

## Lab 2: DC Power Supplies

### GOAL

The overall goal of this lab is to better understand how a DC power supply works.

### OBJECTIVES

To build, test, and understand the following power supply circuits:

- 1) Power transformer
- 2) Full-wave rectifier
- 3) Capacitor filter
- 4) Zener regulator

### GENERAL GUIDELINES

- 1) Each student must build, test, and demo their own circuit.
- 2) Students are allowed (even encouraged) to help each other. Of course, Hedrick and the lab assistant will be around to provide assistance as well.
- 3) Do not worry if you need lots of help during the lab, but make sure you eventually know your stuff! **In addition to the written exams, there will be a lab practical where each student is tested on basic skills in circuit construction and simulation.**
- 4) Ask questions! The more questions you ask, the more you learn.
- 5) Build your circuits with neat wiring! Messy circuits will result in a 10 pt deduction from your lab demo grade.
- 6) Please keep your lab kit and work area organized.

### PARTS AND MATERIALS

- Lab kit, multimeter, oscilloscope, benchtop power supply, power transformer
- Diodes: 1N4002 rectifier (2)
- 1N4742A 12V Zener (1)
- Red LED (1)
- Resistors: 270 ohm (red/purple/brown) (1) (This ½ W resistor is thicker than the usual ¼ W resistors)
- 390 ohm (orange/white/brown) (1) (This ½ W resistor is thicker than the usual ¼ W resistors)
- 1.0 kohm (brown/black/red) (1)
- 10 kohm (brown/black/orange) (1)
- Capacitors: 10 µF electrolytic (1)
- 100 µF electrolytic (1)

## PART 0: POWER TRANSFORMER

The majority of power supplies use a power transformer to step down the 120 V<sub>RMS</sub> from the wall outlet. This lab uses a 28 VCT power transformer, which means the secondary voltage is approximately 28 V<sub>RMS</sub>. The “CT” means a center tap connection is available. This power transformer provides the AC input to your breadboard for this lab.

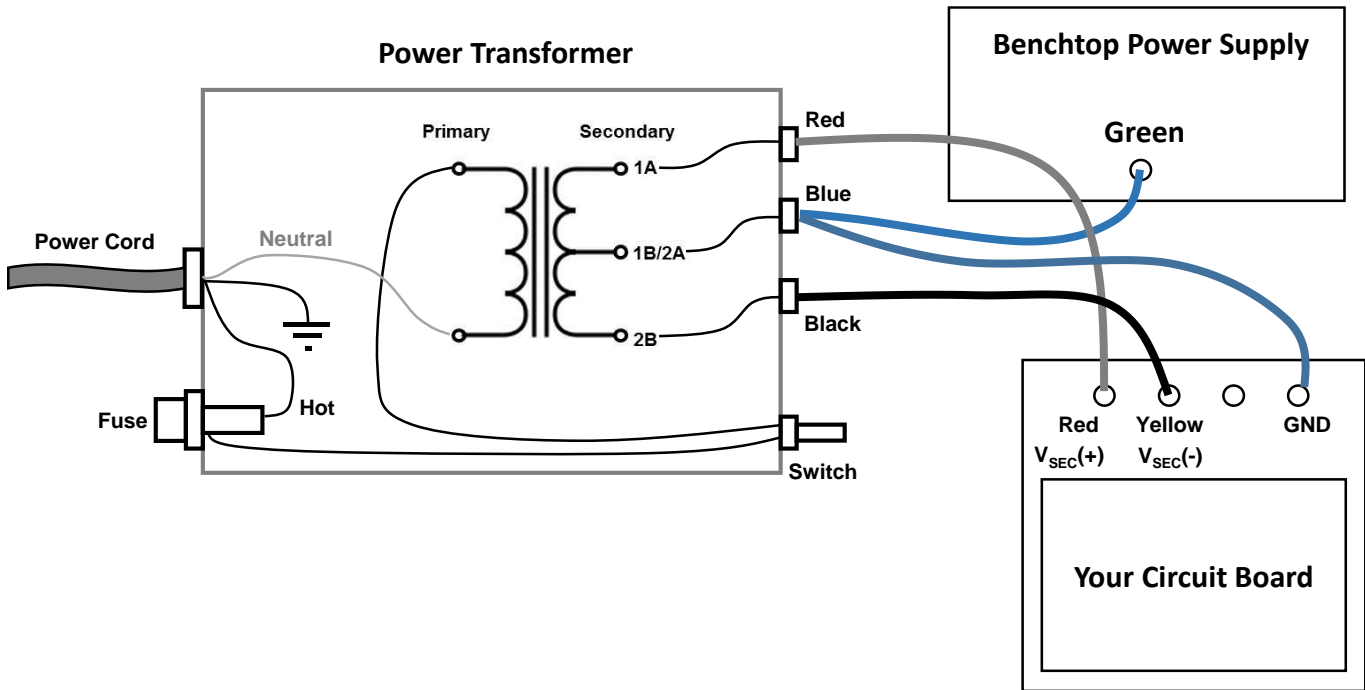


Fig. 1: Schematic of the power transformer and the banana cable connections to your circuit board.

A schematic of the power transformer is shown in Fig. 1.

- The power cord’s **hot** wire goes through a **fuse** and a **toggle switch** before reaching the transformer **primary**.
- The primary’s other terminal is directly connected to the power cord’s **neutral** wire.
- The power cord’s **ground** wire is attached to the metal **case**.
- The transformer’s **secondary** outputs are:
  - 1A (+) output
  - 1B/2A Center tap
  - 2B (-) output

The banana cable connections between the transformer, benchtop supply, and circuit board are described below:

- Transformer’s BLUE socket (Center Tap):
  - Connect to the benchtop supply’s GREEN terminal (earth ground).
  - Also connect to your circuit board’s GND terminal (with the GND symbol).
- Transformer’s RED socket (V<sub>sec</sub>+):
  - Connect to your board’s RED terminal.
- Transformer’s BLACK socket (V<sub>sec</sub>-):
  - Connect to your board’s YELLOW terminal.

Your setup should look like Fig. 1. OK, now you’re all set to test your circuits!

## PART 1: FULL-WAVE RECTIFIER

- **Step 1a:** Build the full-wave rectifier shown in Fig. 2.
  - The “Vsec+” input comes from your board’s RED terminal.
  - The “Vsec-” input comes from your board’s YELLOW terminal.
  - Ground comes from your board’s GND terminal.

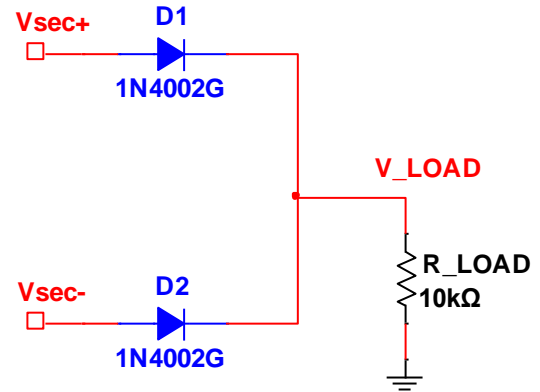


Fig. 2: Full-wave rectifier circuit. The Vsec+ and Vsec- come from the red and yellow terminals on your breadboard.

- **Step 1b:** Measuring the transformer secondary voltage  $V_{SEC}$ .
  - Fill in Table 1 with your RMS measurements of  $V_{SEC+}$  and  $V_{SEC-}$ .
    - Use the **multimeter** to measure the RMS AC voltage between Vsec+ and ground. Repeat for Vsec-.
      - ❖ You should get RMS values of roughly 14 V.
  - Fill in the middle of Table 1 with your measurements of the Vsec+ and Vsec- peak values (not peak-to-peak).
    - Turn on the scope, press “Force Trigger” to enable front panel control and press “Default” to reset the scope.
    - The scope settings should be:
      - ❖ HORIZONTAL: Scale = 5 ms/div
      - ❖ CH1:Probe=1X, Scale=10V/div, Offset=0V
      - ❖ TRIGGER: Source = AC Line
    - NOTE: This trigger setting lets us capture waveforms that are perfectly synchronized with the 60 Hz AC voltage from the wall plug. 😊

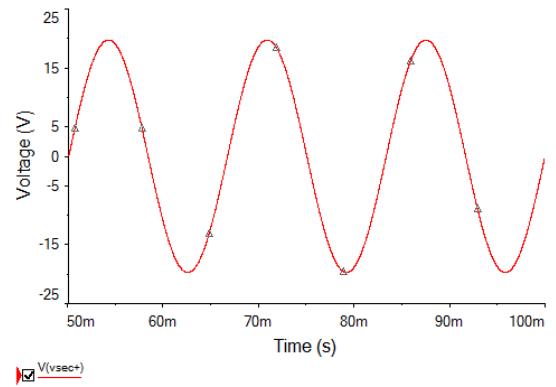


Fig. 3: The scope trace of Vsec should look something like this.

- You should notice that the sine wave for Vsec- is INVERTED with respect to Vsec+.
- Use the scope’s “Measure” or “Cursors” function to measure the Vsec+ and Vsec- **peak voltage**.

Table 1: Fill in this table with your measurements. Make sure your values make sense!

MEASURED $V_{SEC}$				MEASURED $V_{LOAD}$	
RMS $V_{SEC+}$	RMS $V_{SEC-}$	Peak $V_{SEC+}$	Peak $V_{SEC-}$	Peak $V_{LOAD}$	Period (ms)

**Step 1c: Testing the rectifier output.**

- Use the scope to display the rectified waveform of V\_LOAD. Use the following scope settings:
  - CH1: Scale = 5 V/div, Offset = -10V
  - As always, DO NOT PRESS AUTOSCALE!
  - Hedrick will deduct 40,000 pts from your lab grade if he catches you pressing “Autoscale”.
- Fill out the rest of Table 1 with the **peak voltage** and **period** (e.g. time between consecutive peaks) of your rectified waveform.
  - You should find a period close to 8.33 ms.
  - This should make sense, because  $0.5 * 1 / 60\text{Hz} = 8.33 \text{ ms!}$
- Use MATLAB’s “swave” command to save a scope trace (e.g. jpg or emf file) for your report (should look like Fig. 4).
- Do NOT disassemble this circuit! You will add stuff to it in the next section.

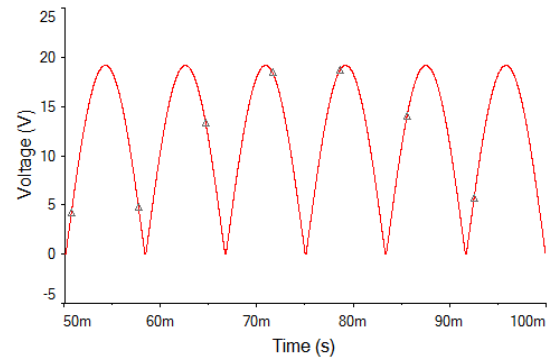


Fig. 4: The rectifier output at V\_LOAD should look something like this.

(End of Part 1)

## PART 2: FULL-WAVE RECTIFIER WITH FILTER CAPACITOR

- **Step 2a:** Insert a filter capacitor into the full-wave rectifier.
  - Place a 10 uF electrolytic capacitor in parallel with the 10 kohm resistor (see Fig. 5).
    - Remember that electrolytic capacitors have polarity! The (+) side is V\_LOAD while the (-) side is GND.
- **Step 2b:** Measure the peak and ripple values of V\_LOAD.

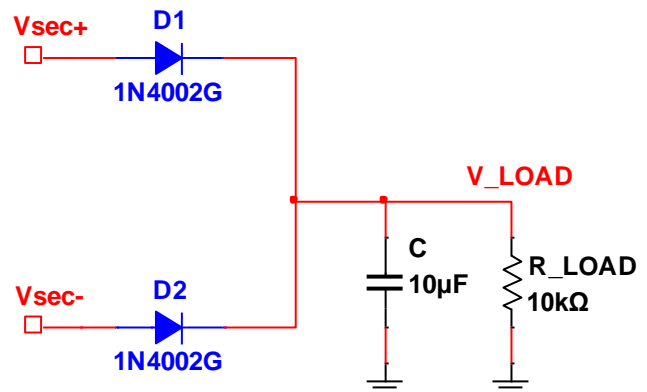


Fig. 5: Remember to properly insert the 10uF filter capacitor so that the (+) end of V\_LOAD and the (-) end is GND!

You will need TWO different scope settings to do this:

- To measure the **peak** value of V\_LOAD:
  - Use the following CH1 settings: **Coupling = DC**, Scale = 5V/div, Offset = -10V.
  - An example trace is shown in Fig. 6a.
- To accurately measure the **ripple** voltage, ZOOM IN on the ripple (see Fig. 6b):
  - To do this, set CH1 to be: **Coupling = AC**, Scale = 500 mV/div, Offset = 0V.

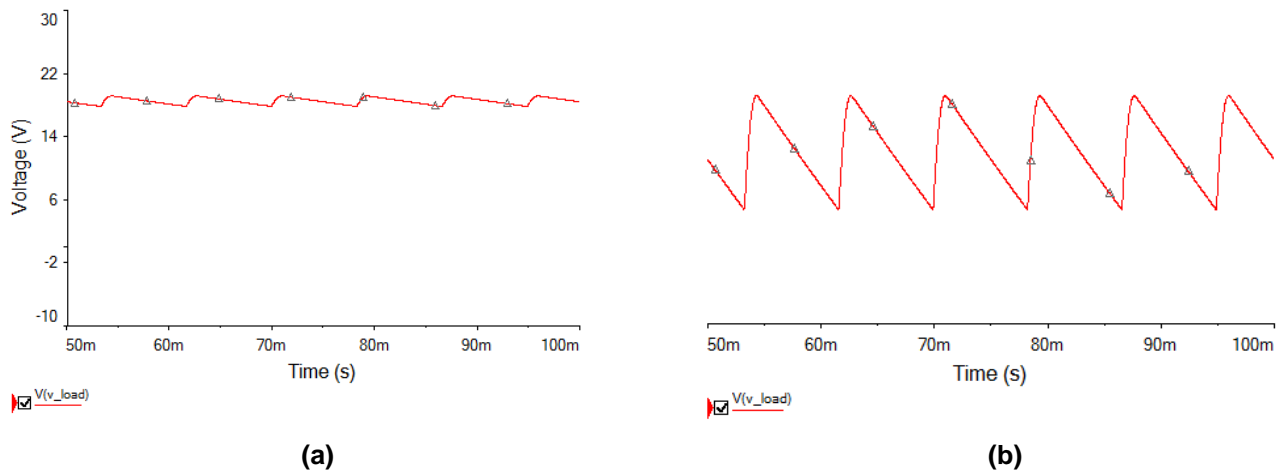


Fig. 6: Your scope trace should look something like this when measuring (a) the peak value and (b) ripple values of  $V\_LOAD$ .

- Fill in Table 2 with your measurements for all three combinations of  $C1$  and  $R1$ .
  - Remember that you must change the CH1 settings (e.g. DC vs AC coupling) to measure peak and ripple voltages.
  - It is a good idea to make sure your experimental measurements are reasonably consistent with your Multisim results from PreLab 2.

Table 2: Measurements of  $V\_peak$  and  $V\_ripple$ .

$C1$	$R1$	$V\_peak$	$V\_ripple$
10uF	10 kohm		
10uF	1 kohm		
100 uF	1 kohm		

- **Save the scope trace for  $C1 = 100 \mu F$  and  $R1 = 1 \text{ kohm}$  (it should look something like Fig. 6a).**
  - Use the following CH1 settings: Coupling = DC, Scale = 5V/div, Offset = -10V.
  - Do NOT disassemble this circuit! You will add more stuff to it in the next section.

(End of Part 2)

## PART 3: ZENER REGULATOR

At this moment, you have an unregulated DC power supply. If the wall plug RMS voltage goes up or down, then the DC output voltage will also go up and down. In this section, you will use a Zener diode to produce a stable 12V output!

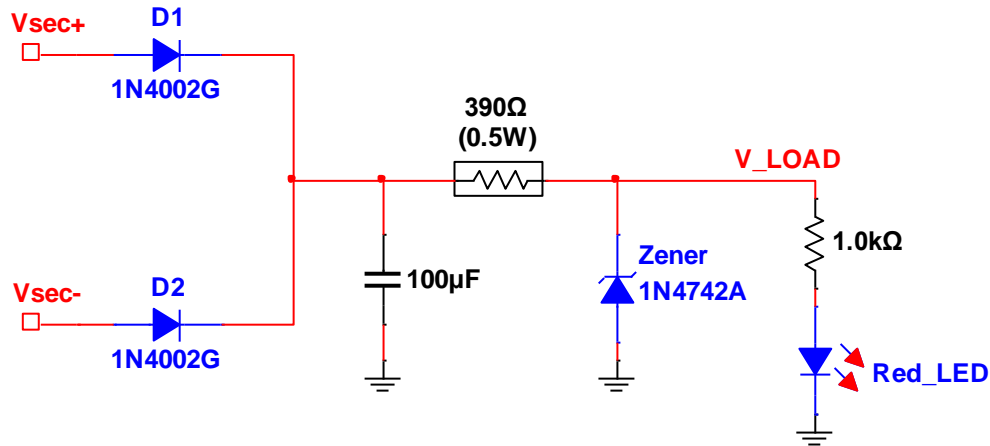


Fig. 7: Build this 12V power supply using a zener diode as the voltage regulator.

- **Step 3a:** Add the Zener diode (and other components) to your full-wave rectifier (see Fig. 7).
  - Do NOT cram your components into a tiny area! You will need to measure current in both the Zener and the LED.
  - The 390 ohm resistor has a  $\frac{1}{2}$  W rating, which means it can withstand more power dissipation than the usual  $\frac{1}{4}$  W variety.
  - The 1N4742A zener has a glassy orange appearance. The black band of the zener is the cathode!
  - The “flat side” of the red LED is the cathode.
  - Your circuit works if the LED is very happily glowing red.
- **Step 3b:** Fill out the first row of Table 3 (next page) with the following measurements:
  - Use the scope to measure  $V_{LOAD}$  (same as the Zener voltage).
    - To measure  $V_{peak}$ , set CH1 to: Coupling = DC, Scale = 2V/div, Offset = -6V.
    - **Save the scope trace of  $V_{LOAD}$  (it should look like a FLAT line near 12V).**
    - To measure  $V_{ripple}$ , set CH1 to: Coupling = AC, Scale = 5 mV/div, Offset = 0.
  - Use the multimeter to measure  $I_{zener}$  and  $I_{LED}$ . You should find that both are roughly 10 mA.

- **Step 3c:** Replace the 1 kohm resistor with a 270 ohm ½ watt resistor.
  - The 270 ohm ½ watt resistor is the other “thick” resistor.
  - The Zener diode should drop out! Very exciting ... except that the LED is still on! So has the Zener actually dropped out?
  - To confirm that Zener drop out has occurred, fill out the second row of Table 3 (below):
    - Use the scope to measure V\_LOAD:
      - ❖ Measure V\_peak with CH1 set to: Coupling = DC, Scale = 2V/div, Offset = -6V
    - **Save the scope trace of V\_LOAD (it should be about 9 to 10V with some ripple).**
    - To measure V\_ripple, set CH1 to: Coupling = AC, Scale = 200 mV/div, Offset = 0.
  - Finally, use the multimeter to measure the DC currents I\_zener and I\_LED. You should find that the Zener has no current!
  - When you are all done, replace the 270 ohm resistor with the 1 kohm resistor.

**Table 3: Zener measurements.**

R_LED	V_peak	V_ripple	I_zener	I_LED
1 kohm				
270 ohm				

(End of Part 3)

(see next page for Part 4: Circuit Demo)

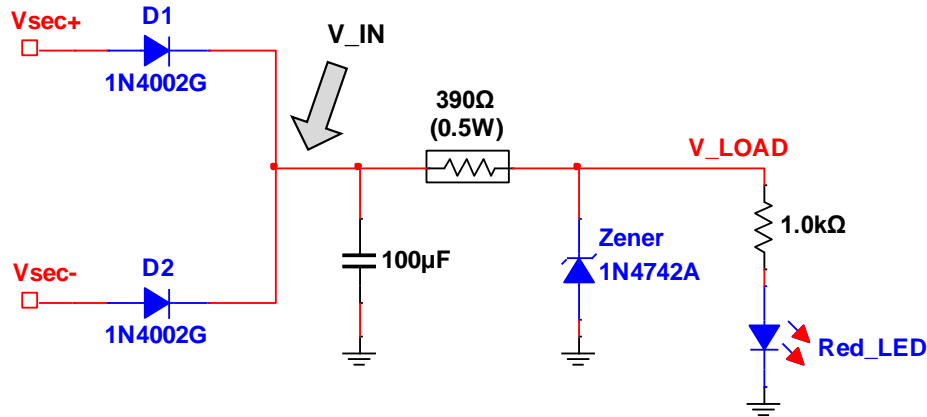
**PART 4: CIRCUIT DEMO (50 PTS OF TOTAL LAB GRADE)**

Fig. 8: Your circuit should look like this for the demo.

- **Step 4a: Vsec Measurement**

- Use the multimeter to show that the RMS voltages of Vsec+ and Vsec- are roughly 14V.

- **Step 4b: Unregulated input**

- Attach a scope probe to monitor V\_IN (see Fig. 8).
- Hedrick will reset the scope and ask you to configure the following settings:
  - HORIZONTAL: 5 ms/div
  - CH1: Probe = 1X, Scale = 5V/div, Offset = -10V
  - TRIGGER: SOURCE = AC Line

- **Display a trace of V\_IN.**

- **Show your completed Table 1 and Table 2.**

- **Step 4c: Zener regulator**

- The LED should be on.
- Move the scope probe to V\_LOAD.
  - CH1: Scale = 2V/div, Offset = -6V
  - **You should see a nice flat 12V trace.**
- Replace the 1 kohm resistor with the 270 ohm resistor – **the scope trace should show Zener drop out!**
- **Show your completed Table 3.**

NOTE: Hedrick will deduct 75,000 pts from your lab grade if he catches you using Autoscale!

(End of Lab 2)