Telemetry receiver board

Contents

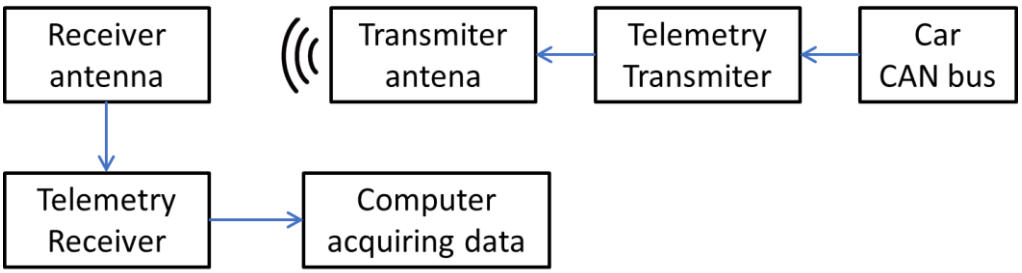
1. Design requirements:

- One way telemetry system for Formula Student car.
- Minimal range – 100m in open field. This could've been achieved without LNA amplifiers, but for extra reliability, it was chosen to use them.
- Transmit power: +20dBm – maximum power allowed in Europe.
- Omnidirectional antenna, with 2dBi gain.
- Transmitter placed in front of the car with other electronic components, on standardized motherboard.
- Acquired data would be transmitted to the computer, where it would be stored and analyzed.
- Transmitter and receiver would be powered with 5V (Voltage provided by the motherboard for the transmitter, and by the USB port for the receiver).
- The car is made out of carbon fiber composite, with aluminum honeycomb between the carbon fiber sheets. Honeycomb and carbon fiber are electrical conductors, so the antenna needs to be mounted outside the monocoque.
- Transmitted data:
    - Accelerator pedal position
    - Brake systems pressures
    - Speeds of all 4 wheels
    - GPS position
    - Power, that the inverter sends to the motor
    - State of charge of the low voltage battery.
    - State of charge of the high voltage battery.
    - Inverter temperature
    - Motor temperature
    - Low voltage battery temperature
    - High voltage battery temperature
    - Water temperature

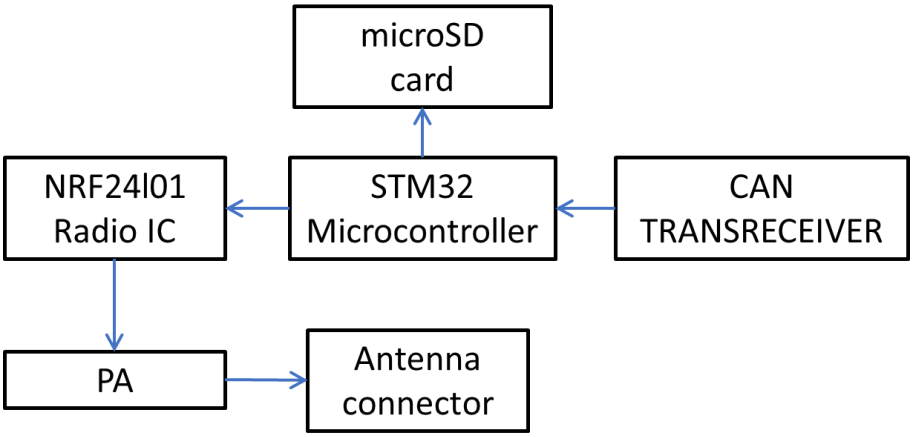
- State of the car
- Tires temperatures

- The car uses 1Mbps CAN bus, so the telemetry system should be able to transmit data with speed >1Mbps.

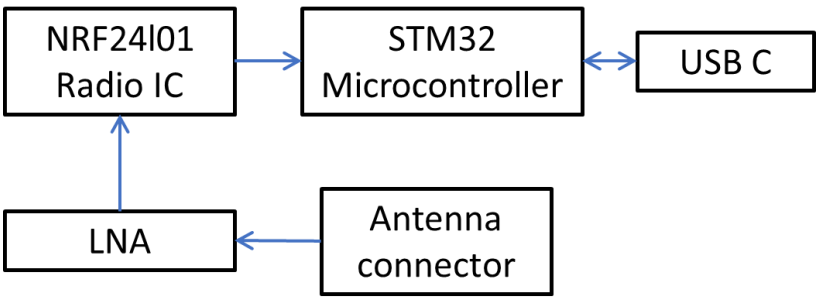
2. Block diagram of the system:



3. Transmitter block diagram:



4. Receiver block diagram:



5. Theoretical range calculation

Silicon Labs calculator has been used:

Simple Range Calculator V1.1

Frequency Band [MHz] Custom Freq	**Enter Custom Fr** 2400

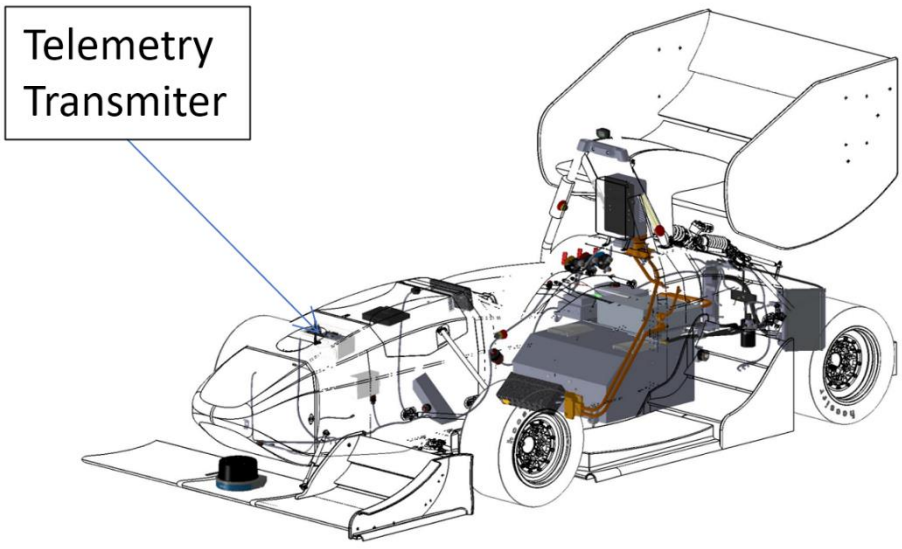
SILICON LABS

TX parameters	**RX parameters**
Enter TX Output Power [dBm] 19	**Enter RX Sensitivity [dBm]** -97
Enter TX Antenna Gain [dBi] 2	**Enter RX Antenna Gain [dBi]** 2

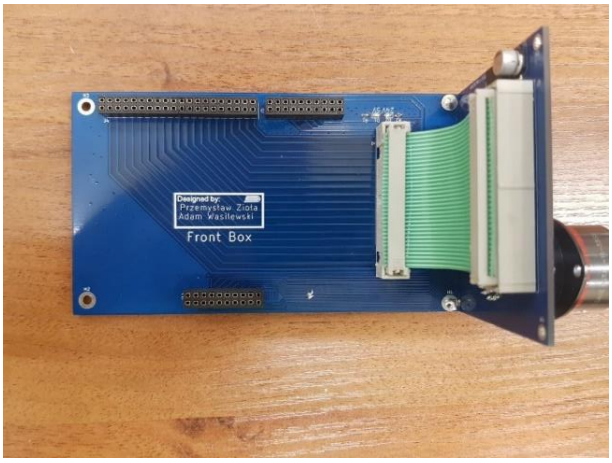
Typical Open Field Outdoor Range [m]	**1099,1**
Typical Indoor, Small Office Range [m]	**226**

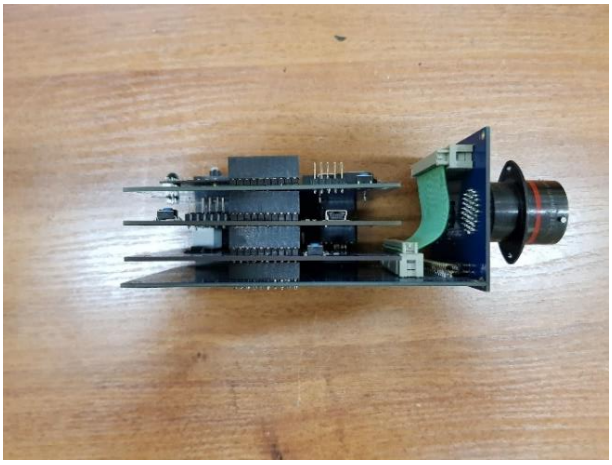
As it can be seen above, the theoretical range with standard antenas is 1099,1m. This range fully satisfy our requirements.

6. Physical location of the telemetry transmitter inside the car:



7. Standardized motherboard:



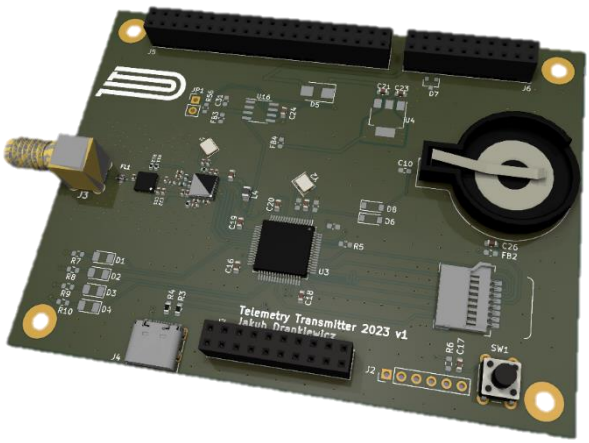


8. PCB project

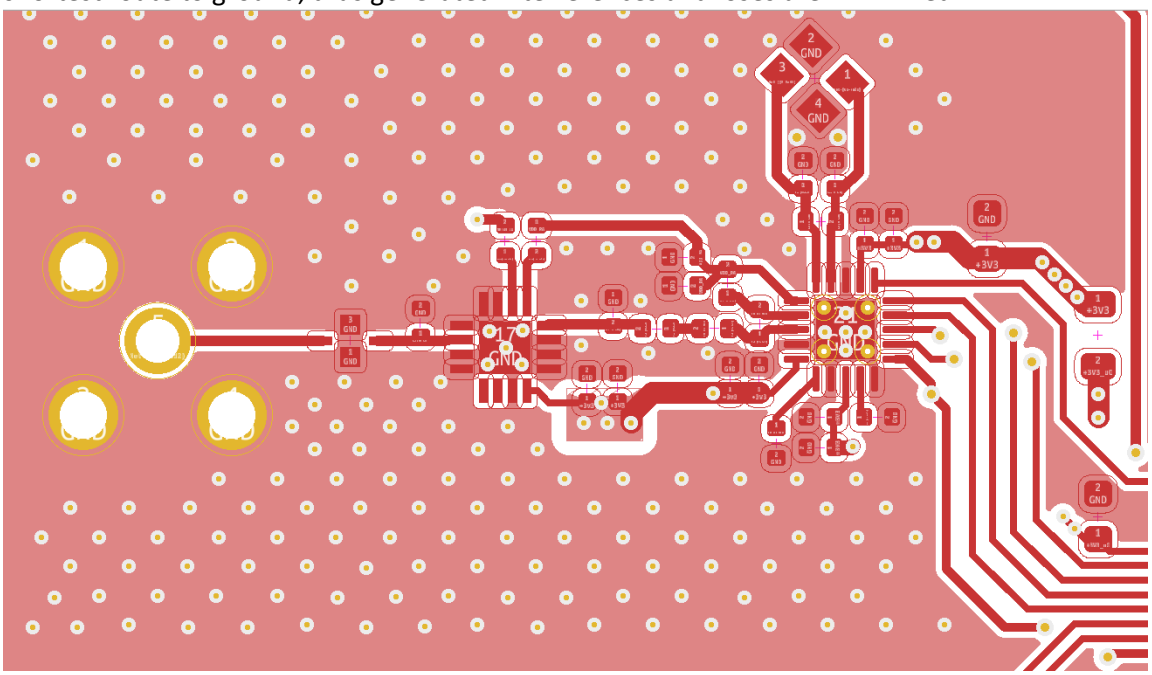
4 layer PCB was used, cause of lower distances between copper layers, and simultaneously not significantly higher cost. The ground plane was poured on every layer. The 3.3V power was routed on layer 2.

Used JLC PCB JLC04161H-7628 stackup was used:

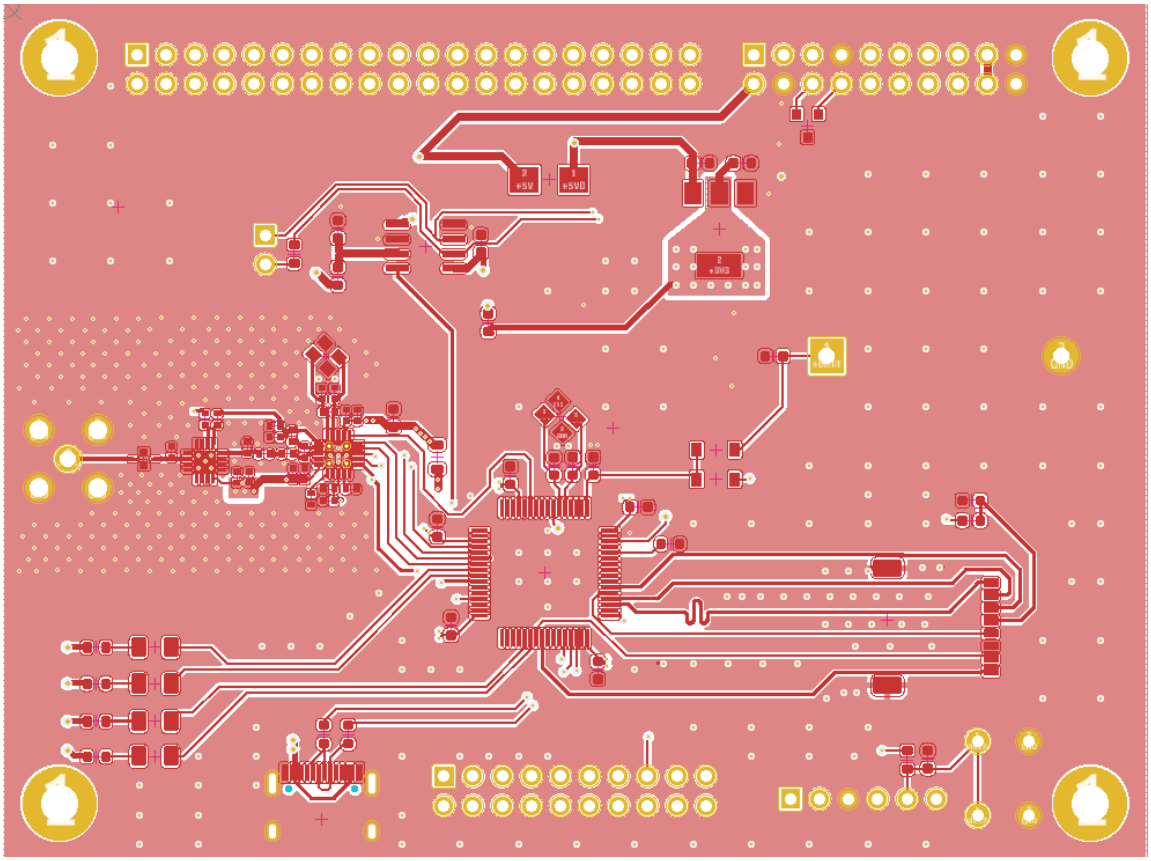
layer	Material Type	Thickness	
Layer	Copper	0.035mm	
Prepreg	7628*1	0.2104mm	
inner Layer	Copper	0.0152mm	1.1mm (with copper c
Core	Core	1.065mm	
inner Layer	Copper	0.0152mm	
Prepreg	7628*1	0.2104mm	
Layer	Copper	0.035mm	

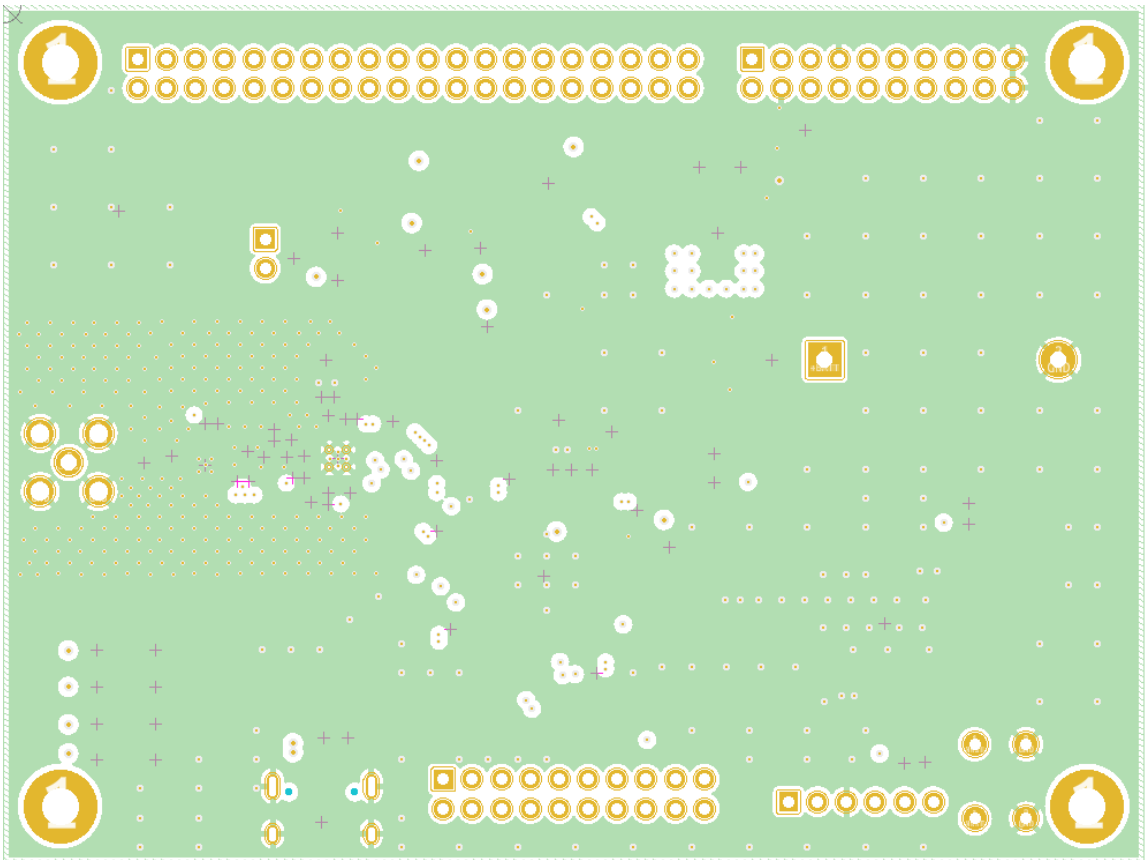


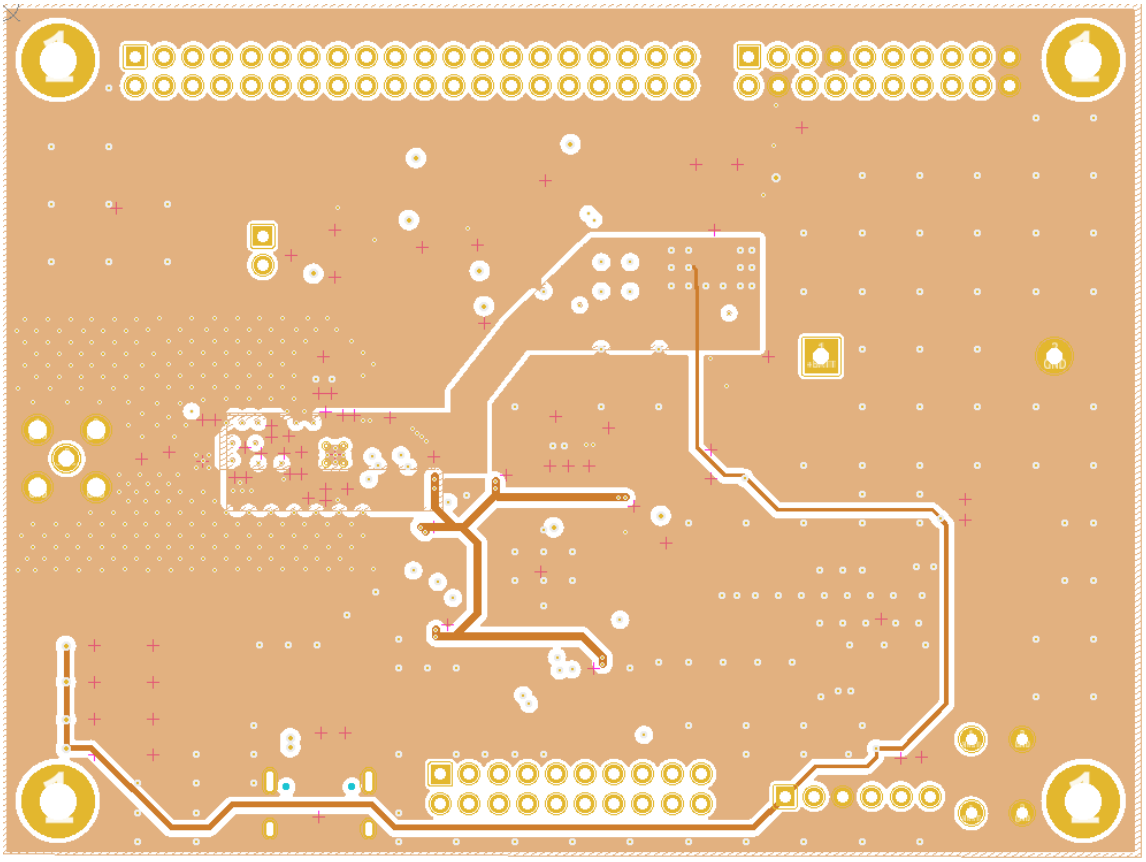
For RF connections coplanar transmission line with ground plane was used. It gives the signal the shortest route to ground, thus generated interferences and loses are minimized.

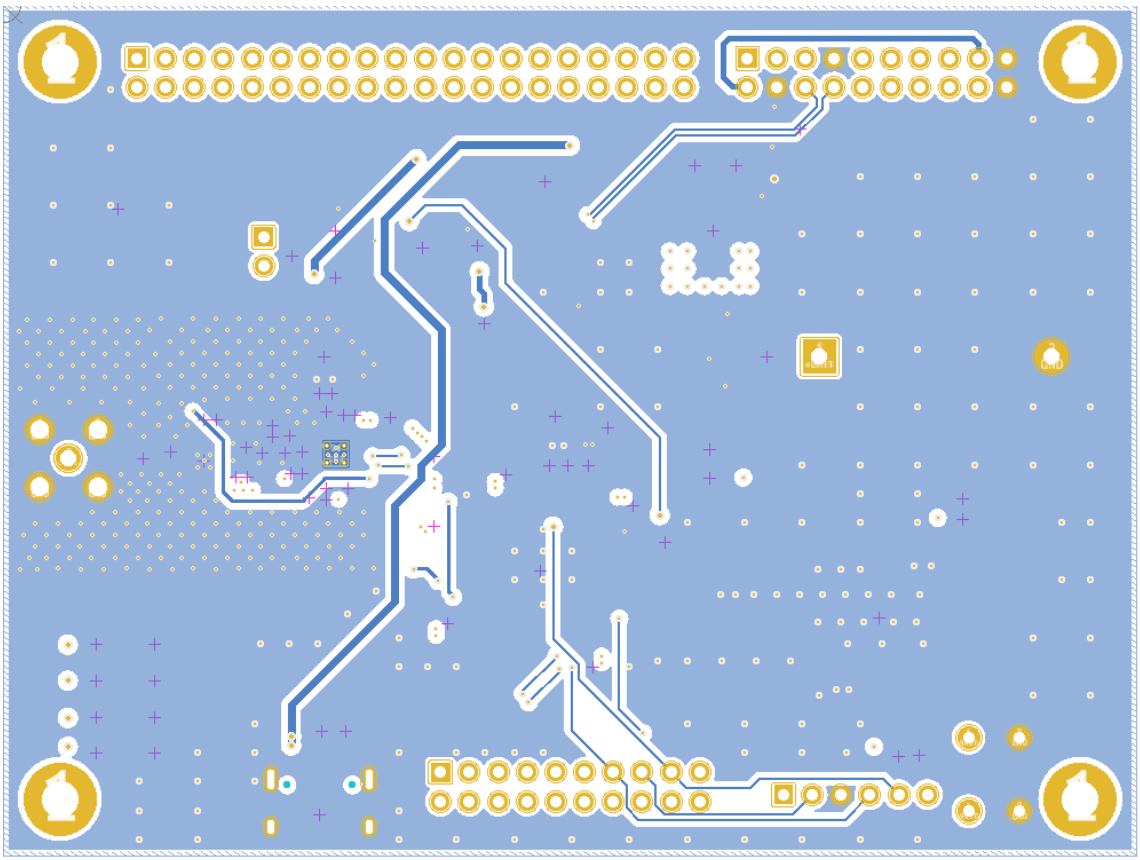


GND planes are connected with via stiching, especialy in RF section. Thanks to via stiching the impedance of ground is minimised in every region of the PCB.


+5V
+5VD
+3V3
GND

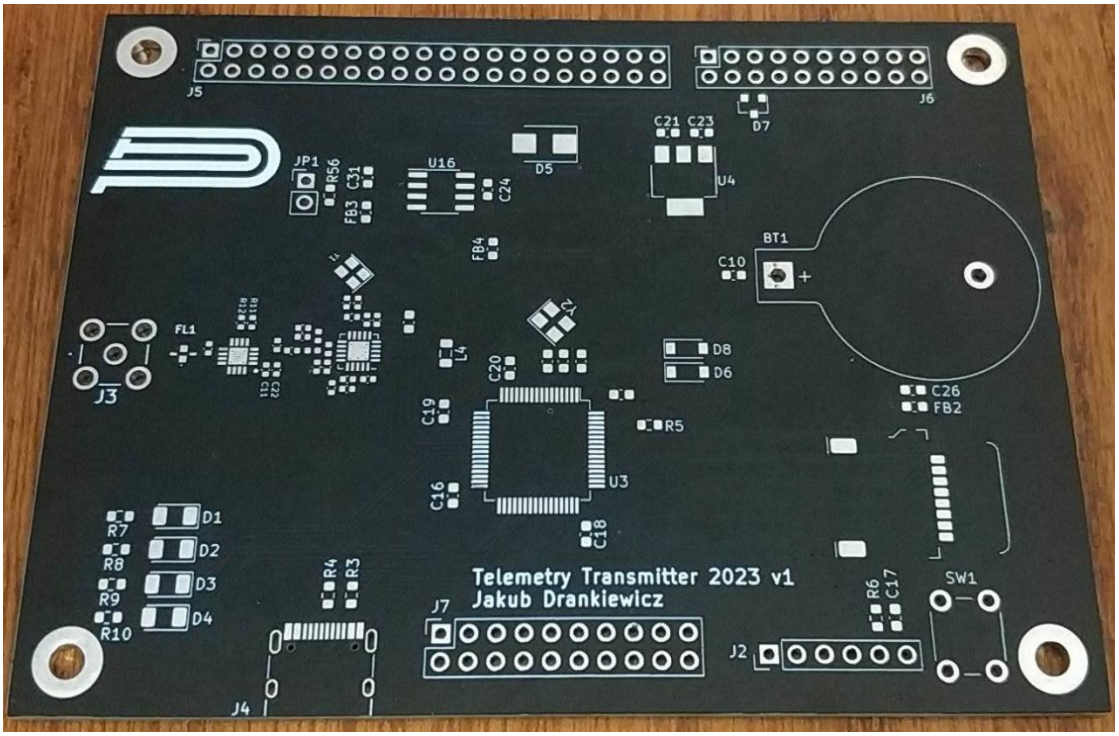

+3V3
GND

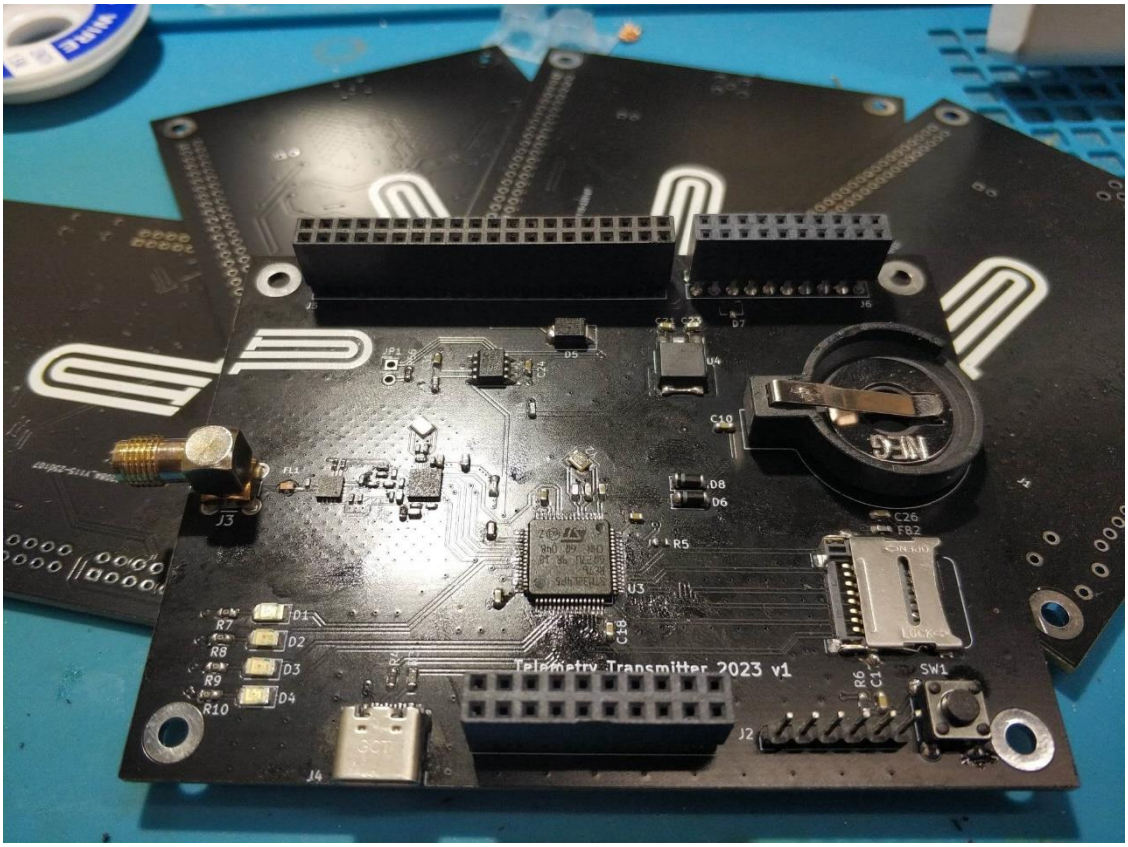


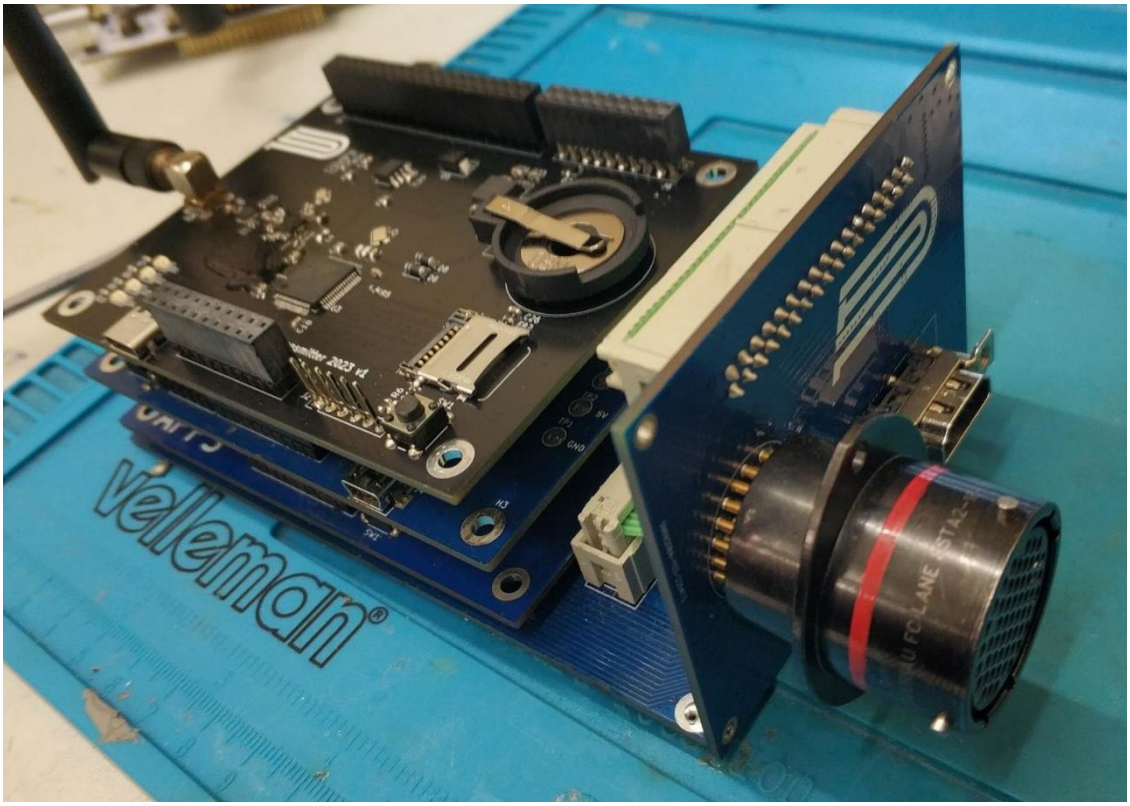


9. Manufacturing

The PCB's were manufactured by JLC PCB. Their services are fast and affordable. The 4 layers PCBs are impossible to do at home, especially with so small spacing between tracks, large amount of vias and the high precision required by the RF signals routing. We've chosen to solder the PCBs ourselfs, but JLC PCB also offers soldering services with huge selection of available components.

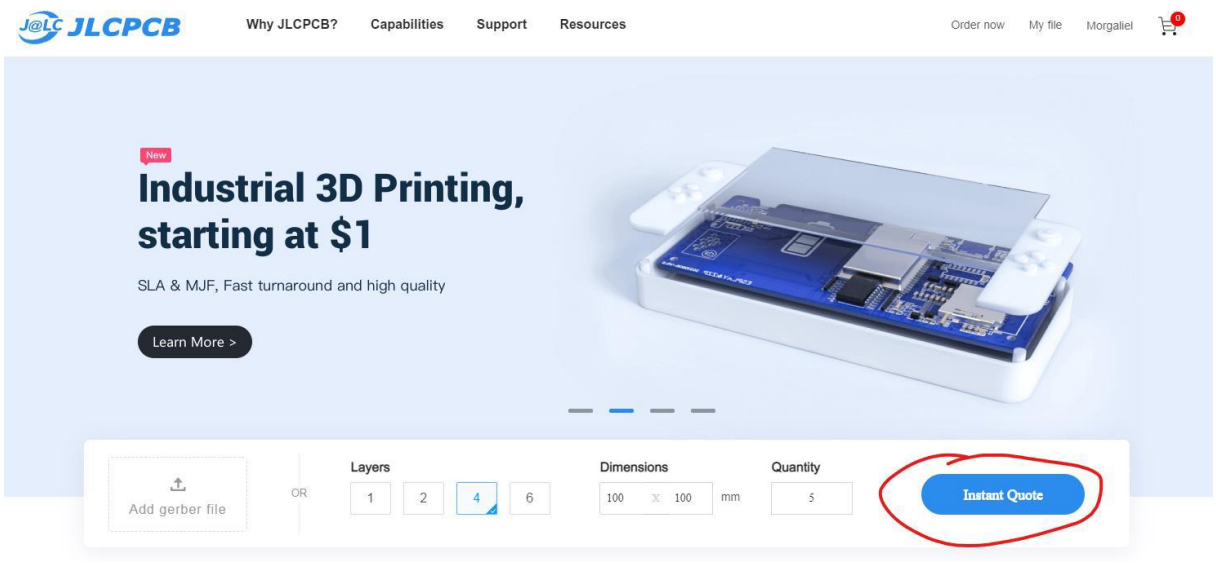

Telemetry Transmitter 2023 v1
Jakub Drankiewicz


Telemetry Transmitter 2023 v1



10. Ordering PCB on JLCPCB

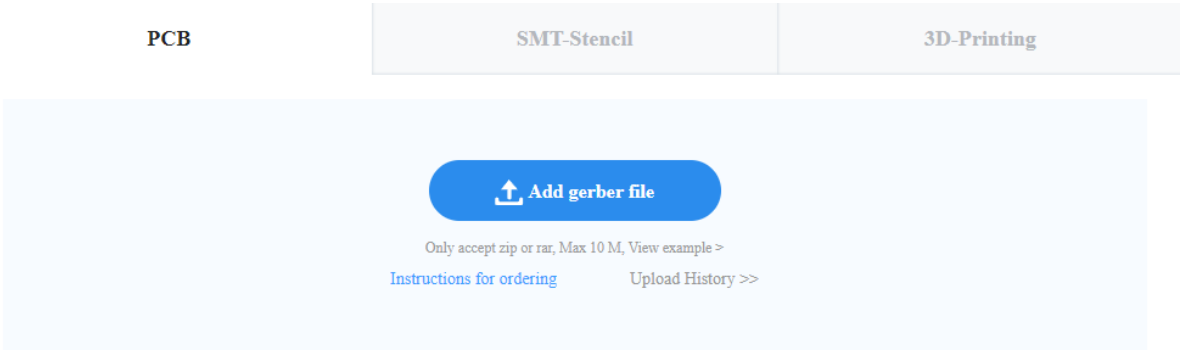
Now that we've got the PCB design, it's time to order. For that, you just have to go to jlcpcb.com, and click on the "Instant Quote" button.



You don't have to worry about the settings here, because you can adjust everything in the new appeared tab.

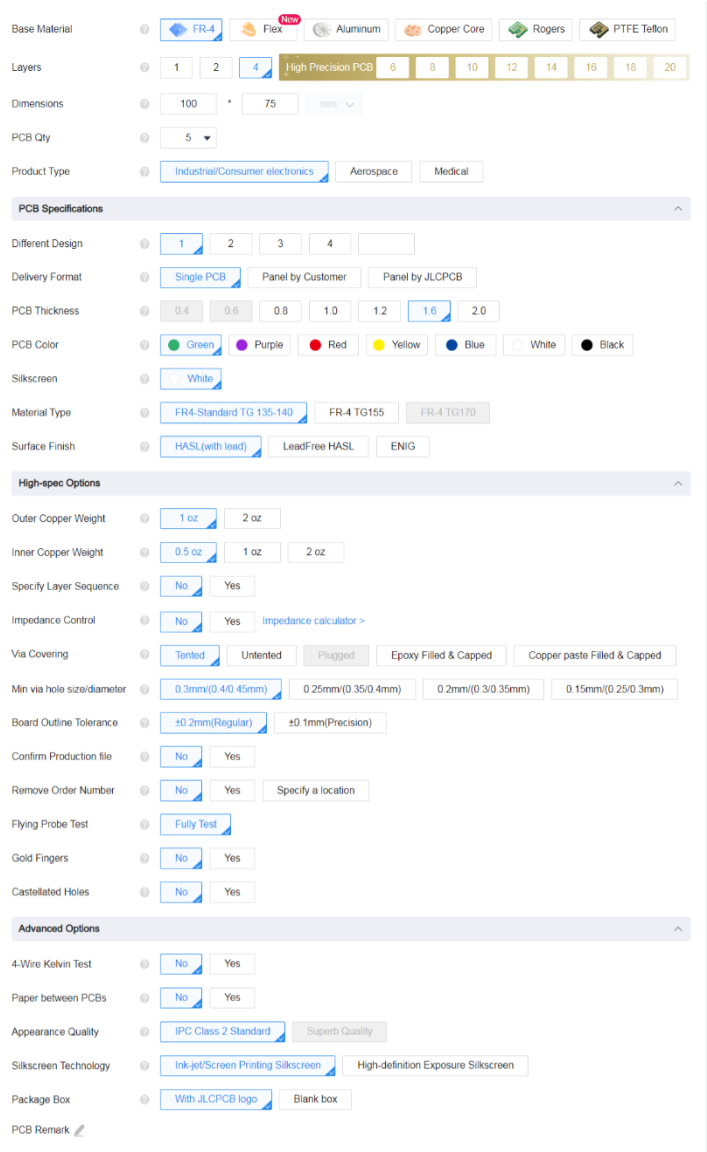
JLCPCB is also a sponsor of this whole project (not only this PCB, but all the PCBs in the car!). JLCPCB (Shenzhen JLC Electronics Co., Ltd.), is the largest PCB prototype enterprise in China and a high-tech manufacturer specializing in quick PCB prototype and small-batch PCB production. You can order a minimum of 5 PCBs for just $2 (2 layers), just enough to have a few test/spare ones.

To get the PCB manufactured, upload zipped Gerber files as you can see below. How to get them in KiCad 5? JLCPCB made the whole tutorial right here: https://support.jlcpcb.com/article/149-how-to-generate-gerber-and-drill-files-in-kicad.

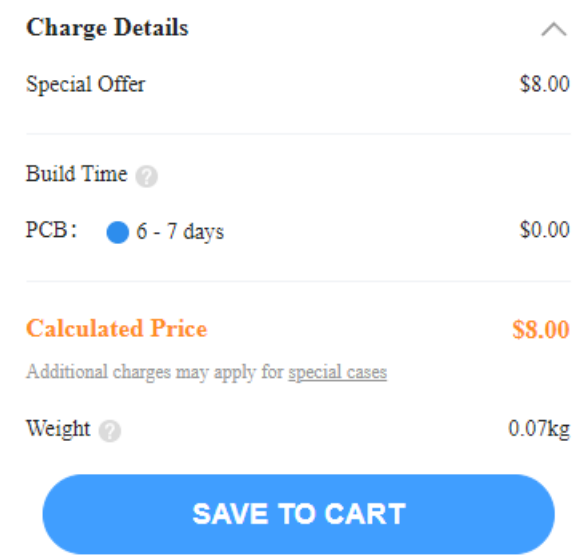


After uploading a zip file, you'll see the top and bottom of your PCB as example shows.

Then, you have multiple options to adjust from number of layers to your PCB colour. Every option here is very clearly marked and described (when you hover over the question mark).



After making sure your PCB looks good – by clicking *Gerber viewer*, you can now place the order at a reasonable price. In case of this project, there is 8$ for 5, 4-layers PCB and it's only 6-7 days build time(the time is extended due to the chosen colour). To place the order, click on the "SAVE TO CART" button. Fast and cheap, right?



The quality is always really satisfying so I sincerely recommend JLCPCB.
jlcpcb.com/HAR