BACHELOR'S DEGREE IN TELECOMMUNICATION ENGINEERING

Bachelor's Thesis

ACADEMIC COURSE 2021/2022

Tree Inspection Kit handheld device

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SUPERVISED BY:

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DEPARTMENT:

Electronics and Computer Technology

UNIVERSIDAD DE GRANADA

GRANASAT

IDIE

Project title: **TIK_HandheldDevice.PrjPcb**			
Date: **2022-04-22**	Revision: **0.2**	Sheet 1 of 17	

Index

draftman inicio

Tree Inspection Kit handheld device

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Designer's signature

Supervisor's signature

Sheet title: **Introduction and PCB renders**

Project title: **TIK_HandheldDevice.PrjPcb**

Desginer: **Juan Del Pino Mena**

Date: **2022-04-22** Revision: **0.2** Sheet 2 of 17

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Changelog (from newer to older)

REVISION 0.2 | 2022-04-19

NEW

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

- Added a rotary encoder (variants: horizontal, vertical)
- 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
- Added net classes and parameter sets to most important ones: power, digital communications, analog signals.

TODO:
- Power budget

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.

Detailed revision history

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Sheet title: **Changelog**		
Project title: **TIK_HandheldDevice.PrjPcb**		
Desginer: **Juan Del Pino Mena**		
Date: **2022-04-22**	Revision: **0.2**	Sheet 3 of 17

Supervisor:
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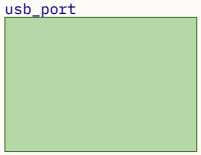
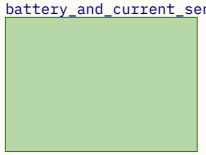
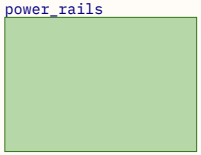
USB PORT
usb_port



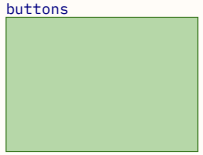
BATTERY AND CURRENT SENSE
battery_and_current_sense



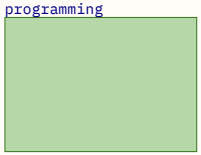
SYSTEM POWER RAILS
power_rails



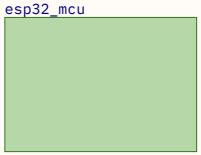
BUTTONS
buttons



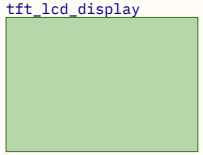
AUTO PROGRAMMING
programming



ESP32-WROOM-32D MCU
esp32_mcu

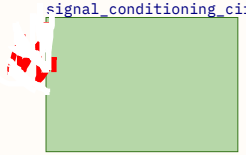


TFT LCD DISPLAY
tft_lcd_display



Fiducials

SIGNAL CONDITIONING
signal_conditioning_circuit



Block diagram

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Sheet title: **Block diagram**			
Project title: **TIK_HandheldDevice.PrjPcb**			
Desginer: **Juan Del Pino Mena**			
Date: **2022-04-22**	Revision: **0.2**	Sheet 4 of 17	

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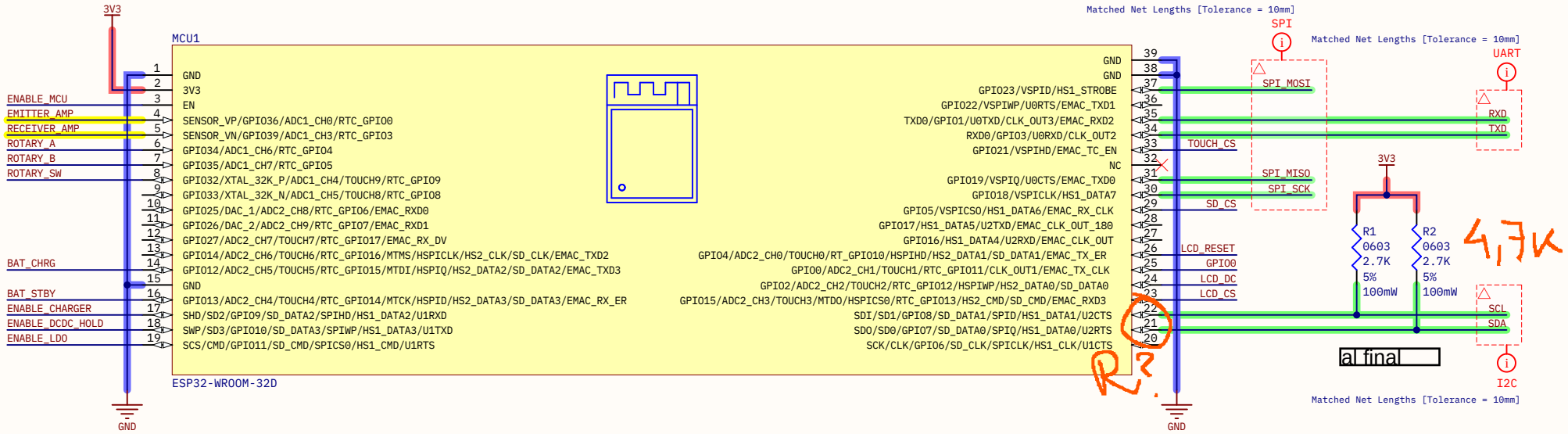
colores diferentes



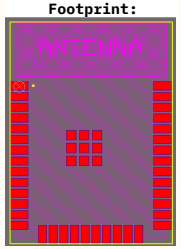
ADC2 pins are not usable while using Wi-Fi or Bluetooth and should be left unused if not necessary

GPIO34, GPIO35, GPIO36 & GPIO39 are input-only

Default I2C pins are in use [SDA: GPIO 21, SCL: GPIO 22] but ESP32 can map any other pins as hardware I2C if necessary

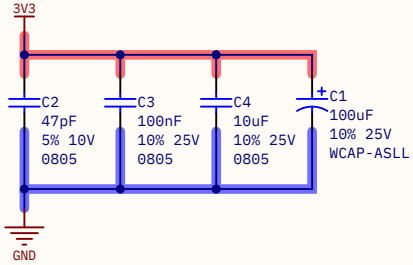
Real model:

Footprint:



Recommended smoothing/bypass capacitors are 0.1 µF and 10 µF, ceramic, low ESR. Should be placed close to the chip and with short return paths. [ESP32-WROOM-32D datasheet, page 21]

Added one extra 100 µF electrolytic cap to filter current spikes during ESP32 RF usage and a small 47pF capacitor to be more effective on high frequencies



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**
Desginer:	**Juan Del Pino Mena**
Date:	**2022-04-22**
Revision:	**0.2**
Sheet	5 of 17

Supervisor:
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3.3 V rail: main system power

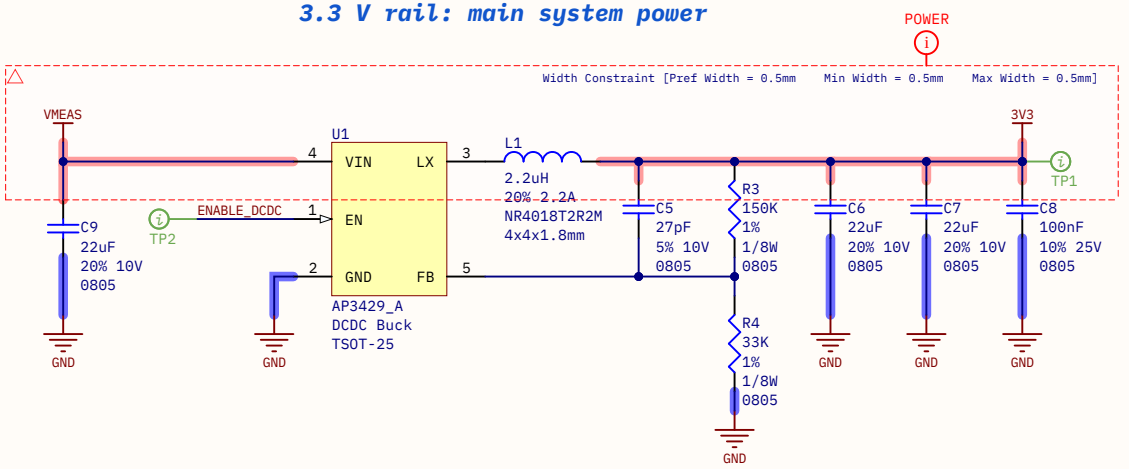
Typical Application Circuit. [AP3429/A datasheet, page 2]
with some values modified as needed and/or part availability.
Capacitors should be placed close to the chip and circuit should be traced in short loops.

Feedback voltage V_FB is 0.6 V const.

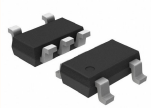
Resistors are adjusted as a voltage divider. So, if 3.3V are needed at the converter output:

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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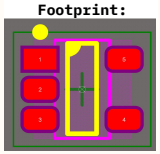
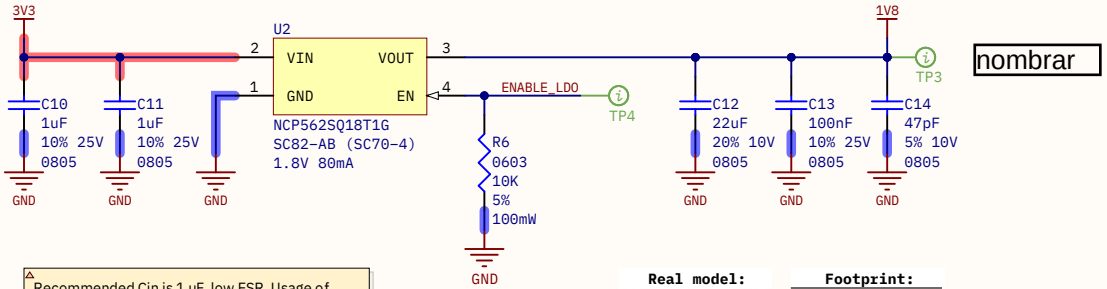


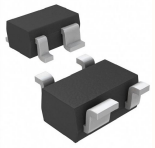
1.8 V rail: Vbias for signal conditioning circuit



nombrar

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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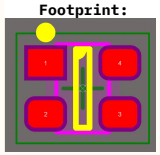
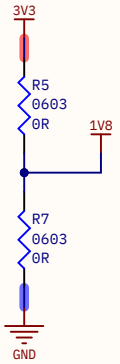


Optional 1V8 rail bypass jumpers



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 resistors at the same time or it will jump VCC and GND. And keep the LDO disabled at all times.

This bypass 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 in place of the 0-Ohm ones.

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.

Power rails

Battery DC/DC step-down converter

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Sheet title:	*
Project title:	TIK_HandheldDevice.PrjPcb
Desginer:	Juan Del Pino Mena
Date:	2022-04-22
Revision:	0.2
Sheet	6 of 17

Supervisor:
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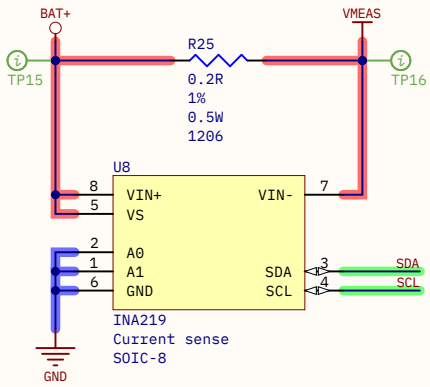
Battery charging circuit variants

BATTERY CHARGER [VARIANT #1: NiMH]
battery_charger_ni_mh

BATTERY CHARGER [VARIANT #2: LI-ION]
battery_charger_li-ion

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.

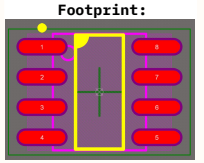
Battery output current sense and voltage monitor



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

Real model:

Footprint:



Battery connector. Charger selection jumper

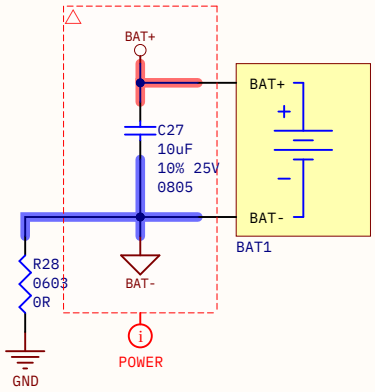
IMPORTANT: 0-Ohm jumper for charger selection:

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.

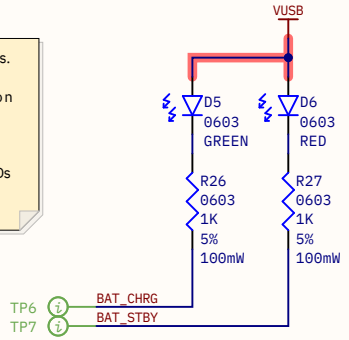


Charging status indicator

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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Sheet title:	**Battery and current sense**		
Project title:	**TIK_HandheldDevice.PrjPcb**		
Desginer:	**Juan Del Pino Mena**		
Date:	**2022-04-22**	Revision: **0.2**	Sheet 7 of 17

Supervisor:
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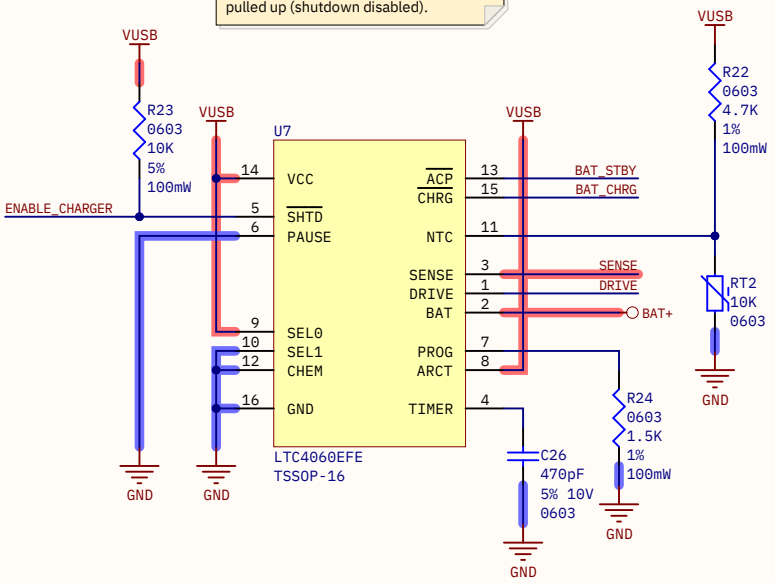
NiMH/NiCd battery charger IC

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

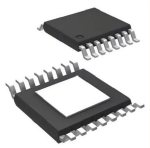


[NOT IMPLEMENTED] This IC has the possibility of implementing a power path control (power the load from external source while charging)

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, and can be substituyed with a much more

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

Real model:



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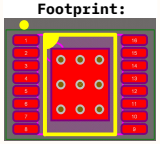


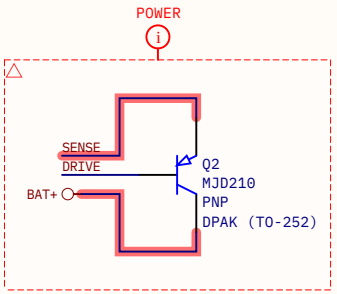
TIMER capacitor and PROG resistor program the charge Tmax (maximum charging time, a security measure). [LTC4060 datasheet, page 13]. These values should complete a full charge in at most 1 h 6'

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

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

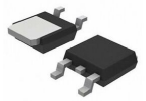
i.e.: a 1000 mAh battery will charge at approx 1C with this configuration, but can be insufficient time for a 3000 mAh one.

External PNP BJT current driver



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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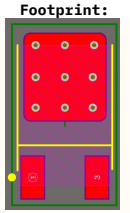

Battery charging circuitry for Ni-MH

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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Sheet title:	**Battery charger**
Project title:	**TIK_HandheldDevice.PrjPcb**
Desginer:	**Juan Del Pino Mena**
Date:	**2022-04-22**
Revision:	**0.2**
Sheet	8 of 17

Supervisor:
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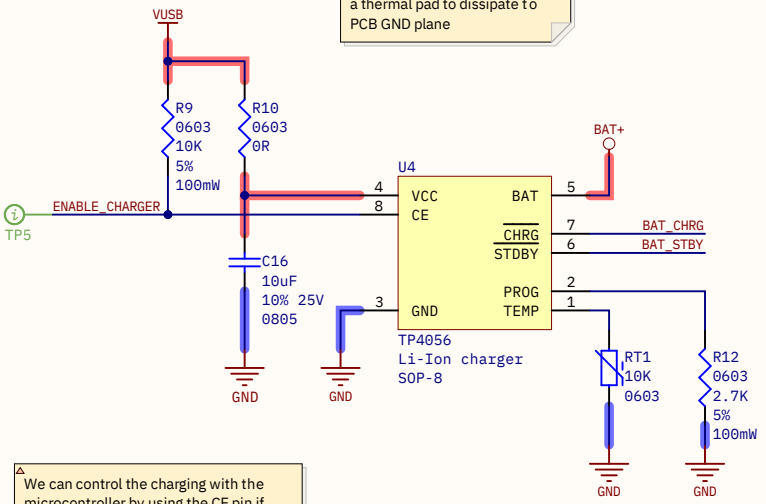
Lithium battery charger IC

0-Ohm resistor is a placeholder for a 0.20.5 Ohm resistor that the datasheet recommends for the TP4056; probably for chip temperature concerns.
However, we don't have any resistor of these values and since some designs don't use any resistor at all, it is omitted at the moment.

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



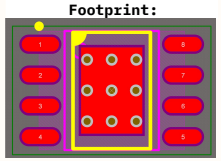
We can control the charging with the microcontroller by using the CE pin if necessary. This pin is normally pulled up (Enabled) by the 10kOhm resistor.

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.

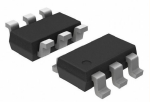
Real model:

Footprint:



Lithium battery protection

Real model:



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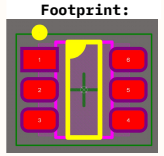
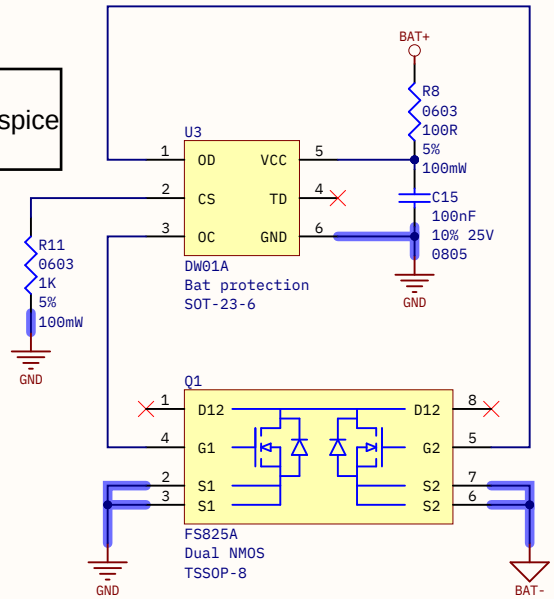
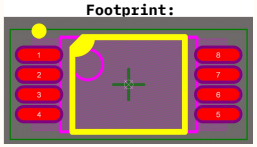


ver modelos spice



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).

Designer's signature

Supervisor's signature

Sheet title:	**Battery charger**		
Project title:	**TIK_HandheldDevice.PrjPcb**		
Desginer:	**Juan Del Pino Mena**		
Date:	**2022-04-22**	Revision: **0.2**	Sheet 9 of 17

Supervisor:
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C/ Fuente Nueva, s/n, 18001
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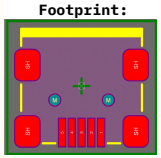
aliexpress fooprint con mues

Real model:

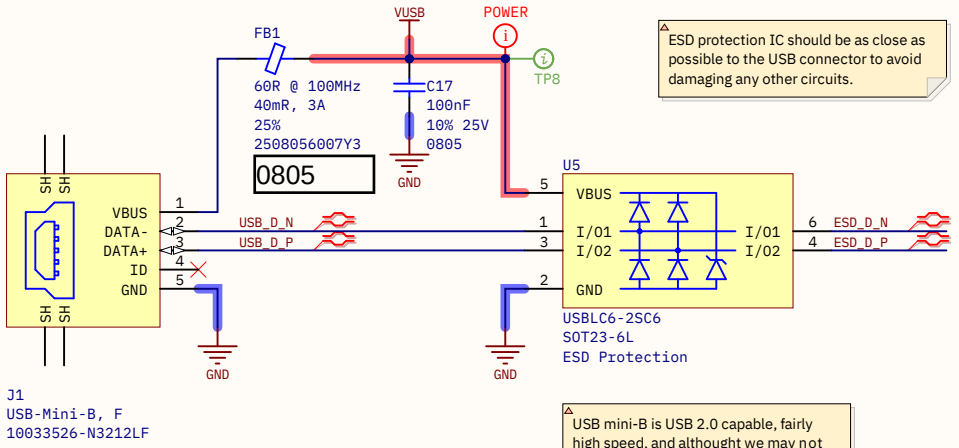
Footprint:



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

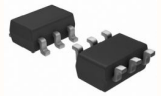
¿Es posible que la resistencia no aguante la corriente?

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

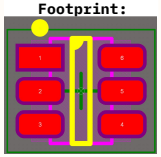


ESD protection IC should be as close as possible to the USB connector to avoid damaging any other circuits.

Real model:



Footprint:



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.

'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 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 reverse polarity.

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:	**2022-04-22**	Revision: **0.2**	Sheet 10 of 17

Supervisor:
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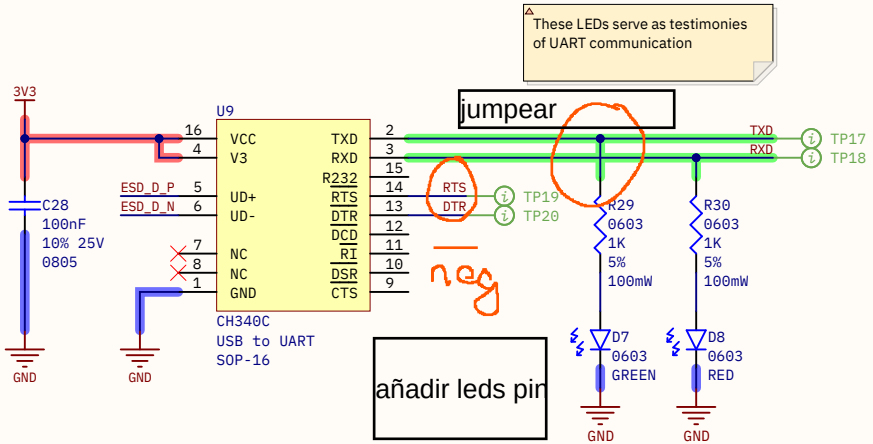
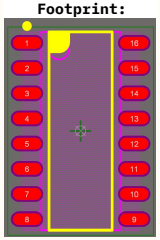
USB to UART conversion

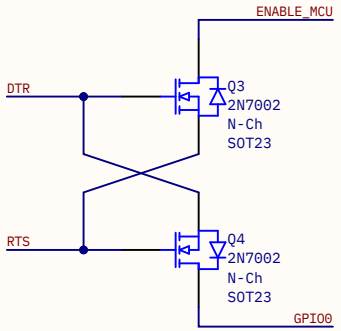


Real model:

Footprint:



Auto programming circuit



ESP32 GPIO0 is a Strapping pin. Strappin 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.

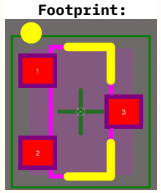
[ESP32 Datasheet, section 2.4, pages 19-20]

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:

Footprint:



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:	**2022-04-22**	Revision: **0.2**	Sheet 11 of 17

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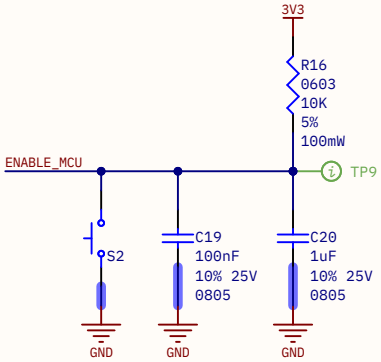
Reset

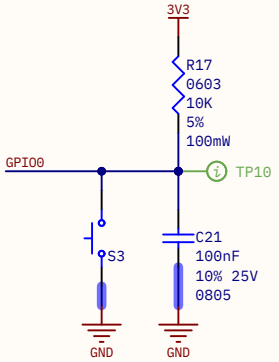
To ensure power stability to the microcontroller during powerup, this RC filter introduces a delay on the ENABLE pin. Usual values are 10 kΩ, 1 µF (τ = 10 ms, t_{10-90} = 22 ms).
[ESP32-WROOM-32D datasheet, page 22]



Boot mode selection (debug)

Allows to force 'Download' boot sequence

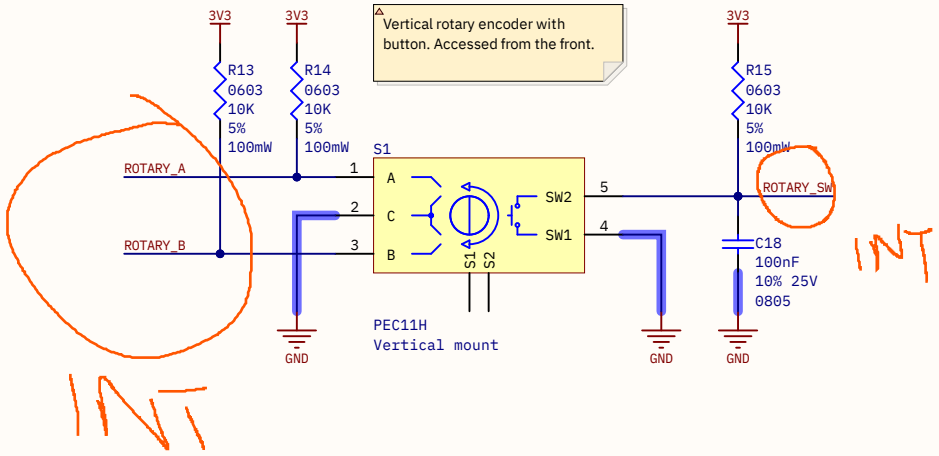
Same design as in ESP32 DevKit boards.
100 nF cap are for debouncing and should be placed close to the buttons



POWERUP BUTTON
powerup_button

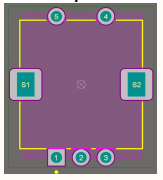
Rotary encoder

Vertical rotary encoder with button. Accessed from the front.



Real model:

Footprint:



poner el rotary horizontal

Buttons

TFT LCD touchscreen, rotary encoder, on/off and reset switches
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Supervisor's signature

Sheet title:	**Buttons**		
Project title:	**TIK_HandheldDevice.PrjPcb**		
Desginer:	**Juan Del Pino Mena**		
Date:	**2022-04-22**	Revision: **0.2**	Sheet 12 of 17

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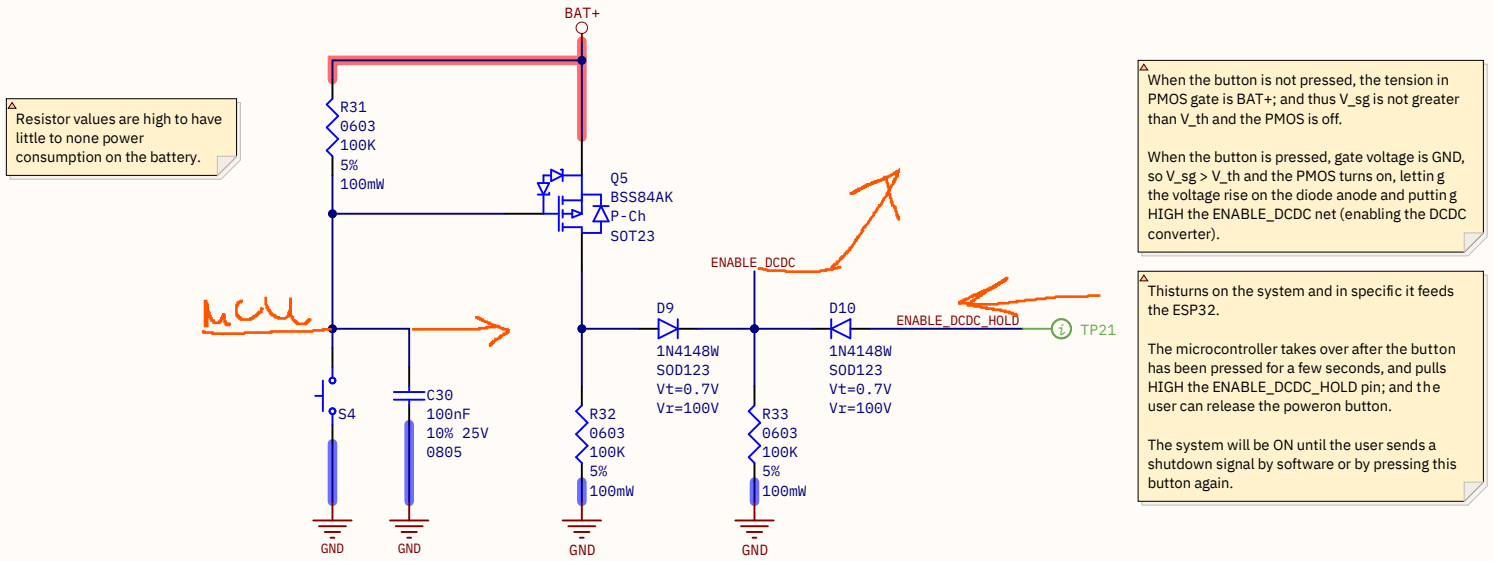

Resistor values are high to have little to none power consumption on the battery.

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, lettin g the voltage rise on the diode anode and puttin g 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**		
Date:	**2022-04-22**	Revision: **0.2**	Sheet 13 of 17

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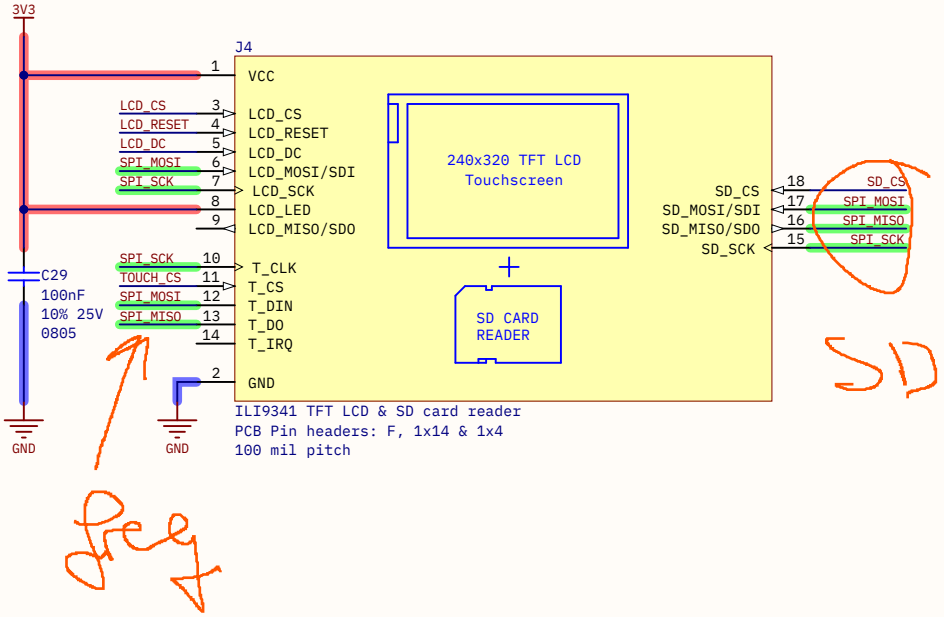
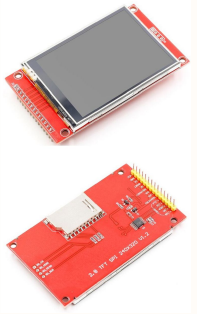


Real model:



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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Supervisor's signature

Sheet title:	**LCD TFT Touch Display & SD card reader**		
Project title:	**TIK_HandheldDevice.PrjPcb**		
Desginer:	**Juan Del Pino Mena**		
Date:	**2022-04-22**	Revision: **0.2**	Sheet 14 of 17

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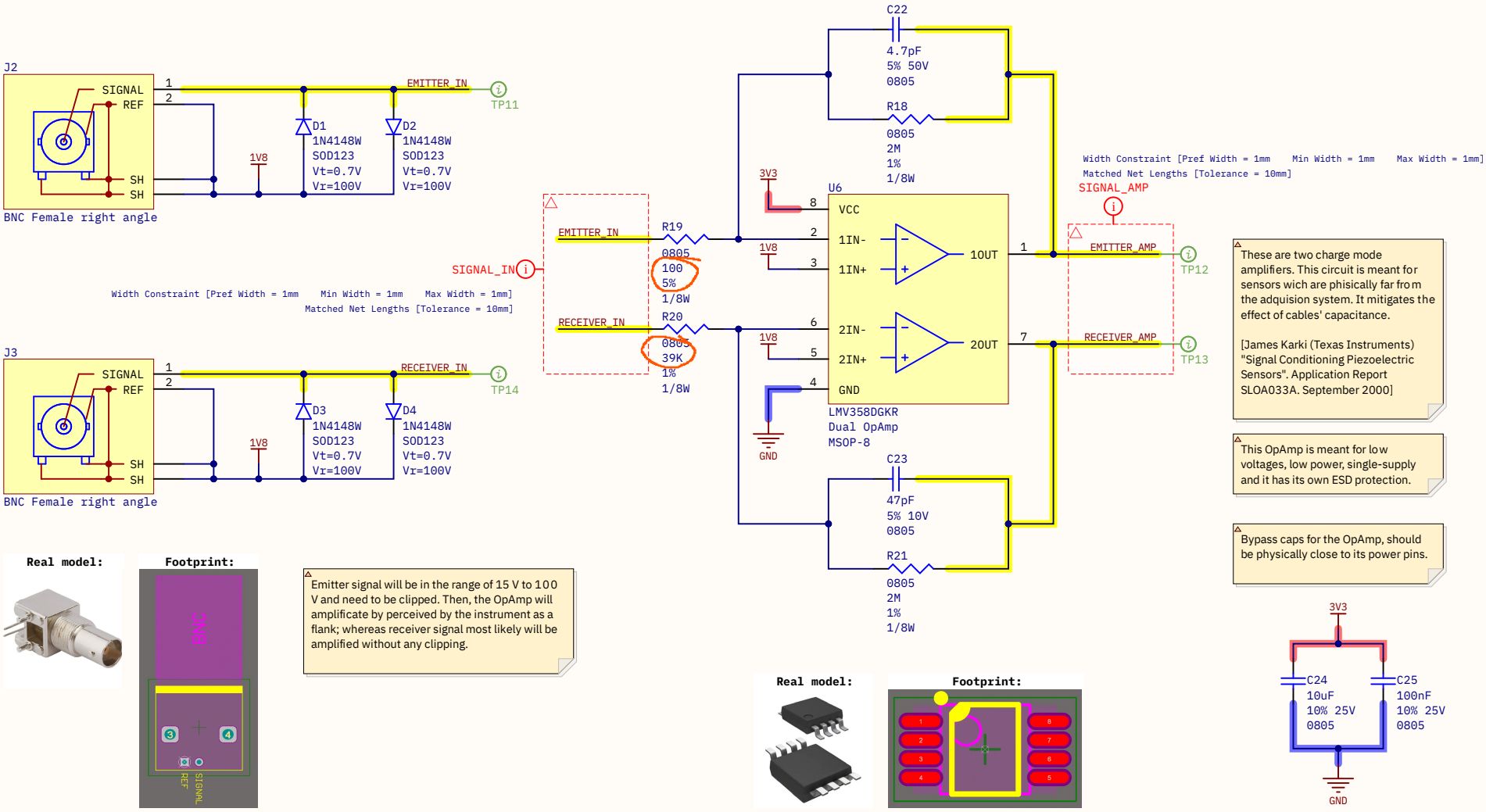
LRC

lrc sonda sensor ciencias



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.

Real model:

Footprint:

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.

Real model:

Footprint:

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

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Supervisor's signature

Sheet title:	**Signal conditioning circuit**		
Project title:	**TIK_HandheldDevice.PrjPcb**		
Desginer:	**Juan Del Pino Mena**		
Date:	**2022-04-22**	Revision: **0.2**	Sheet 15 of 17

Supervisor:
Sr. Andrés Roldán Aranda
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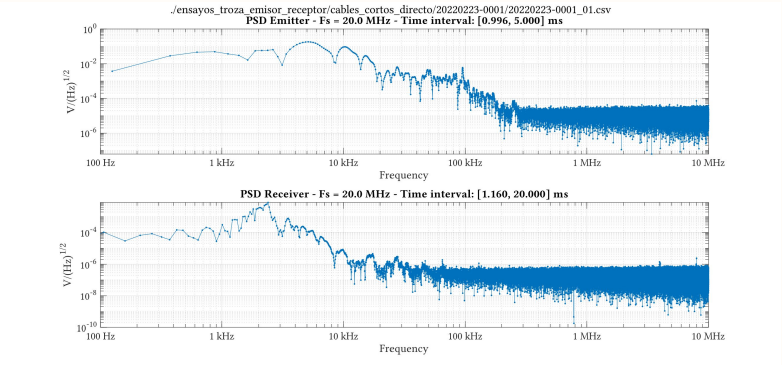
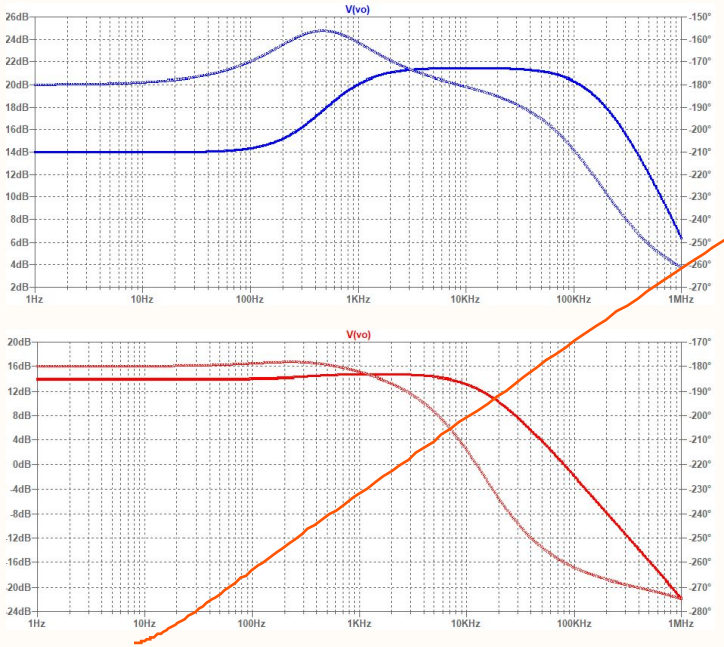
Example of a Voltage Spectral Density of trunk signals



A REVISAR Y REPETIR EN ALTIUM

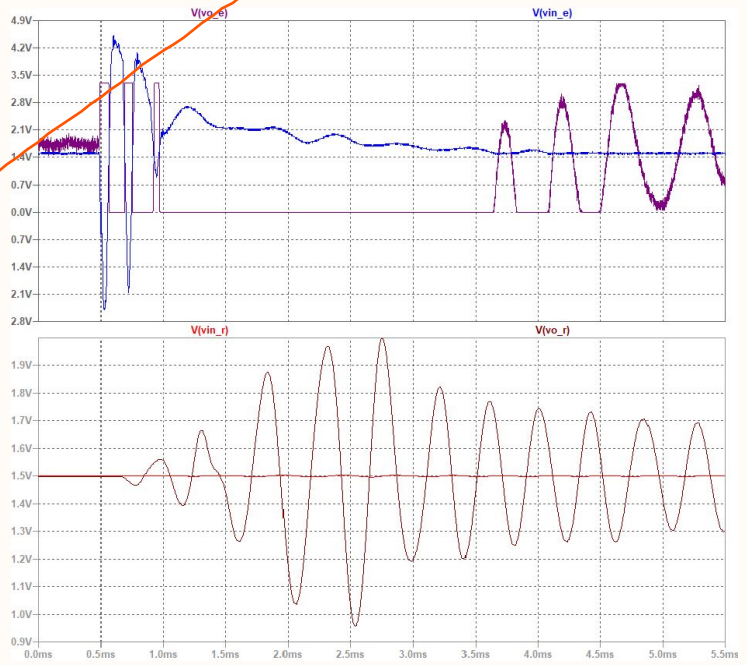
Contitioning circuit theorical frequency response



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

¿Afecta en algo la fase?

Time behavior



Signal conditioning theoreticals

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Supervisor's signature

Sheet title:	**Signal Conditioning Theoreticals**		
Project title:	**TIK_HandheldDevice.PrjPcb**		
Desginer:	**Juan Del Pino Mena**		
Date:	**2022-04-22**	Revision: **0.2**	Sheet 16 of 17

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Power budget

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Sheet title: **Power budget**			
Project title: **TIK_HandheldDevice.PrjPcb**			
Desginer: **Juan Del Pino Mena**			
Date: **2022-04-22**	Revision: **0.2**	Sheet 17 of 17	

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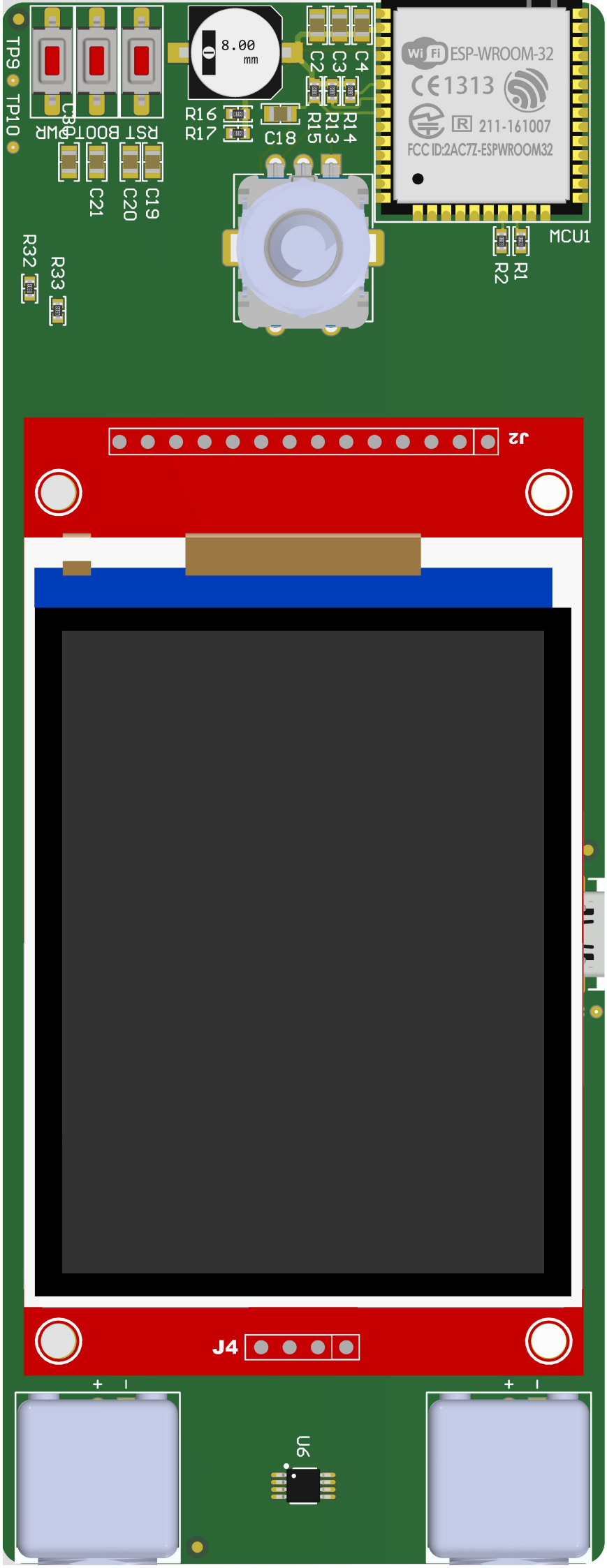
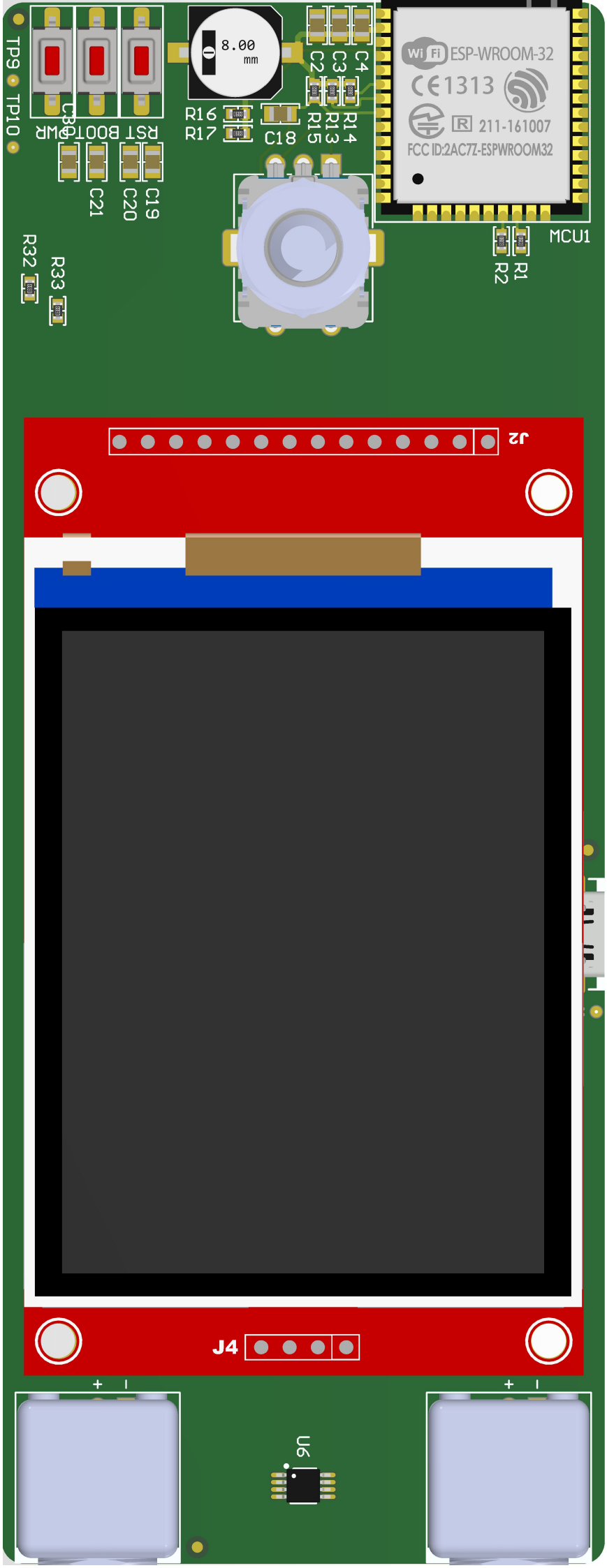

TP9
TP10
PWR
BOOT
RST
C22
C21
C20
C19
R32
R33
8.00
mm
R16
R17
C18
C2
C3
C4
R15
R13
R14
ESP-WROOM-32
1313
211-161007
FCC ID:2AC7Z-ESPWROOM32
MCU1
R1
R2
J2
J4
U6


TP9
TP10
PWR
BOOT
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C22
C21
C20
C19
R32
R33
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mm
R16
R17
C18
C2
C3
C4
R15
R13
R14
ESP-WROOM-32
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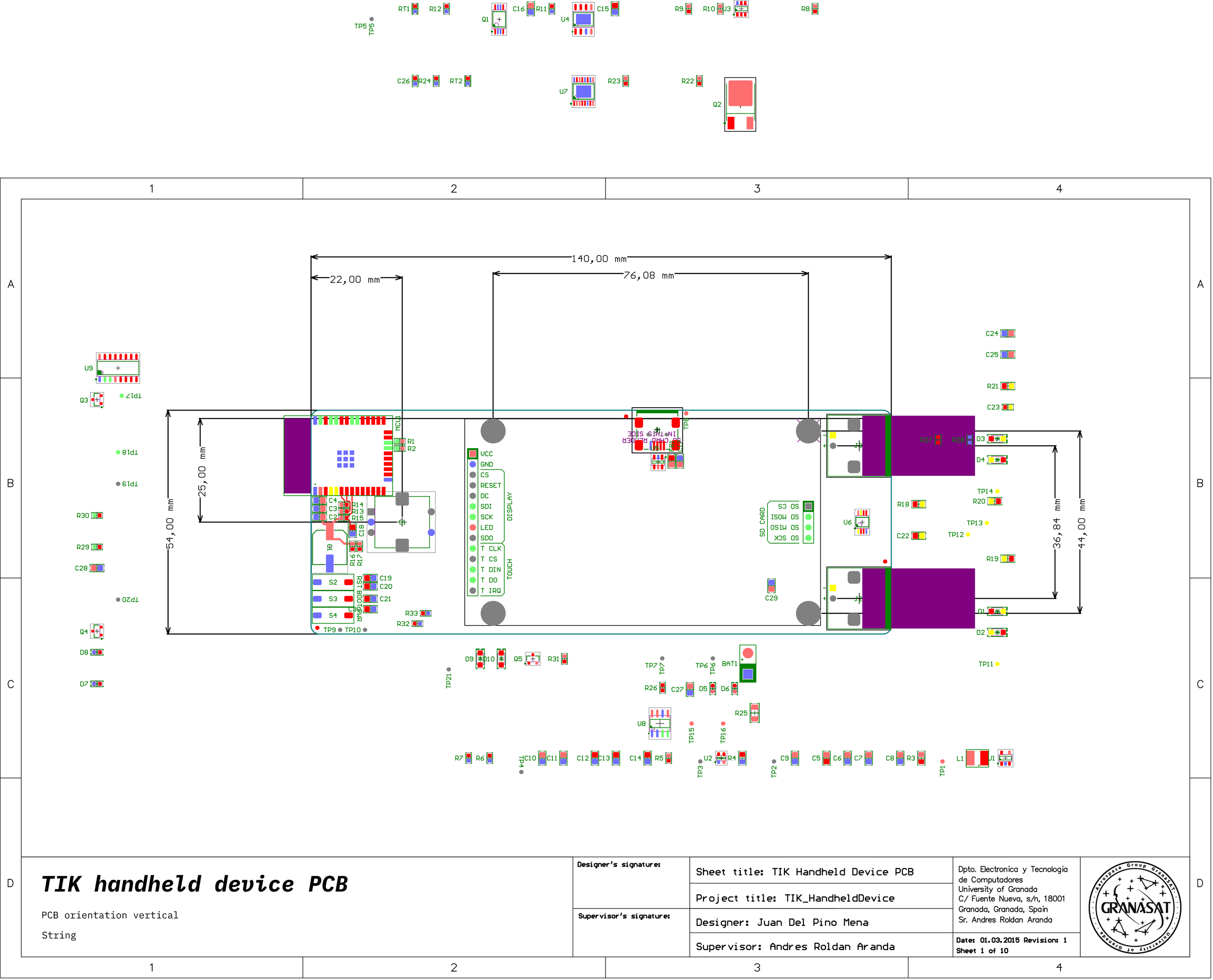
211-161007
FCC ID:2AC7Z-ESPWROOM32
MCU1
R1
R2
J2
J4
U6



TIK handheld device PCB

PCB orientation vertical

String

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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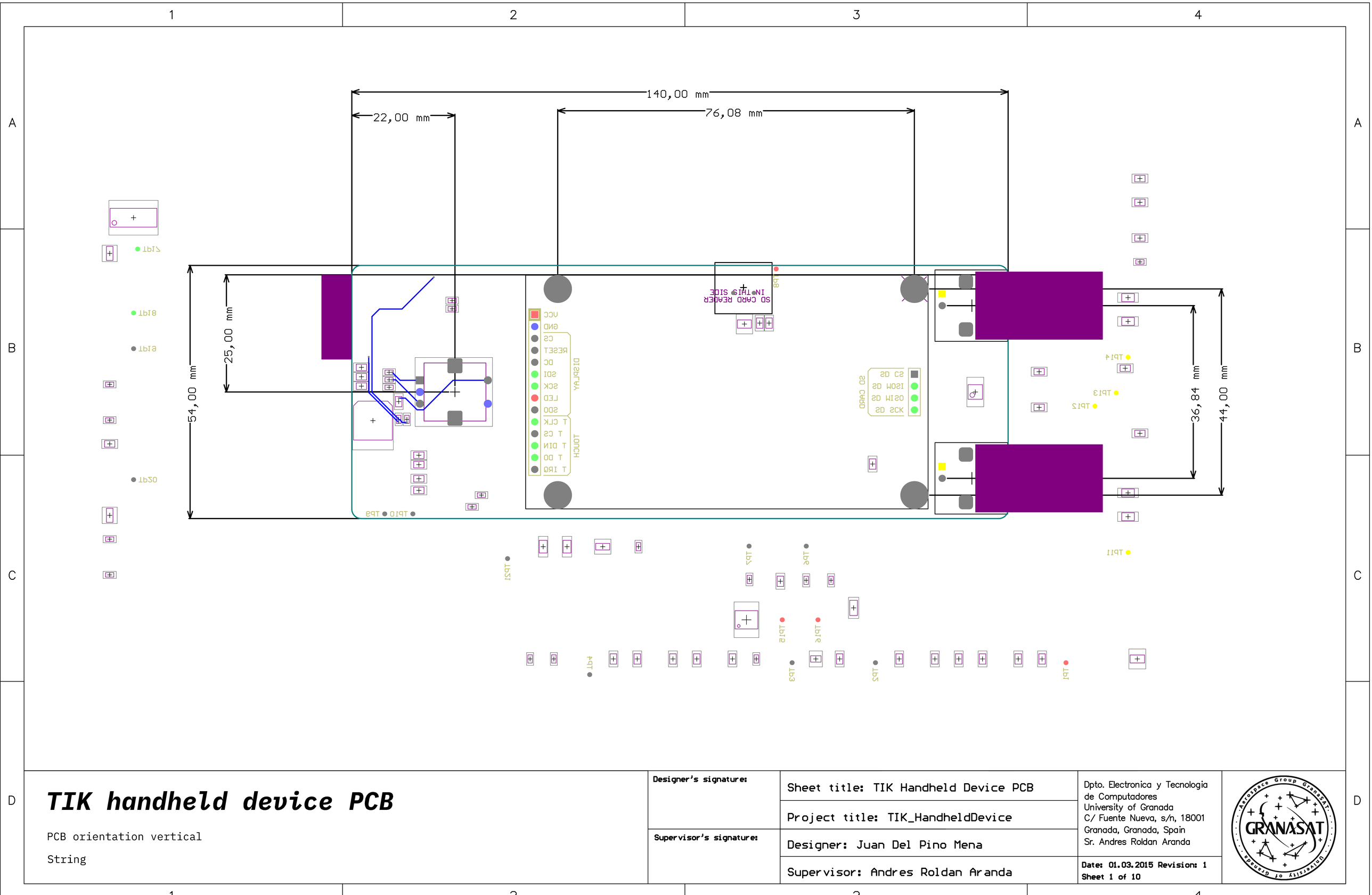
Sr. Andres Roldan Aranda

Date: 01.03.2015 Revision: 1
Sheet 1 of 10



TIK handheld device PCB

PCB orientation vertical

String

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	Project title: TIK_HandheldDevice
Supervisor's signature:	Designer: Juan Del Pino Mena
	Supervisor: Andres Roldan Aranda

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Date: 01.03.2015 Revision: 1

Sheet 1 of 10