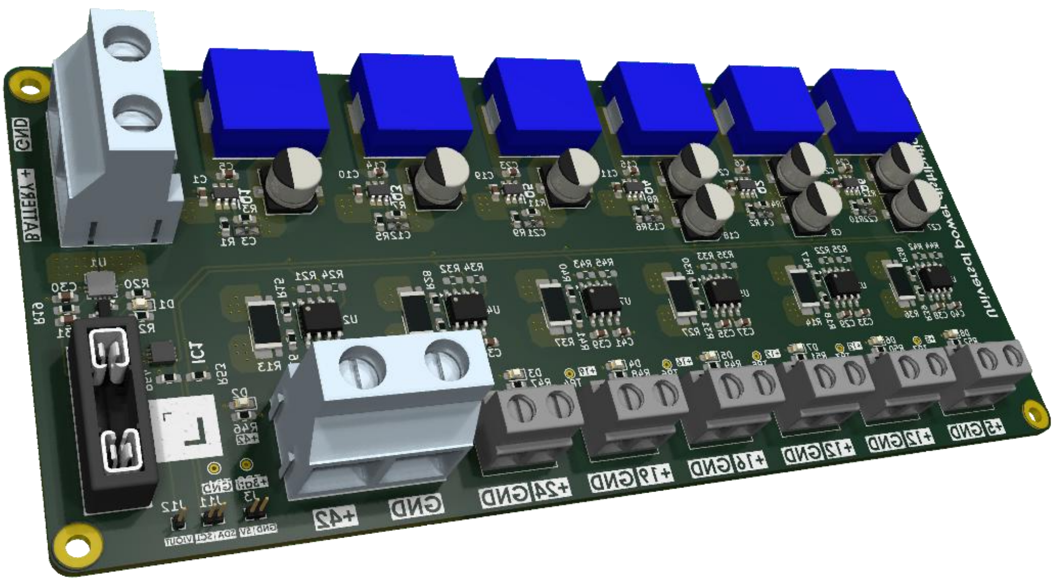
Lapland University of Applied Sciences

Universal Power Distribution PCB
UDP-PCB



User’s Manual

Rev 1.1

May 2025

Designed by Dries Nuttin

Table of Contents

1.0 Introduction

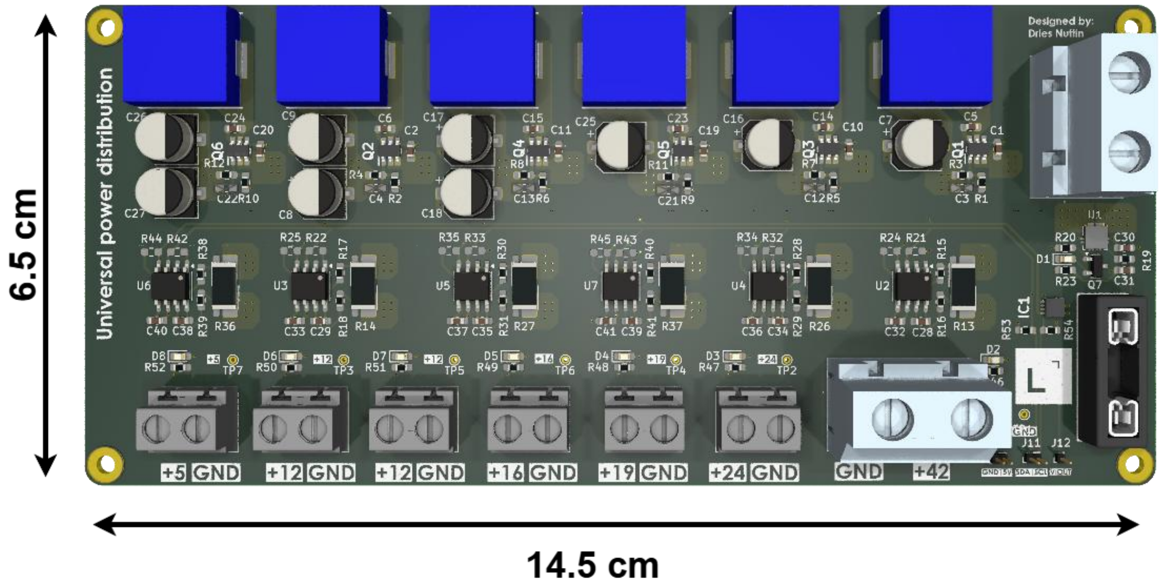
Universal power distribution PCB (UDP-PCB) provides the possibility for quick and easy power distribution in any robotics or electronics project ensuring maximum efficiency. A single battery can provide power to 6 different voltage rails with their respective voltage level (**24V, 19V, 16V, 12V, 12V, 5V**) Each stage can supply up to **3.5 Amps continuously** with a **max voltage input of 60V**. A separate battery output has been provided to allow for a motor driver input equal to the battery voltage, protected by a switchable fuse for easier integration into any project. Each voltage rail (except the battery output) has its own **INA219** current/voltage/power sensor that communicated via I^2C. The current of the entire system is monitored by an **ACS711** HALL sensor which sends out a voltage in relation to the current delivered by the battery. An onboard **STS30** digital temperature sensor supplies the user with real-time temperature data to ensure that the PCB/ambient temperature does not reach self-made limits.

Some of the features for the UDP-PCB

- 7 voltage outputs (BAT+, 24V, 19V, 16V, 12V, 12V, 5V).
- Single battery input of 4.3V to 60V max.
- 6 different voltages from 1 battery input.
- ±1% voltage level accuracy.
- 3.5 Amps continuous, with a maximum pulse current of 4.3 Amps.
- Real-time monitoring of current/voltage/power for 6 voltage rails.
- Real-time HAL current monitoring of the entire current consumption of the PCB.
- Real-time temperature monitoring.
- Main system over current fault indicator.
- Rail supply malfunction indicator.
- ±85% Efficiency for each buck converter stage.
- BAT+ Fuse protection.
- Single rail shutdown that leaves the rest unaffected.
- Over current / temperature protection on each rail.
- No Over-voltage protection.

Note: V1.0 still has specific repair requirements in place, please consult the REPAIR chapter in order to see what needs to be done for newly purchased PCBs.

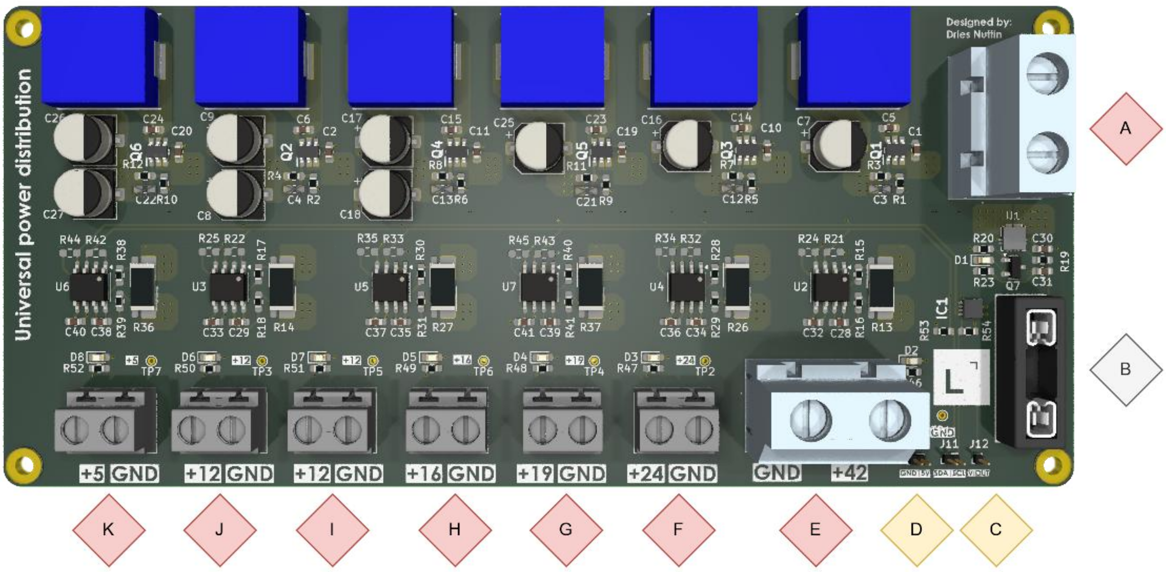
2.0 Product specifications



Absolute **Maximum ratings** of the Universal Power Distribution PCB

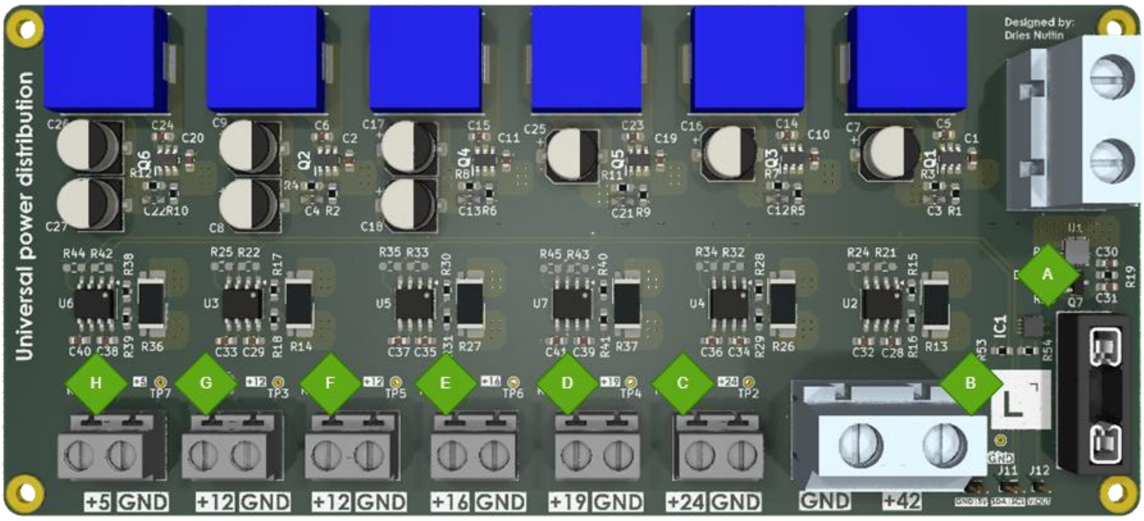
No.	Parameters	Min	Typical	Max	Unit
1	Input voltage (Battery+)	4.3	-	60	V
2	Current Battery input (Continuous)		32		A
3	Current Battery input (1 pulse, 100ms)		100		A
4	Rail current (Continuous)		3.5		A
5	Rail current (pulsed, hiccup mode)		6		A
6	Current usage with no output		54		mA
7	Thermal shutdown threshold		165		°C
8	PCB temperature	-40	35	165	°C

These ratings should not be exceeded, doing so can lead to permanent damage to the PCB or components.



LABEL	FUNCTION
A	**Main battery input (4.2V to 60V)**
B	**Fuse linked to output E**
C	**ACS711 VIout output**
D	**I^2C output**
E	**Main battery output with fuse protection**
F	**24V output**
G	**19V output**
H	**16V output**
I	**12V_1 output**
J	**12V_2 output**
K	**5V output**

* Red = Power input/output
* Yellow = Sensor output
* Grey = Fuse



LED function in the UDP PCB. If all are on = Working as expected

LABEL	FUNCTION	Meaning if not on
A	Fault for ACS711 HALL current sensor	Overcurrent
B	Battery output voltage line	No voltage available
C	24V output voltage line	No voltage available
D	19V output voltage line	No voltage available
E	16V output voltage line	No voltage available
F	12V output voltage line	No voltage available
G	12V output voltage line	No voltage available
H	5V output voltage line	No voltage available

Note: The described reasons might not be the only reasons that the LED is off. The LED itself might be broken, the voltage might be unstable, a connection might have severed, the LED resistor might have broken. Please test the power supplies with multimeter. If the LED is off, please consult the REPAIR chapter.

3.0 How to use?

The UPD-PCB can be utilized in any robotics project that is powered by **1 battery**. This battery can be plugged into the PCB, which will follow by the indicator **LEDs turning on** and each stage delivering an output voltage. Screw terminals have been provided for an ease of use to attach the necessary voltage lines. The **GND is shared** between all terminals, meaning you can switch the ground cables between voltage in / outputs even though this is not recommended.

To integrate the UPD-PCB into any robotics project please ensure the following:

- The battery output is correctly plugged into the screw terminal plug on the PCB
- It is recommended to have a battery switch and anti-spark unit before the PCB
- The Fuse is plugged into the PCB if battery output is required
- All LEDs are on
- The output wires have the correct polarity
- If needed, the I^2c and Viout connections are plugged into an external MCU unit.

> *Note: it is not recommended to plug/unplug any wires while the PCB is on. Doing so can result in permanent damage if any of the live wires touch the IC's or a spark is generated.*

An example of a UPD-PCB plugged in correctly can be found in the image below! Note that the LEDs are not on due to the **battery being switched off**.

As can be seen in the image, the polarity of the wires is ensured and coherent with the silkscreen on the PCB itself. The fuse is in place for, in this specific case, **25A**, and the **I^2c** and **VIout** wires are not connected. If the battery was enabled, the LEDs should light up and the PCB will immediately work without issue.

> *Note: The sensors do not need to be enabled for the PCB to deliver stable power*

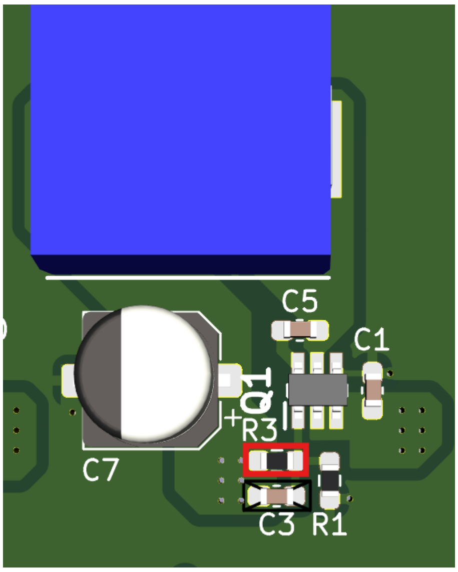
4.0 Power delivery

The power delivery for each rail is being supplied by a fine-tuned LMR516x5 buck converter. This buck converter works at a 400 kHz (might vary due to the FPM version being utilized in this design) More information can be found in the datasheet of the buck converter itself. Each buck converter has been chosen for its high efficiency, low thermal rise, high power output (3.5A continuous).

The output voltage of each rail is decided using an external resistor. This resistor is visible in the image below where the resistor R3 has a red square surrounding it. If the output voltage needs to be replaced or is not at the desired resistance, please change this resistor.

The desired resistor value can be calculated by using this equation. All resistors used are size **0603**.

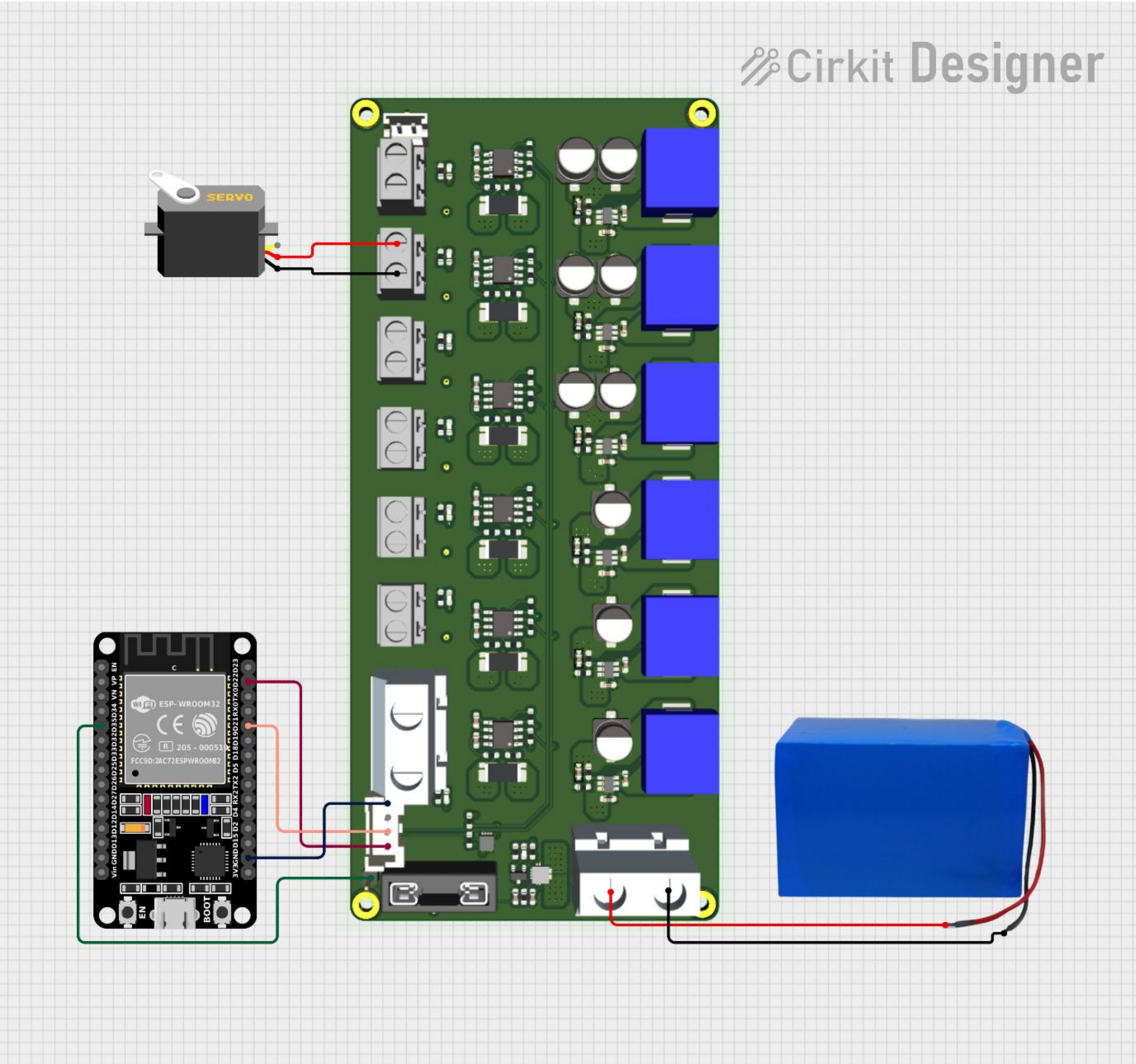
$$Resistor = \frac{Vout - 0.8V}{0.8V} \cdot 10200$$



5.0 Sensor integration

The UPD-PCB can monitor each individual rail for voltage, current and power usage. This can be done by a single MCU which has to read out 1 I^2C bus and read out an ADC voltage signal. By following the steps in this chapter, you will be able to read out these sensors and use them for any application.

An example of the sensor integration can be found in the image below. Here you can see an ESP32 actively reading out both the VIout pin and the I^2C line from the entire PCB.



5.1 INA219

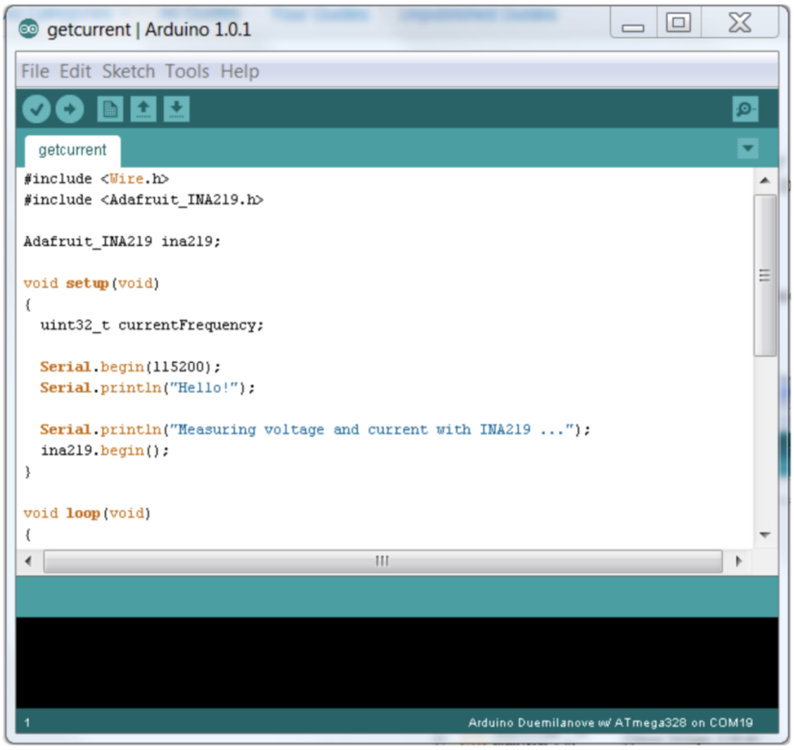
All the relevant I^2C address can be found in the table below. These addresses are changeable if the A1 and A0 connections are changed. ***Please note*** that the I^2C address for the temperature sensor is identical to the **16V** line (**0x4A**), this table below already has the changed I^2C address, the change itself can be found in the **REPAIR** chapter.

Voltage	A1 connection	A0 connection	I^2C address Binary	I^2C address Hexadecimal
+24V	GND	GND	1000000	0x40
+19V	GND	+5V	1000001	0x41
+16V	GND	SDA	1000010	0x42
+12V_1	+5V	GND	1000100	0x44
+12V_2	+5V	+5V	1000111	0x47
+5V	+5V	SDA	1000101	0x45

Arduino Code

Programming the UPD-PCB to receive INA219 data can be done by using the Arduino IDE. This can be done by simply using a library:

1. Open the Arduino library manager
2. Search for the Adafruit INA219 library and install it
3. With this, one of the examples can be opened and it should be ready to use!
4. Ensure that you are using one of the addresses previously mentioned in order to read out from the correct sensor.



More information regarding the INA219 can be found here!

https://cdn-learn.adafruit.com/downloads/pdf/adafruit-ina219-current-sensor-breakout.pdf

An example of choosing a correct address can be found in the image below. Here the code selects a hexadecimal value for which **INA219** sensor to read out. In this code the **0X41** INA219 is selected which, according to the table previously mentioned, will monitor the +19V line.

```
#include <Wire.h>
#include <Adafruit_INA219.h>

Adafruit_INA219 ina219(0x41);

void setup() {
 Serial.begin(9600);
 ina219.begin();
}

void loop() {
 Serial.print("V: "); Serial.print(ina219.getBusVoltage_V());
 Serial.print("V, I: "); Serial.print(ina219.getCurrent_mA());
 Serial.print("mA, P: "); Serial.print(ina219.getPower_mW());
 Serial.println("mW");
 delay(1000);
}
```

Note: The 16V INA219 sensor has the same I^2C address as the Temperature sensor before doing any repairs. Ensure that you either follow the steps in the ***REPAIR*** *chapter, or don't use the temperature sensor*

5.2 ACS711

The **ACS711** is a Hall-effect-based current sensor that outputs an analog voltage proportional to the current passing through the entire system. It can be connected to an MCU's ADC pin to allow for a full-system current monitoring.

- **Output voltage (VIout) at 0A: VCC / 2 = 2.5V**
- **Sensitivity:** ~45 mV per Amp
- **Range:** 30A

A calculation must be made in the MCU to determine the correct amount of current. Since the baseline for the ACS is half of the supply voltage (5V) and any positive current will simply add 0.045V/A on top of that baseline. If the current goes in reverse (which it should never do) the VIout will go lower.

The following calculation can be made:

$$Current(A) = \frac{Vout - \frac{5V}{2}}{0.045V}$$

This formula can be interpreted in code by following the code snippet below.

```
const int ACS_PIN = 36; // e.g., GPIO36 (ADC1)


void setup() {
  Serial.begin(9600);
}


void loop() {
  int adc = analogRead(ACS_PIN);
  float voltage = adc * 5.0 / 4095.0;
  float current = (voltage - 2.5) / 0.045; // 45mV per Amp
  Serial.print("Current: "); Serial.print(current); Serial.println(" A");
  delay(1000);
}
```

Note: The best way to ensure accurate measurement is to read out the 5V line from the INA219 sensor and use that in the calculation for the supply voltage. Replace 5V with the correct voltage measurement.

5.3 STS30

The **STS30** is a digital I^2C temperature sensor made by Sensirion, known for its high accuracy and reliability. It outputs temperature values in °C directly over the I^2C bus.

- Communication: I^2C
- I^2C address: 0x4A
- Accuracy: ±0.2°C
- Range: -40°C to +125°C

To read out the temperature sensor an Arduino library such as SHT31 can be used to make it easier to read out the temperature sensor.

```
#include <Wire.h>
#include "Adafruit_SHT31.h"


Adafruit_SHT31 sht = Adafruit_SHT31();


void setup() {
 Serial.begin(9600);
}


void loop() {
 float temp = sht.readTemperature();
 if (!isnan(temp)) {
  Serial.print("Temperature: ");
  Serial.print(temp);
  Serial.println(" °C");
 }
 delay(1000);
}
```

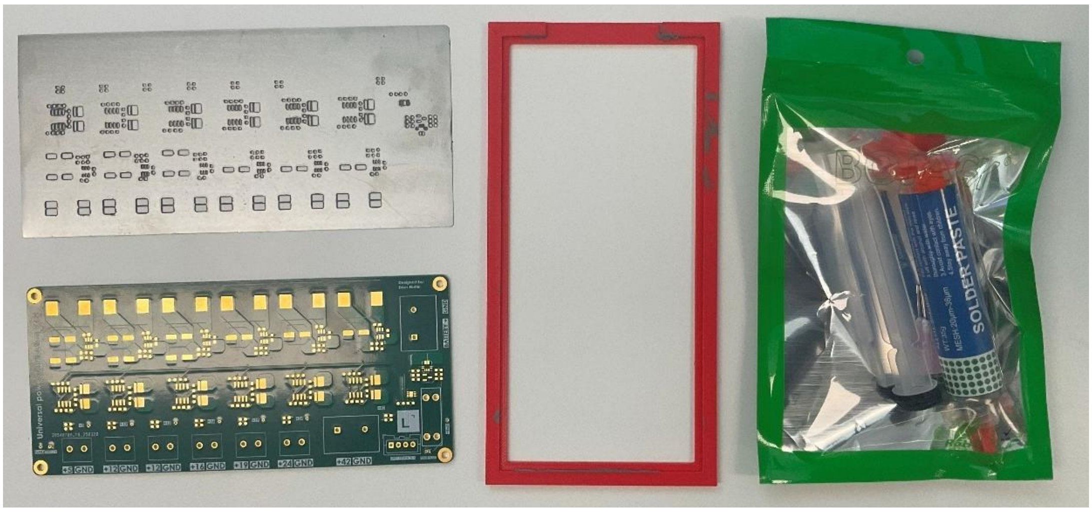
6.0 Fabrication

The fabrication of the PCB can be quite complicated and should be done by someone who is used to component placement, electronics and soldering. This can also be avoided by using the PCB assembly option that is available with some providers such as JLCPCB. This will allow for a full and ready PCB to be delivered instead of ordering the components separately. Do ensure that the latest version of the PCB has been selected to get the best results!

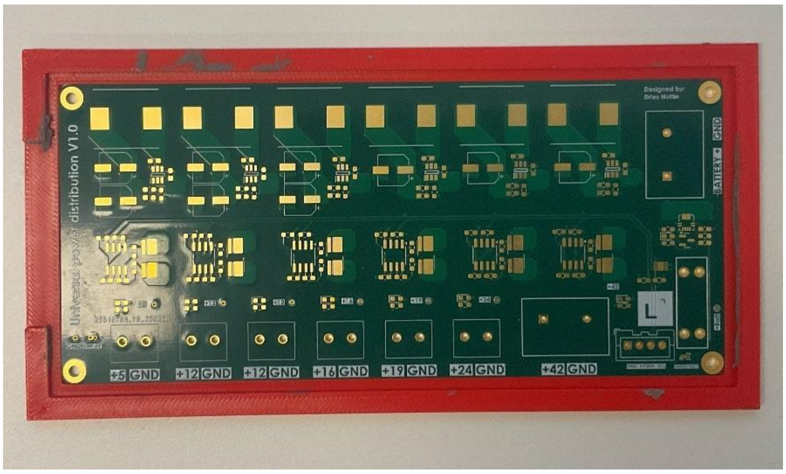
If the PCB will be made in house, please follow the instructions below.

Please ensure that before starting, you have the right equipment, the needed equipment to start is mentioned below. All components can be soldered by hand, but this is **not recommended**.

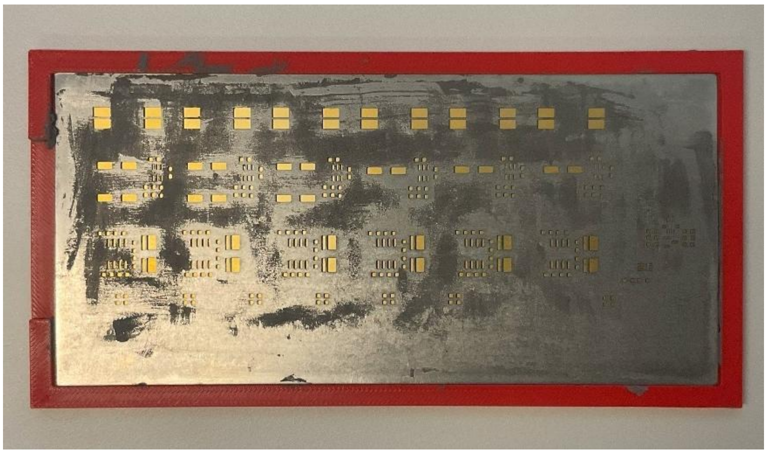
- Printed circuit board with no components
- A metal PCB stencil
- A 3D printed PCB holder that keeps the PCB and stencil in place
- Solder paste



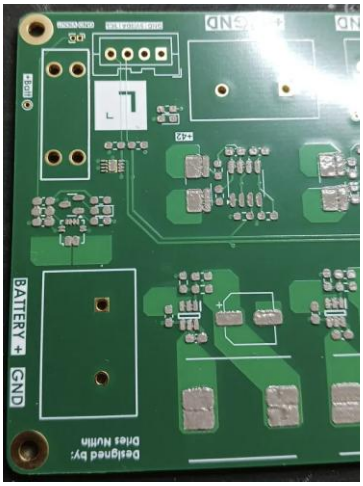
1. Place the PCB into the 3D printed PCB holder



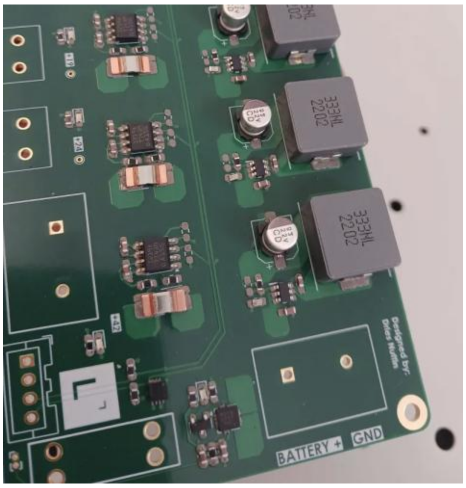
2. Overlay the PCB stencil on top of the PCB to expose the pads



3. Use the solder paste to cover all the pads. Ensure that there is not too much paste.



4. Place the components according to the Kicad files and the BOM. Please make sure that all components have the correct orientation.



5. Place the PCB into a dedicated PCB reflow oven and select the MEDIUM preset.

6. Ensure that there are no short circuits and repair any misaligned components. The PCB should now be ready for use.

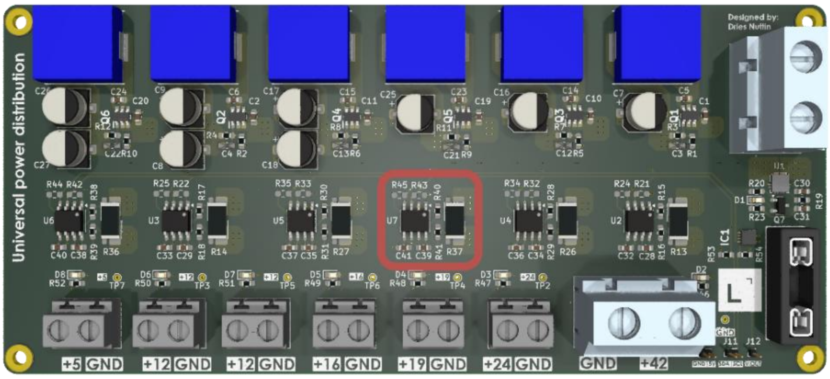
7.0 Repair

7.1 16V INA219 I^{2}C address

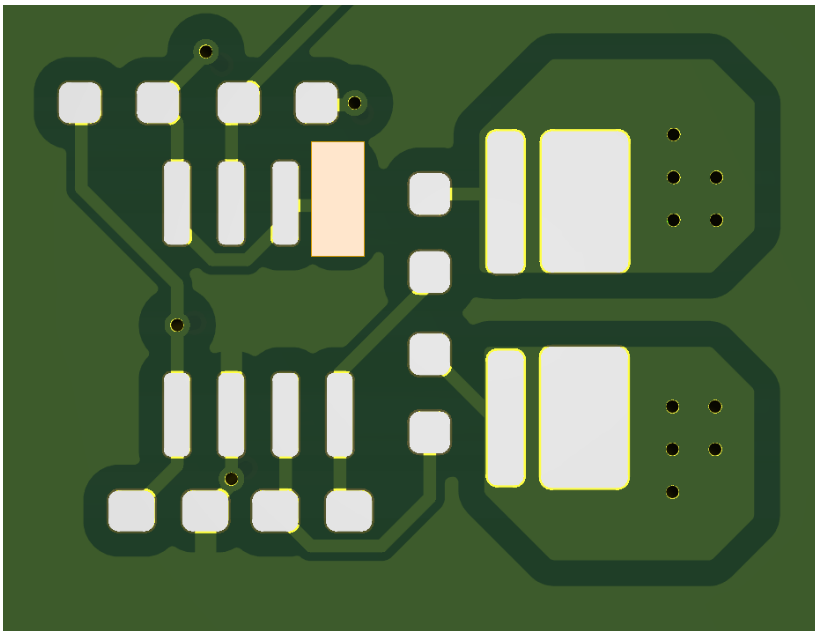
If the Universal Power Distribution V1.0 is selected, please ensure that the change to the 16V I^{2}C address has been made. The address 0x4A is identical to that of the temperature sensor.

UPD V1.1 has an updated version that has this already fixed internally. To fix this please follow these instructions:

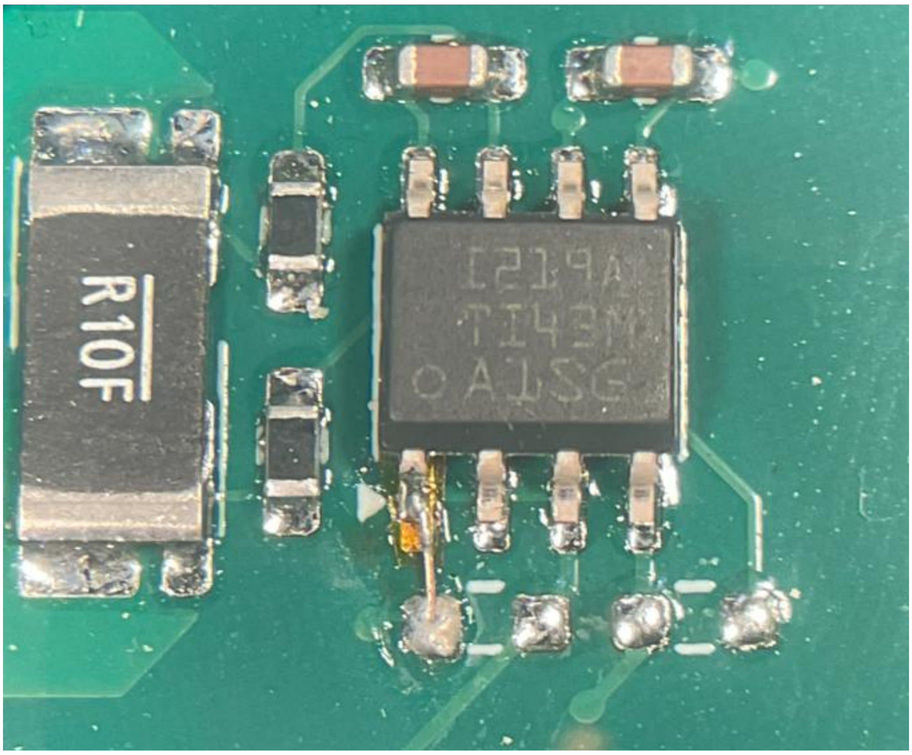
1. Locate the 16V INA219



2. Desolder the U7 chip.
3. Place a piece of Kapton tape on the following pad to sever the connection.



4. Resolder the INA219 chip ensuring that there is no connection between the pad with Kapton tape and the IC.
5. Place and solder a small copper wire between the 5V pad above the Kapton tape and the foot of the IC with Kapton tape on it. If finished it should look something like this.



The I^{2}C address of the 16V INA219 chip should now be changed to 0x42 instead of 0x4A which will allow for the reading of both the 16V INA219 chip and the Temperature sensor.

8.0 Bill of Materials

Type	Quantity	Manufacturer number	Manufacturer	Description	Value	Part on PCB
Capacitor	6	GRM188R61H225ME11D	Murata	Multilayer Ceramic Capacitors MLCC	2.2uF	C1,C2,C10,C11,C19, C20
Capacitor	20	CGA3E3X7S2A104M080AB	TDK	Multilayer Ceramic Capacitors MLCC	0.1uF	C5,C6,C14,C15,C23, C24,C28,C29,C30,C31,C32,C33,C34,C35, C36,C37,C38,C39,C40,C41
Capacitor	5	UCD1V220MCL1GS	Nichicon	Aluminium Electrolytic Capacitors	22uF	C7,C9,C16,C18,C25
Capacitor	2	UCD1V100MCL1GS	Nichicon	Aluminium Electrolytic Capacitors	10uF	C8,C17
Capacitor	2	UCD1V330MCL1GS	Nichicon	Aluminium Electrolytic Capacitors	33uF	C26,C27
LED	8	KT EELP41.12-S2U1-25-2X4X-5-R18	ams OSRAM	Single Colour LEDs	-	D1,D2,D3,D4,D5,D6, D7,D8
IC	1	STS30-DIS	Sensirion	Board Mount Temperature Sensors	-	IC1
IC	1	LMR51635XDDCR	Texas Instruments	Switching Voltage Regulators synchronous buck convert	-	Q1,Q2,Q3,Q4,Q5,Q6
IC	1	INA219AIDR	Texas Instruments	INA219 Current and power monitor	-	U2,U3,U4,U5,U6,U7
IC	1	ACS711KEXLT-31AB-T	Allegro MicroSystems	ACS711 Hall current sensor	-	U1
Mosfet	1	BSS84	onsemi	MOSFETs SOT-23 P-CH ENHANCE	-	Q7
Inductor	3	PA4343.333NLT	Pulse	Power Inductors	33uH 8A	L1,L3,L5
Inductor	2	PA4343.223NLT	Pulse	Power Inductors	22uH 9A	L2,L4

Inductor	1	PA4343.153NLT	Pulse	Power Inductors	15uH 9A	L6
Shunt Resistor	6	WSL2512R1000FEA	Vishay	Current Sense Resistors	0.1R	R13,R14,R26,R27,R36,R37
Resistor	6	CRCW060310K2FKEAHP	Vishay	Thick Film Resistor 0603	10.2K	R1,R2,R5,R6,R9,R10
Resistor	1	CRCW0603294KFKEA	Vishay	Thick Film Resistor 0603	294K	R3
Resistor	2	CRCW0603143KFKEA	Vishay	Thick Film Resistor 0603	143K	R4,R8
Resistor	1	CRCW0603232KFKEA	Vishay	Thick Film Resistor 0603	232K	R7
Resistor	1	CRCW0603196KFKEA	Vishay	Thick Film Resistor 0603	196K	R11
Resistor	1	CRCW060353K6FKEAC	Vishay	Thick Film Resistor 0603	53.6K	R12
Resistor	12	CRCW060350R0FKEA	Vishay	Thick Film Resistor 0603	50R	R15,R16,R17,R18,R28,R29,R30,R31,R38,R39,R40,R41
Resistor	1	CRCW06030000Z0ED	Vishay	Thick Film Resistor 0603	0R	R19
Resistor	2	CRCW06031K00FKED	Vishay	Thick Film Resistor 0603	1.00K	R20, R52
Resistor	14	CRCW060310K0FKEE	Vishay	Thick Film Resistor 0603	10.0K	R21,R22,R24,R25,R32,R33,R34,R35,R42,R43,R44,R45,R53,R54
Resistor	1	CRCW0603330RFKEA	Vishay	Thick Film Resistor 0603	330R	R23
Resistor	1	CRCW06032K40FKEA	Vishay	Thick Film Resistor 0603	2.4K	R51,R50
Resistor	1	CRCW06033K24FKEA	Vishay	Thick Film Resistor 0603	3.2K	R49
Resistor	1	CRCW06033K83FKEA	Vishay	Thick Film Resistor 0603	3.8K	R48
Resistor	1	CRCW06034K87FKEA	Vishay	Thick Film Resistor 0603	4.8K	R47

Resistor	1	CRCW06038K45F KEA	Vishay	Thick Film Resistor 0603	8.4K	R46
Connector	1	3557-2	Keystone Electronics	Fuse Holder 2 IN 1 FUSE HOLDER	-	J1
Connector	2	796739-2	TE Connectivity	Fixed Terminal Blocks 2P SIDE ENTRY 9.52mm	-	J2,J10
Connector	6	1776119-2	TE Connectivity	Fixed Terminal Blocks 2P SIDE ENTRY 5.08mm	-	J4,J5,J6,J7,J8,J9
Connector	1	114020163	Seeed Studio	Seeed Studio Accessories SMD Grove Female Header-Beige	-	J11