ELP305 Design and Systems Lab

Dept of Electrical Engg - IIT Delhi

Final Report #3

Submitted by Team G on 06 Mar 2021

For the period 28 Feb-06 Mar 2021

Design of a SMPS based power supply for charging a mobile phone

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Date : 06 Mar 2021

Doc ID	v2.3
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Date of submission:	06 March 2021, 1800 hours

About this Document

Text Statistics

# sentences	# words	# complex words	% of complex words	Avg # words per sentences	Avg # of syllables per word
861	2995	459	15.33 %	3.48	1.65

Readability Indices

We generate these indices from the online tool .[18]

Test Result

Your page has an average grade level of about 5. It should be easily understood by 10 to 11 year olds.

Description Index	Value	Typical range and explanation
Flesch Kincaid Reading Ease	63.9	Based on a 0-100 scale. A high score means the text is easier to read. Low scores suggest the text is complicated to understand. 206.835 - 1.015 x (words/sentences) - 84.6 x (syllables/words) A value between 60 and 80 should be easy for a 12 to 15 year old to understand.
Flesch Kincaid Grade level	5.2	**Grade Level indicators** -- These equate the readability of the text to the US schools grade level system. **Flesch Kincaid Grade Level** _0.39 x (words/sentences) + 11.8 x (syllables/words) - 15.59
Gunning Fog Score	5.4	0.4 x ((words/sentences) + 100 x (complexWords/words))
SMOG Index	4.6	1.0430 x sqrt(30 x complexWords/sentences) + 3.1291
Coleman Liau Index*	10.2	5.89 x (characters/words) - 0.3 x (sentences/words) - 15.8
Automated Readability Index (ARI)*	1.2	4.71 x (characters/words) + 0.5 x (words/sentences) - 21.43

Requirements

The requirements of the charger are as follows:

- The input of the charger is a standard $220V$, $50Hz$ AC Mains supply.
- It delivers a constant $5V$ DC Output (up to $1A$ current).

- The output voltage should settle to 5% of its final value in less than $5ms$.
- Stable output for a range of inputs ($100V$ - $260V$)

Specifications

- **Electrical Specifications**
  The following electrical components have been used for the circuit design

Device/ Component	Rating/ Value	Quantity
Silicon Diode	$1N4148$	4
High Voltage Buck Converter	$LT8631$	1
Capacitor	4.7 pF	1
Capacitor	0.1 μF	1
Capacitor	5 nF	1
Capacitor	1 μF	1
Capacitor	2.2 μF	2
Capacitor	47 μF	1
Capacitor	100 μF	2
Capacitor	1000 μF	1
Resistor	25.5 $K\Omega$	1
Resistor	1 $K\Omega$	1
Resistor	191 $K\Omega$	1
Inductor	22 μH	1

- **Mechanical Specifications**
  The following mechanical components will be used for the charger

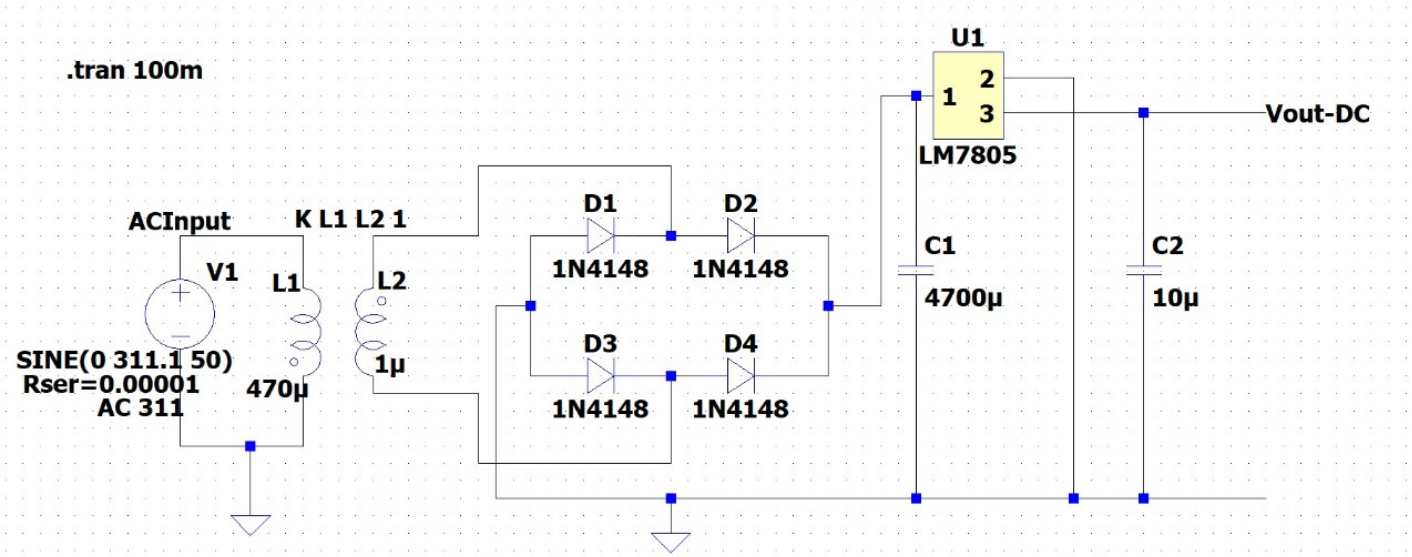
Component	Description (if applicable)	Quantity
USB 3.1 Gen 1 A Male to USB 3.1 Type C Male Cable	IEEE 1394 Cables USB 3.1 Gen 1 A Male to USB 3.1 Type C Male, 1M length, 5Gibps, Black 1, Datasheet	1
USB Connector USB 3.1 GEN2 STD A	USB-A (USB TYPE-A) USB 3.2 Gen 1 (USB 3.1 Gen 1, Superspeed (USB 3.0)) Receptacle Connector 9 Position Board Edge, Cutout; Through Hole, Right Angle Datasheet	1
PCB	LxBxH= (53.340 mm x 29.210 mm x 1.6 mm). Number of layers=6	1
Enclosure	Material- ABS(Acrylonitrile butadiene Styrene) Plastic; Polycarbonate, Weight - 20-25 grams, Input Voltage- 100-200 V, Current 3-5 Amp; 2-5 mm Thickness etc.	1
Relimate connectors/Port for input (male female plugs)	2 pin polarized wired Connecter : Relimate Connector	(2 pin - male + female)
Power plug pins	Material-Brass, Coating-Nickel, Chrome or Tin. Length- Upto 5 Inch, Material Grade-IS 319,BS 249, Finishing- Natural Brass	2

Previous (Failed/ Discarded) Attempts

This subsection aims to list down our attempts at making the mobile phone charger circuit. We started from a very basic circuit [4] and went on improving/changing it with the help of online sources [2]. Our attempts are as follows:

- **Design based on linear power supply**

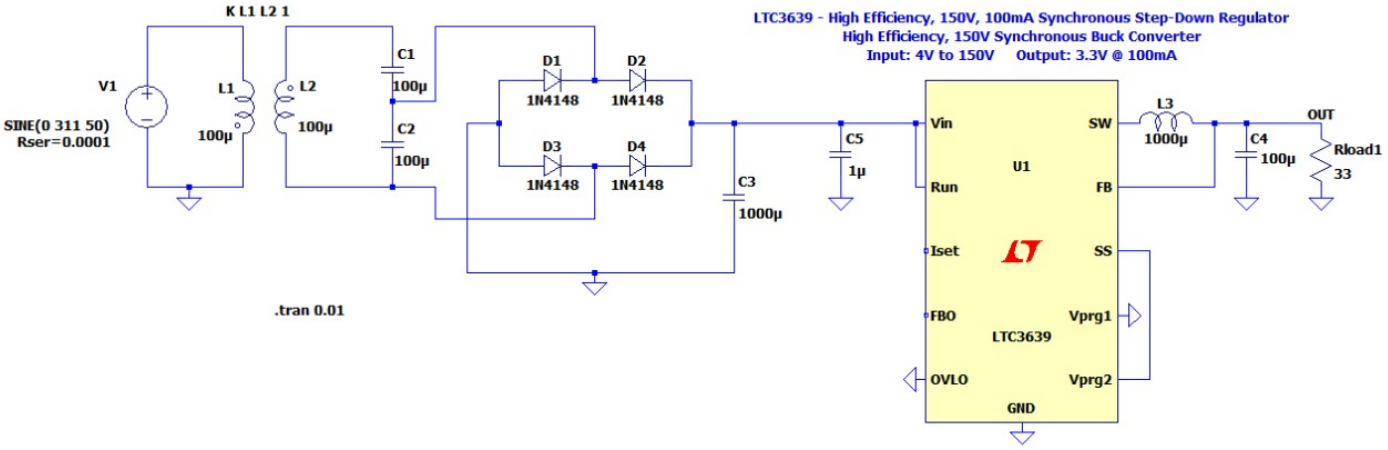
  This design ([4]) was made by (almost) all of our team members as their first design of the charger circuit. The design included a transformer to step down the voltage from 220V, a rectifier for conversion to DC and a regulator for constant 5V output. The typical circuit used by most of our team members is as follows:



This was a simple circuit, and the transformer in such a circuit (working at 50Hz) would take up a lot of space and would be bulky. Due to these disadvantages, we discarded this design completely and designed the circuit from scratch using an SMPS (switched mode power supply)([6][9]).

- **SMPS Design 1**

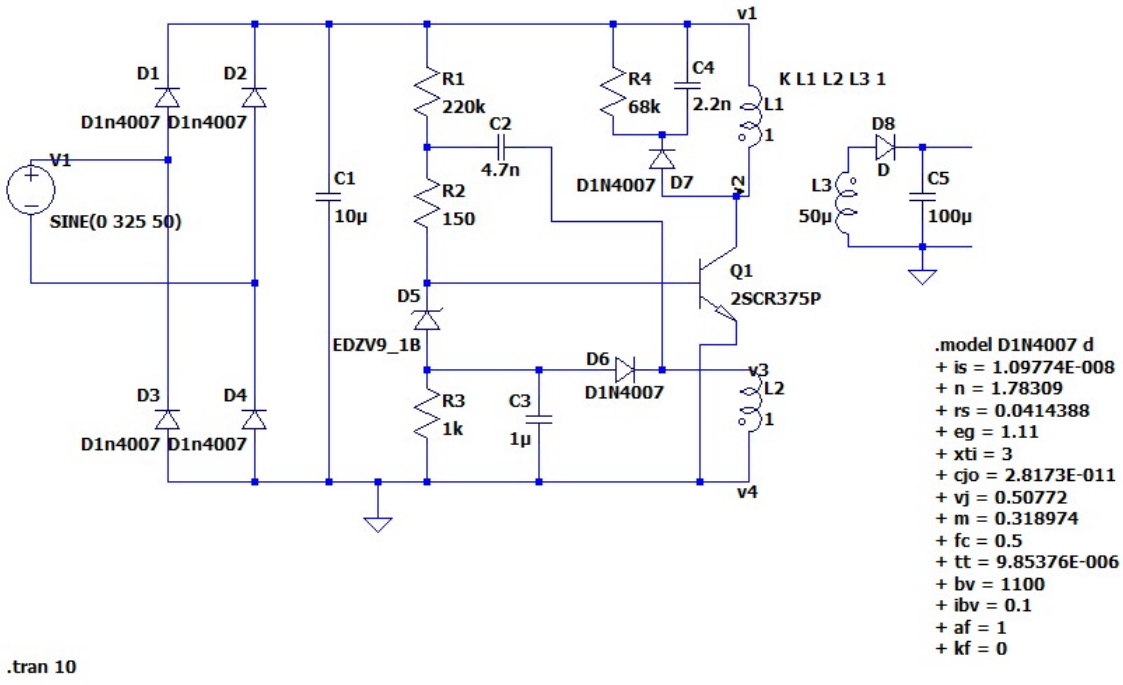
  We now made a Switch Mode Power Supply (SMPS) based design. The following circuit uses LTC3639[1][10]. LTC3639 is a 150V, 100mA, synchronous step-down converter(Buck Converter) + a regulator to step down and regulate the output, respectively. This approach did not work because LTC3639 couldn't handle a load current >100mA.



The AC to DC conversion is achieved using a bridge rectifier. The buck converter is part of LTC3639 and can handle no more than 150V of the input voltage. Hence we use 2 capacitors ($100\mu F$ each) using which some voltage was dropped across the first capacitor and then this voltage (<150V) was fed into the LTC3639 where the buck converter stepped it down further.

- **SMPS Design 2**

  The following circuit was obtained from ([2]). We simulated it in LTSpice but we were not able to get it to work well because we could not find an appropriate transistor (rating 800V, 3A) which was originally mentioned in the source([2]).



This circuit uses a flyback 5V,2A single switching power supply i.e. it uses a transformer to store energy in the primary winding and propagate this energy to the secondary winding. There is no isolation transformer in this circuit.

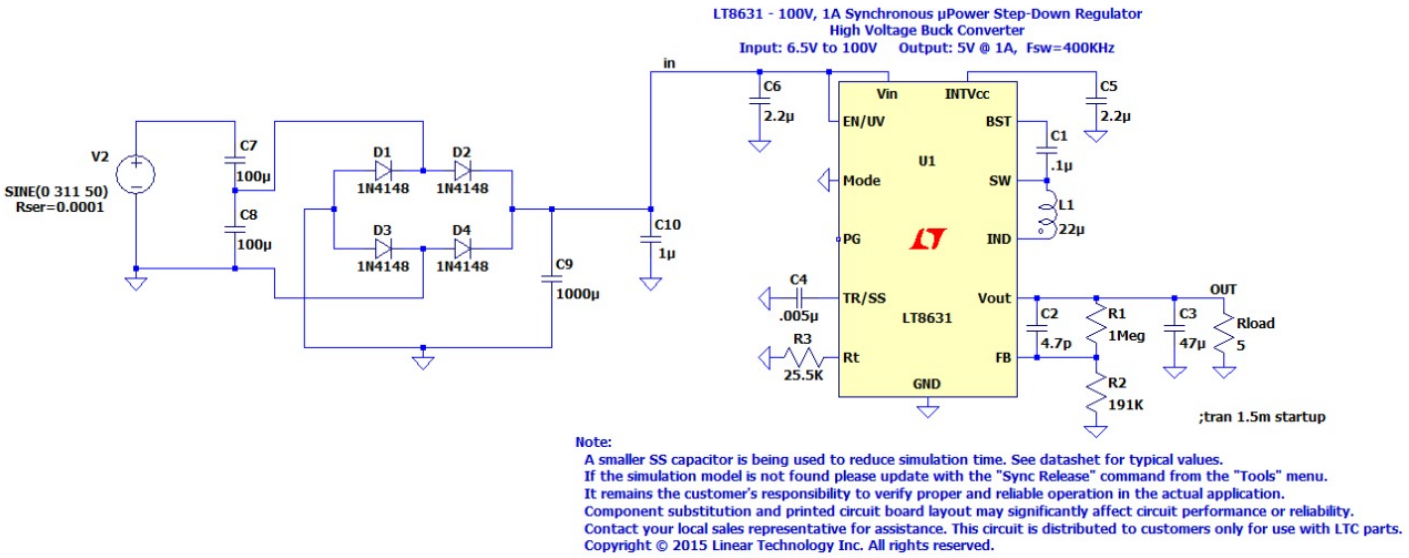
The input voltage (220V) is rectified using the bridge rectifier (constructed using the 4, 1N4007 diodes). The capacitor C1 smoothens out this rectified voltage to output 311V(pk-pk). The voltage step-down is achieved using the primary (L1) to secondary (L3) transformer assembly in the circuit. Voltage regulation is carried out on the auxiliary winding (L2) and this regulates the output voltage.

Flow diagram and Final Schematic

The following flow and schematic were finalised.

- **Flow diagram**

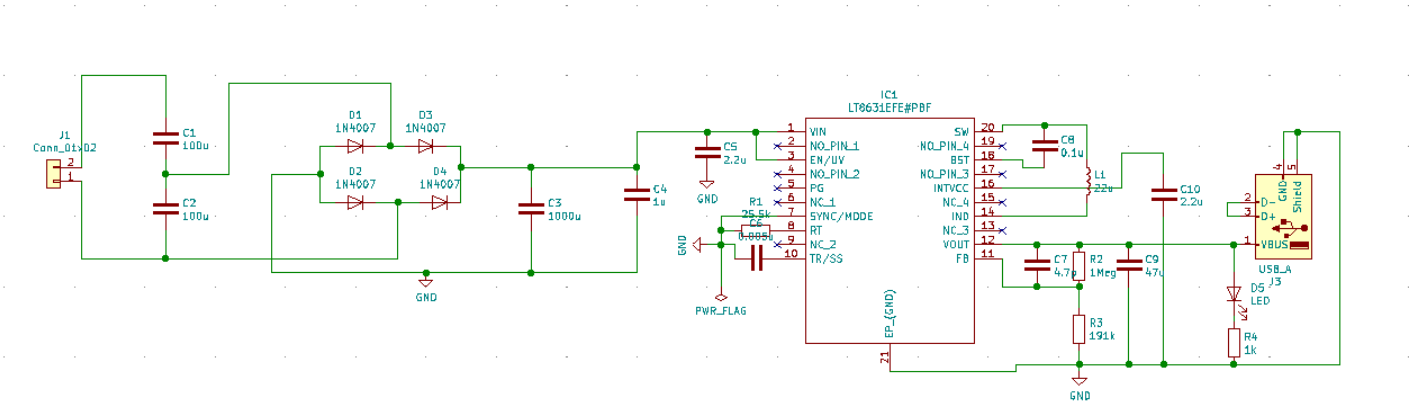
- **Schematic**



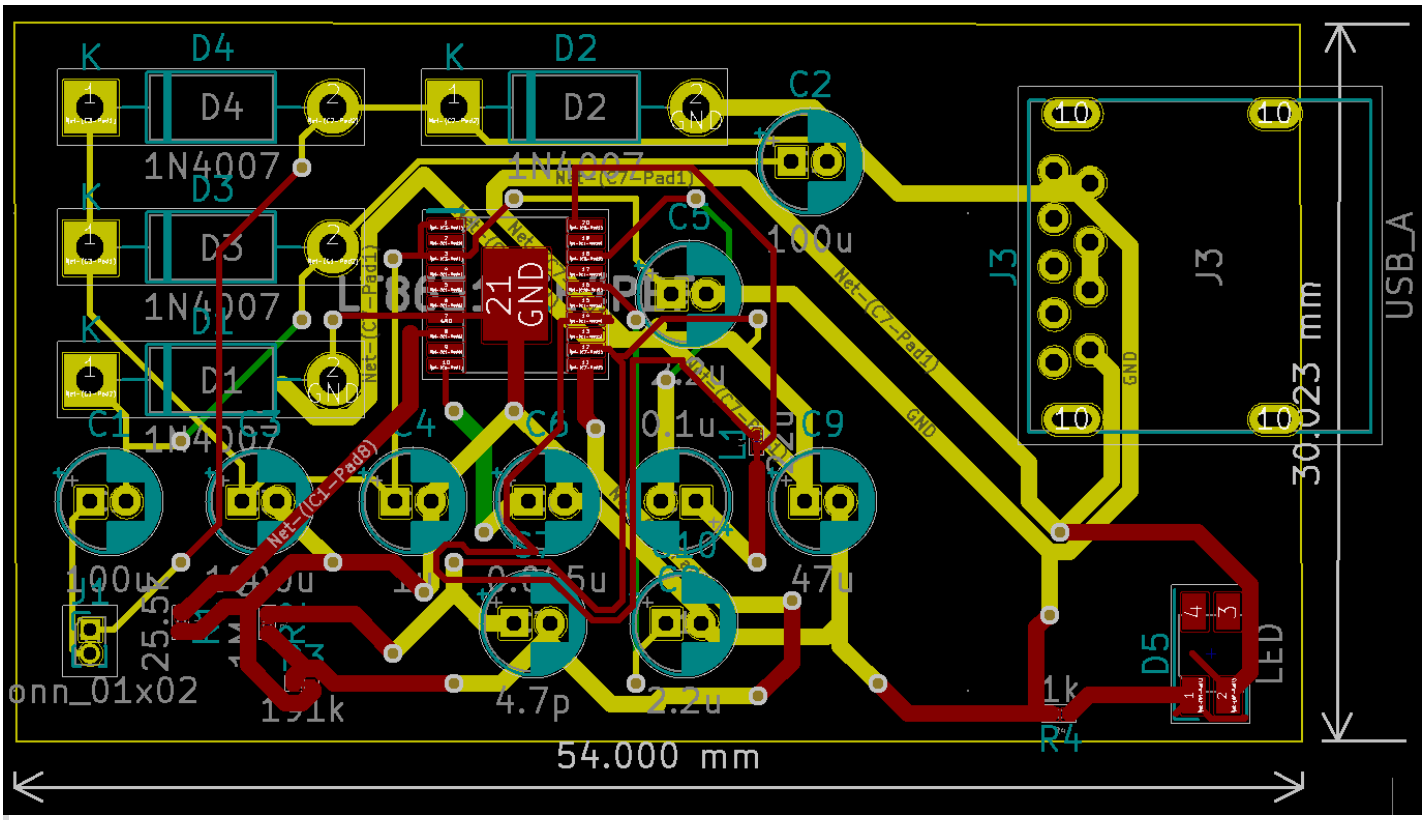
The input (220V, 50Hz) is taken from mains. Voltage division is done using two capacitors, and not via resistors to minimize I^2R losses. This is then rectified using a bridge rectifier, and a capacitor is placed at the output to generate a stable DC voltage. This DC voltage, which is of the order of 100V, is the input into the high voltage buck converter IC. The values of the peripheral components were chosen as given in the datasheet of the IC, to generate a stable 5V output. Another capacitor, $C3$ is placed across the output to smoothen out any residual perturbations in the output voltage.

- **PCB design**

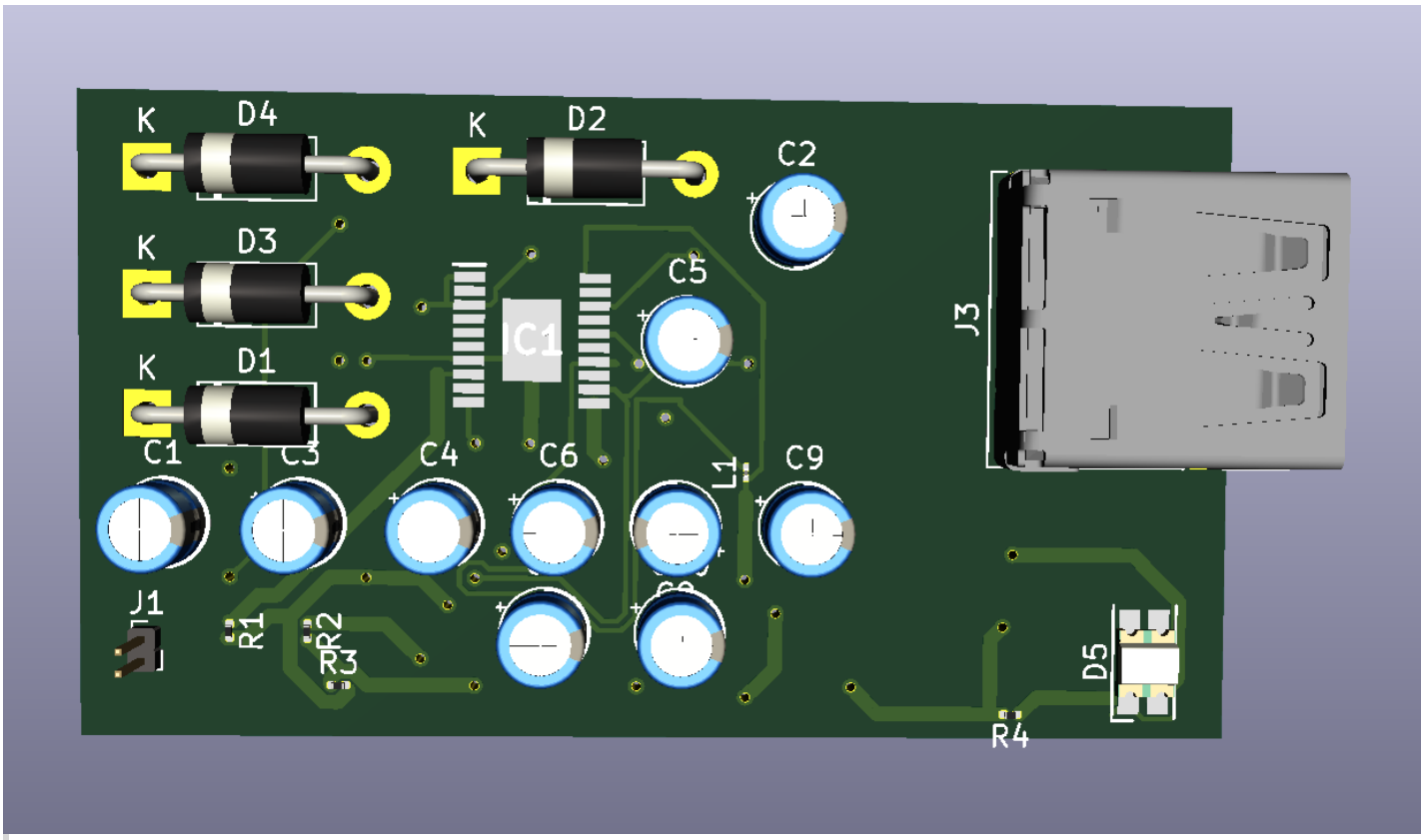
We used a 6 layer pcb design. The dimensions of the pcb are : thickness = 1.6mm, length = 54.00 mm, width = 30.023 mm. Keeping the temperature tolerance into account, the length of the wire used in designing the PCB is calculated using PCV trace width tool ([17]). For instance, a wire of thickness 0.7mm is used from IC to output.
An LED was connected to the output of the circuit along with a resistor to indicate that th ecircuit was working correctly.



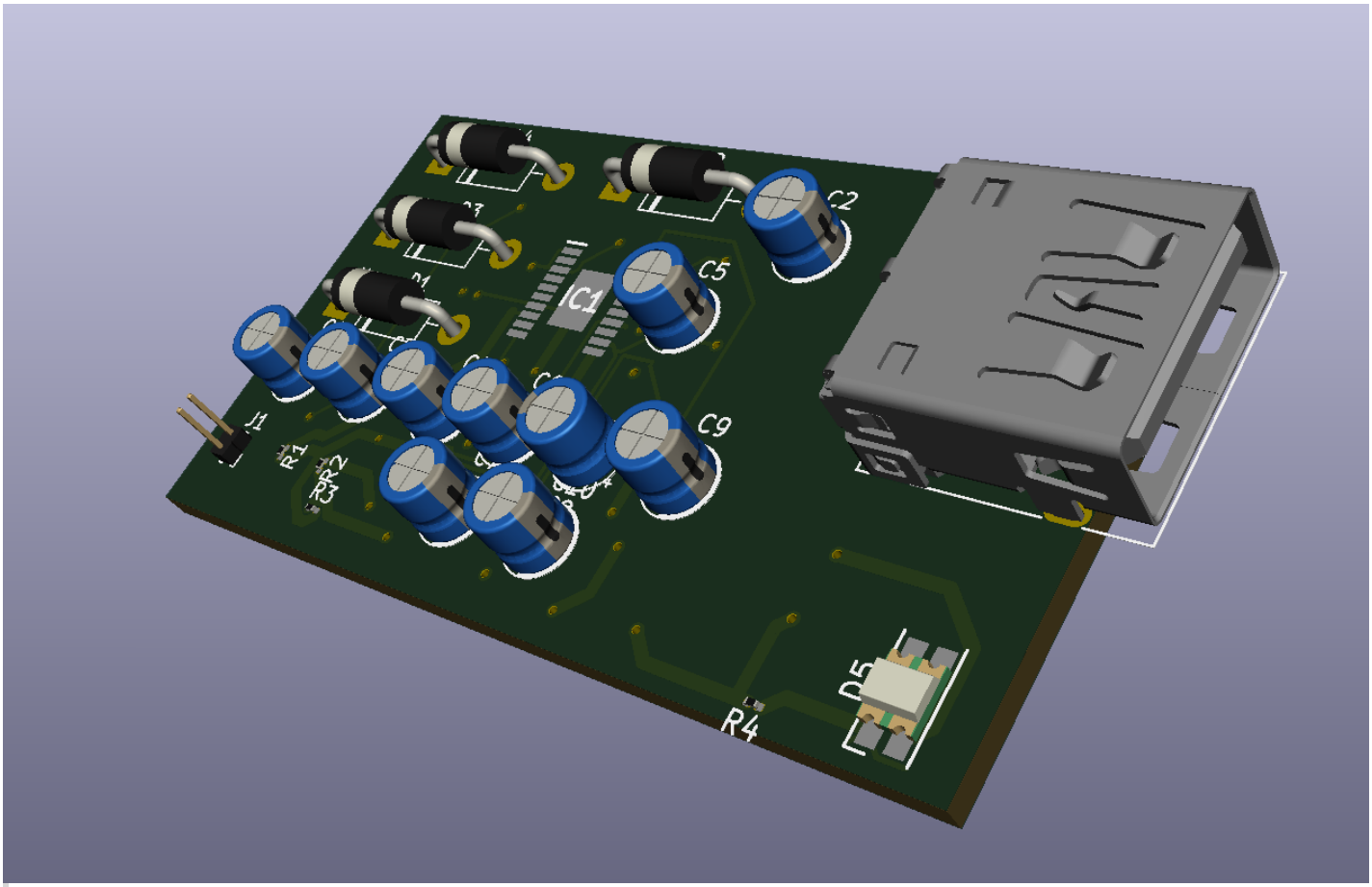
> Circuit Schematic in KiCad



PCB layout



3D model top view



3D model isometric

Inputs:

Current	1.5	Amps
Thickness	2	oz/ft^2

Optional Inputs:

Temperature Rise	10	Deg C
Ambient Temperature	25	Deg C
Trace Length	1	inch

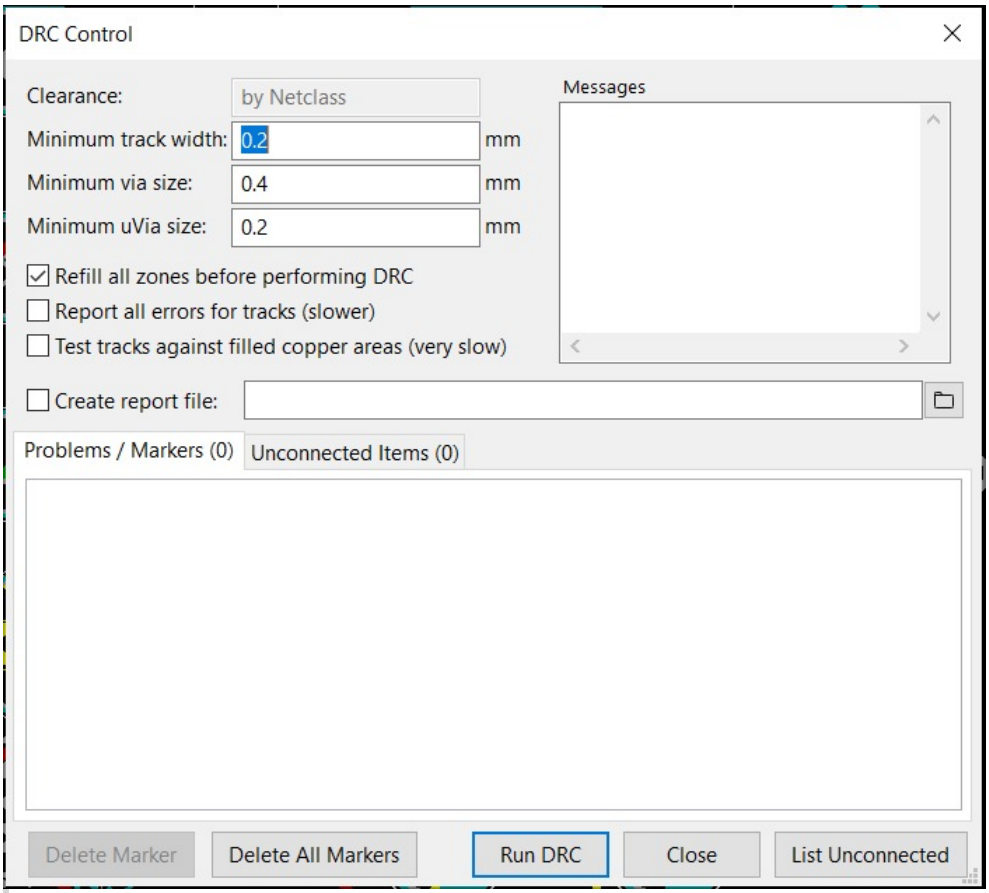
Results for Internal Layers:

Required Trace Width	0.684	mm
Resistance	0.00938	Ohms
Voltage Drop	0.0141	Volts
Power Loss	0.0211	Watts

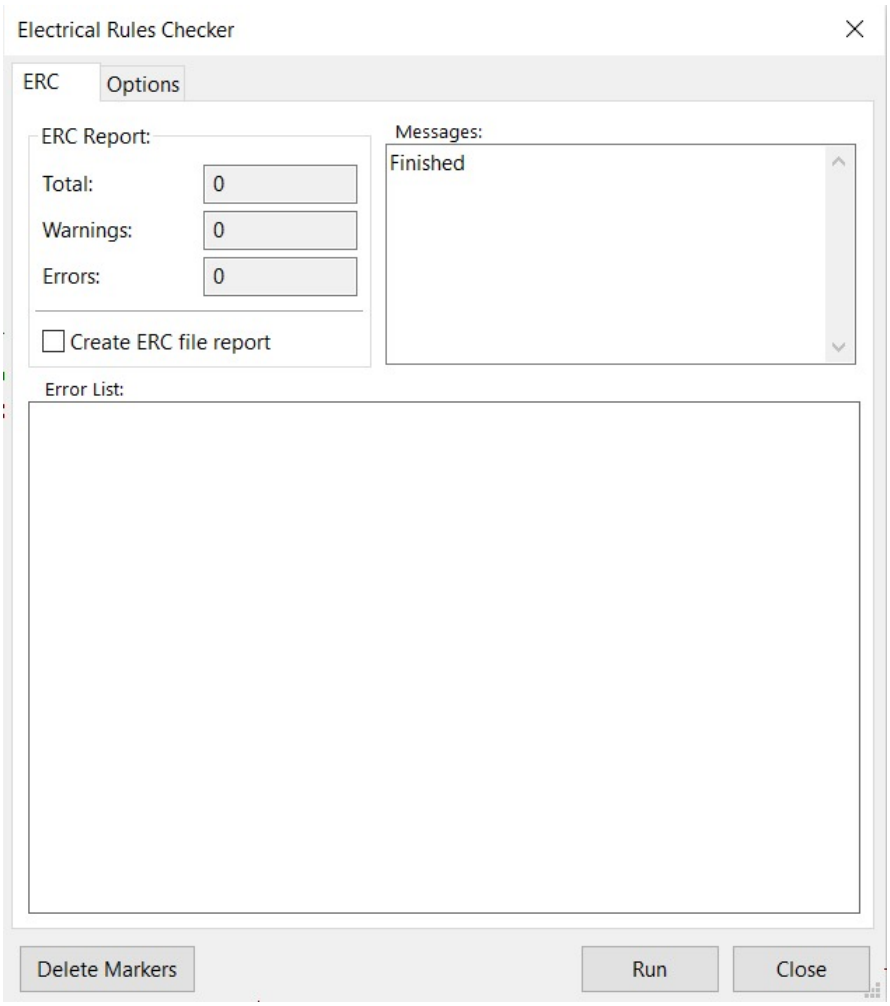
Results for External Layers in Air:

Required Trace Width	0.263	mm
Resistance	0.0244	Ohms
Voltage Drop	0.0366	Volts
Power Loss	0.0549	Watts

Calculation of Track length for the PCB

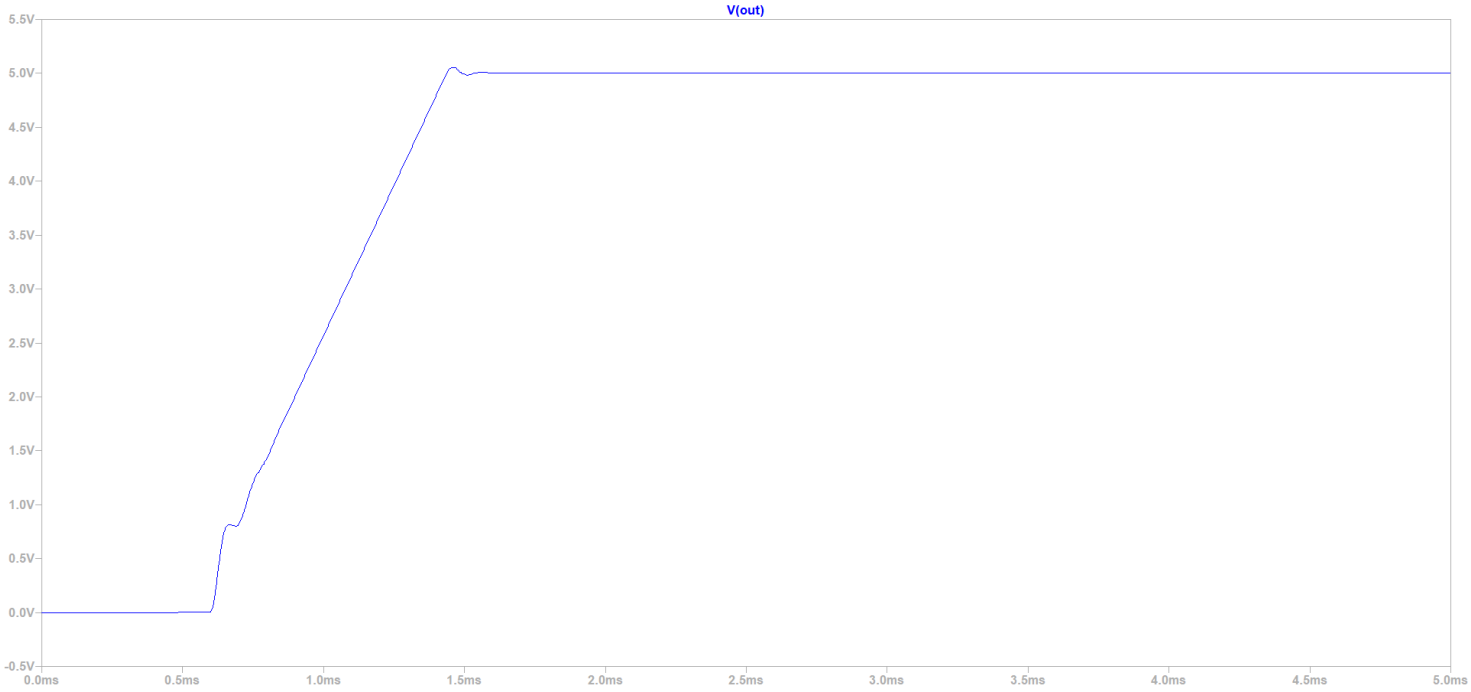


DRC results depicting correctness of PCB

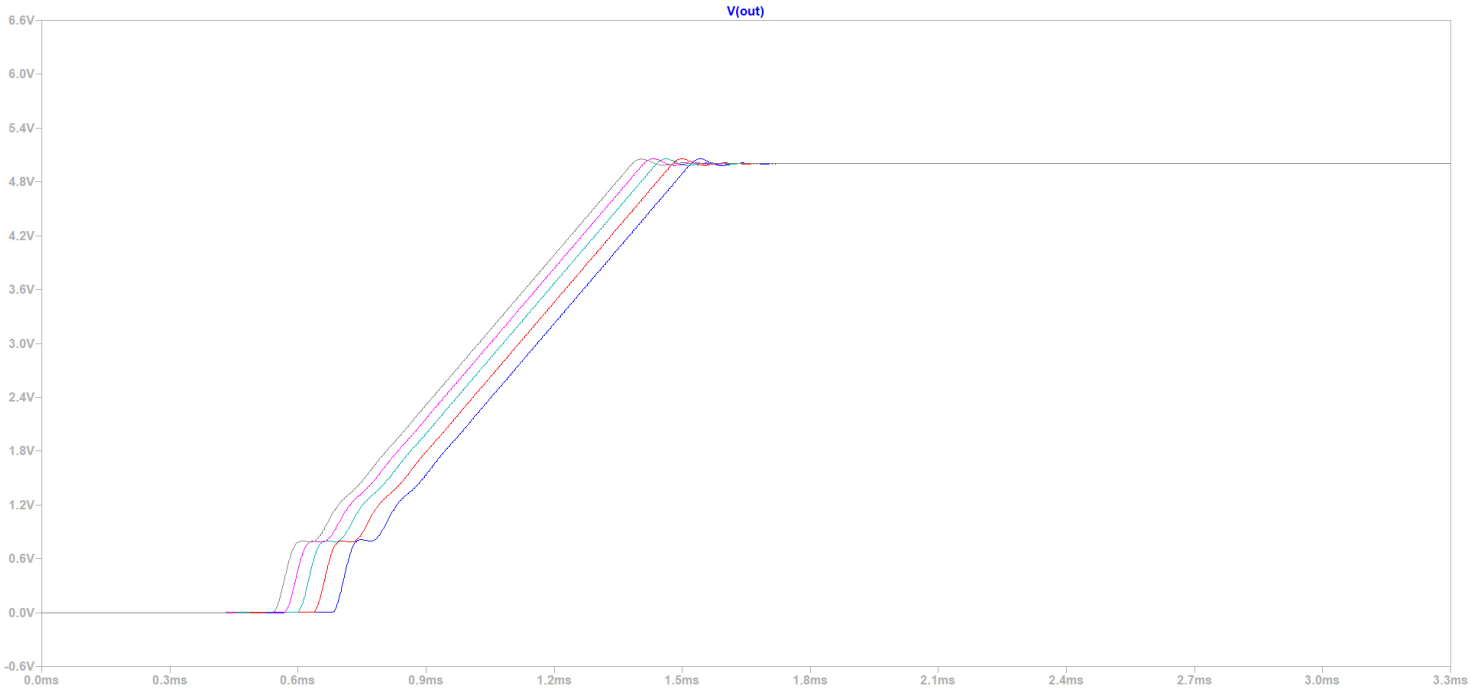


> Electrical Rule Checker of Schematic

Simulation Results

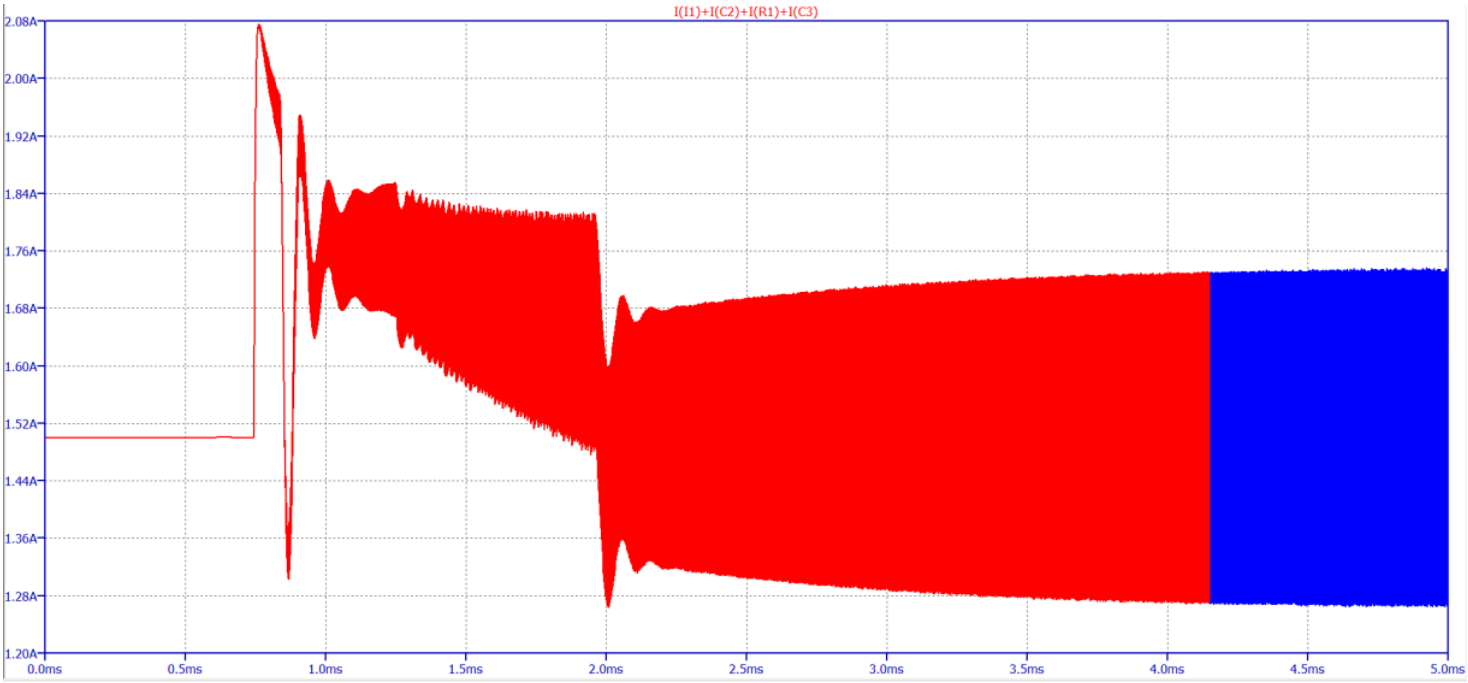


Simulation of regulated DC output(5V).
The time required to attain steady voltage(on 220V,50Hz input) is 1.5 ms.



> The settling time of a dynamical system such as an amplifier or other output device is the time elapsed from the application of an ideal instantaneous step input to the time at which the output has entered and remained within a specified error band

Input voltage (RMS) was varied from 100V (like in Japan)⟶ 260V in steps of 40V. Decreasing the input voltage causes the settling time to increase, that is, it takes longer to settle to 5V. But, the difference is very minute and is of not much practical significance.



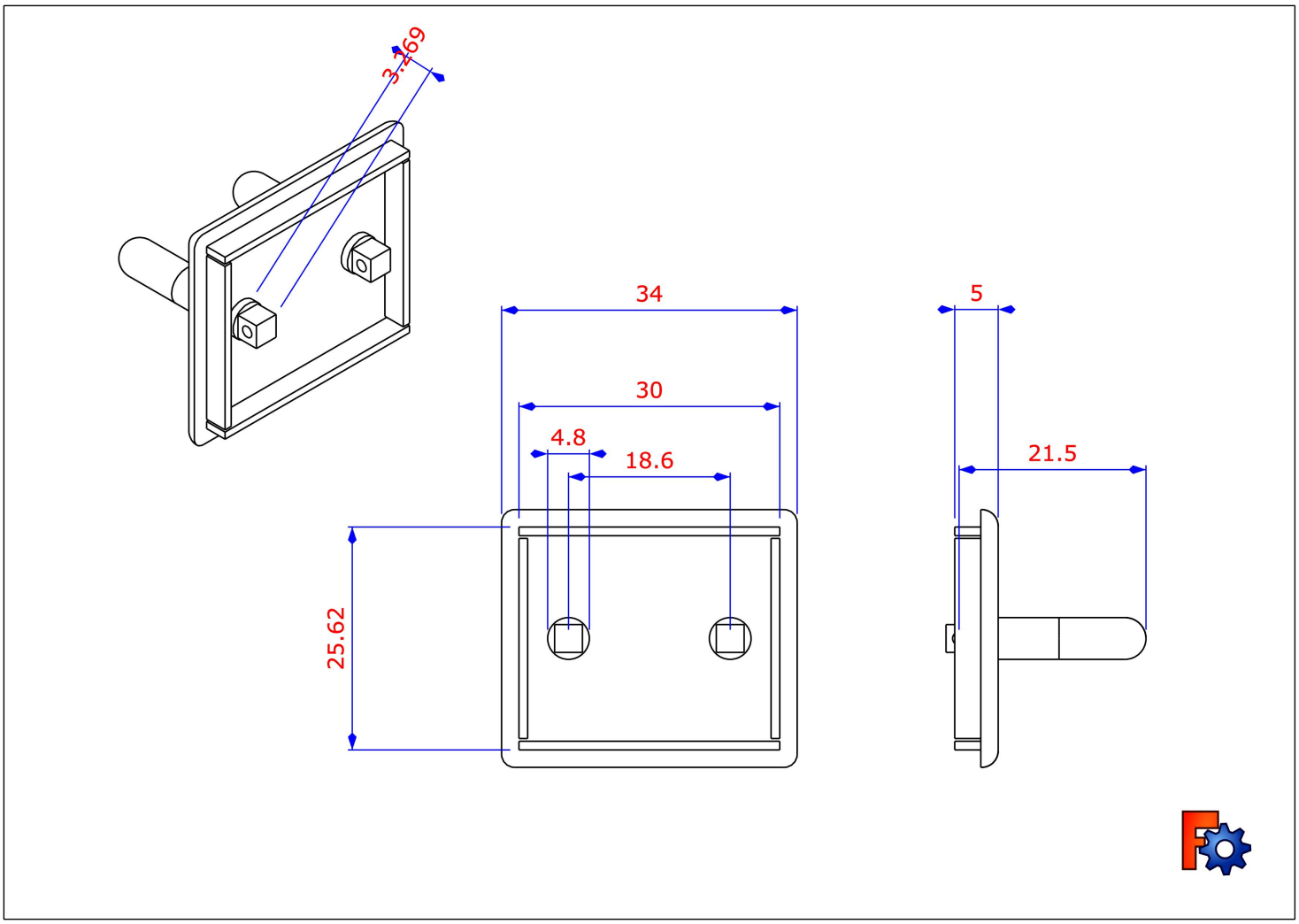
Output current of IC LT8631 at 1.5A output loading.
When a current of more than 1.5A is drawn from the output, the voltage falls steeply.

Enclosure Design

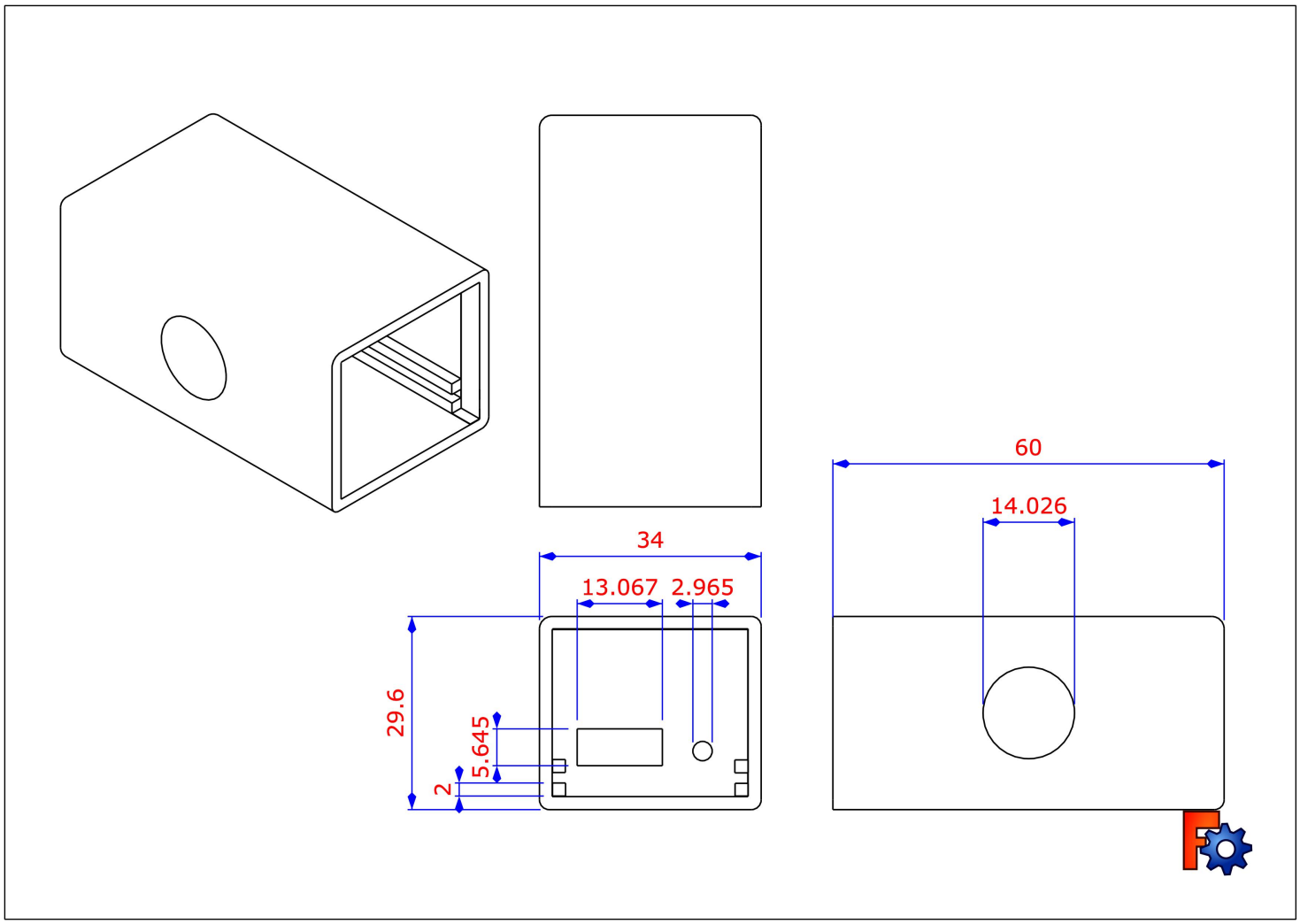
The details and salient features of the enclosure design are as follows:

- Consists of 2 parts, which press fit into each other.
- In Part 1, the pins are placed keeping in mind the standard dimensions of a 2 pin europlug [13].
- Tolerences in the range of 0.0059-0.00059mm are introduced for a satisfactory fitting of part 1 into part 2 of the enclosure.
- Comes with grips on the side easy removal and handling of the charger as well as better ergonomics for the person holding it.
- For inserting the PCB, our enclosure part 2 has rails on the side, which hold the PCB
- We have a slot (hole) for inserting a USB into the PCB and a hole which makes the 3mm led visible and helps the person to see if the phone is charging
- The overall dimensions of the charger is length = 60mm, width = 34 mm, height = 29.6 mm [17].

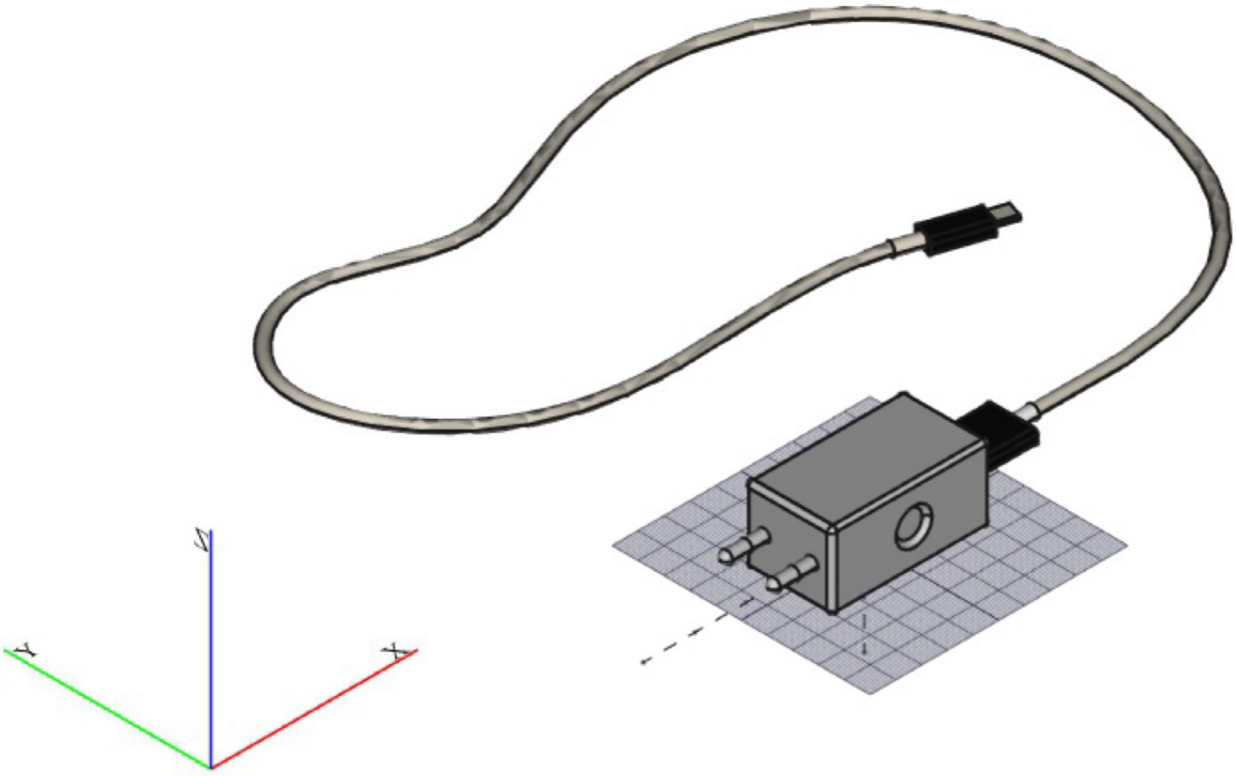
Part 1



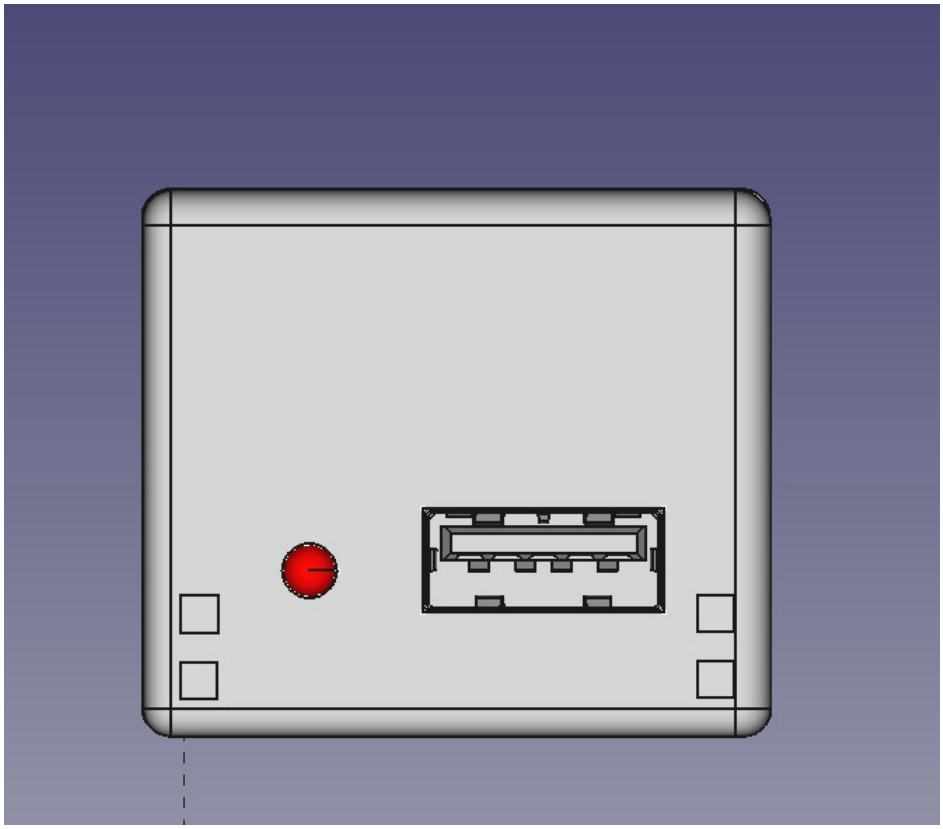
Part 2



Isometric view of 3D charger



Back Side view of 3D charger



Future work/ improvements

We propose and aim to work on the following to improve the design, output and other specifications of the charger by the end of the assignment.

- Increasing the output current of the circuit for faster charging.
- Include safety precautions within our circuit. This can be done by preventing short circuits by the use of fuses so that the charger isn't completely damaged and is usable (after replacing the fuse).
- Increase the rated output from 5W to a higher value (eg 10-15 W).

Bill of Materials[8]

- **Bill of Electrical Materials**

TYPE	RATING	MANUFACTURER	DATASHEET LINK	VENDOR LINK	MIN QTY	PRICE PER UNIT	QTY	SUBTOTAL
Silicon Diodes	1N4148	ON Semiconductor 1N4148	Link	Link	4	₹7.30 for 1unit, ₹0.511 per unit for 50,000 units	2,00,000	₹1,02,500
High Voltage Buck Converter	LT8631	Analog Devices LT8631IFE#PBF	Link	Link	1	₹653.35 for 1unit, ₹365.00 per unit for 1,000 units	50,000	₹1,82,50,000
Capacitor 2	$4.7pF$	AVX 0603ZA4R7CAT2A	Link	Link	1	₹19.71 for 1unit, ₹2.56 per unit for 24,000 units	50,000	₹1,28,000
Capacitor 4	$5nF$	AVX 0402ZC501KAT2A	Link	Link	1	₹23.36 for 1unit, ₹3.36 per unit for 20,000 units	50,000	₹1,68,000
Capacitor 1	$0.1\mu F$	Nichicon UUP1H0R1MCL1GS	Link	Link	1	₹43.80 for 1unit, ₹12.19 per unit for 2,000 units	50,000	₹6,09,500
Capacitor 10	$1\mu F$	Panasonic EEE-1HA010NR	Link	Link	1	₹23.36 for 1unit, ₹5.55 per unit for 2,000 units	50,000	₹2,77,500
Capacitor 5,6	$2.2\mu F$	Panasonic ECE-A1HKA2R2B	Link	Link	2	₹15.33 for 1unit, ₹2.85 per unit for 2,000 units	1,00,000	₹2,85,000
Capacitor 3	$47\mu F$	Panasonic ECA-1EHG470C	Link	Link	1	₹16.06 for 1unit, ₹2.56 per unit for 50,000unit	50,000	₹1,28,000
Capacitor 7	$100\mu F$	Panasonic EEH-ZS1V331P	Link	Link	2	₹130.67 for 1unit, ₹52.12 per unit for 2500 units	50,000	₹26,06,000

TYPE	RATING	MANUFACTURER	DATASHEET LINK	VENDOR LINK	MIN QTY	PRICE PER UNIT	QTY	SUBTOTAL
Capacitor 8	$100\mu F$	Panasonic ECA-1CM101	Link	Link	1	₹11.68 for 1unit, ₹2.12 per unit for 50,000unit	50,000	₹1,06,000
Capacitor 9	$1000\mu F$	Panasonic EEU-FP1E102B	Link	Link	1	₹78.84 for 1 unit, ₹23.00 per unit for 25,000 units	50,000	₹11,50,000
Resistor 3	$25.5k\Omega$	Panasonic ERJ-P06F2552V	Link	Link	1	₹14.60 for 1unit, ₹1.68 per unit for 5,000 units	50,000	₹84,000
Resistor 1	$100k\Omega$	Panasonic ERA-3VEB1003V	Link	Link	1	₹38.69 for 1unit, ₹8.03 per unit for 5,000 units	50,000	₹4,01,500
Resistor 2	$191k\Omega$	Panasonic ERJ-U12D1913U	Link	Link	1	₹48.91 for 1unit, ₹8.54 per unit for 5,000 units	50,000	₹4,27,000
Inductor	$22\mu H$	Coilcraft RFC0807B-223KE	Link	Link	1	₹59.13 for 1unit, ₹27.52 per unit for 2,000 units	50,000	₹13,76,000

Total Cost = ₹26,099,500

Cost Per Charger = ₹521.99

- **Bill of Mechanical Materials**

NAME	DESCRIPTION	MANUFACTURER (if applicable)	DATASHEET LINK	VENDOR LINK	MIN QTY	PRICE PER UNIT	QUANTITY	SUB-TOTAL
USB 3.1 Gen 1 A Male to USB 3.1 Type C Male Cable	IEEE 1394 Cables USB 3.1 Gen 1 A Male to USB 3.1 Type C Male, 1M length, 5Gibps, Black 1	Qualtek	Link	Link	1	₹911.04 for 1 unit, ₹550.42 per unit for 1000 units	50000	₹27521000

NAME	DESCRIPTION	MANUFACTURER (if applicable)	DATASHEET LINK	VENDOR LINK	MIN QTY	PRICE PER UNIT	QUANTITY	SUB-TOTAL
USB Connector USB 3.1 GEN2 STD A	USB-A (USB TYPE-A) USB 3.2 Gen 1 (USB 3.1 Gen 1, Superspeed (USB 3.0)) Receptacle Connector 9 Position Board Edge, Cutout; Through Hole, Right Angle	Molex	Link	Link	1	₹113.12 for 1 unit, ₹60.77 per unit for 50000units	50000	₹3038844
PCB Board	LxBxH= (53.340 mm x 29.210 mm x 1.6 mm) Number of layers=6	PCB Cart		Link	1	₹31.19 per unit for 50000 units	50000	₹15,59,500
Power plug pins	Material-Brass, Coating-Nickel, Chrome or Tin. Length- Upto 5 Inch, Material Grade-IS 319,BS 249, Finishing-Natural Brass	Prime industrial components		Link	1	₹1 per unit for 10000 units	50000	₹50000
Enclosure Manufacturing	Material-ABS(Acrylonitrile butadiene Styrene) Plastic; Polycarbonate, Weight - 20-25 grams, Input Voltage- 100-200 V, Current 3-5 Amp; 2-5 mm Thickness etc.	Sushil Engineering Works; Aditya Enterprises		Link	1	₹80 per unit for 3000 units	50000	₹4000000
Relimate connectors/Port for input (male female plugs)	2pin Polarized wired Connecter : Relimate Connector (2 pin - male + female) Specification Relimate Wired Connector 2 pins Pitch: 2.54mm			Link	1	₹4.24 per unit ₹3.90 per unit for 50 units and above	50000	₹195,000

Total Cost = ₹3,63,64,344

Cost / Unit = ₹727.28

Total Cost / Unit (Electrical Components + Mechanical)= ₹1249.27

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