Lab 6: Filter applications, Diodes, and Power Supply Design

Prelab

Read section 3.8.1 (Transformer Basic Operations) and the beginning of chapter 11 through section 11.6 (Voltage regulators and Power Supplies).

Use EveryCircuit to help you design one of the filters for use in section II. Connect to a a single AC signal source to your filter circuit and click the 'f' yellow arrow to begin a frequency sweep. Select the output voltage node and click the 'eye' to see a Bode plot showing both attenuation and phase. You can adjust the values of your components and watch as the Bode plot changes.

Be ready to show the simulation to me at the beginning of class.

Note that the following real world values are available to you:

- Resistors: 33, 47, 51, 68, 82, 100, 120, 150, 180, 220, 240, 270, 330, 390, 430, 470, 510, 560, 620, 680, 750, 820, 910, 1k, 1.2k, 1.5k, 1.8k, 2.2k, 2.4k, 2.7k, 3.3k, 3.9k, 4.3k, 4.7k, 5.1k, 5.6k, 6.2k, 6.8k, 7.5k, 8.2k, 9.1k, 10k
- Capacitors: 100pF, 1nF, 10nF, 22nF, 33nF, 47nF, 100nF, 220nF, 330nF, 470nF, 560nF, 680nF, 1μF, 2.2μF, 4.7μF,
- Inductors: 100μH, 510μH, 1mH

Part I: Transformers

Check with your TA before plugging in the transformer!

Construct the circuit shown in figure 1.

- What is the secondary coil voltage specification for this transformer? (Look in the datasheet)
- From this V_{rms} value, calculate what you expect the peak-to-peak measurement to be.
- Use your oscilloscope to measure the peak-to-peak voltage. Does this agree with what you predicted? If not, why not?
- Your transformer has a center tapped secondary coil. What would you expect the V_{rms} and V_{pp} to be between the center tap and either of the other wires?
- Connect the center tap wire and ONE of the others wires up to the same circuit as you just used. What do you measure as the peak-to-peak voltage?
- Is the output voltage directly or inversely proportional to the number of windings on the secondary coil? What must the winding ratio (N_P/N_S) be for this transformer?
- Is the current in each coil directly or inversely proportional to the number of turns in that coil?

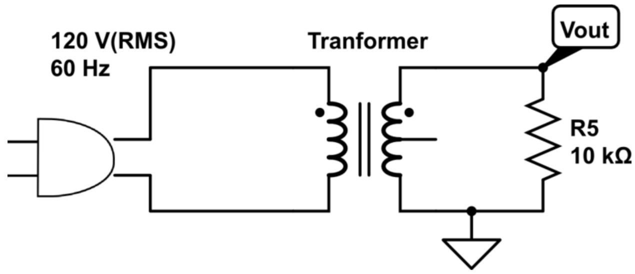

Figure 1: Transformer connected to a load

Part II: Filter application

In the past few labs you have characterized the frequency response of filters over a wide range of frequencies. Often, we are interested in extracting a specific signal or deleting a specific signal.

In this section you will use the transformer along with both function generators to create a composite signal from three sine waves of widely varying frequencies. Then, you will design and implement three filters, each should extract back out only one of the input signals.

First, without any of the filter sections, construct the circuit shown in figure 2.

- **Check with your TA before plugging in the transformer.**
- Use the long "rails" on your breadboard to help neatly organize the circuit.
- Set the output level of each function generator to about half max.

Setup the scope in the usual way and examine the output. Tip: Setting the scope trigger source to 'AC Line' will force it to trigger off the 60 Hz signal only. Explain what you see. Check with your TA before moving on.

Using the knowledge you have gained in the last few labs, design three filters and construct them in parallel.

- Filter 1 should extract only the 90 kHz signal
- Filter 2 should extract only the 5.5 kHz signal
- Filter 3 should extract only the 60 Hz signal

A few reminders and tips

- Don't use electrolytic capacitors
- Avoid resistors less than 25 Ω or more than 100 kΩ
- The cutoff frequency of an RC filter is $f_c = 1/(2\pi RC)$
- The central frequency of an LC notch or bandpass filter is $f_c = 1/(2\pi\sqrt{LC})$
- Keep averaging turned off

Include the circuits you design in your report with all relevant information, also include pictures of the scope output for each one showing the MEASURE menu set to measure frequency.

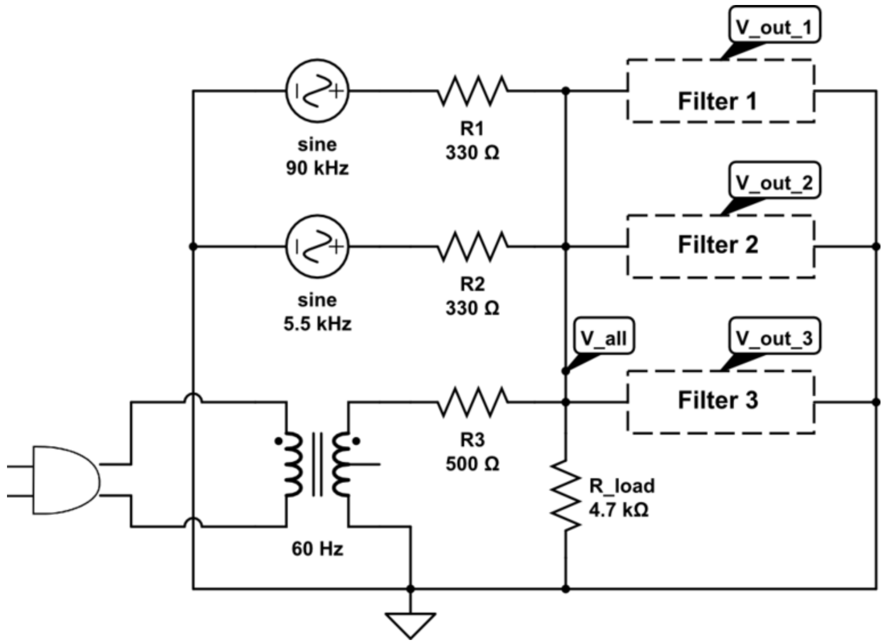

Figure 2: Merging and separating signals

Part III: Diodes and DC Power Supplies

3.1 Diode Types

Obtain a 1N4148 small signal diode, a 1N5819 Schottky diode, and a 1N5232 5.6V Zener diode. *Use your multimeter to measure the forward voltage drop for each. What values do you obtain?*

The small signal diode is designed for very fast switching of small voltages.

Schottky diodes have a lower forward voltage drop and faster switching speeds than standard silicon diodes and are thus more efficient. They are especially preferred when large currents and high frequencies are involved. However, they cost more and have a larger reverse leakage current which can cause problems in certain circuits.

The other common type is the Zener diode. These have a similar forward voltage drop to the silicon diode, but are also designed to conduct in reverse once the reverse voltage exceeds a certain amount. In the case of the 1N4232, it begins to conduct in the reverse direction at 5.6 volts.

What are the symbols for each of these types?

3.2 AC Rectification

Creating a DC power supply first requires "rectification" of the AC signal. That is, removing the negative half of the sine wave. The simplest form is called "half wave" rectification.

3.2.1 Half Wave Rectification

Using the function generator set at about half max amplitude, construct the circuit shown in figure 3. This is effectively three half wave rectifiers in parallel.

1. Compare the input waveform to V1. *Describe what you see and include a picture*
2. Compare V1 and V2. *Find V_{max} for each and compare to what you would expect from the multimeter measurements.*
3. Compare V1 and V3. *Explain what you see.*

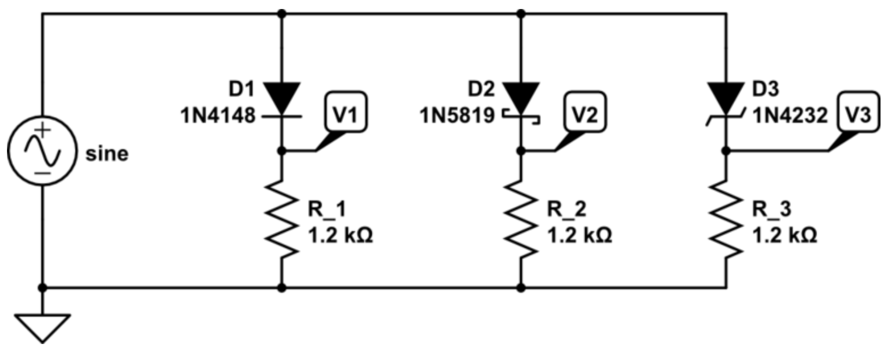

Figure 3: Half wave rectification and diode demonstration

Half wave rectification removes the negative half of the wave, but also wastes half the power. A better method is "full wave" rectification. This method uses four diodes to effectively flip the negative half of the wave and make it positive.

3.2.2 Full Wave Rectification

One downside of full wave rectification is that the "ground" of the AC input and the "ground" of the DC output are no longer at the same potential. Since we would like to measure with the scope across the load, and the scope and the function generator are connected to the same ground wire in the wall, we need to "float" the AC part of the circuit so as to not short out two different potentials during the measuring process.

This is accomplished by using the transformer as the AC source instead of the function generator. **Once again, be sure to have your TA check your circuit before plugging in the transformer.**

Construct the circuit shown in figure 4 and measure the voltage across the load with the scope.

Explain how this circuit works. You are welcome to use sketches along with highlighters or colored pens to show how the current flow changes as the input voltage alternates.

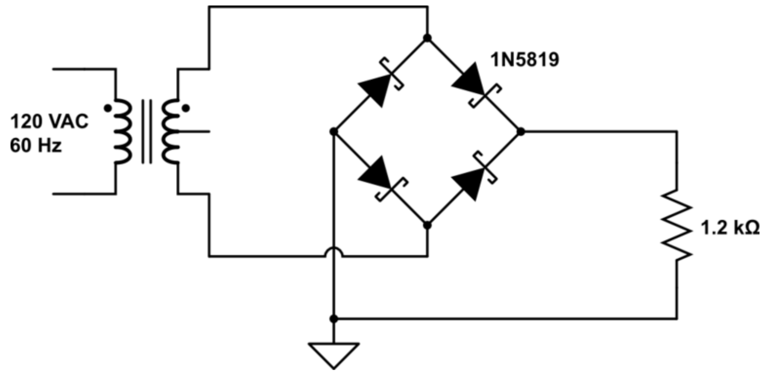

Figure 4: Full wave rectification using a bridge rectifier

3.3 Smoothing

You now have a very bumpy DC signal. To make this useful as a power supply this signal must be smoothed out.

- Add a 10μF capacitor in parallel with the load.
- Measure the mean voltage and the ripple (peak-to-peak) voltage of the resulting signal. Once again, it is helpful to switch the trigger source to AC Line.
- To obtain a smaller ripple voltage, replace the 10μF capacitor with a 100μF capacitor. Once again, measure the mean and the ripple. Note: To obtain a more accurate ripple measurement, switch the channel to AC coupling and then zoom in to the signal which now has the DC component stripped off.

You now have a basic DC power supply, however if you change the load, the mean voltage and the ripple will change. Hence why this is called an unregulated power supply.

3.4 Regulation

The final step is to add a voltage regulator. We are going to use the ubiquitous LM317 linear regulator integrated circuit, shown in figure 5. The output voltage is set using a voltage divider, which can be made variable though the use of a potentiometer.

The LM317 uses a combination of transistors and an internal reference voltage of 1.25 volts to maintain a steady output voltage. However, it must have an input at least 1.25 volts higher than the output for it to function. It effectively works by burning off excess voltage ($\times$ current = power) as heat.

1. The output voltage is given by the equation $V_{out} = V_{ref}(1 - R_2/R_1)$.
2. When R2 is a potentiometer wired as a variable resistor, its resistance varies from zero to 10 kΩ. *What value of R2 will give the smallest output voltage the LM317 is capable of, and what is that voltage?*
3. *Determine what value of R1 will result in a maximum output voltage of about 2 volts less than the average unregulated voltage you found earlier.* (2 volts just give a bit of extra head room to account for ripple.)

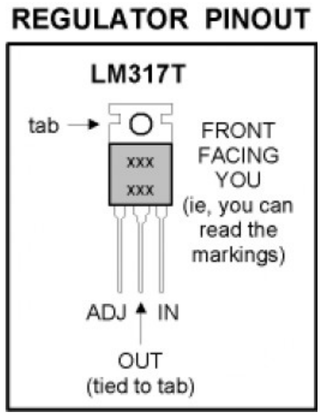

Figure 5: LM317 adjustable voltage regulator pinout

4. Using the value you determined for R1, construct the circuit shown in figure 6.
5. *Use the potentiometer to vary the voltage, what range did you achieve?*
6. *Measure any remaining ripple.*
7. *Set the output to 5 volts (measured with your multimeter) then change the load to a 500 Ω resistor. Does the voltage change? If so, how much? Does your regulator appear to work well?*

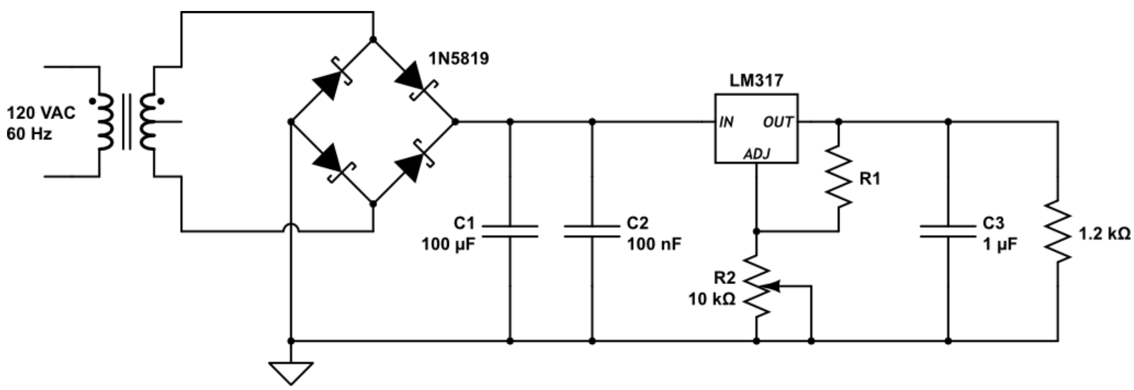

Figure 6: Adjustable regulated DC power supply

3.5 An Example

The circuit you just built is very close to the circuit used in your breadboard power supply box. Take a look at the open unit on the front table as well as the circuit diagram in the manual.

What voltage regulator chips are used? What do these do? Why is one so different from the others? (Use Google to look up the part numbers.)