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, i.e. 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,

\[ V_o + V_{BE} - V_Z = 0 \]

\[ ie \quad V_{BE} = V_Z - V_o \]

![Circuit diagram of series regulator](image)

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 = $(V_{\text{max}} - V_o) I_{\text{max}}$

Select a transistor whose $P_{d\text{max}}$ is greater than the power dissipation calculated above and whose $V_{CEO}$ is greater than $(V_{\text{max}} - V_o)$.

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

Select a zener having breakdown voltage equal to

$$V_Z = (V_o + 0.6) \text{ volts}$$

$$V_Z = 5 + 0.6 = 5.6 \text{ V}$$

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

The wattage rating of the zener = $V_Z I_{Z\text{max}}$

Select zener diode of 5.6 V, 400mW

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

$I_B = 30\text{mA} / 50 = 0.6 \text{ mA}$

$I_{Z\text{max}} = 400 \text{mW} / 5.6 \text{ V} = 71.4 \text{ mA}$

$I_{Z\text{min}} = 10\% \text{ of } I_{Z\text{max}} = 7.14 \text{ mA}$

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

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

Select $R = \text{average of } R_{\text{min}} \text{ and } R_{\text{max}} = 330 \Omega$

Power rating of $R$ is to be fixed considering maximum $I R$ loss.
Power loss, \( I^2 R = \left( \frac{V_{\text{max}} - V_z}{R} \right)^2 \times R = \frac{15 - 5.6}{330} = 0.27 \text{ W} \)

Select \( R \) as 330 \( \Omega \), 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 \( V_{\text{min}} \), 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 \( V_{\text{in}} \).
5. Draw a graph between \( V_{\text{in}} \) (X axis ) and \( V_L \) (Y axis).

**OBSERVATIONS**

<table>
<thead>
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<th>Load Regulation</th>
<th>Line Regulation</th>
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<tr>
<td><strong>Load Current</strong></td>
<td><strong>Input Voltage</strong></td>
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<tr>
<td>( I_L ) mA</td>
<td>( V_i ) V</td>
</tr>
<tr>
<td><strong>Output voltage</strong></td>
<td><strong>Output voltage</strong></td>
</tr>
<tr>
<td>( V_O ) V</td>
<td>( V_O ) V</td>
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EXPECTED OUTPUT PLOTS

![Line Regulation](image1.png)  ![Load Regulation](image2.png)

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?