V. Design of a DC Power Supply

This lab requires the design, analysis, and measurements of a voltage regulated power supply. You will construct the D.C. power supply designed in the homework using a transformer, diode bridge rectifier, and an IC voltage regulator.

V.A. Pre-Lab

Build the voltage regulated power supply designed in the homework. Your circuit probably looks like the circuit of Figure V-1. The voltage $V_s$ is the circuit model for the secondary of a transformer. 11.5 V RMS transformers are available in the lab. Your homework will serve for most of the pre-lab. Make sure you include all of your calculations and PSpice runs in your lab book. Include a data sheet of the diode you use in your lab book.

V.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 $V_{o_{\text{MAX}}}$, then the minimum input voltage must be greater than $V_{o_{\text{MAX}}} + 2.5$. Usually the input voltage is varying with time so you must make sure that the minimum input is greater than $V_{o_{\text{MAX}}} + 2.5$. 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.

**V.C. Prelab Calculations and Measurements**

Simulate the circuit of Figure V-1 with PSpice. You must include the 1Ω resistor in the simulation. 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. 1Ω is used so that it will not affect the operation of the circuit. You may wish to run PSpice with and without this resistor to see how it affects the circuit operation.

With Pspice, obtain plots of the diode current, the capacitor current, the capacitor voltage, and the voltage across the input to the voltage regulator. From these plots obtain values for the peak diode current, one time peak surge current through the diode, the peak capacitor current, and the magnitude of the capacitor ripple voltage.

Compare your design calculations to the values obtained using PSpice. Calculated values are usually larger than the values predicted by PSpice because of our conservative calculations.

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

**V.D. Regulated D.C. Voltage Supply**

Wire up the circuit of Figure V-1. The voltage regulator will fit easily into your bread board if you twist the leads 90° in the azimuthal direction.

- Set the oscilloscope to display both channels simultaneously. On channel A of the scope, monitor the input voltage to the regulator. On channel B, monitor the voltage regulator output. Both channels should be set to D.C. coupling.

- Turn on the power to your transformer. Make sure that the input voltage to the regulator does not exceed the voltage rating of your capacitors. If you exceed this voltage, you will damage the capacitor and it may
explode. The voltage regulator and load resistor will become hot. Do not touch the voltage regulator or the load resistor. Keep plastic away from these components since the plastic may melt.¹

Switch channel B to measure the voltage across the 1 Ω resistor. This resistor displays the capacitor current at 1 amp/volt. When the capacitor is being charged by the current through the bridge, the voltage across this resistor will be positive. When the capacitor is supplying current to the regulator, the voltage across the 1 Ω resistor will be negative and constant. This constant voltage indicates a constant discharging current which should equal \( \frac{V_{\text{out}}}{R_L} \).

Measure the peak capacitor charging current and the magnitude of the constant discharging current.

- Switch the display mode to channel A - channel B (channel A minus channel B). This display will show you the capacitor voltage. The voltage should be a periodic ramp. To make a correct measurement, both channels must be on the same volts per division. Obtain an accurate measurement of the capacitor ripple voltage. To enlarge the display of the ripple, place both channels on AC coupling and reduce the volts per division setting on both channels.

- Turn off the power and remove the 0.1 µF capacitor at the output of the regulator. Turn on the power and measure the input and output voltages of the regulator. You may notice a lot of noise at the regulator output. The purpose of the 0.1 µF capacitor is to remove this noise.

- Measure the A.C. ripple on the output of the regulator. The ripple is very small compared to the magnitude of the D.C. output voltage. To measure the ripple, set the scope coupling to AC and decrease the volts per division setting of the scope.

- Make any additional measurements that you can compare to your PSpice simulations that will verify your design.

**V.E. LAB 5 Check Sheet**

You should have scope traces to support all measurements.

- Regulated D.C. Voltage Supply
  1. Capacitor peak charging current
  2. Capacitor discharging current
  3. Capacitor ripple voltage
  4. Ripple voltage at the output of the regulator

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¹NAU cannot be held responsible for injury caused by a circuit designed by a student.
## EE 349 Lab V Power Supply Results

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<th>Calculated</th>
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<td>Max</td>
<td>Min</td>
<td>PSpice</td>
<td>Measured</td>
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<td>$I_{D_{peak}}$ (Repetitive Peak)</td>
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<td>$I_{C_{peak}}$ (Repetitive Peak)</td>
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<td>Capacitor Ripple (Cap at Regulator Input)</td>
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<td>Ripple Voltage at Output</td>
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<tr>
<td>$I_{FSM}$ (One Time Surge)</td>
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<td>Capacitor Discharge Current</td>
<td>$\frac{V_0}{R_L}$</td>
<td>$\frac{V_0}{R_L}$</td>
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