Power Board

EPFL N-Pulse

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February 26, 2025

1 Introduction

The purpose of this report is to explain all the steps leading up to the last version of the PCB. Different design considerations are discussed and explained.

The purpose of this part of the project is to supply the power that comes from the battery to other devices in the arm. For that we need to split it into branches with different voltage and current levels depending on the device (c.f. Figure1).

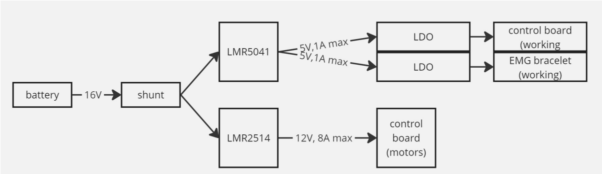

Figure 1: Schematics

2 Requirements

Input : 16.8V to 12V;
Output: 12V (Motors) and 5V (EMG and Control Board);
Size: Mechanical constraints;
Power dissipation : as low as possible to avoid component burning and harming the user.

3 Design Considerations

- Current Mirror

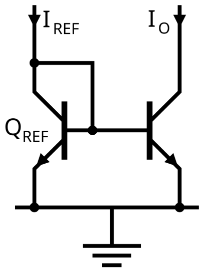

Figure 2: Current Mirror

The advantage is that it can be easily integrated in a PCB and a simple circuit. However, this design outputs a constant current level regardless of the system's requirements. Outputting too much current will empty the battery much faster and potentially damage other parts of the system which do not require high current.

- LDO
  The LDO system is a way of reducing voltage level through heat dissipation. If the voltage drop is too high the temperature can increase very fast which can damage the PCB. On the other hand, they are simple, inexpensive and the output voltage is low-noise (as opposed to a buck regulator).

4 12V Circuit

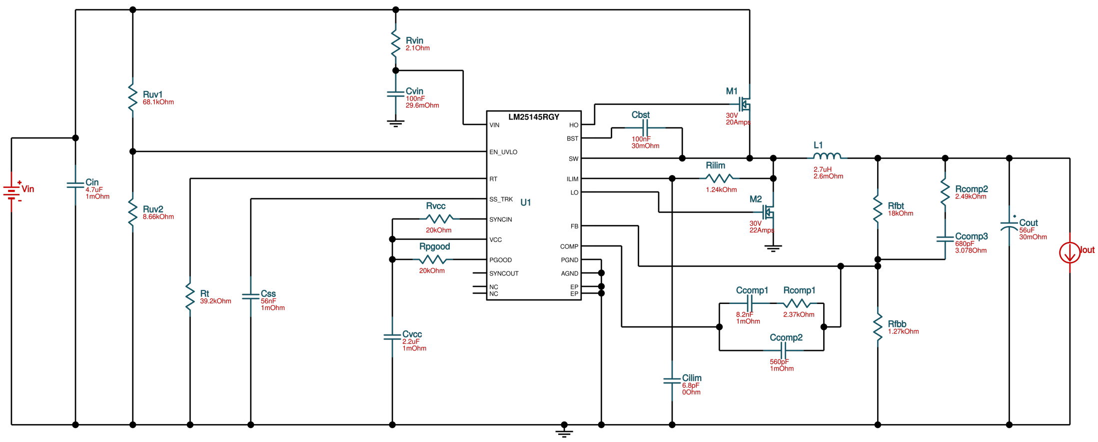

Figure 3: 12V, 8A circuit designed by Webench

This circuit is made to supply the motors of the arm which work with 12V. To design the circuit, we had to estimated the maximum current value passing through this branch to power the motors. Each motor has a stall current of 0.5A. The arm prosthesis is designed to contain a maximum of 8 motors. As such, the maxmimum current requirements for all the motors in stall mode is 4A. To avoid breaking the system if the current suddenly increases, a safety margin of +0.5A is considered per motor which implies that the circuit should ultimately accept 8A.

4.1 Circuit Properties

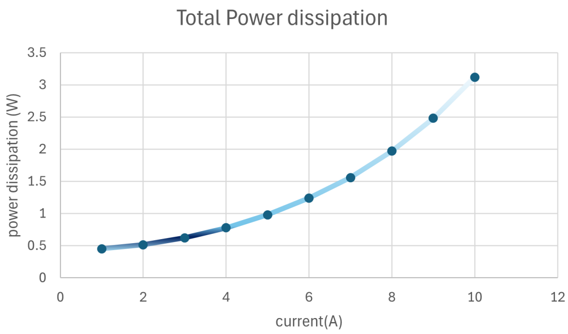

Figure 4: Caption

4.2 Components

Category	model	values	mark	number	Figure3
Capacitors	GRM32ER71H475KA88L	4.7uF50V	murata electronics	1	C_{in}
resistor	CRCW040269K8FKED	69.8k	Vishay	1	R_{uv1}
resistor	CRCW06038K25FKEA	8.25k	Vishay	1	R_{uv2}
resistor	CRCW06032R10FKEA	2.10ohms	Vishay	1	R_{vin}
Condensator	CGA3E2X7R1H104K080AA	0.1uF	TDK	1	C_{vin}
Resistor	CRCW040239K2FKED	39.2k	Vishay	1	R_t
Condensator	GRM155R71C563KA88D	56nF	murata electronics	1	C_{ss}
Condensator	C1005X5R1V225K050BC	2.2uF	TDK	1	C_{vcc}
resistor	RC0603FR-0720KL	20k	Yageo	2	R_{vcc} R_{pgood}
Transitors	CSD17577Q3A	35A Id, 30V	texas instrument	1	M_2 M_1
condensator	GCM1555C1H100FA16D	10pF(echange)	Murata electronics	1	C_{bst}
Resistor	CRCW04021K24FKED	1.24k Ohms	Vishay	1	R_{ilim}
Condensator	GRM1885C2A100JA01D	10pF	murata electronics	1	C_{ilim}
Resistor	CRCW04022K37FKED	2.37k	Vishay	1	R_{comp1}
Condensator	GRM155R71C822KA01D	8200pF	Murata Electronics	1	C_{comp1}
Condensator	CGA2B2X7R1H681K050BA	680pF	TDK	1	C_{comp2}
Inductance	SER1360-272KLD	2.7uH	Coilcraft	1	L_1
Resistor	RC0603FR-0718KL	18k	Yageo	1	R_{fbt}
Resistor	CRCW04021K27FKED	1.27K	Vishay	1	R_{fbb}
Resistor	CRCW04022K49FKED	2.49k	vishay	1	R_{comp2}
Condensator	CGA2B2X7R1H681K050BA	680pF	TDK	1	C_{comp3}
Condensators	20SVPF56MX	56uF	Panasonic	1	C_{out}

- pin connectors
  We transfer all the current to the control board with 2 pins that will have a current max of 10A (worst case). The pin have a a pitch of 5mm

4.3 PCB traces

We need to be carefull with the traces to avoid that they burns. The current that pass in the trace heat the trace and if the resistance is to high the trace can burn after a certain time. The value of the current is an RMS value. To have security margins, we take the RMS current as 3.5A (the case where all the motors work at the maximum in the same time). The 8A will not burn our traces because it will occur only in the worst case and a really short time.
We can have multiple ways of impact the surface of the trace to reduce this resistance. The easiest is during the manufacturing with a change in the thickness (more common are 1oz and 2oz). The calculation depend on the ambiant temperature: we take 25°C. It depend on the temperature rise: we take 10°C. There is a calculation to find what to use.

$$A = \left(\frac{I}{k \cdot (T_{rise})^b}\right)^{\frac{1}{c}} \tag{1}$$

$$W = \frac{A}{t \cdot 1.378} \tag{2}$$

avec :

- A : surface
- W : trace width
- I : Current(A)
- k : Coefficient of proportion for internal layers : 0.024
- T_{rise} : Temperature rise
- b : empirical exposant for internal layers : 0.44
- c : correctionnal exposant for internal layers : 0.725
- t : thickness

Results

$$\text{thickness of } 1oz\text{: } W = 4,398786766mm$$
$$\text{thickness of } 2oz\text{: } W = 2,199393383mm$$

In our PCB, the big traces are only where the current can be high and the other traces are normal (=0.2mm)

5 5V Circuit

The purpose of this circuit is to power the Control Board as well as the EMG bracelet. For this section we estimate that the current should not exceed 1A.

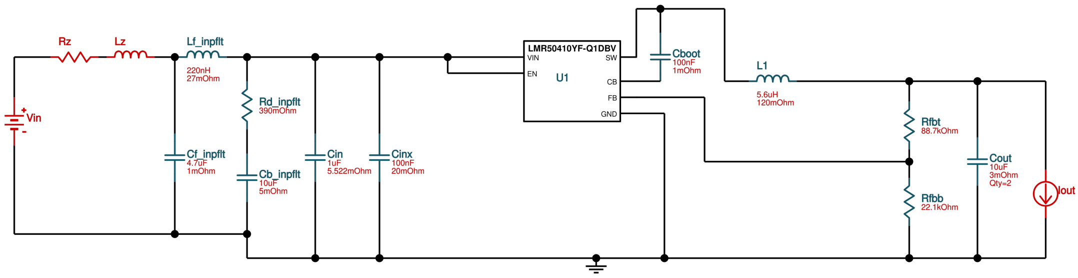

Figure 5: 5V, 1A Circuit made by Webench

5.1 Components

Category	model	values	mark	number	Figure5
Inductor	NLCV32T-R33M-EFRD	0.33uH	TDK	1	$Lf_{inplift}$
Capacitors	GRM31CR71H475KA12L	4.7uF	murata elec	1	$Cf_{inplift}$
Resistor	CRCW04021R00FKED	1 ohm	Vishay	1	$Rd_{inplift}$
Capacitors	C3225X7S2A475M200AB	10uF	TDK	1	$Cb_{inplift}$
Capacitors	C1608X5R1E106M080AC	1uF	TDK	1	C_{in}
Capacitors	GRM188R72A104KA35J	0.1uF	murata elec	1	C_{inx}
Capacitors	GRM155R71C104KA88D	0.1uF	murata elec	1	C_{boot}
Inductor	74438336047	4.7uH	wurth electronic	1	$L1$
Resistor	CRCW040288K7FKED	88.7K	Vishay	1	R_{fbt}
Resistor	CRCW040222K1FKED	22.1K	Vishay	1	R_{fbb}
Capacitors	C0805C106K8PACTU	10uF	KEMET	2	C_{out}

6 Fuse

The fuse that we have chosen can tolerate a certain amount of peak current (c.f. "Typical I2t" as shown in Figure 6). The model we selected is the SF-1206HH120M-2. Its nominal current is take to the max that the circuit can tolerate for a long time. All the components of the power board can tolerate 8A.

Electrical Characteristics

Model	Rated Current (Amps)	Fusing Time	Resistance (Ω) Typ.***	Rated Voltage	Interrupting Rating	Typical I²t (A²s) ****
SF-1206HH10M-2	10.0	Open within 5 sec. at 350 % rated current	0.0045	DC 24 V	DC 24 V 150 A	12.0
SF-1206HH12M-2	12.0		0.0039			19.0
SF-1206HH15M-2	15.0		0.0031		DC 24 V 200 A	34.0
SF-1206HH20M-2	20.0		0.0020			64.0
SF-1206HH25M-2	25.0		0.0016		DC 24 V 250 A	187.0
SF-1206HH30M-2	30.0		0.0012		DC 24 V 300 A	270.0

*** Resistance value measured with ≤10 % rated current at 25 °C ambient.
**** Melting I²t calculated at 1000 % of current rating.

Figure 6: Fuse Characteristics

7 Final PCB

We have a PCB with 2 layers due to the fact that some traces should pass on the bottom layer to avoid to crossing with others.

Final Dimensions: 38.35mm x 37.5mm x 7mm

The 2 holes are to fix the PCB inside the arm and they are M2

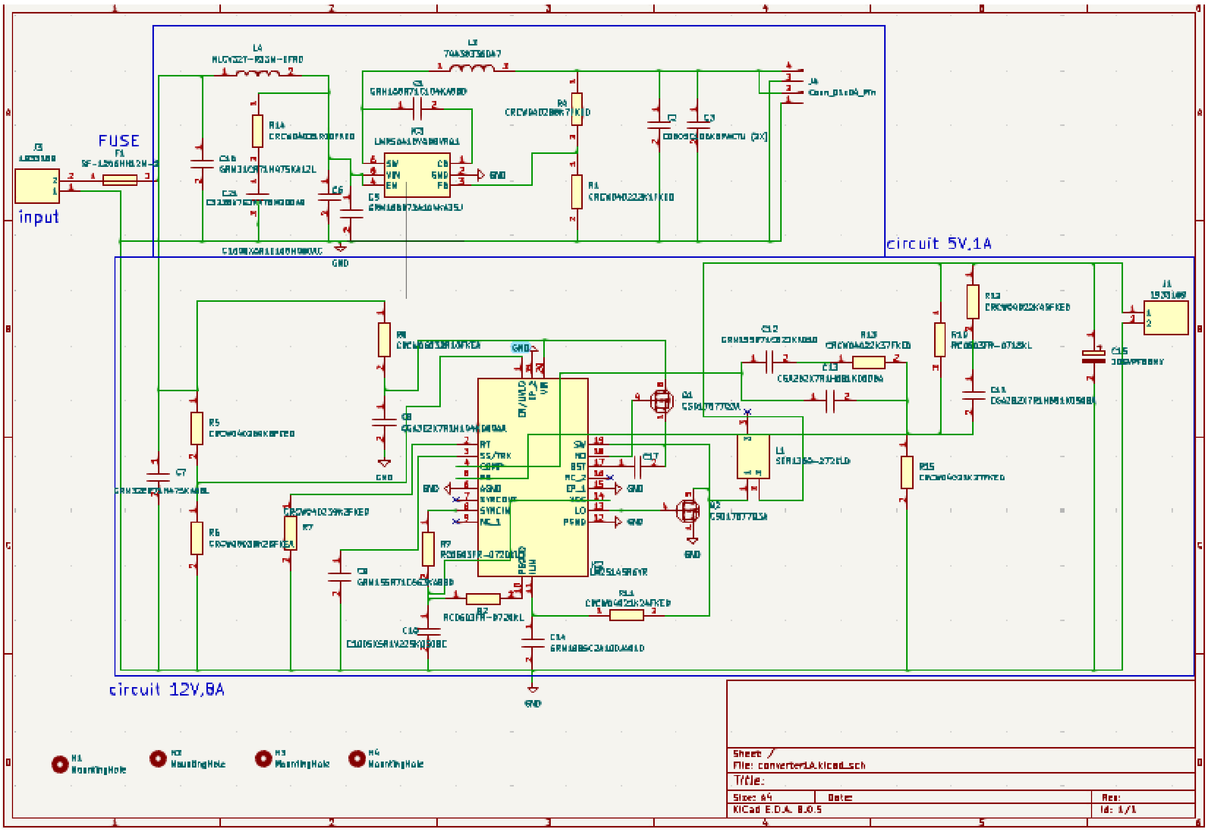

Figure 7: KiCad Circuit Schematics

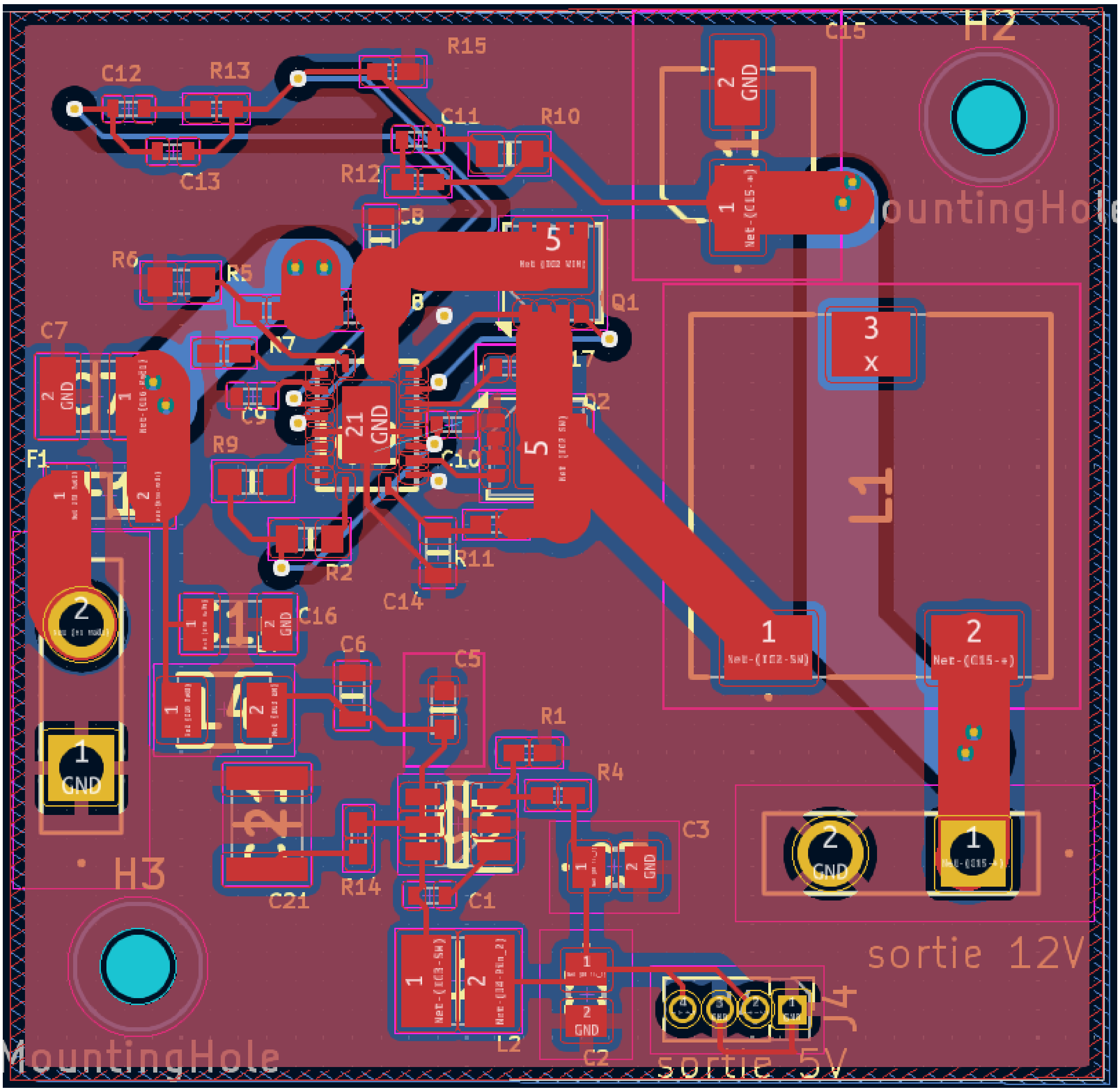

Figure 8: board PCB

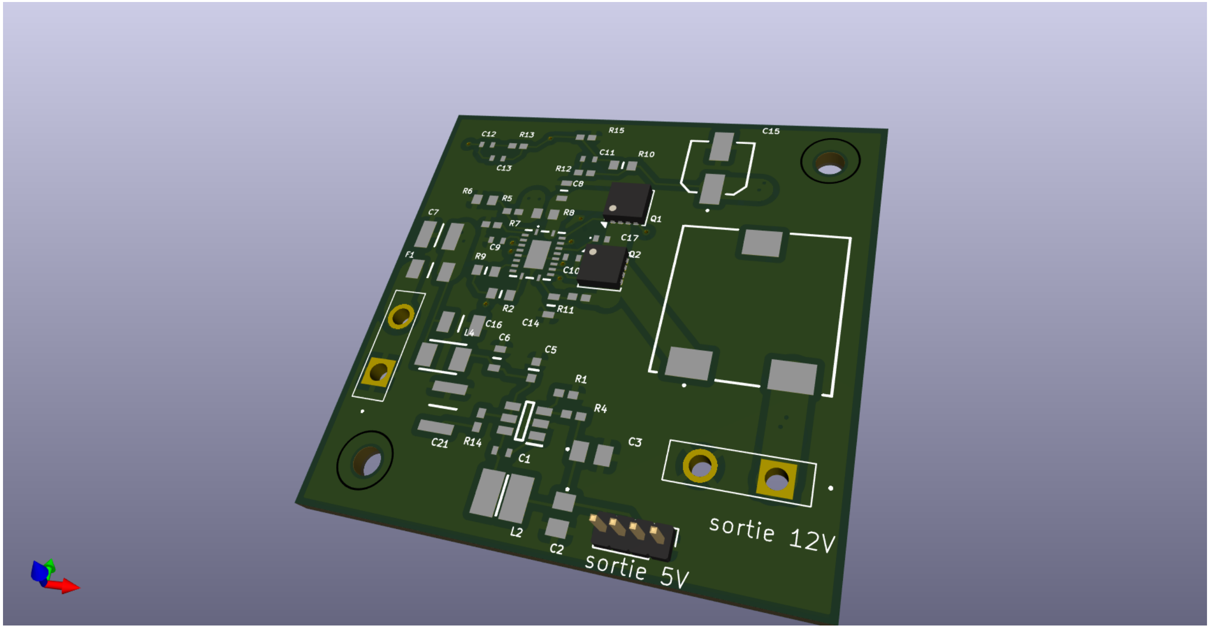

Figure 9: PCB 3D model