BACHELOR'S DEGREE IN TELECOMMUNICATION ENGINEERING

Bachelor's Thesis

ACADEMIC COURSE 2021/2022

Tree Inspection Kit handheld device

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DEPARTMENT:

Electronics and Computer Technology

UNIVERSIDAD DE GRANADA

Project title: **TIK_HandheldDevice.PrjPcb**		
Date: **2022-05-04**	Revision: **0.3**	Sheet 1 of 18

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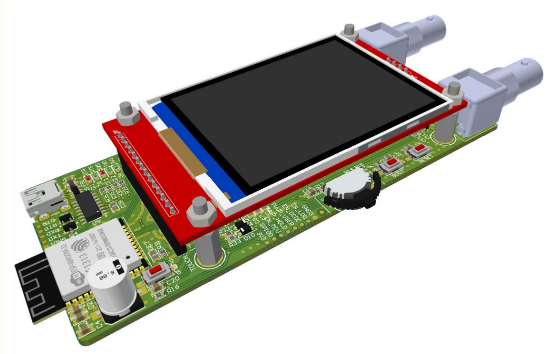

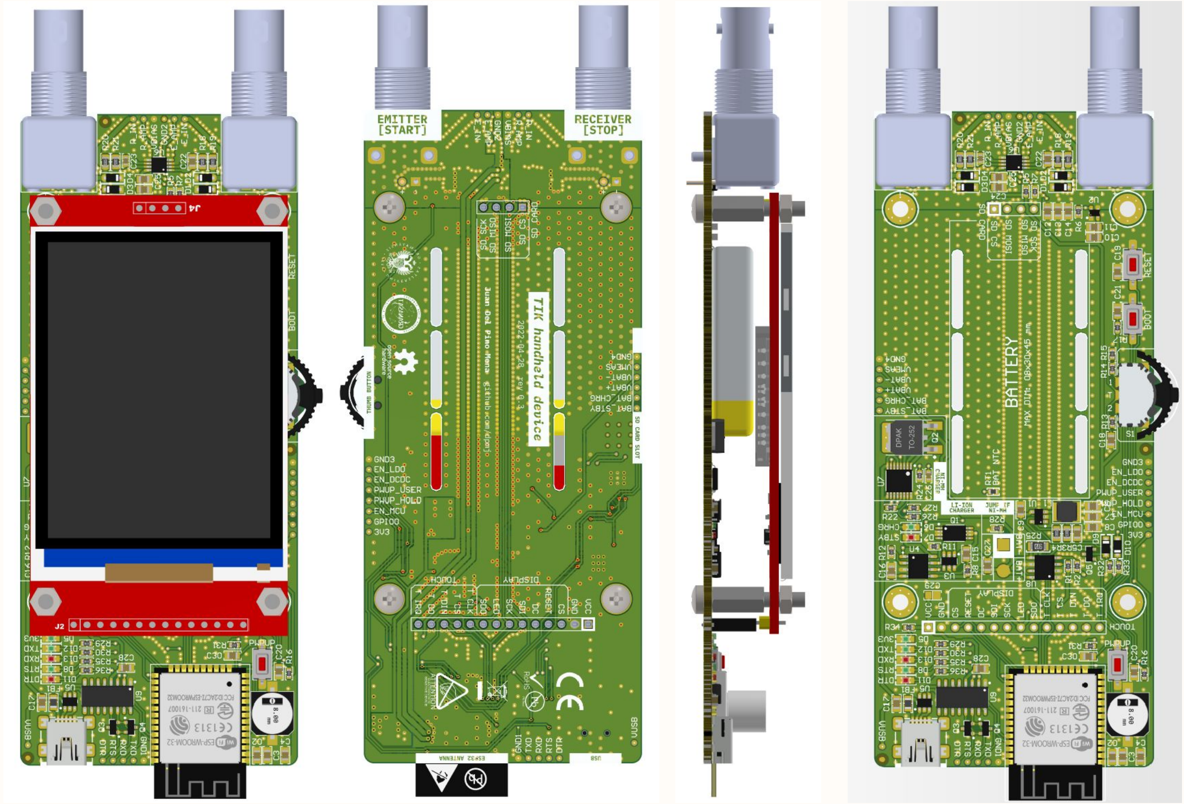

Tree Inspection Kit handheld device

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Designer's signature

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Sheet title:	Introduction and PCB renders
Project title:	TIK_HandheldDevice.PrjPcb
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Revision 0.4 | 2022-05-10 [MOST RECENT]

NEW

- Added fabrication groups and fabrication order parameters
- Added a Bill of Materials. The one in this document is simple. Refer to the manually configured BOM of this project.

FIXED

- Corrected SPI and I2C pins on the ESP32.

Revision 0.3 | 2022-04-28

NEW

- Changed rotary encoder vertical for horizontal, side-placed, SMD type multipurpuse 'thumb button'.
- Added a explanation of PCB trace widths.
- Adopted JLCPCB design rules.
- Full PCB component placement and routing, with no important DRC messages.
- Added silkscreen logos to the back of the PCB, as well as port markings, information and regulatory graphics: CE, WEEE, ESD sensitive warning and RoHS.

FIXED

- Changed numerical test point designators to net/rail names, to be quickly identified.
- Changed LEDs footprints from 0603 to 0805
- Corrected a faulty connection on the DW01A Lithium battery protection IC.
- The MCU has no longer the possibility of cutting battery charge. This is because ENABLE signals worked on 5V logic level and could cause damage to the ESP32.

Revision 0.2 | 2022-04-23

NEW

- New schematic hierarchy and system's block diagram.
- Initial PCB layout

- Added a rotary encoder (vertical). Library contains a 90-degree rotary encoder alternative.
- Added a new alternative Ni-MH charger circuit.
- Added footprints for all neccessary components to the PCB Library.
- Added explanatory footprints and photos to schematic ICs.
- Added board mounting holes (making use of the TFT LCD module mounting hole positions)
- Added test points
- Added fiducials
- Added a power-up button

FIXED

- Removed errors in the lithium charger
- Removed errors in the adequation circuit
- Changed ESD USB Protection IC.
- Changed some adequation circuit values and made topology more clear.
- Revised all passive components values and sizes to match existing component disponibility.
- Corrected various pin definitions from the ESP32-WROOM-32D symbol

REVISION 0.1 | 2022-04-01

NEW

- TFT LCD / SD card connections.
- First adequation circuit iteration
- LiPo battery charger with TP4056
- Auto programming circuit.

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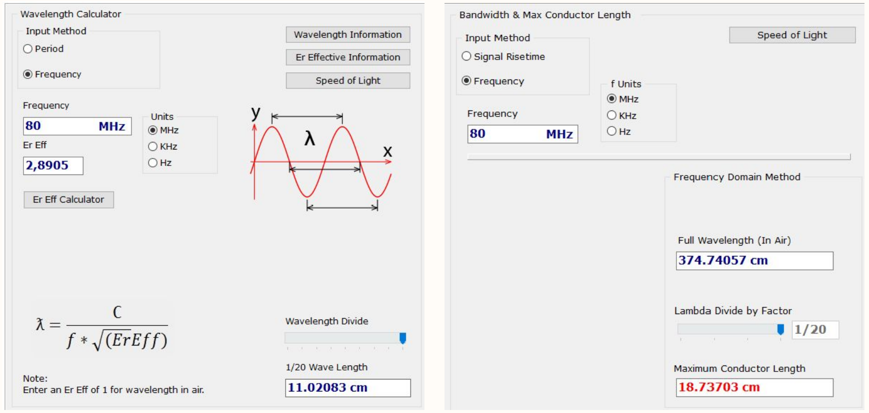
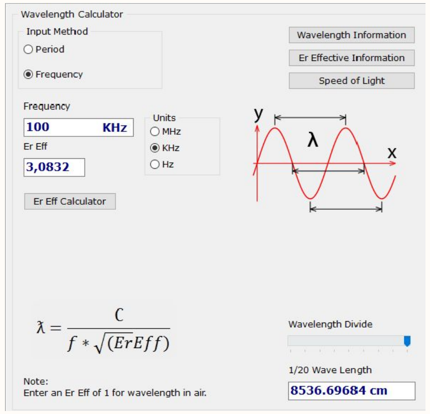
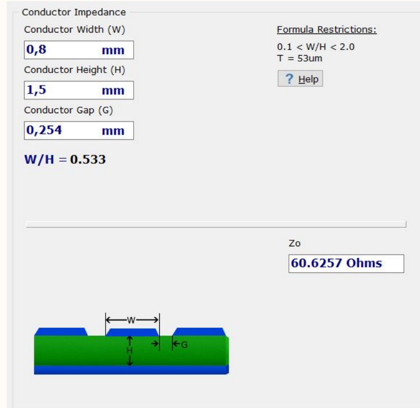
Maximum SPI traces length



Maximum Analog traces length

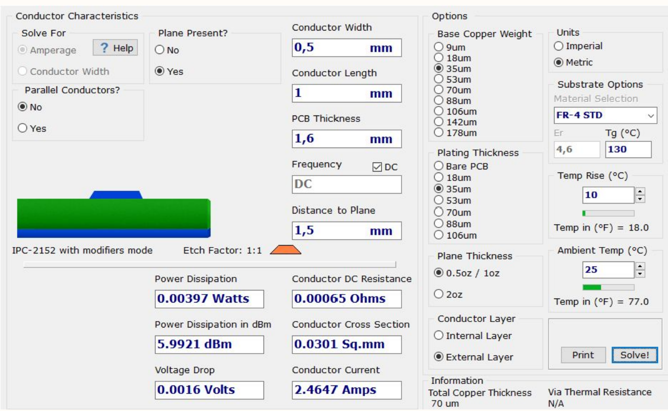


Analog signal trace impedance

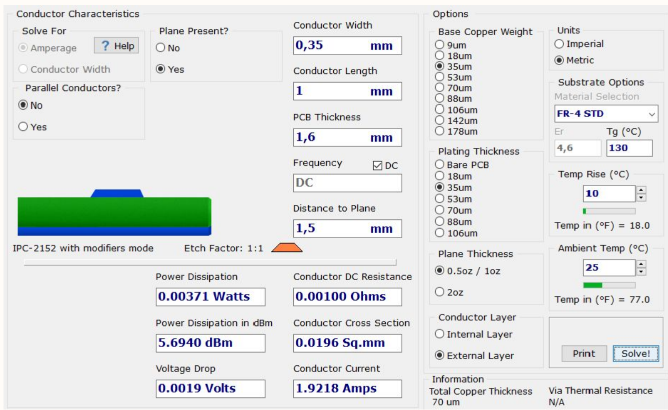


Power traces conductor characteristics (DC)

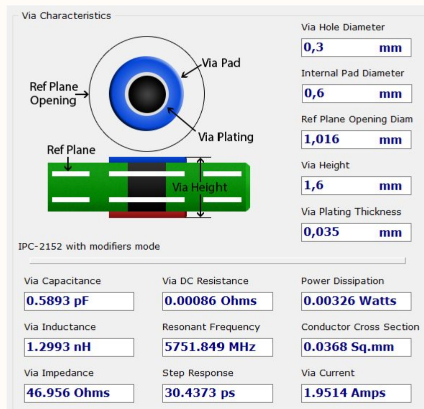
0.5 mm wide traces



0.35 mm wide traces



Via characteristics



Trace & via characteristics

Trace width based on results from PCB Toolkit by Saturn PCB Design INC.

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TO-DO: EXPLAIN DATA. CROP SOME SCREENSHOTS

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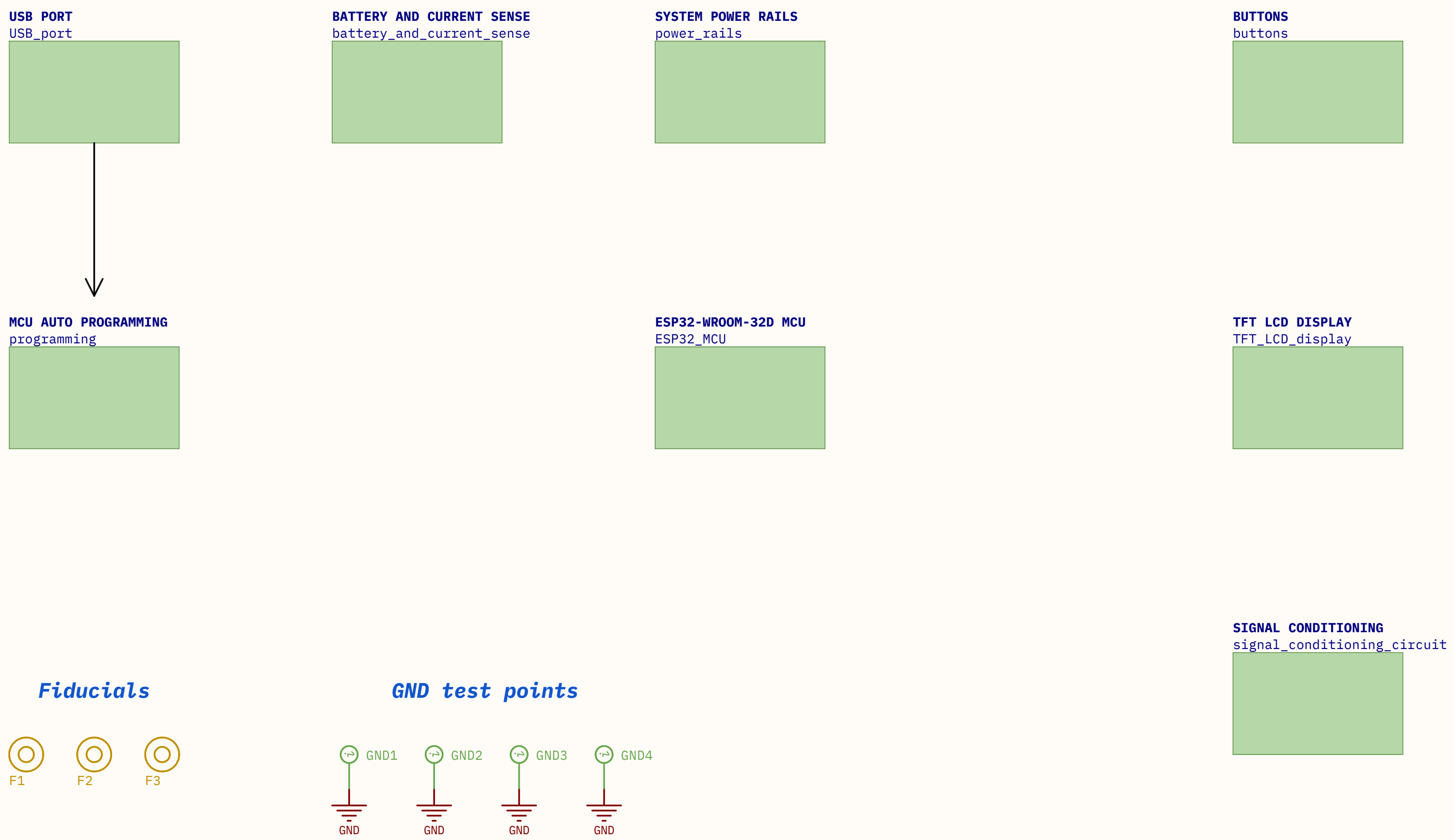

Block diagram

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TO-DO: ARROWS INDICATING WHERE SIGNALS GO

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Sheet title:	**Block diagram**
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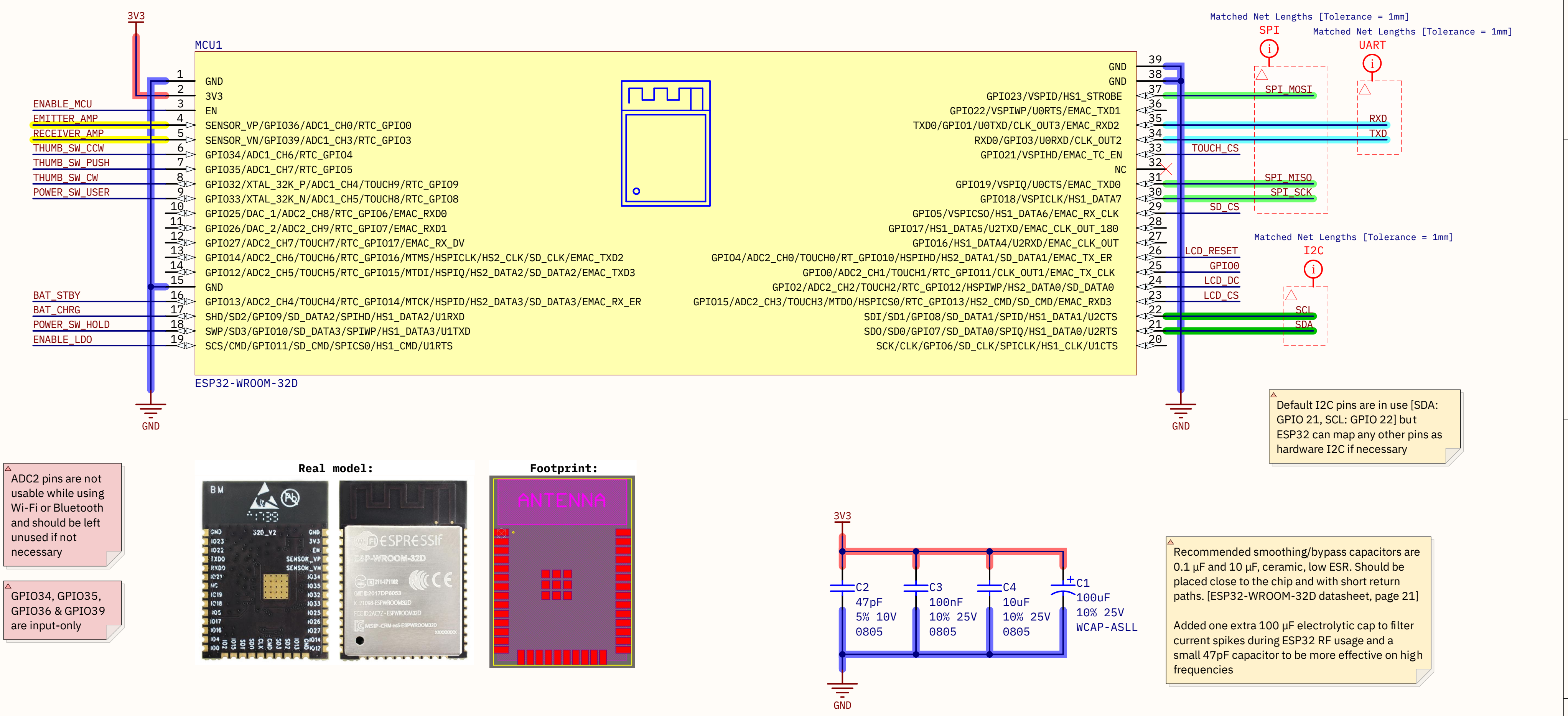

ESP32-WROOM-32D MCU, Wi-Fi + Bluetooth module

MCU hardware configuration and I/O pins

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Sheet title: **ESP32-WROOM-32D MCU**

Project title: **TIK_HandheldDevice.PrjPcb**

Designer: **Juan Del Pino Mena**

Date: **2022-05-04** Revision: **0.3** Sheet 6 of 18

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3.3 V rail: main system power

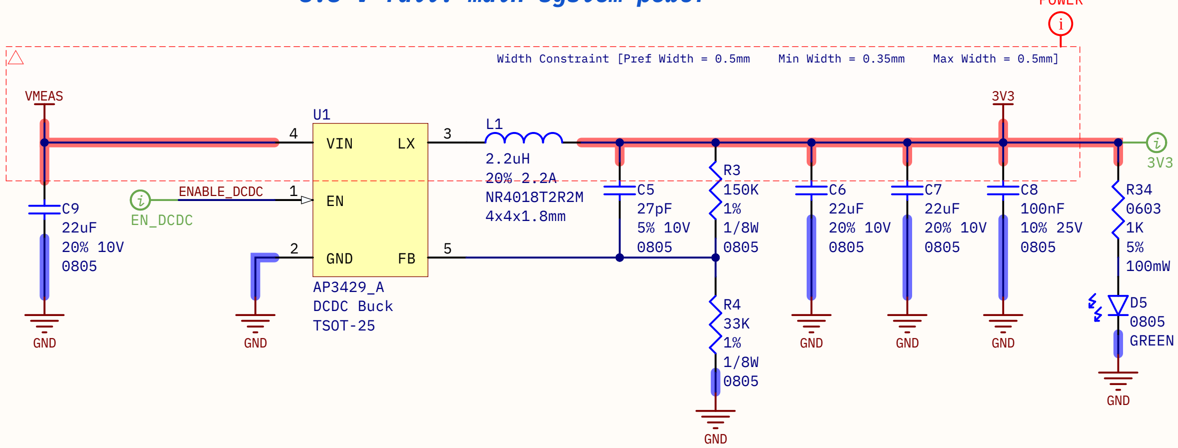
Typical Application Circuit. [AP3429/A datasheet, page 2]
with some values modified as needed and/or part availability.
Capacitors should be placed close to the chip and circuit should be traced in short loops.

Feedback voltage V_FB is 0.6 V const.

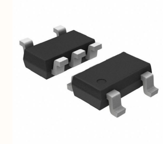
Resistors are adjusted as a voltage divider. So, if 3.3V are needed at the converter output:

V_FB = 0.6V = V_out · (R2)/(R1+R2) -> R2 = 2/9·R1

Resistor values must be high (kOhms) in order to maintain a low power consumption on the feedback circuit.



Real model:



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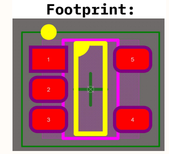
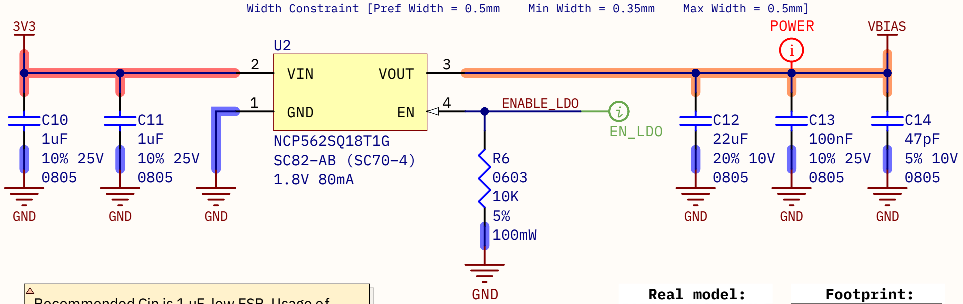
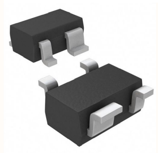


1.8 V rail: Vbias for signal conditioning circuit



Recommended Cin is 1 uF, low ESR. Usage of multiple input capacitors to reduce ESR and ESL. There are no recommended values for Cout but these caps should probe more than enough to have low ESR and reduce ripple at a wide frequency range. Datasheet specifies a typical 100 uVrms noise on Vout, somewhat high.

Real model:



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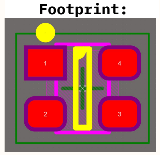
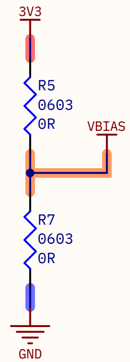


Optional 1V8 rail bypass jumpers



IMPORTANT:
1V8 rail is bypassable by soldering these optional 0-OHM resistors. This is for experimenting with different voltages and if it affects the overall performance of the adquisition circuit.

Do NOT connect both 0R resistors at the same time or it will jump VCC and GND. And keep the LDO disabled at all times.

This can also be used to insert a voltage divider. i.e.: if you want to reduce the rail voltage to VCC/2 you only have to add two >= 10 KOhm 0603 resistors. Just keep in mind that voltage won't be as stable as in a LDO as it will be greatly dependent on the load impedance.

If you do this, populate the LDO's output caps, so VBIAS it behaves as a small-signal GND.

Power rails

Battery DC/DC step-down converter and Vbias for signal conditioning circuit.

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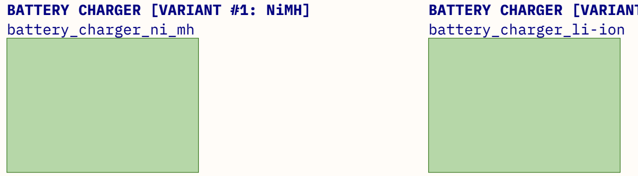
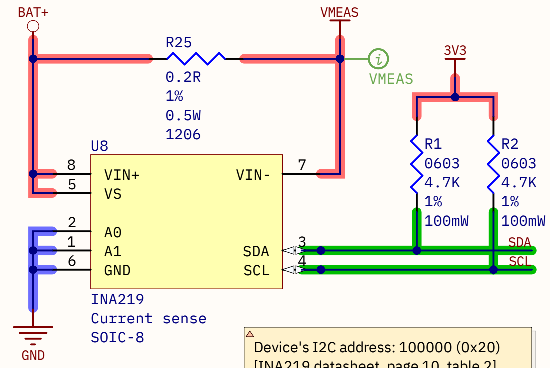
Battery charging circuit variants



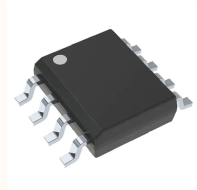
Two circuit variants are implemented BUT NOT USED SIMULTENEOSLY. Only one must be populated at a time.
The usage of one over the other will come by component disponibility.

Battery output current sense and voltage monitor



Device's I2C address: 100000 (0x20)
[INA219 datasheet, page 10, table 2]

Real model:



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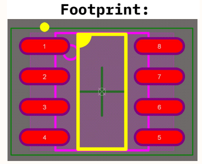


Battery connector. Charger selection jumper. Battery thermistor

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

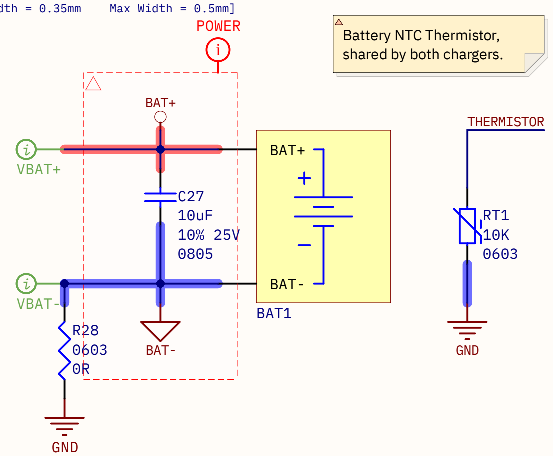
IMPORTANT: 0-Ohm jumper for charger selection:

The battery share the connector between the 2 possible chargers.

However, on the Lithium one BAT- is not connected to the system GND for protection; but in the case of the NiMH one it is.

So, to avoid shorting BAT- and GND on the Li-Ion charger, DO NOT place the 0-ohm jumper.

On the other hand if you are using the NiMH charger solder you MUST use the jumper.



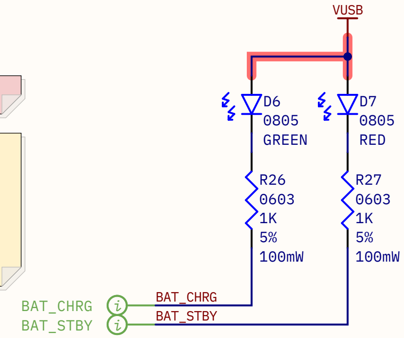
Battery NTC Thermistor, shared by both chargers.

Charging status indicator

These signals come from both charging IC's.

They are status outputs that are normally on high impedance and they are pulled LOW when activated.

We can use these pins to turn on some LEDs and to notify the microcontroller of the charging status.



Battery and current sense

Two circuit variants that will be implemented but not used simultaneously. The usage of one over the other will come by component disponibility. INA219 current sensor is independent and common for both systems.

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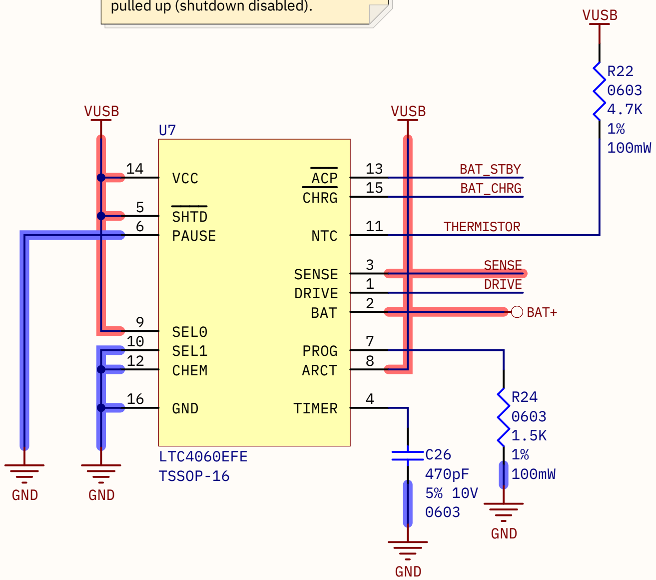
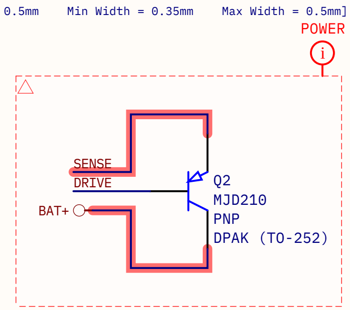
NiMH/NiCd battery charger IC

> We can control the charging by pulling LOW the SHTD. This pin is normally pulled up (shutdown disabled).



External PNP BJT current driver



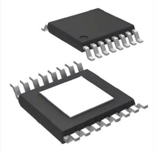
> Following the [LTC4060 datasheet, page 13], if using a 10 K NTC thermistor, Its RHOT should be 4.42 kOhm, 1% to trigger the temperature warning at 45 ºC.
> However, this value being too much specific is problematic.

> This can be disabled by connecting a 0-ohm resistor in place of the thermistor.

> [NOT IMPLEMENTED] This IC has the possibility of implementing a power path control (power the load from external source while charging)

> DRIVE pin on the LTC4060 provides a controlled sink current that drives the PNP base.
> So, it's not necessary to have a base resistor.

Real model:



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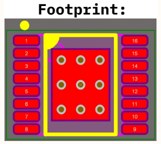
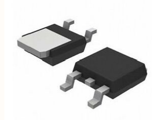


Real model:



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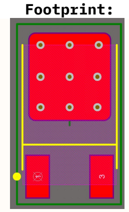

> TIMER capacitor and PROG resistor program the charge Tmax (maximum charging time, a security measure). [LTC4060 datasheet, page 13]. These values should complete a full charge in at most 1 h 6'

> PROG resistor programs the maximum current that the battery will receive while charging. For 1.5 kOhm this is 0.93 A.

> These parameters are heavity dependant of battery capacity. A larger battery cell package should receive more time / current.

> i.e.: a 1000 mAh battery will charge at approx 1C with this configuration, but can be insufficient time for a 3000 mAh one.

Battery charging circuitry for Ni-MH

Battery charger circuit variant #1. By default the device uses a Nickel-metal hydride battery which are chemically and thermally more stable (and safer) than Lithium-based ones; at the cost of a lower charge/volume ratio.

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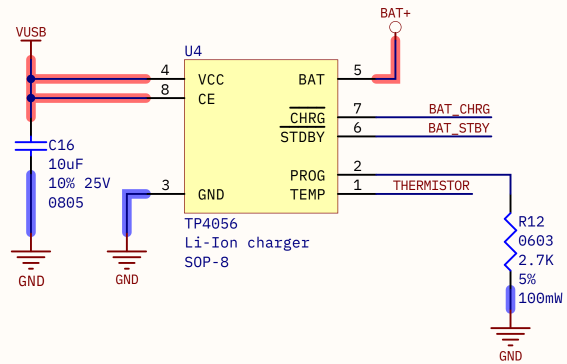
Lithium battery charger IC

The TP4056 datasheet recommends to connect a resistor of 0.2 to 0.5 Ohm between VUSB and its VCC pin. It does not explain why, but probably for chip temperature concerns.

However, it is omitted as we don't have any resistor of these values available. As a note: not a single commercial TP4056 charger module uses any resistor at all (and they work fine at higher charge rates).

The TP4056 is only specified for charging single-cell Li-Ion batteries on its datasheet. However, many sites, forums and online stores list TP4056-based modules as compatible with both Li-Ion and Li-Po. Take this with caution.

This device will get hot, and has a thermal pad to dissipate to PCB GND plane

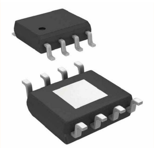


We can control the charging with the microcontroller by using the CE pin if necessary. This pin is normally pulled up (Enabled) by the 10kOhm resistor.

Resistor in PROG regulates the maximum battery charging current. At 2 kOhm, this is 580 mA. At 1 kOhm, it is > 1 A. [TP4056 english datasheet, page 3]

TEMP expects a NTC thermistor (of unspecified value). On some Lithium-Ion batteries this NTC can be integrated on the package.

Real model:



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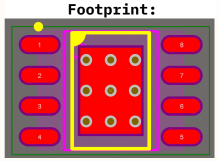
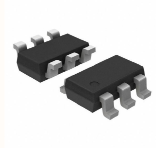


Lithium battery protection

Real model:



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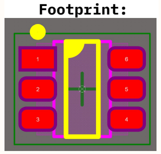
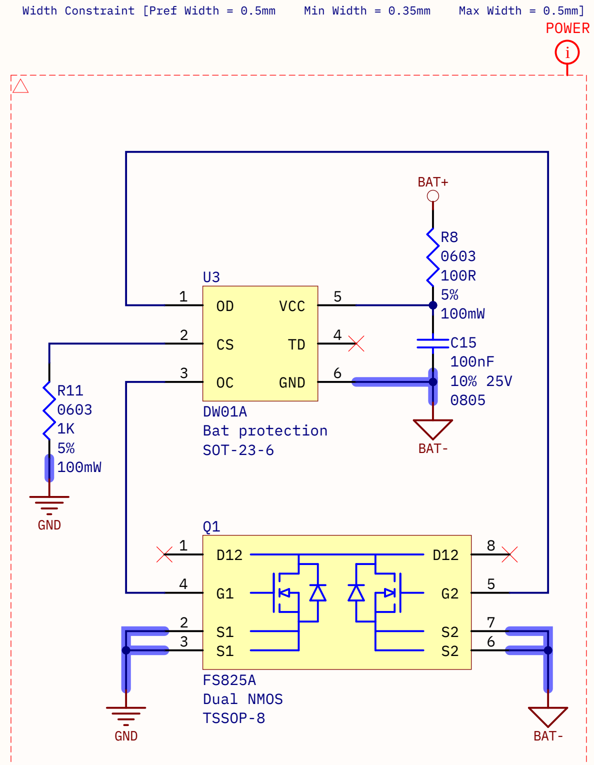
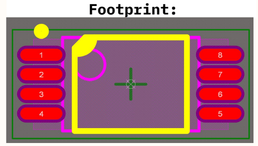




Real model:

Footprint:



Battery charging circuitry for Li-Ion

Battery charger circuit variant #2.

This circuit must NOT be placed if the Ni-MH charger is present on the board (and vice-versa).

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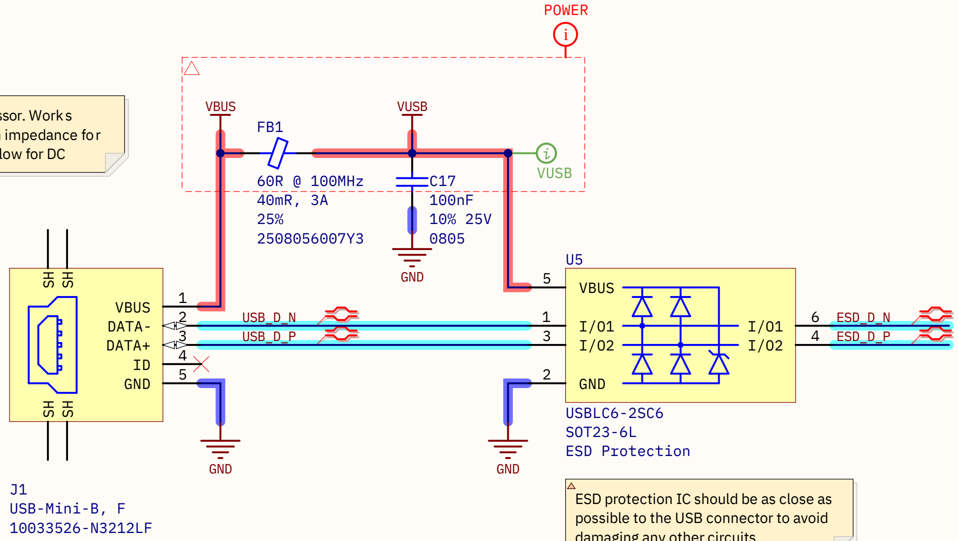
USB connector and ESD protection circuit

USB is used as a programming interface, as well as a power source for the charging circuit. Since it's an external connector, it needs to have a protection circuit against electro-static discharge (ESD) and noise.



Ferrite Bead as EMI supressor. Works similar to an inductor: high impedance for high frequencies and very low for DC

'SH' pads are the USB connector metal shield, which is structural. This particular connector has 4 which are not connected to any circuit traces, not even GND. In any case, it should be connected to the device's metal chassy (as a faraday cage).

An USB-Mini-B has been chosen for various reasons:
- Over an USB-micro: because of the structural robustness of the mini-B.
- Over an USB-Type-C: because of the ease of implementation, less pins, and to make clear this device is not a host.

USB mini-B is USB 2.0 capable, fairly high speed, and althought we may not use all of its capabilities, its data traces need special attention as they are differential.

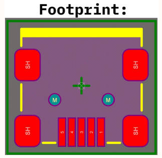
¿Añadir reverse polarity protection? PMOS de potencia (al menos 3A) con una resistencia de 0R para hacer bypass

¿Es posible que la resistencia no aguante la corriente?

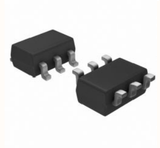
ESD protection IC should be as close as possible to the USB connector to avoid damaging any other circuits.

Real model:

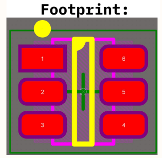
Footprint:



Real model:



Footprint:



Designer's signature	
Supervisor's signature	
Sheet title:	USB connector and ESD protection circuit
Project title:	TIK_HandheldDevice.PrjPcb
Desginer:	Juan Del Pino Mena
Date: 2022-05-04	Revision: 0.3
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Supervisor:
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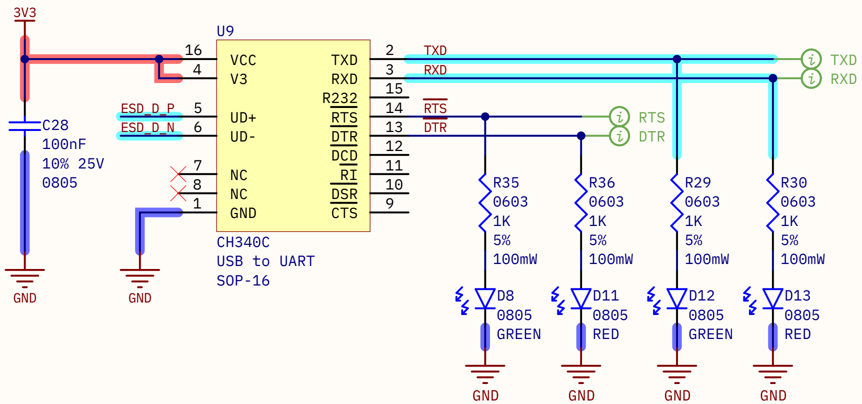
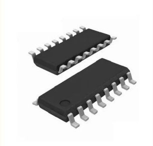
USB to UART conversion



Real model:



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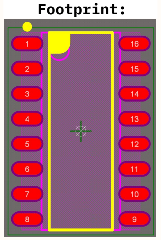
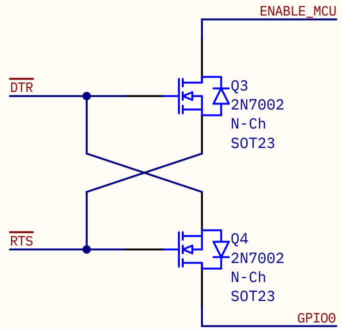


These LEDs serve as testimonies of UART communication and help during debugging process

Auto programming circuit



ESP32 GPIO0 is a Strapping pin. Strapping g pins modify the device's boot mode during chip reset (enable pin pulled down)
GPIO0 is pulled up during reset. ESP_ENABLE is pulled up by an external pullup resistor

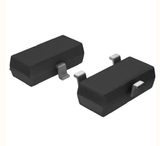
When GPIO0 is HIGH, it boots from internal SPI memory, but when it's LOW the boot sequence changes to 'Download' and we can upload a program to the MCU.

[ESP32 Datasheet, section 2.4, pages 19-20]

Circuit truth table

DTR	RTS	ENABLE_MCU	GPIO0
0	0	1	1
0	1	1	0
1	0	0	1
1	1	1	1

Real model:



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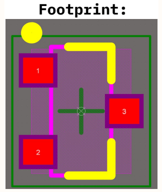

USB to UART and MCU programming

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Supervisor's signature

Sheet title: **USB to UART and MCU programming**

Project title: **TIK_HandheldDevice.PrjPcb**

Desginer: **Juan Del Pino Mena**

Date: **2022-05-04** Revision: **0.3** Sheet 12 of 18

Supervisor:
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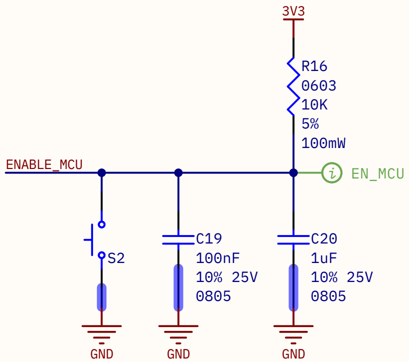
Reset

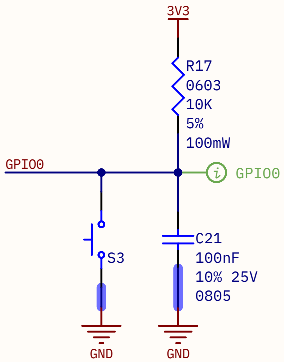
To ensure power stability to the microcontroller during powerup, this RC filter introduces a delay on the ENABLE pin. Usual values are 10 kΩ, 1 µF (τ = 10 ms, t_{10-90} = 22 ms).
[ESP32-WROOM-32D datasheet, page 22]

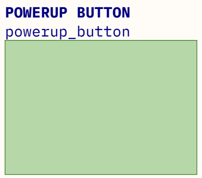


Boot mode selection (debug)

Allows to force 'Download' boot sequence

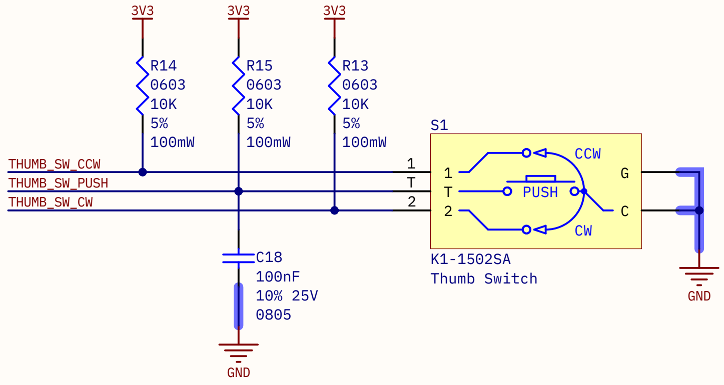
Same design as in ESP32 DevKit boards.
100 nF cap are for debouncing and should be placed close to the buttons





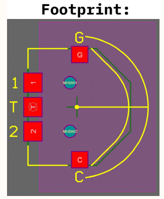
Multidirection 'thumb' button (UI navigation)

Horizontal SMD device, multi-directional / muti-function rotary slider button.
Accessed from the right side.



Real model:

Footprint:



Buttons

TFT LCD touchscreen, rotary encoder, on/off and reset switches
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Sheet title: **Buttons**

Project title: **TIK_HandheldDevice.PrjPcb**

Desgner: **Juan Del Pino Mena**

Date: **2022-05-04** Revision: **0.3** Sheet 13 of 18

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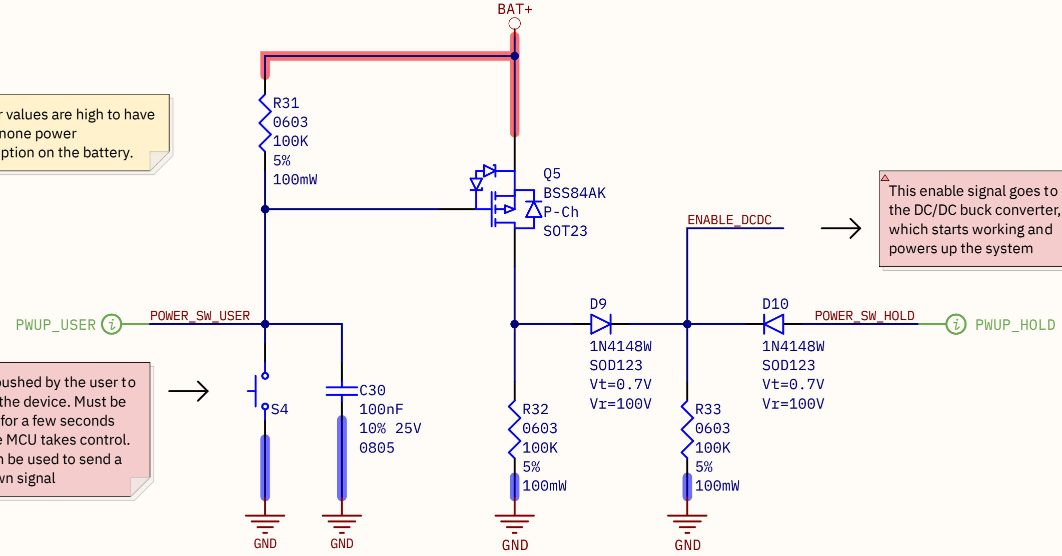
Resistor values are high to have little to none power consumption on the battery.

This enable signal goes to the DC/DC buck converter, which starts working and powers up the system



This signal comes from the MCU. Once the MCU has been initialized, it takes control of the enable signal and keeps the DC/DC ON.

This is pushed by the user to turn on the device. Must be pushed for a few seconds until the MCU takes control. Also can be used to send a shutdown signal

When the button is not pressed, the tension in PMOS gate is BAT+; and thus V_sg is not greater than V_th and the PMOS is off.

When the button is pressed, gate voltage is GND, so V_sg > V_th and the PMOS turns on, letting the voltage rise on the diode anode and putting HIGH the ENABLE_DCDC net (enabling the DCDC converter).

Thisturns on the system and in specific it feeds the ESP32.

The microcontroller takes over after the button has been pressed for a few seconds, and pulls HIGH the ENABLE_DCDC_HOLD pin; and the user can release the poweron button.

The system will be ON until the user sends a shutdown signal by software or by pressing this button again.

Powerup button

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Sheet title:	**Powerup button**
Project title:	**TIK_HandheldDevice.PrjPcb**
Desginer:	**Juan Del Pino Mena**
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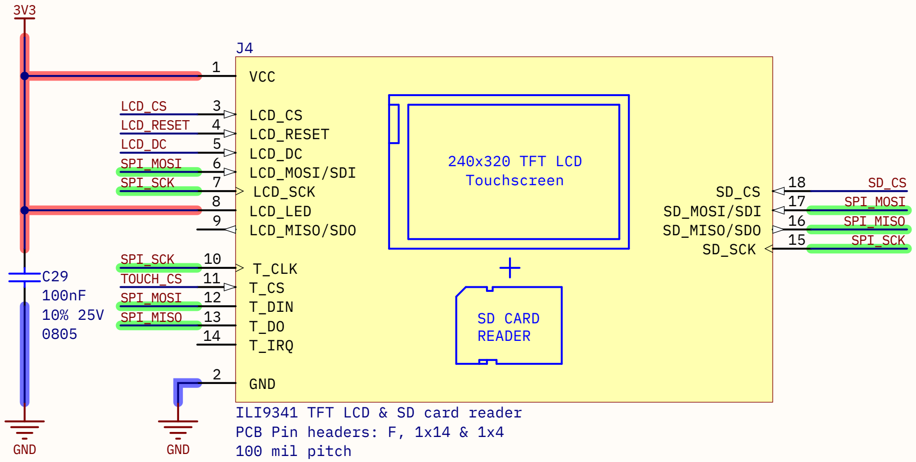
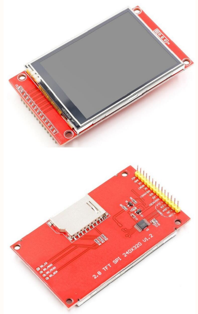
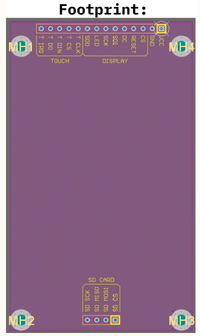


Real model:



Footprint:



As ILI9341 2.8" TFT LCD module has the bigger footprint and may need mechanincal mounting, project's PCB inherits its mounting holes position.

LCD TFT Touch Display & SD card reader

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Sheet title:	LCD TFT Touch Display & SD card reader
Project title:	TIK_HandheldDevice.PrjPcb
Desgner:	Juan Del Pino Mena
Date: 2022-05-04	Revision: 0.3	Sheet 15 of 18

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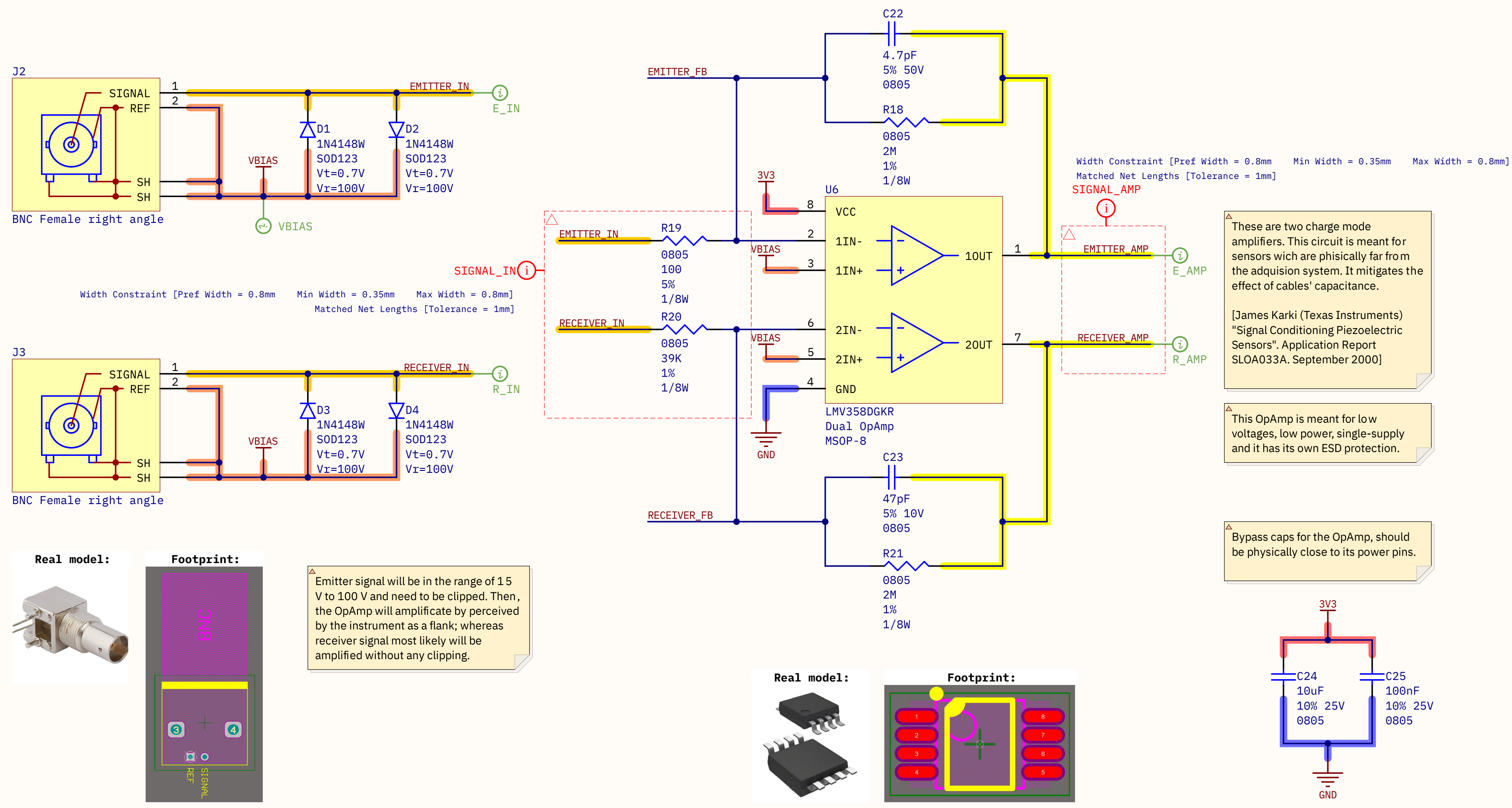

Emitter signal will be in the range of 15 V to 100 V and need to be clipped. Then, the OpAmp will amplificate by perceived by the instrument as a flank; whereas receiver signal most likely will be amplified without any clipping.

These are two charge mode amplifiers. This circuit is meant for sensors wich are phisically far from the adquision system. It mitigates the effect of cables' capacitance.

[James Karki (Texas Instruments) "Signal Conditioning Piezoelectric Sensors". Application Report SLOA033A. September 2000]

This OpAmp is meant for low voltages, low power, single-supply and it has its own ESD protection.

Bypass caps for the OpAmp, should be physically close to its power pins.

Signal conditioning circuit

Signal comes from piezoelectric sensors and need to be converted from charge to voltage. Tree sensors that have been used for this project proved to generate upto -100 volts peak, so it needs clipping

Designer's signature

Supervisor's signature

Sheet title:	**Signal conditioning circuit**
Project title:	**TIK_HandheldDevice.PrjPcb**
Desginer:	**Juan Del Pino Mena**
Date: **2022-05-04**	Revision: **0.3** · Sheet 16 of 18

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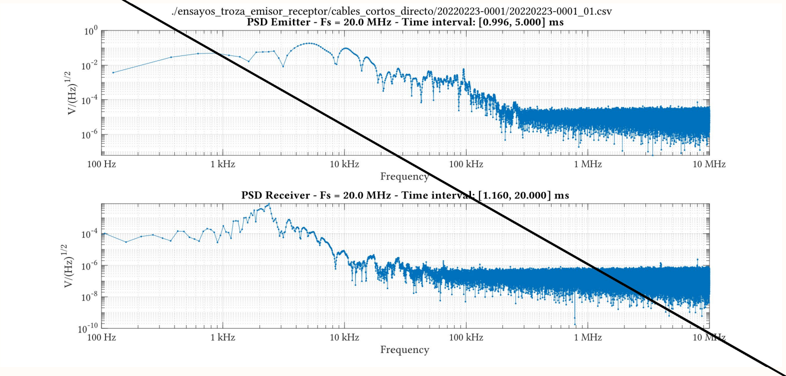
Example of a Voltage Spectral Density of trunk signals



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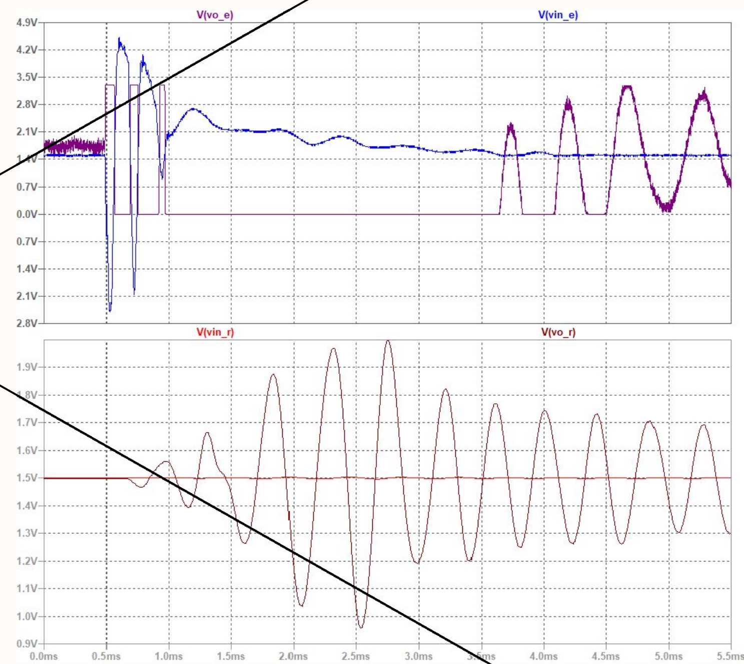
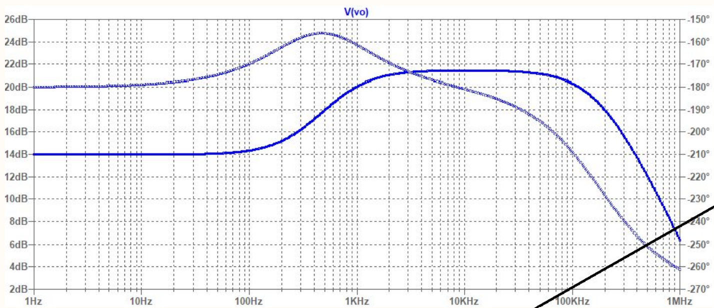
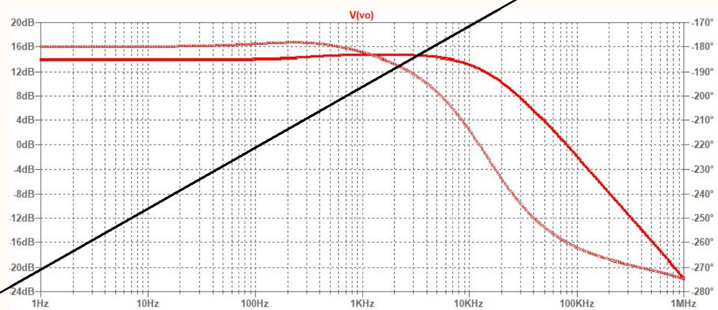
Time behavior



Contitioning circuit theorical frequency response





Respuesta en frecuencia teórica, con el modelo UniversalOpAmp, cable con 700 pF y R del piezo 2 MOhm

¿Afecta en algo la fase?

Signal conditioning theoreticals

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TO-DO

Designer's signature	
Supervisor's signature	
Sheet title:	Signal Conditioning Theoreticals
Project title:	TIK_HandheldDevice.PrjPcb
Desginer:	Juan Del Pino Mena
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Power budget

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TO-DO

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Sheet title:	Power budget
Project title:	TIK_HandheldDevice.PrjPcb
Desginer:	Juan Del Pino Mena
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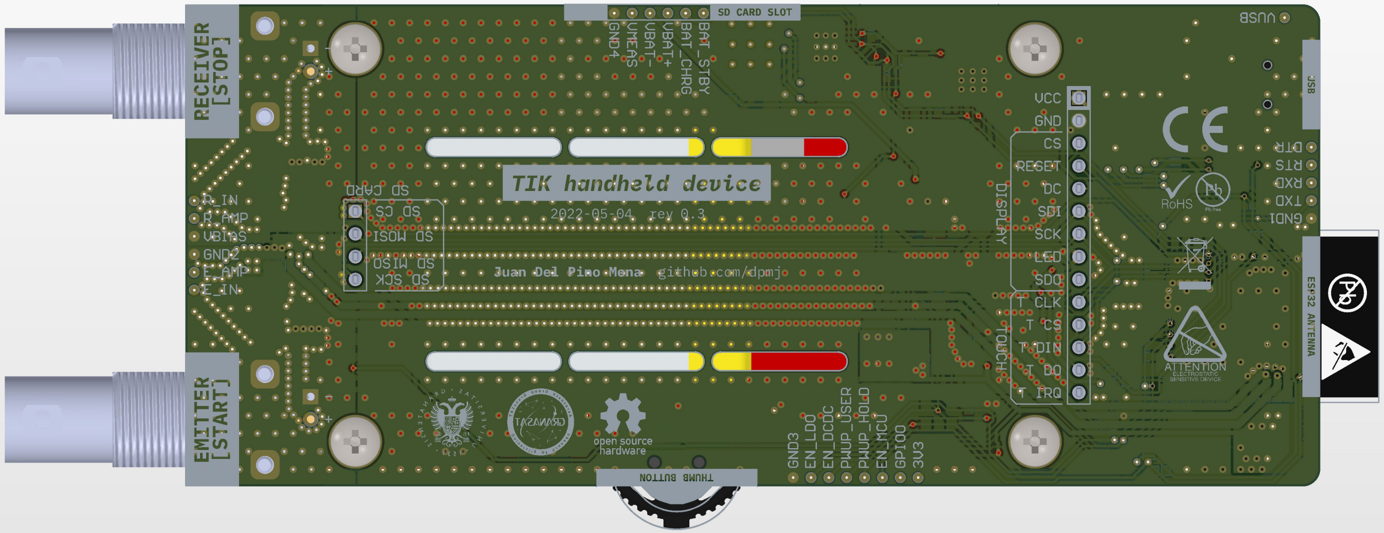
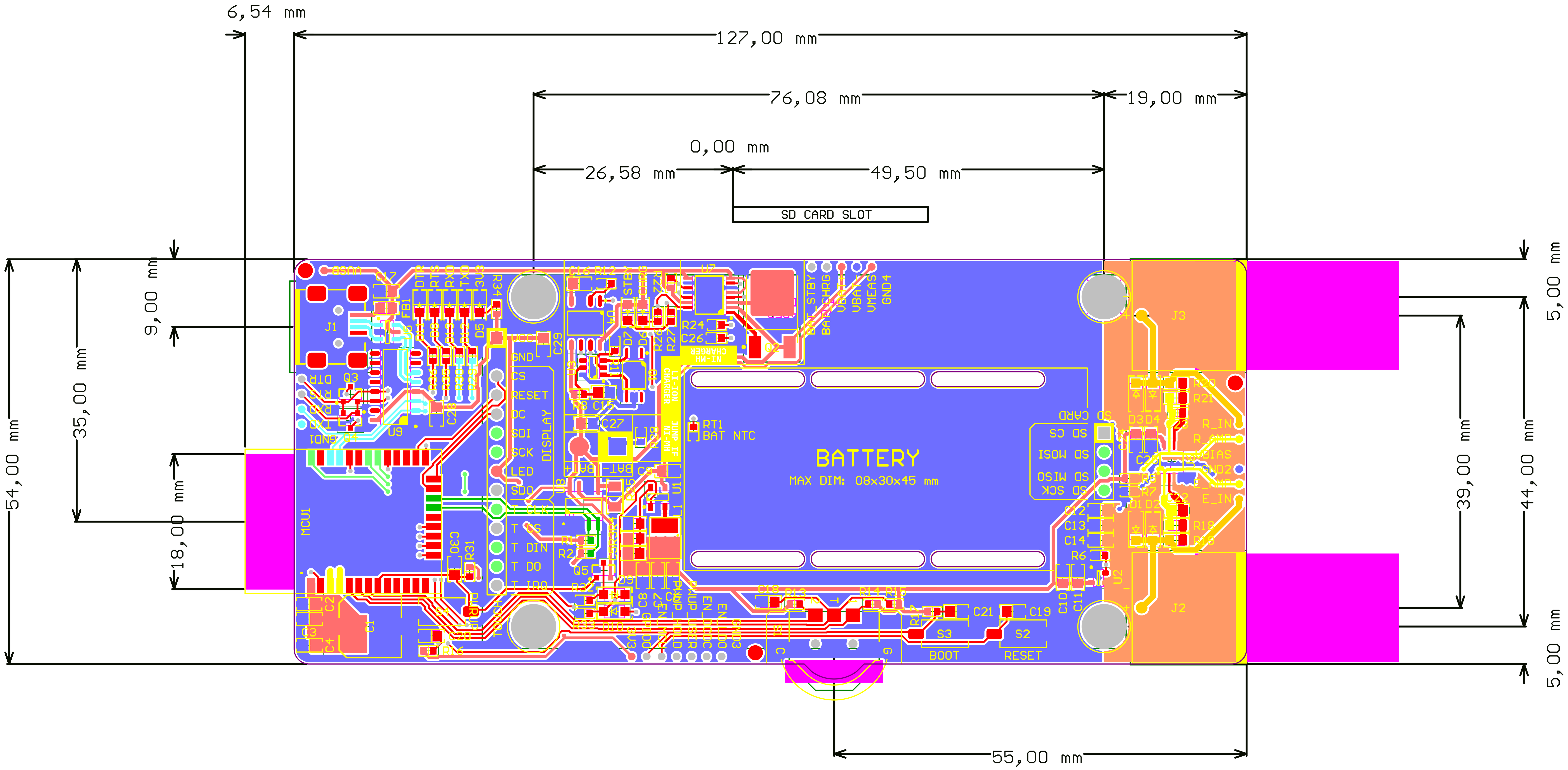
J2
J4
ESP-WROOM-32
BOOT
RESET


RECEIVER [STOP]
EMITTER [START]
SD CARD SLOT
BAT_STBY
BAT_CHRG
VBAT+
VBAT-
VMEAS
GND4
TIK handheld device
2022-05-04 rev 0.3
Juan Del Pino Mena github.com/dpmj
SD CARD
SD CS
SD MOSI
SD MISO
SD SCK
R_IN
R_AMP
VBIAS
GND2
E_AMP
E_IN
VCC
GND
CS
RESET
DC
SDI
SCK
LED
SDO
T_CLK
T_CS
T_DIN
T_DO
T_IRQ
DISPLAY
TOUCH
VUSB
USB
CE
RoHS
DTR
RTS
RXD
TXD
GND1
ESP32 ANTENNA
ATTENTION
open source hardware
GND3
EN_LDO
EN_DCDC
PWUP_USER
PWUP_HOLD
EN_MCU
GPIO0
3V3
THUMB BUTTON



VISIBLE LAYERS:

Board outline + Multilayer + Top overlay + Mechanical 15 + Top layer + Keep-out + dimensions

TIK handheld device PCB

PCB orientation: vertical. Screen facing front, BNCs on top, USB at the bottom, SD Card reader at the left, powerup button at the bottom front right, and multipurpose button on the right side.

Designer's signature:	Sheet title: TIK Handheld Device PCB
	Project title: TIK_HandheldDevice
Supervisor's signature:	Designer: Juan Del Pino Mena
	Supervisor: Andres Roldan Aranda

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Sr. Andres Roldan Aranda

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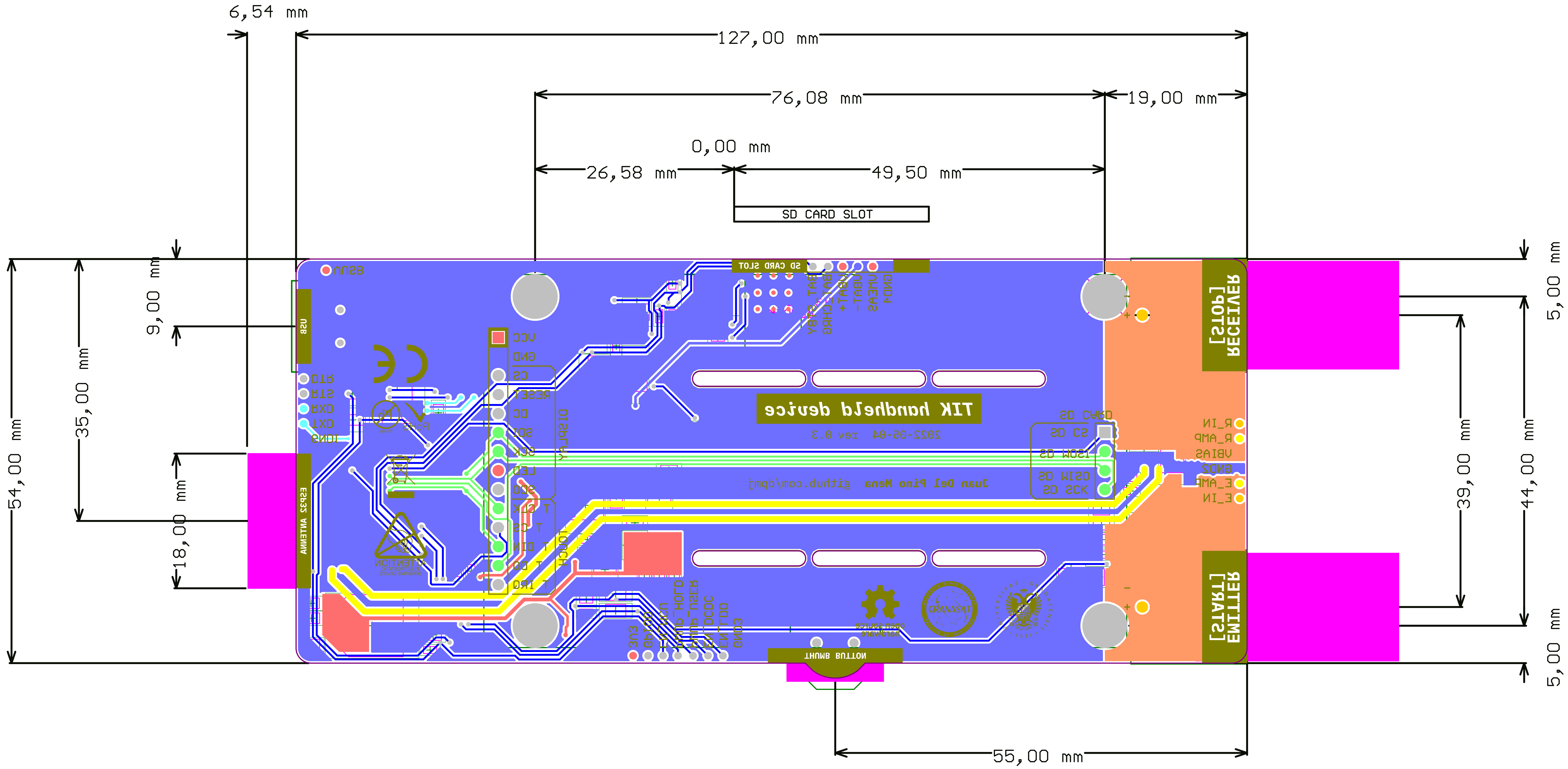

VISIBLE LAYERS:

Board outline + Multilayer + Bottom overlay + Bottom layer + Keep-out + dimensions

TIK handheld device PCB

PCB orientation: vertical. Screen facing front, BNCs on top, USB at the bottom, SD Card reader at the left, powerup button at the bottom front right, and multipurpose button on the right side.

Designer's signature:

Supervisor's signature:

Sheet title: TIK Handheld Device PCB

Project title: TIK_HandheldDevice

Designer: Juan Del Pino Mena

Supervisor: Andres Roldan Aranda

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