

Isolated current meter for particle accelerator

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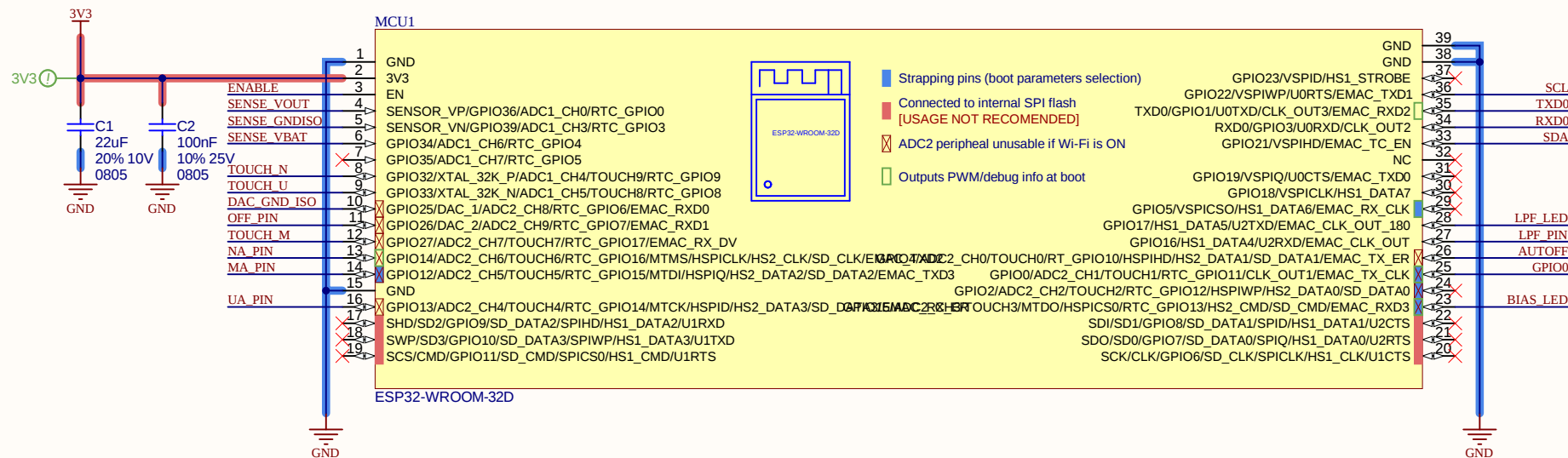


Project title: Isolated_Current_Meter.PrjPcb

Date: 2024-06-05

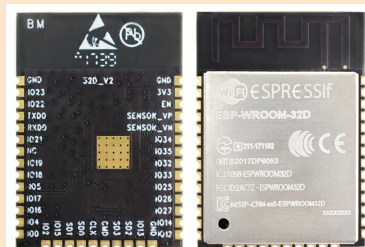
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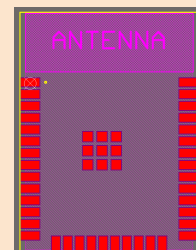


ESP32-WROOM-32D

Real model:



Footprint:



⚠ Pins GPIO0 and GPIO2 are used during boot to enter bootloader mode or to run the program stored in flash memory.

⚠ Pins GPIO6 to GPIO11 are used by internal SPI flash, so it's better to leave them unconnected.

⚠ For this project, no ADC2 pins are used, so there are no problems with wireless communications.

ESP32-WROOM-32D microcontroller unit

Module that integrates Wi-Fi and Bluetooth. It has two CPU cores, 240 MHz clock frequency, and peripherals like SPI, I2C, UART, Ethernet, I2S and capacitive touch sensors. Designed by Espressif.

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Sheet title: ESP32-WROOM-32D microcontroller unit

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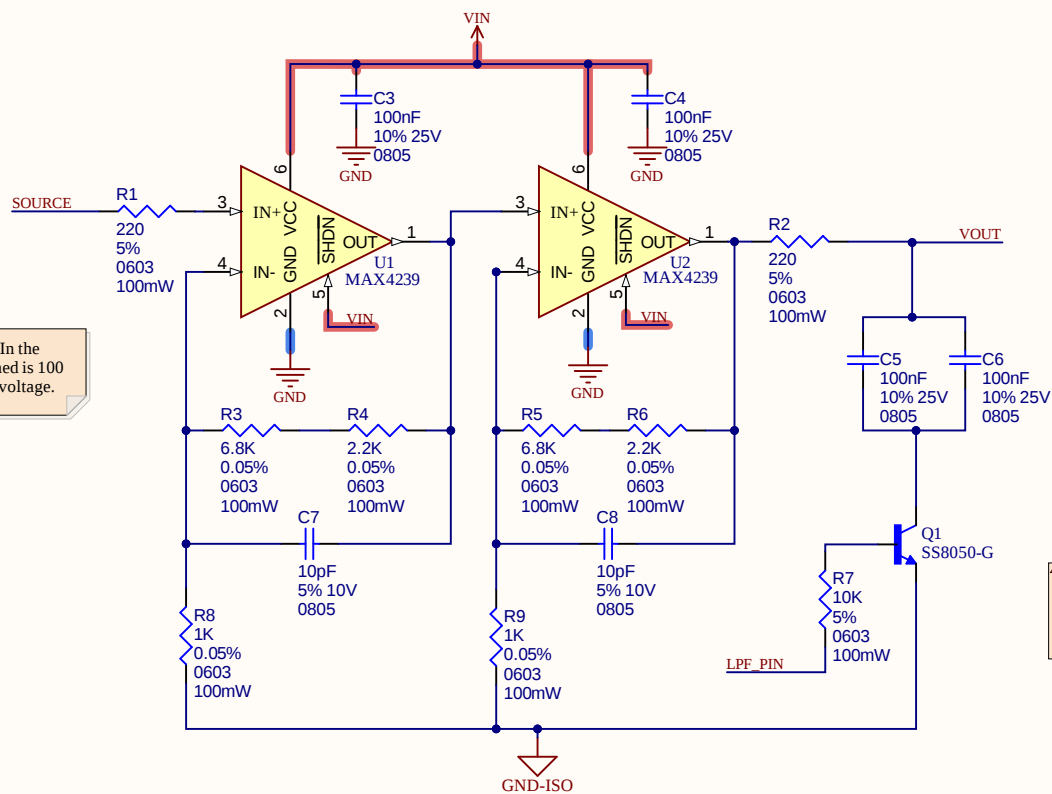
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Each amplifier has a gain of 10. In the VOUT signal, the voltage obtained is 100 times greater than the SOURCE voltage.

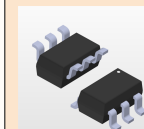


GND-ISO voltage is not 0V, but it's close to it. Its value is determined by the DAC of the microcontroller.

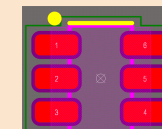
IMPORTANT: GND-ISO is not directly connected to GND.

MAX4239

3D model:

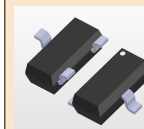


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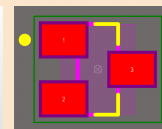


MMBT4401

3D model:



Footprint:



The function of this transistor is to control the activation of the low-pass filter, thus allowing the output signal to be filtered.

Amplifier stage

Two cascaded non-inverting voltage amplifiers, each with a gain of 10, for a total gain of 100. SOURCE voltage is amplified in relation to GND-ISO.

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Sheet title: Amplifier stage

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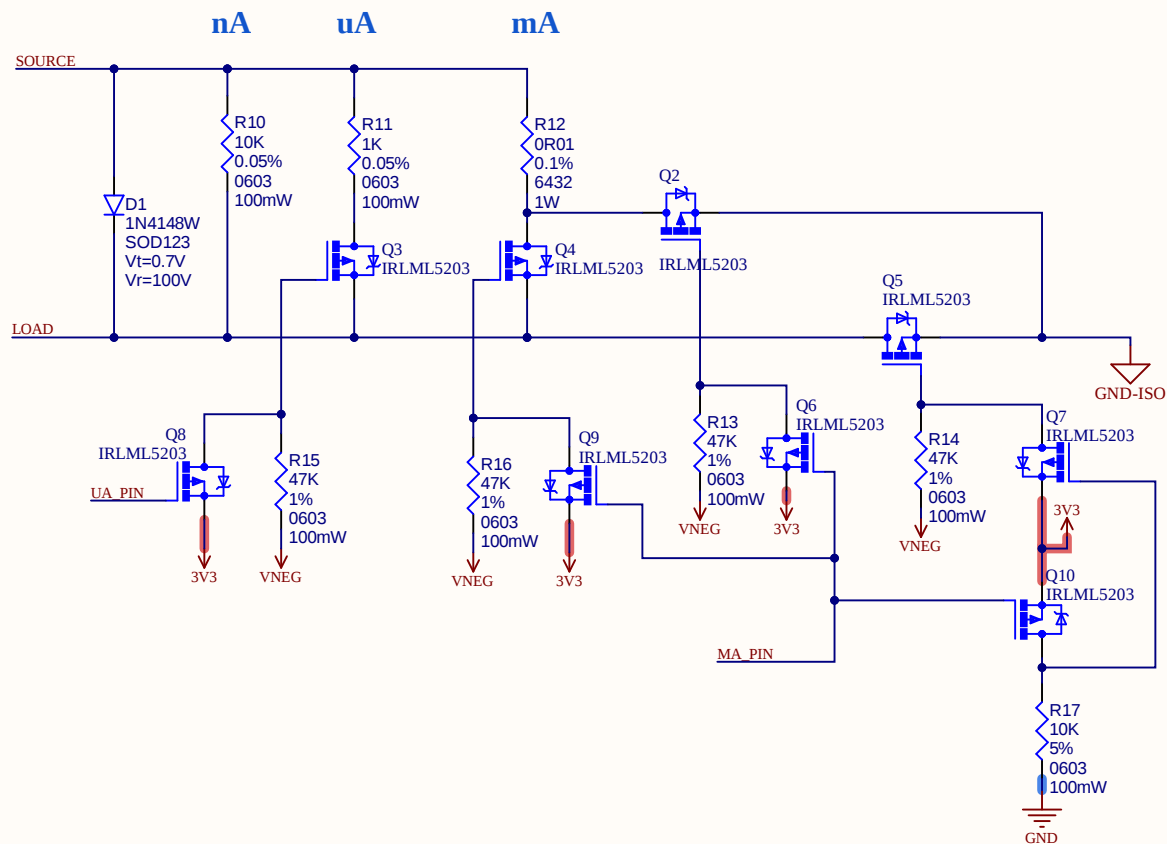
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Each branch corresponds with a different unit of measurement. The function of the PMOS transistors is to open or close each branch.

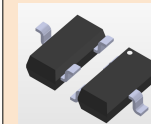
IMPORTANT:
If the input current is much greater than the selected range, the voltage drop might be very high. This could damage the amplifiers or

The diode at the input is optional.
The function of the diode is to limit the maximum voltage drop to 0.7V between the source and the load, as a way to protect the circuit and the unit under test.

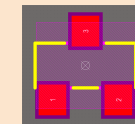


IRLML5203

3D model:



Footprint:



The IRLML5203 is a P-channel MOSFET with an extremely low on-resistance. This allows voltage measurements to be taken accurately.

Measurement control

Circuit for selecting through which branch the measured current will flow.
Each branch has a resistor value suitable for selecting nA, uA or mA.

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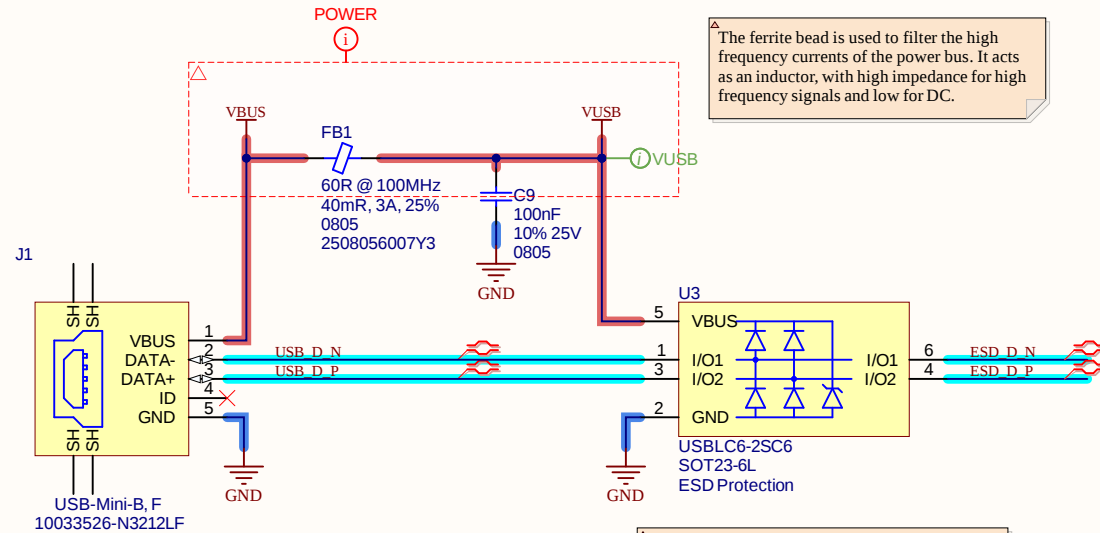
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Width Constraint [Pref Width = 0.5mm Min Width = 0.35mm Max Width = 0.8mm]



The ferrite bead is used to filter the high frequency currents of the power bus. It acts as an inductor, with high impedance for high frequency signals and low for DC.

A USB-Mini-B port is used to program the board and charge the battery.

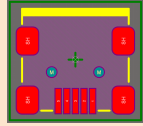
The protection IC is used to prevent electrostatic discharges. It's also used to improve the data signals integrity. It is compatible with USB 2.0, which is used by the USB-Mini-B port.

USB-Mini-B

3D model:

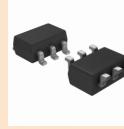


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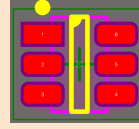


USBLC6-2SC6

3D model:



Footprint:



USB connector and protection circuit

A USB-Mini-B port is used to program the ESP32, power the circuit or read data via serial port. To protect the circuit, an ESD protection IC is employed.

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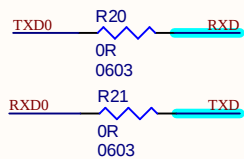
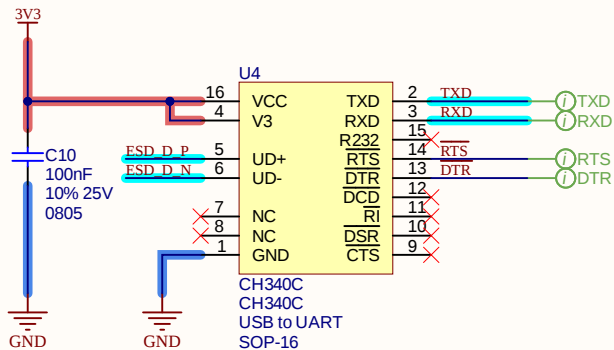
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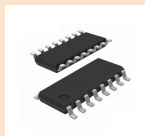




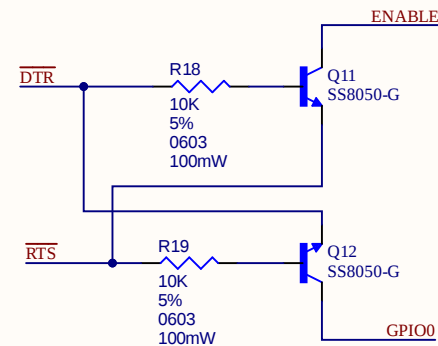
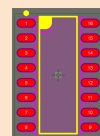
To convert the computer USB signal to UART, which is the protocol used by ESP32 to be programmed, this circuit is implemented using a CH340C. It's also used for serial communication.

CH340C

3D model:



Footprint:



Truth table:

DTR	RTS	ENABLE	GPIO
0	0	1	1
0	1	1	0
1	0	0	1
1	1	1	1

This circuit uses the DTR and RTS signals from the USB to UART converter to make the ESP32 enter bootloader mode.

To enter boot mode manually, the GPIO0 pin must be held low on reset.

ESP32 UART programming

A USB to UART converter allows the ESP32 to be programmed using a USB cable directly from the computer. To enter bootloader mode automatically, a circuit with two transistors is used on pins ENABLE and GPIO0.

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Sheet title: ESP32 programming

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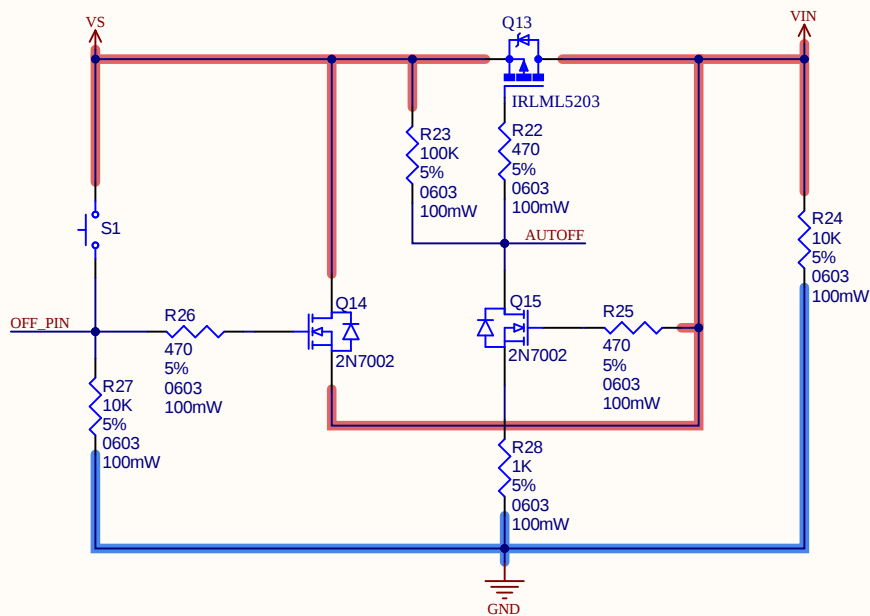
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The power-on/power-off circuit uses a push-button to change its state between high and low, in order to power the microcontroller or turn it off every time the button is pressed.

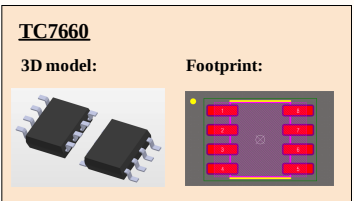
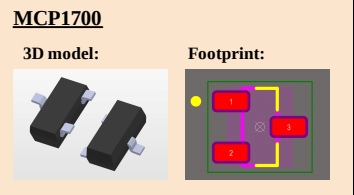
The 470 ohms resistors are placed to prevent high current spikes. The rest of the resistors have high values to reduce current consumption during normal operation.

To shut the microcontroller down, AUTOFF pin sets its value as high, which cuts off the PMOS and sets VIN to 0 V.

IMPORTANT:

The power-on is done analogically by setting the NMOS gates to high when pressing the button.

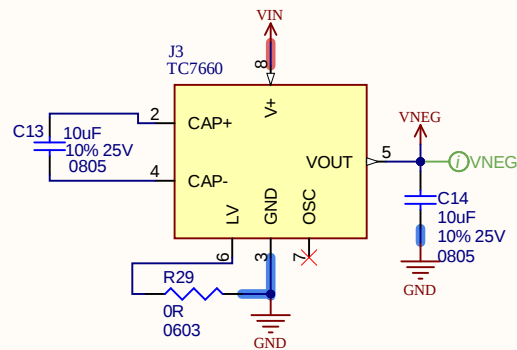
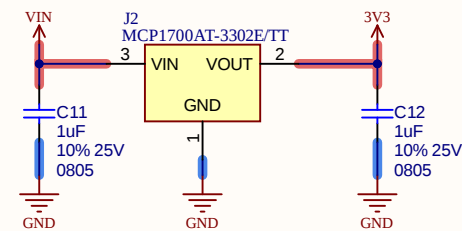
The power-off is only done by software, by continuously monitoring the button voltage. When it is pressed, the microcontroller sets AUTOFF to high to cut off the PMOS transistor.



The MCP1700 LDO regulator has a 350 mV maximum dropout voltage between input and output. For 3.3 V, its minimum input voltage must be 3.65 V in order to maintain a stable output.

IMPORTANT:

The input voltage range for the MCP1700 is 2.3-6.5 V.



The TC7660 is an IC that converts its input voltage into negative voltage at the output. Its function in this system is to allow the switching of the PMOS transistors that control the measurement mode.

Power

The system power up is made with a push-button. It's also used by software to turn off the system. Using two ICs to generate 3.3 V and -3.3 V

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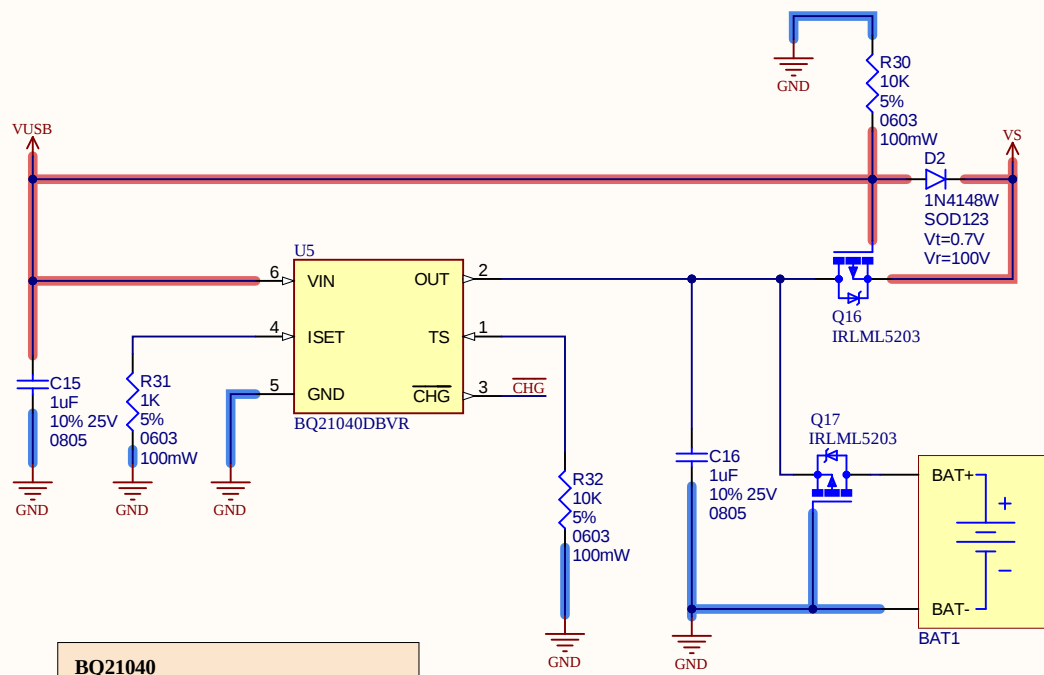
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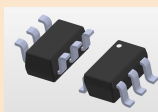
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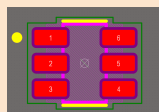


BQ21040

3D model:



Footprint:



The BQ21040 is a single-input, single-cell charger for Li-Ion and Li-Pol batteries. Its output voltage is 4.2 V. To limit the max charge current to 500 mA, the resistor in ISET has a value of 1k.

The TS function is to measure the temperature of the battery. This is not going to be used, so this pin is connected to GND through a 10k resistor.

The PMOS transistors act as protections to the circuit. One of them is placed next to the battery to prevent a reverse connection. The other one's function is to separate the battery from the rest of the circuit while it is being charged.

IMPORTANT:

This circuit has no analog protections against overdischarge. The battery level is continuously monitored by the microcontroller, so when it reaches a low voltage value, it will shut the system down.

Battery charger

The BQ21040 is a 4.2 V Li-Ion and Li-Pol single cell charger.
The circuit uses two PMOS to protect from reverse battery connection and to power the circuit from USB.

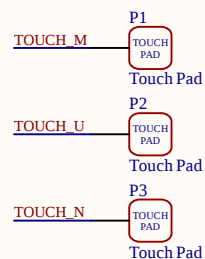
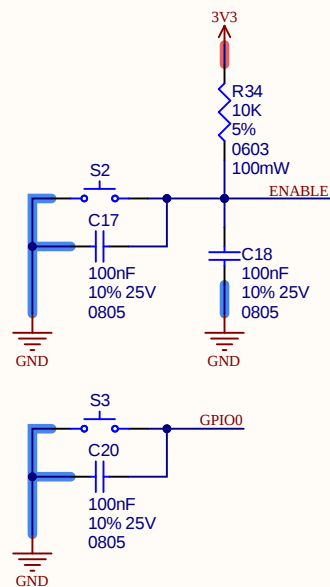
Designer's signature	Sheet title: Battery charger			Supervisor: Sr. Andrés Roldán Aranda Dpto. Electrónica y Tecnología de Computadores University of Granada C/ Fuente Nueva, s/n, 18001 Granada, Granada, Spain	
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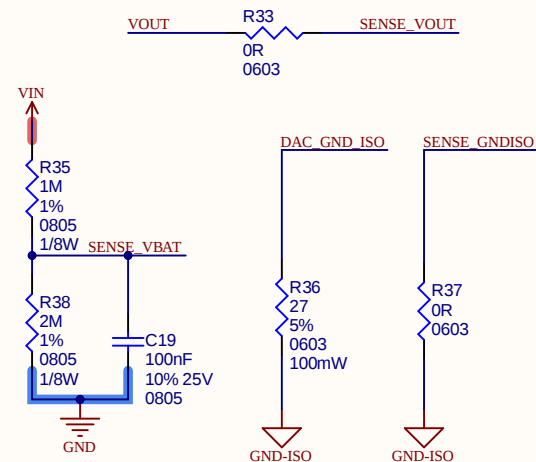
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^A The button configurations are based on the official ESP32-DevKitC V4 schematic by Espressif.

^A The touch pads are squares with sides of 1 cm. They are used to change the operation mode of the system without the need for mechanical buttons.

^A CAUTION:
The pads are intended specially for testing purposes. When it is operating with high voltage, it won't be safe to touch the pads or be near the board.



^A The battery voltage goes through a voltage divider so the ADC can read its value.

$$\text{SENSE_VBAT} = 0.66 \cdot \text{VIN}$$

If VIN = 4.2 V: SENSE_VBAT = 2.77 V
If VIN = 3.1 V: SENSE_VBAT = 2.05 V

The capacitor is used to increase reading accuracy.

^A The DAC sets the GND-ISO level through a 27 ohm resistor. Its function is to protect the DAC from voltage variations in GND-ISO.

Buttons and ADC

ENABLE and GPIO0 buttons act as reset and boot buttons respectively.
The ADC reads the voltage from the battery, GND-ISO and VOUT. The DAC controls GND-ISO voltage.

Designer's signature

Sheet title: Buttons and ADC

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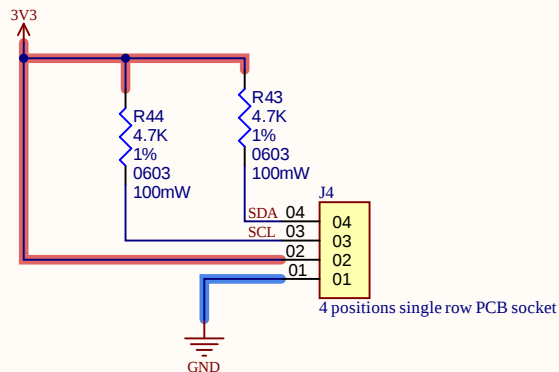
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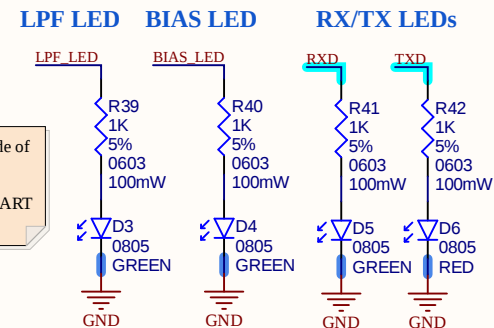
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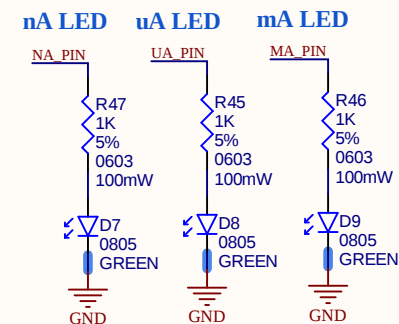


The OLED is connected through a 4-way single row socket with four connections: GND, VCC, SCL and SDA. It uses I2C protocol, so the line terminations are implemented through two 4.7k resistors. It has 128x64 pixels, its size is 30x28 mm and has max current consumption of 27 mA.

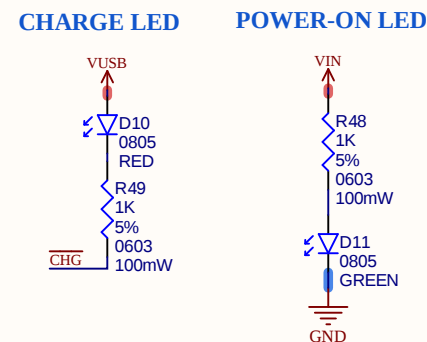
OLED SH1106



LPF and BIAS LEDs indicate which mode of operation is active.
RX and TX LEDs are for checking the UART communications.



nA, uA and mA LEDs are never on at the same time, only one of them is on at any moment, indicating which current unit is being measured.



Charge LED is only on when the device is powered through the USB port, so its consumption is not relevant to battery calculations.

LEDs and OLED

The current meter uses a model SH1106 OLED to show the measured current value.
Also, there are a series of LEDs that allow visual checking of the correct system operation.

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Sheet title: LEDs and OLED

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A

B

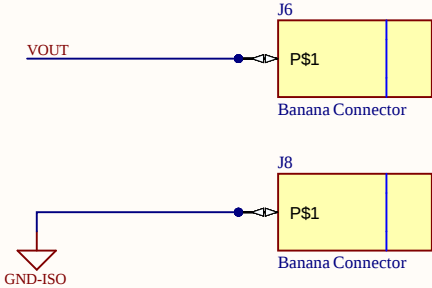
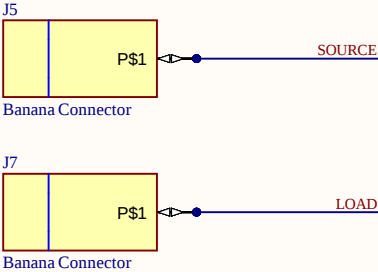
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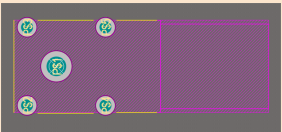
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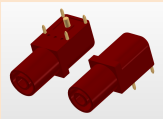


Banana connector 4mm

Footprint:



3D model:



Two 4mm banana type connectors will be used to connect the current meter to the target and the power supply. Two others will be used as a way of measuring the voltage directly from the board.

They will be soldered through-hole to the PCB.

Connectors

Connections between the current meter, the power supply and the target are made with banana connectors. They are also used to allow external voltage measurement.

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