Project 2: Regulated Power Supply

This project is similar to project 1 with two exceptions. First, the reference voltage is provided by an accurate voltage reference. Second, the reference voltage is amplified by the voltage gain of U1. The output voltage is adjustable by varying the gain of U1. This project is about the design, simulation, building and testing a linear variable voltage power supply with the following specifications.

1. Output voltage is continuously variable from 1.5V to 9V.
2. Input 12VDC. Maximum current: 100mA.
3. Good load and line voltage regulation.

Design Principles

Refer to figure 5-3 below. The voltage on the op-amp's non-inverting input is held constant by the 1.2V voltage reference IC, U2 (symbolized as a zener diode) to improve the power supplies line and load voltage regulation. Voltage references are available in a variety of voltage values and accuracies.

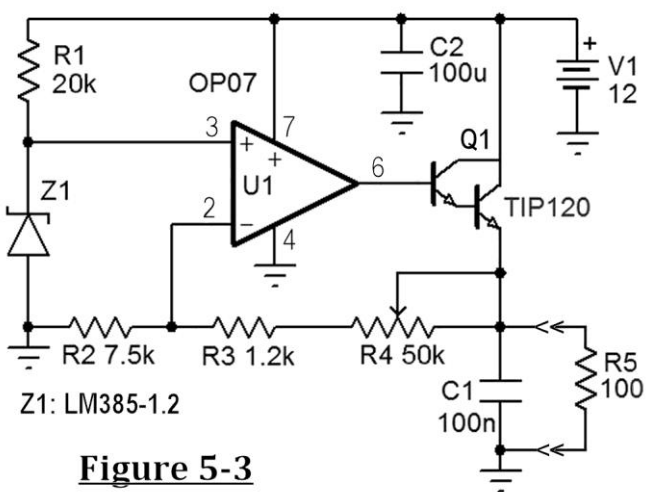


Figure 5-3

The op-amp circuit is a non-inverting amplifier whose output current is amplified by the transistor, Q1. This transistor is configured as an "emitter follower". It has unity voltage gain and a large current gain.

The regulator's output voltage, Vo, depends on the voltage gain of the op-amp.

$$Vo=\left(1+\frac{Rf}{Ri}\right)Vref=\left(1+\frac{Rf}{7.5k}\right)1.25. \qquad 1.2k \le Rf \le 51.2k.$$

$$Vo=1.45V \text{ when } Rf=1.2k. \qquad Vo=9.8V \text{ when } Rf=51.2k.$$

Simulation

The *LTspice* circuit diagram for this project is presented in figure 5-4 on the right. It is a voltage follower circuit whose output current is amplified by the transistor, Q1.

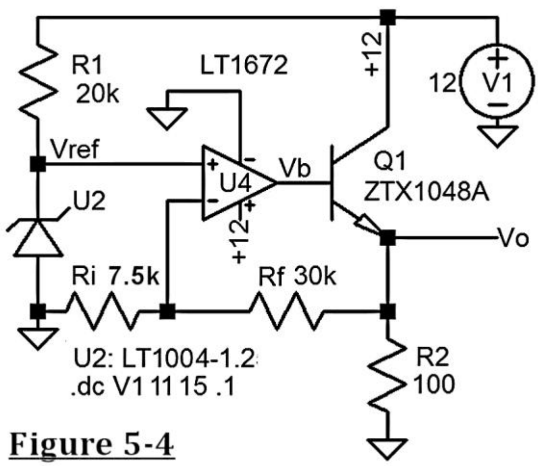
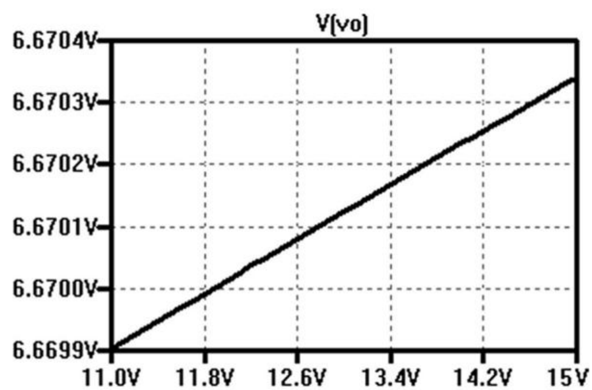


Figure 5-4

A *Linear Technology* LT1004-1.2 is used for the voltage reference in the simulation. This is a precision voltage reference that is similar to the LM385-1.2, but it is considerably more expensive. than the LM355



DC sweep analysis was used to simulate the circuit. The supply voltage was swept from 11V to 15V. The result is shown on the right.

The %Reg calculation below shows that the line regulation using the LT1004-1.2 is very good.

$$\%Reg=\frac{6.66990-6.67034}{6.6699}100\%=.0066\%.$$

$$\Delta V1=4V. \qquad \%Reg\,/\,V=.00165\%\,/\,V.$$

Part Selection

Any general purpose op-amp may be used, such as the OP07. The transistor, Q1, supplies maximum power when the load is 90Ω and the output voltage is 9 volts. P_{load} = 9V(100mA) = 900mW. P_{Q1} = 3V(100mA) = 300mW.

Q1 dissipates maximum power when the output voltage is 6 volts and output current is 100mA.. P_{load} = 6V(100mA) = 600mW. P_{Q1} = 6V(100mA) = 600mW.

A TIP120 power transistor is chosen for Q1. Any similar transistor may be used. Since the op-amp's reference voltage is regulated, the circuit's supply voltage does not need be regulated. A common and inexpensive voltage reference, the LM385-1.2, is used for this project.

Experiment

Parts

Resistors: 50k pot. 100Ω, 2W, 5%. 2k, 7.5k, 20k, ¼W, 5%.
Capacitors: 2-100nF. Q1: TIP120 or equivalent.
U1: OP07CP or equivalent. U2: LM385-1.2

Construction and testing

1. Build the circuit in figure 5-3 on a breadboard. Use a trim-pot for the 50k potentiometer.
2. Apply 12VDC to the circuit and verify that the pot will vary the output voltage from 1.5V to at least 9V.
3. Set the output voltage to 9.0V. Connect a 100Ω, 2W, resistor to the output. Measure and record the resulting output voltage, Vo_1. ______________.

   Increase the circuit's power supply voltage from 12 volts to 15 volts. Measure and record the resulting output voltage, Vo_2. ________________.

   Turn off the power after making the measurements (*warning*: the resistor and transistor will get hot).

Analysis

1. Calculate the circuit's load regulation. $\left(\%Reg = \frac{(9 - Vo_1)100\%}{Vo_1}.\right)$
2. Calculate the "worst case" value of the load regulation from the LM385-1.2 data sheet.
3. The quality of line voltage regulation is often expressed in percent per volt change of input voltage (%/V). $\left(\%/V = \frac{100(Vo_2 - Vo_1)}{(15-12)^2}.\right)$
4. Calculate the "worst case" value of the line regulation from the data sheet for the LM385-1.2 (refer to the appendix).
5. Compare your experimental results to the calculated "worst case" values.