Linear Regulators

This lab consists of several exercises to practice the use of linear voltage regulators, ranging from a crude Zener regulator to a using a variable output LM317 regulator.

Current loads and testing.

A key test for a voltage regulator is the *load regulation*, which is defined as the change in the output voltage divided by the change in the output current, LR = $\Delta V_o/\Delta I_o$. Obviously, the units for load regulation are Ω. An ideal regulator should have no change in the output voltage as the load current changes, i.e. LR = 0. Of course, there are no ideal regulators.

The simplest way to current a load current is to attach a resistor to the output. A potentiometer would allow for varying the resistance and hence varying the current. The problem with using a single resistor or potentiometer is that output currents can be quite large and so the power dissipation is too high for single resistors or potentiometers. For example, a 5-V regulator delivering 0.5 A of current to a load represents 2.5 W, which would require 10 resistors from your 201 lab kit or having available a range of higher power (and more expensive) resistors. During a test, changing load current requires swapping lots of resistors in and out — not a very efficient process. In the lab exercises described below, you can certainly use combinations of resistors as loads, but you will always need to calculate the expected power dissipation and consequent heating issues. For example, if you wanted to test a 10-V regulator with a 100 mA output current, the corresponding resistor would be 100 Ω. However, a 100 mA current would correspond to 1 W — a single resistor will probably burn out, unless you work very quickly. To be safe, it would be better to use four 100-Ω resistors, by connecting two paralleled pairs (making 50 Ω series) in series to make a combination that can handle 1 W. This is tedious, but doable.

A better approach for providing an easily variable output current is to use an *electronic load,* which is essentially a variable current source. A simple version of an active load might consist of little more than high-power MOS or bipolar transistor with some means of controlling the drain (or collector) current. For this lab and future labs, you might consider building a simple electronic load and using that as a means to evaluate the performance of regulator circuits. For the exercises described below, you are certainly welcome (and encouraged!) to build and use an electronic load. Instructions are given here: http://tuttle.merc.iastate.edu/ee333/lab/electronic_load.pdf.

Reporting

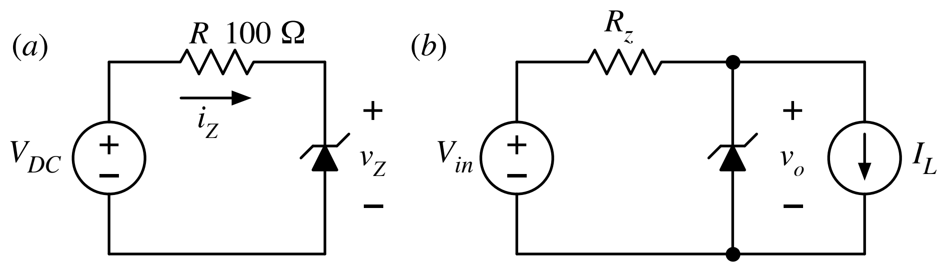
When finished with the lab, prepare and submit a report describing your work and the results.

Simple Zener

The simplest means of regulation is to use the breakdown of a Zener diode to clamp the output voltage. A simple Zener might be appropriate for low power applications where efficiency is not a concern. Simple Zener circuits were discussed in EE 230, and the basic operating principles should be familiar.

First we should do a bit of characterization for the Zener diodes from your EE230 kit — the 1N4733 5.1-V Zener and the 1N4740 10-V Zener. Use the circuit below in Fig 1(a) to measure the Zener voltage for currents ranging from 5 mA to 50 mA. (You can go to higher currents if you want, but you will probably need to change the current limiting resistor to a lower value and make accommodations for power, as described above.) Change the supply voltage in small increments and watch out for things getting hot. In a regulator circuit, the Zener clamps the output directly, so changes in V_Z as i_Z changes give a direct indication of how well the Zener will regulates the load.

Figure 1.



Design a 10-V regulator as shown in Fig. 1(b), using the 1N740 Zener diode. For the input, use the DC supply in the lab, set to 15 V. Design for a maximum load current of 75 mA, with a minimum Zener current of 25 mA. In this case, designing means choosing an appropriate value for R_z. For the value of R_z that you've chosen, build it using a combination of resistors so that it can handle 1 W of power. Check to make sure that the components will be within their power specifications at the extremes of full load current and no load current.

Measure the load regulation by measuring the output voltage for load currents ranging from 5 mA to 75 mA. In the interest of time, 7 or 8 measurements (0 mA, 5 mA, 10 mA and incrementing in 10 mA steps up to 70 mA) should be sufficient, but you can use finer steps if you would like.

Next, measure line regulation, Adjust the load so that the output current is 50 mA. Measure the output voltage for input voltage ranges ranging from 11 V to 20 V.

Finally, make the regulator fail. Do this in two ways. First, with the load current set at 50 mA, find the regulator drop-out voltage by lowering the input voltage until the Zener turns off and stops regulating. Next, set the input voltage to 15 V. Increase the load current until there is not enough current available for the Zener (the load takes all of the current from the source) and it stops regulating.

10-V power supply with a "built-from-scratch" (BFS) regulator

Build the simple regulator circuit shown below. The Zener is the 1N7433 diode from your EE230 lab kit — the expected breakdown is 5.1 V. The BJT is the 180 npn transistor, also from the EE230 kit. For the op amp, use either TL082 (or 072) or the LM324. The output should be twice the Zener voltage.

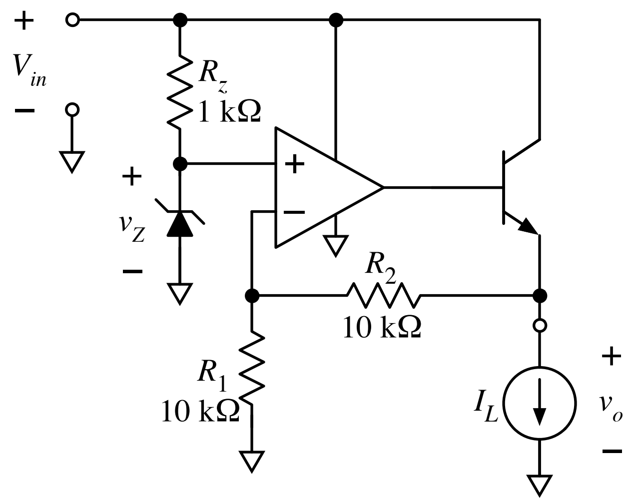


Figure 2.

Set up the circuit using a DC supply set to 15 V as the input. Attach a 10-kΩ resistor as a load and confirm the basic operation by measuring the output voltage. Then perform the following measurements.

Load Regulation — Measure the output voltage as function of load current. Using resistor combinations are an electronic load, measure the output voltage for load currents of 10 mA, 50 mA, 100 mA, 200 mA, 300 mA, 400 mA, and 500 mA. (Again, be careful with power levels and component heating.) For each output current level, calculate the regulator efficiency. (You can ignore currents through the Zener and op amp — assume that the total input current is the same as the output current. There may be some error at low load currents, but this should be a good approximation at higher currents.)

Line Regulation — Set the load current set to 100 mA. Measure the output voltage for input voltages of 12 V, 14 V, 16 V, 18 V, and 20 V. (Check the load current at each point, as well.) For each input voltage, calculate the regulator efficiency. (Use the same approximation as in the previous measurement.)

Then lower the input voltage until the regulator output voltage drops below 10.2 V — this is the drop-out voltage for the regulator.

Optional things to try

Can you change the regulator circuit to make the output adjustable?

If you have set up your project transformer to make a peak rectifier, try using that as the input to the BFS regulator. Repeat some the load regulation measurements above to see if the regulator performs differently with a more typical input source.

7805 regulator

Examine the data sheet for the venerable 7805 voltage regulator— available in your EE333 lab kit.

Set up the 7805 to serve as a 5-V regulator, powered by a DC voltage from the lab power supply. Don't forget the input and output capacitors! Perform the load regulation and line regulation measurements described above for the BFS regulator. For the load regulation measurements, use the DC supply set to 10 V for the input. For the line regulation measurements, use input voltages of 8 V, 10 V, 12 V, 14 V, and 16 V. Determine the drop-out voltage for the 7805.

If you have available a transformer/peak receiver combo, use that as the input to the 7805 and check the performance.

LM317 regulator

Examine the data sheet for the LM 317 adjustable regulator— also available in your EE333 lab kit.

Set up LM317 to serve as a 7.5 V regulator, powered by a DC voltage from the lab power supply. You will need to choose resistor value for the feedback network to set the voltage — read the recommendations from the data sheet. Don't forget the input and output capacitors.

Perform the load regulation and line regulation measurements described above for the BFS regulator. For the load regulation measurements, use the DC supply set to 12.5 V for the input. For the line regulation measurements, use input voltages of 10 V, 12 V, 14 V, 16 V, and18 V. Determine the drop-out voltage for the LM 317.

If you have available a transformer/peak receiver combo, use that as the input to the LM317 and check the performance.

Optional exercises

Try those to gain more knowledge and practice with linear regulators.

1. Use the 7805 as a 25-mA current source. The set up is described in the data sheet. Use a 10-V DC supply as the input. Test the current source by attaching various resistors and measuring the corresponding voltage. As always, pat attention to power levels and heating.

2. Use a 7905 to set up a negative 5-V regulator. (The lab instructor has a few to share.) Perform load regulation and line regulation measurements with that. Obviously, in working with a negative regulator, you must pay particular to attention to ground and voltage polarities.

3. Try making a BFS negative regulator, using the same components as the positive BFS studied above.