**Power supply mini-project**

This week, we finish up 201 lab with a short mini-project. We will build a bipolar power supply and use it to power a simple amplifier circuit.

1. **power supply block diagram**

   ![Block Diagram](image)

2. **Transformer**

   Transformers are available in the lab. These are 10:1 center-tapped step-down transformers, giving a secondary (output) voltage of 13 $V_{\text{RMS}}$. By being center-tapped, the output is also available as two 6.5-$V_{\text{RMS}}$ sinusoids. We will use the center-tapped feature to make the bipolar power supply.

   The transformer is in a protective plastic case so that you don’t electrocute yourself. You will need to steal a power plug from one of the other instruments on your lab bench to connect a 120 $V_{\text{RMS}}$ outlet to the primary of the transformer. (The power cord from the older triple-output supply is a good candidate.) Once the transformer is plugged in, you must flip the switch to connect the power the secondary side of the transformer.

   Check the voltages on the secondary side. There are three connectors there. Use the voltmeter to measure between the outer two connectors – it should be approximately 13 $V_{\text{RMS}}$. The center connector is the center tap on the secondary. Measure between the center connector and each of the outer two connectors. Both should measure approximately 6.5 V.

   Note: The transformer kit has a fuse. It is not unusual for the fuse to have burned out by the previous (probably incompetent) users of the transformer. If you have connected the power cord and flipped the switch, but there is no AC voltage at the outputs, it is likely that the fuse is blown. Ask your TA to replace the fuse or take the entire transformer to the electronics shop and have someone there install a new fuse.

   Observe the secondary voltages on the oscilloscope and confirm the 60-Hz frequency and the 13- and 6.5-$V_{\text{RMS}}$ amplitudes.
3. **Peak rectifiers**

Build two peak rectifier circuits that will provide positive and negative DC voltages using the two 6.5-V\(_{\text{RMS}}\) secondary outputs from the transformer. You can use either half-wave or full-wave rectifiers. The center-tap connection will serve as the common connection (ground) for two DC voltages. You will have to arrange your diodes correctly so that you obtain a positive DC voltage from one side and negative DC voltage from the other. Also, be sure to connect the electrolytic capacitors with the correct polarity. (Spend a little bit of time thinking about proper polarities so that you don’t have to waste time running to the shop for replacement parts.)

To test the supplies, connect 1-k\(\Omega\) resistors at each DC output. Measure the DC value of each source using the voltmeter. Then observe the positive source output with the oscilloscope and measure the ripple voltage. (You may need to change scales and zoom in to see the ripple voltage clearly.) Make sure that the ripple voltage is less than 10% of the peak voltage, \(V_{\text{ripple}} \leq V_{\text{peak}}\). If the ripple is too big, change your circuit to reduce the ripple. Once the ripple is less than 10%, record an oscilloscope screen shot showing the ripple waveform. Repeat the measurement and adjustments for the negative side. Record a screen shot of the negative-supply ripple.

Use the voltmeter to record the DC voltages for both of the supplies. Then switch the voltmeter to AC volts and “measure” the ripple of each supply. (Since the ripple voltage is not a sinusoid, the value given by the meter will not be the same as the value using the oscilloscope. However, the voltmeter value is a quick measure for comparing the size of the ripple in different situations.)

When finished, remove the 1-k\(\Omega\) load resistors.

4. **Power an amplifier**

Now build an inverting amplifier with a gain of -10 using an LM324 chip. Use your two DC supplies from above to power the op amp. Be careful with polarities so that you don’t burn out the op-amp chip.

Connect the function generator – set to produce a sinusoid – to the input of the amplifier. Set the frequency at 1 kHz and set the amplitude to 0.25 V\(_{\text{RMS}}\). Observe the amplifier input and output together on the oscilloscope. Slowly increase the input voltage amplitude until the output just begins saturate at the power supply limits, and then back off slightly so that the output sinusoid is at its maximum value without being distorted. Record a trace showing the input and output sinusoids together.

Use the multi-meter to measure the DC and AC voltages on each of sources with the amplifier circuit in place. Note any changes from the previous measurements where the supplies were loaded with just the 1-k\(\Omega\) resistors.

Finally, attach a 1-k\(\Omega\) resistor between the amplifier output and ground to serve as load. Re-check the sinusoid of the amplifier output. If needed, adjust the input amplitude so that the output is at its maximum value without being distorted. Then use the multimeter to measure the
DC and AC voltages on each of the supplies. Note any changes from the previous measurement when the amplifier output was not loaded.

Whoo hoo! You’ve made complete working circuit using just basic components. In EE 230 and later classes, you will refine all the parts of this voltage-supply/amplifier combination to make circuits that start to approach professional quality.

5. Report
Use the report template (available on the web site) to write a short report. Turn in the report before you leave the lab room. If you think you will need more time to finish the report, you should make arrangements with the grader for your section to turn the report later.
2. Simple diode circuits
Calculate the expected resistor voltages and diode current for each of the circuits below, using the simple “on-off” model of the diode. Then build each of the circuits and measure the resistor voltages and currents. In your report, be sure to compare the measurements and calculations.

Figure 2. Do this first with $V_S = +1.0 \text{ V}$. Then repeat with $V_S = +5 \text{ V}$.

Figure 3. Do this first with $V_S = +10 \text{ V}$. Then repeat with $V_S = -10 \text{ V}$.
3. Fun with light-emitting diodes

Build the circuit below using an LED. (Pick your favorite color.) $R_p$ is a 1-kΩ potentiometer. $R_1$ is a “safety” resistor. Use the potentiometer to vary the diode current. Adjust the potentiometer through about 10 steps from the minimum setting to the maximum setting. (The steps don’t have to be particularly well-defined.) At each step, measure the current (using $R_1$) and the diode voltage. Use your data to make a graph of the forward $i$-$v$ characteristic of your LED. Note the change in the LED brightness as you change the current.

From your data, what would be a good offset voltage to use for a simple “on-off” model of the LED?

![Circuit Diagram]

Figure 4. $R_p$ is a 1-kΩ potentiometer.

Replace the DC source with a square wave source, with the low-level value at 0 V and the high-level value at 10 V. Set the frequency at 1 Hz initially, so that the LED is clearly blinking on and off. Increase the frequency in 2-Hz steps. At what frequency can you no longer see that the LED is blinking?

Switch the function of the generator from square wave to pulse. Set the frequency at 200 Hz – fast enough so that you cannot see the switching. Vary the duty cycle of the pulse from 10% (high 10% of the time and low 90% of time) to 90% (high 90% of the time and low 10% of time) in 10% increments. (To change duty cycle, push the pulse parameter button and then choose “Duty” from the soft keys on the side.) As you change the duty cycle of the pulse, note qualitatively the apparent change in LED intensity as the duty is varied. This is known as pulse width modulation (PWM), and is another means for varying the average power being delivered to an electrical device.
4. Rectifiers

Build the simple single-diode rectifier circuit shown below. The source is the function generator set to a sinusoid with amplitude of 3.5 $V_{RMS}$ (approximately 5 V peak) and frequency of 100 Hz. Use the oscilloscope to observe the source and the resistor voltages simultaneously. Record a clear trace that has at least two periods and clearly shows the rectification. Then zoom in on the area near where the diode turns on so that you can clearly see the slight time delay in the turn-on due to the offset voltage of the diode. Record this oscilloscope trace, also. Finally, switch the waveform type to square-wave and then triangle wave. (The amplitude and frequency can stay the same.) Note the changes in the resistor voltage.

![Half-wave rectifier circuit diagram]

Now use four diodes to build the full-wave rectifier shown in Fig. 6. The source is the same as used for the half-wave rectifier (3.5 $V_{RMS}$, 100 Hz). Observe the resistor voltage using oscilloscope. (Note that you cannot observe both the source and resistor voltages simultaneously because you cannot have a common ground for the two.) Record a clear trace of the full-wave rectified waveform for your report.

![Full-wave rectifier circuit diagram]
Now go back to the half-wave rectifier. Switch the resistor to a 10 kΩ. Make it into a peak rectifier by adding a 10-µF capacitor in parallel with the resistor, as shown in Fig. 7. (Be sure to insert the electrolytic capacitor with the correct polarity.) Observe and record the source and capacitor voltages together using the oscilloscope. The resistor voltage should flatten out to something approximating DC. Measure the DC value use the voltmeter. However, if you zoom in on the oscilloscope trace and look carefully, you will see that the DC is not perfectly flat, but “ripples” a little bit. From the oscilloscope trace, determine the extent of the ripple (difference between the peak voltage and the minimum voltage) of the output waveform.

Repeat the above measurements using resistor values of 4.7 kΩ and 22 kΩ. The changes in the resistor value cause both the DC value and the size of the ripple voltage to change.

For your report, calculate the expected ripple voltage for each of the three different load resistors.

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**Figure 7.** Peak rectifier circuit.

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**Reporting**

Prepare a report describing your measurements and results. Be sure to include all your calculations, measurements, and oscilloscope traces, along with enough discussion to completely describe the work done in this lab. The report is due in one week at your next lab meeting.