Department of Electronic & Telecommunication Engineering
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EN3013 - ANALOG CIRCUIT DESIGN

DESIGN OF LINEAR POWER SUPPLY

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This report is submitted as the fulfillment of Lab-03 of module EN3013

1 INTRODUCTION OF LINEAR POWER SUPPLY

1.1 Objective

* We are designing a fast-charging power supply for modern devices.
* Load regulation and line regulation values apply to the output.
* Adjustable linear power supplies allow for variable output voltage.
* Linear regulators reduce output DC ripple and noise.
* Unregulated power supplies have variable output voltage depending on load and input voltage.

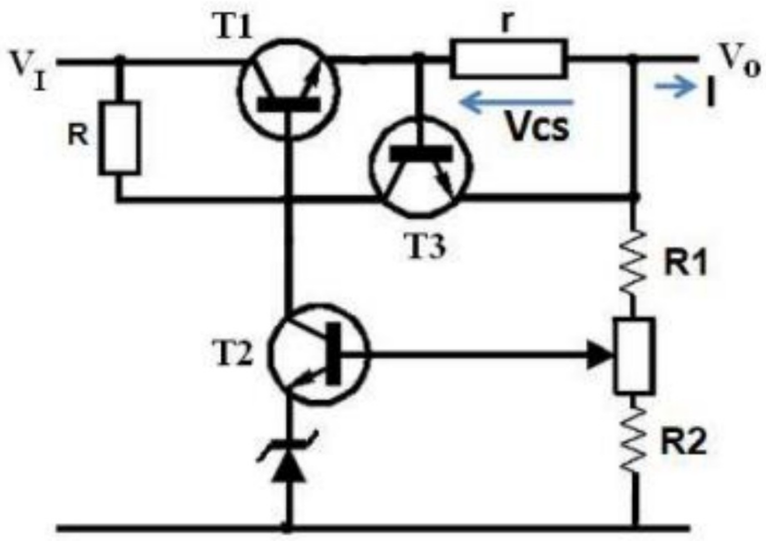

Figure 1 — Circuit

1.2 Constrains

* Typical input voltage = 14V + Reminder of (19/5)= 16 V
* Current Limitation = 1.5 A (for all groups)
* Output voltage range = Mid output voltage ± 3 V = 9 ± 3 V

1.3 Components

* T_1 = TIP31C (40 W)
* T_2 = BD139 (12 W)
* T_3 = BC109

2 CALCULATIONS

2.1 Selection of Zener

$$\text{Vo}_{min} > V_z + V_{be}$$
$$\text{V}_z < 5.3V$$

Therefore we decided to take 1N4732A zener diode, which has 4.7V zener voltage and 500 mW power rating.

2.2 Calculate R1 and R2

2.2.1 For maximum voltage

$$\begin{aligned} V_{omax} \cdot \frac{R_2}{R_1 + R_2 + 1k} &= (V_Z + V_{BE}) \\ V_Z &= 4.7V \\ V_{BE} &= 1V \\ V_o \cdot \frac{R_2}{R_1 + R_2 + 1k} &= 5.7V \\ 6.3R_2 &= 5.7R_1 + 5700 \end{aligned} \tag{1}$$

2.2.2 For minimum voltage

$$\begin{aligned} V_{omin} \cdot \frac{R_2 + 1k}{R_1 + R_2 + 1k} &= (V_Z + V_{BE}) \\ V_Z &= 4.7V \\ V_{BE} &= 1V \\ V_o \cdot \frac{R_2 + 1k}{R_1 + R_2 + 1k} &= 5.7V \\ 0.3R_2 + 300 &= 5.7R_1 \end{aligned} \tag{2}$$

Therefore, we have selected
R1 as 105.26 ohms
R2 as 1 kohms

2.3 Current Limiting

2.3.1 Calculate value of r

To calculate the value of r
To make T_3 transistor in active region, the voltage across the base and emitter must be 0.77V,

hence V_{BE} must be 0.77V. Since 1.5 A should be the maximum current allowed to flow through the resistor,

$$\begin{aligned} r &\geq \frac{0.77V}{1.5A} \\ r &\geq 0.513\Omega \end{aligned} \tag{3}$$

2.3.2 Power dissipation in r

$$\begin{aligned} power &= 0.77V \times 1.5A \\ power &= 1.155W \end{aligned} \tag{4}$$

Due to lack of components we have selected 0.5 Ω resistor(1 Ω and 5 W resistors in parallel)

$$\begin{aligned} new\ maximum\ current &= 0.77\ \mathrm{V}_{\overline{0.5\Omega}} \\ new\ maximum\ current &= 1.54\ \mathrm{A} \\ power &= (1.54)^2 \times 0.5\Omega \\ power &= 1.1858W \end{aligned} \tag{5}$$

2.4 Calculate value of R

To calculate the value of R

$$\begin{aligned} V_{Rmin} &= V_{i(max)} - (V_{o(max)} + 0.7) \\ V_{Rmin} &= 14 - (12 + 0.7)V \\ V_{Rmin} &= 1.3V \end{aligned} \tag{6}$$

$$\begin{aligned} I_{Rmax} &\geq I_{\beta Max} + I_{Knee} \\ I_{Rmax} &\geq \frac{1}{40} + 1 \times 10^{-3} \\ I_{Rmax} &\geq 26 \times 10^{-3}A \\ R &\leq \frac{1.3V}{26 \times 10^{-3}A} \\ R &\leq 50\Omega \end{aligned} \tag{7}$$

Consider the tolerances

$$\begin{aligned} 1.05R &< 50\Omega \\ R &< 47.62\Omega \end{aligned} \tag{8}$$

Therefore, we have selected R as 47 Ω

2.5 Tolerance Consideration

$$\begin{aligned} 1.1 \leq \frac{(R_1 + 1k) \times 0.95}{R_2 \times 1.05} \rightarrow 1.55R_2 = 0.95R_1 + 0.95k \\ 0.05 \geq \frac{R_1 \times 1.05}{(R_2 + 1k) \times 0.95} \rightarrow 0.0475R_2 + 0.0475k = 1.55R_1 \end{aligned} \tag{9}$$

Therefore, we have selected
R1 as 75 Ω
R2 as 658.9 Ω

$$\begin{aligned} i_{Z(max)} &\rightarrow V_{O(min)}, V_{in(max)}, i_{b(min)} \\ i_{Z(max)} &= \frac{11.3V}{47\Omega} - 1mA \\ i_{Z(max)} &= 239.42mA \end{aligned} \tag{10}$$

2.6 Power Calculations of T_1

2.6.1 No loading condition

$$\begin{aligned} P_{max} &\rightarrow i_{c(max)}, V_{O(min)}, V_{in(max)} \\ P_{max} &= i_{c(max)}[V_{in(max)} - V_{O(min)}] \\ P_{max} &= 1A \times [18V - 6V] \\ P_{max} &= 12W \end{aligned} \tag{11}$$

2.6.2 At 1 Ω loading condition

$$\begin{aligned} P_{max} &= 1A \times [18V - (1+1)V] \\ P_{max} &= 16W \end{aligned} \tag{12}$$

2.7 Power Calculations of T_2

$$\begin{aligned} \textit{maximum possible voltage} &= 12.7\text{V - } 4.7\text{ V} = 8\text{ V} \\ \textit{maximum possible current} &= 239.43\text{ mA} \\ \textit{maximum possible Power dissipation} &= 8\text{ V } \times 239.42mA = 1.915W \end{aligned} \tag{13}$$

2.8 Power Calculations of Zener maximum possible

$$P_{max} = 4.7V \times 239.42mA = 1.125W \tag{14}$$

Hence we used two zeners in parallel to withstand power dissipation

3.1 Results of Laboratory Implementation

3.1.1 Line Variation

Line variance was calculated while setting the output voltage at 6V and at 12V. Then the input voltage was increased and the output voltage measured and the graph was plotted.

Input Voltage(V)	Output Voltage(6V)	Output Voltage(12V)
14.0	5.963	11.797
14.5	5.977	11.848
15.0	5.988	11.896
15.5	6.002	11.931
16.0	6.024	11.974
16.5	6.031	11.996
17.0	6.042	12.016
17.5	6.055	12.058
18.0	6.067	12.093

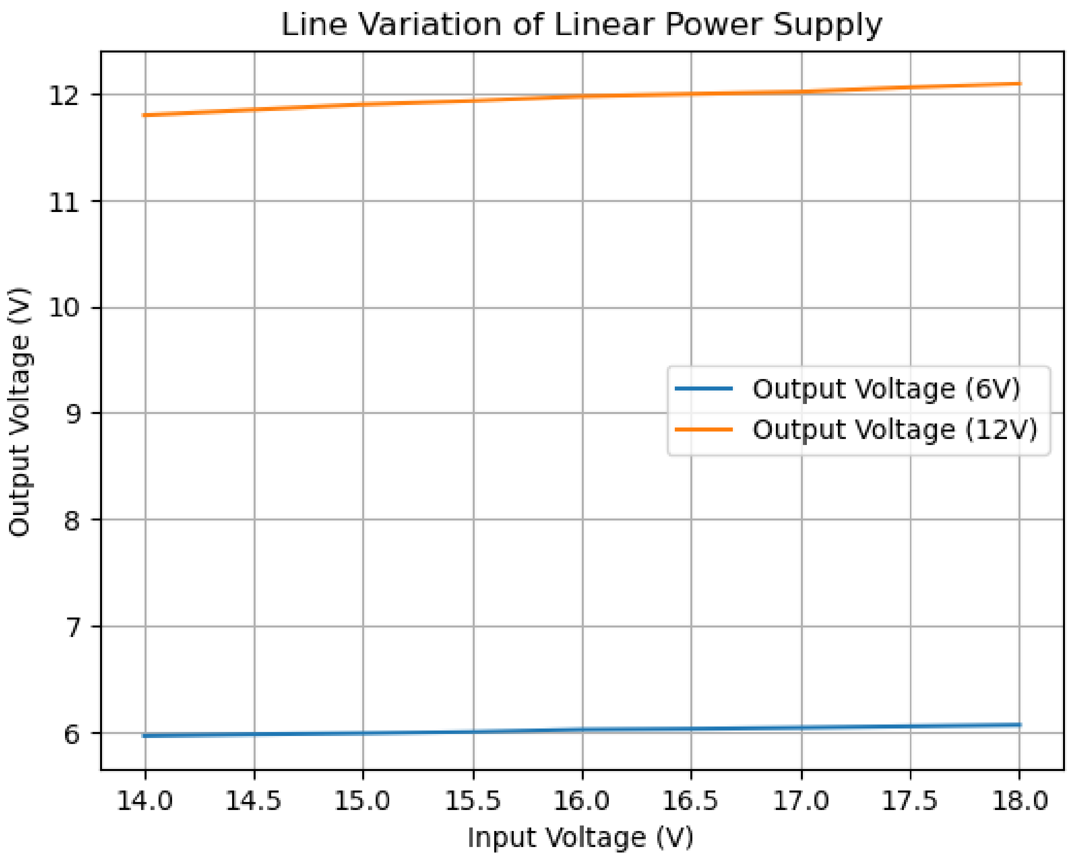

Figure 2 — Line Variation

3.1.2 Load Variation

Load Resistor(ohms)	Output Voltage(6V)	Output Voltage(12V)
5	5.80	11.58
6	5.90	11.73
10	5.945	11.921
47	5.993	11.937
100	5.999	11.959
330	6.002	11.977
470	6.002	11.981
560	6.008	11.984
810	6.008	11.986
2.2k	6.008	11.990
3.9k	6.009	11.992
5.6k	6.009	11.995
10k	6.009	11.996

Table 1 — Load variation

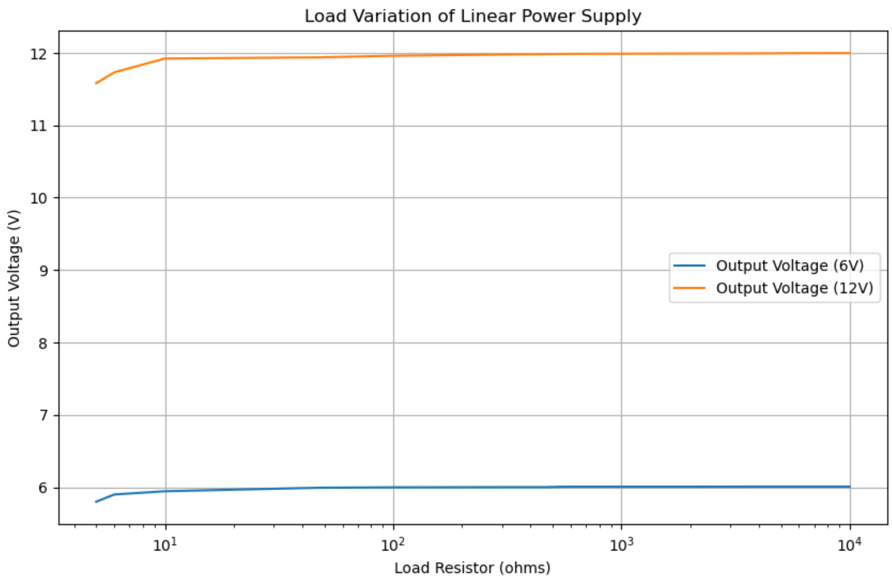

Figure 3 — Load Variation

3.2 Discussions

There were various challenges that we had to face during the implementation of this circuit. The obstacles we had to overcome are as follows:

* Finding the appropriate zener diode and power transistor was difficult.
* We were unable to find exact values for R and r.
* Initially, we couldn't achieve the specified output range.
* Some BD139 and BC109 transistors burnt due to improper connections.