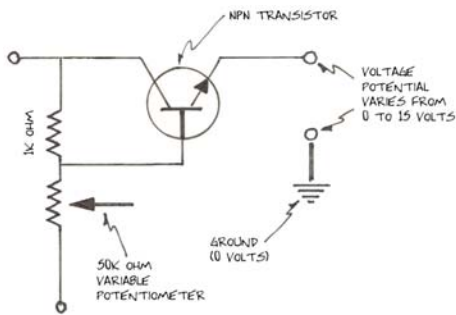
WHEN A DEVICE IS SWITCHED ON OR OFF, IT TAKES A FEW SECONDS FOR THE CAPACITORS TO REACT, WHICH IS WHY THAT PROCESS DOESN'T HAPPEN INSTANTLY.

A very large capacitor is used in the filtering process, and as a result, the capacitor does not have time to release all of its electrons before the next cycle begins. As soon as the voltage pressure of the pulsating DC waveform rises to a point where it is equal to the pressure of the remaining electrons in the capacitor, it will once again charge the capacitor to prepare for the next wave cycle. Although large value capacitors are somewhat

expensive, using too small a component will not filter the waveform sufficiently. The remaining fluctuation in the waveform is known as *ripple*, and is often noted on the specification sheet of an electronic device.

The next section of the power supply unit will control the output of the device so that it goes from 0 to 15 volts. Resistors and transistors are used to vary the voltage. Transistors are most often used to amplify voltage or current, and in this case the voltage. The resistors, including the variable potentiometer, are used to control the transistors.

The transistors in this circuit have three terminals; *base*, *collector*, and *emitter*. Electrons in the power supply flow through the collector to the emitter. The voltage pressure of the output of the transistor is determined by the input of electrons to the base of the transistor. In accordance with Ohm's Laws ($E=IR$ and $R_T=R_1+R_2+R_n\dots$) from chapter three, the potentiometer controls the voltage (as a voltage divider) of electrons entering the base of the transistor. Increasing a small current at the base of the transistor creates a bigger, or amplified change to the voltage, which in this case is the output of the power supply. In this project, the output is continuously variable from 0 to 15 volts.



IN THIS SECTION OF THE POWER SUPPLY, THE COMBINATION OF A TRANSISTOR AND A VARIABLE RESISTOR ARE USED TO VARY THE VOLTAGE OUTPUT.

Kits to build a power supply of this type are easily found on the web from a variety of different suppliers of electronic kits. Or, if you are especially adventurous, the same companies can supply the following components, which you can use to assemble the power supply unit.

- 24 volt, center tapped transformer
- 2200 μF capacitor rated at 35 volts
- μF capacitor
- two half-watt $1\text{k}\Omega$ resistors
- one $50\text{k}\Omega$ potentiometer (linear taper)
- two 1N4003 diodes
- one 2N3904 transistor
- one 2N3055 transistor

Wires, switch, power cord, binding posts for the output.

Remember that this circuit involves connecting the transformer to the line voltage from the wall, and thus can be very dangerous if you touch one of the live wires. Be sure to get help from someone who has experience with that in order to avoid a possibly life-threatening accident.

TERMS USED IN THIS CHAPTER

Capacitor

Diode

Leyden jar

Noise

Peak voltage

Potentiometer

Power supply

Rectify

Resistor

Ripple

Single pole switch

Switch

Transformer

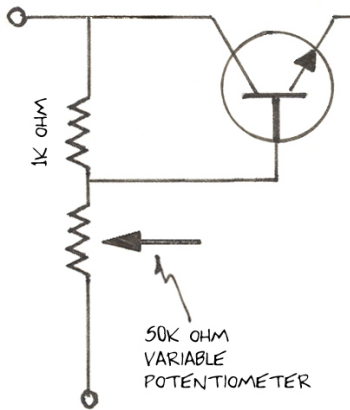
Transistor –Base-Collector-Emitter

Variable power supply

Voltage divider

Waveform

WARNING! SCIENCE CONTENT



VOLTAGE DIVIDER IN ACTION

IN THIS VOLTAGE DIVIDER, A 1000 OHM RESISTOR AND A VARIABLE RESISTOR ARE IN SERIES WITH ONE ANOTHER. THE HIGHEST POSSIBLE VALUE OF THE VARIABLE RESISTOR IS 50 TIMES AS HIGH AS THE STATIC ONE. REMEMBER THAT VOLTAGE IS SPREAD OUT PROPORTIONALLY ACROSS THE DIVIDER. IF THE POT IS SET AT 0 VOLTS, ALL OF THE VOLTAGE IS ACROSS THE 1K RESISTOR, AND THE POTENTIAL AT THE BASE OF THE TRANSISTOR IS 0 VOLTS. THE TRANSISTOR WON'T CONDUCT ANY VOLTAGE TO THE OUTPUT. IF THE POT IS TURNED TO ITS MAXIMUM OUTPUT OF 50,000 OHMS, THE DIVISION WORKS AS FOLLOWS:

ACCORDING TO OHM'S LAWS

$$\frac{E}{I R} \quad \text{SO} \quad \begin{matrix} I = E/R \\ \text{and} \\ E = IR \end{matrix} \quad R_t = R_1 + R_2$$

$$R_t = 1000 + 50000 = 51000 \text{ ohms}$$

$$E = 24 \text{ volts (from the transformer)}$$

$$I_{\text{(entire circuit)}} = 24/51000 = .00047$$

$$E_{\text{(across pot)}} = .00047 \times 50000 = 23.53 \text{ volts}$$

THUS, THE VOLTAGE APPLIED TO THE TRANSISTOR WHEN THE POT IS TURNED TO FULL IS 23.53 VOLTS, CAUSING THE POWER SUPPLY TO HAVE ITS MAXIMUM OUTPUT