



## **Application Note: UHF RFID Fermi Reader**

### **HW-Description**

# **AS3993**

## **UHF RFID Single Chip Reader EPC Class1 Gen2 Compatible**

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## Table of Contents

1. Introduction .....	2
2. Key Features .....	3
3. Applications .....	4
4. Reader System Description.....	5
5 Interfaces.....	7
5.1 USB.....	7
5.2 UART Interface.....	7
5.3 Pin Header Interface Description .....	8
5.4 Programming Interface Description.....	9
6 Reader Part .....	10
6.1 RF Tracks – Impedance Calculation .....	10
6.2 Reader Part – PCB Stackup .....	10
6.3 Reader Part – Schematics.....	11
6.4 OAD Pins .....	16
7 Controller Part.....	16
Copyright .....	17
Disclaimer .....	17
Figure 1 - Reader Part.....	5
Figure 2 - Controller Part.....	6
Figure 3 - Pin Header Position (all dimensions in mm) .....	8
Figure 4 - Programming Interface (all dimensions in mm) .....	9
Figure 5 - RF Tracks - Impedance Calculation (dimensions in mil) .....	10
Figure 6 - RF Part - PCB Stackup .....	10
Figure 7 - Schematic Reader Section .....	11
Figure 8 - Schematic Loop Filter .....	11
Figure 9 - Reader Indicator LEDs.....	12
Figure 10 - Schematic Balun Section .....	13
Figure 11 - Schematic PA Section .....	14
Figure 12 - Schematic Directional Coupler.....	15
Figure 13 - OAD Pads .....	16
Figure 14 - Schematic MCU Section .....	16



## 1. Introduction

The FERMI Reader is a small form factor and low costs EPC Class 1 Gen 2 UHF RFID demonstration reader system. Leveraging AS3993 UHF RFID Reader IC, provides close to the industry's lowest BOM cost, best in class power consumption with the least amount of complexity.

Second only to ams FERMI design the low reader BOM enables UHF RFID markets that have previously been out of reach due to cost restraints. With regards to overall cost vs. performance the FERMI UHF RFID demo reader is unmatched in the industry.

With an external PA delivering up to 22 dBm, it is ideally suited for those applications that have similar cost constraints but require that extra power

The FERMI demo reader comes in two parts namely the analogue (reader) and digital (controller) parts. The user can separate the two stacked boards to fully prove out their own RF and digital parts. With this set up it also means the user can evaluate the suitability of RFID in their current system.

The reader portion is designed such that it can be easily connected to a host MCU via SPI. The high level of integration found on the AS3993 UHF RFID Reader IC allows for minimal code loading and quick implementation.

The designs come with free, fully portable code and all Gerber data and schematics. This allows for a quick, trouble free design in.

## 2. Key Features

- Interface
  - Between the Controller and Host Computer: USB (optional UART)
  - Between the Controller and the AS3993 is SPI via a low cost pin header connection
  - Between the RF board and the Antenna we use a U.FL (50 Ohm) SMA (Male)
- 5V power supply from USB.
- GUI
  - Adjust Output Power
  - Adjust Receive – Sensitivity
  - Adapt to different frequency schemes (FCC ETSI)
  - Change Gen2 specific parameters like BLF, Coding, Anti-Collision Slots, ...
  - Diagnostic Features: RSSI Measurement, Reflected Power Measurement
  - Support for sending AS3993 related direct commands
  - Advanced Tag Manipulations: R/W to different memory banks, define passwords
  - Associate tags with other applications like media player
  - View and easily manipulate register settings with advance tool tip text.
- Low Power Consumption: complete reader system is only 780mW (typ), 830mW (max)
- Fully Gen 2 compliant, ISO 18000-6b & 6c
- Differential TX chip-output configuration
- Differential RX chip-input configuration
- External power amplifier RF2172
- Maximum output power 22 dBm scalable in 20 steps
- Low cost MCU: Microchip (PIC24FJ64GB004)
- Indicator LEDs

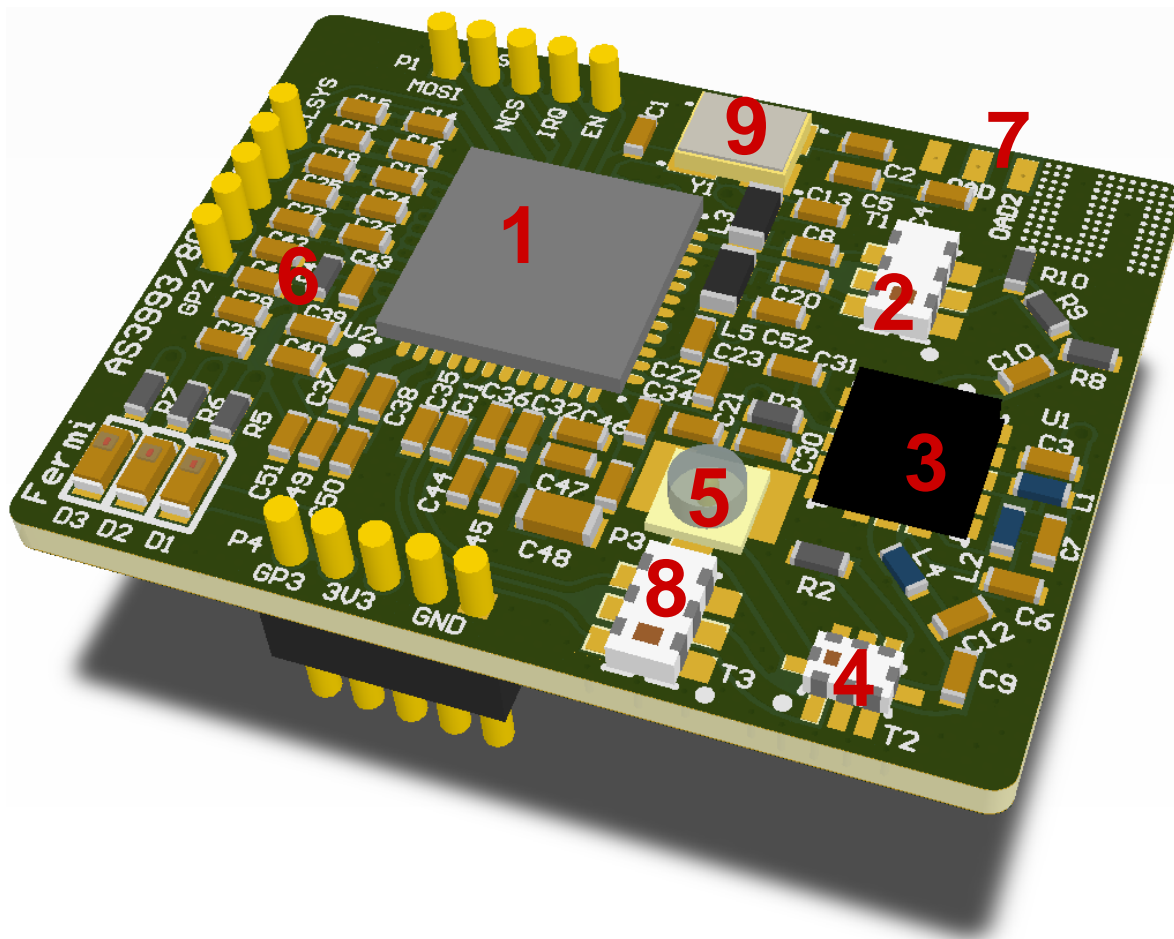


### 3. Applications

Typical applications for the FERMI demo reader include:

- Embedded Consumer Applications
- Mobile Applications (Low Power Handheld, PDA's, Smart Phones)
- Embedded Industrial Applications
- Gaming
- Desk top readers
- Low/Mid powered modules

## 4. Reader System Description



*Figure 1 - Reader Part*

1. AS3993 UHF RFID reader IC (ams)
2. Balun 2:1 (Johanson Technology)
3. Power Amplifier RF2172 (RFMD)
4. Directional coupler / Low pass filter combination (Johanson Technology)
5. U.FL antenna port (Hirose)
6. Loop Filter
7. OAD pins for debugging purposes
8. Balun 2:1 (Johanson Technology)
9. Crystal 20 MHz +/- 10ppm

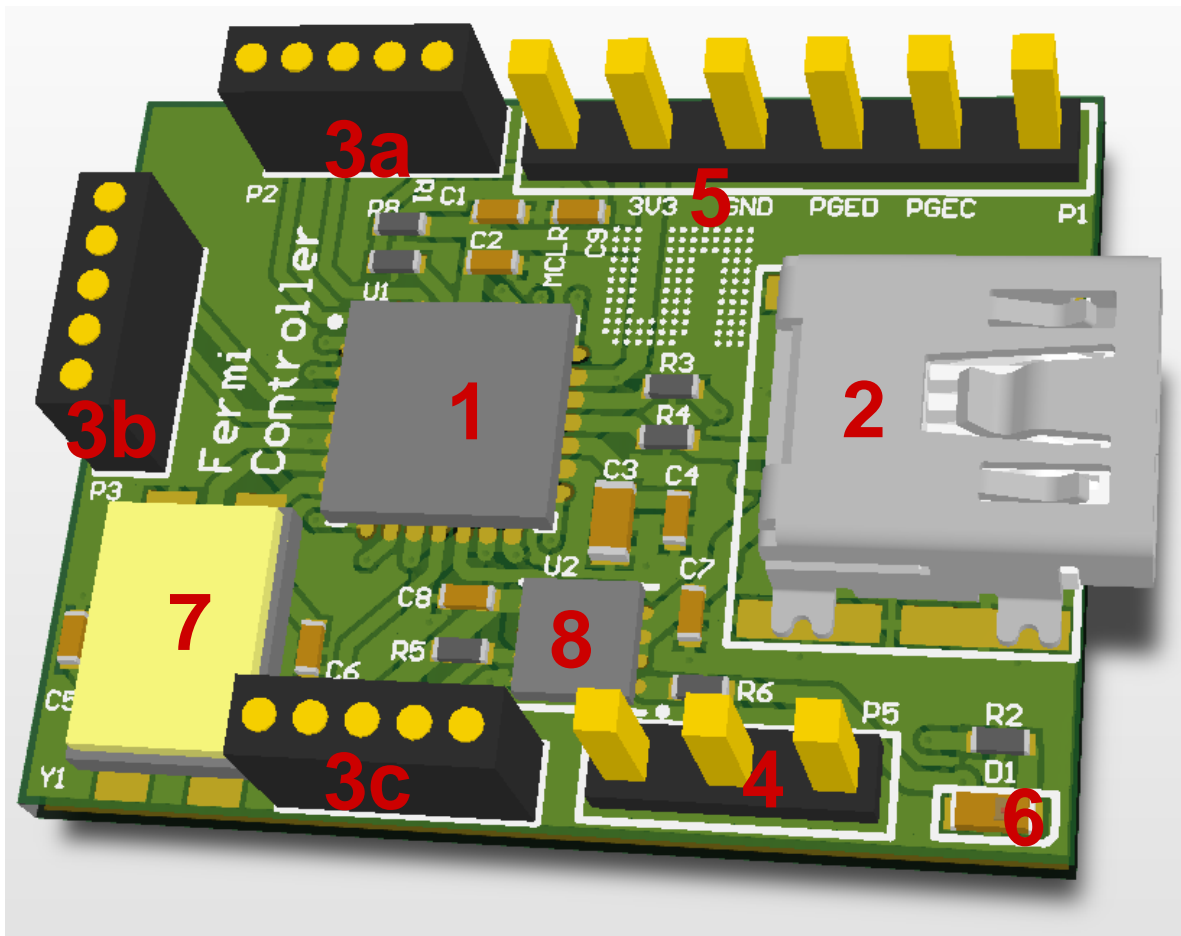
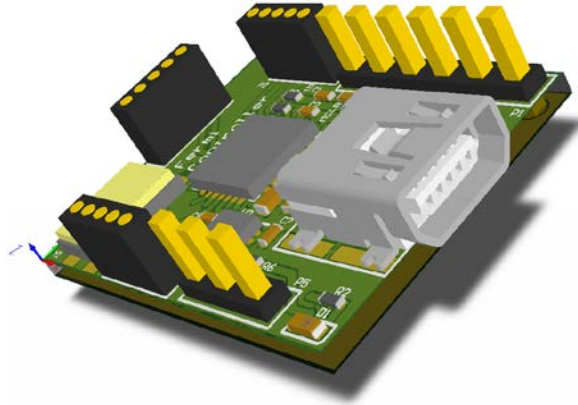


Figure 2 - Controller Part

1. MCU C8051F340 (Silabs)
2. USB connector
3. Interface connectors to reader PCB
4. UART connector
5. C2 programming interface for boot loader
6. Indicator LED
7. X-tal (for extended USB functionality)
8. LDO (5 V → 3.5 V)

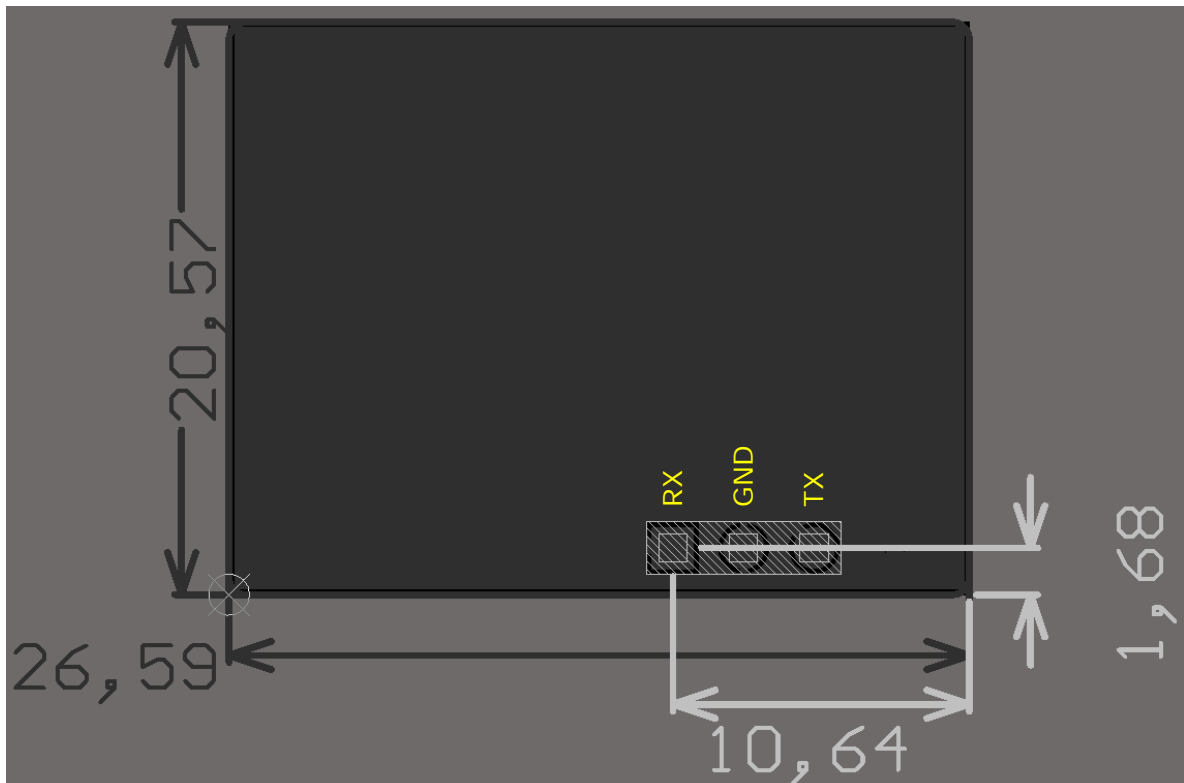
## 5 Interfaces

### 5.1 USB



The USB is used to communicate to the host computer and to supply the reader system. The 5V USB voltage is regulated down to 3.5 V.

### 5.2 UART Interface





In order to establish a connection to the host computer via UART it is recommend to use an USB TTL serial cable with 3.3 Volt (FTDI TTL-232R-3V3-WE).

### 5.3 Pin Header Interface Description

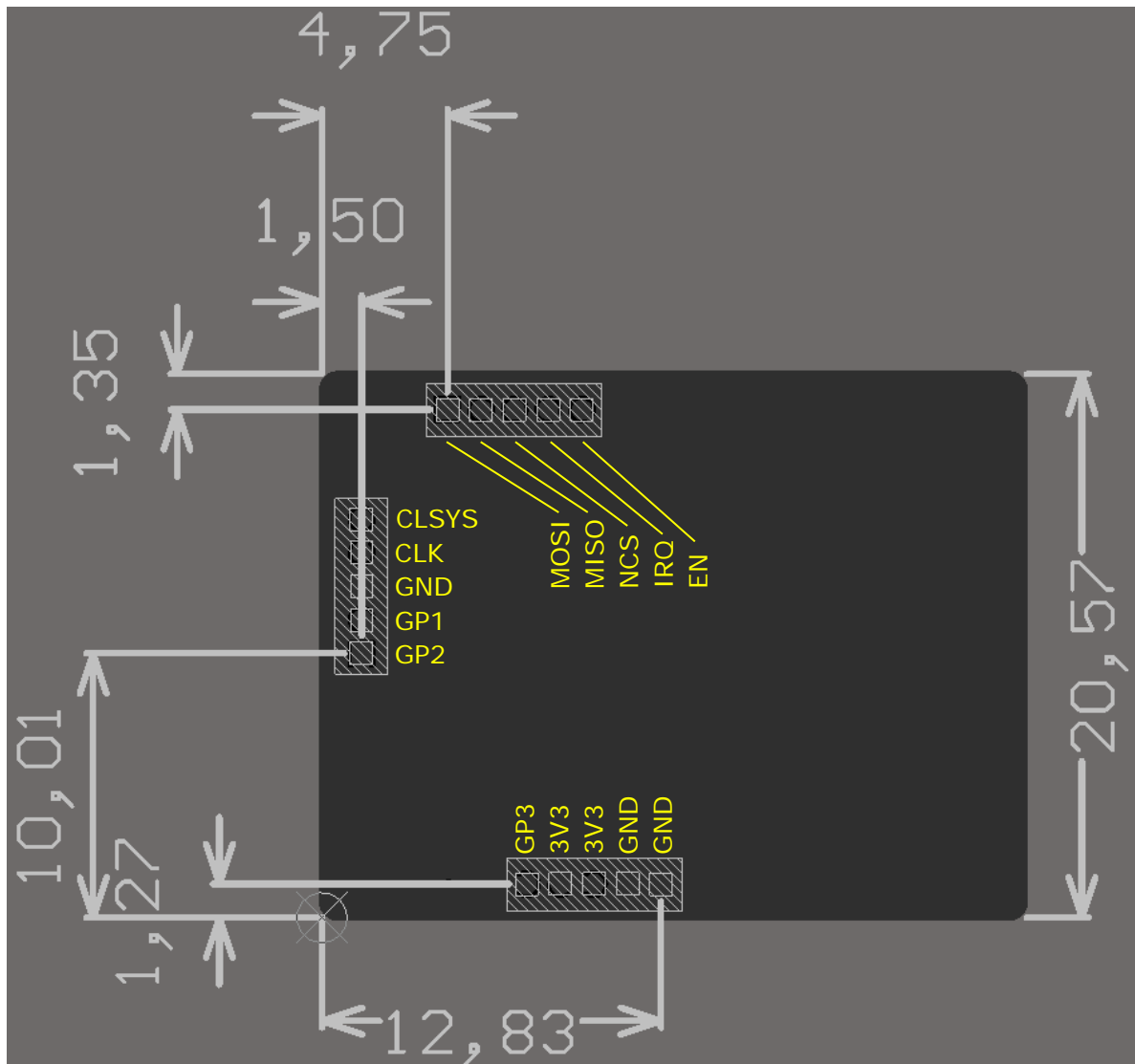


Figure 3 - Pin Header Position (all dimensions in mm)

## 5.4 Programming Interface Description

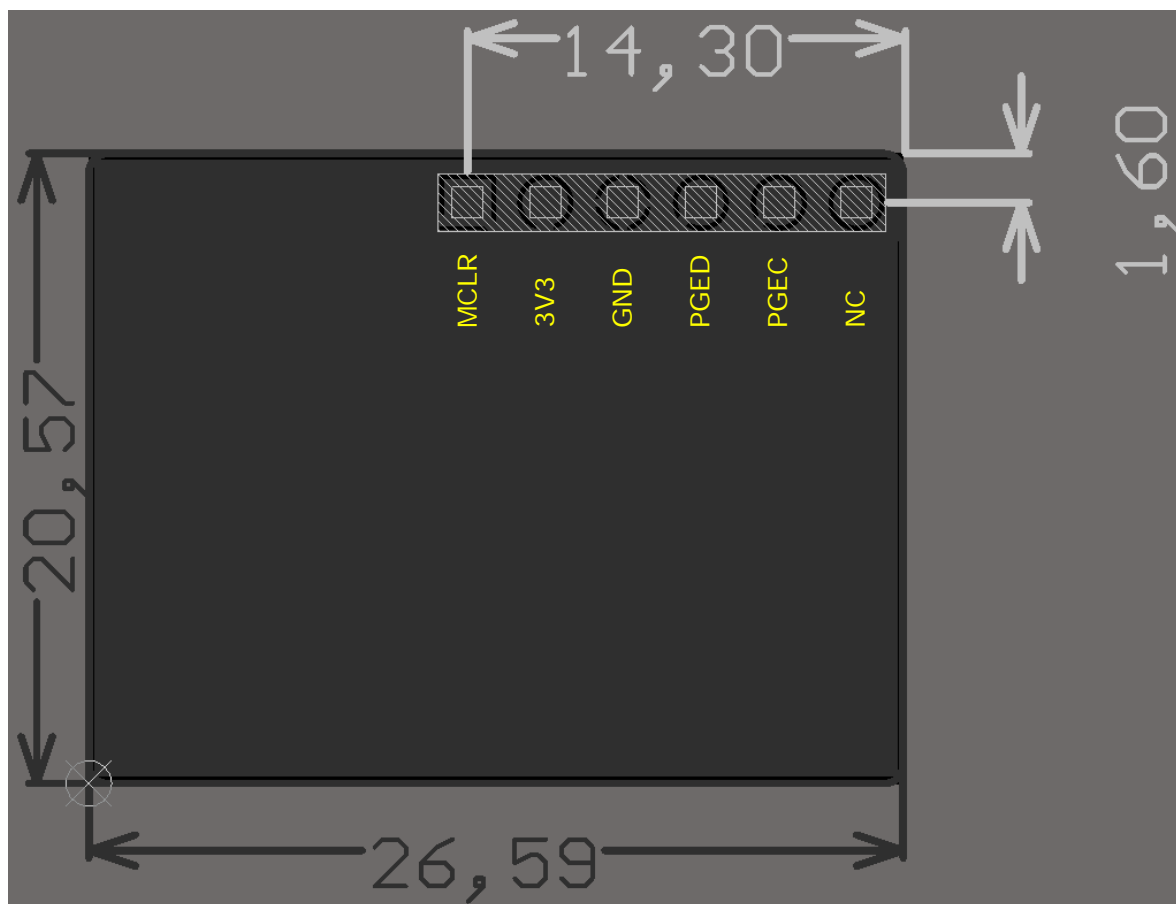


Figure 4 - Programming Interface (all dimensions in mm)

## 6 Reader Part

The reader part contains all RF and UHF RFID relevant components. In order to keep PCB costs low the reader part is 2-layer PCB only while all components are located on the top layer. The component placement was chosen to reach a small form factor PCB.

### 6.1 RF Tracks – Impedance Calculation

**Coplanar Waveguide** ☒ With Groundplane ☐ No Groundplane

Calculate Z0 [F4]

Z0 = **53.8** Ω

Elect Length = **0.130** λ

Elect Length = **46.7** degrees

1.0 Wavelength = **7701.840** mil

Vp = **0.653** fraction of c

ε eff = **2.35**

Shape factor = **0.647**

Dielectric: ε r = **4.3**

-> Enter custom Er value

Frequency: **1** GHz

Length Units: **mil**

Dimensions: L=1000, W=22, G=6, H=40, T=1.69

Figure 5 - RF Tracks - Impedance Calculation (dimensions in mil)

### 6.2 Reader Part – PCB Stackup

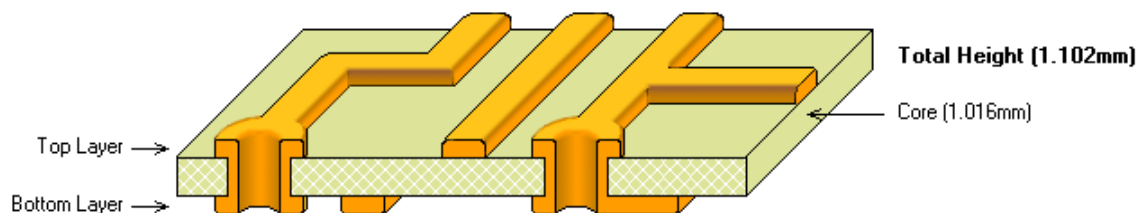


Figure 6 - RF Part - PCB Stackup

## 6.3 Reader Part – Schematics

Reader Section:

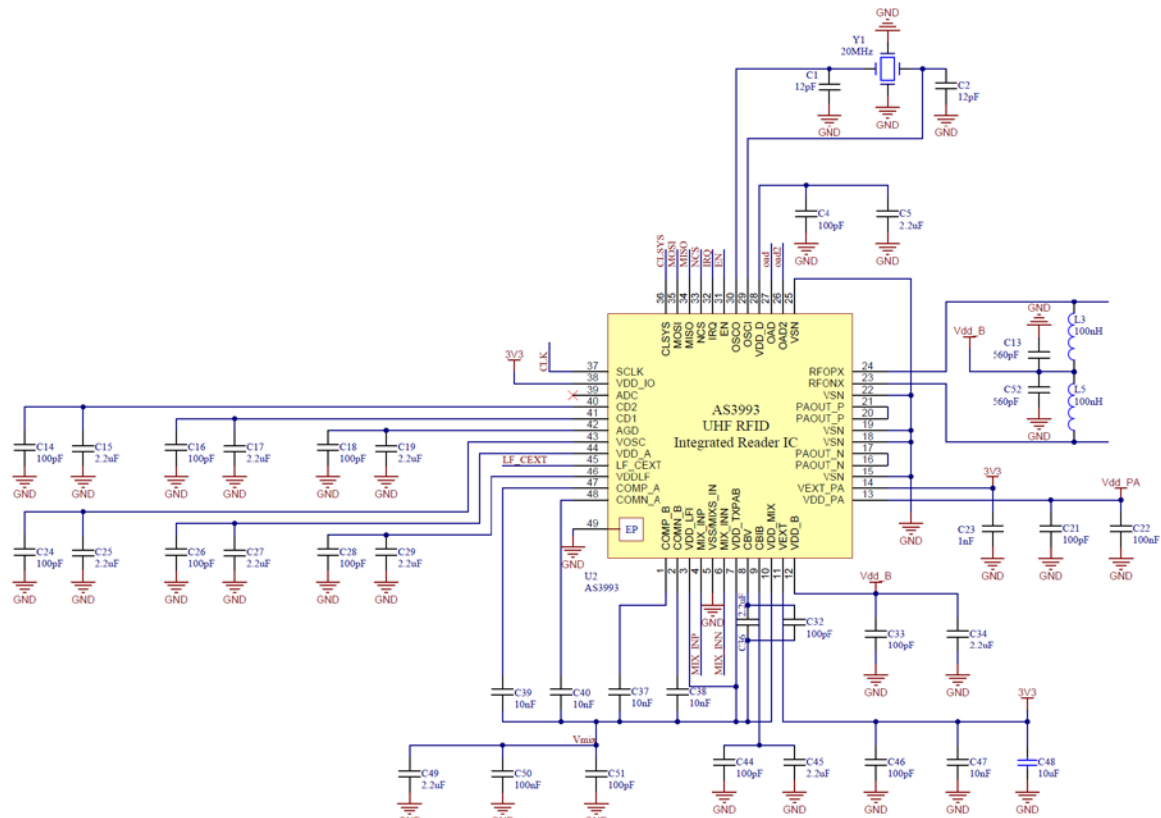


Figure 7 - Schematic Reader Section

Loop Filter:

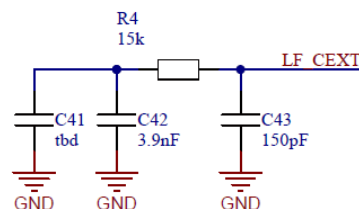


Figure 8 - Schematic Loop Filter

The loop filter used for the PLL is partly inside the reader IC. The external part is shown above. The loop filter values are provided by ams. Other values are possible and are mentioned in a separate application note.

### Indicator LEDs:

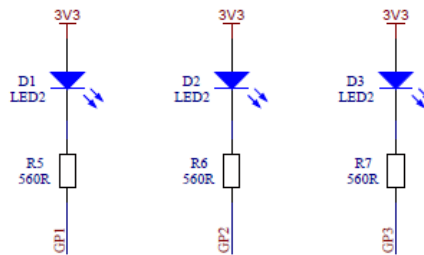


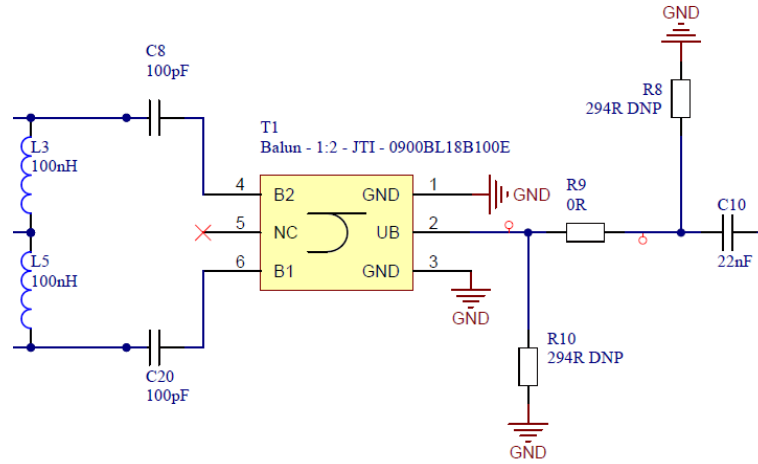
Figure 9 - Reader Indicator LEDs

The three indicator LEDs on the reader part together with the LED on the controller part are used to display error states at the start-up of the reader system. LSB (bit 0) is the controller LED and reader LEDs D1 – D3 are bit 1 – bit 3. If an error occurs during the start-up the LEDs are slowly flashing the error code.

### Error Codes:

- 0 : Everything OK. Controller LED flashes fast.
- 1 : writing + reading SPI failed.
- 2 : Reset via EN low + high failed.
- 3 : IRQ line failed.
- 4 : Crystal not stable (Bit0 in AGC and Internal Status register 0x2A)
- 5 : PLL not locked (Bits1 in AGC and Internal Status register 0x2A)

Example - PLL not locked: Controller LED and reader LED D2 are flashing slowly.

Balun Section:*Figure 10 - Schematic Balun Section*

The output impedance of the 0 dBm (low power) outputs are 100 ohm differential. Therefore a 2:1 Balun is used to convert the RF track impedance to 50 ohm single ended. In case the output power should be very low the resistor R8, R9 and R10 (Pi-Pad) can be used to attenuate the RF signal. It would be also possible to reduce the output power via reader IC register settings but this should be done only down to -6 dB as the local oscillator signal inside the IC would become too low. Per default the Pi-Pad is not installed.

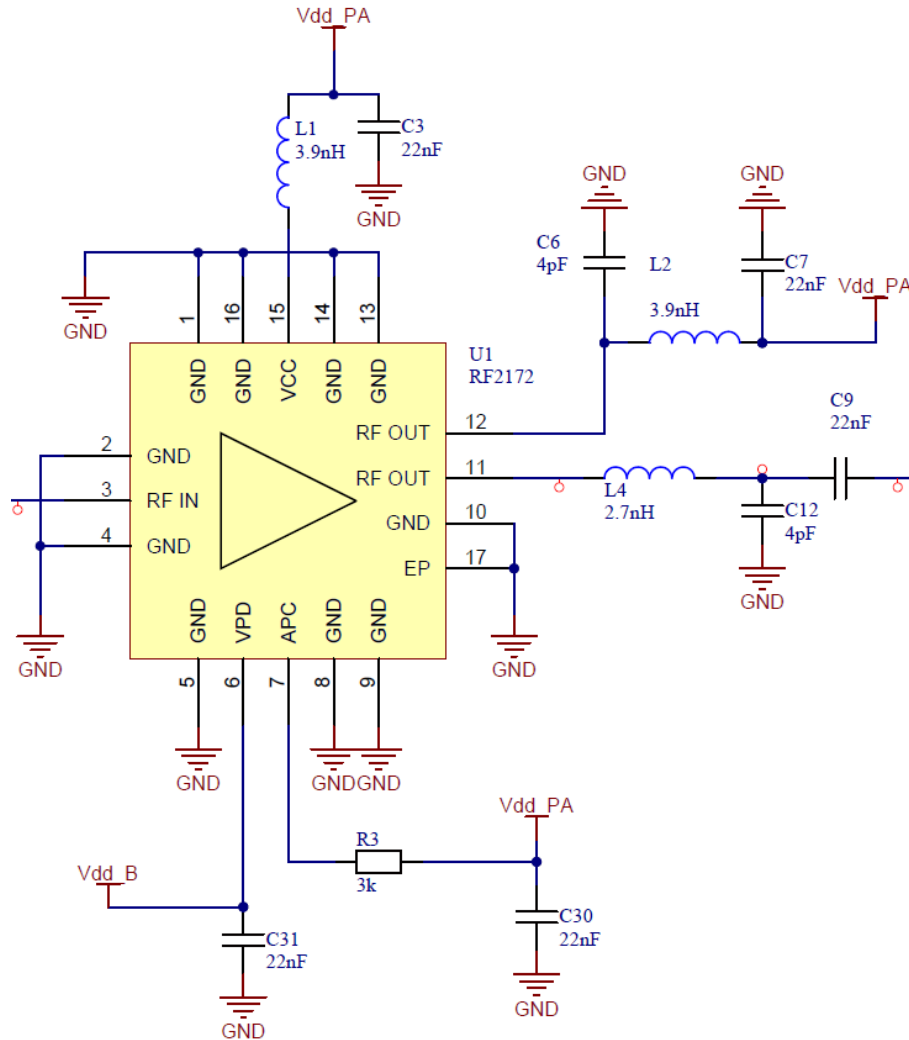
PA Section:

Figure 11 - Schematic PA Section

The PA is supplied by the reader ICs internal voltage regulators. Since the reader ICs internal PA is not used the corresponding voltage regulator (VDD\_PA) is used for the external PA supply. The power down pin of the external PA is supplied by the VDD\_B regulator which is also supplies the 0 dBm output driver of the reader IC. The PA circuitry matches the proposal of the RF2172 datasheet.

### Directional Coupler and RX Balun Section:

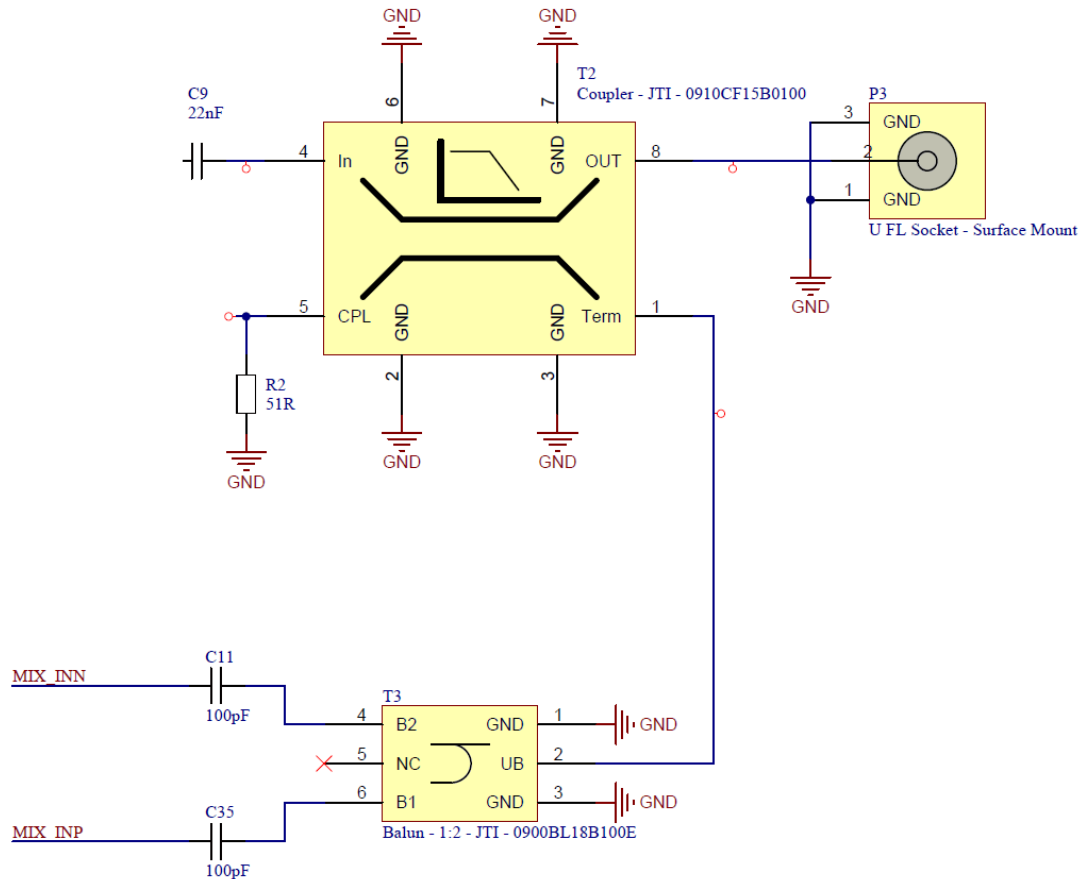


Figure 12 - Schematic Directional Coupler

The directional coupler also includes a low pass filter which attenuates the higher order harmonics of the carrier signal. The directional coupler is needed in order to prevent the TX signal leaking into the receiver. The used coupler is a trade-off between cost and directivity. The antenna connector is a U.FL connector which is compatible with a microcoaxial connectors. Since the directional coupler is a 10 dB coupler only 10 dB of the incoming tag signal is fed to the RX Balun which converts the 50 ohm single ended impedance back to 100 ohm differential need for the differential RX ports of the reader IC.



## 6.4 OAD Pins

The pads J1 and J2 are connected to the OAD pins of the reader IC which can be used to output analog/digital RX subcarrier signals or TX / RX based band signals.

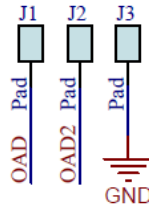


Figure 13 - OAD Pads

## 7 Controller Part

The controller part contains the low cost MCU and the LDO used for reducing the USB voltage down to 3.5 Volts. All the interfaces (USB, UART, ...) are located on the controller part as well. In order to allow USB functionality across all tolerances a crystal with 12 MHz is available.

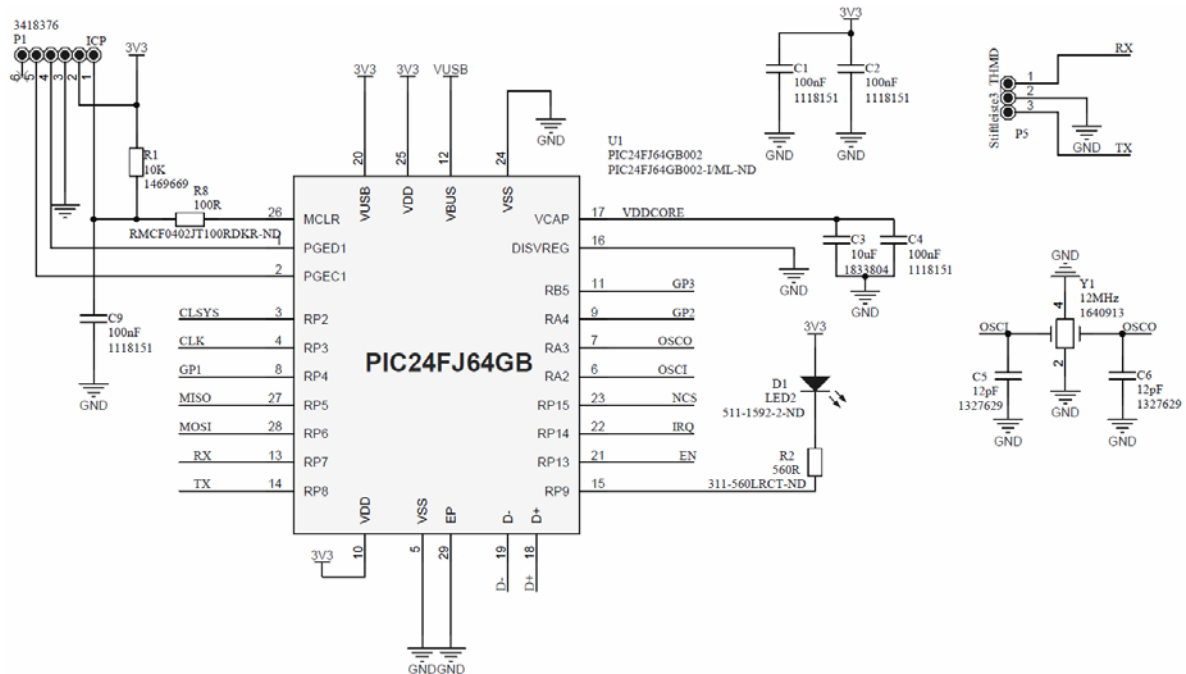


Figure 14 - Schematic MCU Section



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