LAB 9

Voltage Regulators

Reading: Malvino, Chapter 23

Hayes and Horowitz, Class 12 and Lab 12.

These experiments will introduce the basic ideas about voltage regulators. The first circuit uses three discrete transistors to demonstrate the principles of voltage regulation and current limiting. Usually one uses prepackaged, three-terminal, voltage regulators instead of building a discrete circuit. The second experiment introduces a very practical voltage regulator whose voltage can be varied and which can also be used as a current source.

1. Discrete Transistor Voltage Regulator

The circuit of Fig. 11.1 shows a circuit which will regulate the output voltage and limit the current output. It uses three transistors, Q1, Q2 and Q3, and a Zener diode. We use a Zener voltage of 6.2 V because Zener diodes around 5 V to 6 V are the most stable against temperature variations. One of the transistors acts as a common emitter amplifier so that the output voltage can be more than the Zener voltage. Another, called the "pass transistor," is an emitter follower which delivers most of the current to the load. The third transistor performs the current limiting task. Identify the amplifier transistor, the pass transistor and the current limiting transitor.

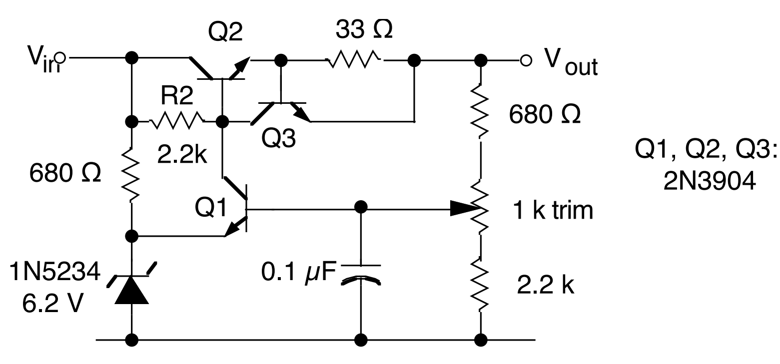

Fig 11.1

a) Find the feedback resistors and calculate the values of feedback resistors which will give V_{out} = 10 V.

Build the circuit and use the variable power supply set at 15 V. Adjust the trim pot so that V_{out} is 10 V with no load. Compare the voltages at the emitter and base of Q1, i.e., the Zener and feedback voltages. Measure the value of both arms of the trim resistance and compare with the calculated values. Reconnect the trim pot and put a 1 kΩ load on the output. Measure how much the load voltage drops. Calculate the percent load regulation, %LR = 100% x $\Delta V_{out}/V_{full\ load}$.

Now decrease the supply voltage to 12 V, measure the drop in the output voltage and express this drop as a percent supply regulation, %SR = 100% x $\Delta V_{out}/V_{nominal}$. Find the drop-out voltage, i.e., the input voltage below which the regulator won't regulate.

b) Find the current-sensing resistor and calculate the expected maximum output current if the output is shorted, I_{SL}. Does the current through the voltage divider need to be considered in this calculation?

Measure the short-circuit output current by putting an ammeter across the output to ground. Now make a table showing the output voltage, V_{out}, the base-emitter voltage of the limiting transistor, $V_{BE(lim)}$, and the base voltage of the pass transistor, $V_{B(pass)}$. Measure these voltages for load resistances of 1 kΩ, 330 Ω, 100 Ω and 0 Ω (short circuit output). Explain the voltages you measure in terms of the current-limiting mechanism.

c) Tabulate the values of V_{out} for each of the following troubles and compare with expected values:

i) R_2 open.

ii) Zener open

iii) Zener short

iv) Q1 open.

2. Three-terminal Voltage Regulator

Prepackaged voltage regulators exist for many commonly used output voltages. If you're a hacker though, it is convenient to have one regulator that can be adjusted for many different voltages. The LM317 is one such device. Its pins are labelled "out," "adjust," and "in." Two external resistors form a feedback circuit that controls the output voltage.

a) Design a +5 V regulated power supply using the 317 and the diode bridge of Lab 4. The 317 maintains 1.25 V between the ADJ and OUT pins and the current in the ADJ lead is about 50 μA. Provide a ±20% voltage adjustment range with a trim pot. Figure 11.2 shows the skeleton design. Allow about 20% ripple on the output of the filter capacitor with a 1 k load. Test the regulator as in part 1. Measure the %LR, %SR and dropout voltage. Try to measure the ripple rejection.

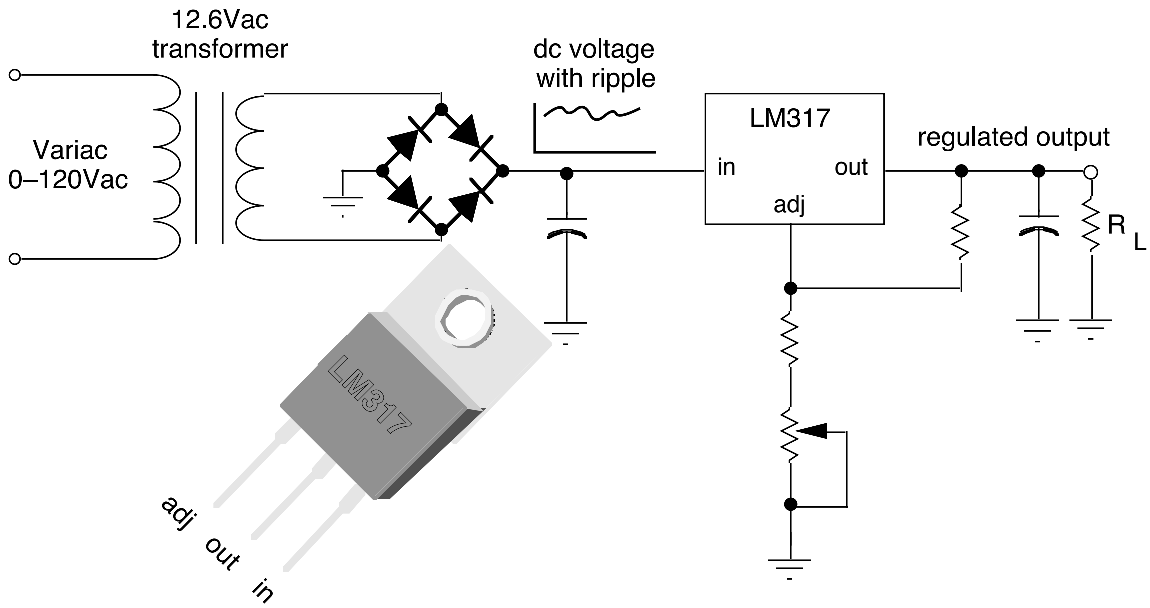

Fig. 11.2

3. Three Terminal Regulator as a Current Source

The 317 maintains about 1.25 V between the ADJ and OUT pins. That's the basis of its use as a variable voltage regulator. This property can also be used to configure it as an adjustable current source. Fig. 11.3 shows the idea. The 220 Ω resistor establishes just over 4 mA. Most of this current goes through the load because the ADJ input passes very little current. Connect this circuit and check if the current varies as the load resistance is changed. What is the voltage compliance? What limits its performance at high and low currents?

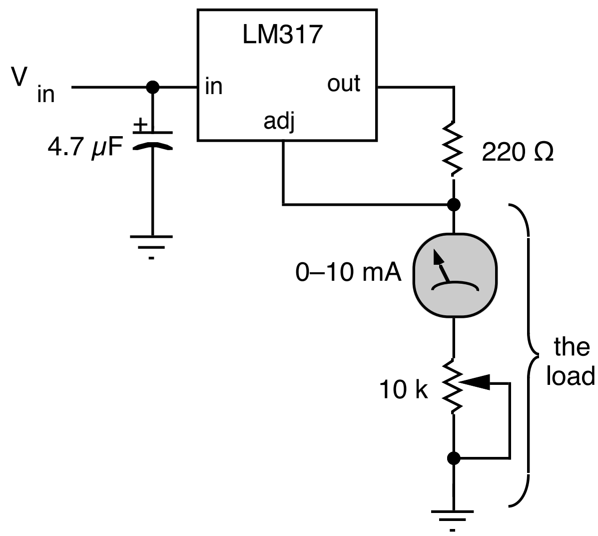

Fig. 11.3

Homework

1. Calculate the values of the feedback resistors for the three-transistor regulator of part 1 which gives a regulated output voltage of +10 V. Find the expected value of the short circuit output current limit.

2. Design the +5 V regulator of part 2 using the LM317 adjustable regulator. Find reasonable values for all unlabelled capacitors and resistors and provide for a ±20% adjustment.