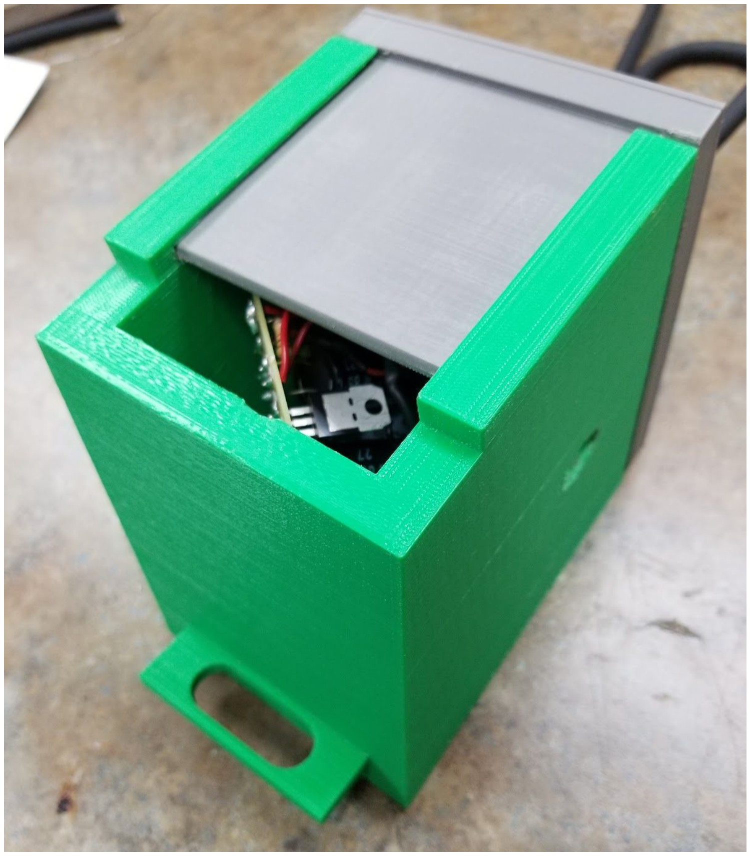
-Power Supply



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Objectives:

Upon completion of this project, this will be learned:

- To build a power supply with a 100Ω load and a ripple wave difference that is under 10mV

Materials:

The following materials were used:

- 110V to 12.6V step down transformer
- Contact voltage regulator (0V-130V)
- Terminal Block
- W01M bridge rectifier
- (2) 2200μF Capacitors
- 39Ω and 100Ω Resistors
- L7805cv voltage regulator
- Multisim
- Ultiboard
- Autodesk Inventor
- Makerbot Desktop
- MakerBot Replicator series 3D printers
- 3d Printed material

Procedures:

Building the Circuit:

1. First, the ac voltage coming from the outlet has to be reduced. Outlets are typically expected to have 110 volts rms with a frequency 60 Hz. Set the contact voltage regulator to 110V and measure the wave coming across it. Figure 1-1 shows the ac voltage wave across the contact voltage regulator which is simulating the outlet voltage with 100 volts per division and 5 ms per division.

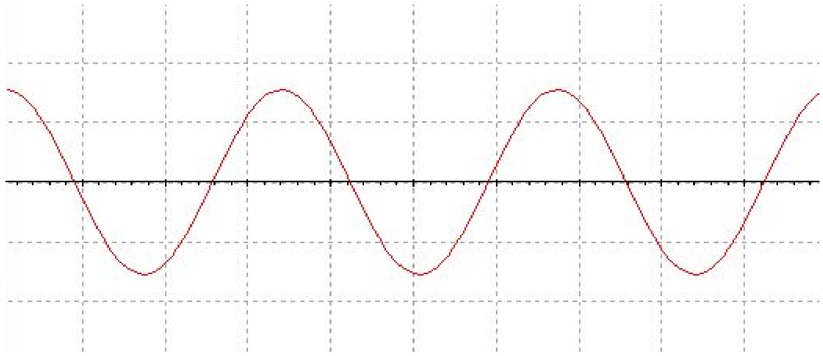

Figure 1-1

2. Connect a 110V to 12.6V (Or any transformer with a ratio close to 8.7:1) iron core step down transformer to the contact voltage regulator with a terminal block; 110V would damage the protoboard. The transformer is iron core to increase conductivity. This will reduce the voltage down to 12.6V which is enough to power the circuit.

3. Measure the voltage across the output of the transformer with an oscilloscope. The output of the transformer was measured to be 12.6V. Figure 1-2 shows the ac voltage wave across the output of the transformer with 10 volts per division and 5 ms per division.

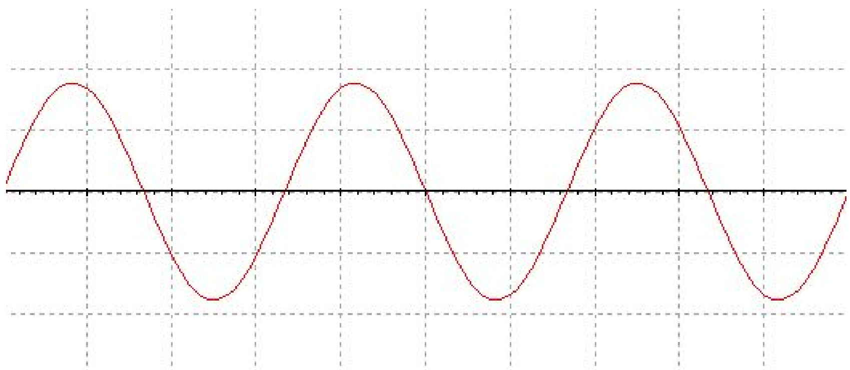

Figure 1-2

Based on Figure 1-1 and 1-2, the step down transformer reduced the outlet voltage thus supplying a circuit with a manageable voltage that won't damage the components.

4. Next, a W01M bridge rectifier was connected to the transformer as shown in Figure 1-3.

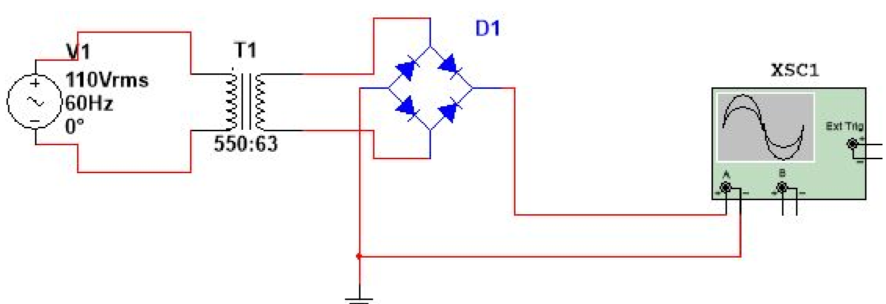

Figure 1-3

5. Measure the voltage across the bridge rectifier. Figure 1-4 shows a dc voltage wave and table 1-1 shows what we measured across the output of the transformer with 10 volts per division and 5 ms per division.

Multisim (Vrms)	Breadboard (Vrms)
11.2	11.1

Table 1-1

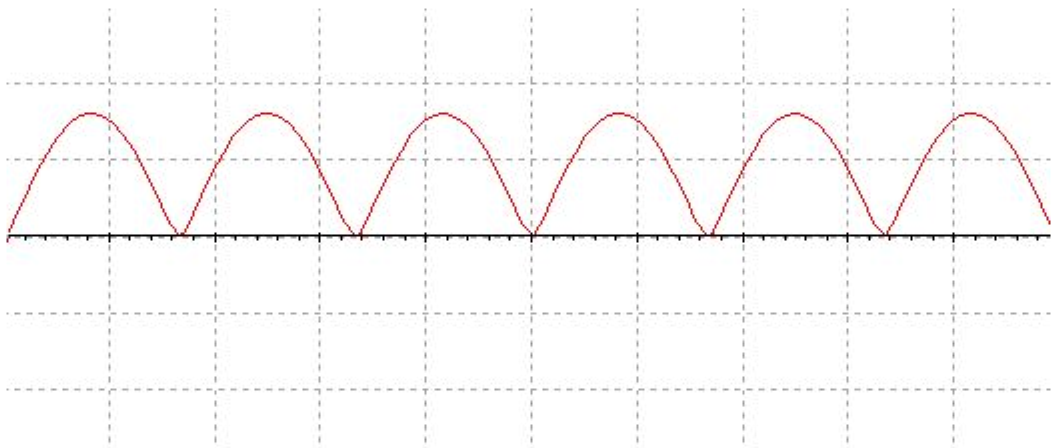

Figure 1-4

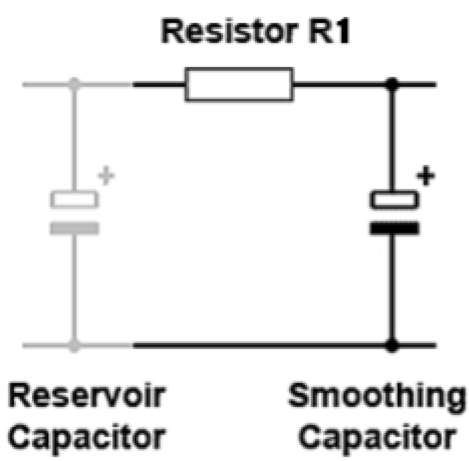

Figure 1-5

6. Next, is the pi filter which consists of a reservoir capacitor, resistor, and smoothing capacitor as shown in Figure 1-5. The reservoir capacitor acts as a temporary storage for the power supply output current. The larger the capacitor the less ac voltage ripple is shown but the longer the capacitors take to charge. Use 2200uF for the reservoir and

smoothing capacitor as they are large capacitor values that don't sacrifice a lot of physical space as capacitance can often mean larger capacitors.

ripple frequency = 2 * input frequency
Equation 1-1

7. The duration of the time constant in the circuit needs to be ten times larger than the period of each wave on the power supply in order to be a long time constant where the capacitor isn't given enough time to fully charge and it's voltage becomes more DC. The period of the waves of the power supply was calculated by plugging in the input frequency, 60 Hz, into Equation 1-1 to get the ripple frequency. 60Hz * 2 = 120Hz.

T=1/f

T= period of wave

f= frequency

Equation 1-2

8. Plug in the ripple frequency into Equation 1-2 to find the period of each wave. 1/120Hz =8.333x10^-3 s
9. Multiply the period by 10 to calculate the time constant. 8.333x10^-3 s * 10 = 8.333x10^-2 s.

R=τ/C

τ = time constant

R = resistance

C = capacitance

Equation 1-3

10. Based on Equation 1-3, the larger the capacitor value and resistor value, the larger the time constant. The resistance value for R1 can't be more than 25 times the reactance of the smoothing capacitor to ensure enough voltage is dropped across it thus across the voltage output. Use a value of 2200uF for the smoothing capacitor , a large value capacitor that isn't too physically big to make it convenient for the box. Plug the capacitance of the smoothing capacitor and the time constant calculated in step 4 to find the resistance of R1. 8.333x10^-2 s / 2200uF = 37.877 ohms.

Xc = 1/ ripple frequency * capacitance
Equation 1-4

11. Calculate the capacitive reactance of the smoothing capacitor by plugging its values into Equation 1-4. 1/ 120Hz * 2200uF = 3.788 ohms.
12. Determine whether R1 is not more than 25 times the capacitive reactance. 37.877 ohms / 3.788 ohms = 9.999. This means that the value of R1 is small enough to allow a great enough voltage drop across the smoothing capacitor.
13. 37.877 ohms represents the minimum value the R1 has to be. The voltage across R2 was measured and larger resistors would replace R1 until there is a resistor that gets close to 5V to ensure that the voltage regulator doesn't need to drop much voltage thus won't heat up as much. This resistor was 150 ohms.

fc=1/(2*3.14*C*R)
fc=passed frequency
C=capacitance of C2
R=resistance of R1
Equation 1-5

14. R1 and C2 make up a low pass filter. The resistance and capacitance value was plugged into equation 1-5 to determine what frequencies are passed. 1/(2*3.14*2200uF*150ohms)=0.482Hz.
15. Use the values for the pi filter calculated in the previous steps with a 100 ohm resistor in parallel with the smoothing capacitor to act as a load to determine whether the load voltage ripple is less than 10 mV. Figure 1-6 shows the schematic on Multisim.

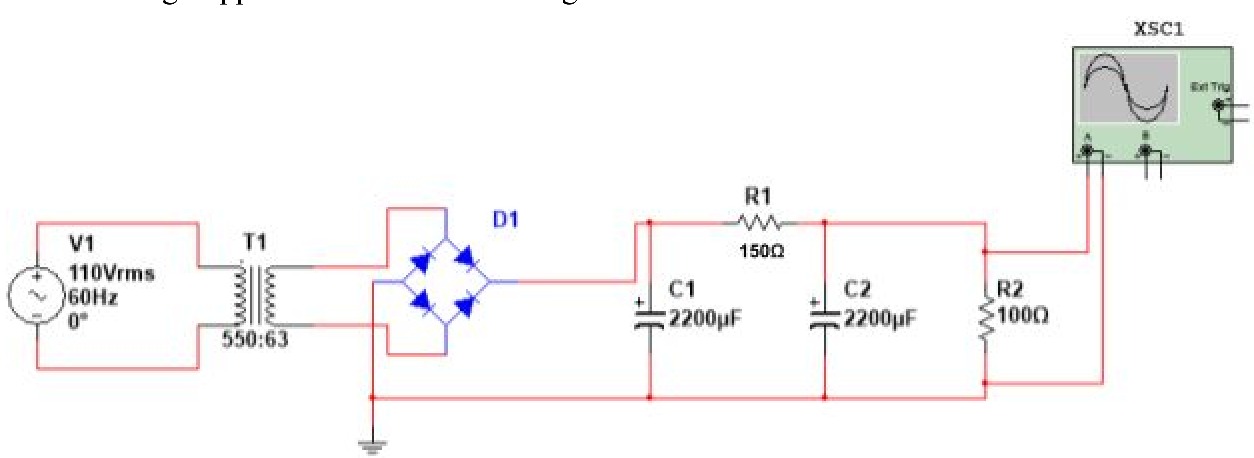

Figure 1-7

16. Using an oscilloscope, connect the probe across the 100-ohm resistor and set it to measure ac voltage. Set the volts per division to 1mV and the time per division to 10ms. The multisim ac peak to peak voltage ripple is measured to be 5mV(Table 1-2) which fits the requirement of the power supply having a ripple less than 10 mV. The dc voltage across the 100-ohm resistor drops 5V table 1-2 which is the right voltage to through a USB. Figure 1-8 shows the voltage ripple for the 100-ohm resistor load with 2ms per division and 2mV per division.

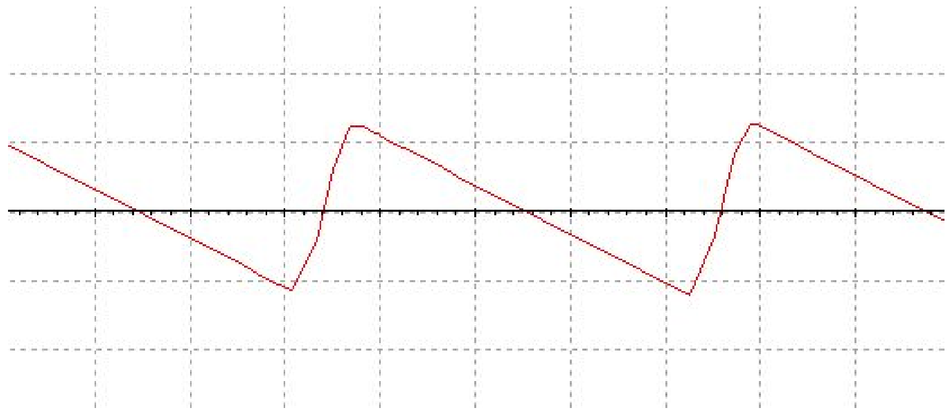

Figure 1-8

17. Measure the current and voltage of the reservoir capacitor. Table 1-2 shows the current and voltage of the reservoir capacitor.

	Multisim	Breadboard
Voltage across cap (V)	16.202	16.3
Current through cap (mA)	114.054	114.1

Table 1-2

Q=VC

Q= charge

V=voltage

C=capacitance

Equation 1-5

t=Q/I

t= time

Q=charge

I = current

Equation 1-6

18. Plug the multisim values from Table 1-3 into Equation 1-5 then 1-6 to find the time delay in the circuit to start up. 16.202V * 2200uF = 35.644mC 35.644mC / 114.054mA = 0.31s. This means that the capacitor value is small enough that it doesn't delays the circuit a considerable amount.

Based on Figure 1-8, the voltage across the load isn't 5V. A 5V voltage regulator will ensure that the voltage across the load will be 5V despite minor changes in supplied voltage. The pins of the a L7805CV voltage regulator are shown in Figure 1-10.

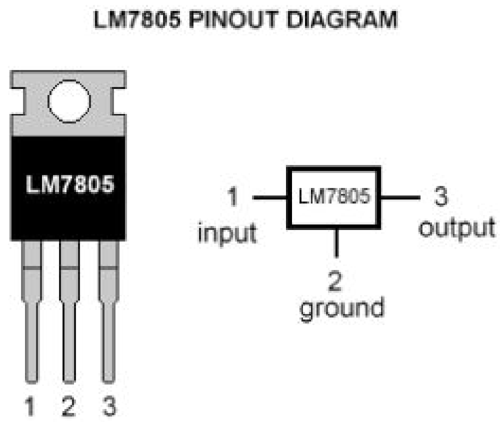

Figure 1-9

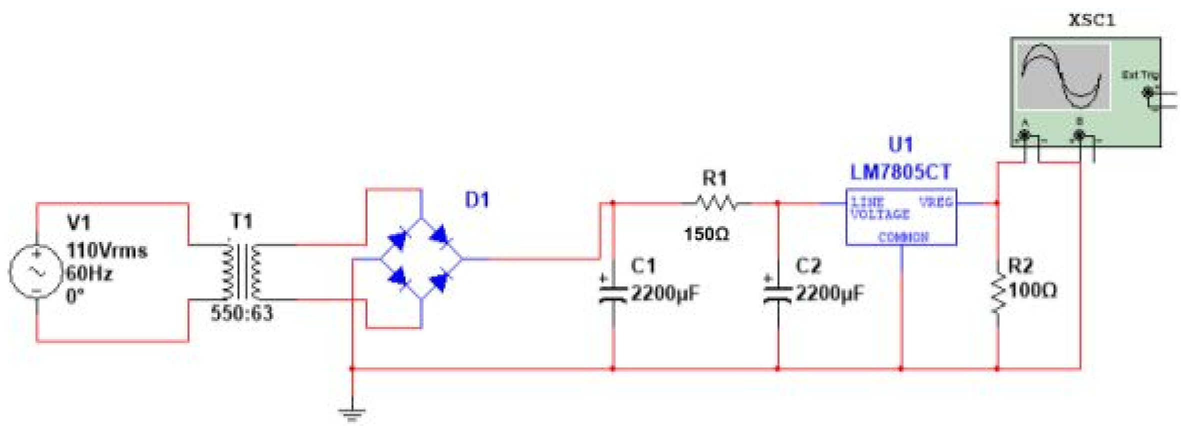

Figure 1-11

19. Connect a L7805CV 5V voltage regulator into the circuit as shown in Figure 1-10.
20. Measure the dc voltage across the load. Table 1-4 shows the voltage across the load with the voltage regulator in the circuit.

	Multisim	Breadboard
Voltage across R1 (V)	2.114	2.1
Current through R1 (mA)	54.63	54.6
Voltage across regulator (V)	9.173	9.1
Current through regulator (mA)	54.63	54.6
Voltage across load (V)	5.002	5

Table 1-4

21. Table 1-5 shows the maximum amount voltage, current, and temperature that the voltage regulator can handle. Measure the voltage across and current through the voltage regulator to determine whether it fits the data sheet. If the current or voltage is above its listed max voltage or current then the voltage regulator will likely overheat and become damaged.

Current (A)	1.5
Volagte (V)	35
Temperature (°C)	125
Temperature (°F)	257

Table 1-5

22. Measure the voltage and current going into the voltage regulator. Table 1-6 shows the voltage and current of the voltage regulator and R1.

	Multisim	Breadboard
Voltage across R1 (V)	2.131	2.1
Current through R1 (mA)	54.63	54.6
Voltage across regulator (V)	9.173	9.1
Current through regulator (mA)	54.63	54.6

Table 1-6

Based on Table 1-4 and 1-5, the current and voltage of the voltage regulator is below its max specifications and thus won't be damaged.

$P=IV$

Equation 1-7

23. Calculate the wattage for the resistor using Equation 1-7. 54.635mA * 2.131V = 116.427 mW This means a quarter watt (250mW) resistor can be used and won't experience a damaging amount of heat.
24. Measure the voltage across the load and set the contact voltage regulator to zero volts then increase it until the voltage across the load is 5V. Table 1-7 shows the voltage of the power supply when the output voltage was 5V.

	Multisim	Breadboard
Voltage of power supply	64V	61V

Table 1-7

25. Place a 1A fuse on the primary of the transformer to prevent excess current damaging the entire circuit. Most of the components will be damaged if a current of 1A went through them.
26. The ground pin of the USB port was connected to ground and the 5V+ was connected to the positive end of the smoothing capacitor.

Ultiboard:

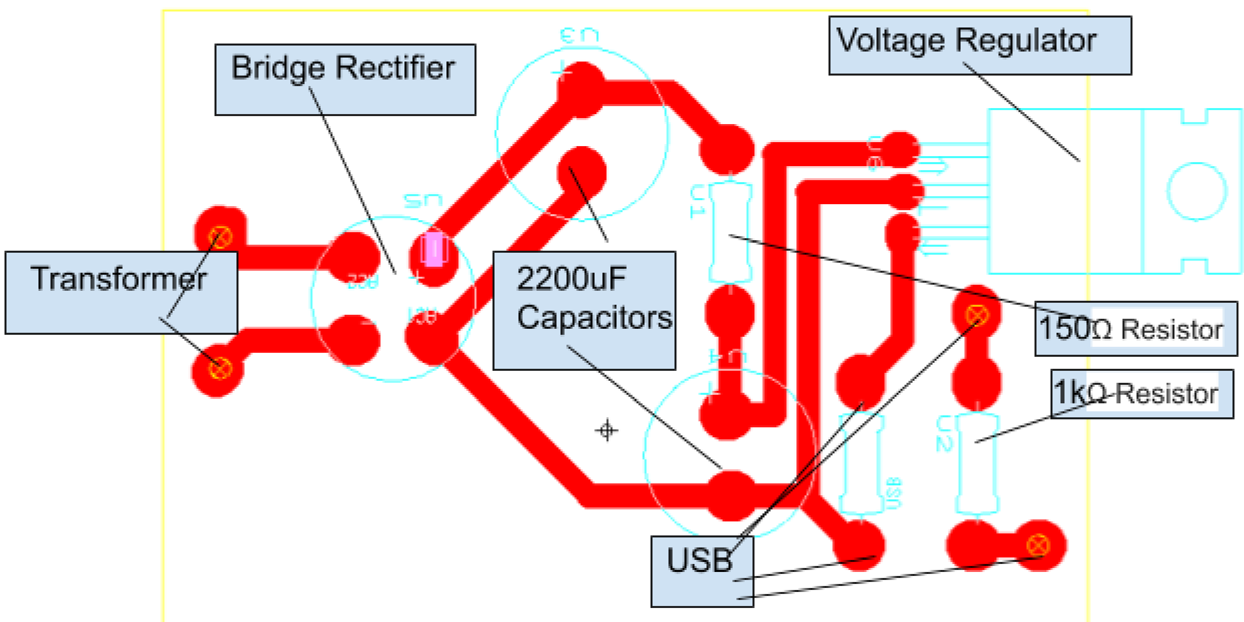

Figure 2-1

1. A good way to start an ultiboard is to take the components required for it from the database which can be found at the top of the screen in the place menu. This can help make it more visible as to what components will take up certain spaces on the screen.
2. Once any and all components are placed, they are arranged in a way that makes it so no connections can interfere with another. This should be a similar design to the multisim, but it doesn't specifically require the parts to not interfere at all until connections are actually made. It's best to get an idea of how the connections will be made before making any actual line connections.
3. Once components are moved into a place that is seemingly comfortable such as figure (3-1), it's time to make connections. Connections of copper trace are made by selecting

the bottom copper layer and then selecting the line tool. Once the tool is selected, click the end of any component, marked by a blue hole, and move to the next component that the previous is meant to be connected to and click again. This should be repeated until all connections are properly made.

4. Once the connections are made, the board should look quite similar to figure (3-1). Double check the connections with multisim and ensure that they both follow the same route through each component and end at the same places. Make sure holes are added as well by using the hole tool in the place section. The diameter should be about 25 mil. Once these are added, and the circuit seems complete, it's time to finally produce the circuit.

Inventor:

1. To start creating an idea for a box, the ultiboard for the circuit needs to be made, so that a place to hold the circuit board can be made.
2. Take the dimensions of the ultiboard, shown in table 3-1.

Length	Width
3 in.	1.5 in.

Table 3-1

3. Next, create the base of the box, in Autodesk Inventor, that follows the shape and dimensions shown in figure 3-1

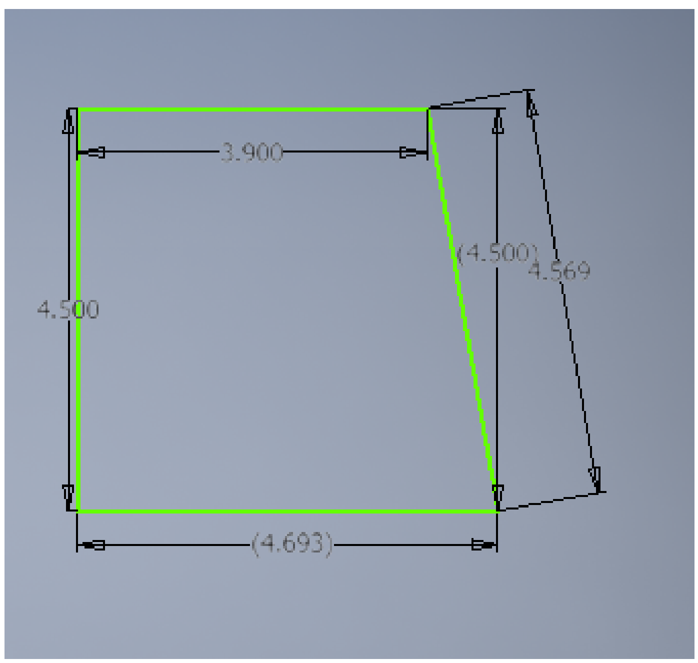

Figure 3-2

4. Finish the sketch, then extrude the sketch 3.5 inches.

5. On the slanted side, draw a rectangle that uses the dimensions shown in figure 3-2

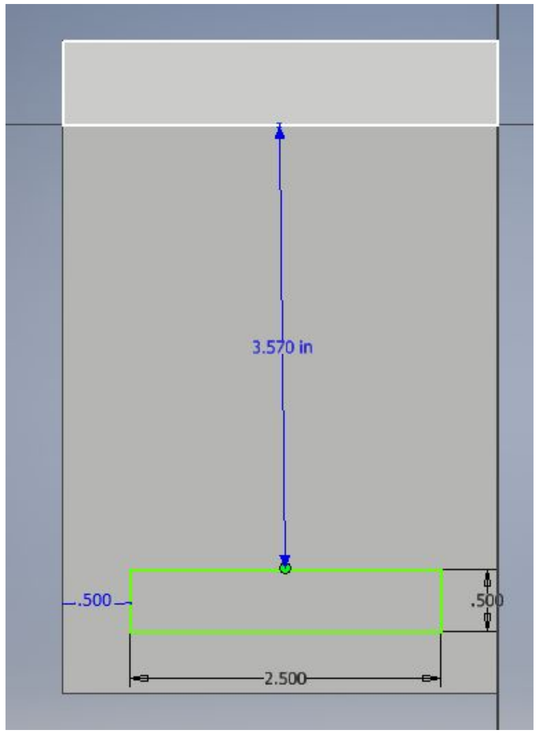

Figure 3-2

6. Extrude the rectangle .75 inches. This will be a phone stand.
7. On the phone stand, place a center to center slot that follows the dimensions shown in figure 3-3, then extrude the slot downwards as far as to make a hole going through the rectangle.

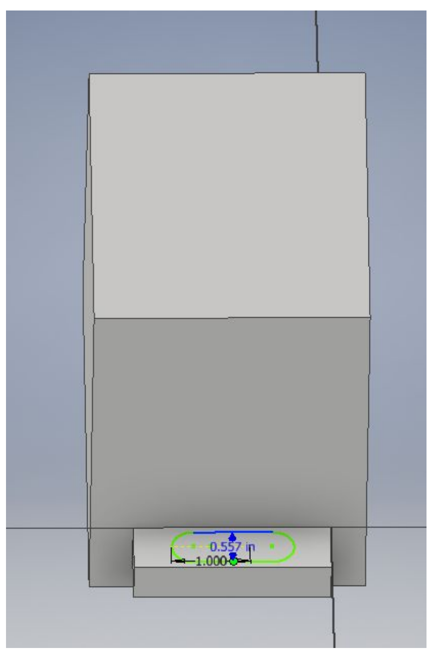

Figure 3-3

8. Next, create a rectangle on the top of the box that follow the dimensions in figure 3-4 the rectangle will need to be centered. Also, extrude it downwards 3.5 inches. This is where the circuit will go.

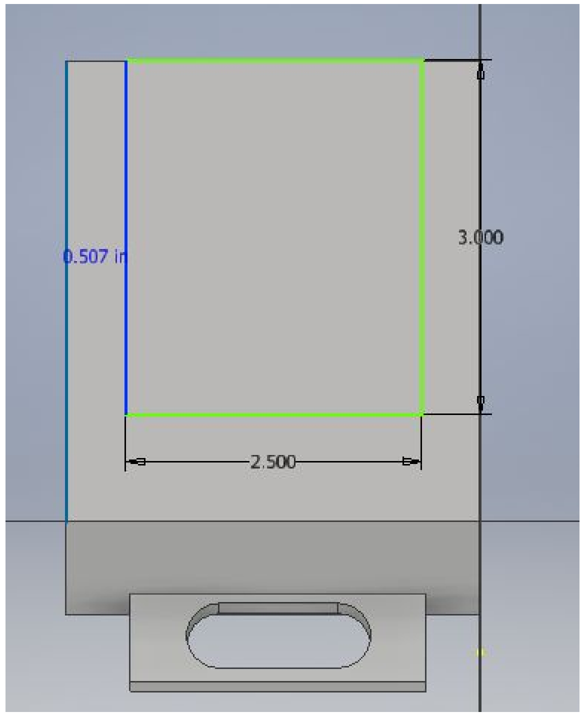

Figure 3-4

9. Add two rectangles that follow the dimensions in figure 3-5 on the sides of the cutout that the circuit goes. Then extrude them .25 inches upwards.

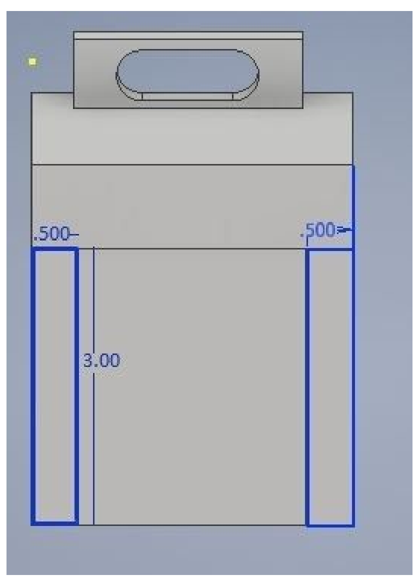

Figure -5

10. Draw a rectangle on the inside of the rectangles that were just extruded. The rectangles should be 2.75 inches long and .15 inches wide. These should be extruded .25 inches inwards. Also draw four .3 diameter circles shown in figure 3-6. The circles will be extruded .25 inches inwards. These will hold the cover in place.

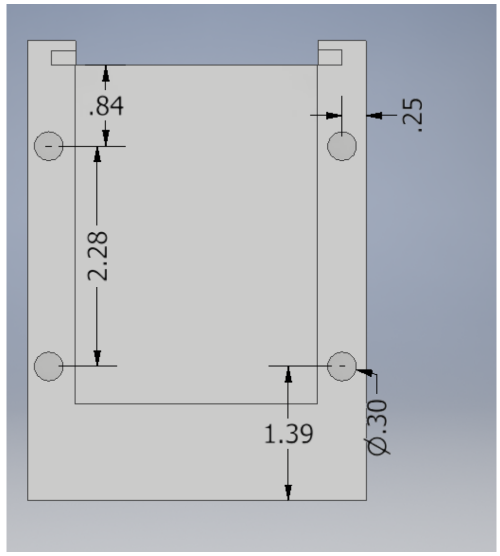

Figure 3-6

11. For reassurance of any dimensions for the box, they are shown in figure 3-7

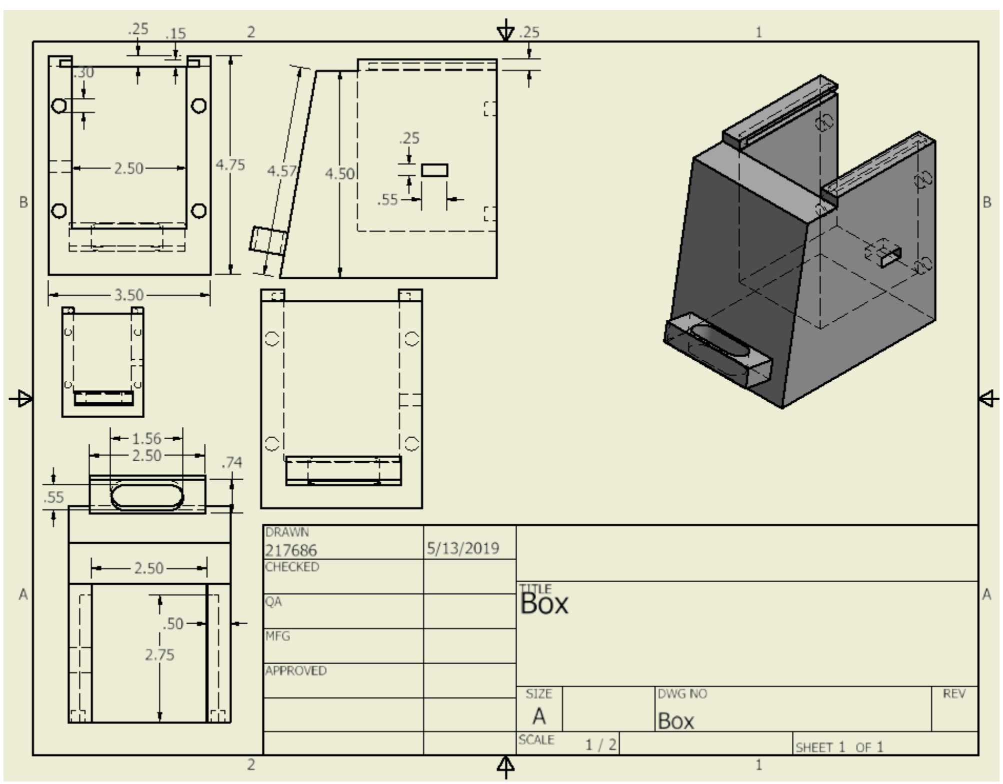

Figure 3-7

12. For the lid, follow the drawing shown in figure 3-8

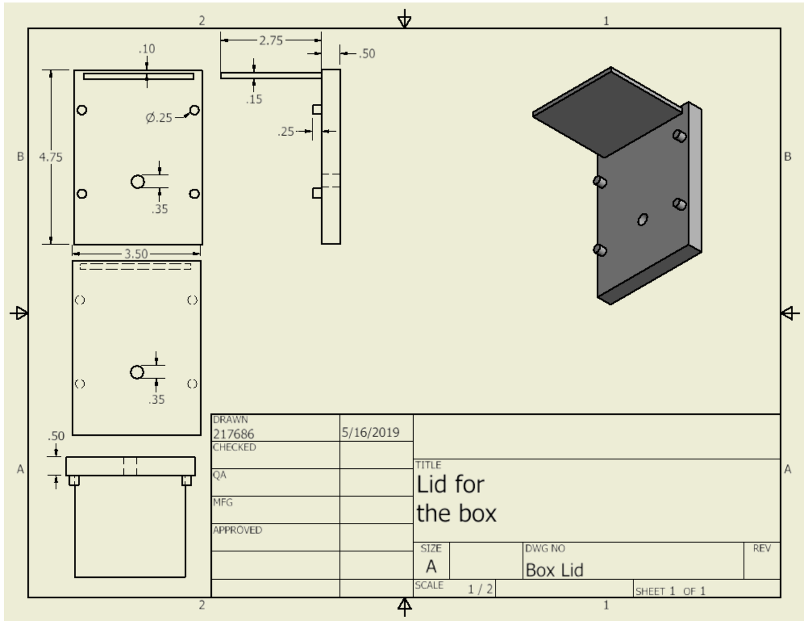

Figure 3-8

Assembly

1. Solder all the components to the PC board's corresponding labels in Figure 2-1 excluding the fuse and out plug.
2. Solder the fuse holder onto the positive or negative end of the outlet.
3. Insert the PC board into the box (Figure 3-7).
4. Insert the outlet plug into the small hole in the back of the lid (Figure 3-8).
5. Solder the outlet to the PC board's corresponding labels in Figure 2-1.
6. Push the USB port into the rectangular hole in the side of the box (Figure 3-7).
7. Slide the lid on.
8. The final product is shown in Figure 4-1.

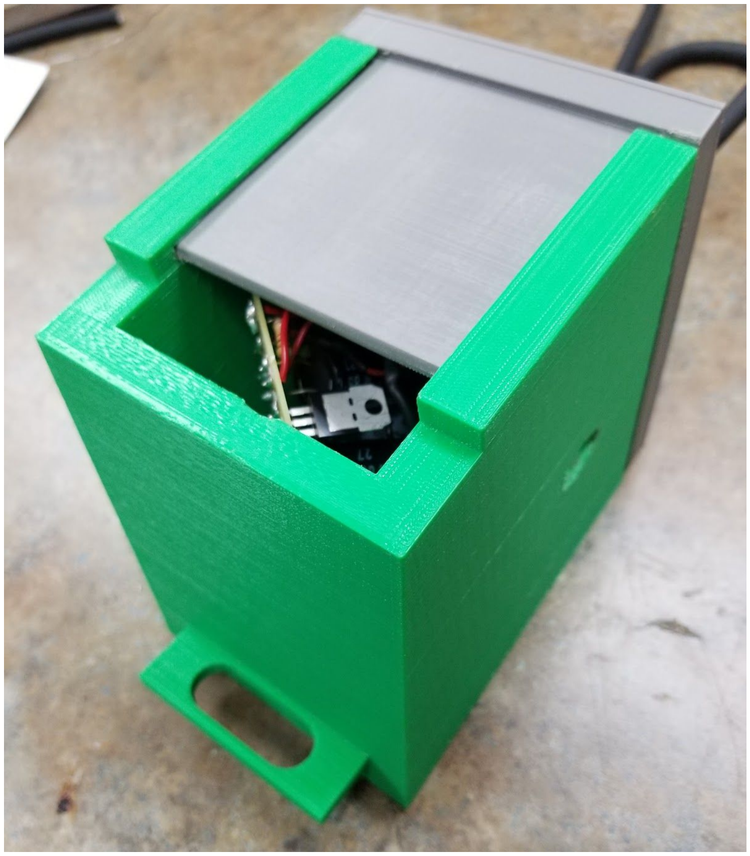

Figure 4-1

Discussion

To begin this project, we needed to come up with a working multisim of the circuit. This multisim became somewhat problematic as a number of new components were involved such as a bridge rectifier. It seemed to be complex to handle these new components at first, but with trial and error, a working multisim could be achieved. We had first begun moving capacitors around and editing their values until the proper 10 millivolt line was achieved going through the resistor load.

Further on, we had to breadboard this circuit. With breadboard, things were mainly straight forward once the bread board was down, but we still had requirements including the peak of the resulting voltage being below 10 millivolts. Our original circuit with the diodes and capacitors would work fine, but the line was above 10 millivolts. We had soon realized that one capacitor was being shorted by being placed in parallel with the incorrect component. Once resolved by moving the components and checking some connections, the circuit finally achieved a proper reading below 10 millivolts.

The ultiboard was not too challenging considering that its connections are based off the multisim and breadboard connections. With the breadboard and multisim complete, the different connections that must be made for a working circuit are easy to understand and put into the ultiboard. This made the ultiboard section quite easy as long as there is an understanding of how to use ultiboard especially since values were not required to be found for the circuit design. One problem might've been the lack of a few components such as a transformer that can't be placed directly in the circuit. To compensate for this, holes were added for the corresponding pins of the transformer. When we etched the circuit, it came out fine and seemed to work alright with all proper connections.

The box design was another somewhat easy portion compared to the previous calculations and breadboarding. Although that may be true, it still had its own challenges. A number of variables had to be considered including a place for the transformer, a working cover, and a place to hold the circuit with the corresponding usb port and power plug. With these in mind, our box was carefully designed and measured in order to find places for these factors. When the prototype was printed, the idea for error was forgotten. When making the lid, the idea for having the 3d printer making parts larger or small never crossed a mind. The lid was a perfect fit on inventor, but not in reality. To fix this, about 4 hours and a file was needed.

The final construction of the circuit had its own problems. These included safety issues, problems with the usb, and an incorrect voltage reading. To start, There were issues with testing the circuit. When we plugged the circuit into a wall, we lacked a variable transformer and the proper safety materials that go with handling uncontrolled voltage. These dangers lead to a small explosion from the accidental connection of the two positive and negative leads from the outlet. IT IS IMPERATIVE to follow proper safety protocols to ensure this does not happen again. This includes using a variable transformer and box connections to keep anything from shorting. The USB also provided its own troubles with the pins. Lack of knowledge caused the data and normal pins to be connected by mistake. Also, some of the pins broke off which caused even more trouble. The only way to solve this was to get a new USB. The voltage across where the USB would be was reading a voltage far too low. Considering such, there could be problems with any of the components due to the previous explosion.

Conclusion

The power supply is made up of voltage rectifier and a pi filter. A voltage rectifier is a system of four diodes attached to a transformer that is capable of turning an AC voltage into a DC lower voltage. The wave form from the rectifier is a full-wave where it has continuous bumps that can be considered halves of the positive sides of sine waves. This voltage can be controlled more accurately and carefully by a pi filter. This filter will close the ripples between the waves and make a DC line that is more accurate than previous. A DC line has to be below 10 millivolts with a 5 volt DC line.

A pi filter consists of a reservoir capacitor, resistor, and smoothing capacitor. The reservoir capacitor acts as a temporary storage for the power supply output current. The larger the capacitor the less ac voltage ripple is shown but the longer the capacitors take to charge. The duration of the time constant in the circuit needs to be ten times larger than the period of each wave on the power supply in order to be a long time constant where the capacitor isn't given enough time to fully charge and it's voltage becomes more DC. Based on Equation 1-3, the larger the capacitor value and resistor value, the larger the time constant. The resistance value for R1 can't be more than 25 times the reactance of the smoothing capacitor to ensure enough voltage is dropped across it thus across the voltage output. Based on step 9, the 2200uF capacitor is large enough to fit the requirement of a ripple below 10 mV and the resistance is small enough to ensure that the voltage across the 100-ohm resistor is 5V.