Experiment No. 7

SERIES VOLTAGE REGULATOR

AIM

To design and set up a transistor series regulator and plot

1. Load current vs output voltage
2. Input voltage vs output voltage for a constant load current

THEORY

An ideal power supply maintains a constant voltage at its output terminals, no matter what current is drawn from it. The output voltage of a practical power supply changes with load current, generally dropping as load current increases. The power supply specifications include a full load current rating, which is the maximum current that can be drawn from the supply. The terminal voltage when full load current is drawn is called the full load voltage (V_{FL}). The no load voltage (V_{NL}) is the terminal voltage when zero current is drawn from the supply, that is, the open circuit terminal voltage.

One measure of power supply performance, in terms of how well the power supply is able to maintain a constant voltage between no load and full load conditions, is called its percentage voltage regulation.

An unregulated power supply has poor regulation, ie. output voltage changes with load variations. If a power supply has poor regulation it possesses high internal impedance. A simple emitter follower regulator is shown in Fig. 4.1. It is also called a series regulator since the control element (transistor) is in series with the load. It is also called as the pass transistor because it conducts or passes all the load current through the regulator. It is usually a power transistor. The zener diode provides the voltage reference, and the base to emitter voltage of the transistor is the control voltage.

The value of R_S must be sufficiently small, to keep the zener in its reverse breakdown region. Writing Kirchoff's voltage law to the output circuit,

$$V_o + V_{BE} - V_Z = 0$$
$$ie \quad V_{BE} = V_Z - V_o$$

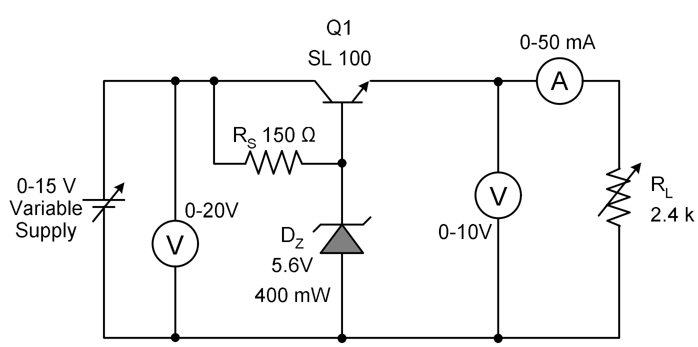


Fig. 1 Circuit diagram of series regulator

If V_Z is perfectly constant, the above equation is valid at all times, and any change in V_o must cause change in V_{BE}, in order to maintain equality.

When current demand is increased by decreasing R_L, V_o tends to decrease. From the above equation, it is seen that as V_Z is fixed, decrease in V_o increases in V_{BE}. This will increase the forward bias of the transistor, thereby increasing level of conduction. Thus, the output current is increased to keep $I_L R_L$ a constant. The reverse process occurs when R_L is increased. Thus, the above circuit keeps the output voltage constant, even if the load varies widely.

DESIGN

Specifications

Output Voltage, V_o = 5 volts (regulated)

Output Current, I_L = 0 - 30 mA

Input Voltage, V_i = 10-15 V

Maximum power dissipated in the transistor = $(V_{imax} – V_o)\ \underline{I_{max}}$

Select a transistor whose P_{dmax} is greater than the power dissipation calculated above and whose V_{CEO} is greater than $(V_{imax} – V_o)$.

Calculate base current $I_B = I_{max} / h_{FE.min.}$

Select a zener having breakdown voltage equal to

$V_Z = (V_o + 0.6)$ volts

$V_Z = 5 + 0.6 = 5.6$ V

Referring datasheet for zener diodes, power dissipation of the zener diode is found.

The wattage rating of the zener = $V_Z I_{Zmax}$

Select zener diode of 5.6 V, 400mW

Input = 10 – 15 V Output = 0 - 30 mA at 5V

I_B = 30mA / 50 = 0.6 mA

I_{Zmax} = 400 mW / 5.6 V = 71.4 mA

I_{Zmin} = 10% of I_{Zmax} = 7.14 mA

$$R_{\max} = \frac{V_{i\min} - V_z}{I_{z\min} + I_B} = \frac{10 - 5.6}{(7.14 - 0.6) \times 10^{-3}} = 673\ \Omega$$

$$R_{\min} = \frac{V_{i\max} - V_z}{I_{z\max}} = \frac{15 - 5.6}{71.4 \times 10^{-3}} = 132\ \Omega$$

Select R = average of R_{min} and R_{max} = 330 Ω

Power rating of R is to be fixed considering maximum I^2R loss.

Power loss, $I^2 R = \left(\frac{V_{i\max} - V_z}{R} \right)^2 \times R = \frac{15 - 5.6}{330} = 0.27\, W$

Select R as 330 Ω, 0.5 W

PROCEDURE

Load regulation

1. The circuit is wired as per the circuit diagram shown in fig. 1.
2. Keep the input voltage constant at V_{imin}, ie 10 V.
3. Vary the load resistance. Note I_L and V_O for each setting of R_L. Ensure that V_i remains same throughout.
4. Draw a plot between I_L and V_O.

Line Regulation

Percent line regulation is another measure of the ability of a power supply to maintain a constant output voltage. In this case, it is a measure of how sensitive the output is to the changes in input or line voltage rather than to the changes in load. The specification is usually expressed as the percent change in output voltage that occurs per volt change in input voltage, with the load R_L assumed constant.

1. The circuit diagram is wired as per the circuit diagram shown in fig. 1.
2. Keep the load resistance R_L a constant.
3. Vary the input voltage between the limits for which the regulator is designed (10 to 15V).
4. Note the load voltage V_O for each setting of V_{in}.
5. Draw a graph between V_{in} (X axis) and V_L (Y axis).

OBSERVATIONS

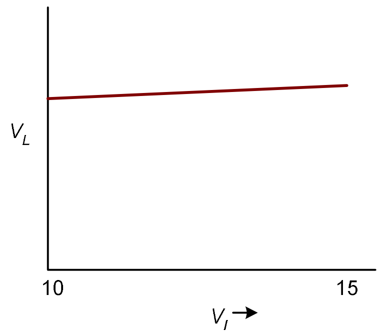
Load Regulation

Load Current I_L mA	Output voltage V_O V

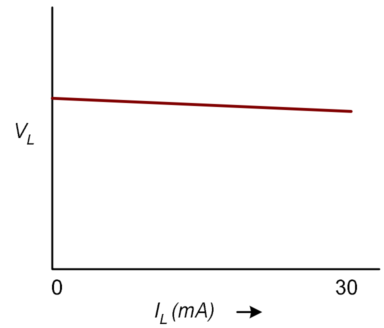
Line Regulation

Input Voltage V_i V	Output voltage V_O V

EXPECTED OUTPUT PLOTS



Line Regulation



Load Regulation

RESULT

Line regulation and load regulation curves are plotted.

QUESTIONS

1. Define percentage line and load regulation, what are the typical values?
2. What are the demerits of a series voltage regulator? How can they be avoided?
3. What is an SMPS? Where is it used?