MPPT

What is MPPT?

MPPT follows the peak value of the power obtained in certain periods and sends it to the load in DC-DC inverters. The regulator will work out at which point the cell will output the maximum power and derive from this the voltage and current outputs required for maximum power to be achieved.

Some core specifactions about MPPT[26,17]

- 12 V or 24V battery output
- 20 A peak charging current
- 55 V max PV (photovoltaic)
- 32 bit MCU (in our project STM32)
- CAN communication interface with standard RJ45 jacks

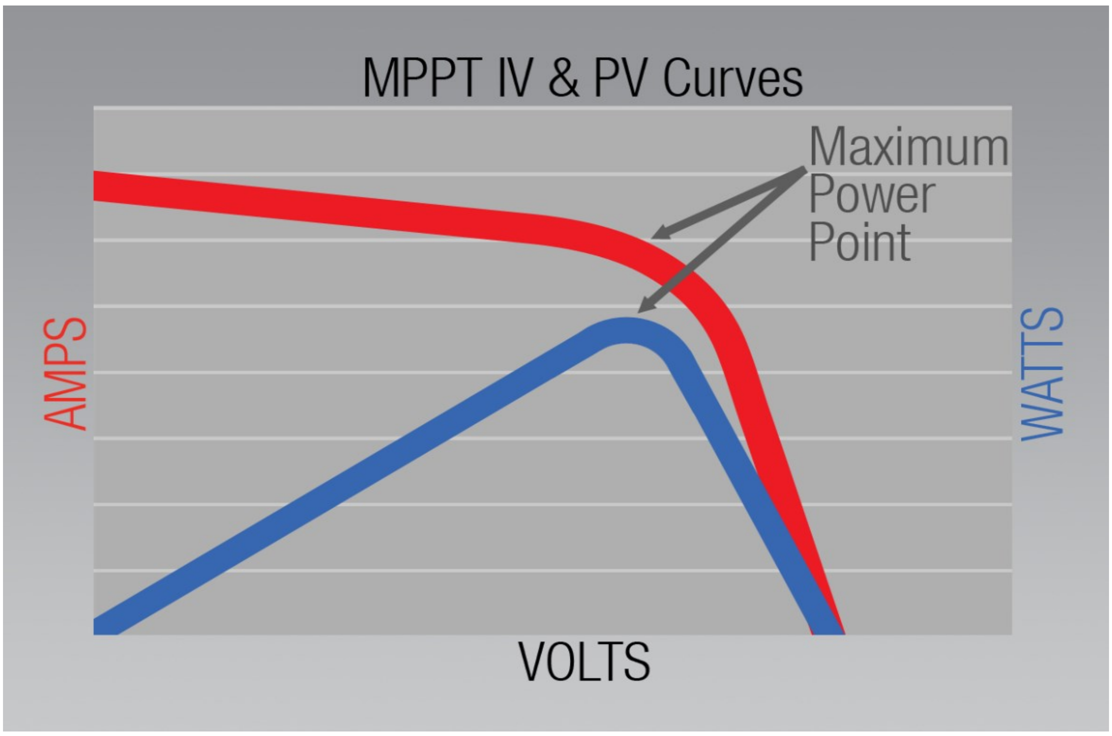


Fig. 46 MPPT Graphs

MPPT ALGORITHM

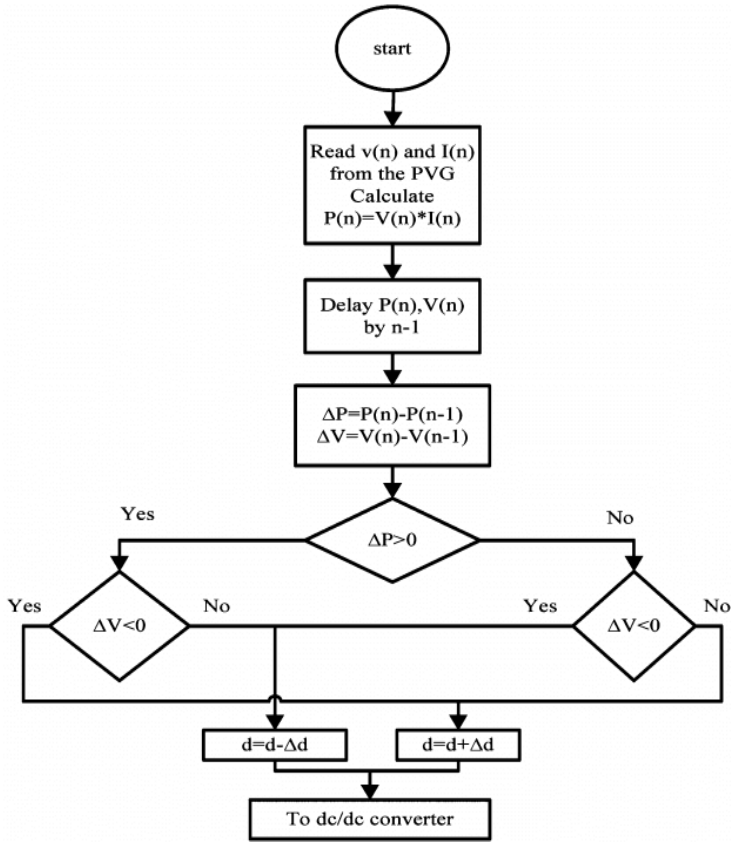


Fig. 47 MPPT Algorithms

To arrange the maximum power point, MPPT has an algorithm inside of it. MPPT tries to find maximum power point with changing the duty.

Logic in this algortihm is simple; we want to reach maximum power and to reach that we should check delta power first. After that we should look for voltage value to understand what we should do with duty cycle (Vo=Vs x D).

If delta power (power difference) is bigger than 0 which also means if change on power is positive, then we will look for delta voltage. If delta voltage is smaller than 0, that means we should increase the duty which is shown as d.

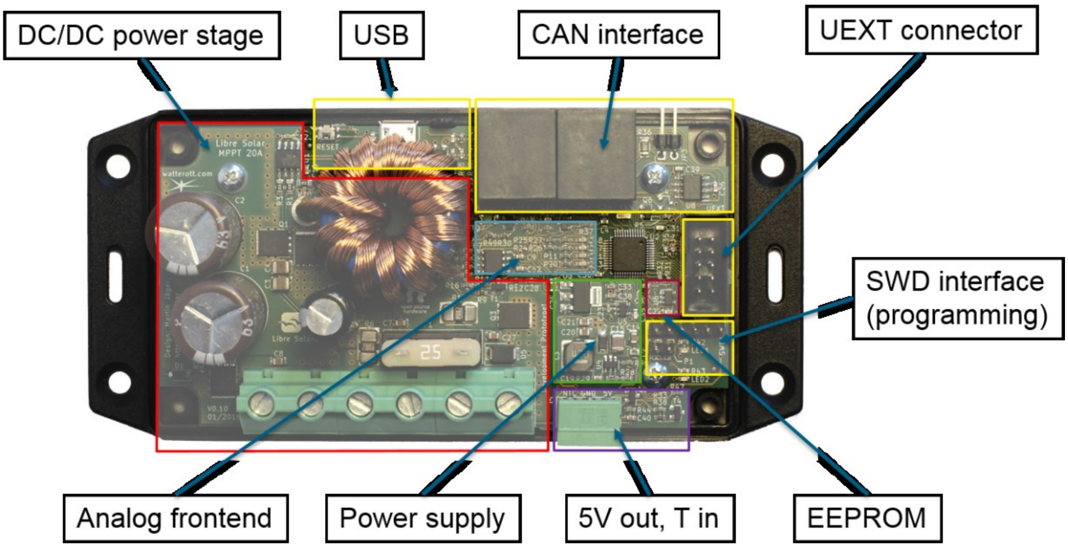


Fig. 48 Parts of MPPT

Parts of MPPT

EEPROM

It means electrically erasable programmable read-only memory.

UEXT Connector

Universal EXTension (UEXT) is a connector layout which includes power and three serial buses: Asynchronous, I2C, and SPI.

CAN Interface

CAN (Controller Area Network), CANopen'ın fiziksel katmanını oluşturan ve otomotiv otomasyonunda kullanılmak üzere Bosch firması tarafindan geliştirilen bir seri ağ teknolojisidir

CAN is a half duplex high speed network system with double twisted cables. It meets many needs, including real-time communication between microcontrollers.

SWD Interface

Serial wire debug is an ARM-specific protocol specifically designed for micro debugging.

DC/DC Power Stage

DC/DC converters are used in applications where an average output voltage is required, which can be higher or lower than the input voltage.

The converter presents an electrical load to the solar panel that varies as the output voltage of the converter varies. This load variation in turn causes a change in the operating point (current and voltage characteristics) of the panel. Thus by intelligently controlling the operation of the DC-DC converter, the power output of the panel can be intelligently controlled and made to output the maximum possible.

There are 3 types of DC-DC converter;

1- **Buck-Boost Converters (bidirectional)**

Buck / boost converters are an inverting DC-DC converter, that is, it converts the alternans of the input voltage to reverse polarity. While the positive end is on the upper side at the input, the polarity of the voltage has changed by passing to the lower side at the output.

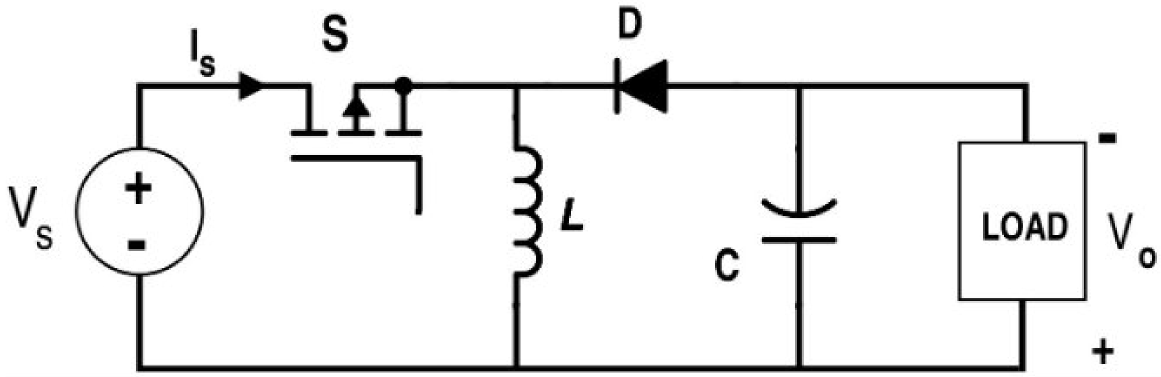


Fig. 49 Buck-Boost Converter Circuit

Like boost converters, there are 2 modes:

- **Closed Switch**
- **Open Switch**

Closed Switch

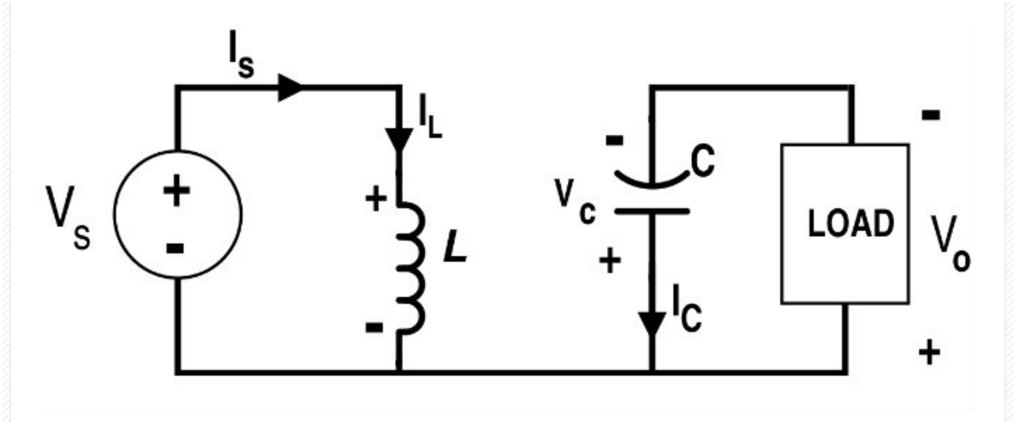


Fig. 50 Closed Switch

The coil in the circuit is energized by the energy coming from the source. On the right, the energy on the capacitor is transferred to the load. In this case, D diode in the circuit is cut. Since the average voltage of the coil and the average current of the capacitor are zero in direct current circuits, the voltage of the coil will be reversely induced in the other (when the switch is cut) in the circuit and the current of the capacitor will flow in the opposite direction.

Open Switch

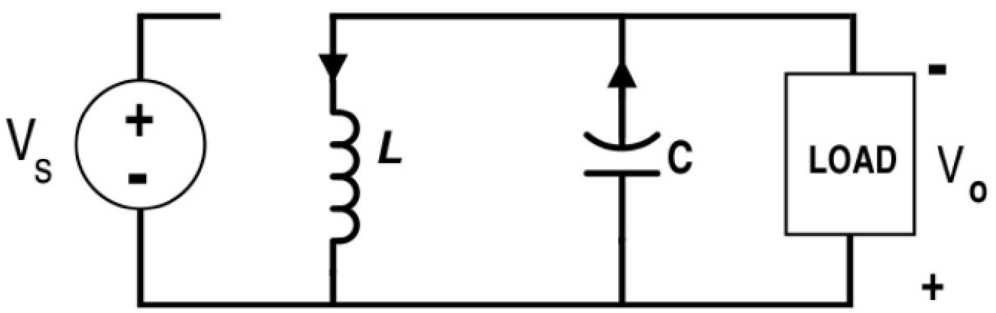


Fig. 51 Open Switch

In the previous case, the coil energized through the input source discharges its energy on C and load. The capacitor, which transferred its energy to the load in the previous case (Switch transmission), is re-energized with the energy coming from the coil in the second case. The circuit diagram of the second situation, in which the switching element is cut, is given in the following figure. In this case, since the input source will be completely disconnected from the circuit, the circuit is fed through the coil. In the circuit below, current flows through the D diode until the coil is de-energized, and the capacitor is fed with this current.

*Here its what i find on libre solar site; **'As a synchronous buck converter, the DC-DC power stage can be changed into a boost converter by software. In this case, current flow goes from the battery output to the solar input. This feature can be used to charge an electric bike battery pack with 36V nominal voltage using a 12V solar pannel. Sounds strange, but works and has been tested already. The 5V output is needed to switch on the bicycle battery (e.g. Bosch or Specialized).'**

2- Boost Converter (Step Up)

Boost Converters are using for increasing the voltage to wanted value. These converters works with 2 mode which are open and closed switch.

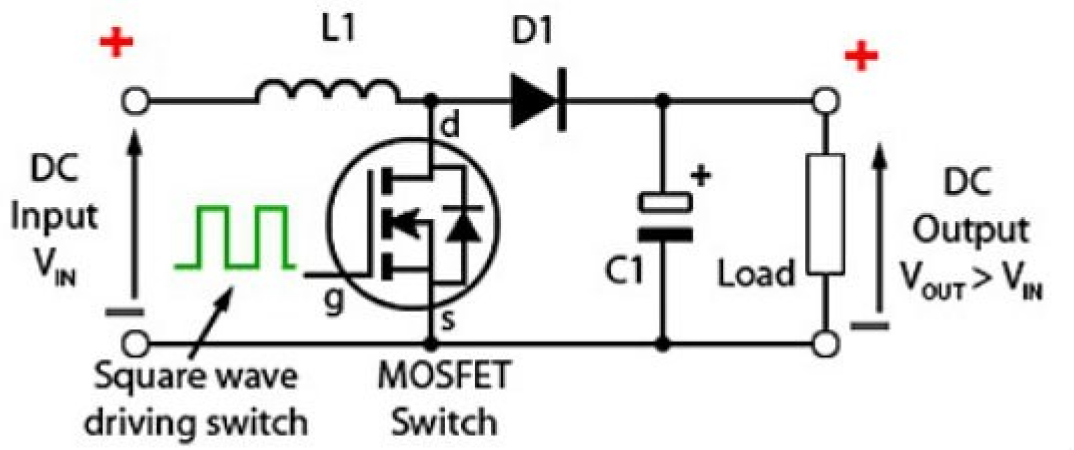


Fig. 52 Boost Converter

The difference is obtained between the value obtained from the output of the circuit and the desired voltage value at the output. This difference obtained is compared with the wave obtained in the triangular wave generator. If the result of the comparison is greater than the difference between the desired value and the actual value, the switching element in the circuit is triggered. If the current value of the triangle wave signal is less than the

Vcontrol value, the input end of the switching element in the circuit is reset and its trigger is cut.

Open Switch

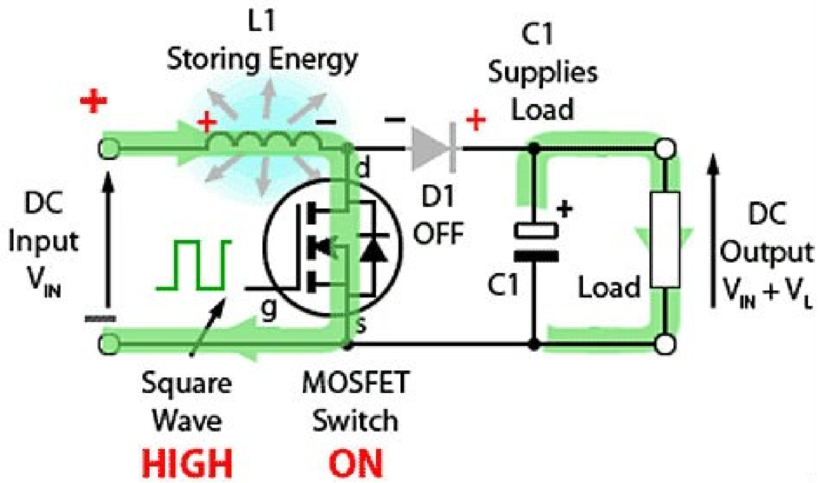


Fig. 53 Open Switch

Closed Switch

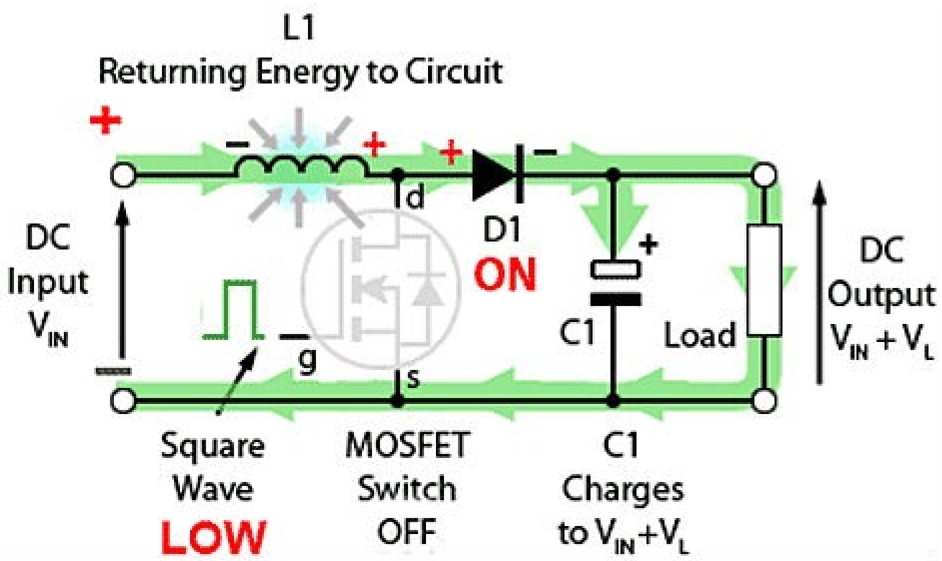
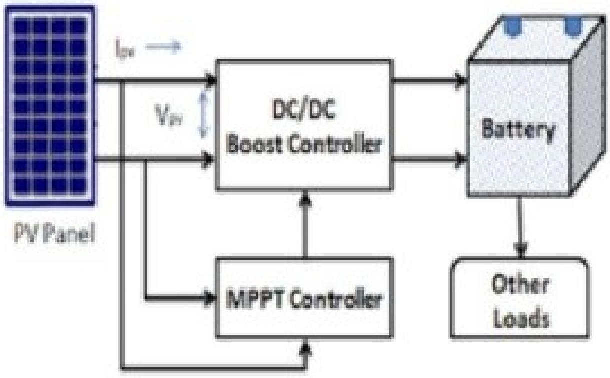


Fig. 54 Closed Switch

Since the current on the coil can be unidirectional in boost converter circuits, the voltage between the ends of the coil is induced in two different polarities between the two modes. Since the voltage of the capacitor cannot be reverse induced in this circuit due to the nature of the capacitor, the current flows in two different directions through the capacitor in two modes. Thus, the average voltage of the coil and the average current of the capacitor become zero in the circuit.

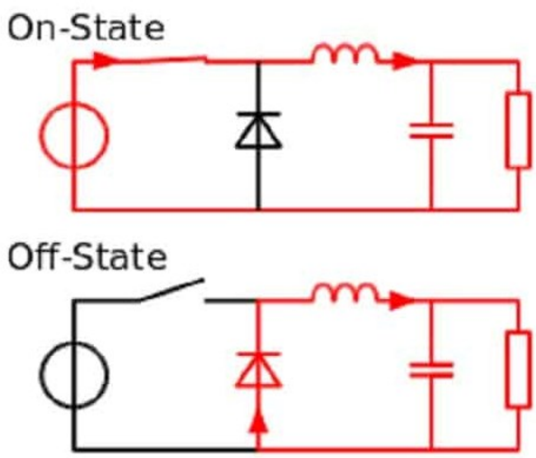


Block diagram of how MPPT stays in PV schematic.

Fig. 55 PV schematic

3- Buck Converters (Step Down)

We need Buck Converters because of reducing the loses and voltages.



Main schematic of Buck Converters is in near. Mosfet is generally used as circuit switch here. The reason why it is preferred over BJT is that the mosfet in power electronics causes **less power loss[2].**

Fig. 56 On and Off State

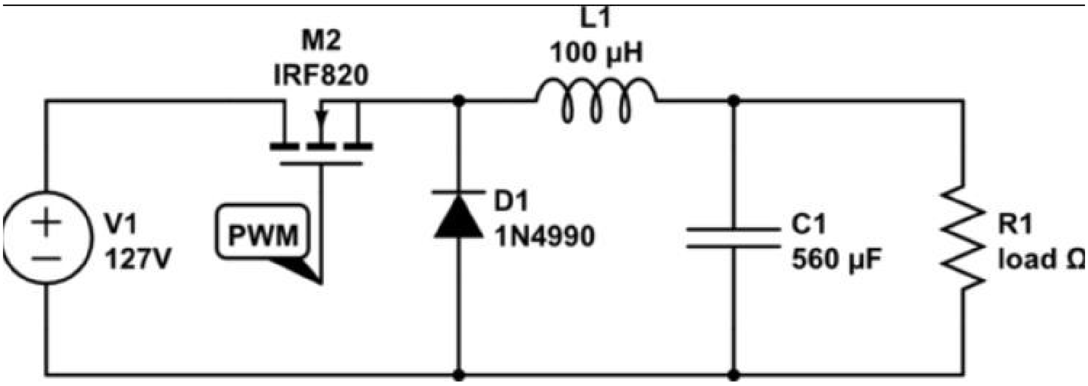


Fig. 57 Buck Converter Circuit

With the Mosfet PWM, it will transfer some of the power from the battery / voltage source to the Load, with 100 times of opening and closing per second. But when we did this, we added **capacitor** because Load would be nonfunctional at 0 V. Thus, the capacitor will be charged together with the MOSFET and will discharge its energy when the MOSFET is turned on, so the load will not be 0 V. However, in this case, since the capacitor cannot change the voltage instantly, we added **inductance** instead of resistance. However, while Mosfet is opening, the inductane tries to prevent Mosfet because the current cannot change instantaneously. We have added **diodes** in it. Thus, the current is always circulating.

Buck Converter Formulas

Analysis for the Switch Closed

$$v_L = V_s - V_o = L\frac{di_L}{dt}$$

$$(\Delta i_L)_{\text{closed}} = \left(\frac{V_s - V_o}{L}\right)DT$$

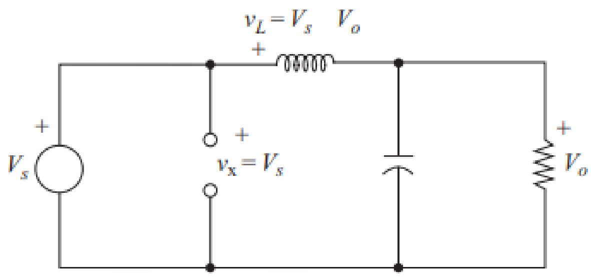


Fig. 58 Closed Switch

Analysis for the Switch Open

$$v_L = -V_o = L\frac{di_L}{dt}$$

$$(\Delta i_L)_{open} = -\left(\frac{V_o}{L}\right)(1-D)T$$

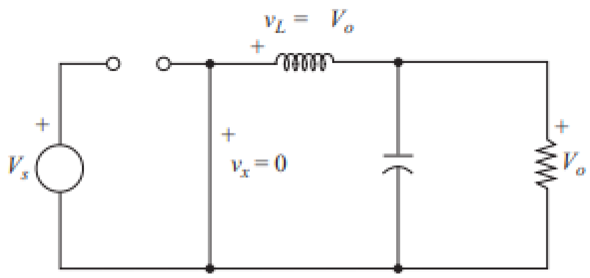


Fig. 59 Open Switch

General Formulas of Buck Converter[24]

One of the main formulas:

$$\boxed{V_o = V_s D}$$

To find Imax an Imin we already know change in inductor current.

$$I_{max} = I_L + \frac{\Delta i_L}{2}$$
$$= \frac{V_o}{R} + \frac{1}{2}\left[\frac{V_o}{L}(1-D)T\right] = V_o\left(\frac{1}{R} + \frac{1-D}{2Lf}\right)$$
$$I_{min} = I_L - \frac{\Delta i_L}{2}$$
$$= \frac{V_o}{R} - \frac{1}{2}\left[\frac{V_o}{L}(1-D)T\right] = V_o\left(\frac{1}{R} - \frac{1-D}{2Lf}\right)$$

If the desired switching frequency is established;

$$\boxed{L_{min} = \frac{(1-D)R}{2f} \quad \text{for continuous current}}$$

The value of inductance for a specified peak-to-peak inductor current for continuous-current operation:

$$\boxed{L = \left(\frac{V_s - V_o}{\Delta i_L f}\right) D = \frac{V_o(1 - D)}{\Delta i_L f}}$$

Output Ripple Voltage:

$$\boxed{\frac{\Delta V_o}{V_o} = \frac{1 - D}{8LCf^2}}$$

To make easier we put these formulas on excel file. So when we need to change the values we will not have to be calculate everything.

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	CLOSED SWITCH	OUTPUT	Vs	Vo	L	D	T	R	f	C			INPUTS
2	Delta iL	159,7794118	18	7,40	0,000272	0,41	0,01	20	1	0,000125			OUTPUTS
3	Vl	10,6											
4	OPEN SWITCH												
5	Delta iL	160,5147059											
6	Vl	-7,4											
7	GENERAL												
8	Vo	7,38											
9	Imin	80,62735294											
10	Imax	-79,88735294											
11	Lmin (min. İnductance for continuous current	11,8											
12	Delta iL	16051,47059											
13	L	0,000272											
14	delta Vo/Vo (%) Ripple	2960											

Fig. 60 Our excel table of formulas

Some values can look wrong (output ripple) this is because we did not enter all the values (frequency).

PSPICE DESIGNING OF OUR OUR BUCK CONVERTER

We used MOSFET instead of diode because MOSFET has more efficieny than diode. Also it has diode inside of it so it will work us. We need to reduce 18.3 V (Panel Output Voltage) to 7.4V(Nominal Charge Voltage of Battery) thats why we need to use step down (Buck Converter).

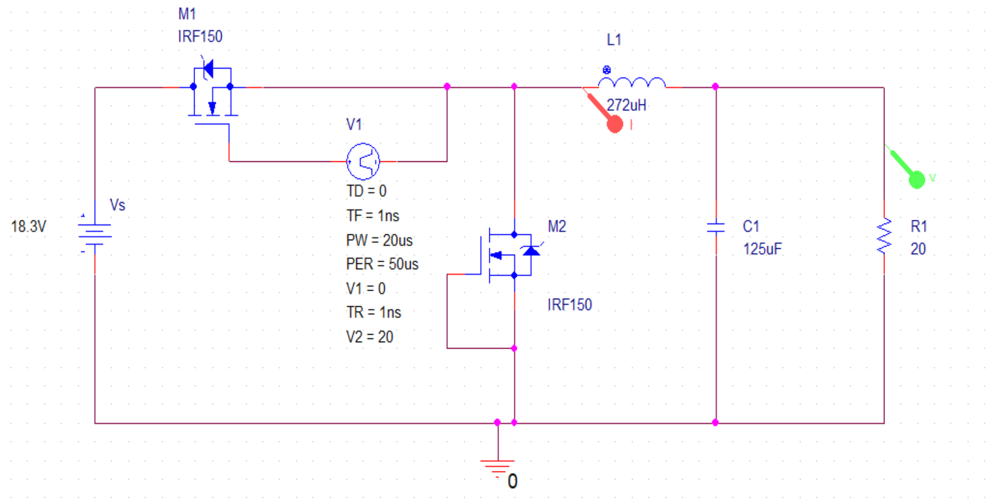


Fig. 61 Buck circuit design of our system

Our Simulation Results

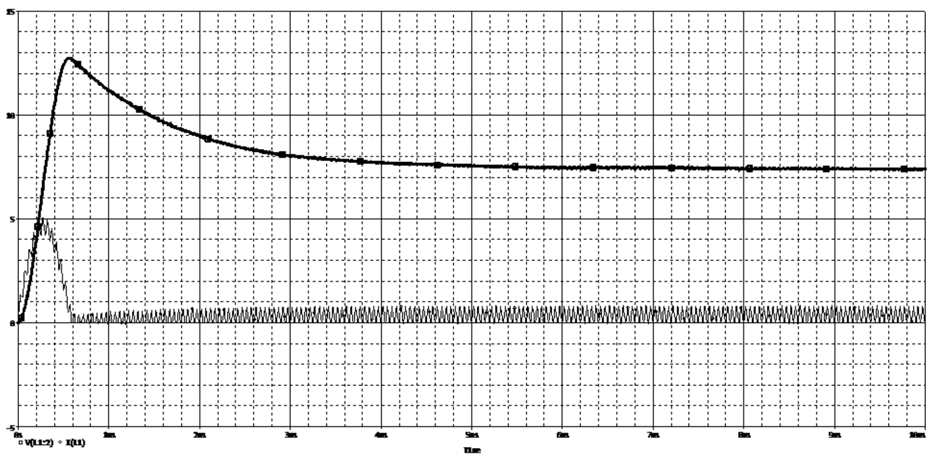


Fig. 62 Voltage and Amps. Result (higher one is voltage)

	Trace Color	Trace Name	Y1	Y2	Y1 - Y2		Y1(Cursor1) - Y2(Cursor2)		7.4023		
		X Values	9.4208m	0.000	9.4208m		Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	CURSOR 1,2	V(L1:2)	7.4031	823.509u	7.4023		0.000	0.000	7.4031	823.509u	3.7020
		I(L1)	775.458m	41.175u	775.417m		-6.6277	-782.333u	775.458m	41.175u	387.750m

Fig. 63 Table of result

Solar Panel

We need energy to work with circuits and we thought that solar panel are the most suitable one to use. The biggest reasons for choosing solar energy are;

-The most potential energy production method to be used in the future

-It is a renewable energy method

-Solar energy (UAVs) can access any locations. That is why it has more efficieny.

How we choose the Solar Panel?

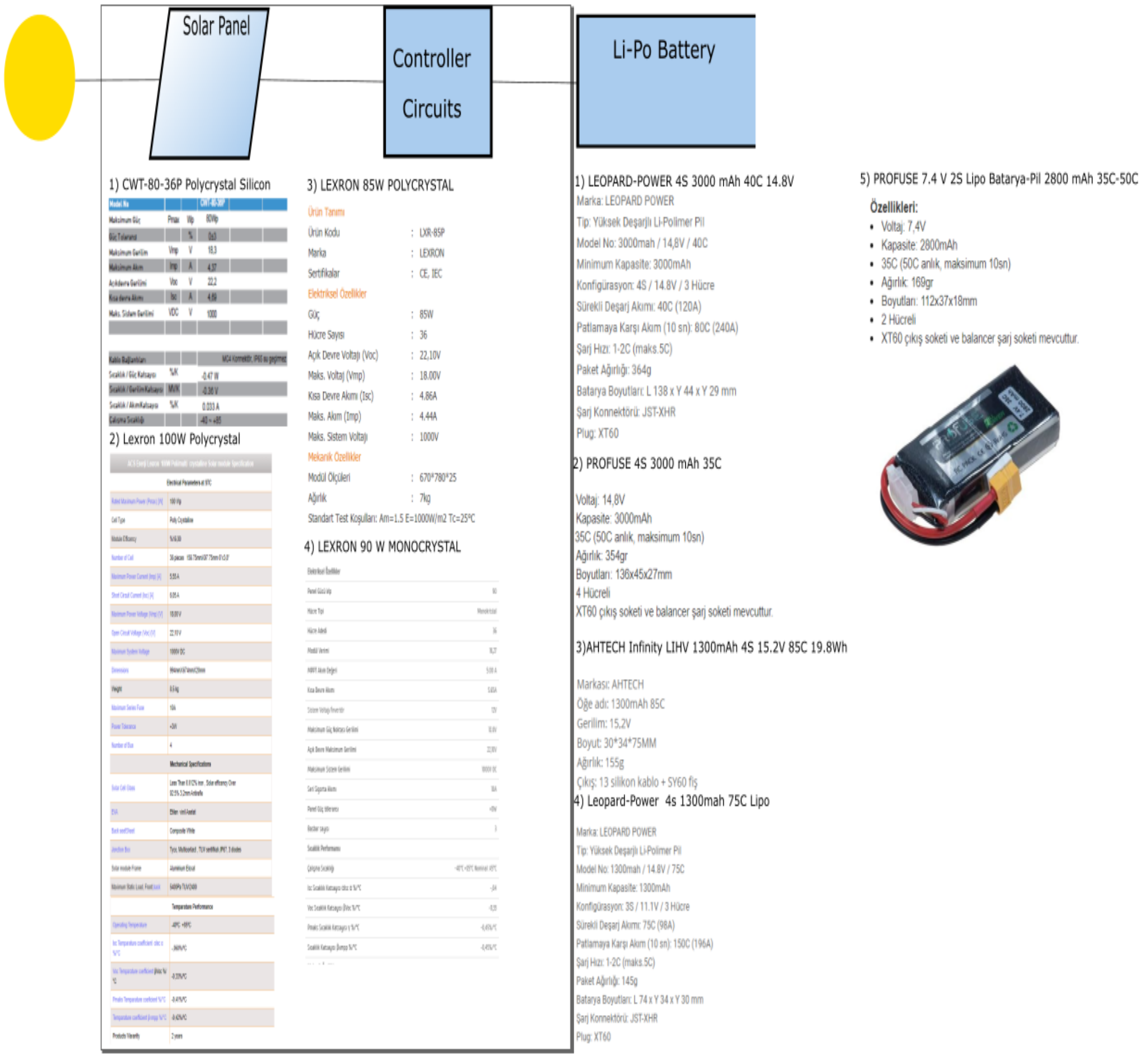


Fig.64 Solar Charger Chart

Types of Solar Panels

There are three types of solar panels to choose so first lets look for them[25].

1- Thin-film Solar Panels

Not at all like monocrystalline and polycrystalline sun-powered boards, thin-film boards are made from an assortment of materials. The foremost predominant sort of thin-film sun based board is made from cadmium telluride (CdTe).

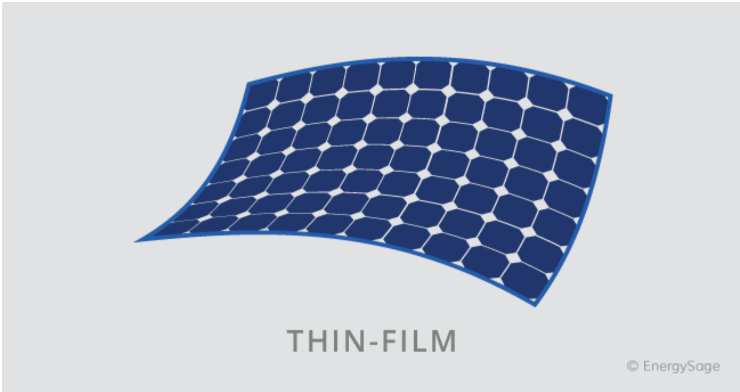


Fig. 65 Thin -film

Biggest *disadvantage* of thin-film panels is they have *lower effiency* than other panels (11%). Also they are tend to corruption faster.

2- Monocrystalline Solar Panels

Monocrystalline solar cells are cut from a single crystal of silicon.

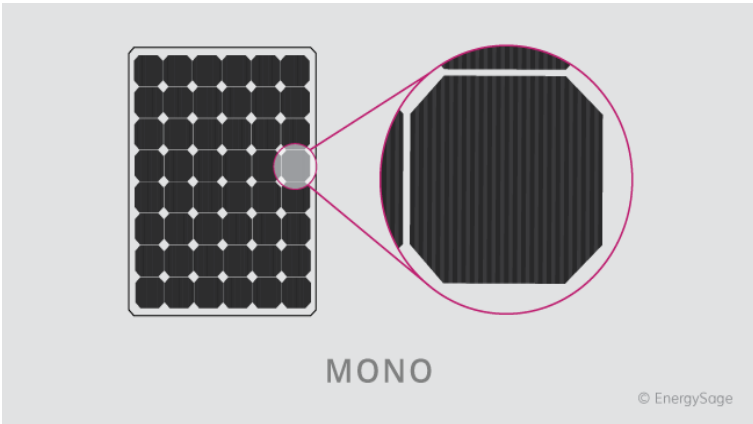


Fig. 66 Monocrystalline

Of all panel types, monocrystalline typically have the highest efficiencies and power capacity. Monocrystalline solar panels can reach efficiencies higher than 20 percent. They have come in higher wattage modules so that means they can generate more power. However they are most expensive type of solar panel.

3- Polycrystalline Solar Panels

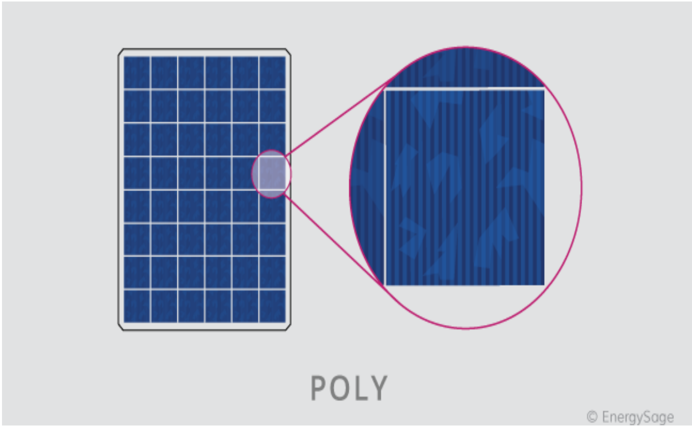


Fig. 67 Polycrystalline

Polycrystalline solar cells are composed of fragments of silicon crystals that are melted together in a mold before being cut into wafers.

Polycrystalline solar panels usually have efficiencies between 15 to 17 percent. Polycrystalline solar panels are typically cheaper than monocrystalline solar panels. This is because the cells are produced from silicon fragments rather than a single, pure silicon crystal.

When we think of pros and cons, we decided to choose polocrystalline solar panels because + plus efficiency is not worth the extra cost for monocrystalline solar panels.

Then we have two option to choose:

Ürün Tanımı		
Ürün Kodu	:	LXR-85P
Marka	:	LEXRON
Sertifikalar	:	CE, IEC
Elektriksel Özellikler		
Güç	:	85W
Hücre Sayısı	:	36
Açık Devre Voltajı (Voc)	:	22,10V
Maks. Voltaj (Vmp)	:	18.00V
Kısa Devre Akımı (Isc)	:	4.86A
Maks. Akım (Imp)	:	4.44A
Maks. Sistem Voltajı	:	1000V
Mekanik Özellikler		
Modül Ölçüleri	:	670*780*25
Ağırlık	:	7kg
Standart Test Koşulları: Am=1.5 E=1000W/m2 Tc=25°C		

Fig. 68 Lexron 85 W

Model No			CWT-80-36P		
Maksimum Güç	Pmax	Wp	80Wp		
Güç Toleransı		%	0±3		
Maksimum Gerilim	Vmp	V	18,3		
Maksimum Akım	Imp	A	4,37		
Açıkdevre Gerilimi	Voc	V	22,2		
Kısa devre Akımı	Isc	A	4,69		
Maks. Sistem Gerilimi	VDC	V	1000		
Kablo Bağlantıları			MC4 Konnektör, IP65 su geçirmez		
Sıcaklık / Güç Katsayısı	%/K		-0.47 W		
Sıcaklık / Gerilim Katsayısı	MV/K		-0.36 V		
Sıcaklık / Akım Katsayısı	%/K		0.033 A		
Çalışma Sıcaklığı			-40 ~ +85		

Fig. 69 CWT 80 W

These are similar to each other. Lets look our calculations for CWT-80-36P.

As we know, power can change depends to temperature and these panels are tested for 25° C. But what if the temperature is not 25 °C? Then we have to use this formula:

80 W- (T-25 C) *0.47 W= Power that we have in our T (temperature)[3].

As we can see, there are more coefficients like voltage coefficient and current coefficient which depend on temperature. These also can be calculated with the same logic.

Another calculation for panel is coming from battery.

To understand our panel power is enough, we have to calculate the batteries power.

We know that, **our battery** has these datas:

11.1 V and we need 3.4 A to charge battery

So, 11.1x3.4= **37.74** W

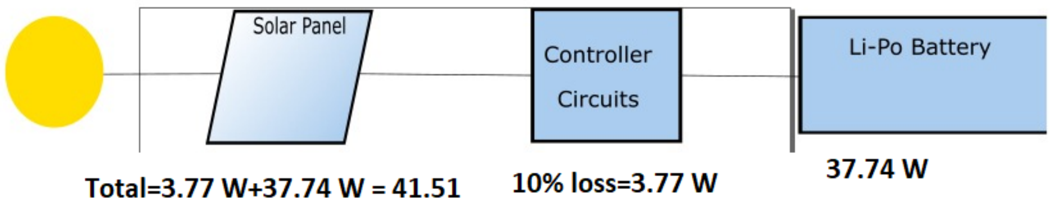


Fig. 70 Chart of Total Power

Also when we think about the loss on controller circuits as 10% (37.74*0.1=3.77W) and when we add to required power, we will reach the total power that we need which is 39.40tW (3.77W+37.74W). Easy to see that with considering the temperature our panels have enough power.

MPPT Components Selection and Charger Calculations

Component's Selections

Our Circuit:

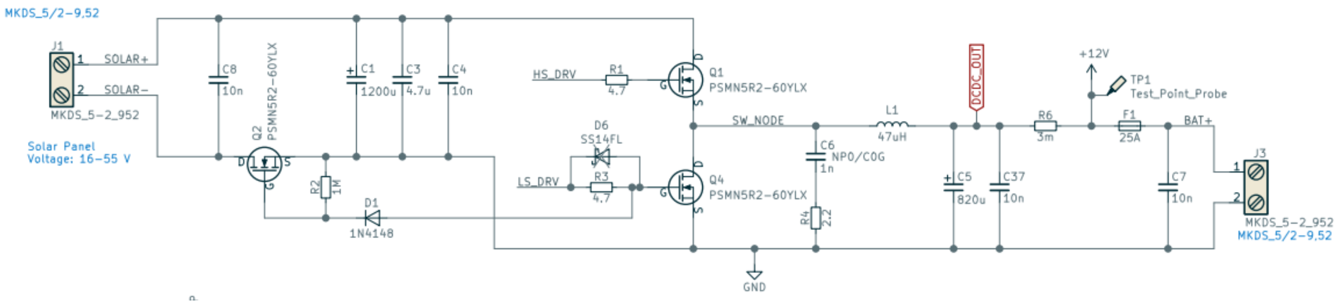


Fig. 71 MPPT Circuit

The data that we already have:

Vin = 18V, Voltage that is produced by solar panel,

Vout = 12V, this is the needed output voltage for 3S li-po battery,

D = 0.66, Duty Cycle is $\frac{Vo}{Vi}$**,**

fs = 50 kHz, switching frequency,

L = 47 uH,

Pout = 100 W, this is the power capacity that can be produced by our solar panel,

Iout = 8.33 A, We can find this with P=V*I. (100 W = 12 V * Iout)

To select the proper components we will need to find inductor ripple current:

<u>Inductor Ripple Current</u>

$$\text{Inductor Ripple Current: } \Delta I_L = \frac{\left(V_{IN(max)} - V_{OUT}\right) \times D}{f_S \times L}$$

$$\Delta iL = \frac{\left((18V - 12V) \; * \; 0.66\right)}{\left(50 \; kHz \; * \; 47 \; uH \; \right)} \; = \; 1.7 \; A$$

Also there is another situation; when the battery discharge, we will see lower Vo values like **9.5 V**.

Accordingly, if we calculate for also this situation:

$$\Delta iL = \frac{\left((18V - 9.5V) \; * \; 0.66\right)}{50 \; kHz \; * \; 47 \; uH} \; = \; 1.9 \; A$$

<u>Capacitor Voltage Ripple</u>

$$\Delta Vo \; = \frac{\Delta iL \; * \; T}{8C}$$

$$\Delta Vo = \frac{\left(1.7 * 2 * \left(10^{-6}\right)\right)}{\left(8 * 820 * 10^{-6}\right)} \; = \; 518 * 10^{-6}$$

<u>Inductor Selection</u>

We used that formula to pick the proper inductor for our circuit.

$$L = \frac{V_{OUT} \times \left(V_{IN} - V_{OUT}\right)}{\Delta I_L \times f_S \times V_{IN}}$$

$$L \; = \; \frac{\left(12 * (18 - 12)\right)}{\left(1.7 * 50 * \left(10^3\right) * 18\right)} = \; 47 * 10^{-6} H$$

Inductor current ripple will be calculated with ripple percentage (in this case, it is assumed between 20% and 40%)

$$\Delta I_L = (0.2 \text{ to } 0.4) \times I_{OUT(max)}$$

In our project it is found as 20 %:

$$\Delta iL\ (\%) = \left(\frac{\Delta iL\ (A)}{Io}\right)*100 = \left(\frac{1.7}{8.33}\right)*100 = 20.42\ \%$$

Again for the discharging (9.5V) the percantage will be :

$$\Delta iL\ (\%) = \left(\frac{\Delta iL\ (A)}{Io}\right)*100 = \left(\frac{1.9}{8.33}\right)*100 = 18.13\ \%$$

<u>Output Capacitor Selection</u>

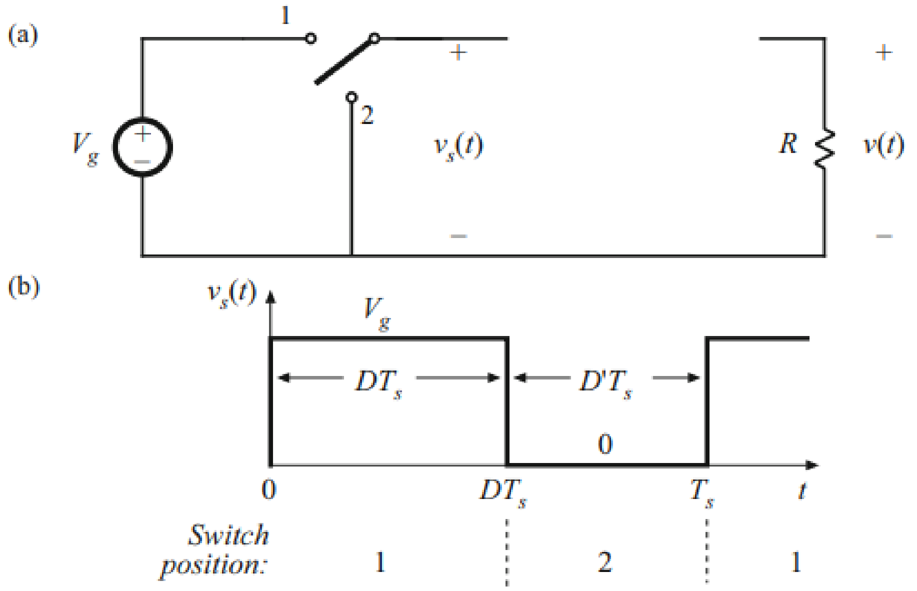
With that formula, we will choose our capacitor.

$$C_{OUT(min)} = \frac{\Delta I_L}{8 \times f_S \times \Delta V_{OUT}}$$

$$Cout = \frac{1.7}{\left(8*50*10^3*518*10^{-6}\right)} = 820\ uF$$

<u>Steady-State Analysis [24]</u>

The buck converter is a means of reducing the dc voltage. The switch produces a rectangular waveform vs(t) as illustrated.



Ideal switch, (**a**), used to reduce the voltage dc component, and (**b**) its output voltage waveform

Fig.72 [24]

From Fourier we know that :

$$\langle v_s \rangle = \frac{1}{T_s} \int_0^{T_s} v_s(t)dt$$

From the graph, we can evaluate that as :

$$\langle v_s \rangle = \frac{1}{T_s}(DT_sV_g) = DV_g$$

Hence, the output voltage is essentially equal to the dc component of vs(t):

$$v \approx \langle v_s \rangle = DV_g$$

In our project:

12 V = 0.66 * 18 V

Making a perfect low-pass filter that only passes the DC components is impossible. Thus, our low-pass filter allows the least some small amount of the high-frequency harmonics generated by the switch to reach the output.

This is why our output voltage waveform and formula will have the **ripple** voltage, so it will look like this:

$$v(t) = V + v_{ripple}(t)$$

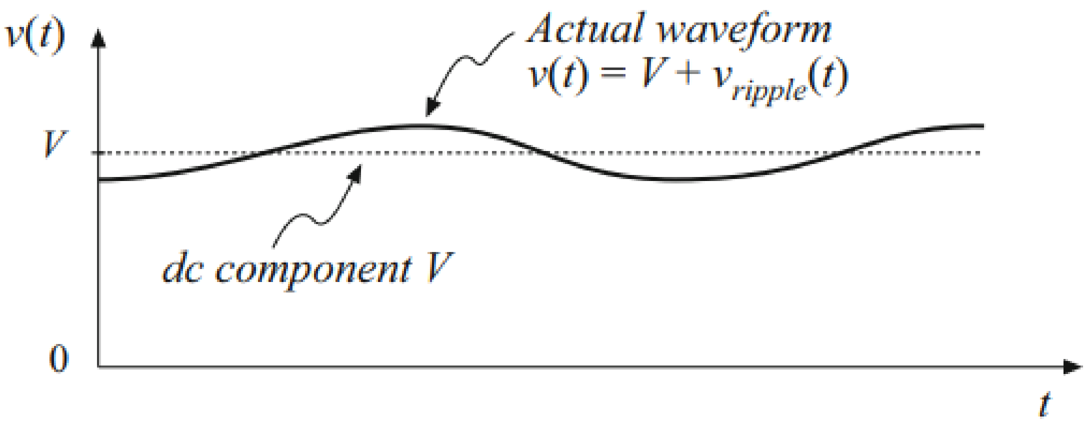


Fig. 73 [24]

There is two condution for the buck converter.

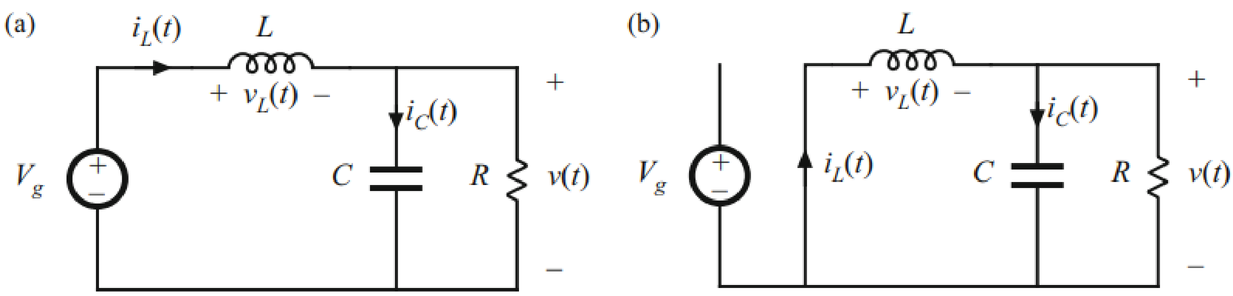


Fig. 74 [24]

Buck converter circuit: (**a**) while the switch is in position 1, (**b**) while the switch is in position 2

First, let's look for an inductor for switch position 1.

$$v_L = V_g - v(t)$$

We can neglect the ripple as its too small so we can rewrite this equation as:

$$v_L \approx V_g - V$$

In our project:

VL = 18-12 = 6 V

We know that:

$$v_L(t) = L\frac{di_L(t)}{dt}$$

Hence, the slope of the inductor current waveform will be:

$$\frac{di_L(t)}{dt} = \frac{v_L(t)}{L} \approx \frac{V_g - V}{L}$$

The graph will look like this:

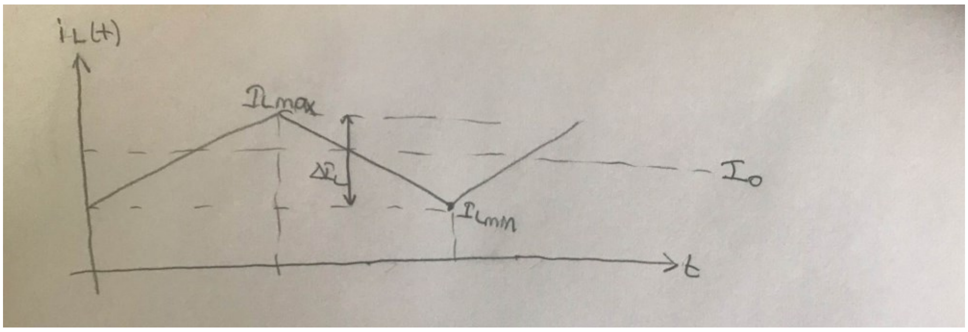


Fig. 75 Graph

For the switch is in position 2, our inductor will equations:

$$v_L(t) \approx -V$$

And so,

$$\frac{di_L(t)}{dt} \approx -\frac{V}{L}$$

And the voltage-current waveform will be:

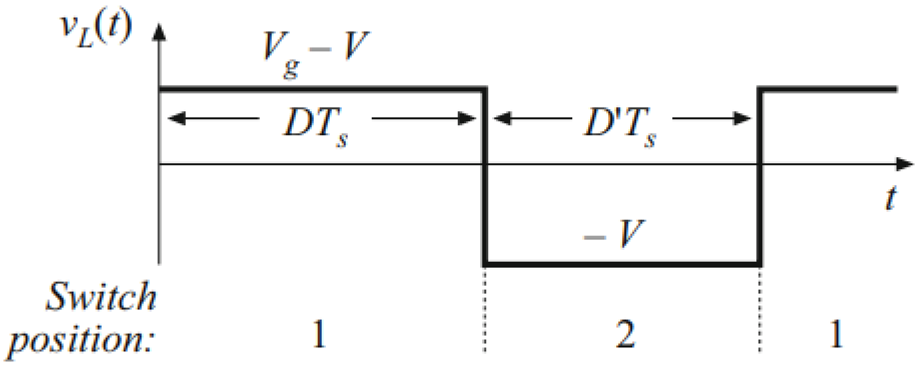


Fig. 76 [24]

The total graph of inductor current waveform will be:

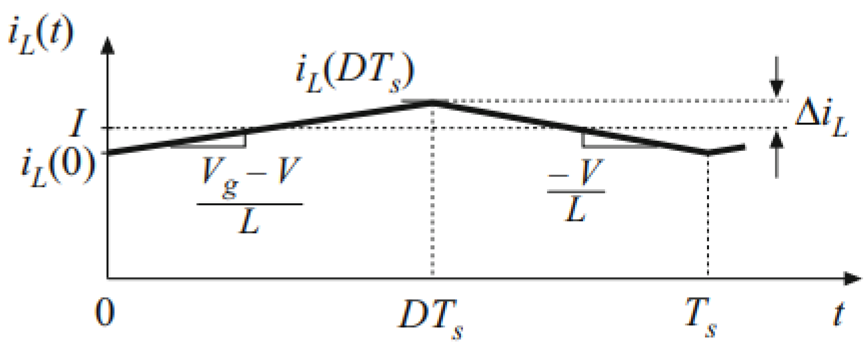


Fig. 77 [24]

When we looked at the ripple with these two positions for inductor; the formula is changed in current i_L is equal to slope times length of the first interval (DT_S):

$$(2\Delta i_L) = \left(\frac{V_g - V}{L}\right)(DT_s)$$

In our project:

$$\mathbf{2\Delta iL\ (peak\ to\ peak)\ =\ \frac{(18\ -12)*0.666*2*10^{-5}}{(47*10^{-6})}\ =\ 1.7\ A}$$

Inductor volt-second balance

$$i_L(T_s) - i_L(0) = \frac{1}{L}\int_0^{T_s} v_L(t)dt$$

Change in inductor current is zero so:

$$0 = \int_0^{T_s} v_L(t)dt$$

Plant Transfer Function of Buck Converter [24]

$$Plant\ T.F.\ =\ \frac{Vo(s)}{d(s)}$$

$$\frac{L*diL}{dt} = Vin*d - Vo$$ **(I)**

$$\dot{I}c\ =\ iL - io$$

$$\frac{C*dVo}{dt} = iL\ -\ Vo/R$$ **(II)**

from here we get with differential

$$\frac{diL}{dt} = \frac{c*d^2Vo}{dt^2} + \frac{1}{R} * \frac{dVo}{dt} \qquad \textbf{(III)}$$

Let's put (**III**) into (**I**):

$$L* \left[c*\frac{d^2Vo}{dt^2} + \left(\frac{1}{R}\right)*\frac{dVo}{dt} \right] = Vin*d - Vo$$

Laplace: $c*L*s^2*Vo(s) + \left(\frac{L}{R}\right)*s*Vo(s) = Vin*d(s) - Vo(s)$

Then when we collect the transfer function on one side; we have the plant transfer function:

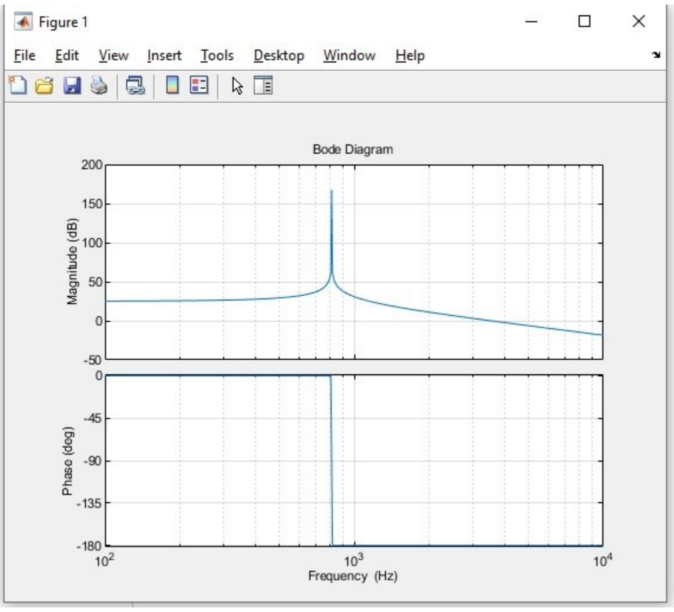
$$\frac{\mathbf{Vo(s)}}{\mathbf{d(s)}} = \frac{\mathbf{Vin}}{\left[\mathbf{1} + \mathbf{s}\left(\frac{\mathbf{L}}{\mathbf{R}}\right) + \mathbf{s^2*L*C}\right]}$$

In our project:

$$\textbf{Plant T.F.} = \frac{\mathbf{18}}{[\mathbf{1+s}\left(\frac{\mathbf{47*10^{-6}}}{\mathbf{3*10^{6}}}\right)\mathbf{+s^2*47*10^{-6}*820*10^{-6}}]}$$

Bode Diagram of Transfer Function

```
s = tf('s');
num = [18];
den = [3.84*10^(-8) 1.5*10^(-11) 1]
G=tf(num,den)
options = bodeoptions;
options.FreqUnits = 'Hz'; % or 'rad/second', 'rpm', etc.
figure(1)
bode(G,options);
grid
```



Our numerator was $s^0(18)$

Denominator is calculated from coefficents of s^0,s^1 and s^2.

Demonitor of Plant T.F. = $1+s\left(\frac{47*10^{-6}}{3*10^{6}}\right)+s^{2}*47*10^{-6}*820*10^{-6}$

Demonitor of Plant T.F = $\mathbf{s^2(3.84*10^{-8})+s^1(1.5*10^{-11})+s^0(1)}$

ALTIUM DESIGNER

While designing the charger controller circuit in our project, we used Altium Designer, a program that offers PCB design with an integrated design interface.

Altium Designer is a PCB and electronics design automation software package for printed circuit boards. Starting from very simple designs, many designs such as flex circuits can be realized with Altium Designer. With the help of Altium Designer, we can see how the circuits we designed with the 3D view will look. The basic features of Altium Designer are schematic design and PCB design

Considering these basic features, we decided to design the charger controller circuit with Altium Designer.

We first determined the components we will use in our circuit and adjusted them according to our own scheme. We created a BOM list. Then, according to the properties of the required materials, we looked at sites such as Digi-key and mouser and uploaded them to the Altium Designer program with their manufacturing part numbers. We created the schematic and footprint libraries. While creating the footprint of the components, we created it by paying attention to the data sheets given for the components. We also found 3D models of components from sites like 3D Content Central and Grabcad.

Schematic Part:

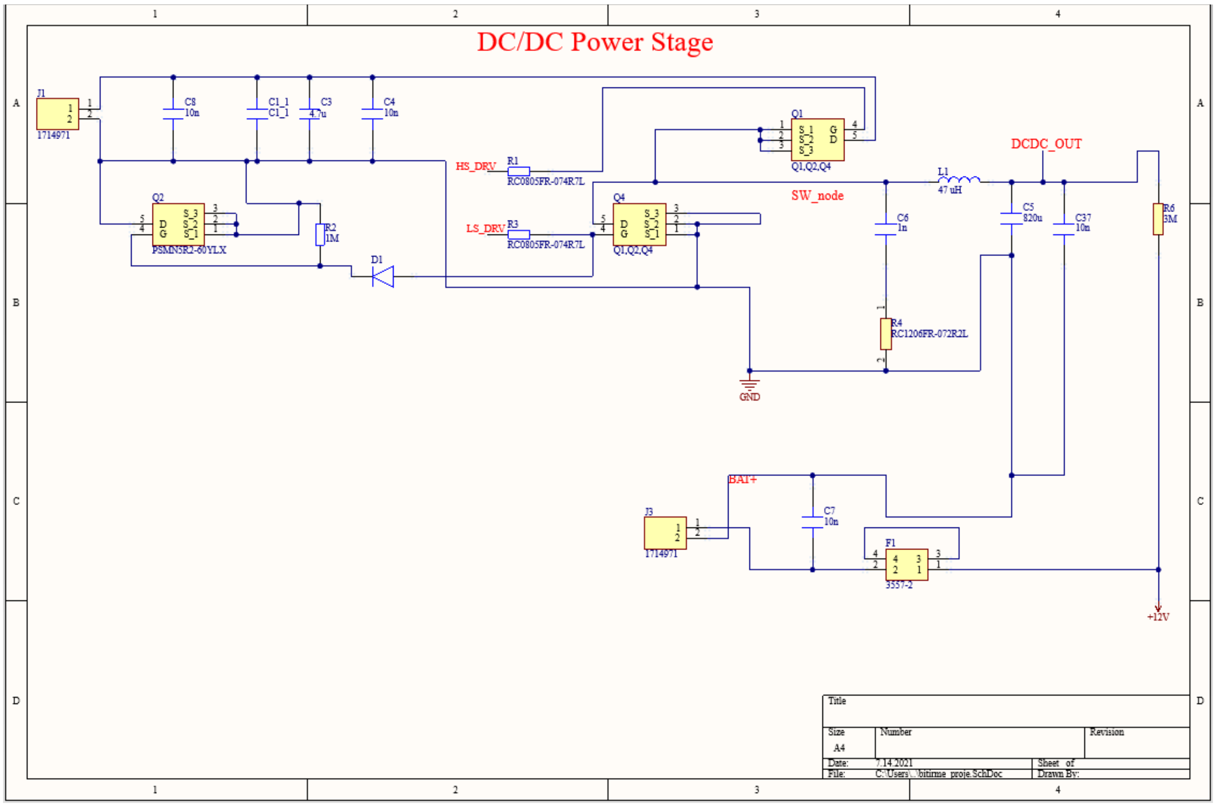


Figure 78:DC/DC Power Stage Schematic

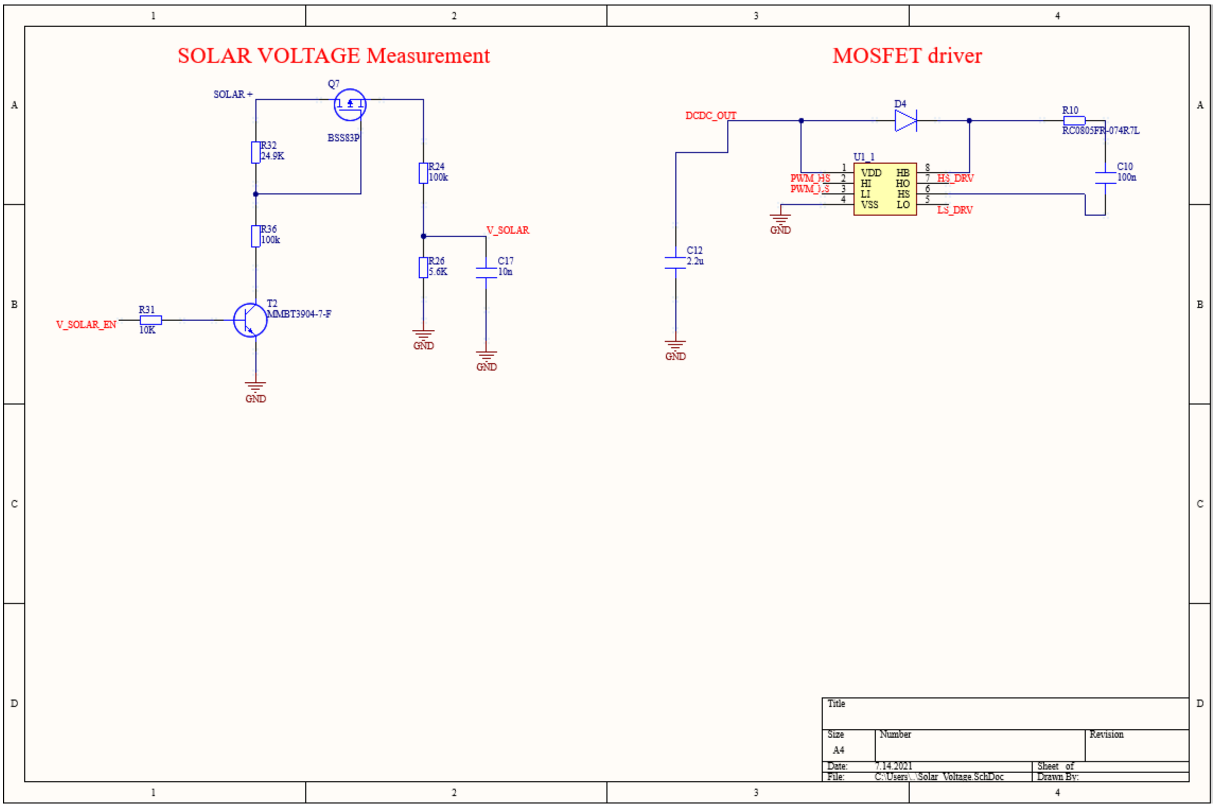


Figure 79: Solar Voltage Measurement and Mosfet Driver Schematic

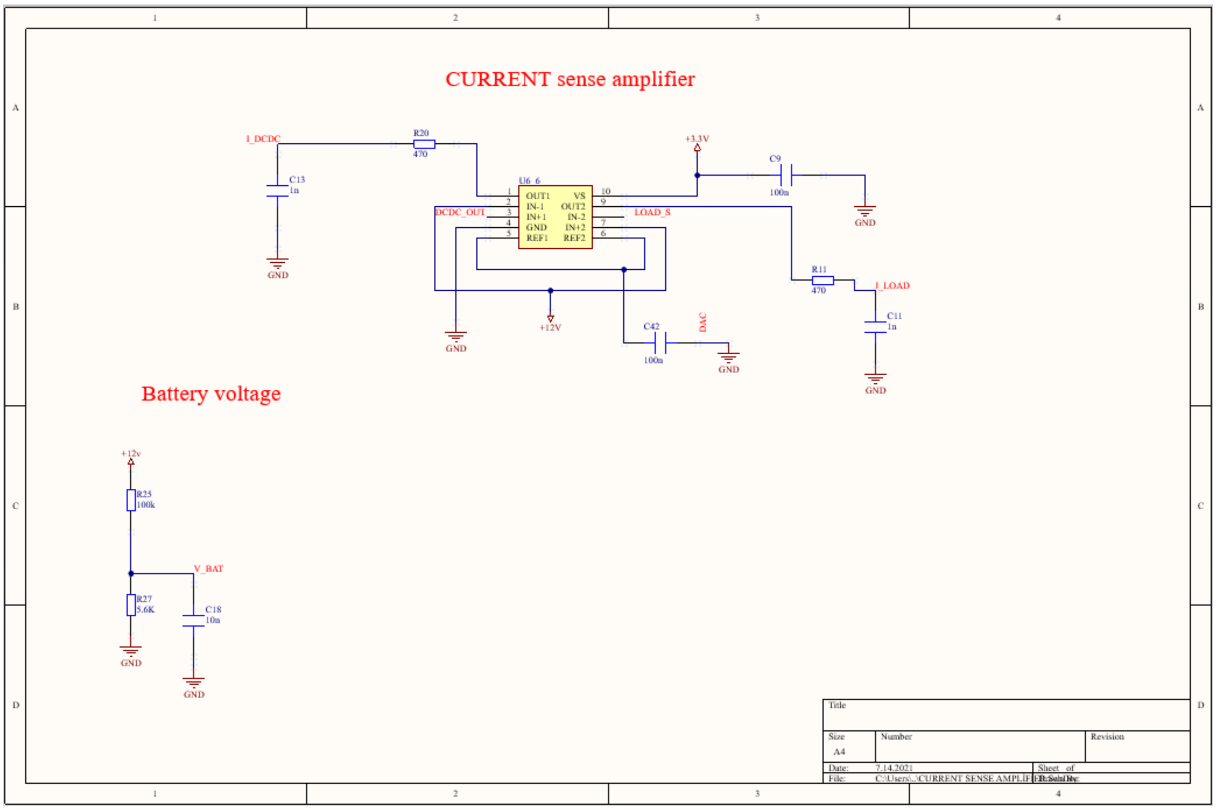


Figure 80: Current sense amplifier Schematic

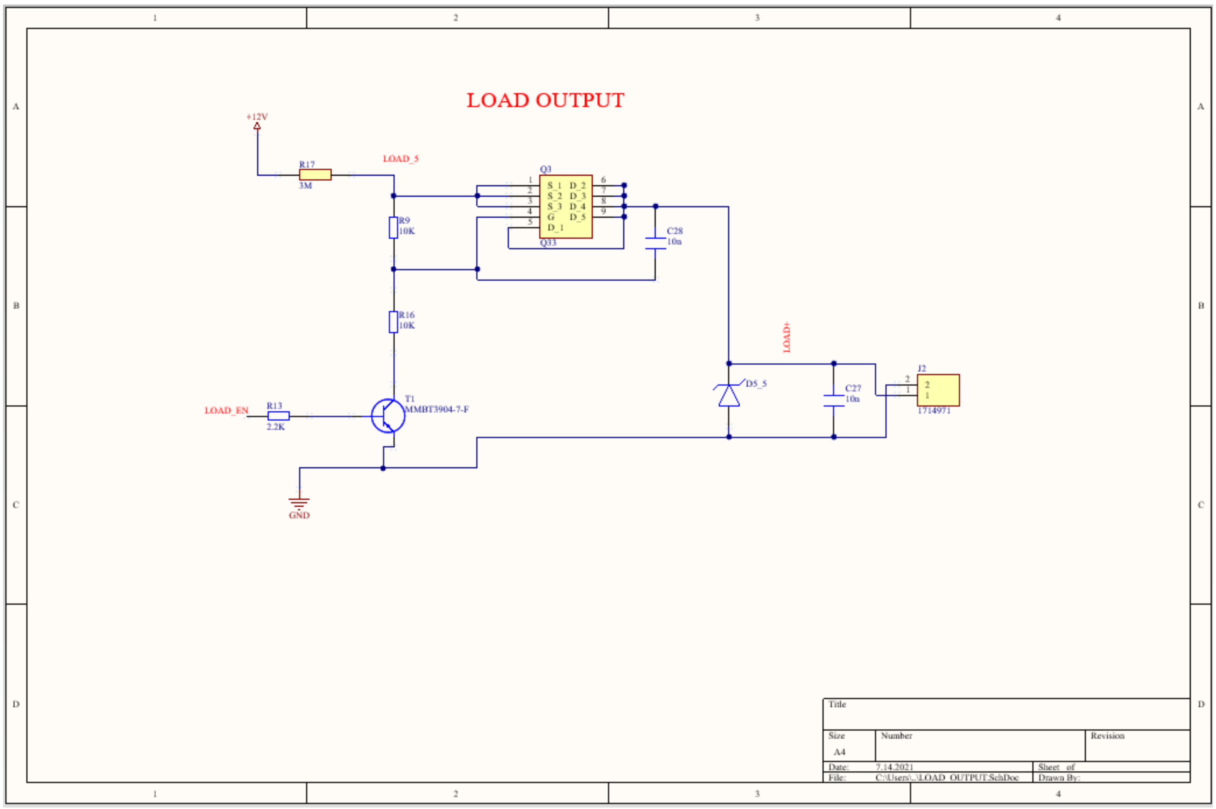


Figure 81: Load Output Schematic

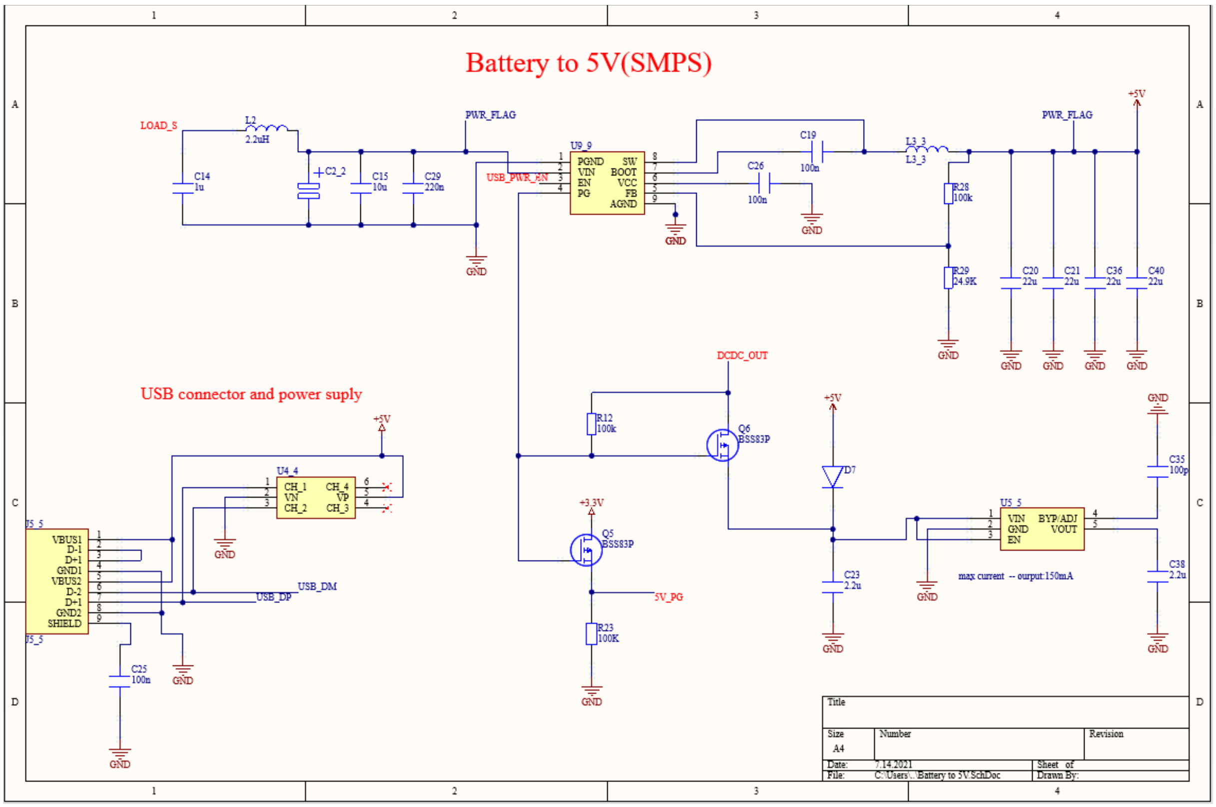


Figure 82: Battery to 5V(SMPS) Scheamtic

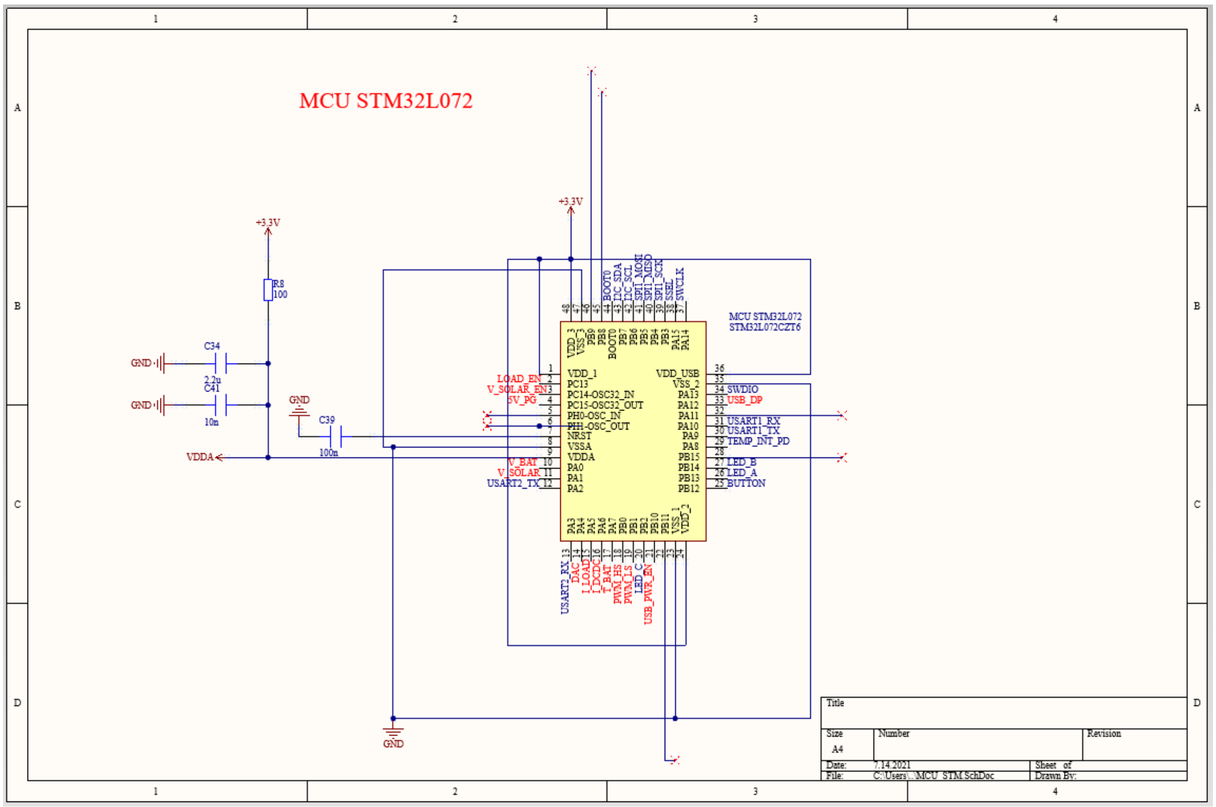


Figure 83: MCU STM32L072 Schematic

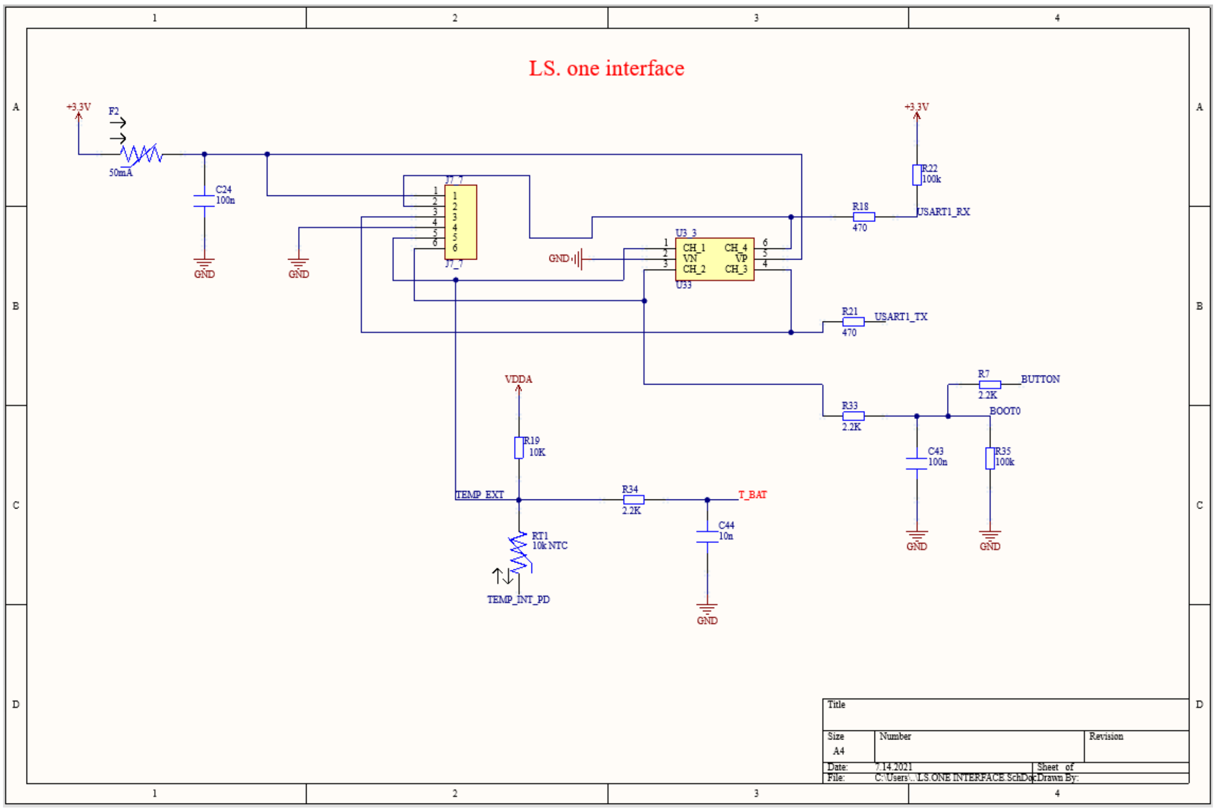


Figure 84: LS. One Interface Schematic

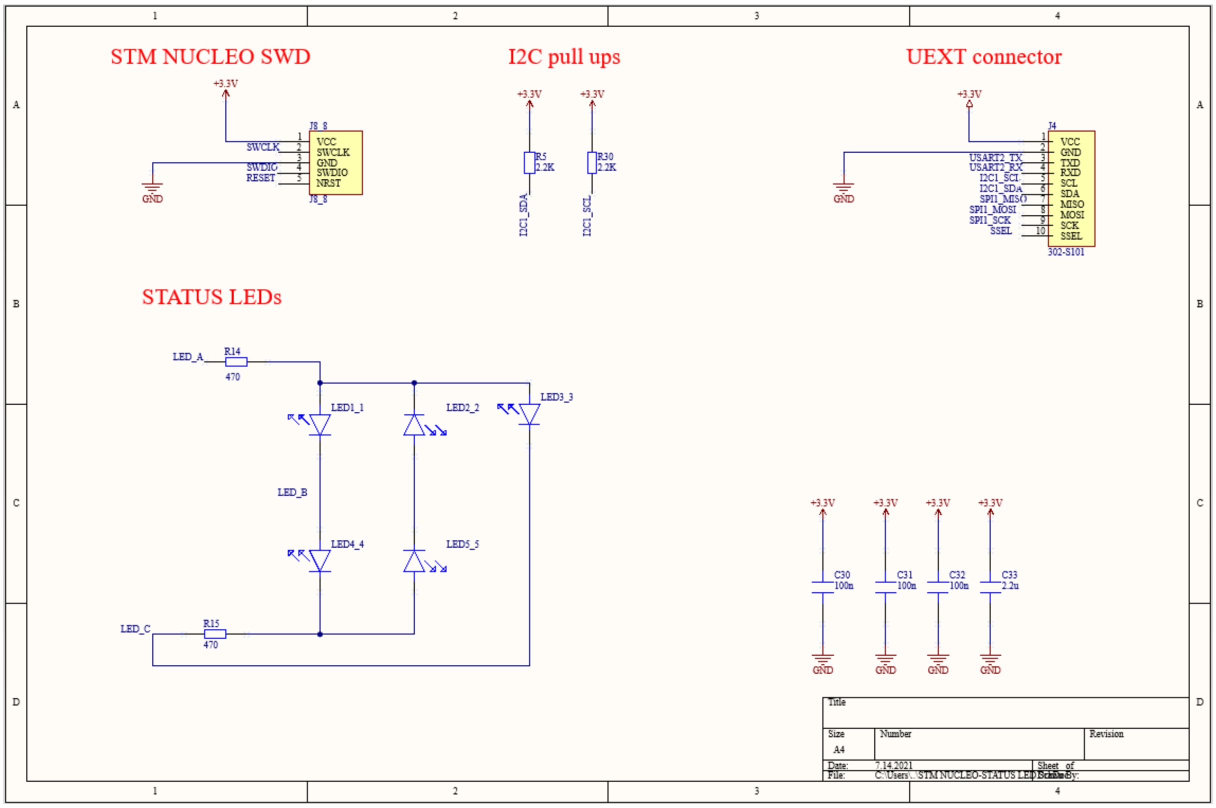


Figure 85: STM Nucleo SWD, I2C Pull Ups, UEXT Connector and Status LEDs Schematic

After creating each circuit diagram, we uploaded it to the PCB document. PCB is a circuit board with conductive paths on the circuit and the area outside these paths is an insulator. Here, we have implemented the physical placement on the PCB and electrically interconnected via paths, taking into account the libre solar MPPT-1210 charge control scheme.

While designing the PCB layout;

- Overall smooth layout of components and paths
- Components are accessible and easily visible
- Design for the suppression of Electromagnetic Noises
- Economics is taken into account.

PCB Part:

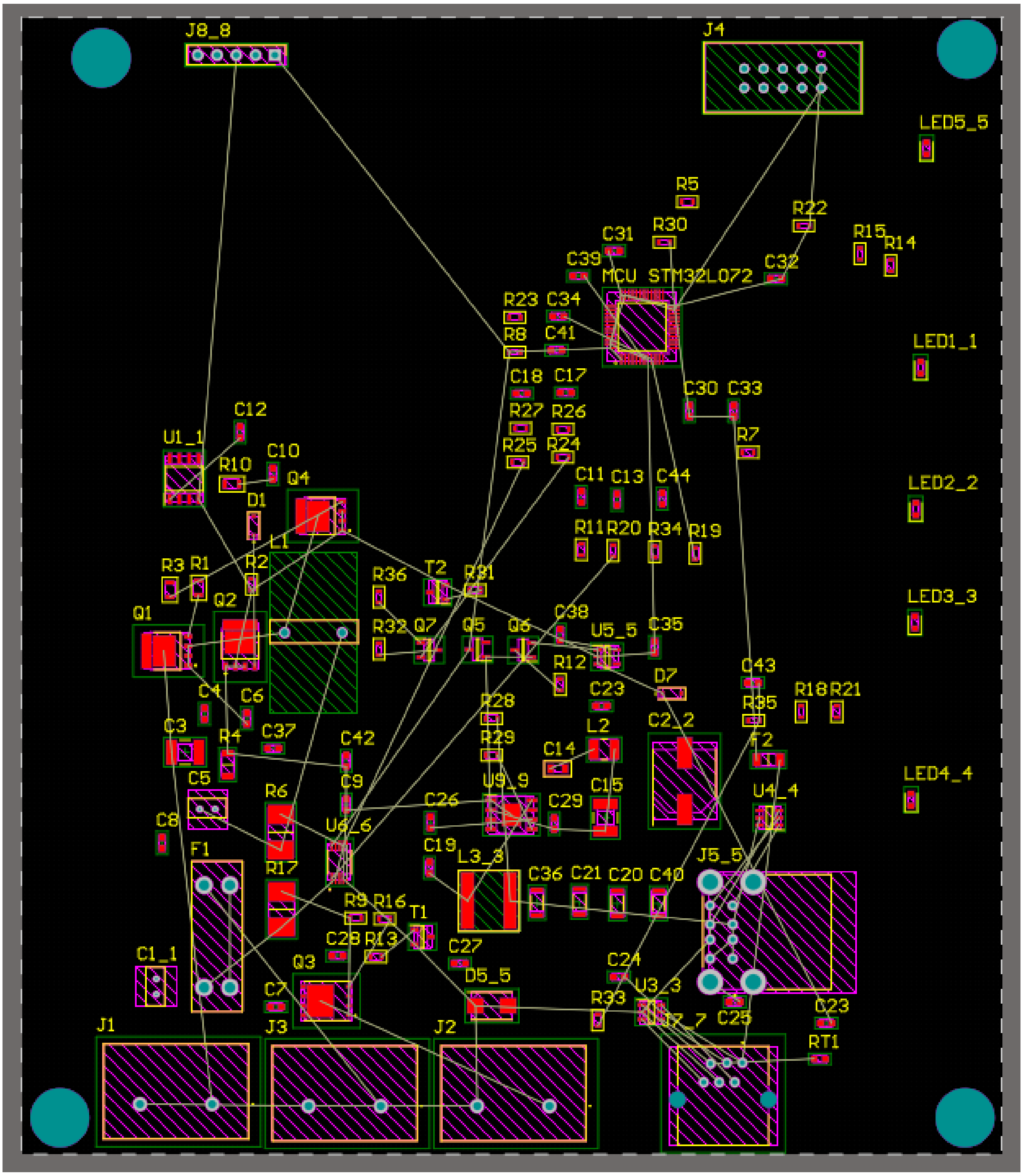


Figure 86: MPPT-1210 pcb design (2D model)

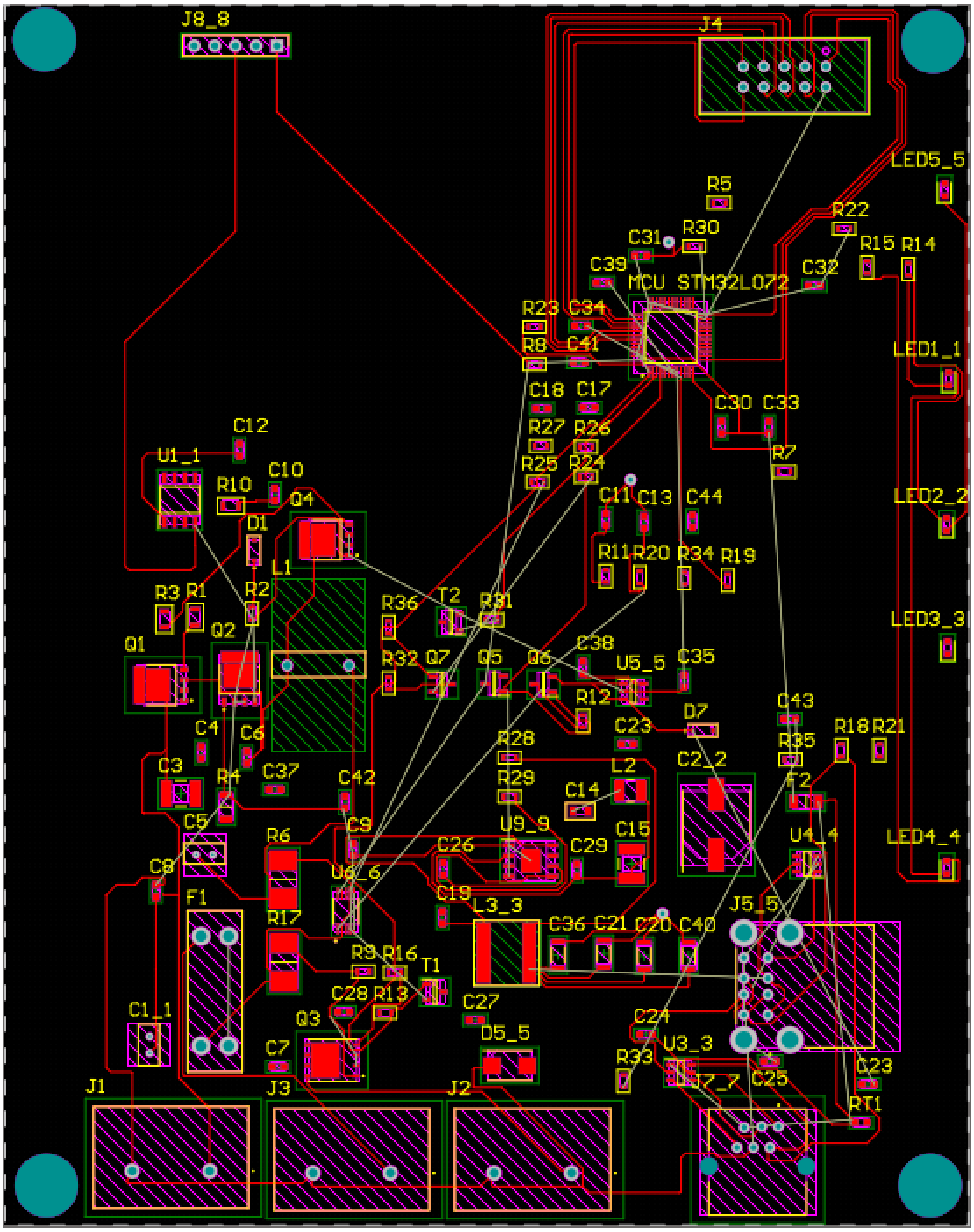


Figure 87: MPPT-1210 pcb design (2D model)

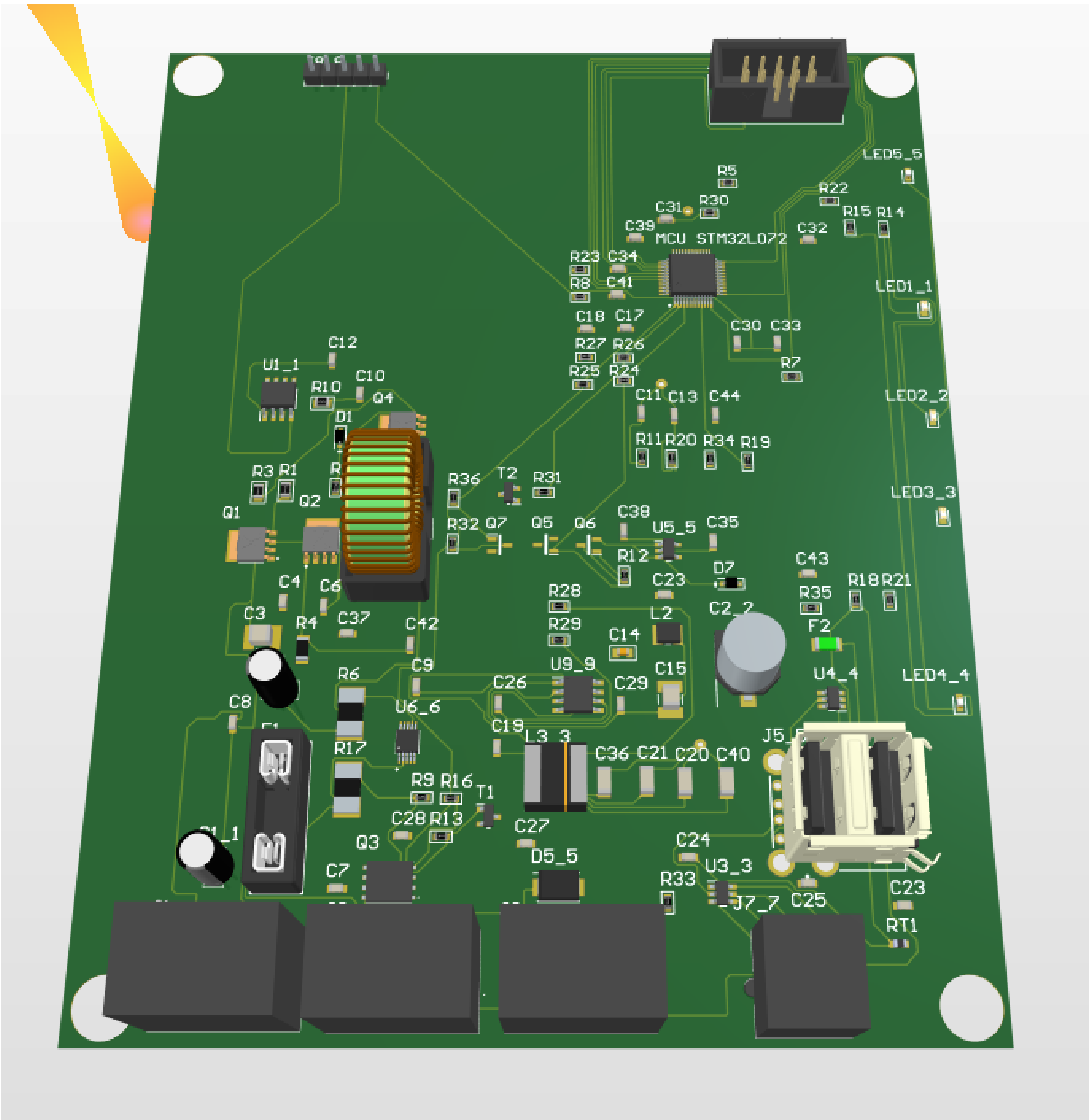


Figure 88: MPPT-1210 pcb design (3D model)

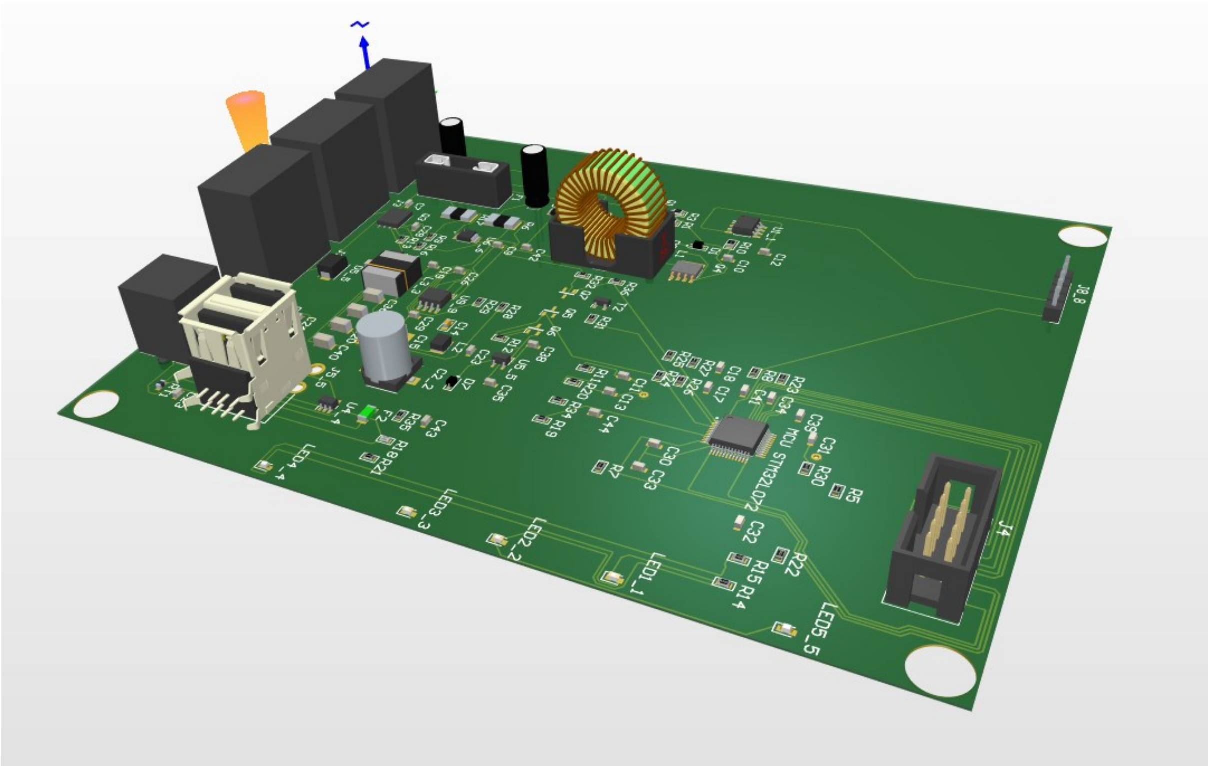


Figure 89: MPPT-1210 pcb design (3D model)

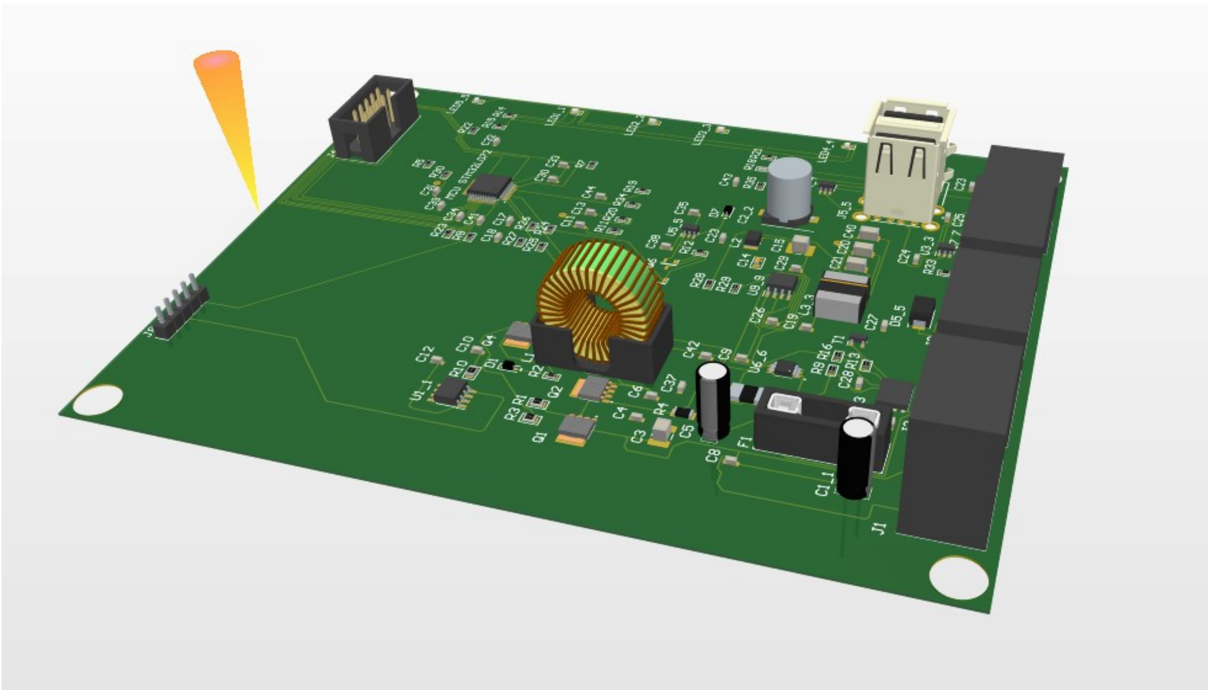


Figure 90: MPPT-1210 pcb design (3D model)

Componer	References	Value	Footprint	PartNumber	Remarks	Config	DNF	Supplier
1	C35	100p	C_0603_1608	CC0603JRNPO9BN101	NP0/C0G			
2	C6 C11 C13	1n	C_0603_1608	GRM1885C2A102JA01D	NP0/C0G			
3	C4 C7 C8 C17 C18 C27 C28 C37 C41 C44	10n	C_0603_1608	GCM188R72A103KA37D	100V, X7R 100V (not needed), X7R			
4	C9 C10 C19 C24 C25 C26 C30 C31 C32 C39 C42 C43	100n	C_0603_1608	CC0603KRX7R9BB104				
5	C29	220n	C_0603_1608	GCM188R71E224KA55D	25V, X7R			
6	C14	1u	C_0805_2012	CC0805KKX7R9BB105				
7	C12 C23 C33 C34 C38	2.2u	C_0603_1608	GRM188R61E225KA12D	25V, X5R			
8	C3	4.7u	C_1210_3225	GRJ32DC72A475KE11L	100V, X7S			
9	C15	10u	C_1210_3225	CL31A106KAHNNNE	25V, X7R			
10	C20 C21 C36 C40	22u	C_1206_3216	CL31B226MPHNNNE	10V			
11	C2	150u	CP_Elec_8x6.2	EEEFK1E151P	25V			
12	C5	820u	CP_Radial_D10.0mm_P5.00mm	EEU-FR1E821	25V, 2.18A, 10x20 mm			
13	C1	1200u	CP_Radial_L31.5mm_D16.0mm_P7.50mm_horizontal	EKYB630ELL122MLN3S	63V, 3.0A, 16x31.5			
14	D1 D4 D7	1N4148	D_SOD-123	1N4148W-7-F				
15	D5	SMBJ24A	D_SMB	SMBJ24A				
16	F1	25A	KEYSTONE-FUSE-3557-2	3557-2				
17	F2	50mA	R_1206_3216	0ZCJ0005FF2E				
18	J7	6P6C	RJ25_6P6C_TabUp	PJ006-6P6C	Alternative: Pulse E5566-Q0LK22-L			
19	J1 J2 J3	MKDS_5-2_952	Phoenix_Contact_MKDS_5-2-952	1714971 Phoenix Contact				
20	J6	PWR_12V	JST_XH_B02B-XH-A_1x02_P2.50mm_Vertical	B2B-XH-A (LF)(SN)				
21	J8	ST_Nucleo_SWD	PinHeader_1x05_P2.54mm_Vertical	M20-9990546	Alternative: Standard 2.54 mm pitch header 1x5			
22	J4	UEXT	Box_Header_2x05x2.54mm_Straight	302-S101				
23	J5	USB_A_stacked	USB_A_Wuerth_61400826021_Horizontal_Stacked	UJ2-ADH-1-TH	Alternative: Wuerth 61400826021			
24	L2	2.2uH	L_1210_3225Metric	BRL3225T2R2M				
25	L3	10uH	Bourns_SRN8040TA	NR8040T100M	Alternative: Bourns SRN8040TA-100M			

Figure 91: MPPT-1210 Bom[27]

26	L1	47uH	L-FERYSTER-DTMSS-27_47uH	DTMSS-27/0,047/15-HX				Feryster
27	LED4 LED5	green	LED_0603_D3.0mm	LTST-C190KGKT	Alternative: LTL-4231 (3mm THT)			
28	LED1 LED2 LED3	yellow	LED_0603_D3.0mm	LTST-C191KSKT	Alternative: LTL-1CHY (3mm THT)			
29	Q3	BSC084P03NS3	5X6_MOSFET	BSC084P03NS3GATMA1	Alternative: SI7149ADP-T1-GE3			
30	Q5 Q6 Q7	BSS83P	SOT-23	BSS83P H6327				
31	Q1 Q2 Q4	PSMN5R2-60YLX	5X6_MOSFET	PSMN5R2-60YLX	Alternative: BUK9Y6R0-60E			
32	R6 R17	3m	R_Bourns_CRE2512	CRE2512-FZ-R003E-3				
33	R4	2.2k	R_1206_3216	RC1206FR-072R2L				
34	R1 R3 R10	4.7k	R_0805_2012	RC0805FR-074R7L				
35	R8	100 Ohms	R_0603_1608	RC0603FR-07100RL				
36	R11 R14 R15 R18 R20 R21	470 Ohms	R_0603_1608	RC0603FR-07470RL				
37	R5 R7 R13 R30 R33 R34	2.2k	R_0603_1608	RC0603FR-072K2L				
38	R26 R27	5.6k	R_0603_1608	RC0603FR-075K6L				
39	R9 R16 R19 R31	10k	R_0603_1608	RC0603FR-0710KL				
40	R29 R32	24.9k	R_0603_1608	RC0603FR-0724K9L				
41	R12 R22 R23 R24 R25 R28 R35 R36	100k	R_0603_1608	RC0603FR-07100KL				
42	R2	1M	R_0603_1608	RC0603FR-071ML				
43	RT1	10k NTC	R_0603_1608	NCU18XH103E6SRB				
44	T1 T2	MMBT3904	SOT-23	MMBT3904-7-F				
45	U5	AP2210-3.3	SOT-23-5	AP2210K-3.3TRG1	Alternative: MIC5225			
46	U3 U4	D1213A-04SO	SOT-23-6	D1213A-04SO	Alternative: IP4220CZ6			
47	U6	INA2181	VSSOP-10_3.0x3.0mm_P0.5mm	INA2181A2IDGS	Gain 50			
48	U1	LM5109BMA	SOIC-8_3.9x4.9mm_Pitch1.27mm	LM5109BMAX/NOPB				
49	U9	LMR33630	TI_SO-PowerPAD-8_ThermalVias	LMR33630ADDA	400 kHz version			
50	U2	STM32L072CZT6	LQFP-48_7x7mm_P0.5mm	STM32L072CZT6	Alternative: STM32L073CZT6			

Figure 92: MPPT-1210 Bom [27]