Department of Electronic & Telecommunication Engineering
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EN2111 - ELECTRONIC CIRCUIT DESIGN

LINEAR POWER SUPPLY DESIGN

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ABSTRACT

We had to create a linear power supply with a maximum current restriction (also known as over-current protection).Our power source need to be able to deliver consistent output voltage for various variable output loads as well as to a fluctuating input line voltage.

This report explains the functionality of Linear power supply which can give output as from 8V to 14V.This is bassed on the module EN2111 - Electronic Circuit Design, Which is conducted by Dr. Thayaparan Subramaniam.

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1 INTRODUCTION OF LINEAR POWER SUPPLY

* Output voltage of an unregulated power supply will vary depending on the load and on variations in the AC supply voltage
* Linear regulator may be used to set the voltage to a precise value, stabilized against fluctuations in input voltage and load
* Regulator also greatly reduces the ripple and noise in the output direct current
* Linear regulators often provide current limiting, protecting the power supply and attached circuit from over-current
* Adjustable linear power supplies allow the output voltage to be adjusted over a range
* Line regulation is a measure of the circuit's ability to maintain the specified output voltage with varying input voltage
* Load regulation is a measure of the circuit's ability to maintain the specified output voltage under varying load conditions.
* Load regulation and Line regulation values apply to the output
* The worst case value is the addition of both line and load tolerance percentages.

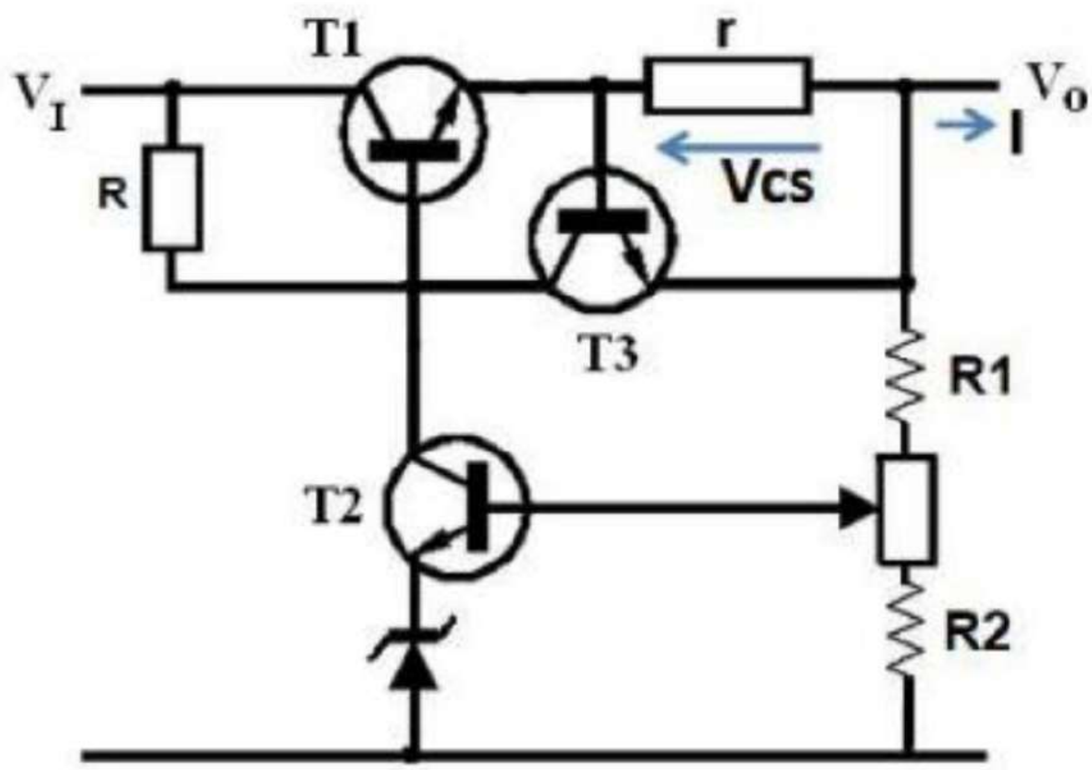


Figure 1 — Circuit

2 CALCULATIONS

2.1 Calculate Input & Output ranges

* Group Number = 19
* Typical input voltage = 14V + Reminder of (19/5)= 14 + 4 V = 18 V
* Input voltage range Vi = Typical Input voltage ± 2 V = 18 ± 2 V
* Current Limitation = 100 mA (for all groups)
* Mid output voltage Vo = Vi - 8 + Reminder of (19 /3) = 11 V
* Output voltage range = Mid output voltage ± 3 V = 11 ± 3 V

2.2 Selection of Zener

$$\text{Vo}_{min} > V_z + V_{be}$$
$$\text{V}_z < 7.4V$$

Therefore we decided to take more zener diode with 4.7V zener voltage.

2.3 Calculate R1 and R2

$$\begin{aligned} V_o.\frac{R_2}{R_1+R_2} &= (V_Z + V_{BE}) \\ V_Z &= 4.7V \\ V_{BE} &= 0.62V \\ V_o.\frac{R_2}{R_1+R_2} &= 5.32V \end{aligned} \tag{1}$$

To calculate the maximum ratio between R1 and R2

$$\begin{aligned} V_{OMax} &= 15V \\ 1+\frac{R_1}{R_2} &= \frac{15V}{5.32V} \\ \frac{R_1}{R_2} = 2.8195 - 1 &= 1.8915 \\ \frac{R_1}{R_2}_{Max} &= 1.8915 \end{aligned} \tag{2}$$

To calculate the minimum ratio between R1 and R2

$$\begin{aligned} V_{OMin} &= 7V \\ 1+\frac{R_1}{R_2} &= \frac{7V}{5.32V} \\ \frac{R_1}{R_2} = 1.3158 - 1 &= 0.3158 \\ \frac{R_1}{R_2}_{Min} &= 0.3158 \end{aligned} \tag{3}$$

$$\text{let } \mathrm{R}_2 = 5k\Omega$$
$$\text{For } \mathrm{V}_{OMax} \rightarrow \mathrm{R}_1 = 1.8195 \times 5k\Omega = 9.0975k\Omega$$
$$\text{For } \mathrm{V}_{OMin} \rightarrow \mathrm{R}_1 = 0.3158 \times 5k\Omega = 1.579k\Omega$$
$$\delta R_1 = (0.0975 - 1.579)k\Omega$$
$$\delta R_1 = 7.5185k\Omega$$

Therefore, we have selected
R1 as 1.5 kohms
R2 as 5 kohms

2.4 Selection of variable resistor(V_R)

To find V_R

$\mathrm{V}_R \geq \delta R_1 = 7.5185k\Omega$

Therefore, we have selected 10 kohms variable resistor.

2.5 Calculate value of R

To calculate the value of R

$$\begin{aligned} I_{Rmin} &\geq \frac{I_{LMax}}{\beta} + I_{Knee} \\ \frac{16-(14+0.62)}{R} &\geq \frac{100 \times 10^{-3}}{100} + 1 \times 10^{-3} \\ R &\leq \frac{1.38 \times 10^{-3}}{2} \\ R &\leq 0.69 \times 10^{-3} \\ R &\leq 690\Omega \end{aligned} \tag{4}$$

Therefore, we have selected R as 650 Ω

2.6 Calculate value of r

To calculate the value of r
To make T3 transistor in active region, the voltage across the base and emitter must be 0.62V, hence VcE must be 0.62V. Since 100mA should be the maximum current allowed to flow through the resistor,

$$\begin{aligned} r &\geq \frac{0.62V}{100 \times 10^{-3}A} \\ r &\geq 6.2\Omega \end{aligned} \tag{5}$$

Therefore, we have selected r as 6.8 Ω

2.7 Selection of Transistor

T1 transistor's maximum power dissipation is
$(VI\ max - Vo\ min) \cdot Imax = (20V - 8V) \cdot 100mA = 1.2W$.
Therefore we chose TIP31C transistor which has a power rating higher than 1.2W.

3 METHODOLOGY & OBSERVATIONS

3.1 Functionality description

* Current limiting should be 100 mA
* We should be able to change the input and same time output voltage should be constant
* Output voltage should be adjustable

3.2 Breadboard Implementation

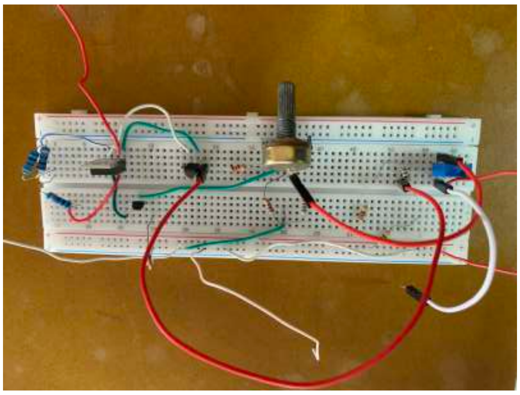


Figure 2 — Breadboard Implementation

3.3 Observations

We achieved a voltage range of 6.8325 V to 14.1534 V and a maximum current of 103 mA due to changes in resistors and impedance.

3.3.1 Circuit connections

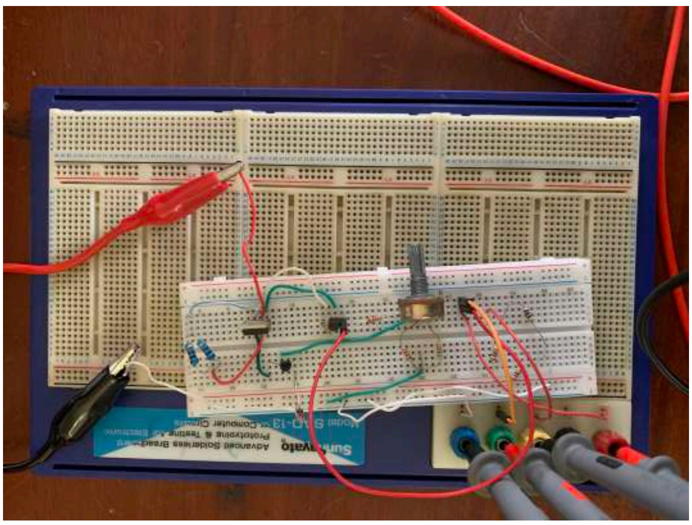


Figure 3 — Breadboard Implementation

3.3.2 Output voltages at minimum Input(16V)

(a) Minimum Output

(b) Maximum Output

Figure 4 — Output voltages at minimum Input(16V)

3.3.3 Output voltages at Input= 17V

(a) Minimum Output

(b) Maximum Output

Figure 5 — Output voltages at Input= 17V

3.3.4 Output voltages at Input= 18V

(a) Minimum Output

(b) Maximum Output

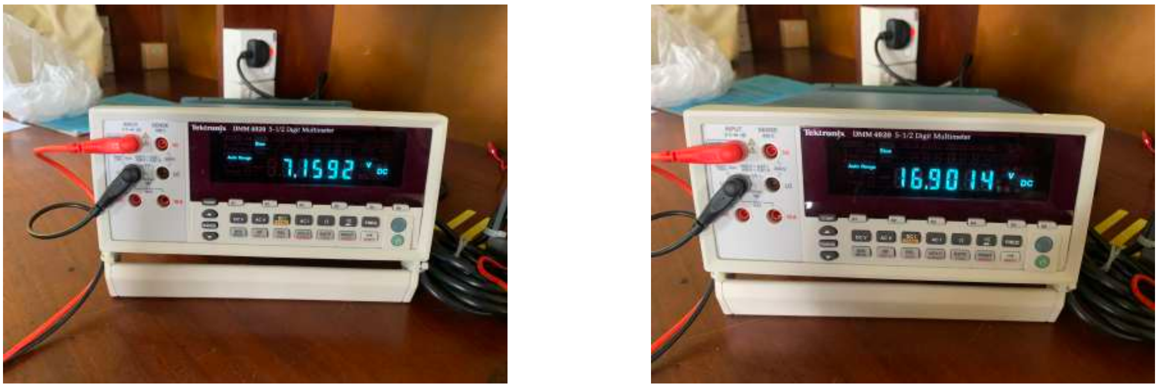
Figure 6 — Output voltages at Input= 18V

3.3.5 Output voltages at Input= 19V

(a) Minimum Output (b) Maximum Output

Figure 7 — Output voltages at Input= 19V

3.3.6 Output voltages at maximum Input(20V)



(a) Minimum Output (b) Maximum Output

Figure 8 — Output voltages at maximum Input(20V)

3.3.7 Set Output voltage to 10V

Figure 9 — Set Output voltage to 10V

3.3.8 Change the Input at particular output voltage = 10V

(a) Input = 16V

(b) Input = 17V

(c) Input = 18V

(d) Input = 19V

(e) Input = 20V

Figure 10 — Set Output voltage to 10V and change the input

3.4 Results of Laboratory Implementation

3.4.1 Current Limitation

Load Resistor(ohms)	Load current(mA)
6	103.00
25	102.00
56	99.60
71	99.40
240	40.20
500	21.05
750	13.62
1000	10.23
2000	4.02
3000	2.49
4000	2.01
5000	1.84

Table 1 — Current Limitation

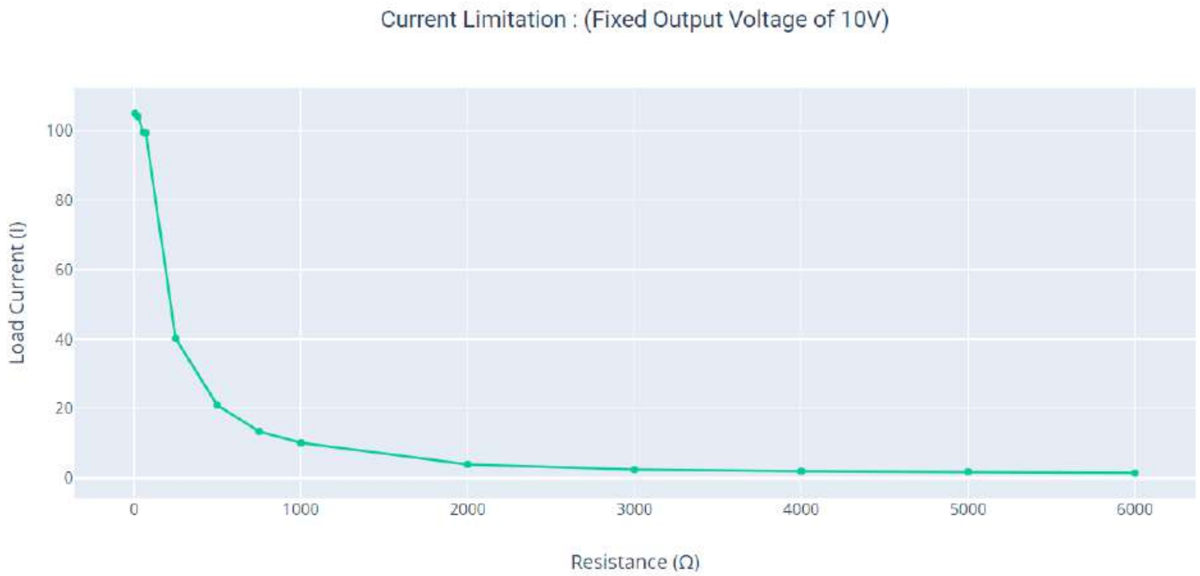


Figure 11 — Current Limitation-Vast range

Figure 12 — Current Limitation-Zoomed in small range

3.4.2 Line Variance

Line variance was calculated while setting the output voltage at 8V for the input voltage 16V. Then the input voltage was increased and the output voltage measured and the graph was plotted.

Input Voltage(V)	Output Voltage(V)
16.0	8.0
16.5	8.06
17.0	8.12
17.5	8.19
18.0	8.24

Input Voltage(V)	Output Voltage(V)
18.5	8.30
19.0	8.35
19.5	8.41
20.0	8.47

Table 2 — Line variance

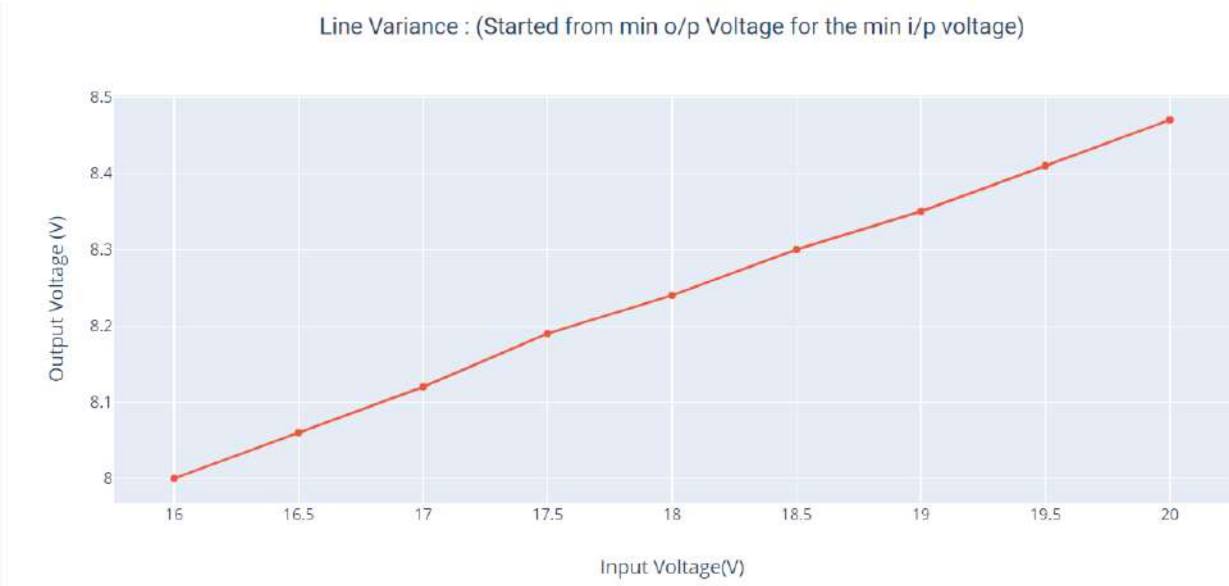


Figure 13 — Line Variance

3.4.3 Load Variance

Load Resistor(ohms)	Output Voltage(V)
6	0.98
25	3.54
56	6.60
71	8.00
240	9.95
500	9.98
750	9.99
1000	10.01
2000	10.02
3000	10.02
4000	10.03
5000	10.04

Table 3 — load variance

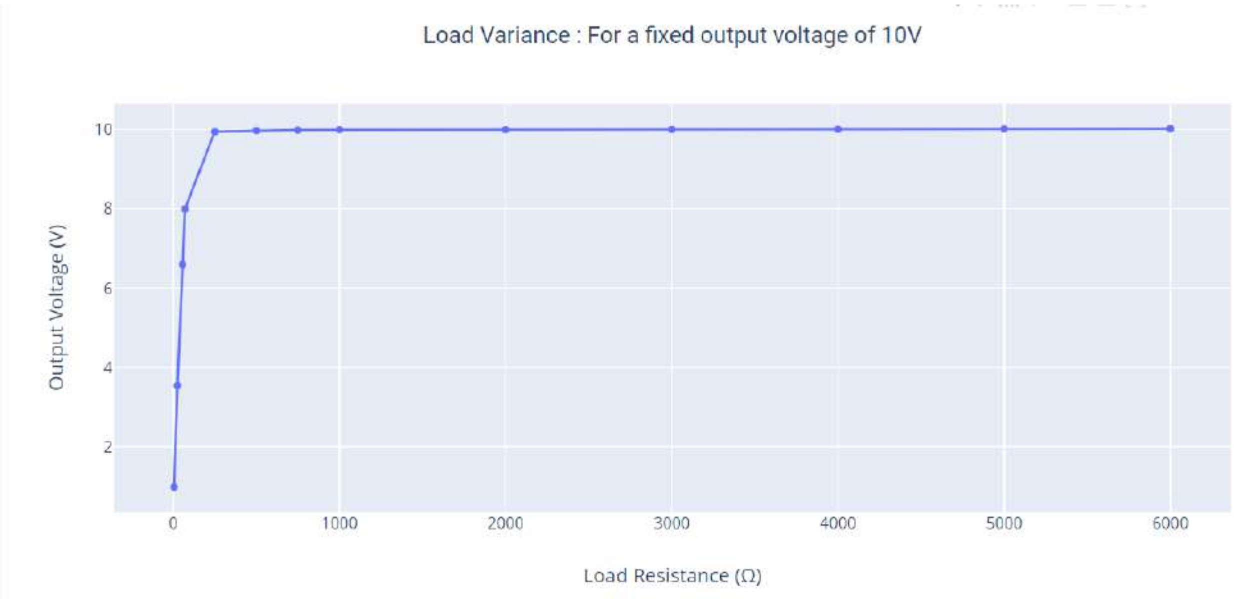


Figure 14 — Load Variance-Vast range

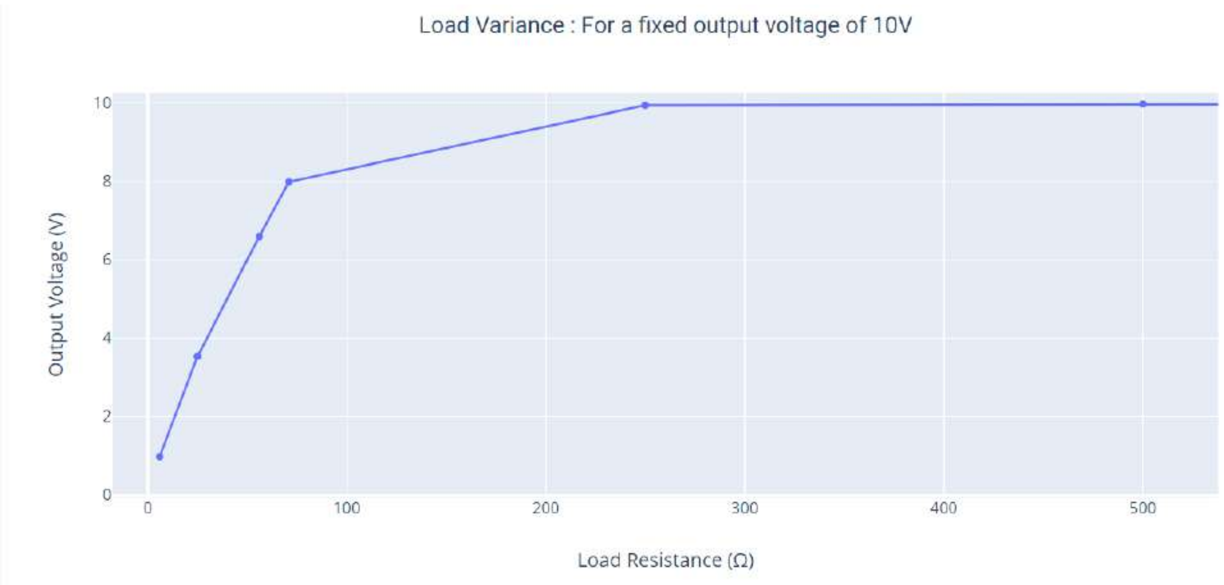


Figure 15 — Load Variance-Zoomed in small range

4.1 List of components

As this is an analog linear power regulation circuit, we used a variety of transistors and resistors.

Item	Quantity	Description
TIP31C	1	Medium power amplification, able to tolerate high voltages
BC109	2	A General NPN transistor.
4.7 V zener	1	Maintain voltage across it at 4.7V when maximum current passes
Resistor(5KΩ)	1	
Resistor(1.5KΩ)	1	
Resistor(6.8 Ω)	1	
Resistor(650 Ω)	1	
10kΩ*Trimmer*	1	We can get any resistance between 0 and 10000 ohms

Table 4 — List of components

4.2 Circuit Simulation Diagram

The simulation results for the computed values we obtained are shown in the photos below. Multisim was the simulation program that we employed.

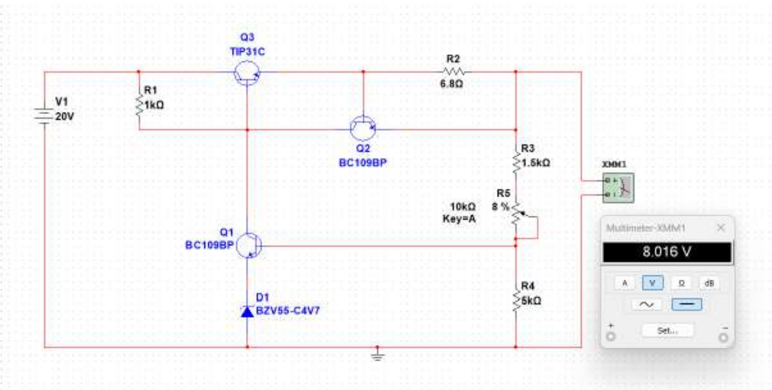


Figure 16 — Circuit simulation-Minimum Voltage

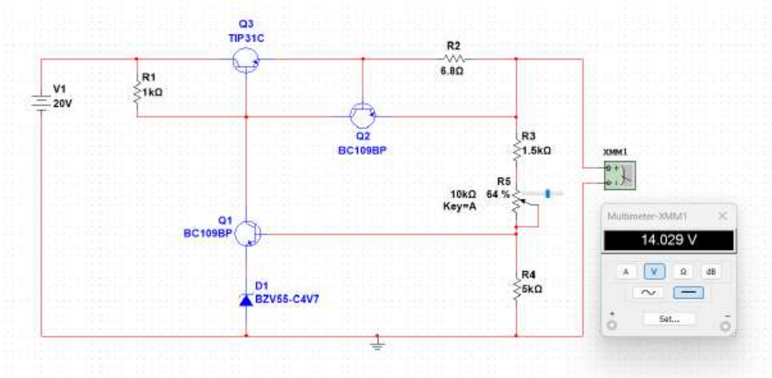


Figure 17 — Circuit simulation-Maximum Voltage

4.3 PCB Design

The schematic of the circuit was drawn first and the PCB was designed accordingly using Easyeda.

4.3.1 PCB Schematic

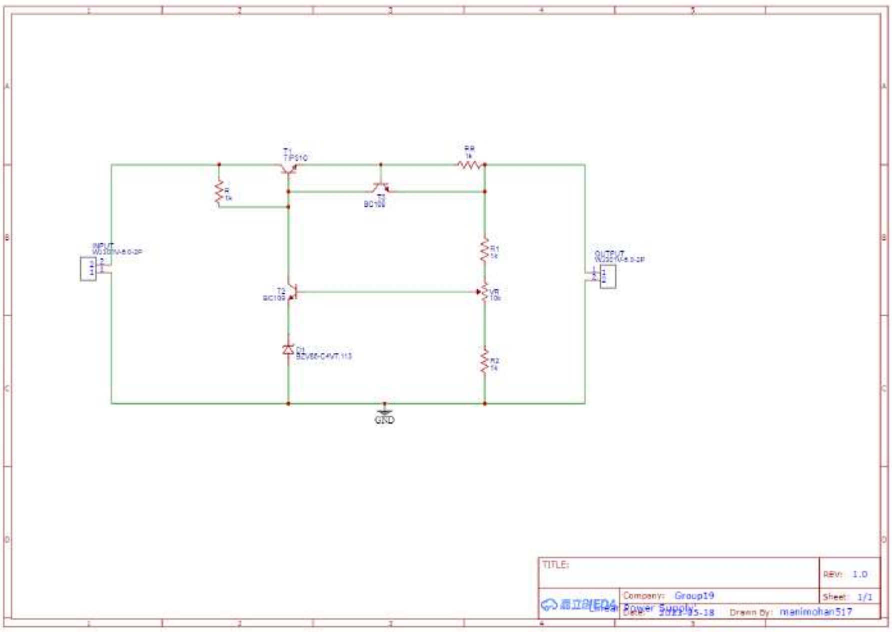
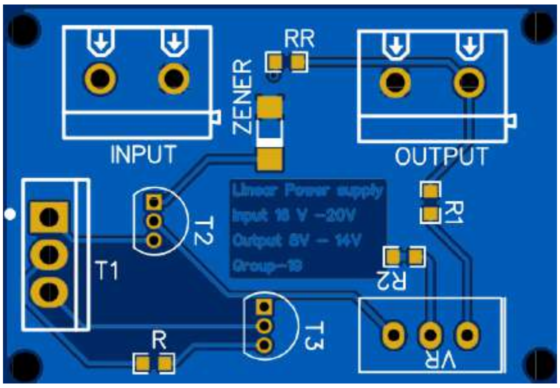


Figure 18 — PCB Schematic

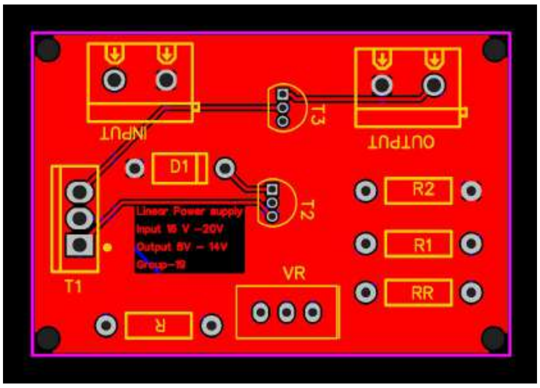
4.3.2 PCB Design rules

* PCB length – 46 mm
* PCB width - 31 mm
* PCB clearance between two copper lines - 0.152 mm
* width of copper wire - 0.254 mm
* Hole size - 0.3 mm

4.3.3 PCB Footprint



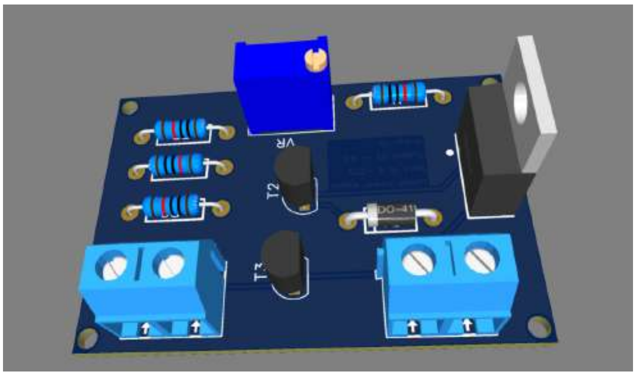
(a) PCB Footprint



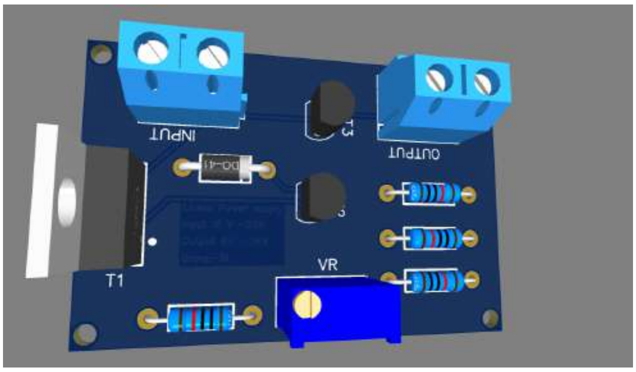
(b) Layered View

Figure 19 — PCB 2D View

4.3.4 PCB 3D Model



(a)



(b)

Figure 20 — PCB 3D model

5 DISCUSSIONS & REEFERENCES

5.1 Discussions

There were various challenges, which we had to face during the implementing this Circuit. The obstacles we had to go through were stated follow.

* Finding the appropriate zener and the power transistor was difficult.
* We couldn't able to find exact values for R and r
* Initially we couldn't able to get the output range which assigned for us.
* some BC109 burnt due to improper connections

5.2 References

Below is an appendix with data sheets for the utilized components:

1. BC109
2. TIP31C
3. C4V7