RFIDiceBoard

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System Design

The RFIDiceBoard operates on an RP2040 microcontroller, a PN532 RFID writer/reader, a TFT display, and user operated buttons. The PN532 receives data from RFID tags and sends that data over I^2C to the RP2040. The RFID tag data is then identified by the RP2040 to determine which subset of random numbers to generate. The random numbers may also be modified by the user operated buttons. The final number generated by the RP2040 is the displayed on the display over SPI.

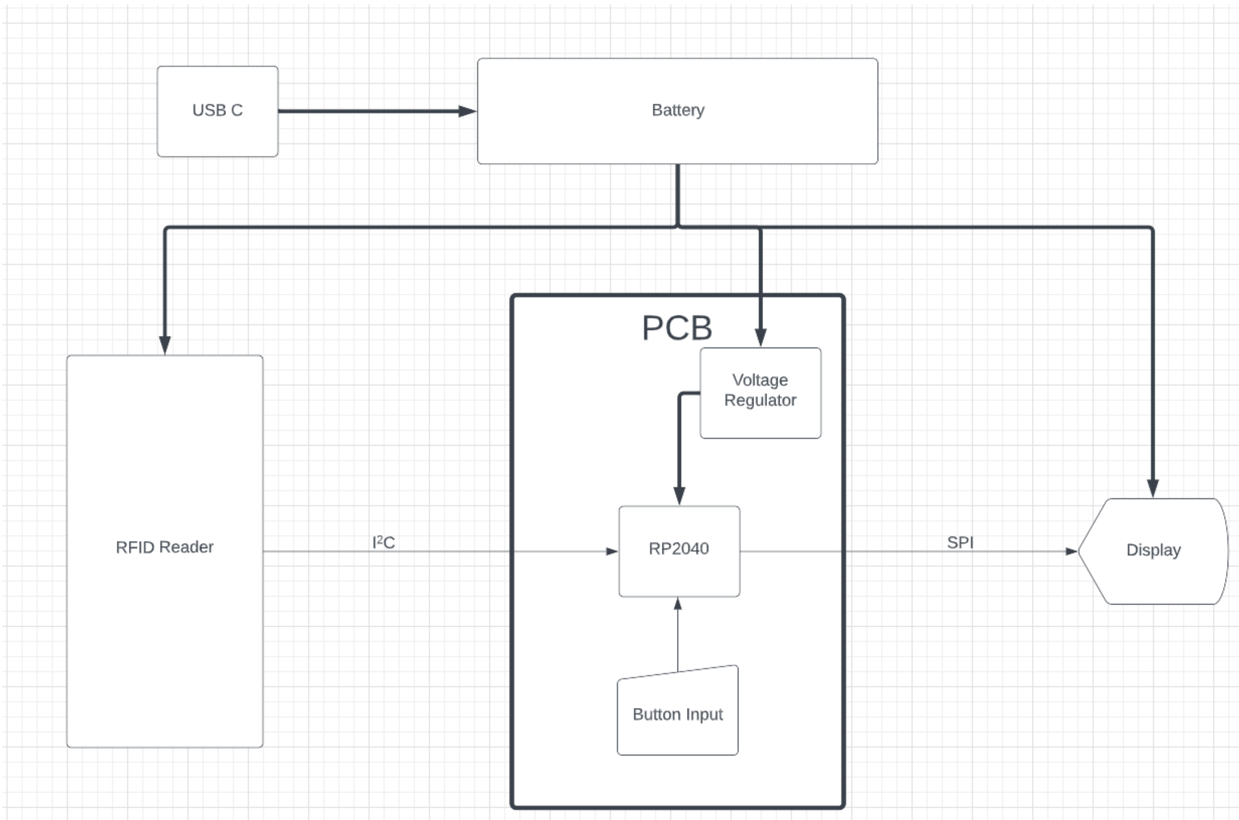

Figure 1 – System Design Flow Chart

System Schematic

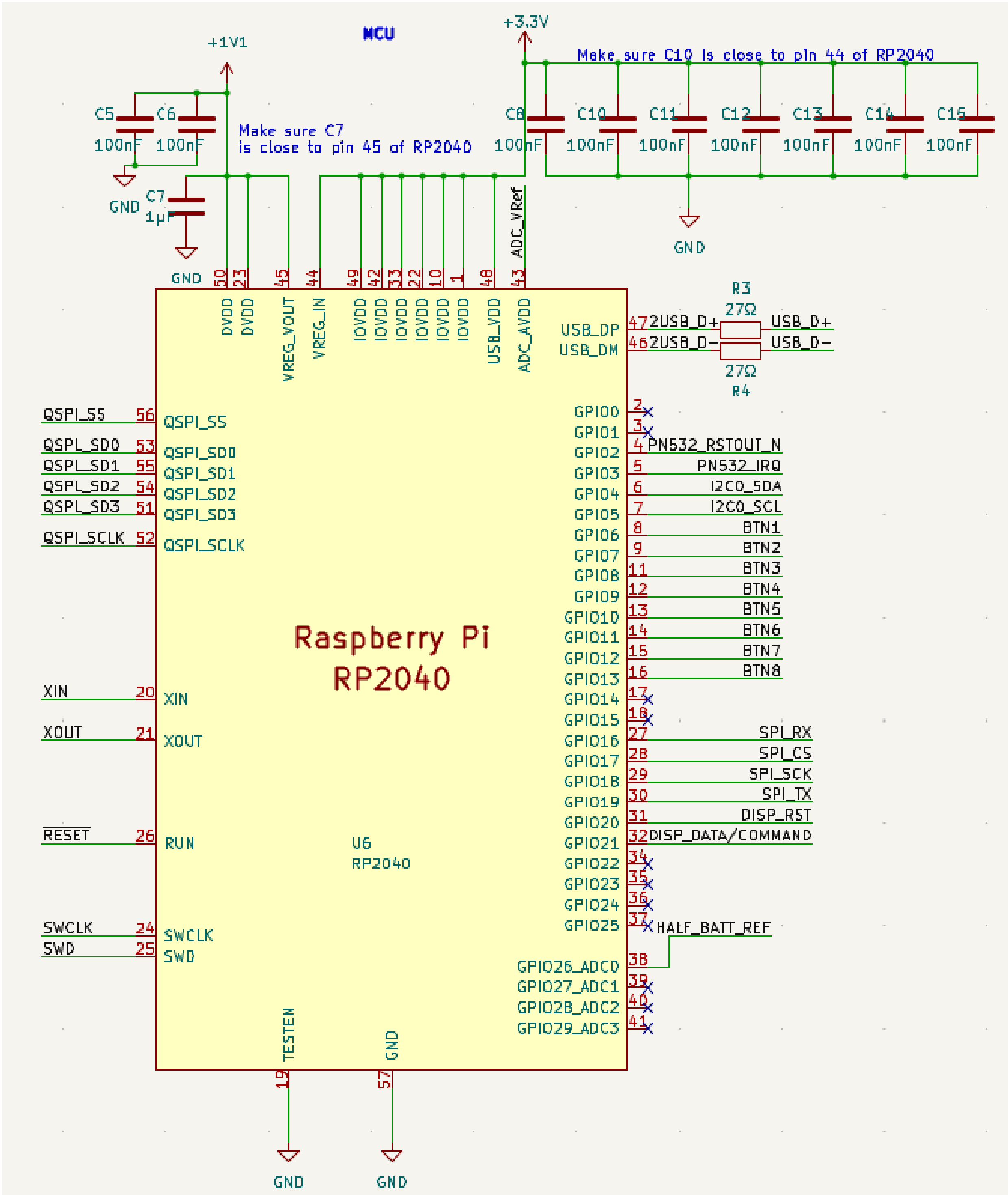

Figure 2 – MCU

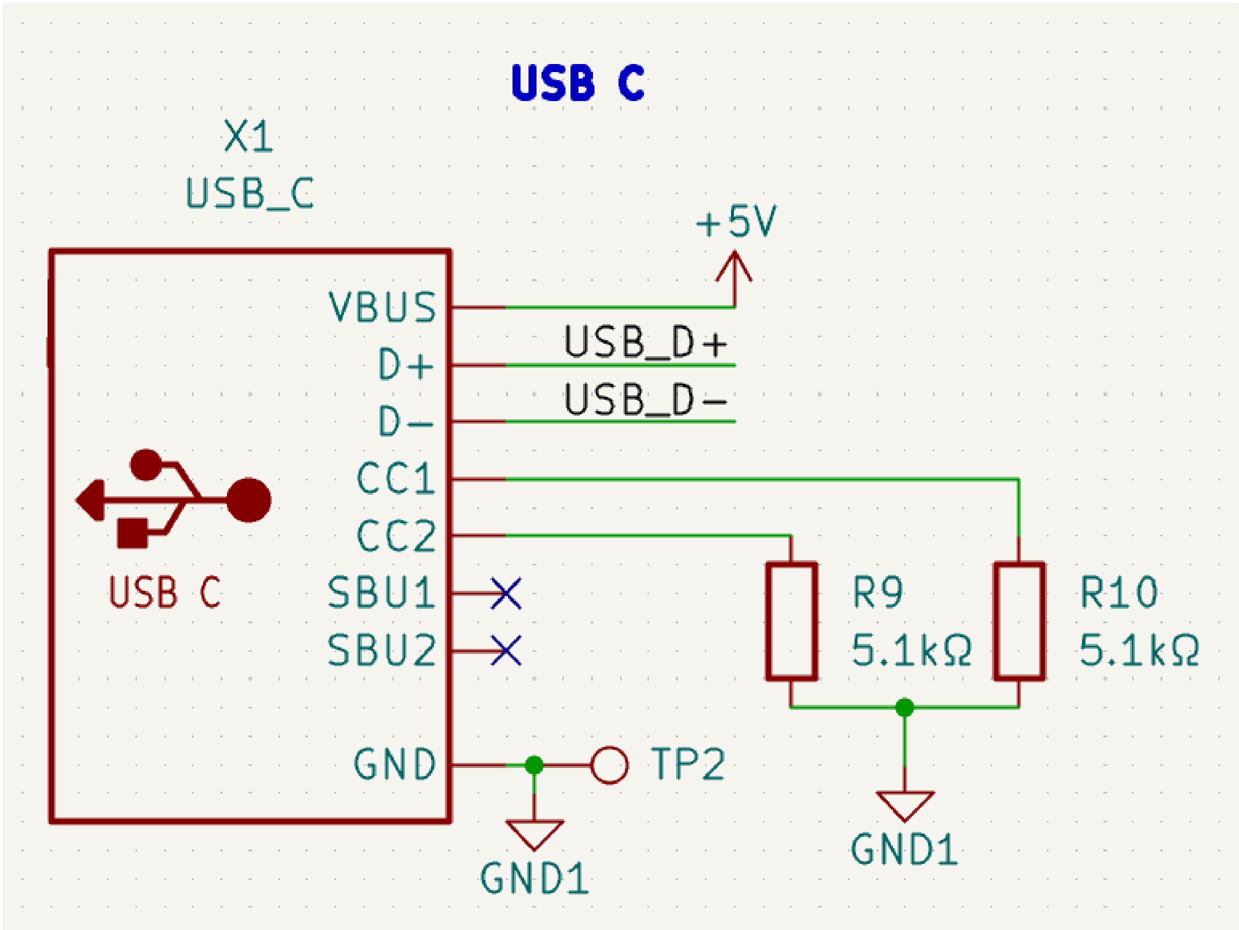

Figure 3 – USB C Connector

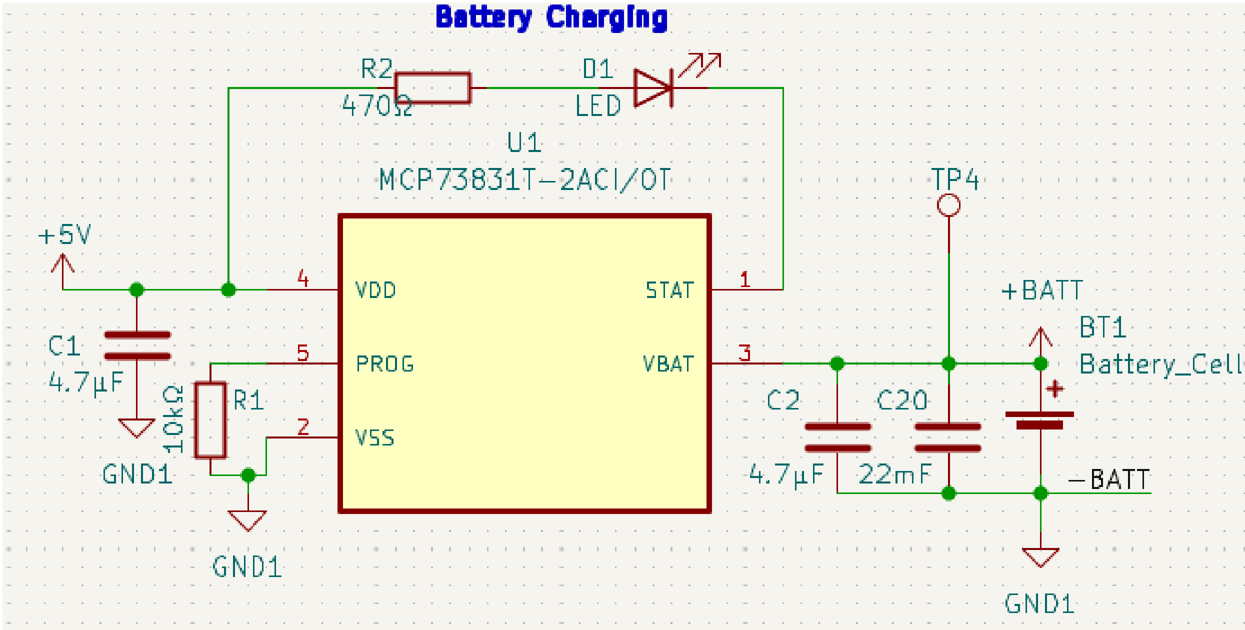

Figure 4: Battery Charger

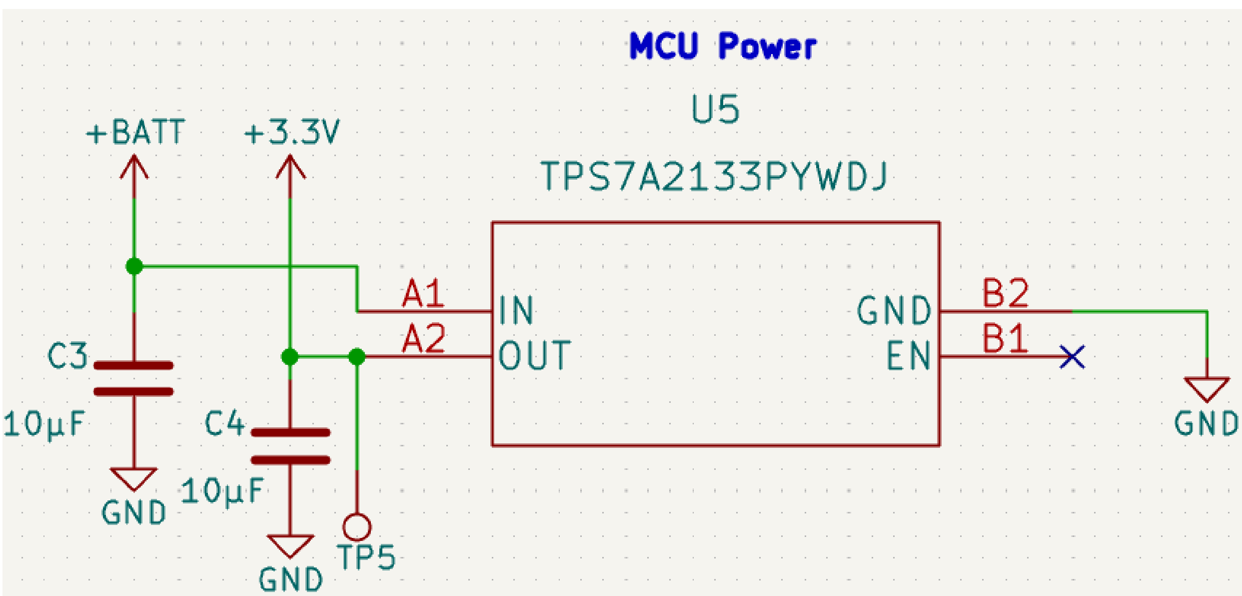

Figure 5: Linear Regulator

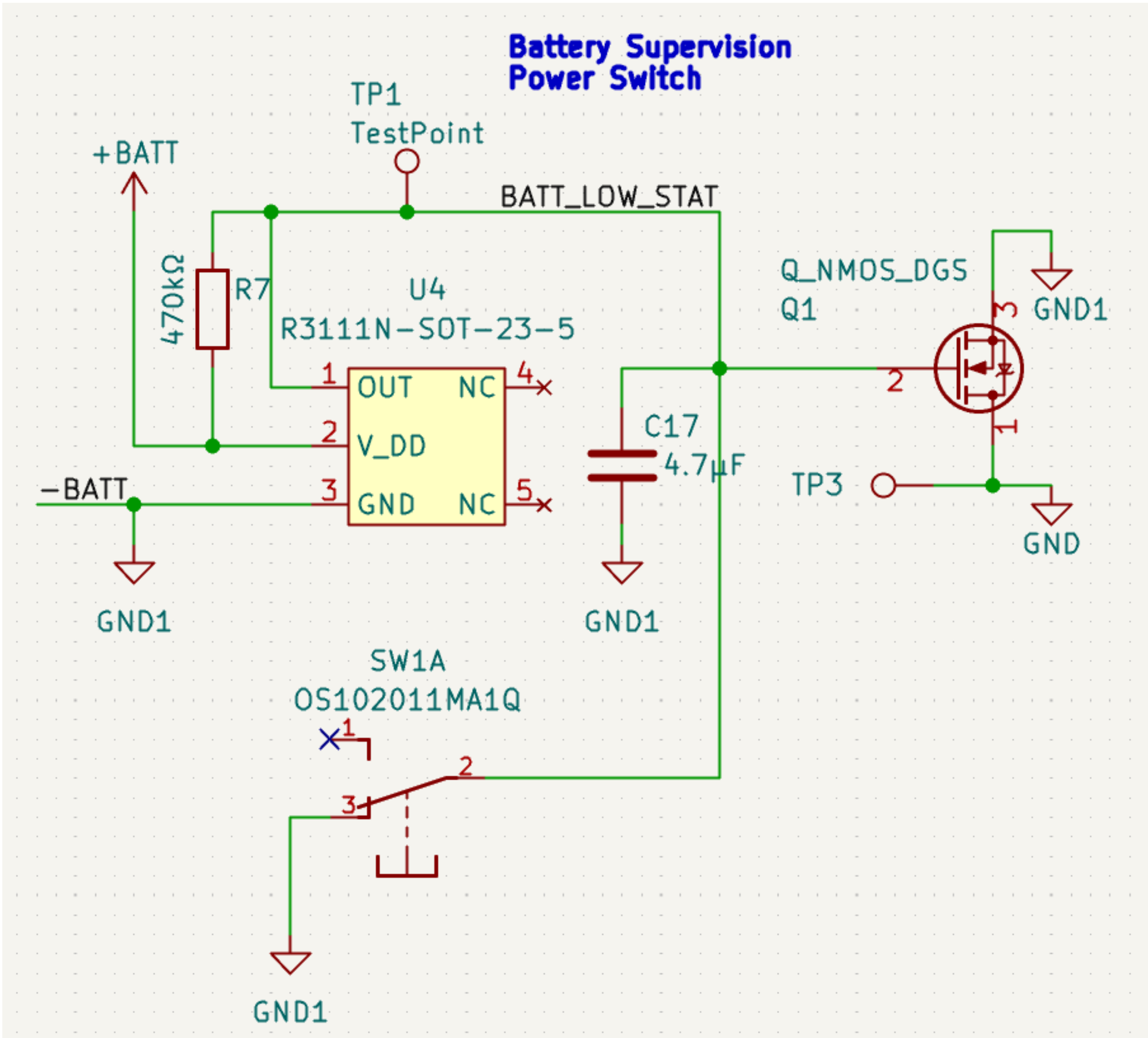

Figure 6: Low-Voltage Detector and Power Switch

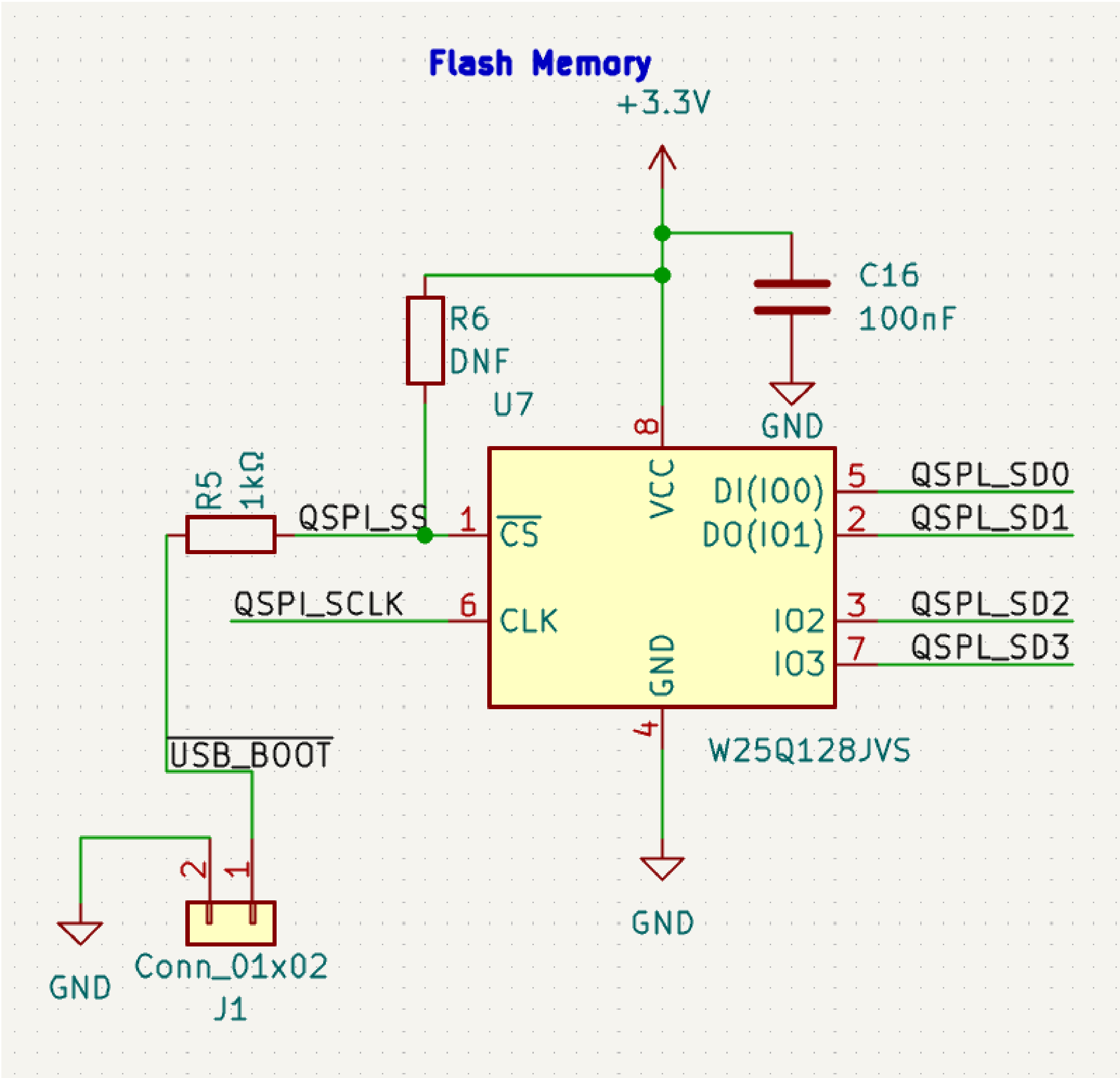

Figure 7: MCU’s Flash Memory

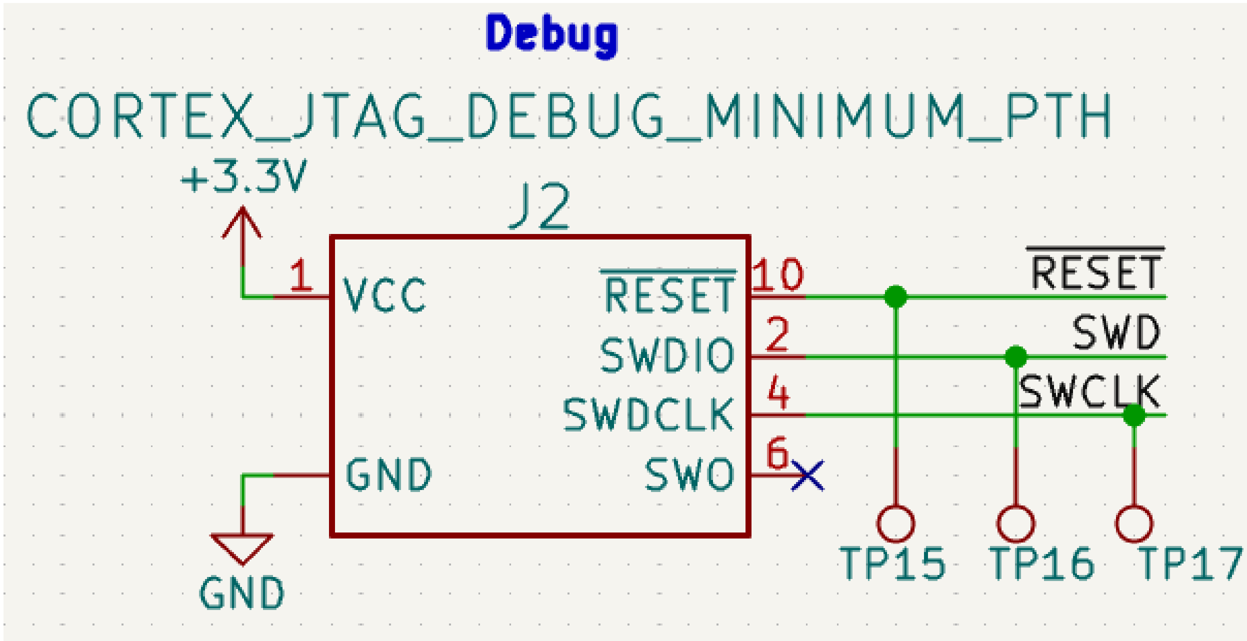

Figure 8: SWD Debug Header

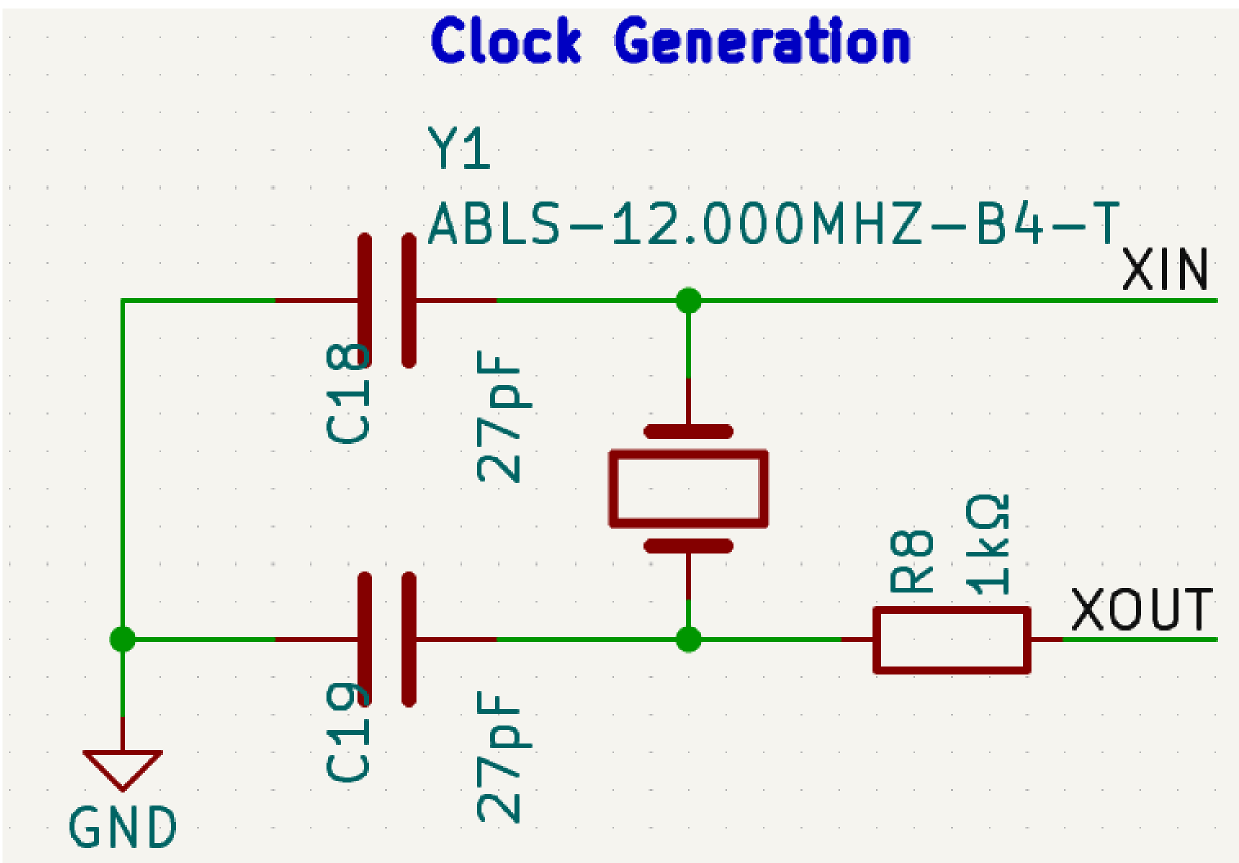

Figure 9: Exterior MCU Crystal Oscillator

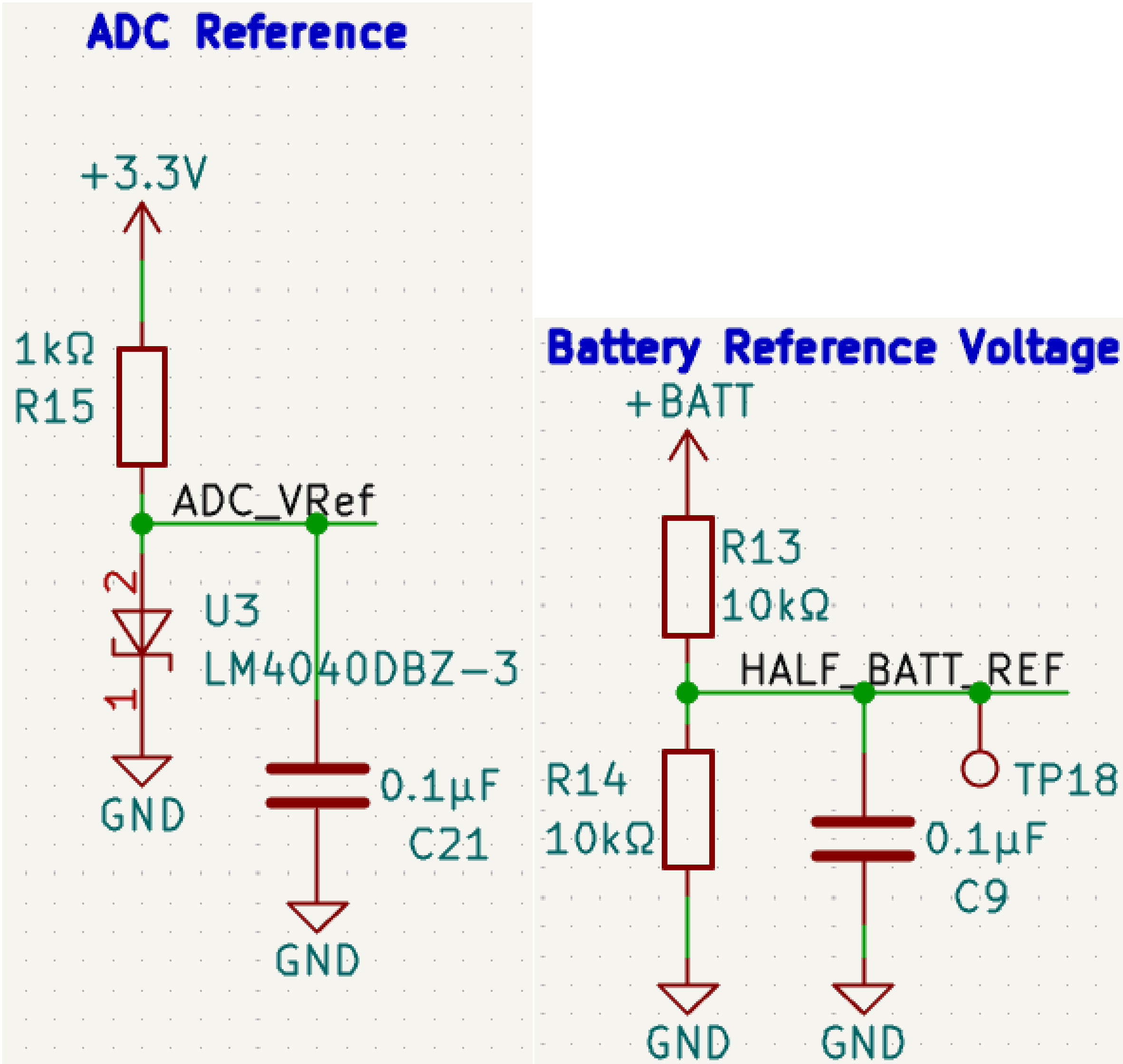

Figure 10: Reference Voltages

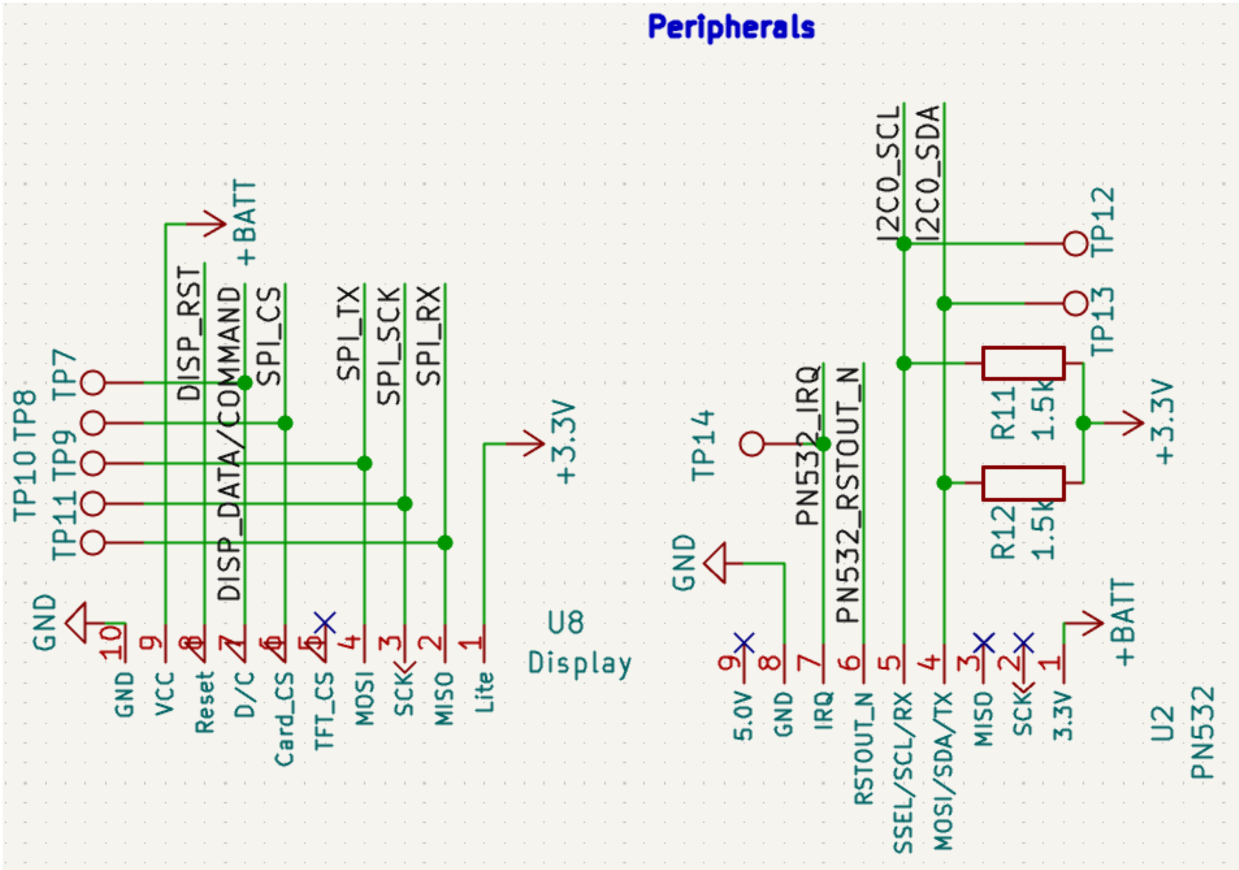

Figure 11: Display and RFID Reader/Writer Through-hole

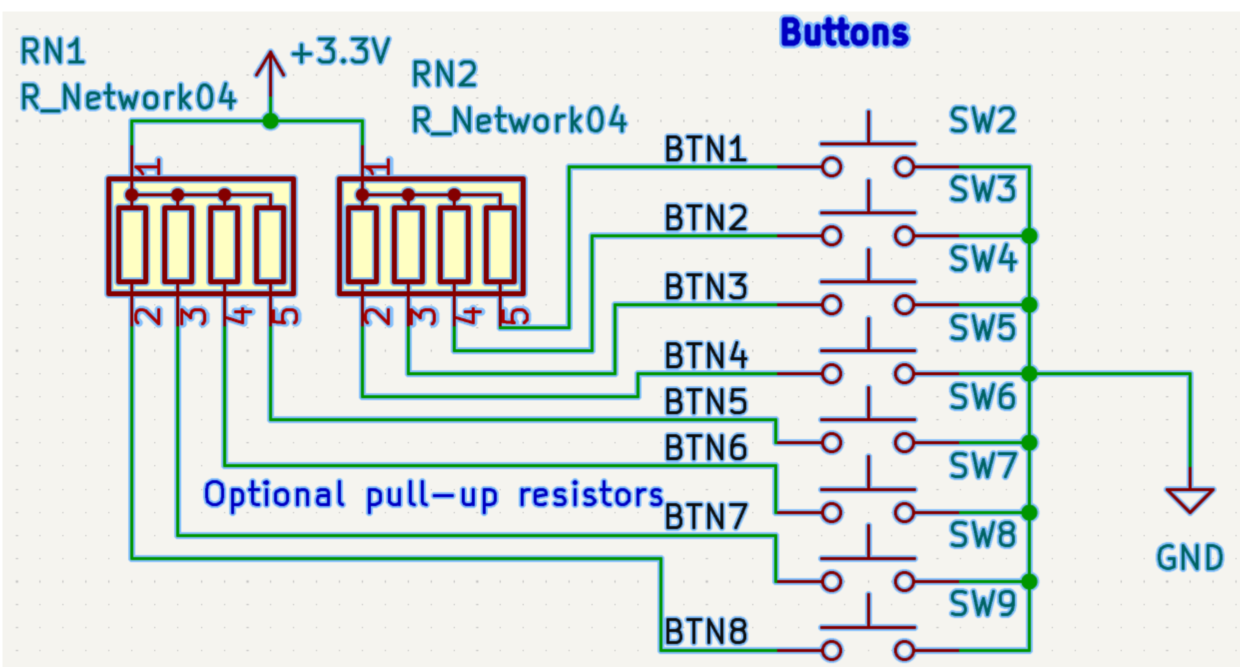

Figure 12: Buttons

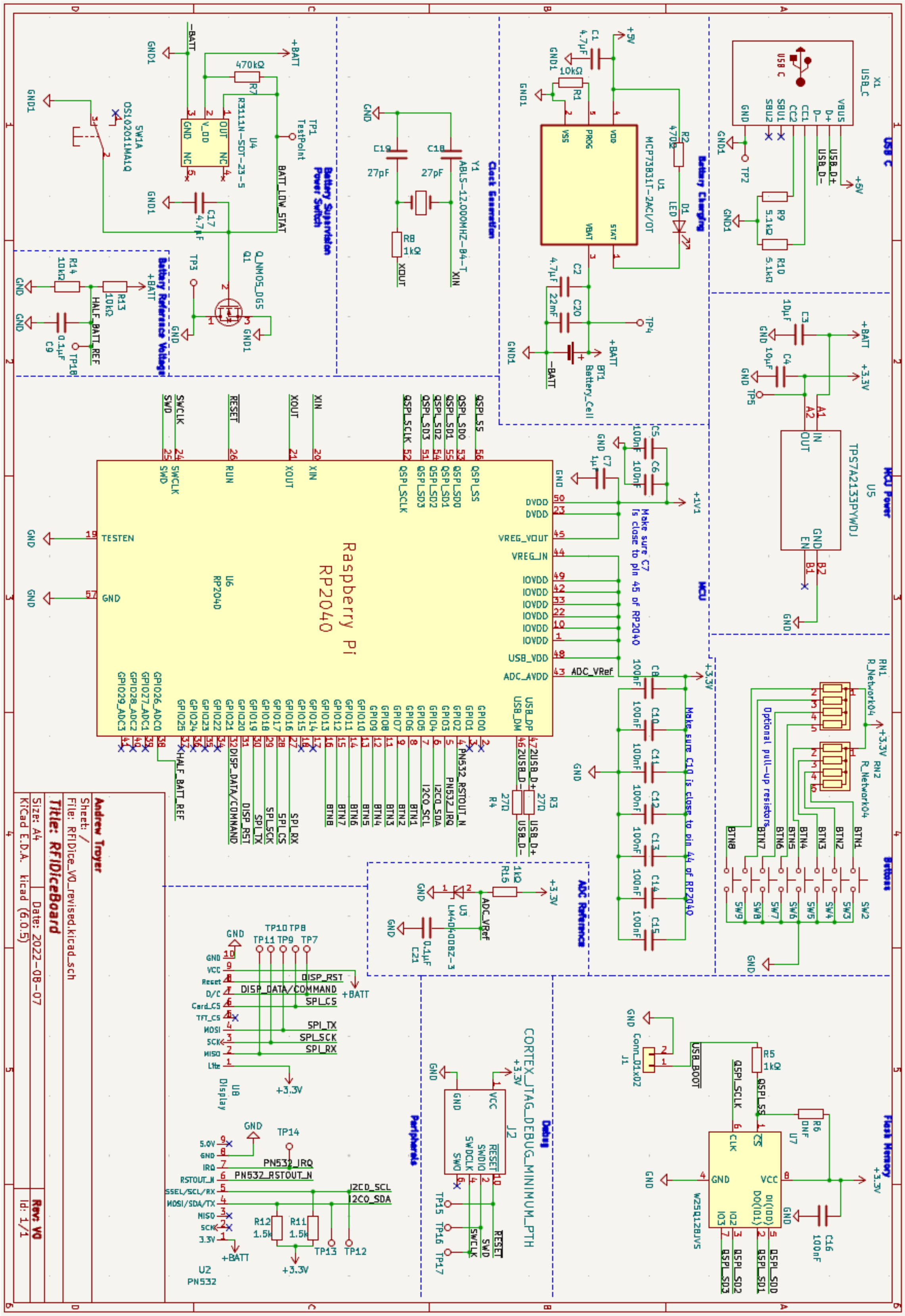

Figure 13: Full Schematic Design

PCB Design

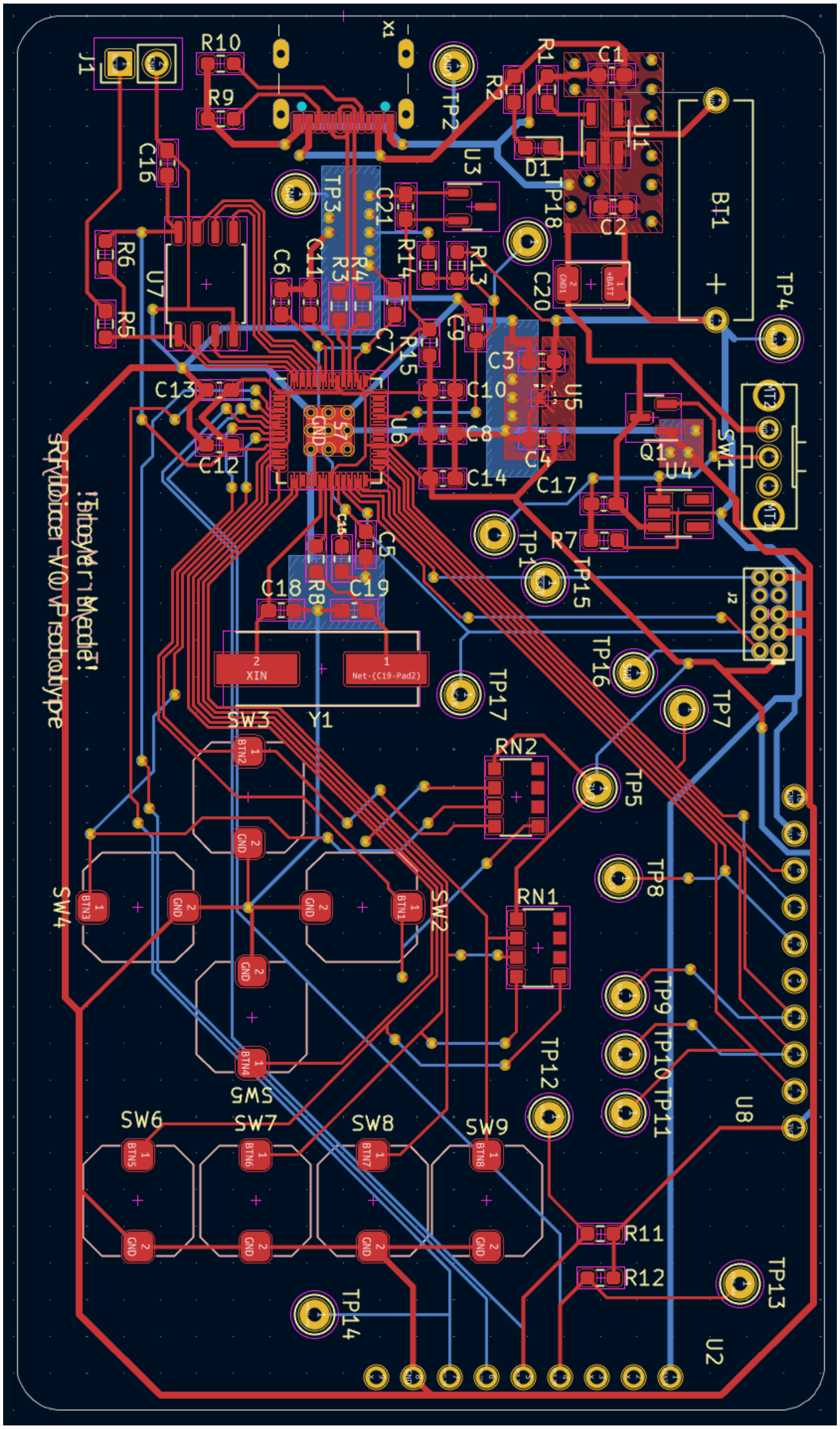

Figure 14: PCB Front

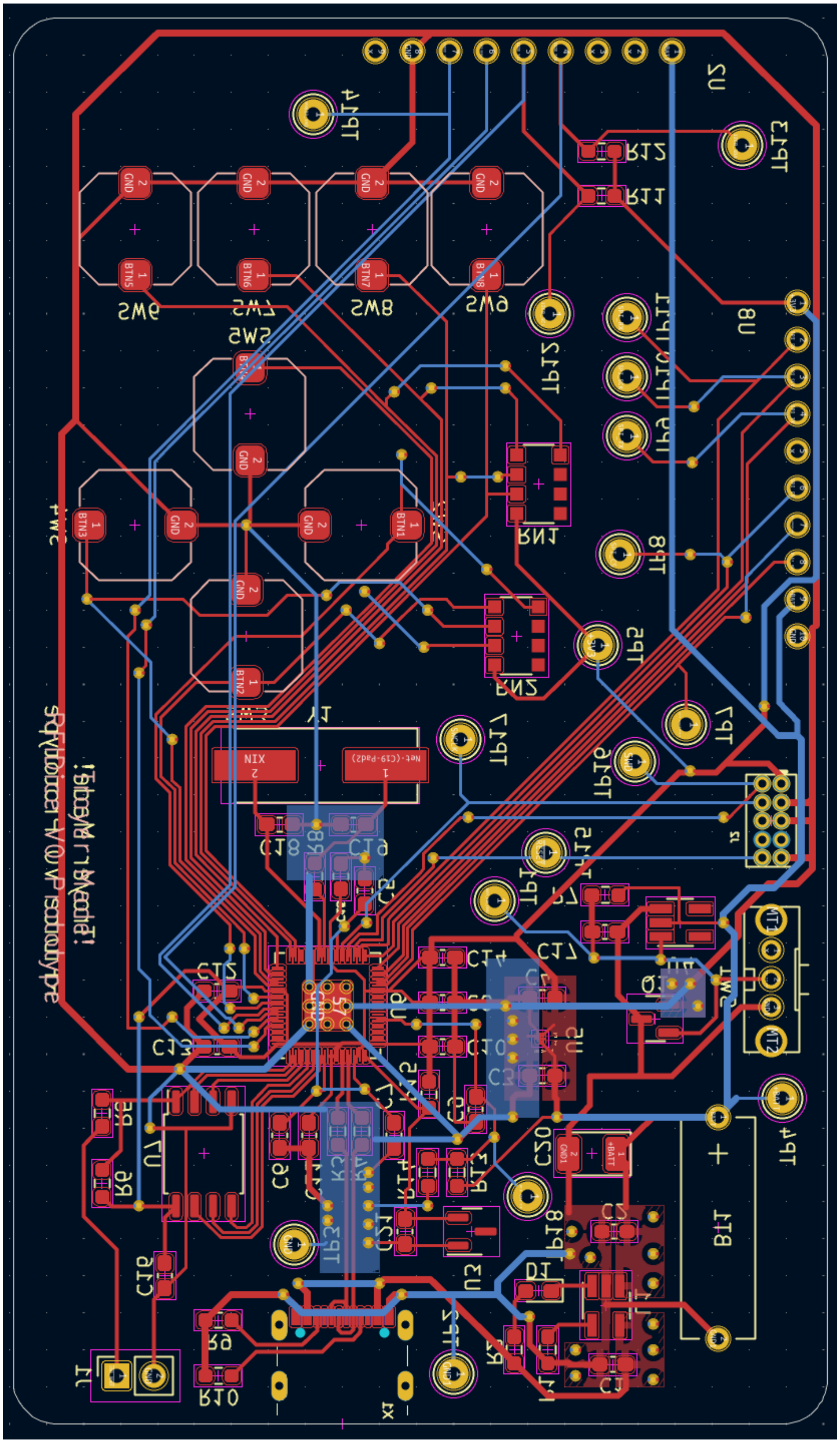

Figure 15: PCB Back

Bill of Materials

USB C Connector	Adafruit	Adafruit/4458	N/A	X1	USB_C_CUSB31-CFM2AX-01-X	1
Linear Regulator	Texas Instruments	TPS7A2133PYWDJ	N/A	U5	SOT-23-3	1
Button	Panasonic Electronic Components	P16856CT-ND	N/A	BTN1-BTN8	Handmade	8
Battery Charger	Spark Fun	MCP73837T-2ACI/OT	N/A	U1	SOT-23-5	1
Crystal Oscillator	Abracon LLC	ABLS-12.000MHZ-B4-T	N/A	Y1	Crystal_SMD_HC49-US	1
Supervisor	Nisshinbo Micro Devices Inc.	R3111N-SOT-23-5	N/A	U4	SOT-23-5	1
NMOS	Generic	Generic	N/A	Q1	SOT-23-3	1
MCU	Raspberry Pi	RP2040	N/A	U6	QFN-56	1
Flash Memory	Winbond Electronics	W25Q128JVS	N/A	U7	SOIC-8_5.23x5.23mm_P1.27mm	1
SWD Debug Header	Generic	Generic	N/A	J2	2X5-PTH-1.27MM	1
RFID Writer/Reader	Adafruit	PN532	N/A	U2	Dev-board Through-hole	1
Display	Adafruit	Adafruit/358	N/A	U8	Dev-board Through-hole	1
Voltage Reference	Texas Instruments	LM4040DIM3-3.0/NOPB	N/A	U3	SOT-23	1
2-Pin Connector	Generic	Generic	N/A	J1	PinHeader_1x02_P2.54mm	1
Slide Switch	C&K	108-PTS847MM160LSMTR2LFSCT-ND	N/A	SW1A	OS102011MA1Q	1
LED	Generic	Generic	N/A	D1	Imperial 0603	1
Resistor	Generic	Generic	10kΩ	R1, R11-14	Imperial 0603	5
Resistor	Generic	Generic	470Ω	R2	Imperial 0603	1
Resistor	Generic	Generic	27Ω	R3, R4	Imperial 0603	2
Resistor	Generic	Generic	1kΩ	R5, R8, R15	Imperial 0603	3
Resistor	Generic	Generic	470kΩ	R7	Imperial 0603	1
Resistor	Generic	Generic	5.1kΩ	R9, R10	Imperial 0603	2
Capacitor	Generic	Generic	4.7µF	C1, C2, C17	Imperial 0603	3
Capacitor	Generic	Generic	10µF	C3, C4	Imperial 0603	2
Capacitor	Generic	Generic	100nF	C5, C6, C8, C10-C16	Imperial 0603	9
Capacitor	Generic	Generic	1µF	C7	Imperial 0603	1
Capacitor	Generic	Generic	27pF	C18, C19	Imperial 0603	2
Capacitor	Generic	Generic	0.1µF	C9, C21	Imperial 0603	2
Tantalum Capacitor	Generic	Generic	22mF	C20	Imperial 3528	1
Test Point	Generic	Generic	N/A	TP1-TP5, TP7-TP18	TP_Imperial_5000-5004_Miniature	17

Part Selection Mini-Report

The RFIDiceBoard requires 3.3 Volts to operate. Table top gaming excels in mobility so mobility of the RFIDiceBoard is a priority. Requiring the board to be within reach of an electrical outlet would limit the devices mobility. As a result the RFIDiceBoard has a battery component to allow wireless usage.

Two common options for powering mobile devices via battery are AA batteries and Lithium Polymer (Li-Po) batteries. AA batteries are available in many chemistries and can be either single use or rechargeable. They are widely available and accessible. Li-Po Batteries use polymer electrolyte to store energy. The availability of Li-Po batteries has increased with the rise of applications requiring light energy storage such as cell phones, drones, and other highly mobile devices.

Non-rechargeable AA batteries often come in 1.5 volt packages and rechargeable AA batteries come in 1.2 volt packages. The RFIDiceBoard requires 3.3 volts to run so at least three AA batteries would be needed. The consumer could decide to run the RFIDiceBoard with rechargeable batteries at a voltage of 3.6 volts or could use non-rechargeable batteries which would sit at 4 volts.

Li-Po batteries run from 4.2 Volts to 3.6 volts over the course of a discharge with a nominal voltage of 3.7 Volts.

AA batteries come in one standard size and Li-Po batteries standardly come in slim cylinders or flat rectangles. Li-Po batteries also can come in stranger shapes like horse-shoes.

AA batteries only require a sturdy housing for the batteries. Most devices that include Li-Po batteries require an on-board battery charger.

AA batteries tend to corrode when stored for long periods of time or when stored incorrectly. Alkaline AA batteries leak potassium hydroxide which can irritate eyes and skin. Li-Po batteries tend to last longer in storage than AA batteries. However, Li-Po batteries catch fire fast when pierced and are notoriously difficult to put out.

Both batteries are commonly disposed of in incorrect ways. Both AA and Li-Po batteries leak manganese in landfills but Li-Po batteries also can cause terrible fires when disposed of.

In the end, the Lithium Polymer battery was chosen for its static flexibility. It allows the user to go mobile if they wish to and doesn’t require them to keep other batteries on hand.

Assembly and Test Procedure

Initial MCU Test

Solder on Y1, C18 and C19.

Solder on U7, C16, and Connector J2.

Solder on C5-C8 and C10-C15.

Solder on TP5 and TP3

Continuity test all the previous nets for strange continuities.

Use the stencil to apply solder paste to the pads for the MCU U6. Use the solder reflow oven to bake the MCU onto the PCB.

Use a power supply to provide 3.3 Volts across TP5 (3.3V) and TP3 (GND). Program the MCU through the JTAG connector with test code to flip one of the button's pads or a pin for the display or RFID reader to a 0 to 1 repeatedly to test signs of life in the MCU.

Linear Regulator Test

Using a Solder mask and a solder reflow oven solder on U5, C3 and C4. Continuity test

Solder on TP4

Use a power supply to provide 4 Volts across TP4 and TP3. Test the voltage at TP5 for 3.3 Volts.

USB Test

Solder on X1, R3, R4, R9, R10, and TP2. Continuity test.

Plug in the USB connector and test for 5V across the USB C 5 VBus pin (Top most pin if USB C connector is facing left) and GND (TP2).

Solder on R5, and J1

Short J1 and plug in the USB C Connector into a computer's USB slot. A folder for the RP2040 should show up on the file explorer, allowing UF2 Files to be dropped in to program.

Battery Charging Test

Solder on U1, R1, R2, D1, C1, C2, and C20. Continuity test.

Solder on the Battery to BT1.

Solder on U4, R8, C18, SW1, and Q1. Continuity test

Test if the device get correctly powered by the battery through the linear regulator

Test if the switch correctly turns on and off the device

Display, RFID Reader, and Buttons

Solder on U8, U2, and SW2-SW9

Programming of the Microcontroller is required to test if these components correctly work

RN1 and RN2 are optional

Final Status

I’ve got the PCB printed and in hand with all the necessary components as well. A few PCB errors that I’ve noticed:

The USB C connector needed slotted holes for mounting.

The thermal relief zone around the battery charger is full of unintentional holes.

The RFID reader is mounted backwards.

C20 is the wrong size capacitor for what Western has on hand.

I am ready to start testing what is wrong with my PCB but I am a bit behind as of writing this paper.