EN2160 - Electronic Design Realization

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Department of Electronic and Telecommunication Engineering
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Project Report - Application of the Cambridge EDC Inclusive Design Methodology

RFID Based Warehouse Management System – UHF RFID Reader

Abstract

This project involves the design and development of an Ultra-High Frequency (UHF) RFID reader intended for warehouse management systems. The RFID reader aims to streamline inventory tracking by providing reliable, real-time updates and reducing manual errors. The project includes the creation of detailed circuit schematics, a 6-layer PCB layout, and the selection of key components such as the ST25RU3993 IC and STM32 microcontroller.

A critical aspect of the design is the Planar Inverted-F Antenna (PIFA), which has been meticulously designed and optimized using advanced simulation tools to ensure optimal performance in reading RFID tags over a range of at least 2 meters. Through the application of these simulation tools and rapid prototyping, the design achieves high gain and efficiency while maintaining compactness. Despite facing challenges such as component delays and complex impedance control, the team has successfully progressed to the prototyping and testing phase. This project demonstrates a comprehensive approach to designing a cost-effective, high-performance RFID reader tailored to the needs of modern warehouse environments.

To address the multifaceted nature of the project, a cross-functional team structure has been adopted. Each team, consisting of two members, is assigned to a specific module—UHF Portal, HF Handheld Scanner AND HF forklift scanner Module. This strategic team alignment focuses on achieving learning outcomes of the EDR module. Each team have to design their own PCB and enclosure to ensure the proper understanding of the concepts.

This report delves into the key components of the UHF RFID Reader including RFID tags/stickers, readers, antennas, and software integration. Furthermore, it outlines the benefits of implementing such a system including improved inventory accuracy, enhanced operational efficiency, reduced labor costs, and increased customer satisfaction. Practical considerations such as system design, implementation challenges, and cost analysis are also discussed. Overall, this report serves as a valuable resource for organizations seeking to optimize their warehouse operations through the adoption of RFID technology.

Contents

1 Review progress.

The starting point for inclusive concept generation is to review our status and plan the next steps. For that we must consider available resources and associated risks. We considered previous works related to our project for better understanding of risks and to define what to do next. Here are some related previous works.

Existing products and related research.

Research Papers in the scope of RFID and Warehouse Management,

- https://ieeexplore.ieee.org/document/4178418
- https://www.computer.org/csdl/proceedings-article/icebe/2011/4518a178/12OmNC4wtIB
- https://www.researchgate.net/publication/321835292_Flexible_circuits_and_material_for_largearea_UHF_RFID_reader_antenna_systems

Companies,

- Zebra Technologies
  https://www.zebra.com/gb/en/products/rfid.html?tactic_type=WBP&tactic_detail=Desc_AV_GL_None_Youtube
- Impinj
  https://www.impinj.com/partners/products/partner-fixed-readers
- Intrasys
  https://www.intrasys.com.sg/RFIDSolution/Retail/RFID-Warehouse-Inventory-Management-System

Some of the YouTube video links,

- https://www.youtube.com/watch?v=YAI-ggjYFlU
- https://www.youtube.com/watch?v=8IpYYkLebJ8
- https://www.mecalux.com/warehouse-manual/the-warehouse/tasks-and-functions(what is a warehouse)

Review Progress - June 2024

- Current Status:

The UHF RFID reader project is currently in the prototyping and testing phase. The design and layout of the PCB have been completed, and it has been fabricated and shipped and is now in the initial testing of the assembled prototype is underway.

- **Completed Tasks:**
- ➢ Schematic Design: Finalized the circuit schematics based on the ST25RU3993 manual.
- ➢ PCB Layout: Completed the design of a 6-layer PCB, incorporating impedance control, via stitching, shielding, and teardrops.
- ➢ Component Sourcing: Procured all necessary components and received the fabricated PCBs from JLCPCB.

- Antenna Design: Designed and simulated a Planar Inverted-F Antenna (PIFA) using advanced simulation tools to ensure optimal performance.

- **Challenges and Issues:**
- Design Complexity: Ensured proper impedance control and shielding for high-frequency signals, which required several iterations.
- Component Delays: Faced delays in receiving some components, impacting the assembly schedule. Alternative suppliers were identified to mitigate further delays.
- Antenna Tuning: Fine-tuning the PIFA design to achieve the desired performance parameters posed a challenge.

- **Solutions Implemented:**
- Impedance Control: Utilized simulation tools to optimize impedance matching and minimize signal loss.
- Alternate Suppliers: Sourced alternative suppliers to expedite component delivery.
- Antenna Optimization: Conducted iterative simulations and adjustments to optimize the PIFA design for improved performance.

- **Next Steps and Upcoming Tasks:**
- Complete Prototype Assembly: Finish assembling the remaining components on the PCB.
- Comprehensive Testing: Conduct thorough testing of the assembled prototype, focusing on RFID reading.
- Documentation Updates: Update the project documentation to reflect changes and progress made.
- Final Antenna Testing: Validate the performance of the PIFA in real-world conditions and make necessary adjustments.

- **Timeline and Schedule:**
- Current Timeline: The project is slightly behind schedule due to component delays but is on track with the adjusted timeline.
- Revised Schedule: Outline any adjustments made to the project schedule and how these will impact the overall timeline.

- **Quality and Compliance:**
- Quality Checks: Document results from initial quality checks and any issues identified during testing.
- Compliance: Ensure the design adheres to relevant industry standards and regulatory requirements.

2 Stakeholder Mapping

2.1 Introduction

This document outlines the development of an Ultra-High Frequency (UHF) RFID reader designed for warehouse management systems. The reader is engineered for seamless integration onto warehouse portals, facilitating the efficient tracking and management of inventory as it moves through the supply chain. This project aims to leverage advanced RFID technology to enhance operational efficiency, reduce manual scanning errors, and provide real-time inventory updates.

2.2 Market Analysis

The logistics and warehousing sectors are increasingly seeking automated solutions to streamline inventory management, reduce losses, and improve overall efficiency. Our RFID reader addresses these needs by offering a robust, reliable, and scalable solution that can significantly reduce manual intervention and errors in inventory tracking.

2.3 Existing Product Analysis

A thorough examination of existing RFID readers reveals a market characterized by a mix of high-cost, high-performance readers and more affordable but less capable options. Many existing solutions lack the range, durability, or ease of integration required for optimal warehouse management. Our design seeks to bridge this gap by offering a high-performance reader at a competitive price point.

In evaluating the competitive landscape, we've analyzed several leading RFID readers in the market, such as the Zebra FX9600 and the Impinj Speedway Revolution R420. These devices represent the upper echelon of current RFID technology in warehouse management but also come with certain limitations that our design seeks to address.

- **Zebra FX9600**: The Zebra FX9600 is known for its high read performance and durability, making it a popular choice in industrial settings. However, its high cost and complexity in integration with existing systems pose challenges for smaller operations or those with budget constraints. Our RFID reader aims to offer comparable or superior performance at a more accessible price point, with streamlined integration features.

- **Impinj Speedway Revolution R420**: The Impinj R420 is celebrated for its advanced features, such as support for multiple antenna configurations and low power consumption. Despite these advantages, users report difficulties in customization and a steep learning curve for optimal deployment. In contrast, our RFID reader is designed with user-friendly configuration tools and flexible deployment options to accommodate a wide range of warehouse environments without extensive setup time.

- **Alien ALR-F800**: The Alien ALR-F800 is another competitor, offering a versatile solution with a self-optimizing enterprise feature set. While it boasts impressive read rates and ease of deployment, its adaptability in complex RF environments and high-density tag scenarios is sometimes questioned. Our design incorporates advanced signal processing and environmental tuning capabilities to ensure reliable performance even in the most challenging conditions.

By addressing these gaps and leveraging the latest advancements in RFID technology, our UHF RFID reader is positioned to offer a compelling alternative in the warehouse management market. It combines high performance, ease of use, and cost-effectiveness, making it an attractive solution for a broad range of inventory tracking applications.

2.4 User Profile

The primary users of our RFID reader will be warehouse personnel, including forklift operators and inventory managers. They require a user-friendly, durable device that can withstand the rigors of a warehouse environment while seamlessly integrating with existing Warehouse Management Systems (WMS).

2.5 Specifications

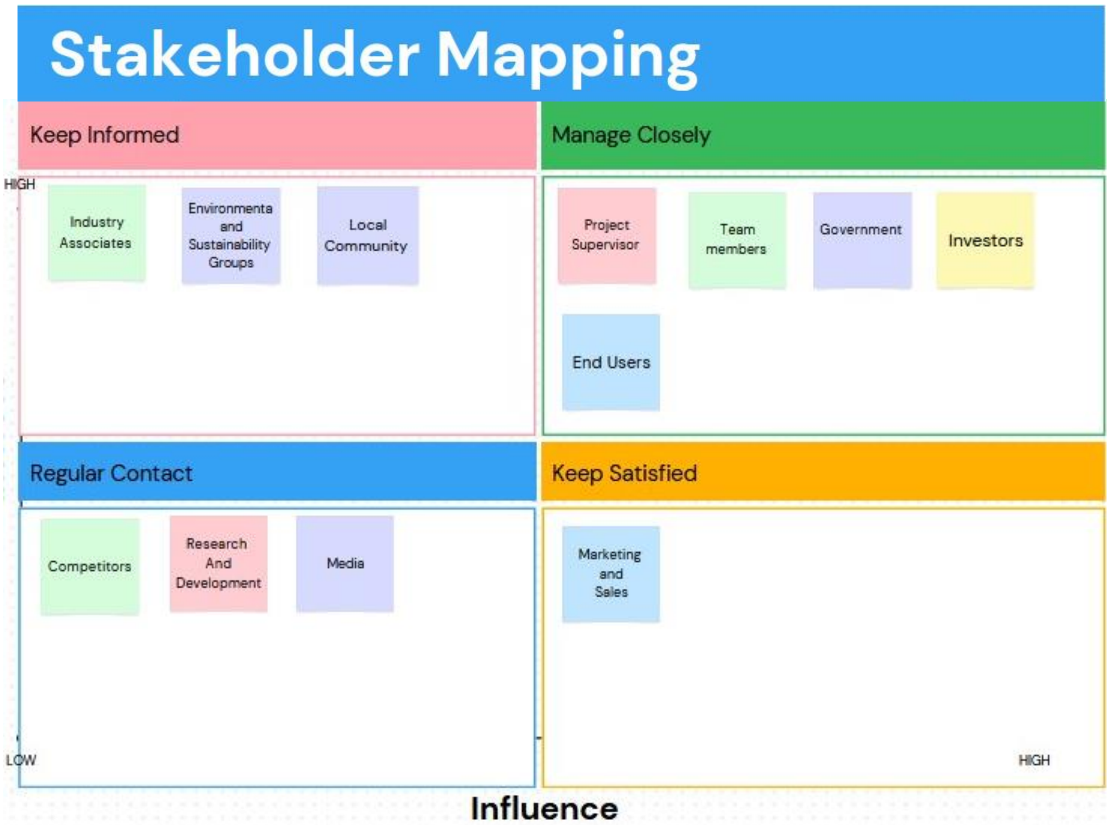
The RFID reader is designed to operate within the UHF spectrum, offering a read range of at least 2 meters. The device also features seamless data transfer and indicators for clear identification of tag reading.

2.6 Stakeholders

While researching on the topic of RFID Readers for Warehouse Management Systems (WMS) we identified a wide variety of stakeholders.

1. Project Team Members
2. Project Supervisor
3. End-Users/ Customers
4. Regulatory Bodies (Government)
5. Industry Associations (Large Warehouse owners/owning companies)
6. Financial Stakeholders
7. Marketing and Sales
9. Community
10. Competitors (Competing companies in the same industry)
11. Research and Development
12. Media

As their level of influence and interest may fluctuate during the project, it is imperative to continuously communicate with stakeholders to maintain the correctness of their categorization. User observation data plays a crucial role in this scenario.



3 User observation

Below is the process we went through to observe our users.

1) **Before Implementation:**

   a) **Observe current process:**

      (i) How do staff currently bring in and out goods? Manually scan barcodes and use paperwork?

      (ii) What challenges do they face in the current process (e.g., scanning errors, slowness, data accuracy)?

      (iii) How long does it typically take to process incoming/outgoing goods?

2) **During Observation:**

   a) **Ease of use:**

      i) Can staff easily carry items through the gate without triggering false reads?

      ii) Do they understand how to position items for optimal tag reading?

      iii) How quickly do they adapt to using the new system?

      iv) Are there any physical limitations (e.g., gate size, tag placement) that hinder workflow?

   b) **System responsiveness:**

      i) How quickly does the system register and update after reading tags?

      ii) Are there any delays or error messages that impede the process?

      iii) Does the system handle multiple items passing through simultaneously effectively?

   c) **User feedback:**

      i) Ask staff directly for their opinions on the system's ease of use, efficiency, and impact on their workload.

      ii) Do they have any suggestions for improvement or concerns about the system?

After our observation here is what we identified that the users expect and are concerned about.

1. Government Entities

- Concerned with regulatory compliance and security in cargo transportation and interested in technologies that enhance border control and monitoring.

2. Logistics Companies

- Prioritize efficient and timely cargo movement.

3. Warehousing Companies

- Focus on optimizing warehouse space and improving inventory accuracy and interested in technologies that enhance inventory visibility and management.

4. RFID Technology module manufacturers

- Invested in the adoption and success of RFID solutions.
- Interested in market feedback to improve and innovate their products.

5. Manufacturers

- Emphasize supply chain efficiency and timely delivery.

6. Financial Institutions

- Primarily concerned with financial viability and returns on investment.
- Less interest in the technical aspects of the RFID system.

7. IT and Software Developers

- Concentrate on creating and improving software solutions and interested in technical specifications, compatibility, and integration possibilities.

8. Customers and End-Users

- Primarily concerned with the efficiency of cargo services and timely deliveries and less involved in the technical aspects of the inventory management system.

9. Supply Chain Partners

- Interested in smooth collaboration within the supply chain.
- Focus more on their specific role in the supply chain than the overall technical details of the RFID system.

4 User Needs

Users' needs can be categorized based on what type of a need it is.

4.1 Functional Needs

- RFID Tag Reading

Must reliably read RFID tags within a range of at least 2 meters. Should accurately identify and log the tags even in environments with potential RF interference.

- Antenna Designing for transmission and reception

The antenna must operate within the Ultra-High Frequency (UHF) band, specifically at the center frequency of 915 MHz, to ensure compatibility with standard RFID tags.

4.2 Performance Needs

1) **RFID Tag Reading**
   - i) **Read Accuracy:**
     - (a) High accuracy in reading multiple tags simultaneously.
     - (b) Minimization of read errors and false positives.
   - ii) Speed:
     - (a) Fast processing of RFID data to ensure real-time updates without

4.3 User Specific Needs

1) **User Interface:**
   - a) Easy-to-use interface for warehouse personnel, including visual indicators for successful scans.
   - b) Touchscreen interface for advanced models to allow manual control and monitoring.
2) **Durability:**
   - a) Robust design capable of withstanding harsh warehouse environments, like dust and moisture.
   - b) Durable housing to protect the internal components from physical damage.

4.4 Operational Needs

1) **Power Management:**
   - a) Efficient power usage to ensure long operational periods without frequent recharging or battery replacements.
2) **Maintenance:**
   - a) Ease of maintenance, with easily accessible components for repair or replacement.
   - b) Availability of troubleshooting guides and support for quick issue resolution.

4.5 Scalability Needs

1) **Expandability:**
    a) Capability to scale the system to accommodate additional readers or integration points as the warehouse operations expand.
2) **Futureproofing:**
    a) Design considerations for future technological advancements and compatibility with upcoming RFID standards.

5 Idea Stimulation

Our initial plan was to develop a RFID Portal reader/ Gate Systems (in which the reader and the antenna will be developed). After capturing data from RFID tags using readers in a warehouse management system, the captured information undergoes a series of processes to ensure effective inventory management. Firstly, the system processes the received data. This processed data is then integrated into the warehouse management database, where it is stored alongside existing inventory records. The database facilitates real-time tracking of inventory levels and movements, enabling accurate and up-to-date visibility into warehouse operations. Utilizing this data, the system can automate various tasks such as inventory replenishment, order picking, and shipping, optimizing warehouse workflows and minimizing human error. Furthermore, the stored RFID data serves as a valuable resource for generating reports, analyzing trends, and making data-driven decisions to improve overall warehouse efficiency and productivity.

To generate innovative concepts for our UHF RFID reader, we employed several creative strategies. We held regular brainstorming sessions where team members freely discussed ideas and solutions. We analyzed existing RFID readers and kept up with technological trends to identify opportunities for innovation. We had to do extensive research on the different ICs used for RFID Readers and other RFID applications. Additionally, we compared different antenna types to choose which is most suitable for our application. We looked into instances in which these antennas are used. These strategies helped us develop a range of innovative ideas to enhance the functionality and usability of our RFID reader for the project.

6 Concept development

6.1 Conceptual designs and block diagrams

6.1.1 Conceptual Design 1 – Basic RFID Reader

The Basic RFID Gate Reader is engineered for simplicity and efficiency, focusing on the core function of scanning RFID tags on crates as they pass through gates. It integrates a high-gain antenna for broad coverage and effective tag detection, coupled with a streamlined signal processing system for fast and accurate data interpretation. The design emphasizes durability and ease of installation on various gate types, making it ideal for environments that require robust and straightforward solutions for inventory tracking. Real-time updates to the inventory system and clear scan indicators further enhance its utility, ensuring seamless operational integration.

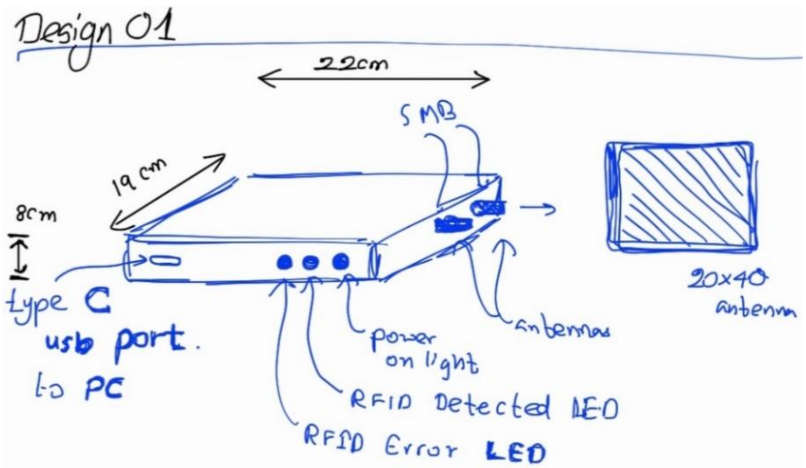


Figure 1: Conceptual Design 1 1

6.1.2 Functional Block Diagram 1

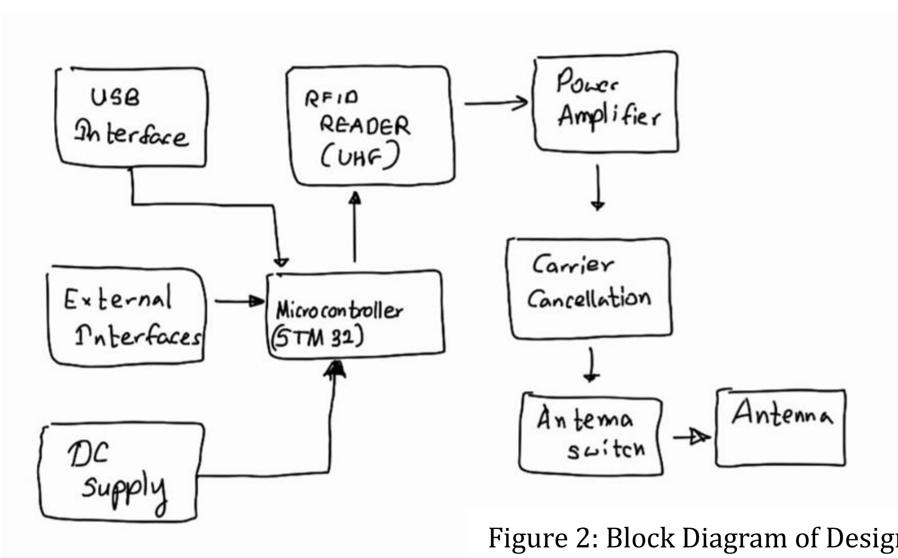


Figure 2: Block Diagram of Design 1

6.1.3 Conceptual Design 2 – Smart RFID Reader with Data Logging

This design advances RFID technology by incorporating automated data collection with each scan, including detailed logging of timestamps, gate IDs, and forklift IDs. It's designed with connectivity at its core, offering Wi-Fi or Ethernet options for seamless data integration. The Smart RFID Reader is compact and sleek, making it suitable for environments where space is at premium and data analytics are crucial for operational efficiency. Its focus on data logging and connectivity makes it a powerful tool for detailed inventory management and analysis.

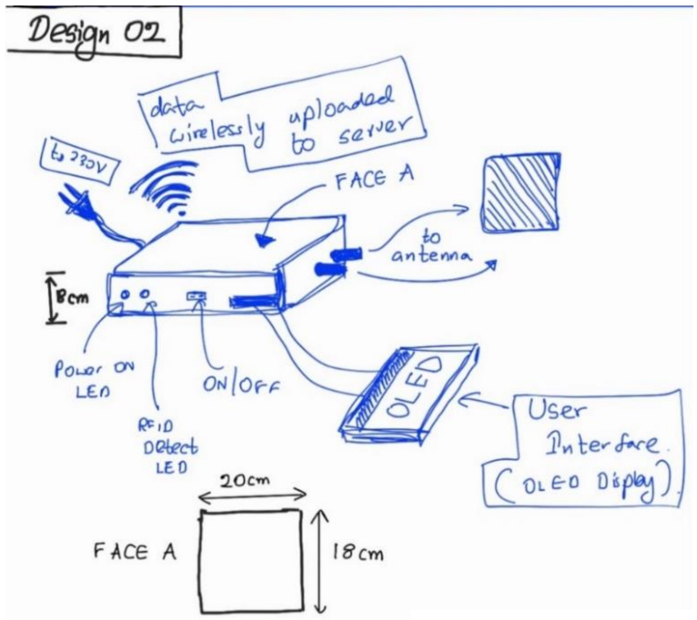


Figure 3: Conceptual Design 2

6.1.4 Functional Block Diagram 2

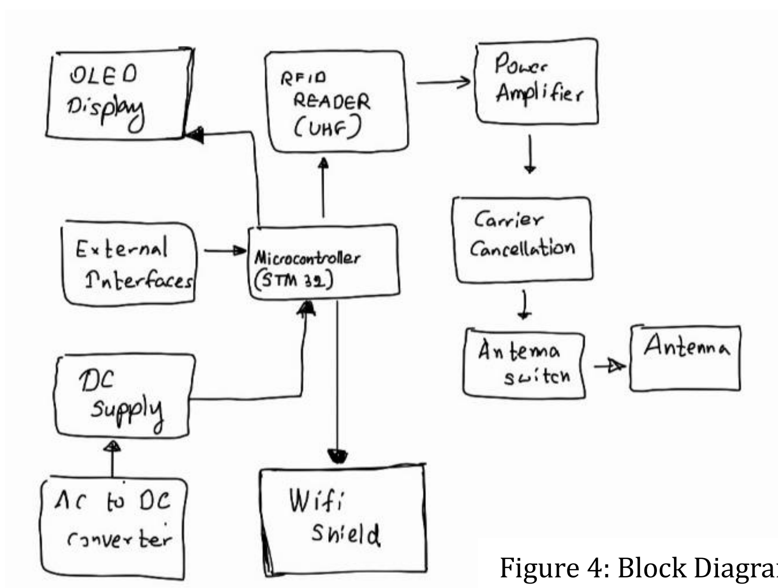


Figure 4: Block Diagram of Design 2

6.1.5 Conceptual Design 3 - RFID Reader with Enhanced User Interface

The third conceptual design prioritizes user interaction through an intuitive touchscreen interface, allowing for manual control and real-time monitoring of RFID scans. It features user authentication for secure access, ensuring that system adjustments and data monitoring are restricted to authorized personnel. This design is characterized by its user-friendly and ergonomic approach, catering to environments where user interaction and system control flexibility are key requirements.

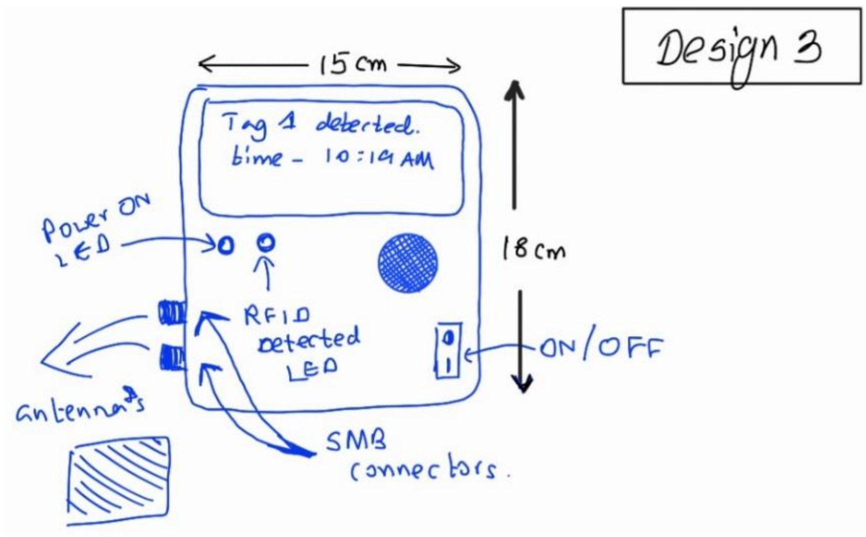


Figure 5: Conceptual Design 3

6.1.6 Functional Block Diagram 3

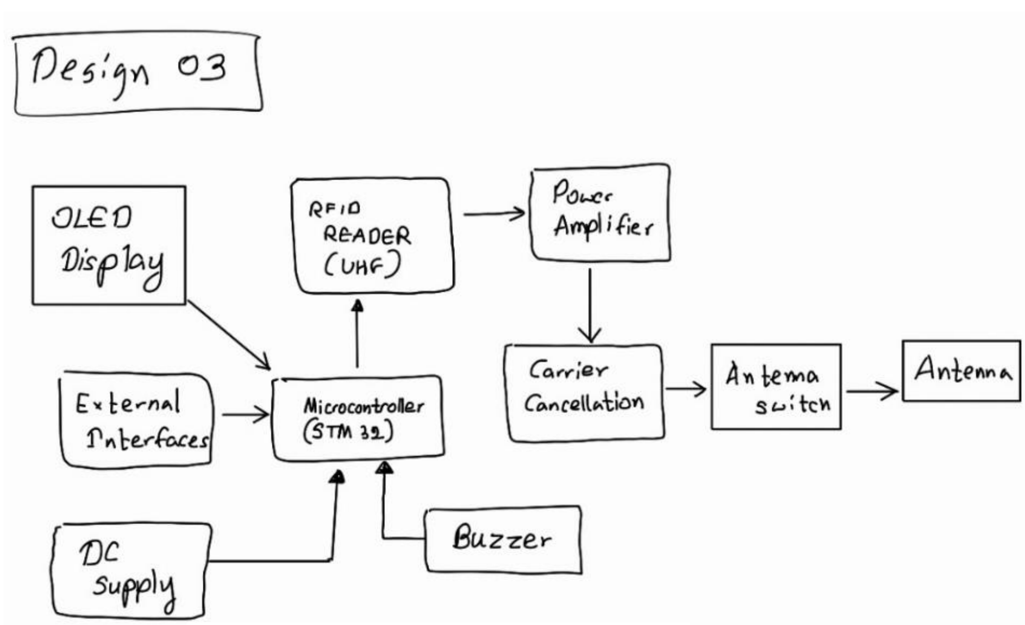


Figure 6: Block Diagram of Design 3

6.2 Evaluation of Conceptual Design

Comparison of designs

		Conceptualdesign 1: Basic RFID Gate Reader	Conceptual design 2: Smart RFID Reader with Data Logging	Conceptualdesign 3: RFID Reader with Enhanced User Interface
Newly added features		Real-time inventory updates. Visual scan indicators.	Data logging for scans with timestamps, gate ID, forklift ID. Wi-Fi or Ethernet connectivity.	Touchscreen interface for monitoring and manual gate control, User authentication for secure access.
Removed features		High-end data processing External display and extensive controls.	External display and extensive controls.	Audio and Visual Indicators. Wi-Fi or Ethernet connectivity.
Enclosure design criteria comparison	Functionality	6	8	9
	Aesthetics	8	8	8
	Heat dissipation	6	9	8
	Assembly and serviceability	9	6	7
	Ergonomics	8	8	8
	Simplicity	9	7	8
	Durability	9	8	6
Functional block design criteria comparison	Functionality	9	7	8
	User experience	6	8	9
	Manufacturing feasibility	10	8	8

	Cost	6	9	7
	Performance	7	8	7
	Future proo1ng	5	9	7
	Power	9	6	6
Total		108	107	98

Decision Rationale

Among the three conceptual designs, the first was chosen for its simplicity and ease of construction. The Basic RFID Gate Reader stands out for its straightforward approach to RFID technology, focusing on essential functionalities without the complexities of advanced data logging or user interfaces. This simplicity not only makes it more cost-effective and quicker to develop but also ensures reliability and ease of maintenance. Its design aligns well with operational needs that prioritize efficient tag scanning and real-time inventory updates, without the overhead of additional features that might complicate the system or its deployment. This choice underscores a preference for practicality and effectiveness, particularly in settings where the primary goal is the seamless tracking of goods through RFID technology.

7 Schematic Design

7.1 System Overview – The A4 size Schematics and PCB is at the end of the document

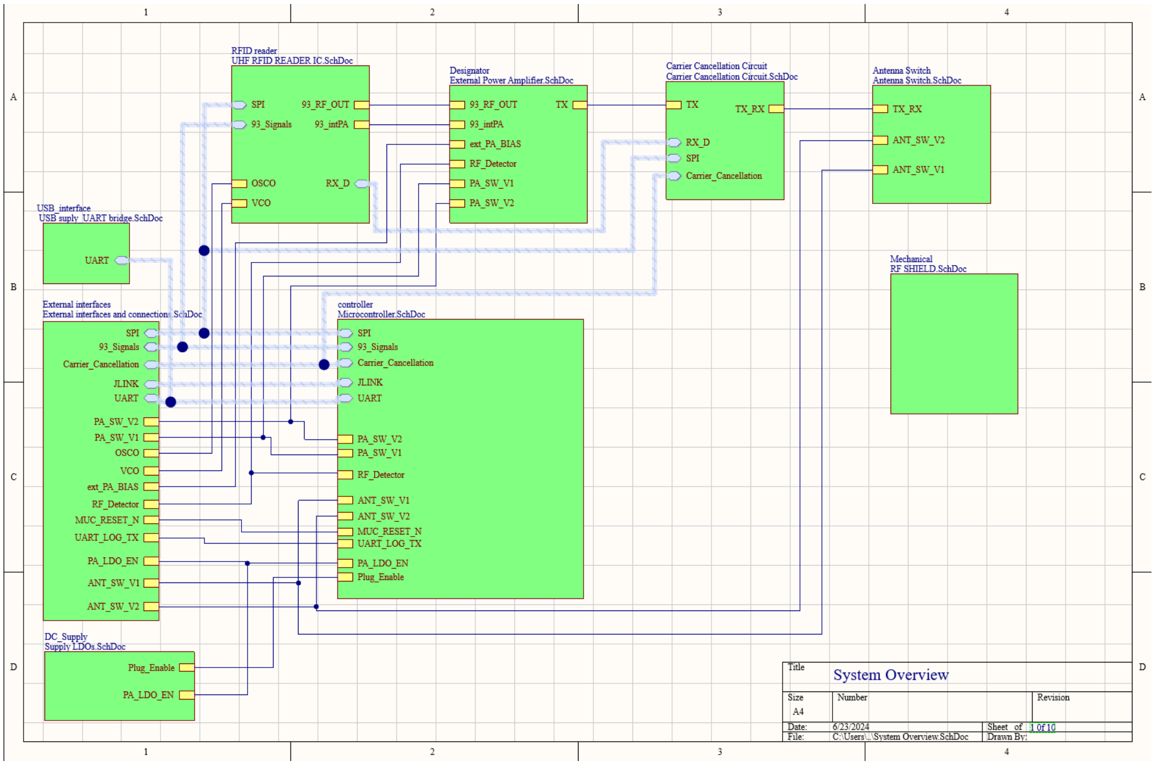


Figure 7: System Overview

7.2 UHF RFID Reader IC

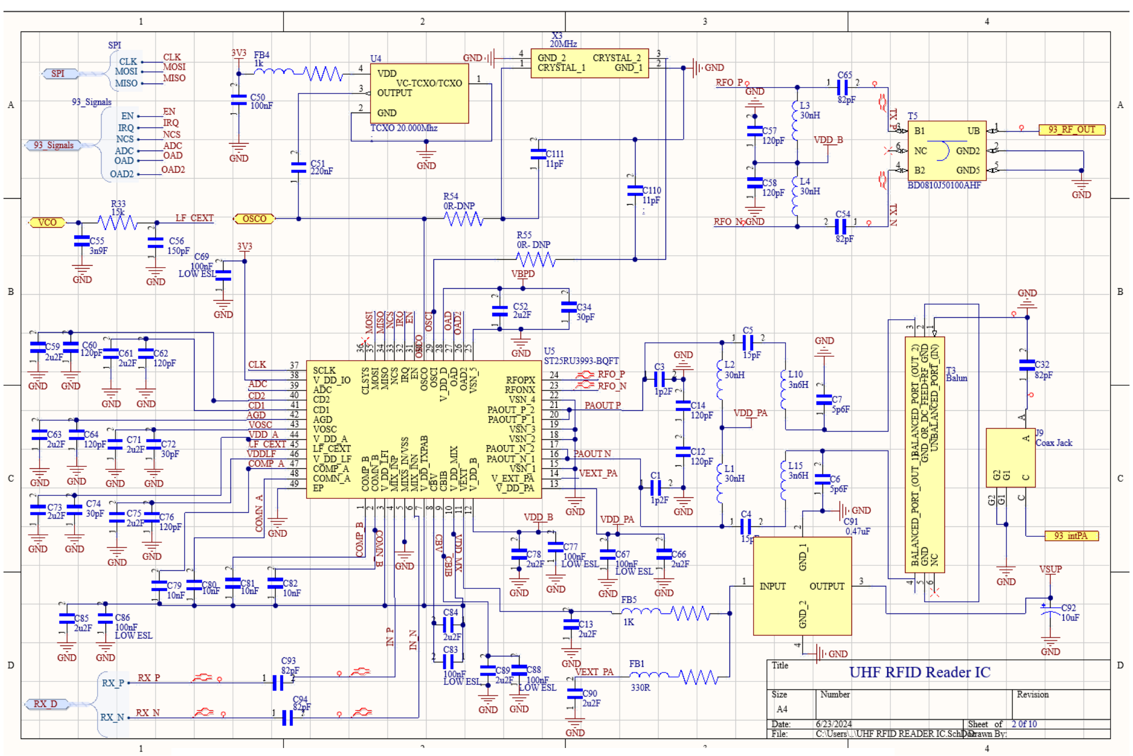


Figure 8: Schematic of UHF RFID Reader IC Circuit

7.3 External Power Amplifier

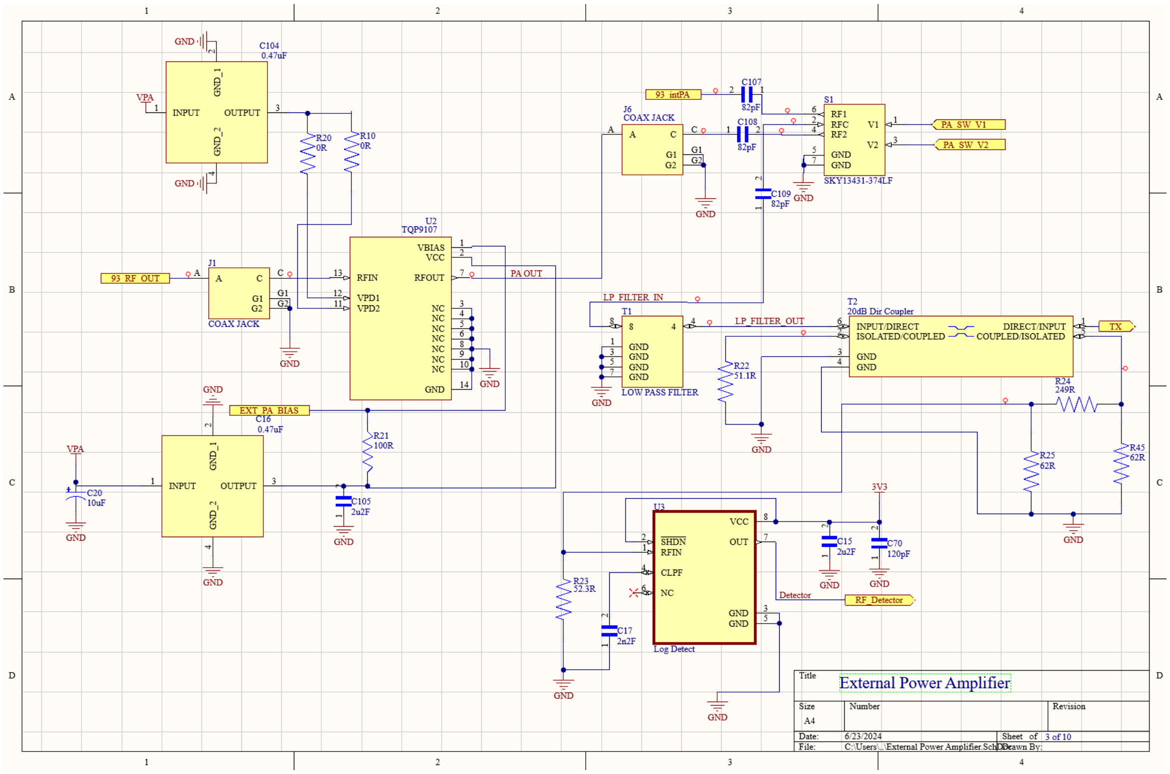


Figure 9: Schematic of External Power Amplifier

7.4 Carrier Cancellation

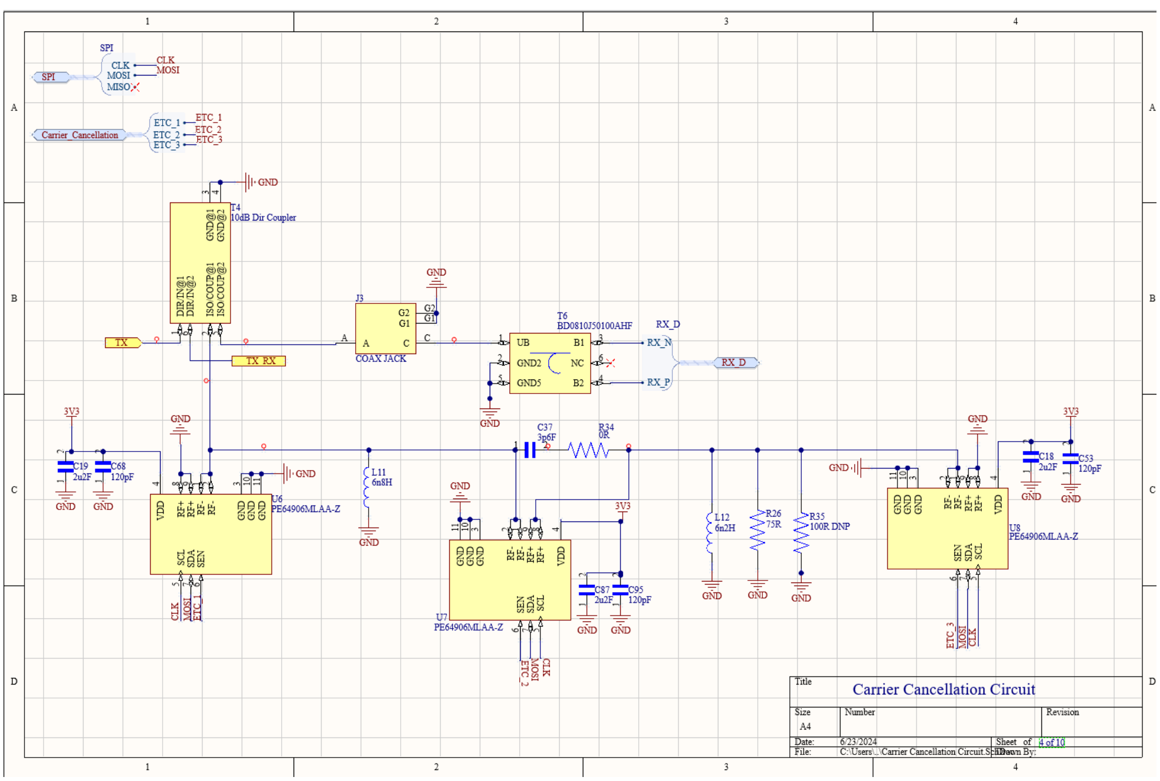


Figure 10: Schematic of Carrier Cancellation

7.5 Antenna Switch

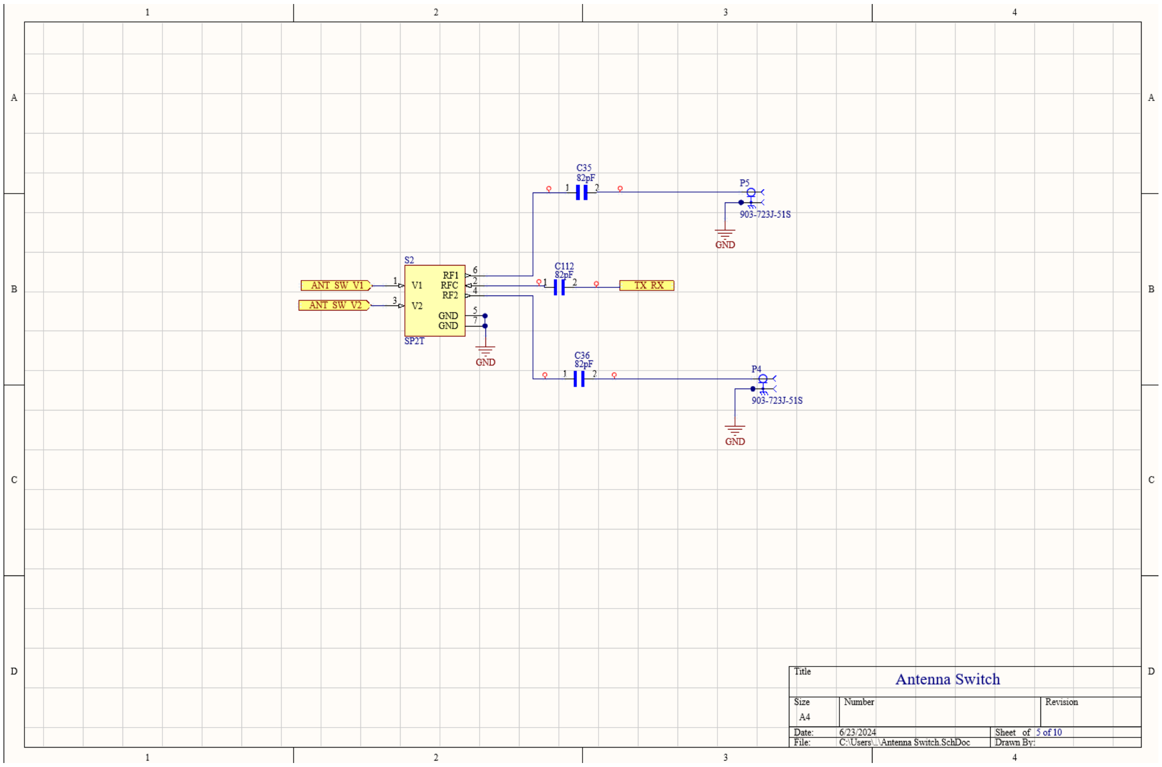


Figure 11: Schematic of Antenna Switch

7.6 RF Shield

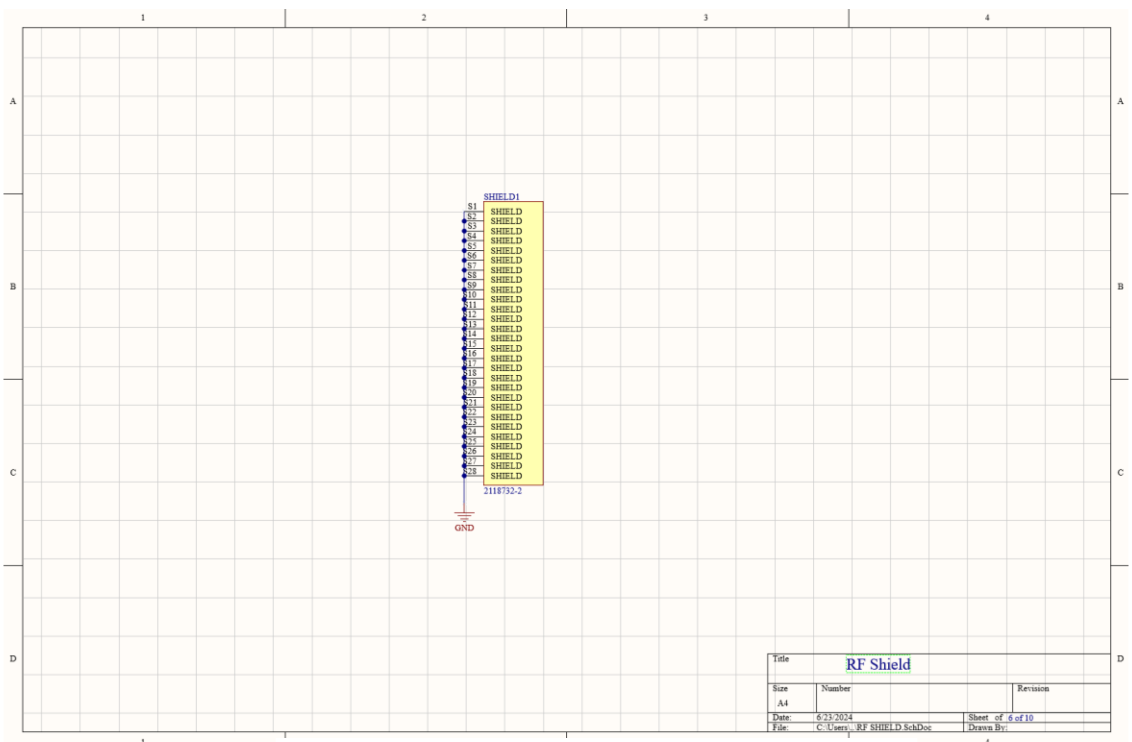


Figure 12: Schematic of RF Sheild

7.7 USB Supply/UART Bridge

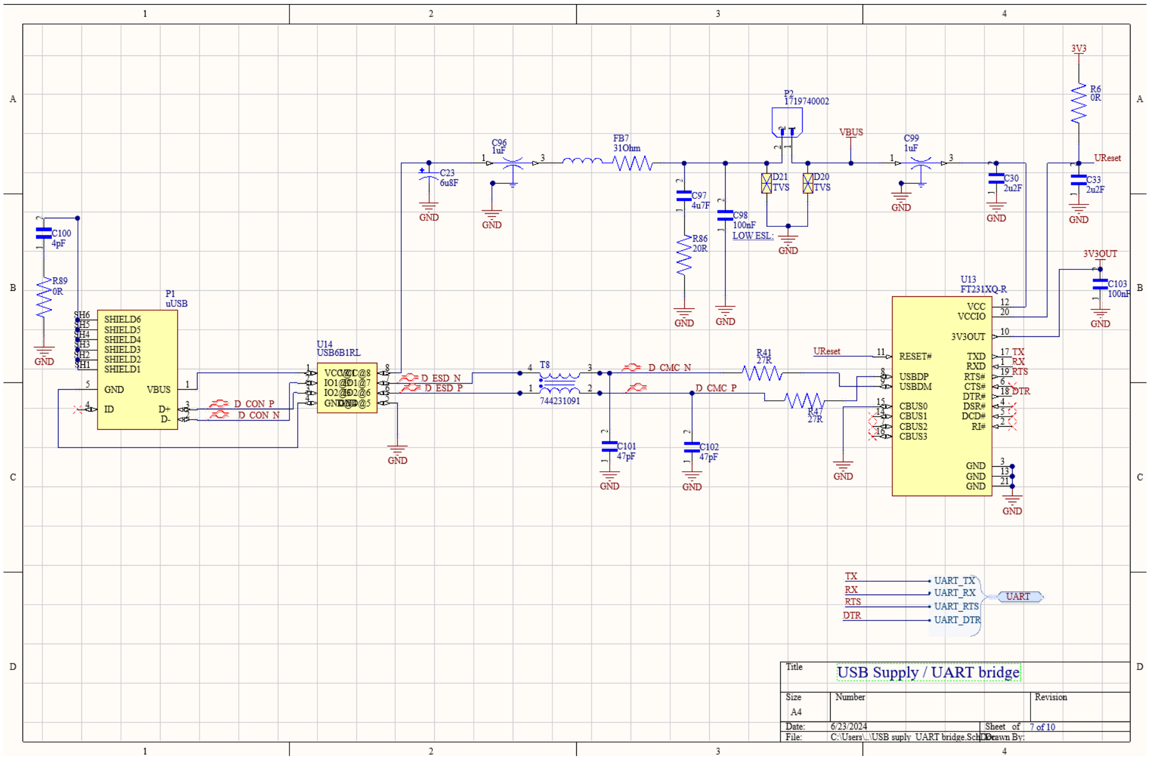


Figure 13: Schematic of USB Supply

7.8 Microcontroller IC

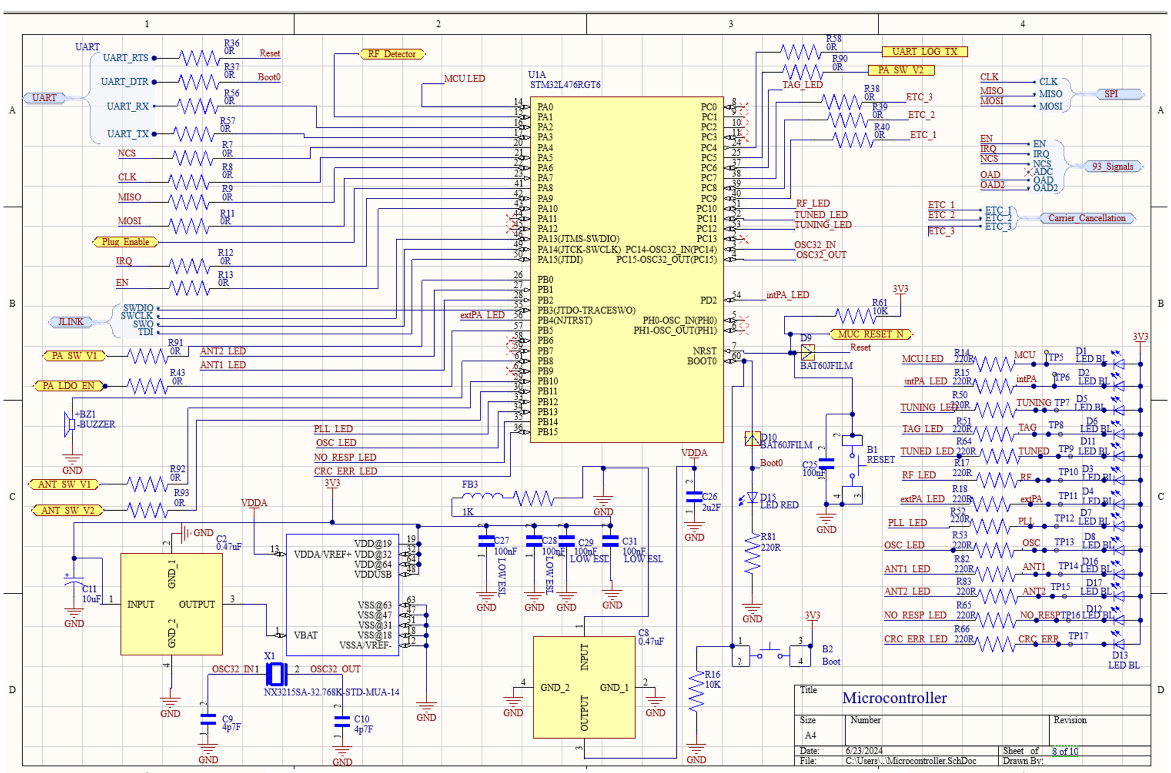


Figure 14: Schematic of Microcontroller

7.9 Supply LDOs

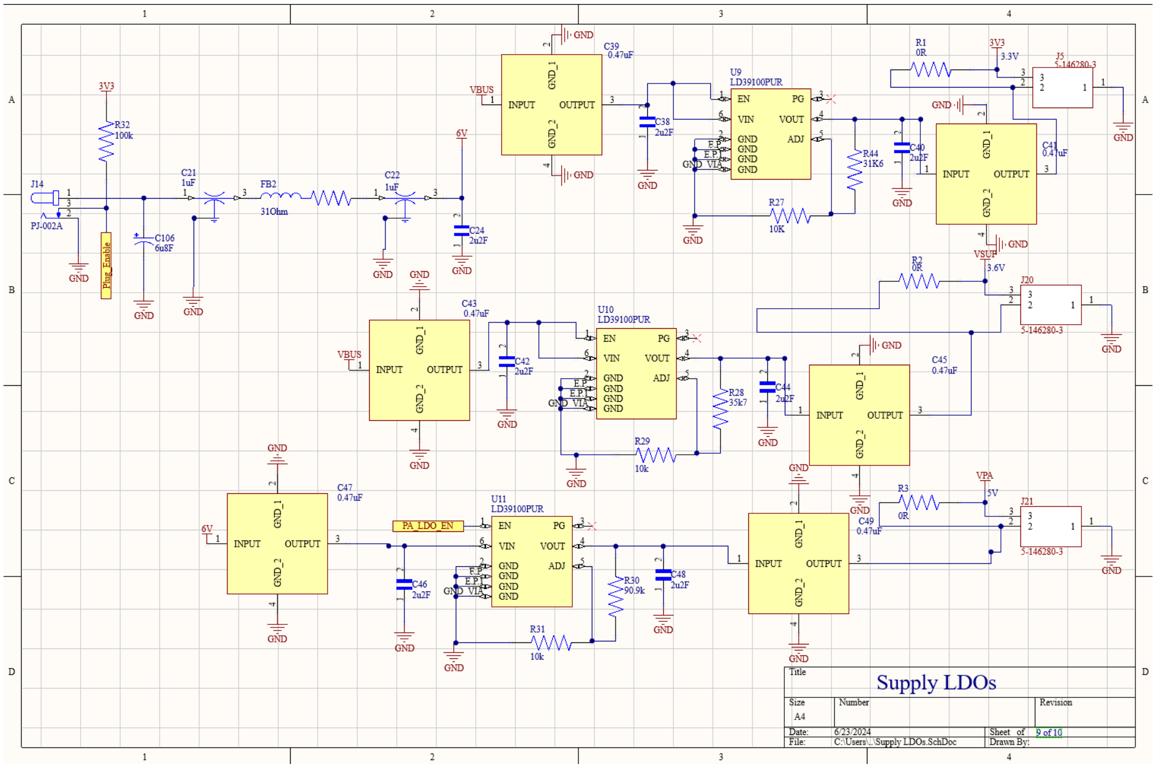


Figure 15: Schematic of Supply LDOs

7.10 External Interfaces

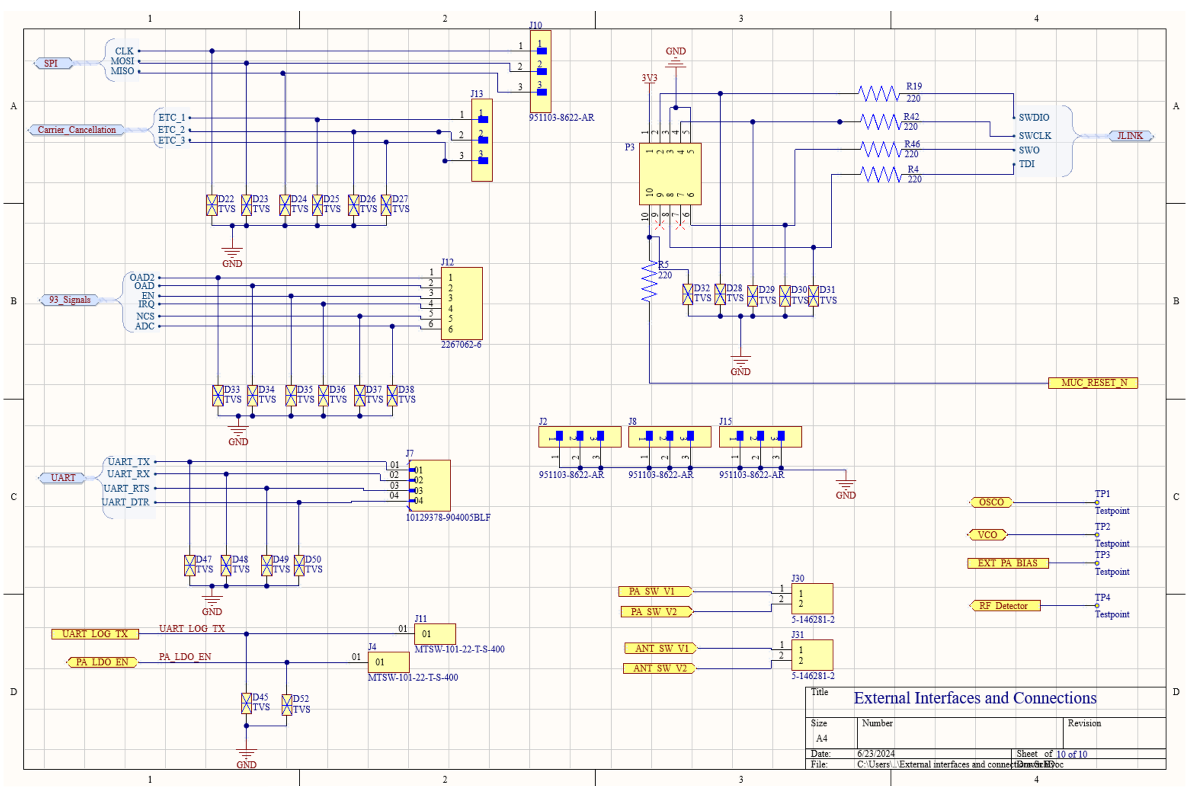


Figure 16: Schematic of External Interfaces

8 PCB Design

8.1 Main circuit

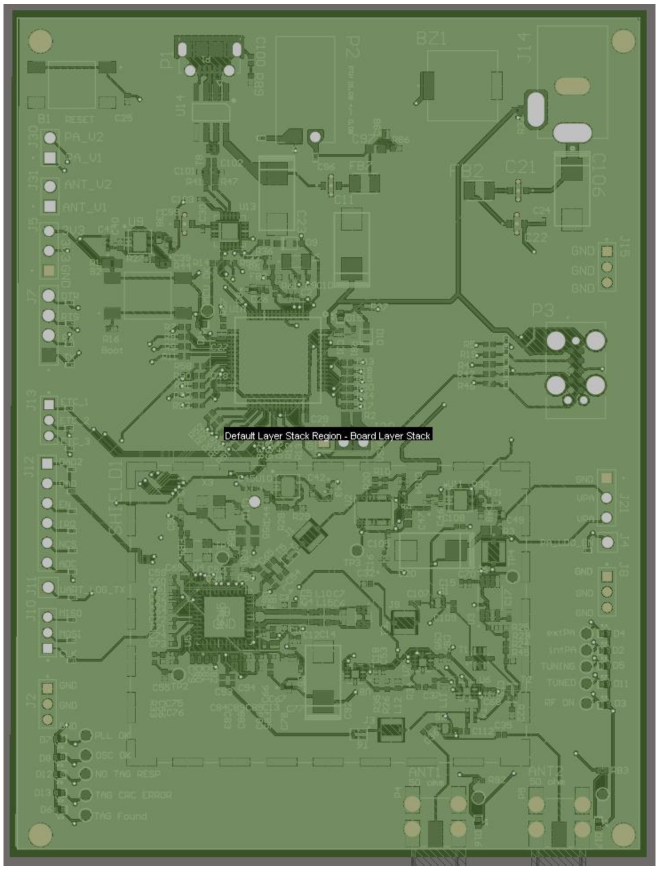


Figure 17: Board Planning View

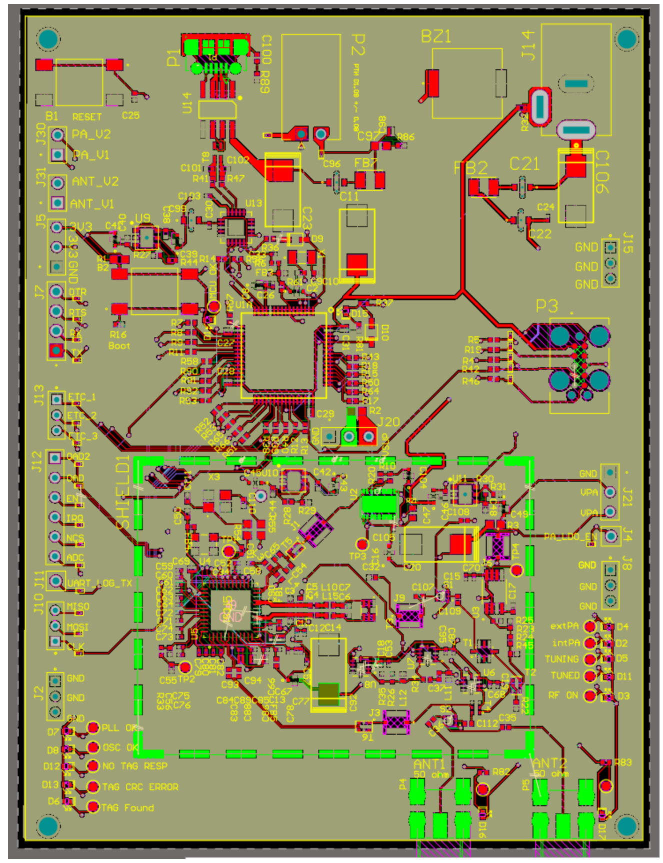


Figure 18: 2D View

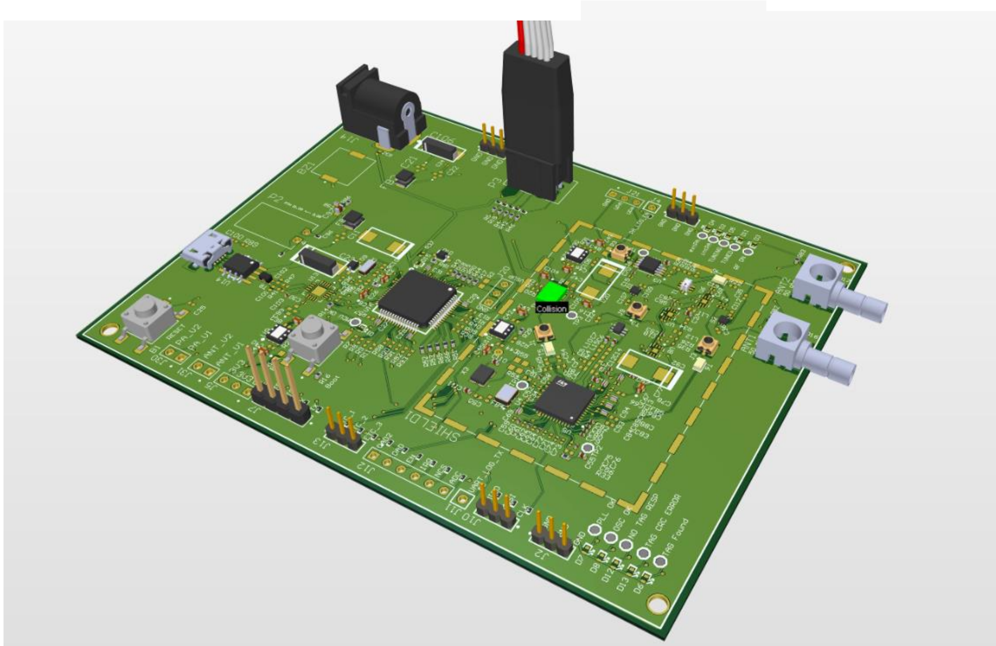


Figure 20: 3D Isometric View

- **Top Layer**:
  - All components and almost all interconnections are located on the top layer (Figure 22).
  - Impedance-controlled RF traces (single-ended 50 Ω CBCPW and differential 100 Ω traces) are situated here.
  - Direct connection of all component ground terminals to the surrounding GND plane without thermal relief connections ensures optimal grounding.

- **RF Ground Layer**:
  - Positioned directly below the top layer to support the 50 Ω and 100 Ω waveguide traces.
  - The solid and uninterrupted nature of this layer is critical for providing a direct path for RF return currents, ensuring efficient signal transmission.

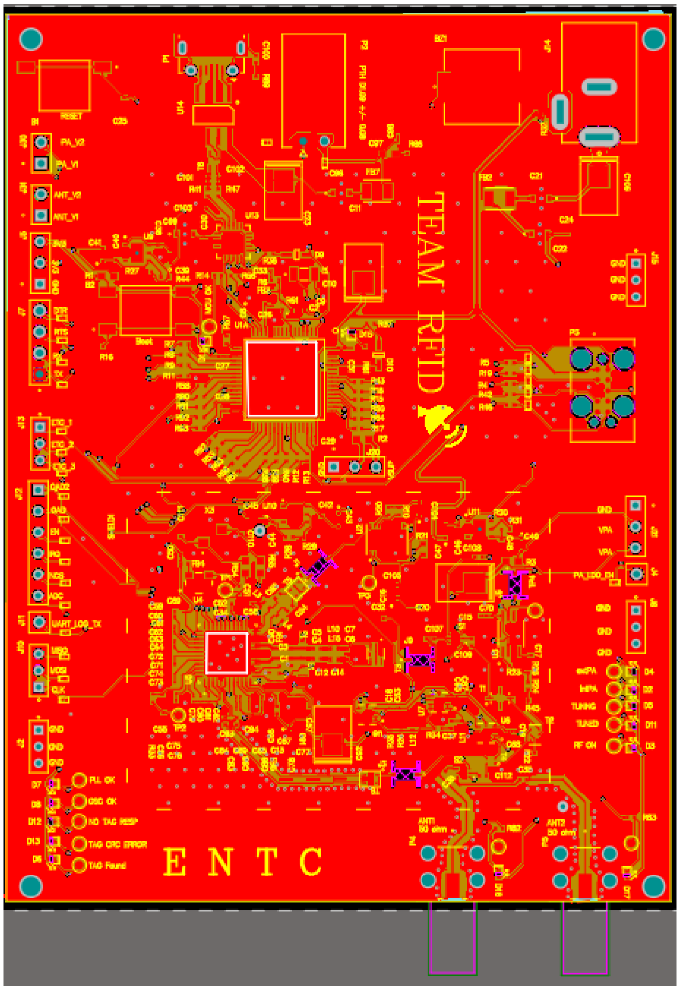


Fig: Top Layer

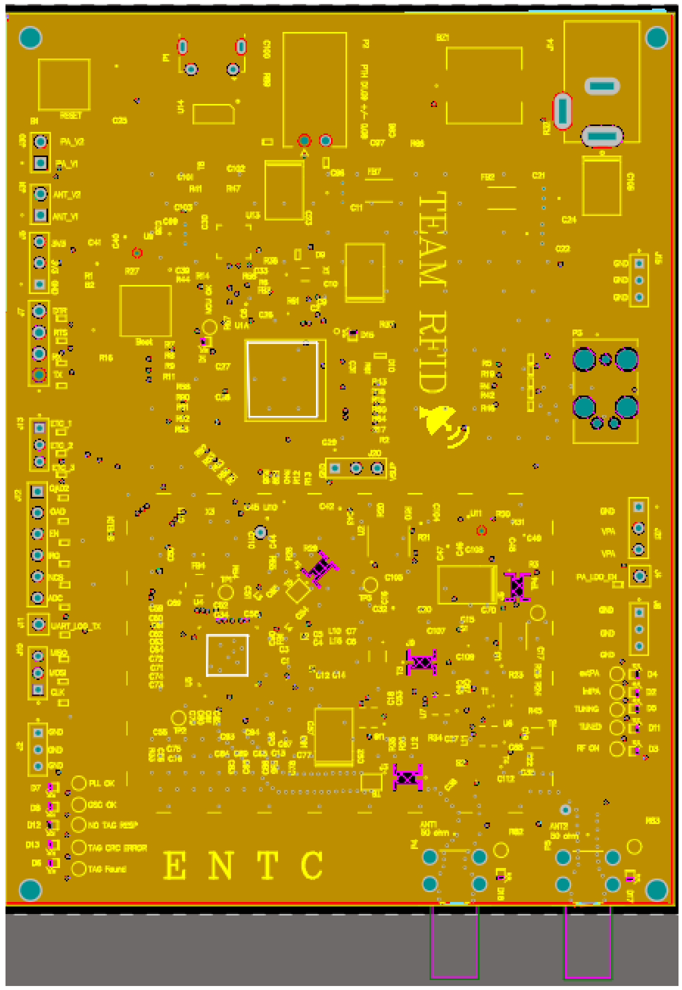


Fig: RF Ground Layer

- **Power Layer**:
    - Utilized primarily for distributing supply voltages through power planes, with minimal traces to avoid interference.

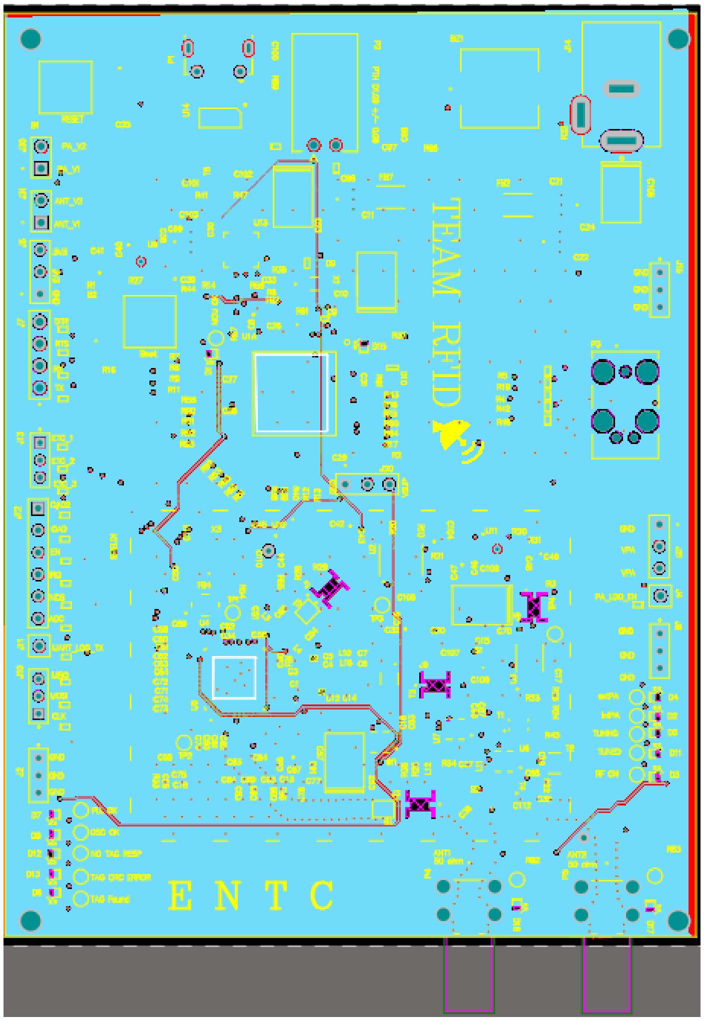


Fig: Power Layer

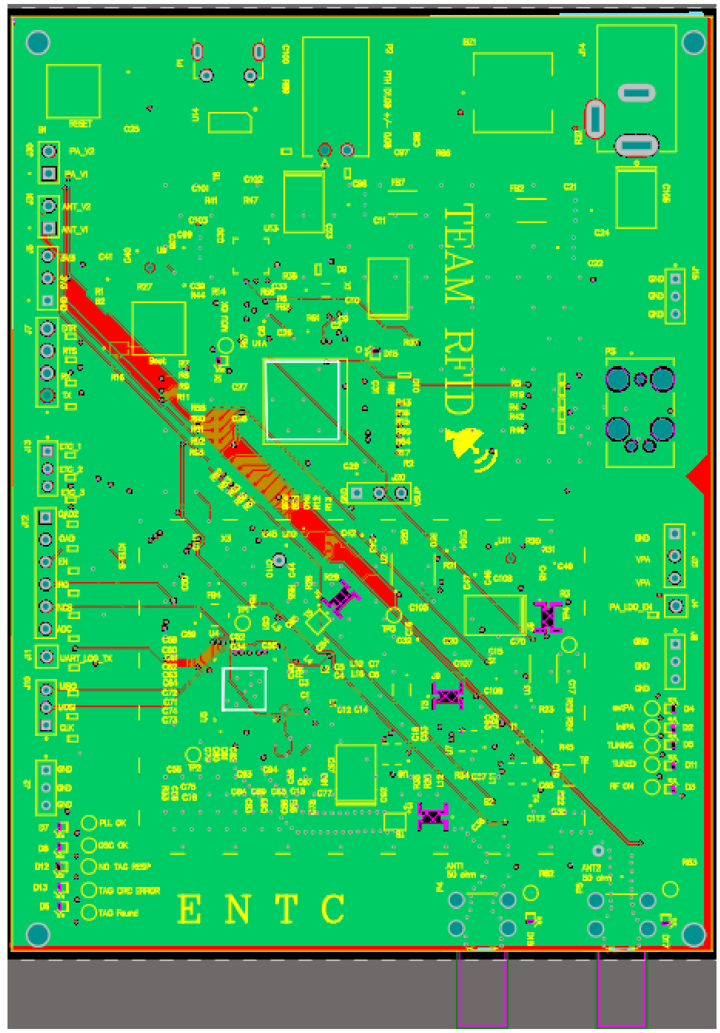


Fig: Power Ground Layer

- **Routing Layer**:
    - Dedicated to interconnecting components while minimizing cross-talk effects on RF traces.

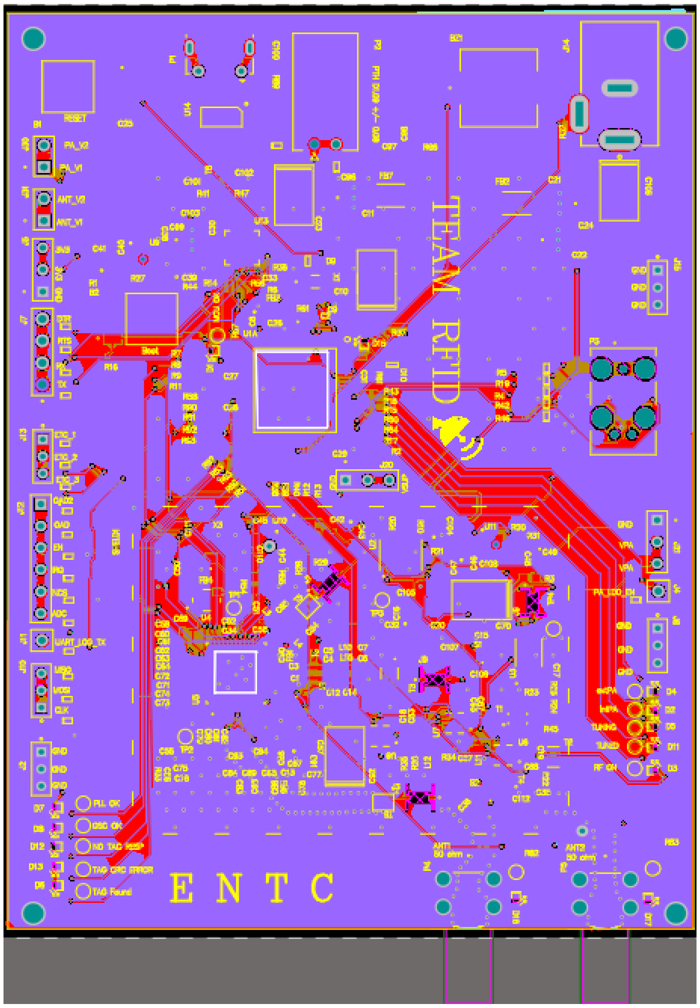


Fig: Routing Layer

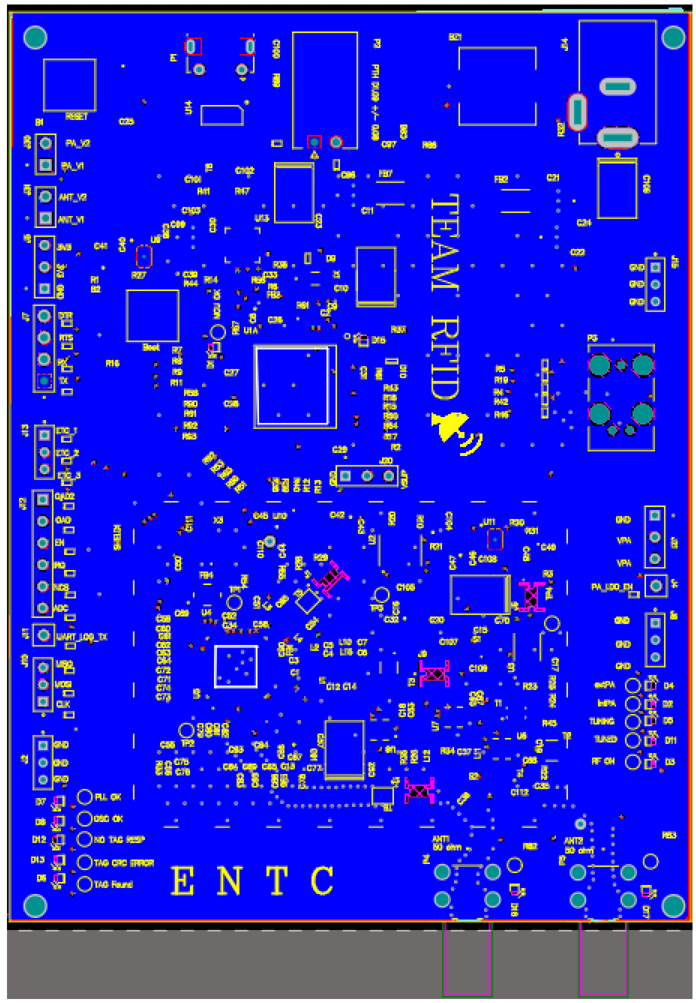
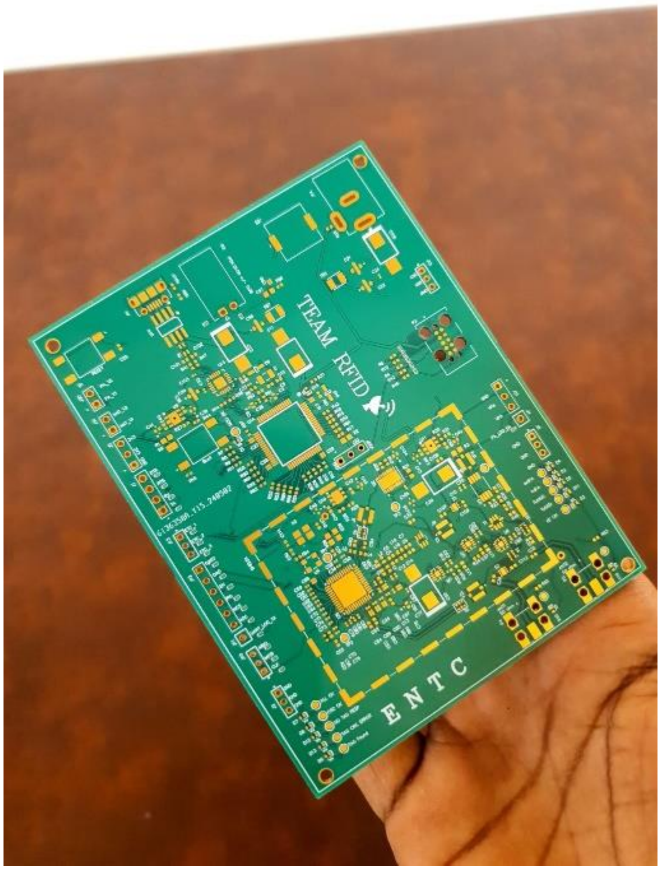
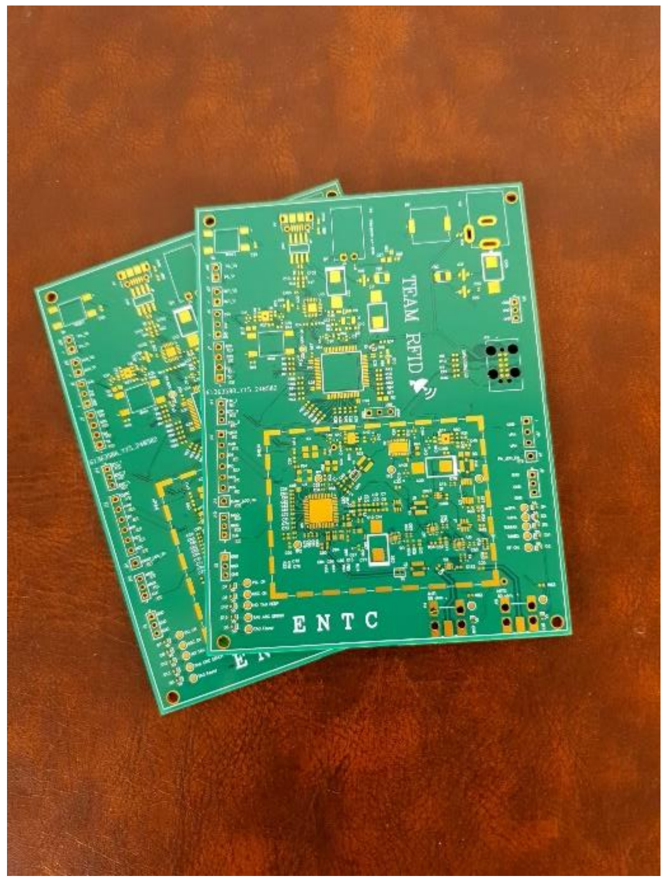


Fig: Bottom Ground Layer

- **Material**: FR4
- **Thickness**: 1.6mm
- **Surface Finish**: ENIG (Electroless Nickel Immersion Gold)
- **Copper Weight**: 1 oz for outer layers, 0.5 oz for inner layers

Bare PCB





9 SolidWorks Design Antenna Design

9.1 Enclosure Design

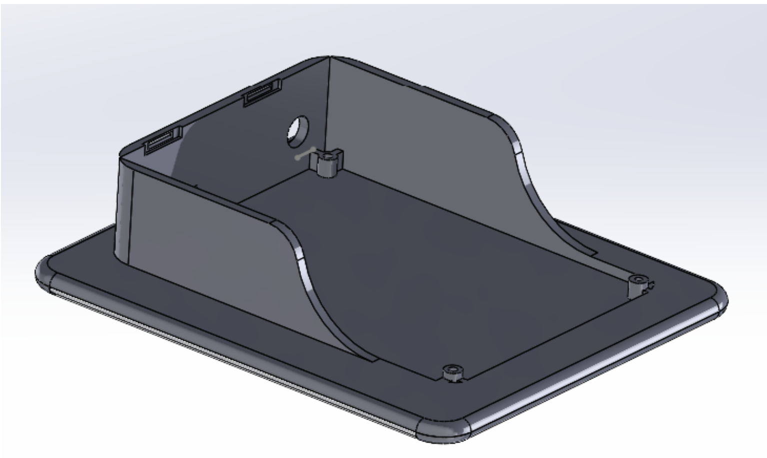


Figure 21: Enclosure

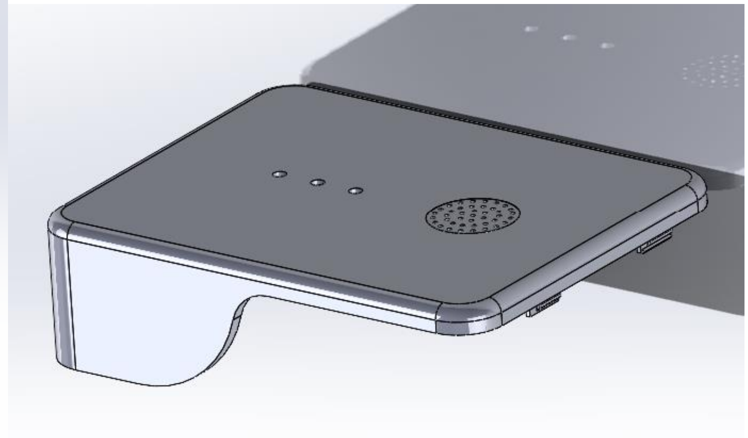


Figure 22: Lid

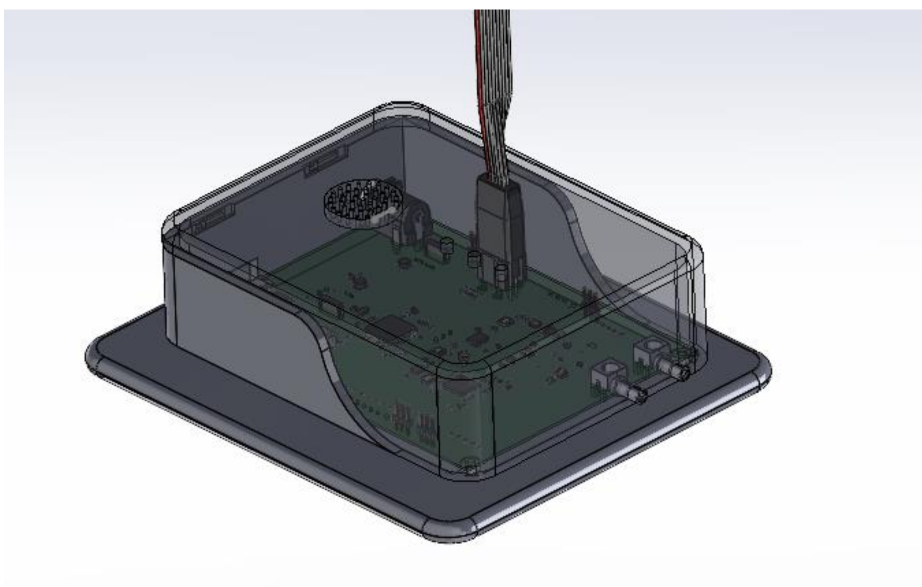


Figure 23: Assembly

9.2 PIFA Antenna Design

Schematic Diagram

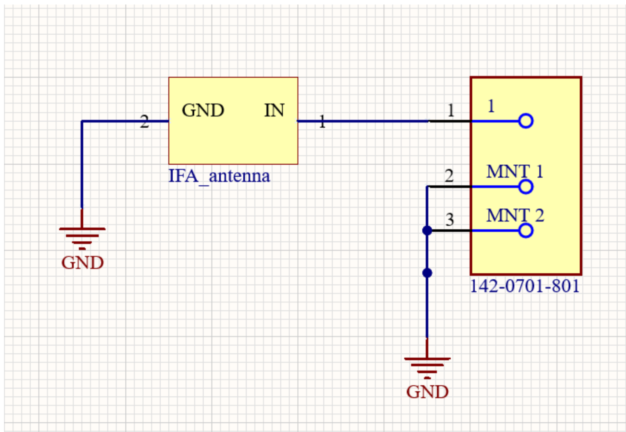


Fig: Schematic Diagram of the Antenna PCB

PCB Diagram

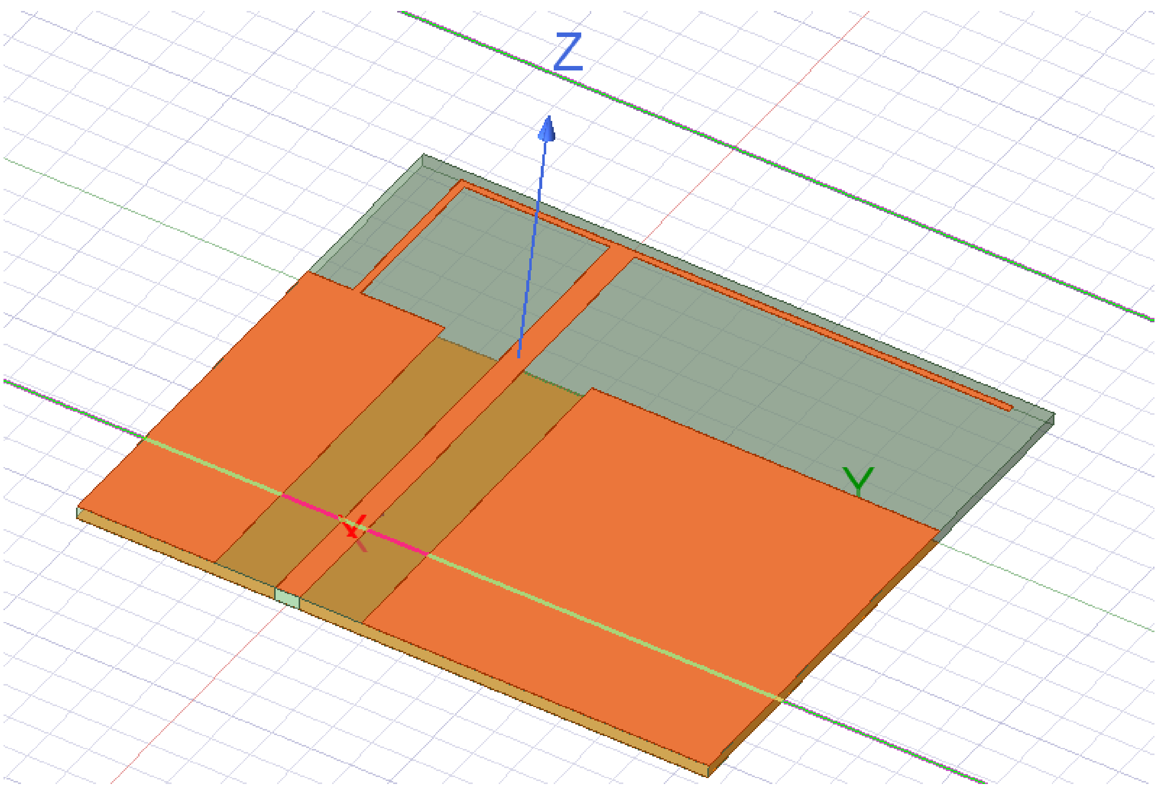


Figure 24: PIFA Antenna Design

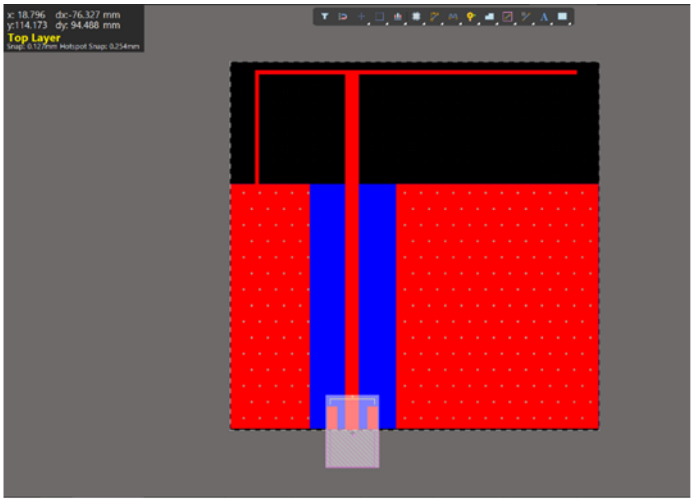


Fig: Top Layer of Antenna PCB

Fig: Multi-Layer View

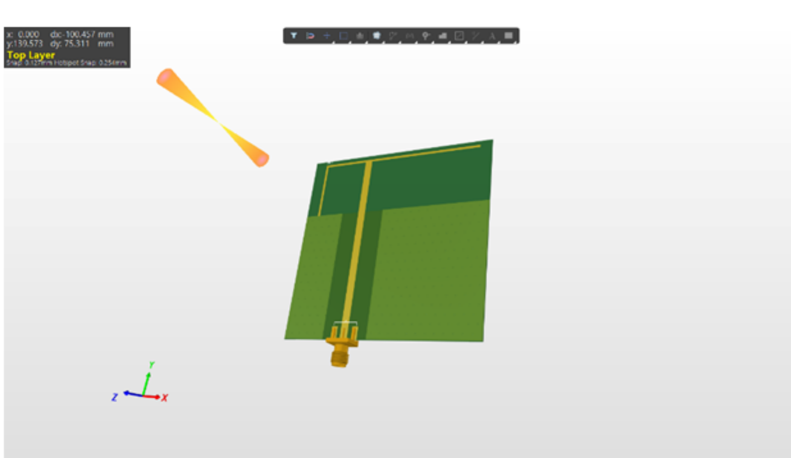


Fig: 3D View

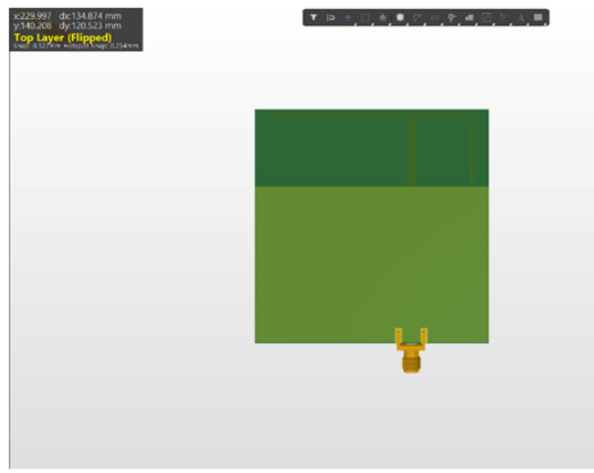


Fig: Bottom View

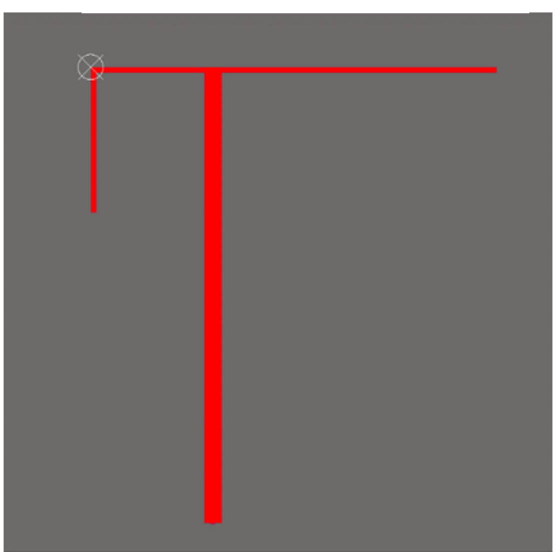


Fig: Antenna

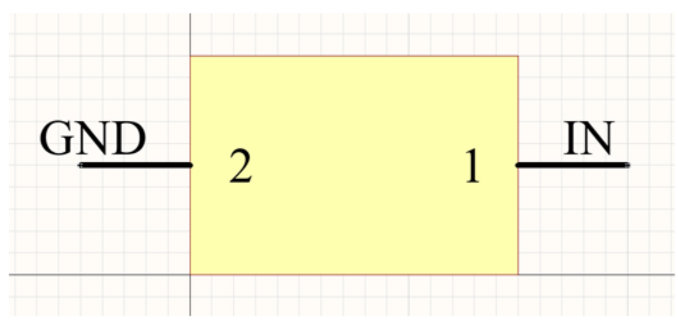
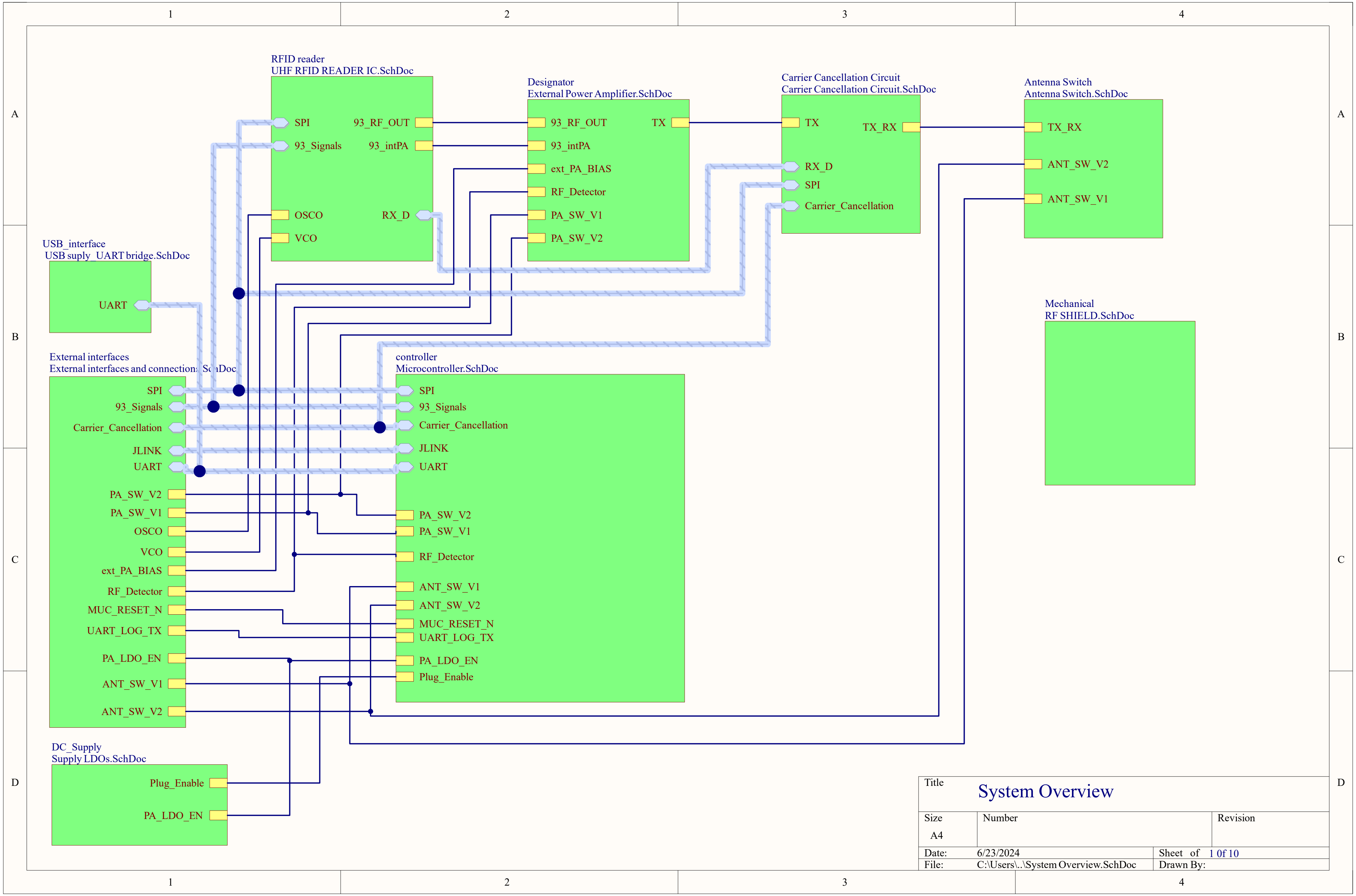


Fig: Schematic Library


1
2
3
4
A
B
C
D
RFID reader
UHF RFID READER IC.SchDoc
SPI
93_Signals
93_RF_OUT
93_intPA
OSCO
RX_D
VCO
Designator
External Power Amplifier.SchDoc
93_RF_OUT
TX
93_intPA
ext_PA_BIAS
RF_Detector
PA_SW_V1
PA_SW_V2
Carrier Cancellation Circuit
Carrier Cancellation Circuit.SchDoc
TX
TX_RX
RX_D
SPI
Carrier_Cancellation
Antenna Switch
Antenna Switch.SchDoc
TX_RX
ANT_SW_V2
ANT_SW_V1
USB_interface
USB suply_UART bridge.SchDoc
UART
Mechanical
RF SHIELD.SchDoc
External interfaces
External interfaces and connections.SchDoc
SPI
93_Signals
Carrier_Cancellation
JLINK
UART
PA_SW_V2
PA_SW_V1
OSCO
VCO
ext_PA_BIAS
RF_Detector
MUC_RESET_N
UART_LOG_TX
PA_LDO_EN
ANT_SW_V1
ANT_SW_V2
controller
Microcontroller.SchDoc
SPI
93_Signals
Carrier_Cancellation
JLINK
UART
PA_SW_V2
PA_SW_V1
RF_Detector
ANT_SW_V1
ANT_SW_V2
MUC_RESET_N
UART_LOG_TX
PA_LDO_EN
Plug_Enable
DC_Supply
Supply LDOs.SchDoc
Plug_Enable
PA_LDO_EN
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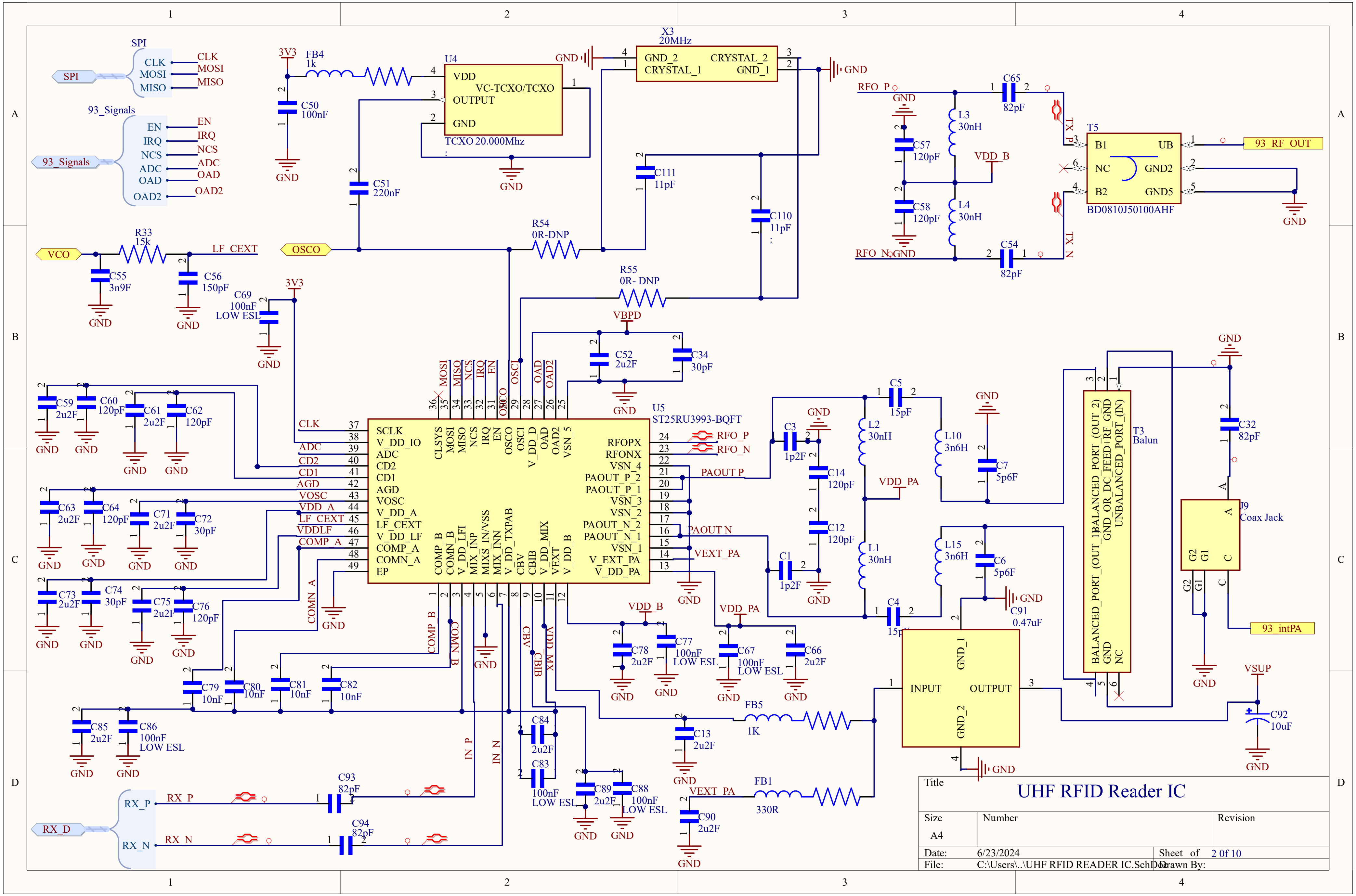
Size A4
Number
Revision
Date: 6/23/2024
File: C:\Users\..\System Overview.SchDoc
Sheet of 1 0f 10
Drawn By:



SPI
CLK
MOSI
MISO
93_Signals
EN
IRQ
NCS
ADC
OAD
OAD2
VCO
R33 15k
LF_CEXT
C55 3n9F
C56 150pF
OSCO
3V3
FB4 1k
C50 100nF
U4
VDD
VC-TCXO/TCXO
OUTPUT
GND
TCXO 20.000Mhz
C51 220nF
X3 20MHz
GND_2
CRYSTAL_2
CRYSTAL_1
GND_1
C111 11pF
C110 11pF
R54 0R-DNP
R55 0R- DNP
C69 100nF LOW ESL
VBPD
C52 2u2F
C34 30pF
RFO_P
RFO_N
C65 82pF
C54 82pF
C57 120pF
C58 120pF
L3 30nH
L4 30nH
VDD_B
TX_P
TX_N
T5
B1
UB
NC
GND2
B2
GND5
BD0810J50100AHF
93_RF_OUT
U5
ST25RU3993-BQFT
SCLK
V_DD_IO
CD2
CD1
AGD
VOSC
V_DD_A
LF_CEXT
V_DD_LF
COMP_A
COMN_A
EP
CLSYS
OSCO
OSCI
V_DD_D
OAD2
VSN_5
RFOPX
RFONX
VSN_4
PAOUT_P_2
PAOUT_P_1
VSN_3
VSN_2
PAOUT_N_2
PAOUT_N_1
VSN_1
V_EXT_PA
V_DD_PA
COMP_B
COMN_B
V_DD_LFI
MIX_INP
MIXS_IN/VSS
MIX_INN
V_DD_TXPAB
CBV
CBIB
V_DD_MIX
VEXT
V_DD_B
VDDLF
PAOUT P
PAOUT N
VEXT_PA
VDD_PA
C59 2u2F
C60 120pF
C61 2u2F
C62 120pF
C63 2u2F
C64 120pF
C71 2u2F
C72 30pF
C73 2u2F
C74 30pF
C75 2u2F
C76 120pF
C79 10nF
C80 10nF
C81 10nF
C82 10nF
C85 2u2F
C86 100nF LOW ESL
C84 2u2F
C83 100nF LOW ESL
C89 2u2F
C88 100nF LOW ESL
C78 2u2F
C77 100nF LOW ESL
C67 100nF LOW ESL
C66 2u2F
C13 2u2F
C90 2u2F
FB5 1K
FB1 330R
IN_P
IN_N
RX_D
RX_P
RX_N
C93 82pF
C94 82pF
C3 1p2F
C1 1p2F
C14 120pF
C12 120pF
C5 15pF
C4 15pF
L2 30nH
L1 30nH
L10 3n6H
L15 3n6H
C7 5p6F
C6 5p6F
C91 0.47uF
INPUT
OUTPUT
GND_1
GND_2
T3 Balun
BALANCED_PORT_(OUT_1)
BALANCED_PORT_(OUT_2)
GND_OR_DC_FEED+RF_GND
UNBALANCED_PORT_(IN)
J9 Coax Jack
C32 82pF
93_intPA
VSUP
C92 10uF
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UHF RFID Reader IC
Size A4
Number
Revision
Date: 6/23/2024
Sheet of 2 0f 10
File: C:\Users\..\UHF RFID READER IC.SchDoc
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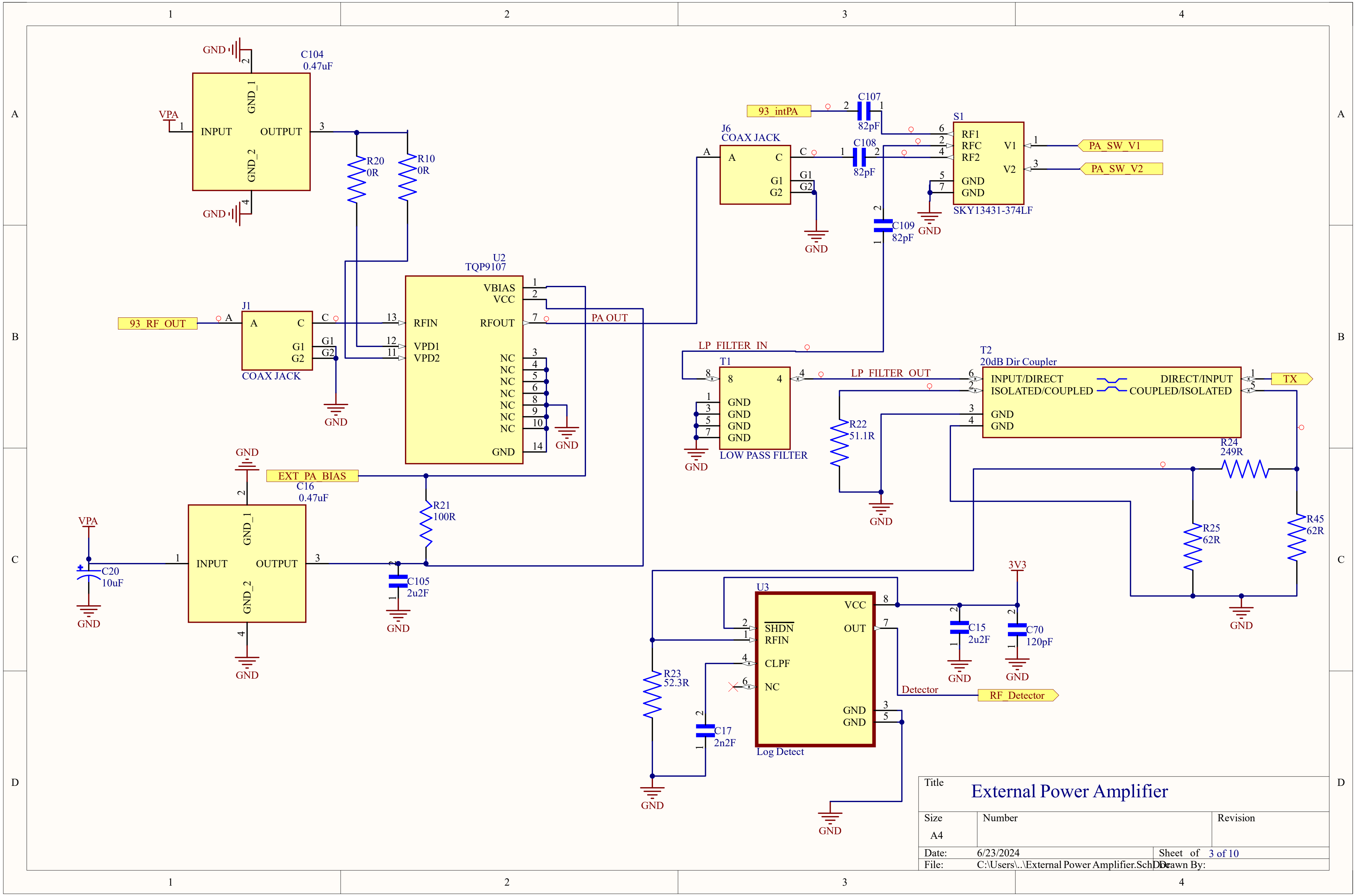
GND
C104
0.47uF
VPA
INPUT
OUTPUT
GND_1
GND_2
R20
0R
R10
0R
93_intPA
C107
82pF
S1
RF1
RFC
RF2
V1
V2
GND
GND
SKY13431-374LF
PA_SW_V1
PA_SW_V2
J6
COAX JACK
C108
82pF
G1
G2
C109
82pF
U2
TQP9107
VBIAS
VCC
RFIN
RFOUT
VPD1
VPD2
NC
GND
93_RF_OUT
J1
COAX JACK
PA OUT
LP_FILTER_IN
T1
LOW PASS FILTER
LP_FILTER_OUT
T2
20dB Dir Coupler
INPUT/DIRECT
ISOLATED/COUPLED
DIRECT/INPUT
COUPLED/ISOLATED
TX
R22
51.1R
R24
249R
R25
62R
R45
62R
EXT_PA_BIAS
C16
0.47uF
R21
100R
C20
10uF
C105
2u2F
3V3
U3
SHDN
RFIN
CLPF
NC
VCC
OUT
Log Detect
C15
2u2F
C70
120pF
Detector
RF_Detector
R23
52.3R
C17
2n2F
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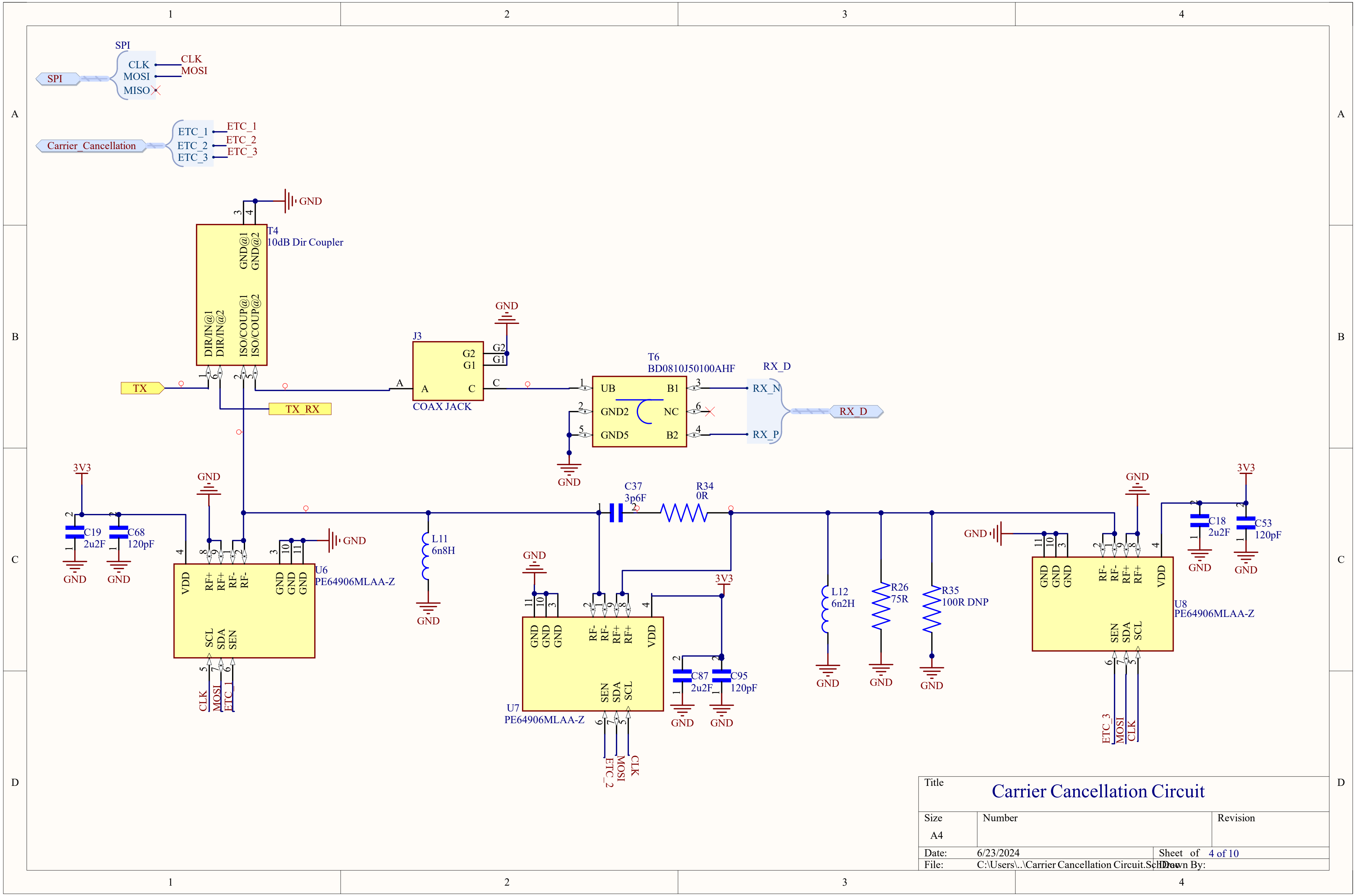
External Power Amplifier
Size
A4
Number
Revision
Date:
6/23/2024
Sheet of
3 of 10
File:
C:\Users\..\External Power Amplifier.SchDoc
Drawn By:


SPI
CLK
MOSI
MISO
Carrier_Cancellation
ETC_1
ETC_2
ETC_3
GND
T4
10dB Dir Coupler
GND@1
GND@2
DIR/IN@1
DIR/IN@2
ISO/COUP@1
ISO/COUP@2
TX
TX_RX
J3
G2
G1
COAX JACK
T6
BD0810J50100AHF
UB
B1
GND2
NC
GND5
B2
RX_D
RX_N
RX_P
3V3
C19
2u2F
C68
120pF
U6
PE64906MLAA-Z
VDD
RF+
RF-
SCL
SDA
SEN
L11
6n8H
C37
3p6F
R34
0R
U7
PE64906MLAA-Z
C87
2u2F
C95
120pF
L12
6n2H
R26
75R
R35
100R DNP
U8
PE64906MLAA-Z
C18
2u2F
C53
120pF
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Carrier Cancellation Circuit
Size
A4
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Revision
Date:
6/23/2024
Sheet of
4 of 10
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C:\Users\..\Carrier Cancellation Circuit.SchDoc
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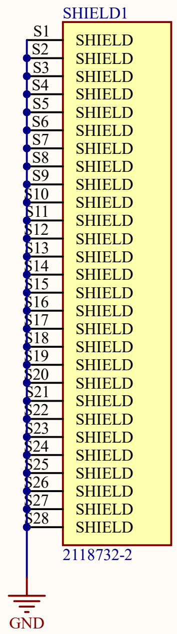

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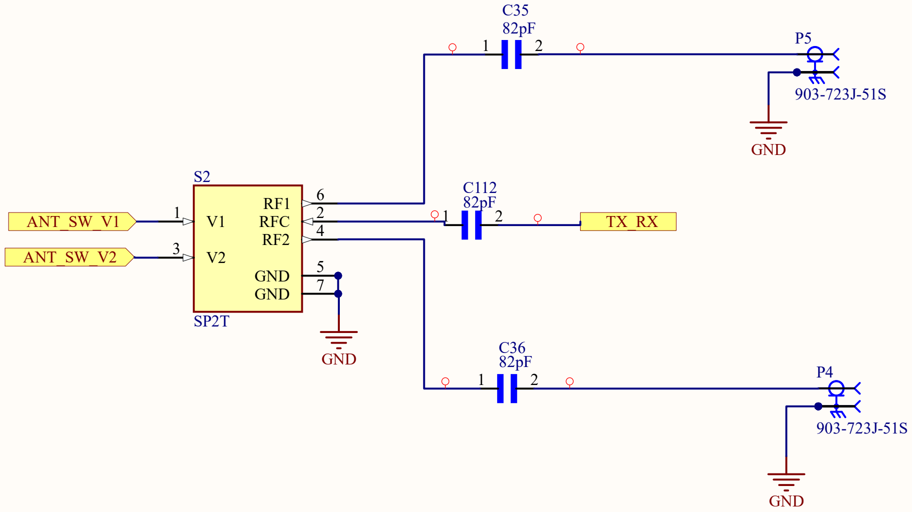

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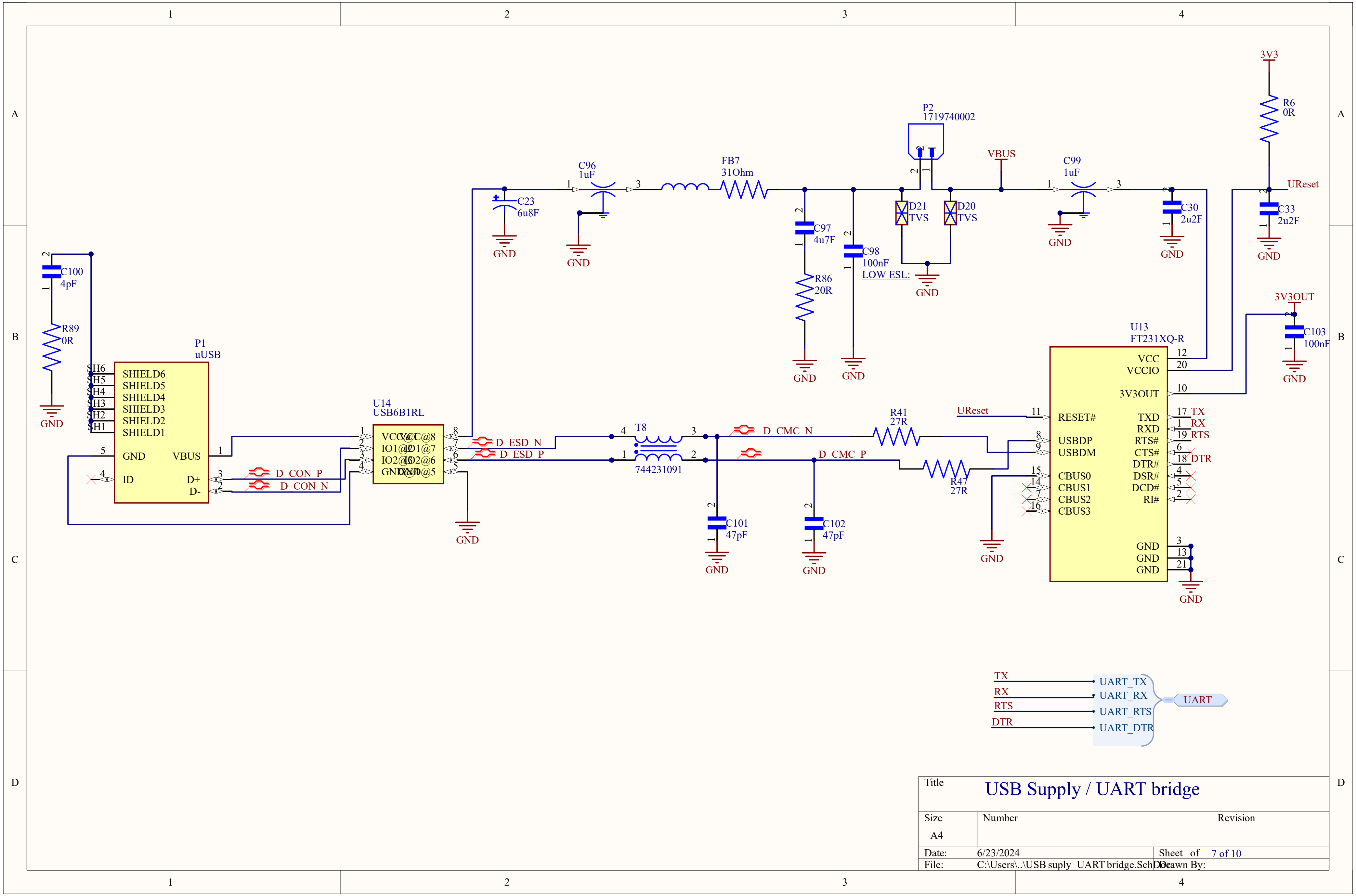

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Size A4	Number		Revision
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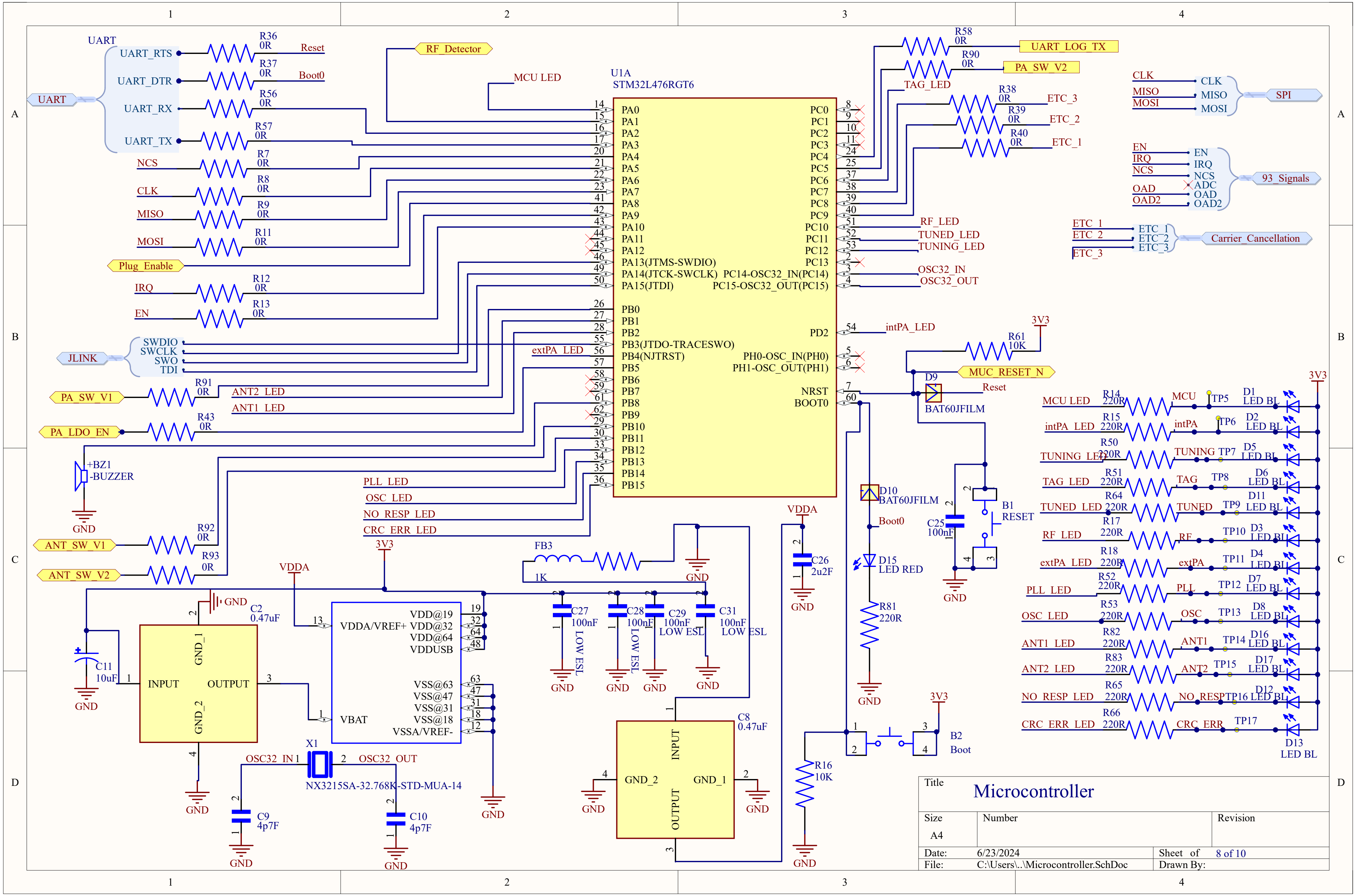
File:	C:\Users\..\USB suply_UART bridge.SchDoc	Drawn By:	



UART
UART_RTS
UART_DTR
UART_RX
UART_TX
R36 0R Reset
R37 0R Boot0
R56 0R
R57 0R
R7 0R
R8 0R
R9 0R
R11 0R
R12 0R
R13 0R
NCS
CLK
MISO
MOSI
Plug_Enable
IRQ
EN
SWDIO
SWCLK
SWO
TDI
JLINK
PA_SW_V1
R91 0R
ANT2_LED
ANT1_LED
PA_LDO_EN
R43 0R
+BZ1
-BUZZER
GND
ANT_SW_V1
R92 0R
ANT_SW_V2
R93 0R
RF_Detector
MCU LED
U1A
STM32L476RGT6
PA0
PA1
PA2
PA3
PA4
PA5
PA6
PA7
PA8
PA9
PA10
PA11
PA12
PA13(JTMS-SWDIO)
PA14(JTCK-SWCLK)
PA15(JTDI)
PB0
PB1
PB2
PB3(JTDO-TRACESWO)
PB4(NJTRST)
PB5
PB6
PB7
PB8
PB9
PB10
PB11
PB12
PB13
PB14
PB15
PC0
PC1
PC2
PC3
PC4
PC5
PC6
PC7
PC8
PC9
PC10
PC11
PC12
PC13
PC14-OSC32_IN(PC14)
PC15-OSC32_OUT(PC15)
PD2
PH0-OSC_IN(PH0)
PH1-OSC_OUT(PH1)
NRST
BOOT0
extPA_LED
intPA_LED
PLL_LED
OSC_LED
NO_RESP_LED
CRC_ERR_LED
R58 0R UART_LOG_TX
R90 0R PA_SW_V2
TAG_LED
R38 0R ETC_3
R39 0R ETC_2
R40 0R ETC_1
RF_LED
TUNED_LED
TUNING_LED
OSC32_IN
OSC32_OUT
3V3
R61 10K
MUC_RESET_N
D9
BAT60JFILM
Reset
CLK
MISO
MOSI
SPI
EN
IRQ
NCS
ADC
OAD
OAD2
93_Signals
ETC_1
ETC_2
ETC_3
Carrier_Cancellation
MCU LED R14 220R MCU TP5 D1 LED BL
intPA_LED R15 220R intPA TP6 D2 LED BL
TUNING_LED R50 220R TUNING TP7 D5 LED BL
TAG_LED R51 220R TAG TP8 D6 LED BL
TUNED_LED R64 220R TUNED TP9 D11 LED BL
RF_LED R17 220R RF TP10 D3 LED BL
extPA_LED R18 220R extPA TP11 D4 LED BL
PLL_LED R52 220R PLL TP12 D7 LED BL
OSC_LED R53 220R OSC TP13 D8 LED BL
ANT1_LED R82 220R ANT1 TP14 D16 LED BL
ANT2_LED R83 220R ANT2 TP15 D17 LED BL
NO_RESP_LED R65 220R NO_RESP TP16 D12 LED BL
CRC_ERR_LED R66 220R CRC_ERR TP17 D13 LED BL
B1 RESET
C25 100nF
D10 BAT60JFILM
Boot0
D15 LED RED
R81 220R
VDDA
C26 2u2F
B2 Boot
R16 10K
FB3 1K
C27 100nF LOW ESL
C28 100nF LOW ESL
C29 100nF LOW ESL
C31 100nF LOW ESL
VDDA/VREF+
VDD@32
VDD@64
VDD@19
VDDUSB
VBAT
VSS@63
VSS@47
VSS@31
VSS@18
VSSA/VREF-
C2 0.47uF
INPUT
OUTPUT
GND_1
GND_2
C11 10uF
X1
OSC32_IN
OSC32_OUT
NX3215SA-32.768K-STD-MUA-14
C9 4p7F
C10 4p7F
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Number
Revision
Date: 6/23/2024
Sheet of 8 of 10
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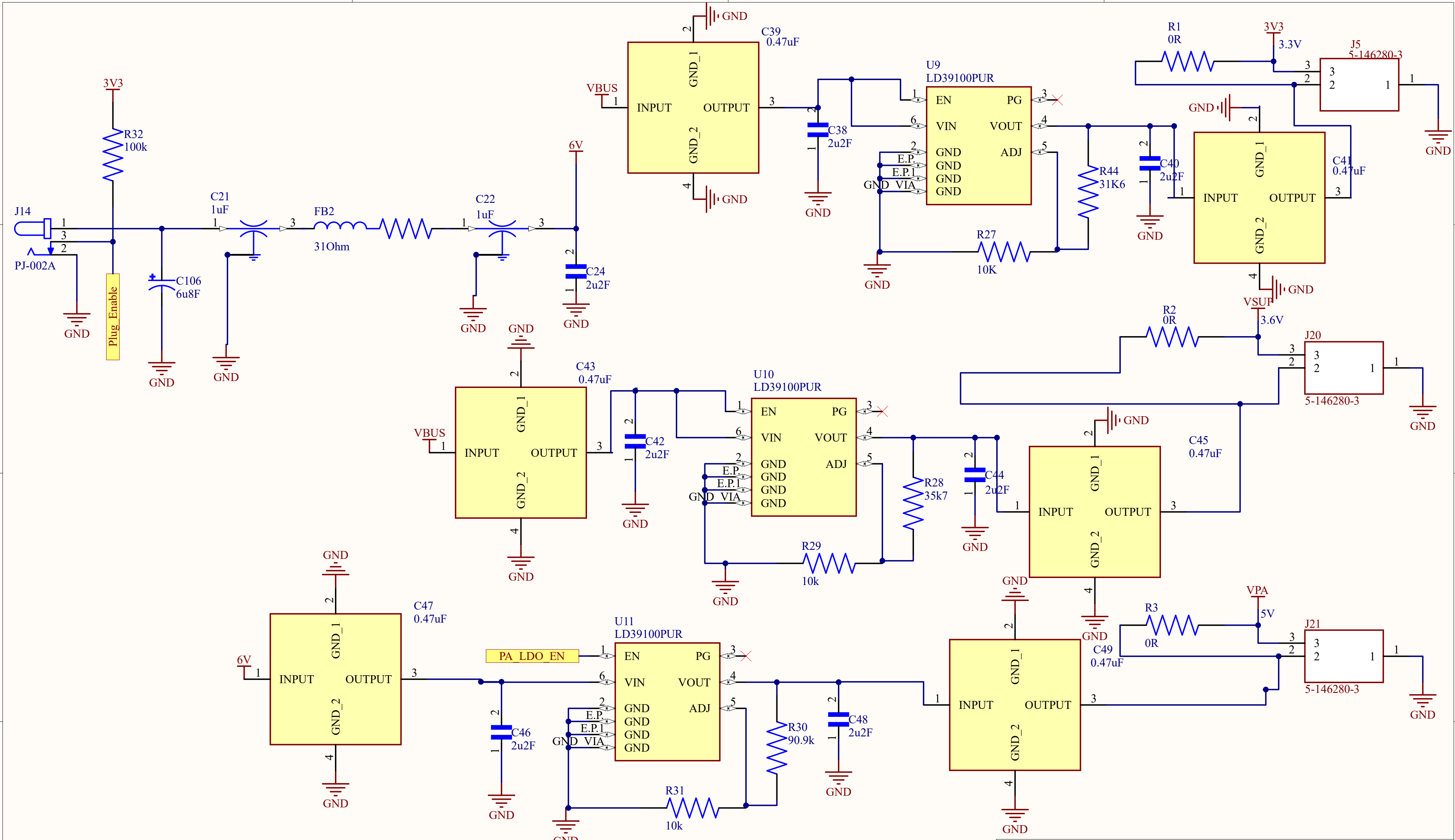

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Size	Number		Revision
A4			
Date:	6/23/2024	Sheet of	9 of 10
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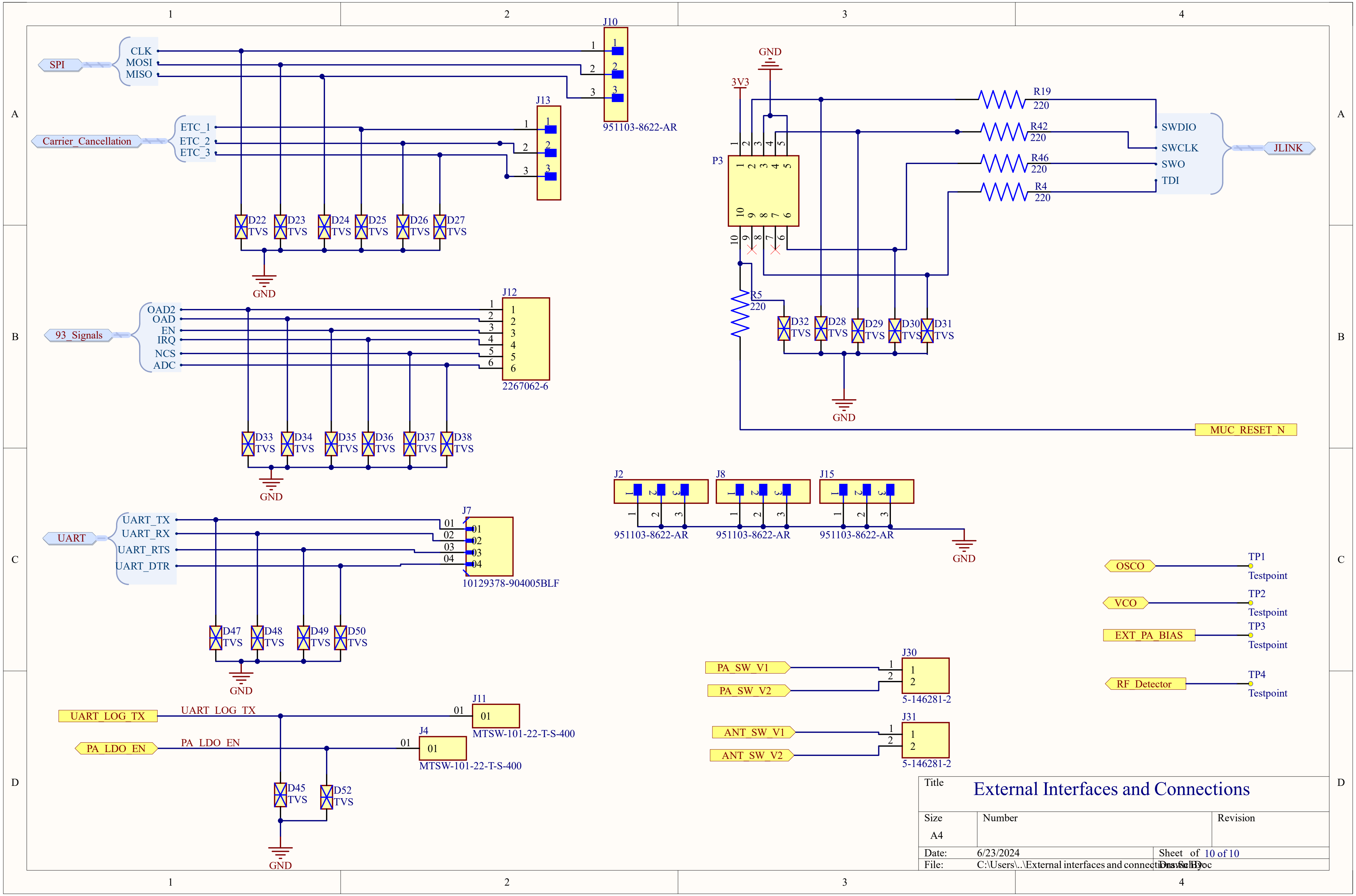
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CLK
MOSI
MISO
J10
951103-8622-AR
Carrier_Cancellation
ETC_1
ETC_2
ETC_3
J13
D22 TVS
D23 TVS
D24 TVS
D25 TVS
D26 TVS
D27 TVS
GND
93_Signals
OAD2
OAD
EN
IRQ
NCS
ADC
J12
2267062-6
D33 TVS
D34 TVS
D35 TVS
D36 TVS
D37 TVS
D38 TVS
GND
UART
UART_TX
UART_RX
UART_RTS
UART_DTR
J7
10129378-904005BLF
D47 TVS
D48 TVS
D49 TVS
D50 TVS
GND
UART_LOG_TX
J11
MTSW-101-22-T-S-400
PA_LDO_EN
J4
MTSW-101-22-T-S-400
D45 TVS
D52 TVS
GND
GND
3V3
P3
R19 220
R42 220
R46 220
R4 220
SWDIO
SWCLK
SWO
TDI
JLINK
R5 220
D32 TVS
D28 TVS
D29 TVS
D30 TVS
D31 TVS
GND
MUC_RESET_N
J2
951103-8622-AR
J8
951103-8622-AR
J15
951103-8622-AR
GND
OSCO
TP1 Testpoint
VCO
TP2 Testpoint
EXT_PA_BIAS
TP3 Testpoint
RF_Detector
TP4 Testpoint
PA_SW_V1
PA_SW_V2
J30
5-146281-2
ANT_SW_V1
ANT_SW_V2
J31
5-146281-2
Title
External Interfaces and Connections
Size
A4
Number
Revision
Date: 6/23/2024
Sheet of 10 of 10
File: C:\Users\..\External interfaces and connections.SchDoc
Drawn By: