

# EE 43/100 FINAL PROJECT: AN AUDIO AMPLIFIER

## Part 1: Power Supply

### Lab Guide

In this lab we will build and analyze a simple AC to DC converter. You will receive a breadboard and some parts that you may keep and take home. Take care to build this circuit carefully so that it will last a while. Treasure it forever.

## 1 Analyzing The Transformer

The transformer we will be using in lab is shown in Figure 1. The primary winding is connected directly to the wall outlet. Place an oscilloscope probe across the secondary winding, plug the transformer into the wall, and sketch  $V_{out}$ . **DO NOT SHORT THE SECONDARY WINDING.**

What is the maximum voltage you see at  $V_{out}$ ? What is the minimum? How does the waveform differ from your expectations, and why is it this way?

## 2 Adding In The Bridge Rectifier

Now change your circuit to look like Figure 2. We've taken the output of the transformer and fed it through a bridge rectifier circuit. Sketch  $V_{out}$ .

What is the maximum voltage you see at  $V_{out}$ ? What is the minimum?

What is the frequency of  $V_{out}$ ? Why?

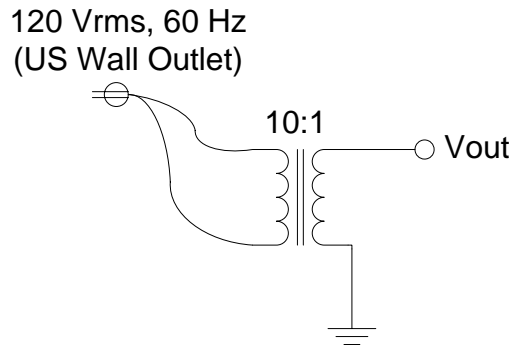


Figure 1: Transformer circuit.

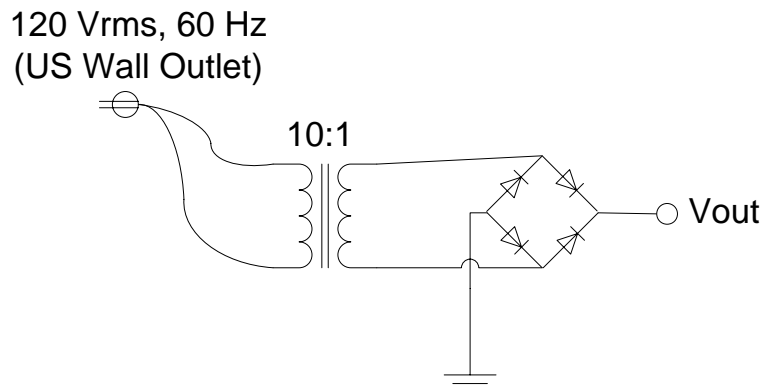


Figure 2: Adding in the bridge rectifier...

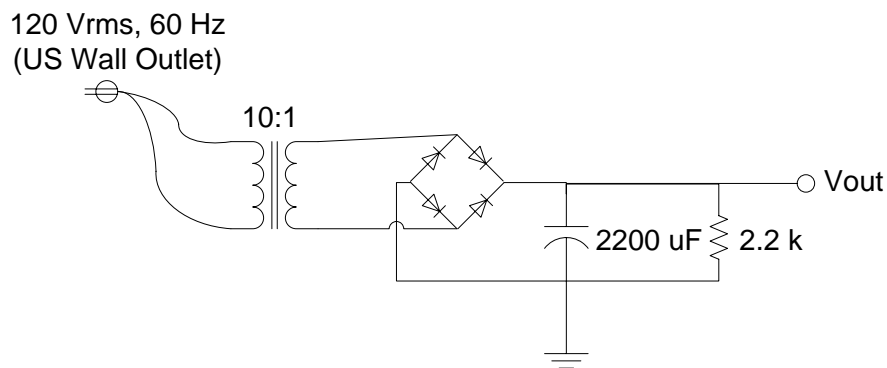


Figure 3: Loading the bridge rectifier...

### 3 Analyzing The Bridge Rectifier

Usually we place a capacitor on the output of the bridge rectifier. We then use this signal to power another circuit or electric device. The other circuit we power is known as the load and can usually be approximated by placing a resistor on the output of the bridge rectifier.

When we make these two changes to the circuit, we end up with something like Figure 3. Together, the  $R$  and  $C$  form a low pass filter. Sketch  $V_{out}$ .

What is the average voltage seen at  $V_{out}$ ?

### 4 Bridge Rectifier Ripple

We like to power our circuits or electronic devices with an constant DC voltage. However, it's extremely difficult to get a truly constant DC voltage. We can get an approximation to it however, and often we like to compare DC power supplies based on how closely they can approximate this constant DC voltage.

A useful metric to measure the quality of an AC to DC converter is the output voltage ripple,  $V_{ripple}$ . Often the output of a DC power supply will be approximately the DC value we want, but it may rise above

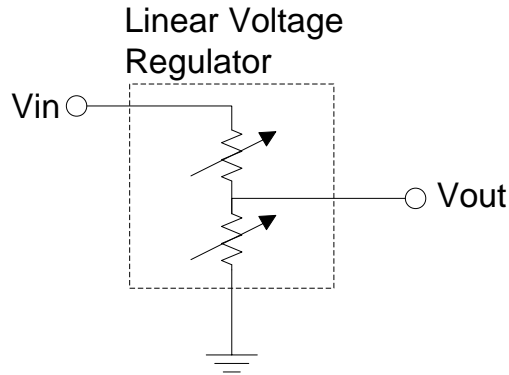


Figure 4: A simple linear voltage regulator.

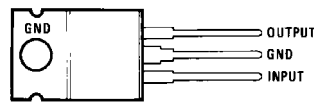


Figure 5: LM340T5 linear voltage regulator.

or fall below the DC value from time to time. We say that the output voltage “ripples.” We define  $V_{ripple}$  as the peak to peak voltage of the ripple.

Use your oscilloscopes to measure  $V_{ripple}$  for this very simple AC to DC converter. What is the frequency of this ripple voltage?

## 5 Linear Voltage Regulator

One way to combat ripple voltage is to use a device called a linear voltage regulator (v-reg). This device is illustrated in Figure 4. In the most simplistic view, a v-reg can be thought of as two variable resistors.  $V_{out}$  is then obtained from  $V_{in}$  through a simple voltage divider circuit. The v-reg then adjusts the values of the two variable resistors until the output voltage is desirable. If the input voltage changes, it will dynamically adjust the two resistors so that the change is not seen on the output. Using a v-reg is a great way of cleaning up a power supply to generate a constant DC voltage.

The voltage regulator we will use in this lab is an LM340T5 . The 5 suffix means that this v-reg is designed to output 5 volts. The pinout of this voltage regulator is shown in Figure 5.

Modify your circuit to look like Figure 6. Notice that the load resistance has been moved to the output of the v-reg. This is because we will power our circuit or electronic device from the v-reg output. Recall that the resistor approximates the load, so it needs to connect to the v-reg output just like another circuit or electronic device would.

Sketch  $V_{out}$ . What is the average value (DC component) of  $V_{out}$ ? What is  $V_{ripple}$ ?

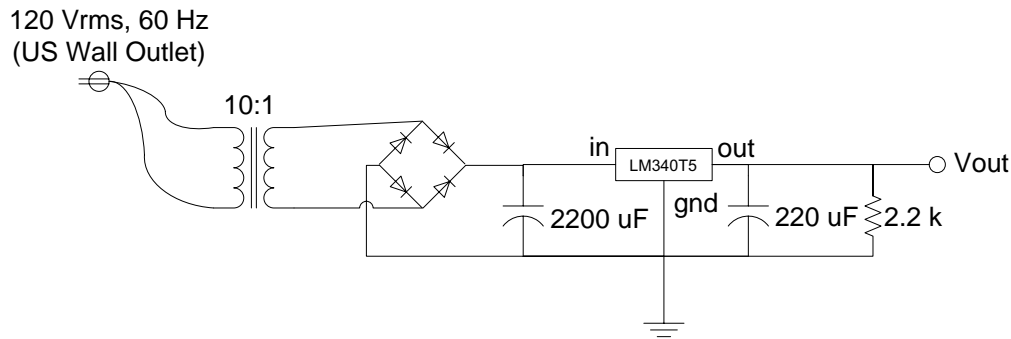


Figure 6: Adding a linear voltage regulator...

## 6 Response To A Changing Load

Suppose the v-reg is powering another circuit (the load). Then there will be some current flowing from the v-reg output to the load. Suppose the load suddenly changes. This will cause the current to change, and because the v-reg is just generating the voltage with a voltage divider (Figure 4), the output voltage will change as well. A good v-reg will notice this change and quickly adjust the two variable resistors to compensate. However, this compensation takes some time. Another way to measure the quality of an AC to DC converter is to measure how quickly it can respond to a changing load.

Modify your circuit so that it looks like Figure 7. Note that the pinout for the MOSFET is shown in Figure 8.

Sketch  $V_{out}$  and  $I_L$  on the same axes. To get  $I_L$ , measure the voltage across  $R$  and use Ohm's law.

Approximately how long does the v-reg take to stabilize the output voltage?

## 7 Efficiency

We define the efficiency of a power supply to be the ratio of the output power to the input power. It's interesting to find the efficiency of this simple AC to DC converter. Finding this efficiency does require a few circuit modifications. The modified circuit is shown in Figure 9.

The output power is relatively easy to find. Simply measure the current going through the  $50\Omega$  load resistor and use  $P = V^2/R$ . **Note:** the load resistance changed here to provide a slightly higher output power.

The input power is slightly harder to find. Insert a  $1\Omega$  shunt resistor as shown in Figure 9\*. Now, if we measure the voltage across this resistor we will actually be measuring the current flowing into the circuit. Over one period, make several measurements of the input current  $I_S$  and  $V_S$ . Use the fact that  $P = IV$  to get the instantaneous power for each measurement. Now average all your values to get the average power flowing into the circuit.

After doing all this, you should be able to get an efficiency for the circuit to the right of the transformer. If we know that the transformer is 97% efficient, what is the total efficiency of this AC to DC converter?

Why is this efficiency so low? Where did all the excess power go? How can we build a better AC to DC converter?

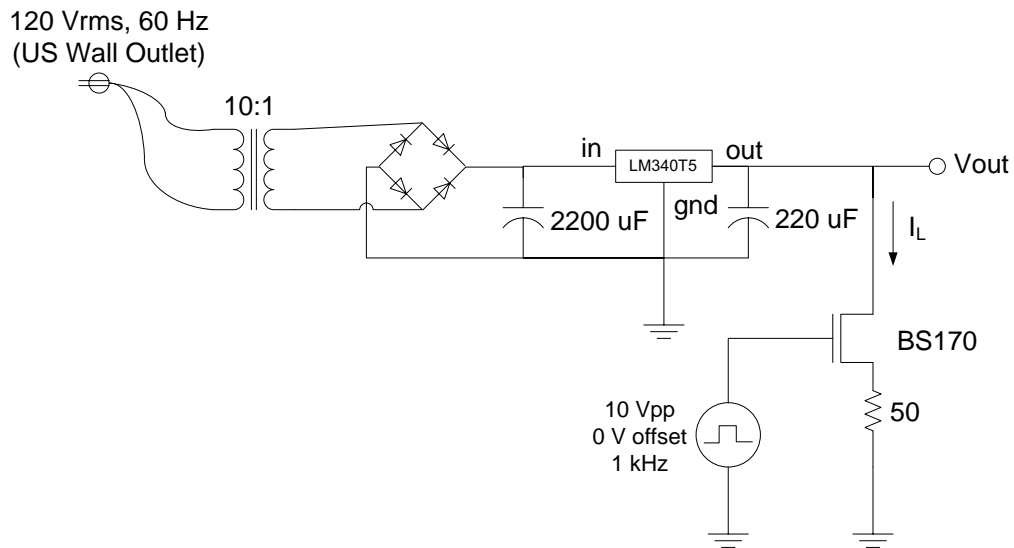


Figure 7: AC to DC converter with a dynamic load.

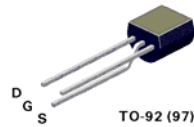


Figure 8: Pinout for the BS170 MOSFET.

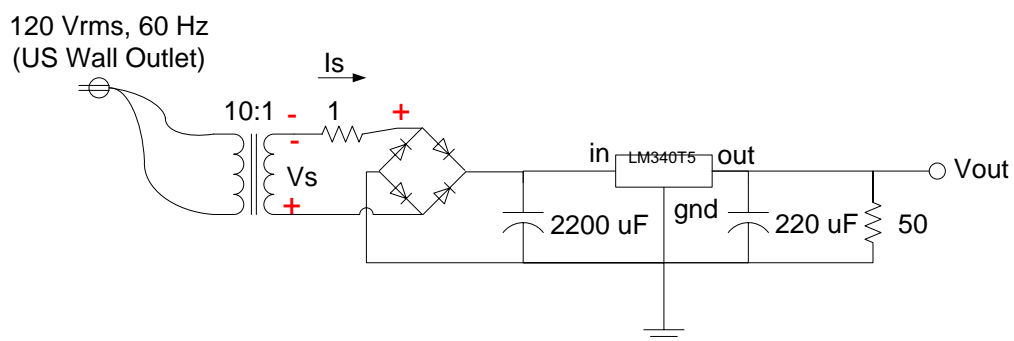


Figure 9: Circuit to be used for efficiency measurement.

**\* IMPORTANT:** Please make sure your oscilloscope probes are hooked up as shown in the diagram above. The black ground clips should be at the - symbols, and the grey probe tip should be at the plus symbol. Failure to hook this up correctly will short out your transformer, and probably destroy it! (remember that the black ground clips are shorted together inside the oscilloscope)