EE431 Lab 7
Voltage Regulators

Dec. 27, 2014

Introduction

The purpose of this laboratory exercise is to gain experience with Zener diode shunt regulators and amplifier based series regulators. You will be using the following equations.

$$\text{Line regulation} = \frac{\text{Vo at high line} - \text{Vo at low line}}{\text{High line voltage} - \text{Low line voltage}} * 100\% \qquad (1)$$

$$\text{Load regulation} = \frac{\text{Vo at low load current} - \text{Vo at high load current}}{\text{Vo at low load current}} * 100\% \qquad (2)$$

Procedure

1.0 Zener Diode Characteristics

1.1 Build the circuit in Figure 1.

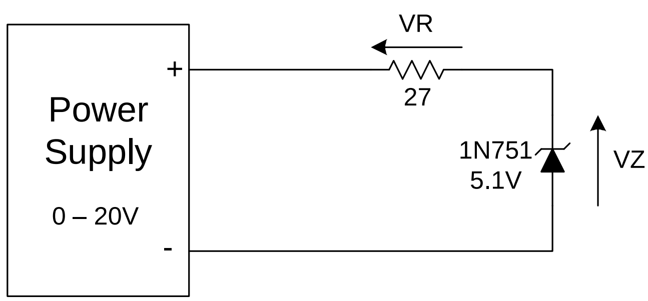

Figure 1: Circuit to measure Zener breakdown characteristics

1.2 Apply the following voltages from the power supply and record the voltage across the Zener diode (should range from 1 to around 5.1 over the experiment) and the voltage across the resistor (should range from 0 to 2.6 over the experiment). Record the resistance of the 27 ohm resistor to use for current calculations later. Nominal voltages from power supply: 1, 2, 3, 4, 4.2, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9, 5.0, 5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.8, 6.0, 6.2, 6.4, 6.6, 6.8, 7.0, 7.2, 7.4, 7.6, and 7.8. For applied voltages less than about 5 the voltage across the resistor will be very small. For voltages over about 5 the current will increase rapidly and the parts will become warm and hot enough to burn your finger at the higher applied voltages so use caution. Never allow the voltage across the resistor to exceed about 2.6 volts as that would mean there is excessive current.

1.3 Enter your data from 1.2 into Excel and produce a column of voltages across the Zener diode and a column of current through it – the current is VR/27. Plot the data (voltage on X and current on Y) using a linear axis for both. Because the temperature of the Zener and the resistor changes during the experiment the plot may have some unusual characteristics and not quite fit the general character described in class – but it is still representative.

2.0 Zener Diode Shunt Regulator

2.1 Build the circuit in Figure 2. Do not connect the load resistor until later.

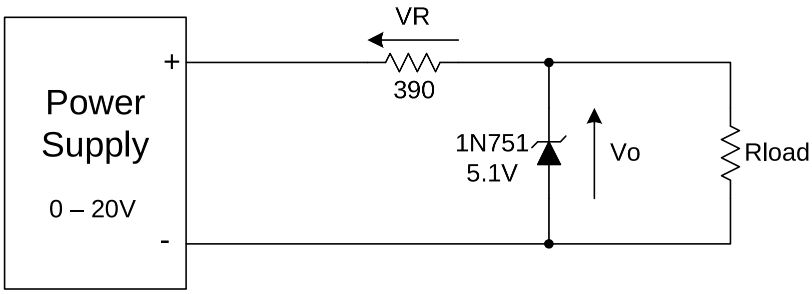

Figure 2: Zener diode shunt regulator

2.2 Set the applied voltage to 12.0 volts and record the voltage across the Zener to the nearest 10 millivolts after the voltage settles – may take about a minute. You should measure something close to 5.1 volts.

2.3 Set the applied voltage to 15.0 volts and record the voltage across the Zener to the nearest 10 millivolts after the voltage settles – may take about a minute. You should measure something close to 5.1 volts.

2.4 Using the data from 2.2 and 2.3, compute the line regulation.

2.5 Set the applied voltage to back to 12.0 volts.

2.6 Connect a load resistor of 680 ohms and record the voltage across the Zener to the nearest 10 millivolts after the voltage settles.

2.7 Using data from 2.2 and 2.6, compute the load regulation.

2.8 Connect the following load resistors and measure and record the voltage across the Zener: 470 ohms, 330, 270, 240, 220, and 180.

2.9 Enter the data from 2.2, 2.6, and 2.8 into Excel and create a plot of output voltage (Y-axis) versus load current (X-axis) computed using your various resistive loads. *Note: The full load current was designed for 7.5 mA (680 ohms). You will observe that the voltage stays up for significantly higher loads until finally the voltage drops because the regulator is over loaded.*

3.0 Series regulator

Note that the circuit in Figure 3 is a differential amplifier (Q2, Q3) and a low impedance output stage (Q1). This is a crude operational amplifier (about the simplest that can be built) with an open loop gain in the hundreds. The base of Q2 is the non-inverting input and the base of Q3 is the inverting input. The emitter of Q1 is the output. The non-inverting gain is determined by the feedback resistors, R4 and R5 and computes to be 2.0 although the effect of low open-loop gain in the hundreds will reduce that a bit. The voltage at the non-inverting input is the zener voltage of 5.1. Note that the non-inverting gain is 2 and the output voltage is nominally 2 * 5.1 = 10.2. C1 provides high frequency stability.

3.1 Build the circuit in Figure 3. Do not connect a load resistor until later.
Q1, Q2, Q3 are 2N3904 or 2N2222
D1 is 1N751 (5.1 volt)
R1 is 1K
R2 is 10K
R4, R5 are 4.7K
R3 is 2.2K
C1 is 0.1 uF

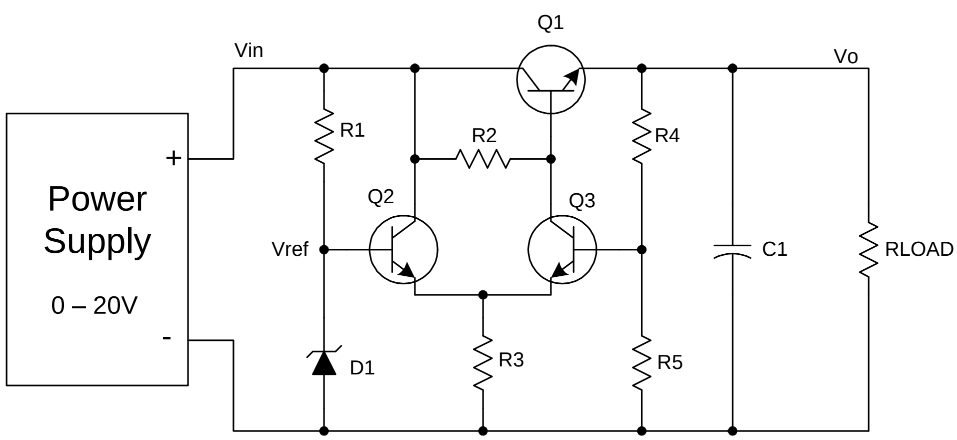

Figure 3: Series regulator

3.2 Apply 15 volts to the circuit and confirm that the output voltage is close to 10 volts. If not then check your wiring, verify that the voltage at the base of Q2 is 5.1 volts and verify that the voltage at the base of Q3 is half of the output voltage.

3.3 Record the output voltage to the nearest millivolt – allow time for the voltage to settle – around 1 minute. This is the no load voltage.

Note: In steps 3.4 through 3.8, the output voltage should remain close to 10 volts. Something is wrong if it drops significantly. Record the output voltage to the nearest millivolt after the output has settled.

3.4 Connect a 1K load resistor and record the output voltage.

3.5 Connect an additional 1K load resistor (two 1K resistors in parallel) and record the output voltage.

3.6 Use a load resistance of three 1K resistors in parallel and record the output voltage.

3.7 Use a load resistance of four 1K resistors in parallel and record the output voltage.

3.8 Use a load resistance of five 1K resistors in parallel and record the output voltage. Note that transistor Q1 is becoming very warm, perhaps hot. This is the designed full-load value. The circuit can probably drive a higher load current but Q1 will become overstressed and fail.

3.9 Using data from 3.3 and 3.8 compute the load regulation of this circuit. It should be much smaller (i.e. better) than that for the Zener diode.

3.10 Using data from 3.3 and 3.8 and voltage divider equations compute the output resistance of the power supply. It should be remarkably small.

3.11 Plot the data from steps 3.3 through 3.8 with current on the X-axis and output voltage on the Y-axis. Use an expanded scale for Y (such as 9.5 to 10.5 volts for example) so that the change in output voltage with increasing load is very visible. The plot should generally be a straight line but probably "erratic" because of small measurement errors and some other circuit construction factors.