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(MIMO Buck Converter) Multi-Input Multi-Output DC-DC Buck Converter

Vipin Verma[1], Aruna Patel[2]
[1]Research Scholar, [2]Associate Professor, Department of Electrical and Electronics Engineering, Oriental College of Technology, Bhopal, India

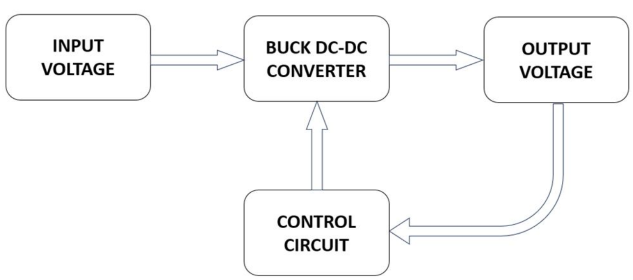
Abstract: Designs of the power electronics circuitry are nowadays reducing the size, space, and weight of converter and inverter circuits. This is possible because of the availability of new high-switching frequency devices. This paper presents a generalized model of buck converters that is multi-input multi-output(MIMO) fixed and variable. The converter used for stepping down the voltage is called a buck converter. The buck converter is designed, analyzed simulated & developed. The proposed model of this Buck converter consists of two parts: (a) Main converter circuits with the components like switch, inductor, diode, capacitor, and load, (b) A control circuit for controlling the operation of the switch using 10 10-turn potentiometer. This model can accurately give the power output voltage.

I. INTRODUCTION

The objective of this design is to design a programmable DC-DC buck converter for embedded users and for industrial purposes. This is the first version of a programmable DC-DC step-down converter (Buck converter) in this board there are two inputs which is used to provide input power supply to the board one is a Micro USB socket and another is a two pin male header and in the output side there are four two pin headers out of which three headers having fixed supply 1.5V, 3.3V and 5V and one is variable 1.23V to 37V.

Input voltage can be 3V to 40V

II. BLOCK DIAGRAM



III. INDENTATIONS AND EQUATIONS

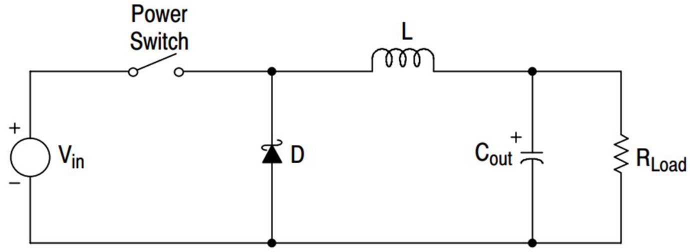
In this project I used LM2576 voltage regulator IC to get the adjustable output voltage, this is an industrial use voltage regulator IC which is widely used. The range of the output voltage vary from 1.23v to 37v with 4% tolerance. It is a monolithic integrated circuits ideally suited for easy and convenient design of a step-down switching regulator or buck converter. This ICs are available in fixed and variable output version. These regulator ICs is designed to reduce the number of components and minimize the size of buck converter and simplify the design.

IV. BASICS OF BUCK CONVERTER

The LM2576 is a "Buck" or Step−Down Converter which is the most elementary forward−mode converter. Its basic schematic can be seen in Figure 16. The operation of this regulator topology has two distinct time periods. The first one occurs when the series switch is on, the input voltage is connected to the input of the inductor. The output of the inductor is the output voltage, and the rectifier (or catch diode) is reverse biased. During this period, since there is a constant voltage source connected across the inductor, the inductor current begins to linearly ramp upwards, as described by the following equation.

$$I_{L(on)} = \frac{(V_{in} - V_{out})\, t_{on}}{L}$$

During this "on" period, energy is stored within the core material in the form of magnetic flux. If the inductor is properly designed, there is sufficient energy stored to carry the requirements of the load during the "off" period



The next period is the "off" period of the power switch. When the power switch turns off, the voltage across the inductor reverses its polarity and is clamped at one diode voltage drop below ground by the catch diode. The current now flows through the catch diode thus maintaining the load current loop. This removes the stored energy from the inductor. The inductor current during this time is.

$$I_{L(off)} = \frac{(V_{out} - V_D)\, t_{off}}{L}$$

This period ends when the power switch is once again turned on. Regulation of the converter is accomplished by varying the duty cycle of the power switch. It is possible to describe the duty cycle as follows:

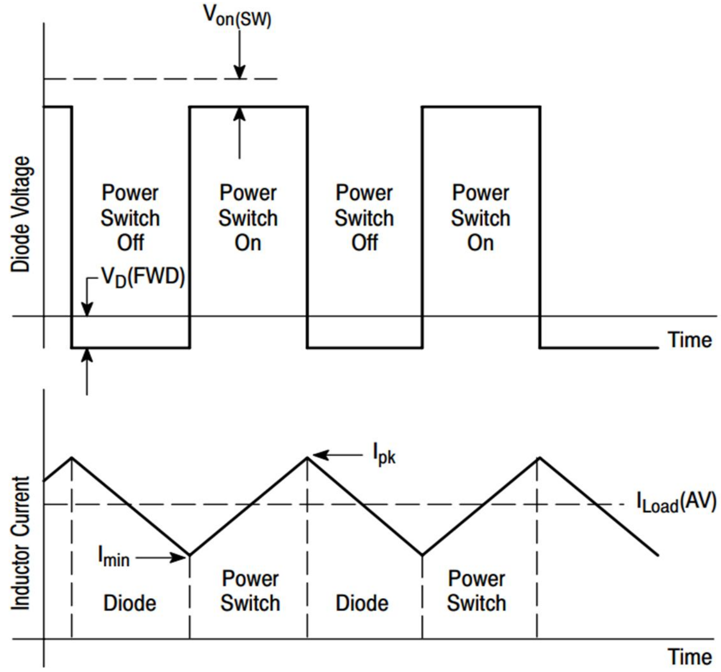
$$d = \frac{t_{on}}{T}$$

where T is the period of switching.

For the buck converter with ideal components, the duty cycle can also be described as:

$$d = \frac{V_{out}}{V_{in}}$$

Figure 17 shows the buck converter, idealized waveforms of the catch diode voltage and the inductor current.



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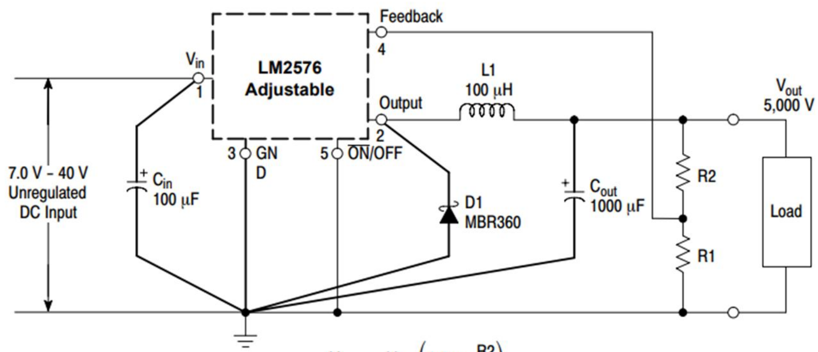
V. MATHMATICA ANALYSIS

C_{in} – 100 μF, 75 V, Aluminium Electrolytic
C_{out} – 1000 μF, 25 V, Aluminium Electrolytic
D1 – Schottky, MBR360
L1 – 100 μH, Pulse Eng. PE−92108
R1 – 2.0 k, 0.1%
R2 – 6.12 k, 0.1%

Adjustable Output Voltage Versions



$$V_{out} = V_{ref}\left(1.0 + \frac{R2}{R1}\right)$$

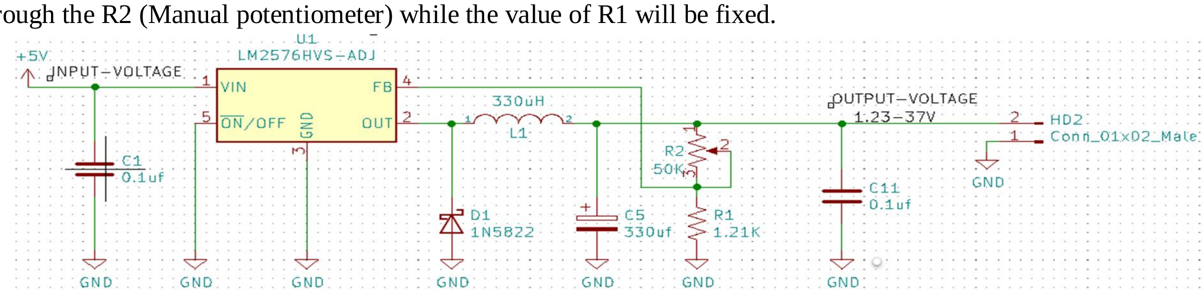
$$R2 = R1\left(\frac{V_{out}}{V_{ref}} - 1.0\right)$$

Where V_{ref} = 1.23 V, R1 between 1.0 k and 5.0 k

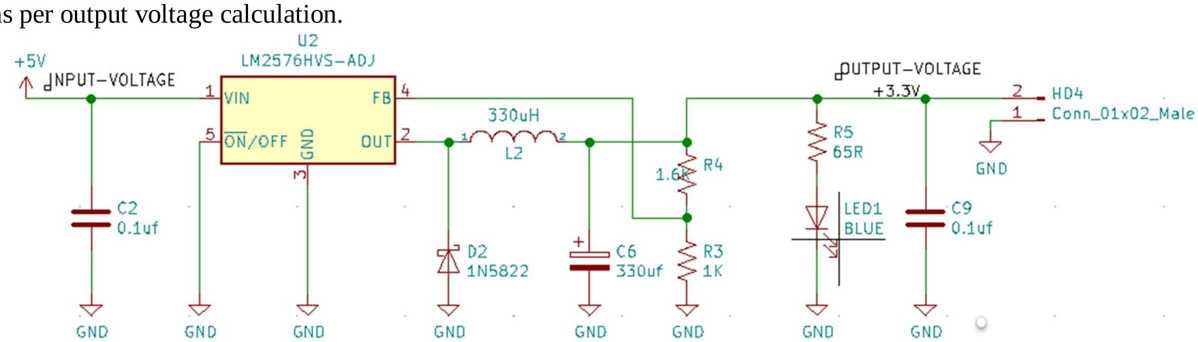
Where the R2 is 10 turn Potentiometer 50KRwhich is controlled by manually, by varying the R2 value we can adjust the output voltage from 1.23 to 37V when R1 needs to be fixed as per calculation.
(Ref. No. 2 Onsemi conductor datasheet)

A. Below is the Circuit Diagram of the Final Circuit

This diagram represents the basic circuit of a voltage regulator, where HD2 connector provides the output voltage which you can adjust through the R2 (Manual potentiometer) while the value of R1 will be fixed.



This is the schematic of fixed 3.3V output power supply and same will be for 1.5V and 5V. only R3 and R4 resistors value will be changed as per output voltage calculation.



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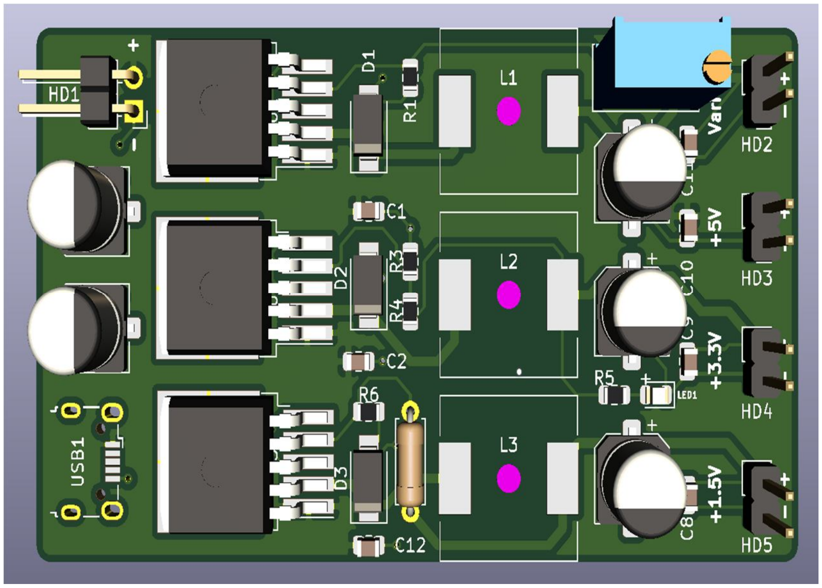
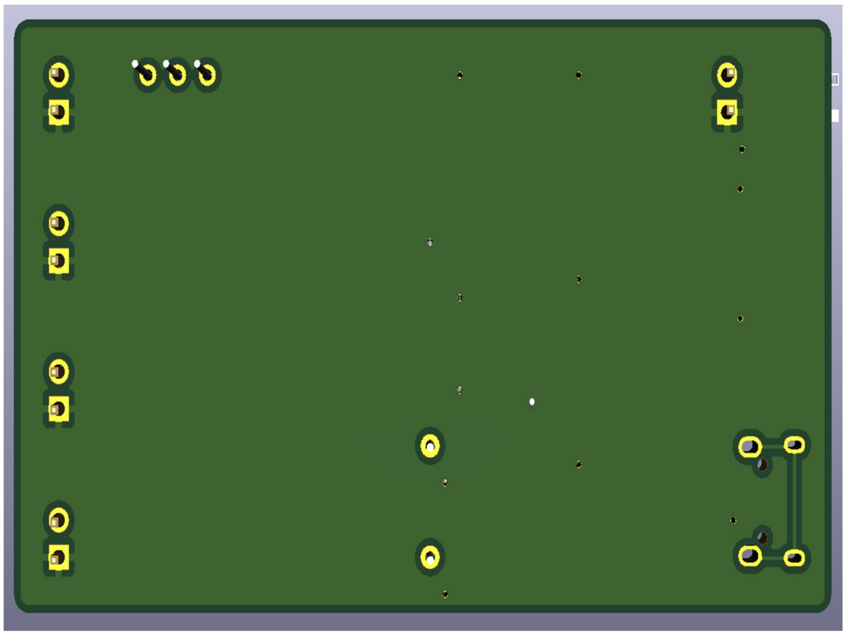
VI. DESIGNING PART

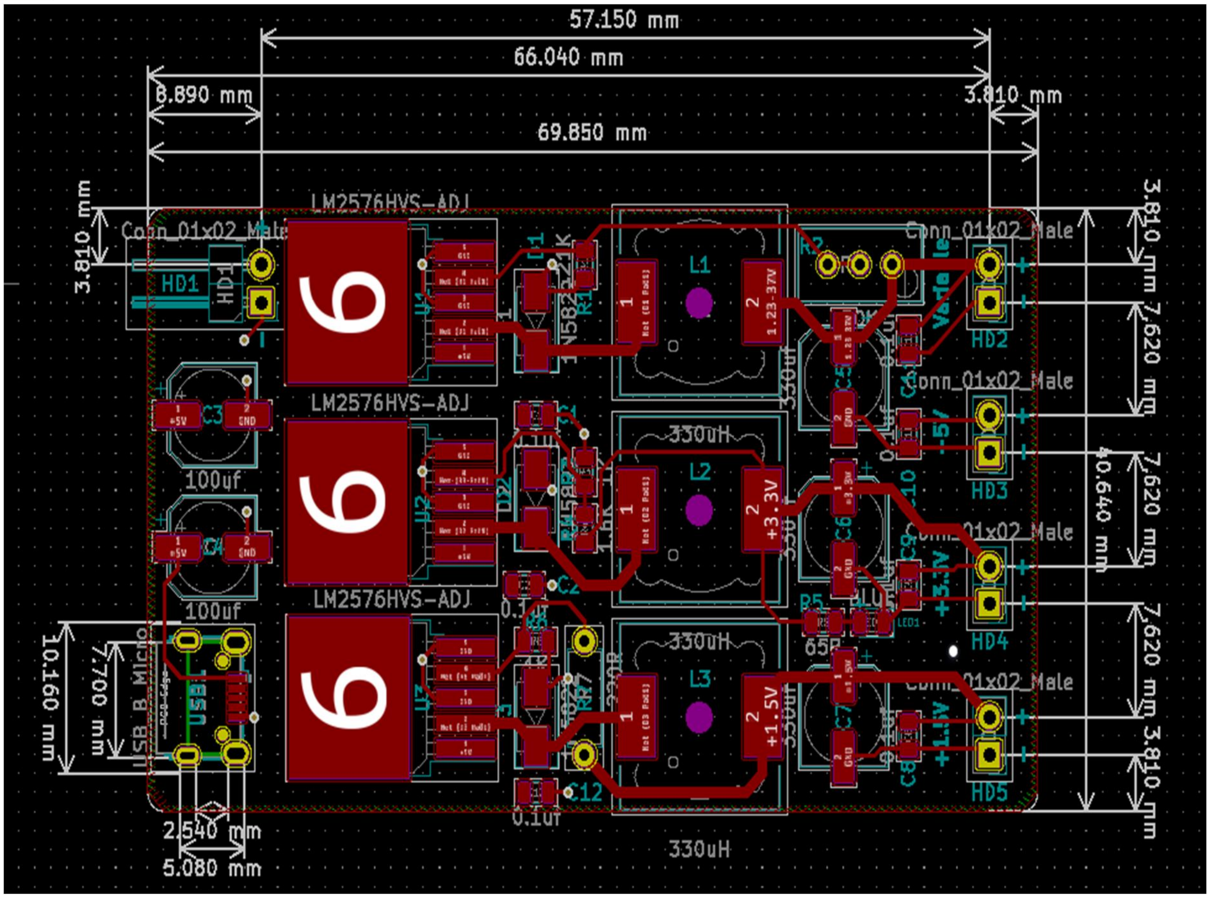
This is the final design that I had done on PCB designing tools. I used to prefer KiCAD for my work but there are many tools to design a PCB. The final design has come up with the very minimum size and in good look.
Here you can see the no. of components which are SMD and THT type. It has two input connectors HD1 and USB1 and four output connectors HD2-HD5.

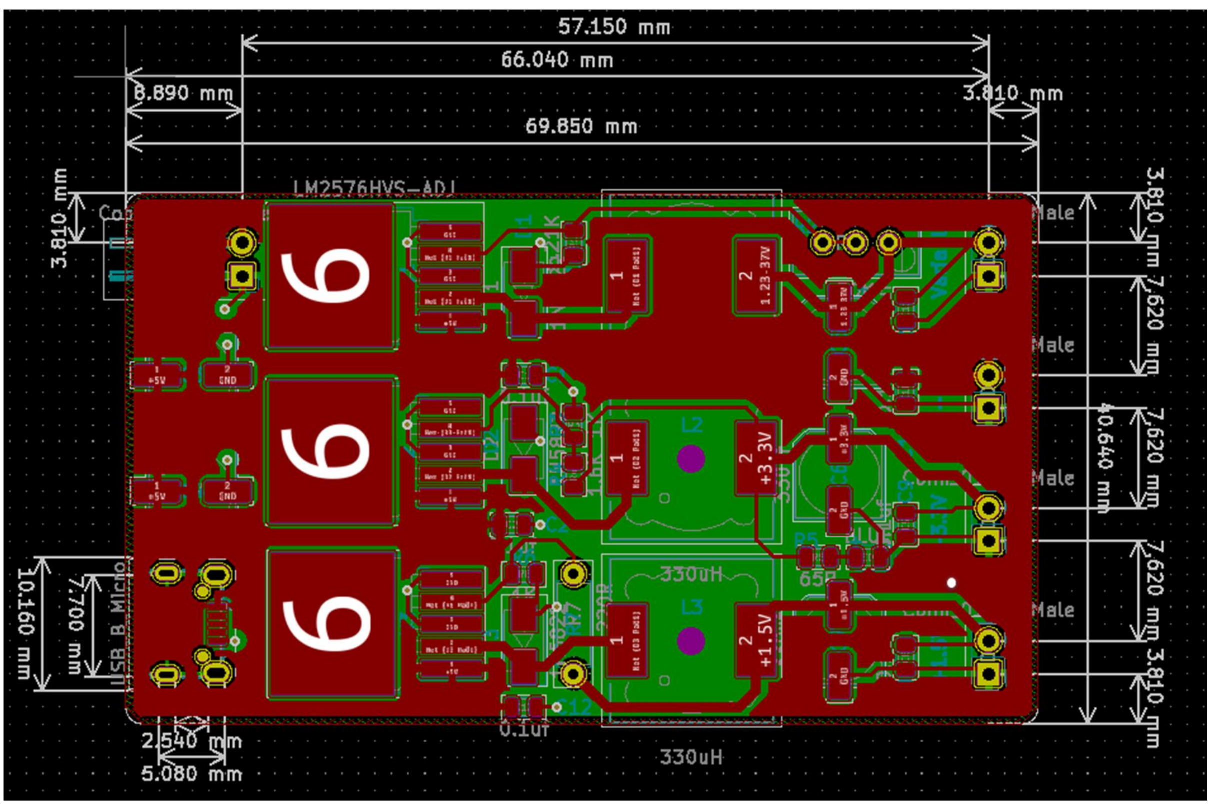


The back side of the board has plane area with solder points to provide good mechanical strength to the through hole components like potentiometer and headers.



Below is the actual PCB design process where you can see the routing traces of front copper and back copper(in Red and green color), the Components footprint for ICs "LM2576", Inductors, Capacitors, Resistors, Diodes, LED, Headers and USB Connector.
To Identify the components using the reference designator we used a silkscreen layer(F.Silk "Front Silk") which is very important for manual assembly of the components called PCBA.
To connect the front and back copper layers I used some through vias which you can see in the left side inductors.


57.150 mm
66.040 mm
8.890 mm
3.810 mm
69.850 mm
3.810 mm
LM2576HVS-ADJ
Conn_01x02_Male
HD1
HD2
HD3
HD4
HD5
L1
L2
L3
330uH
100uf
10.160 mm
7.700 mm
USB_B_Micro
2.540 mm
5.080 mm
0.1uf
C12
7.620 mm
40.640 mm
+3.3V
+1.5V
1.23-37V


57.150 mm
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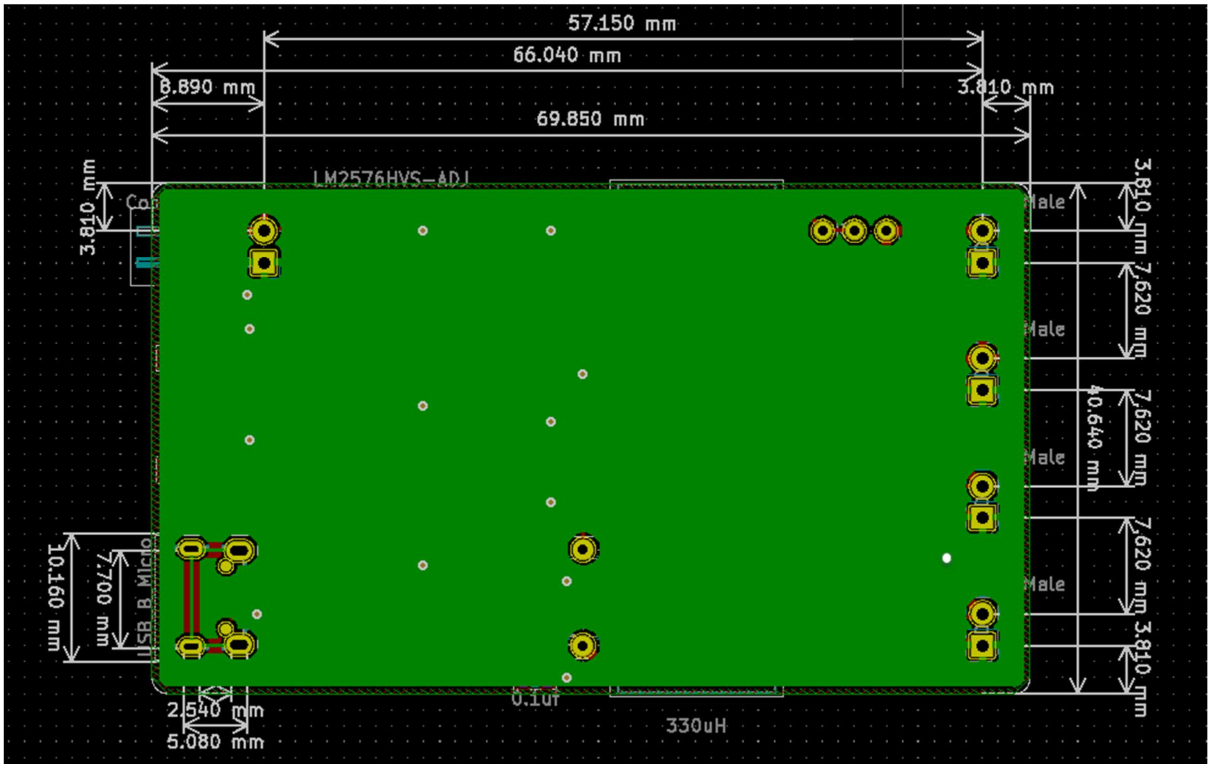

VII. FINAL OUTPUT

The final output of the designed power supply as expected.

I used a 12V input power supply on 2-pin header and measured the output supply using a multimeter and the output was 1.5V, 3.3V, 5V, and the variable was 1.23 to 11V.

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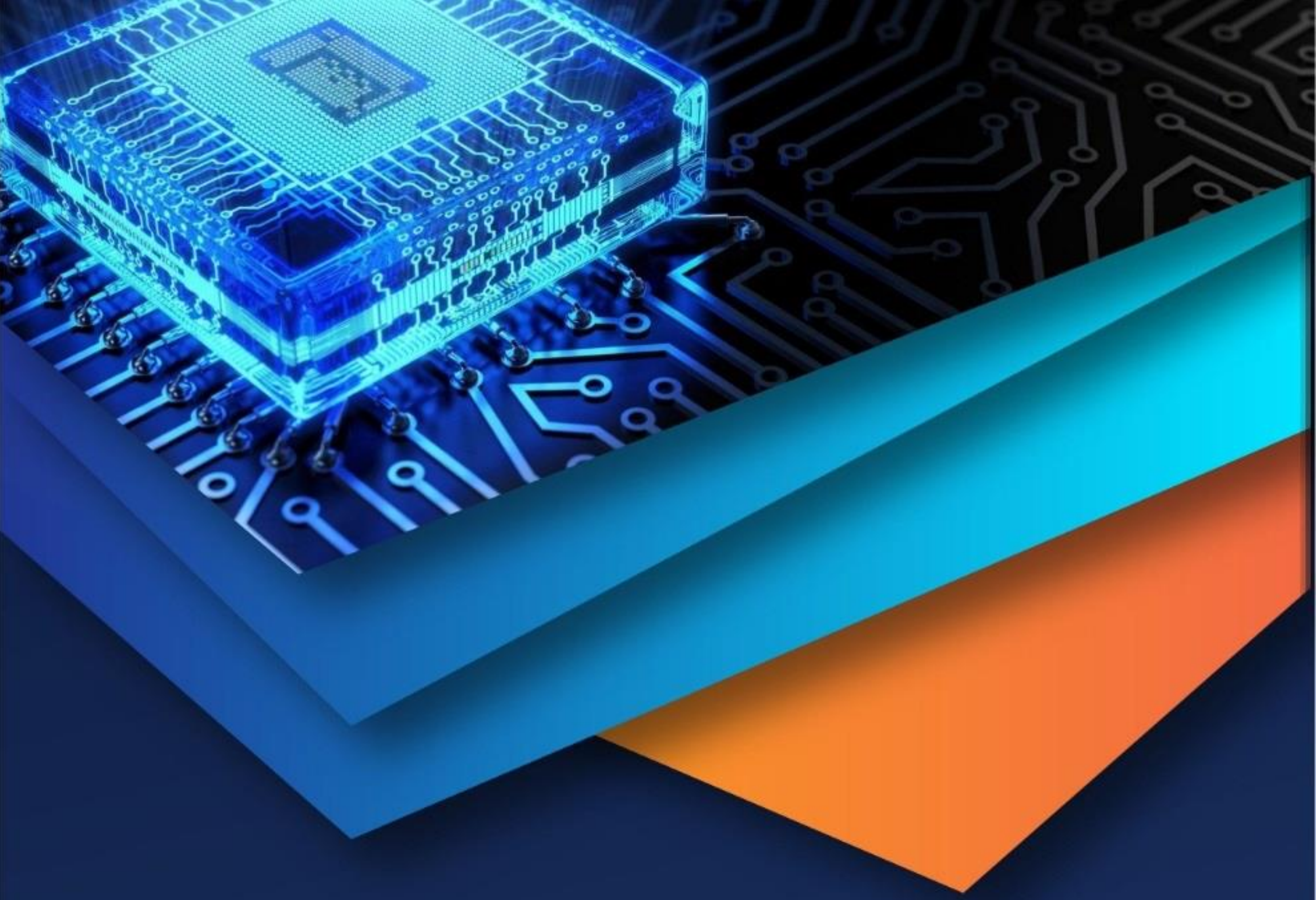
[2] On Semiconductor datasheet
https://www.skytech.ir/DownLoad/File/924_LM2576T-ADJ%20DIP.PDF
http://onsemi.com



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