

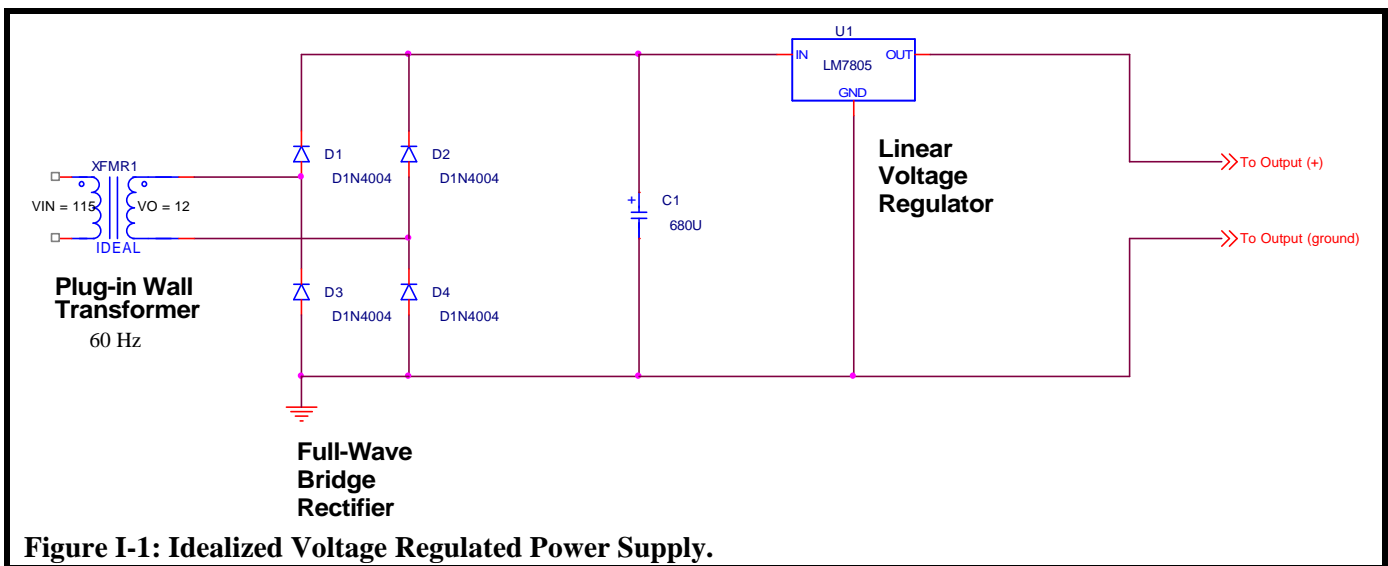
ECE 351 Lab 1

Design of a DC Power Supply

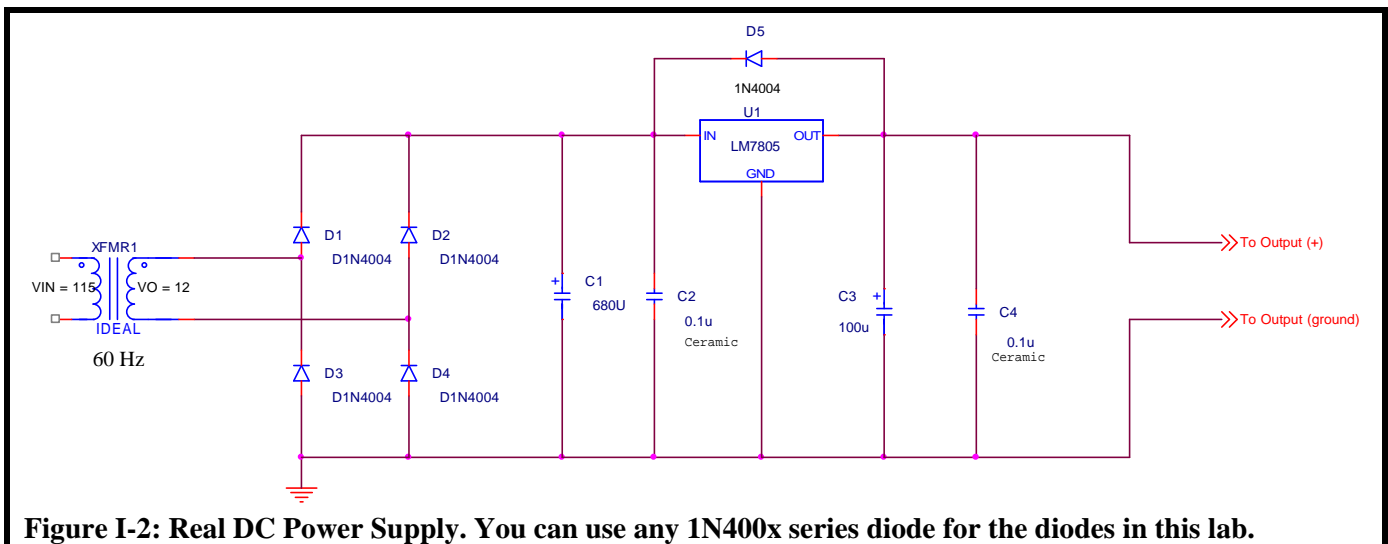
In this lab we will construct a 5V DC power supply. We will briefly describe the operation of the supply during the Lab period. The complete design and analysis of this supply will be covered in a later class. However, the basic operation of the supply is easy to understand, and we can build and test the circuit quite easily.

I.A. Pre-Lab

The circuit below is a 5 V DC power supply that can supply up to 0.5 A of current:



The circuit of Figure I-1 is the circuit you would use for design and analysis. However, in the real world, we need a few more components. A more realistic supply is shown below:



For an ideal voltage regulator, the output voltage would be pure DC. Thus, C3 and C4 would be open circuits and unnecessary. However, in a real supply, there will always be noise and ripple at the regulator's output and we add C3 to eliminate this noise and ripple. Large electrolytic capacitors such as C1 and C3 have a high series inductance. (Electrolytic capacitors have a high capacitance, but we pay for this high capacitance with added series inductance.) To eliminate the series inductance, we place a 0.1 uF capacitors in parallel with the electrolytic capacitors. Thus, C2 and C4 are added to make C1 and C3 better capacitors.

For many regulators, D5 is unnecessary. In normal operation, the input voltage to the regulator is higher than the output voltage, and D5 will be off. When you turn off the power supply, it may be possible that the input voltage becomes less than the output voltage, and this can damage some regulators. To prevent this problem, D5 was added. D51 may be unnecessary if the regulator has this protection incorporated in the regulator. You should always check a regulator's data sheet to see if D5 is not necessary.

The circuit of Figure I-2 is what you would use for a real supply. Since this is an academic exercise, we would like to be able to measure the capacitor current and we will add a 1 Ω sensor as shown in Figure I-3:

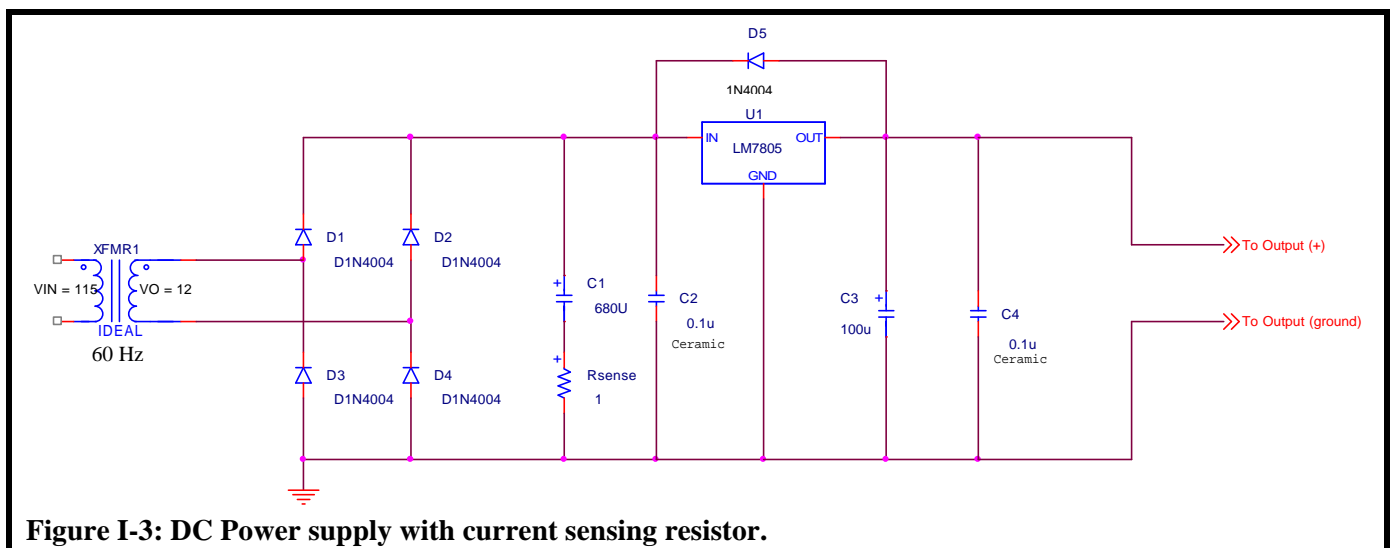


Figure I-3: DC Power supply with current sensing resistor.

This resistor is referred to as a “current sensing resistor” and is used in the lab to measure the capacitor current. This resistor is not normally used in a power supply design. Its only function is to measure the capacitor current. 1 Ω is used so that it has a small effect on the operation of the circuit.

We will build the power supply shown in Figure I-3 with and without the current sensing resistor. Before coming to lab, you may want to think about the following questions:

- What is the voltage rating of a capacitor and why is it important?
- How do I determine the polarity of an electrolytic capacitor and why is it important?
- Why is the output of the transformer not grounded in the circuit of Figure I-3?
- What is the wattage rating of your resistors and why is it important?
- What will you use as a load for this lab, and how much power does the load have to absorb?
- What is the power absorbed by each element in the circuit and can each element handle that power?

- Does it make any sense to test the circuit with no load?
- Does it make any sense to simulate the circuit with PSpice with no load hooked to the output?

I.B. Devices and Physical Limitations

The LM7815 and LM7915 are fixed voltage regulators capable of supplying ± 15 V at 1.5 A. The LM7805 is a fixed voltage regulator capable of supplying +5 V at 1.5 A. The LM78xx series are positive voltage regulators and the LM79xx series are negative voltage regulators. These are fixed regulators and are normally used to provide stiff D.C. supplies for your circuit. A fixed regulator means that it was designed to be used at a single output voltage. Other regulators, such as the LM317, are variable regulators. These regulators can have their output voltage changed by varying resistor ratios.

For the LM7815, if the input voltage is between +17.5 and +35 V, the output of the regulator will be constant at +15 V as long as the output current is less than or equal to 1.5 A. The LM7915 operates analogous to the LM7815 except for negative voltages. For the LM7915, if the input voltage is between -17.5 and -35 V, the output will be constant at -15 V as long as the magnitude of the output current is less than or equal to 1.5 A.

The LM317 is a variable positive voltage regulator. The maximum output voltage of the regulator is determined by the minimum input voltage to the regulator. If the maximum output voltage of the regulator is to be V_{oMAX} , then the minimum input voltage must be greater than $V_{oMAX} + 2.5$. Usually the input voltage is varying with time so you must make sure that the minimum input is greater than $V_{oMAX} + 2.5$. For a 5 V output voltage, the input voltage must be greater than 7.5 V at all times.

For a voltage regulator, $I_{in} = I_{out}$ but $V_{in} \neq V_{out}$. The power dissipated by the voltage regulator is

$$P_{reg} = V_{in}I_{in} - V_{out}I_{out} = I_{out}(V_{in} - V_{out})$$

Since $V_{in} > V_{out}$, the regulator will always dissipate power. Since, V_{in} is usually time dependent, the time average input voltage must be used to find the average power dissipated by the regulator.

The power delivered to the load is $V_{out}I_{out}$. If I_{out} is constant, then the power delivered to the load is constant since V_{out} is held constant by the regulator. If V_{in} is increased, the power delivered to the load will remain the same because V_{out} is constant. However the power dissipated by the regulator will increase because V_{in} has increased. This increased power will heat up the regulator and may damage it if you have not considered heat dissipation.

I.C. Prelab Calculations and Measurements

Simulate the circuit of Figure I-1 with PSpice. You must add a load to the output of the supply that draws 0.5 Amp of current so that you simulate the power supply at full load. Instead of using the transformer in the simulation, use the Vsin part and set its amplitude to $12\sqrt{2}$ Volts. With PSpice, obtain plots of the diode current, the capacitor current, and the capacitor voltage. From these plots obtain values for the peak repetitive diode current, the peak repetitive capacitor current, and the magnitude of the capacitor ripple voltage. Enter these values in **Table I-1**.

The design method used to create this supply was very conservative. You will notice that all PSpice and measured results will be less than the calculated values. This means that the supply will never fail, but the cost of the components is more than necessary.

Note: Observe the voltage across the capacitor. It should be less than the rated maximum voltage of your capacitor.

I.D. Regulated D.C. Voltage Supply

Wire up the circuit of Figure I-2. The voltage regulator will fit easily into your bread board if you twist the leads 90° in the azimuthal direction. **Make sure that you attach a heat sink to the voltage regulator or it will burn up.**

- With no load on the output, measure the input and output of the regulator with an oscilloscope and a Multimeter. Verify that the output is 5 V DC and the voltage across C1 does not exceed the voltage rating of C1. If the supply is operating correctly, proceed to the next step.
- Add a load to the DC supply output that draws 0.5 Amp. Measure the following quantities:
 - The output of the regulator. It should be 5 V DC.
 - The ripple voltage across C1. Enter the value in **Table I-1**.
 - The ripple voltage at the output. You will need to use the oscilloscope AC setting to see the ripple. Enter the value in **Table I-1**.
- Add the 1 Ω current sensing resistor as shown in Figure I-3. At full load make the following measurements and enter the values in **Table I-1**.:
 - The peak capacitor charging current.
 - The capacitor discharge current.
 - Calculate the diode peak current. The diode current is the capacitor current plus the current into the regulator.

Note: This is a conservative design. Measured and PSpice values for the diode current, capacitor current, and capacitor ripple voltage are usually less than the calculated minimum values.

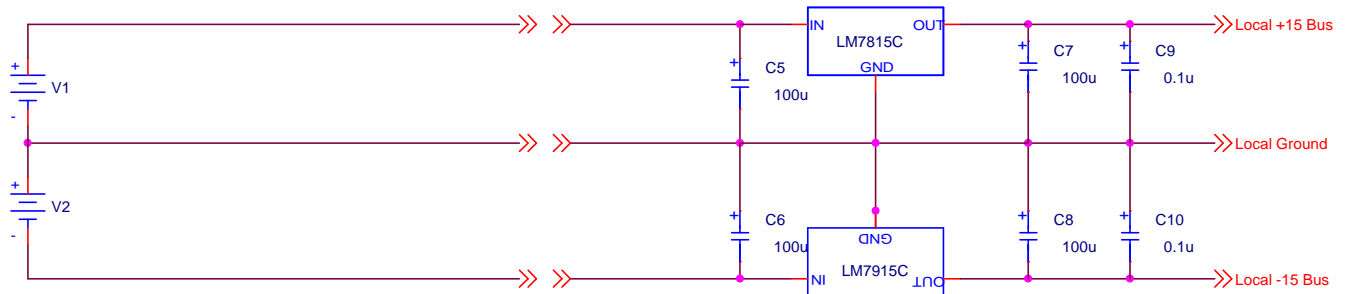
Table I-1: ECE351 Lab I Power Supply Results				
You must have PSpice plots and scope traces to support the data in this table.				
	Calculated		PSpice	Measured
	Max	Min		
$I_{D_{peak}}$ (Repetitive Peak)	5.7	3.9		
$I_{C_{peak}}$ (Repetitive Peak)	4.7 Amps	2.9 Amps		
Capacitor Ripple (Cap at Regulator Input)	7.7 Volts	3.4 Volts		
Ripple Voltage at Output	3 mV	0.34 mV		
Capacitor Discharge Current	$V_o / R_L = 0.5 \text{ Amp}$	$V_o / R_L = 0.5 \text{ Amp}$		
DC Value of Regulator Output	(From Data Sheet)	(From Data Sheet)		

I.E. Local +/- 15 Volt Supply

For the remaining labs, we would like to create local positive and negative supplies for your protoboard using positive and negative linear regulators. These regulators will provide several benefits, including:

- The regulators eliminate the inductance of the long wires that connect your circuit to the bench power supply.
- The voltage output of the regulators will be the same each time you use them.
- The input voltages to the regulators do not need to be very accurate.
- Your circuits will have a solid, low noise supply that is close to the circuit on which you are working.

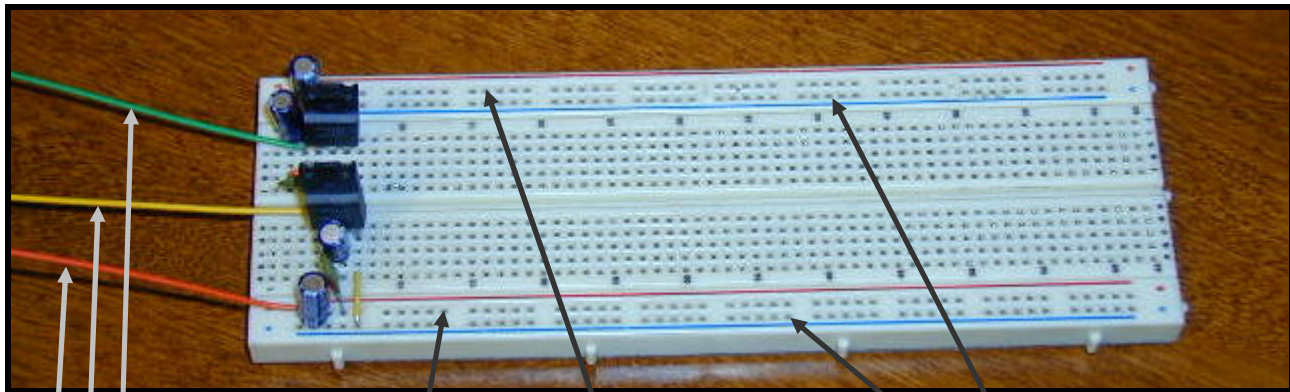
We will use the circuit below:



**Bench Top
Supply**

Long Wires

This circuit should be built so that it uses a minimal amount of board space and uses the bus strips on the sides of your boards. An example board is shown below:



Long wires
to bench top
supply.

- 15 volt bus.

+15 volt bus.

Ground bus.

The two blue rails is the ground bus, the top red rail is the +15 volt bus, and the bottom red rail is the -15 volt bus. Everyone is required to use this convention to make debugging of circuits easier. Leave this circuit assembled for the remainder of the course since it will be used as the power supplies for the remaining labs. Demonstrate the operation of this circuit to me.