

Lab 2: DC Power Supplies (Week of Apr 13)

GOAL

The overall goal of this lab is to gain some experience simulating, building, and testing some rectifier circuits commonly used in power supplies.

OBJECTIVES

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

- 1) Full-wave rectifier with smoothing capacitor
- 2) Zener regulator
- 3) Adjustable power supply

GENERAL GUIDELINES

- 1) Each student must simulate, build, test, and demo all circuits.
- 2) During the lab session, students must share test stations.
- 3) Students are allowed (even encouraged) to help each other. Of course, Professor Hedrick will be around to provide assistance as well. Use neat wiring for your circuits! A messy circuit will cost you 10 pts from your lab demo grade.
- 4) Do not worry if you need lots of help during the lab. Just make sure you know your stuff for the exams. **In addition to the written exams, there will be two laboratory exams where each student is tested on basic skills in circuit construction and simulation.**
- 5) Ask questions! The more questions you ask, the more you learn (assuming Professor Hedrick can provide adequate answers ☺).
- 6) Build your circuits with neat wiring! Messy circuits will result in a 10 pt deduction from your lab demo grade.
- 7) Please keep your lab kit and work area organized.

PARTS AND MATERIALS

- Lab kit, scope, two scope probes, four banana cables
- Power transformer
- Diodes: 1N4002 rectifier (2)
- LM317 adjustable voltage regulator (1)
- 10 k Ω potentiometer (pot) (1)
- Resistors: 750 ohm (purple/green/brown) (1)
1.0 kohm (brown/black/red) (1)
1.2 kohm (brown/red/red) (1)
10 kohm (brown/black/orange) (2)
- Capacitors: 1 μ F electrolytic (1)
10 μ F electrolytic (1)
470 μ F electrolytic (1)
- Motor: 12 V DC (1)

NOTE: Before you begin the lab measure and record the values of all your resistors.

PART 0: POWER TRANSFORMER

The majority of power supplies use a power transformer to step down the $120\text{ V}_{\text{RMS}}$ from the wall outlet. This lab uses a 28 VCT power transformer, which means the secondary voltage is approximately 28 V_{RMS} . The “CT” means a center tap connection is available. This power transformer provides the AC input to all circuits in this lab.

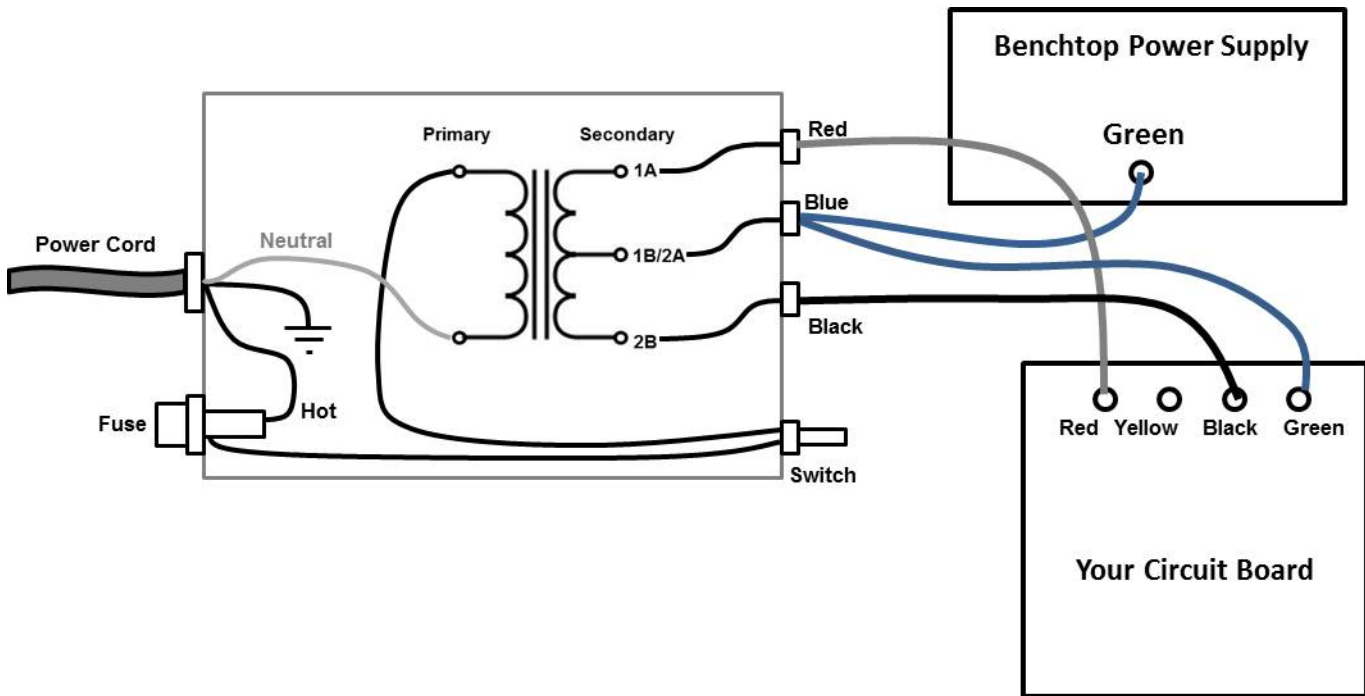


Fig. 1: Schematic of the power transformer and the banana cable connections to your circuit board.

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 RED socket is the (+) output of the secondary coil.
- The BLACK socket is the (-) output of the secondary coil.
- The BLUE socket is the center tap.
- Use a banana cable to connect the BLUE socket of the power transformer to the GREEN terminal of the benchtop power supply. This establishes the grounded center tap.

Fig. 1 also shows how to connect the power transformer to your circuit board.

- Use a banana cable to connect the RED socket of the power transformer to your board's red terminal.
- Use a banana cable to connect the BLACK socket of the power transformer to your board's black terminal.
- Use a banana cable to connect the BLUE socket of the power transformer to your board's green terminal.

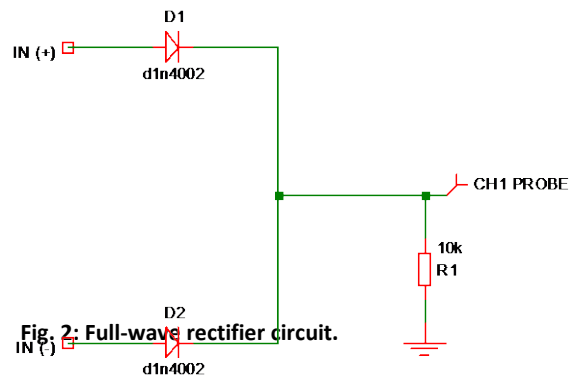
OK, now you're all set to test your circuits!

PART 1: FULL-WAVE RECTIFIER

GOAL: Measure the rectified voltage.

- Step 1a: Fig. 2 shows the full-wave rectifier circuit for testing.

- A messy circuit will cost you 10 pts from your lab demo grade.
- The “IN(+)” input comes from the red terminal of your breadboard.
- The “IN(-)” input comes from the black terminal.
- Attach a scope probe to the load (10 kohm).



- Step 1b: Configure the scope trigger. In this lab, we will use a different trigger setting than last week.
 - We will change the scope’s “Trigger Source” to be “AC Line” instead of “CH 1”.
 - Why do this?
 - The input to the power transformer is the wall socket’s 120 V_{RMS}, 60 Hz voltage.
 - The power transformer’s output is fed into all of your circuits for this lab.
 - Therefore, all of your circuit outputs are synchronized to the 120 V_{RMS}, 60 Hz wall socket voltage.
 - Therefore, we can get a nice steady scope trace if we trigger off the wall socket voltage! ☺
 - Press the “Default” button on the scope. This resets the scope.
 - Configure the scope trigger.
 - Trigger source = AC Line (Trig Menu >> Source >> AC Line)
- Step 1c: Measure a few cycles of the rectified voltage. You can ask Professor Hedrick for assistance if you are unable to configure each of the settings below. **Your scope trace should similar to your PreLab1 (Circuit 1) simulation!**
 - Use CH1 of the scope to measure a few cycles of the rectified voltage.
 - **DO NOT PRESS AUTOSCALE!**
 - Professor Hedrick will deduct 400 pts from your lab grade if he catches you pressing “autoscale”.
 - CH1 voltage scale = 5 V/div
 - CH1 zero position = -10 V
 - Horizontal time scale = 5 ms/div
 - Make sure you scope probe is set to 10X, otherwise your measured voltages will be off by a factor of 10!
 - Measure the peak voltage using “Measure >> Vmax” on the scope and record this value.
 - Use the “swave” command in MATLAB to capture a scope trace.
 - Save this scope snapshot (e.g. jpg or emf file) for your lab report.

(see next page for Part 2)

PART 2: FULL-WAVE RECTIFIER WITH SMOOTHING CAPACITOR

GOAL: Measure the ripple factor.

- Step 2a: Fig. 3 shows the circuit for testing.
 - Place a 10 uF (not a 47 uF) electrolytic capacitor in parallel with the 10 kohm resistor.
 - Remember that electrolytic capacitors must be properly inserted into the circuit!
 - Have Professor Hedrick check your circuit.

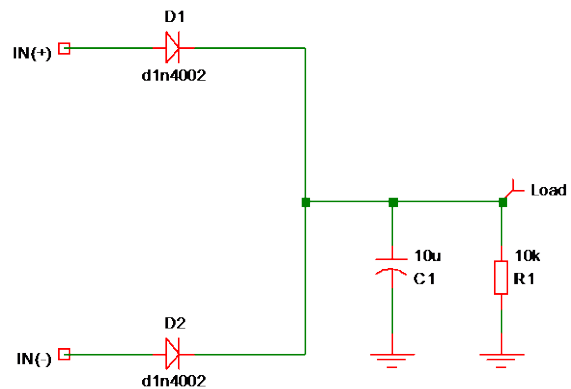


Fig. 3: Full-wave rectifier with 10 uF smoothing capacitor.

- Step 2b: Measure the load voltage with the scope. Your scope trace should like the PreLab1(Circuit2) simulation!
 - Use the same scope settings as Step 1c.
 - Measure and record the average and ripple voltage using “Measure >> V_{AVG}” and “Measure >> V_{PP}”.
 - Compute the ripple factor, which is equal to V_{PP}/V_{AVG} .
 - Capture a scope trace in MATLAB and save this scope snapshot for your lab report.

DO NOT DISASSEMBLE THIS CIRCUIT!

(see next page for Part 3)

PART 3: ZENER REGULATOR

GOAL: Measure the ripple factor.

Many power supplies use zeners as voltage references. In this part, you will use two 5.6 V zeners in series to produce an approximately 11.2 V reference.

- Step 3a: Fig. 4 shows the circuit for testing.
 - The 1N4734A zeners have a glassy orange appearance.
 - The black band of the zener points toward positive voltage.
 - Use a 10 uF capacitor (not the 47 uF from class).
 - Remember that electrolytic capacitors must be properly inserted into the circuit!
 - Have Professor Hedrick check your circuit.

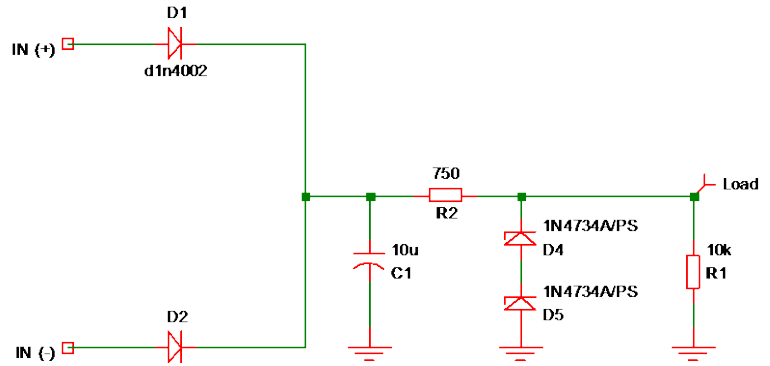


Fig. 4: Zener regulator using two 1N4734A zeners.

- Step 3b: Measure the DC output voltage. You can ask Professor Hedrick for assistance if you are unable to configure each of the settings below.
 - Use CH1 of the scope to measure the voltage across the 10 kohm resistor.
 - CH1 voltage scale = 2 V/div
 - CH1 zero position = -6 V
 - Measure and record the average voltage.
 - You do NOT need to record a scope trace.
- Step 3c: Measure the voltage ripple. The voltage ripple should be very small, so you will need to change the CH1 settings to measure the AC portion of the signal.
 - In order to get a nice view of the voltage ripple, you will need to make several changes to the scope:
 - CH1 coupling = AC (Press "1" >> Coupling >> AC)
 - CH1 voltage scale = 20 mV/div (or 50 mV/div if the scope trace does not fit on the screen)
 - CH1 zero position = 0
 - Measure the voltage ripple and record this value.
 - Compute the ripple factor of your zener regulator.
 - Capture a scope trace in MATLAB and save this scope snapshot for your lab report.

DO NOT DISASSEMBLE THIS CIRCUIT!

(see next page for Part 4)

PART 4: ADJUSTABLE POWER SUPPLY

GOAL: Adjust the speed of a 12V DC motor.

Many power supplies use a chip such as the LM317 to produce an adjustable voltage supply. Your last circuit will use a full-wave rectifier and the LM317 to make a high quality 1.2V-to-12V power supply.

- Step 4a: Fig. 5 shows the circuit for testing.

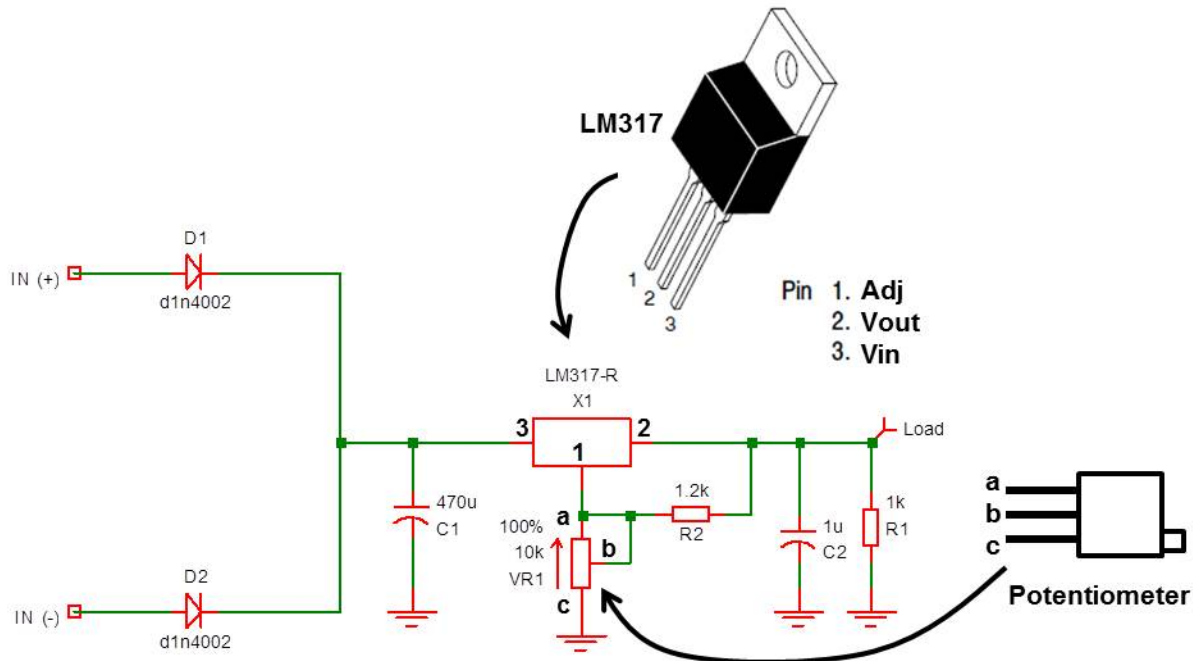


Fig. 5: Adjustable power supply using a full-wave rectifier and LM317 voltage regulator chip.

- The two 1N4002 diodes are the full-wave rectifier.
- The 470 uF capacitor is the BIG one.
- The LM317 is the three-pin chip (see Fig. 5 for pin diagram).
 - Pin 3 is connected to the 470 uF capacitor.
 - A 1.2 kohm resistor connects Pin 1 to Pin 2.
 - A 10 kohm potentiometer connects Pin 1 to ground.
 - Note that Pin “a” and “b” of the potentiometer are shorted together.
- Have Professor Hedrick check your circuit!
- Step 4b: Confirm your power supply produces 1.2V-to-12V operation.
 - Place the CH1 scope probe to measure the voltage on the 1 kohm load resistor.
 - Change the CH1 scope settings to the following:
 - CH1 coupling = DC (Press “1” >> Coupling >> DC)

- CH1 voltage scale = 2 V/div
 - CH1 zero position = -6 V
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- The scope should display a constant voltage that lies somewhere between 0 and 12V.
 - Use the screwdriver to adjust the potentiometer by several turns. You should see the voltage should go up or down. If this does not happen and you cannot figure out why, Professor Hedrick can provide assistance.
 - Once you have confirmed proper operation, adjust the potentiometer to make $V_{AVG} = 12V$.
 - You do NOT need to record a scope trace.
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- Step 4d: Use your adjustable power supply to control the speed of a 12V DC motor.
 - Replace the 1 kohm load resistor with the 12V DC motor.
 - The motor should be spinning at its full speed of about 120 rpm (same as 2 turns per second).
 - Adjust the potentiometer to reduce the motor voltage – you should see the scope trace drop while the motor speed slows down!
NOTE: It takes over 10 turns of the potentiometer to cover the entire range.
 - You do NOT need to record anything. This circuit is purely for fun, although it is probably the most useful circuit in this lab.

NOTE: Later in the course we will use a better method to control speed using “pulse width modulation” (PWM).

(see next page for Part 5)

PART 5: CIRCUIT DEMOS

Professor Hedrick will reset the scope and ask you to show the following scope traces with the proper scope settings:

- Full-wave rectifier with 10 μ F capacitor (10 pts of lab demo grade)
 - Scope probe measures load voltage (across 10 kohm resistor)
 - Scope settings:
 - Trigger source = AC Line
 - CH1 voltage scale = 5 V/div
 - CH1 zero position = -10 V
 - Horizontal time scale = 5 ms/div
 - Measurements = V_{AVG} and V_{PP}

- Zener regulator (10 pts of lab demo grade)
 - Scope probe measures load voltage (across 10 kohm resistor)
 - Scope settings:
 - CH1 voltage scale = 2 V/div
 - CH1 zero position = -6 V
 - Measurements = V_{AVG} and V_{PP}

- Adjustable power supply (10 pts of lab demo grade)
 - Scope probe measures motor voltage
 - Scope settings are same as zener circuit.
 - Adjust power supply voltage from 12 V down to zero. The motor speed should change!

NOTE: When you demo your circuits, Professor Hedrick will ask you to operate the scope WITHOUT USING THE AUTOSCALE

BUTTON. Professor Hedrick will deduct 500 pts from your lab grade if you press Autoscale!

(End of Lab 2)