Final Project Design Documentation and User Manual

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EE 110c

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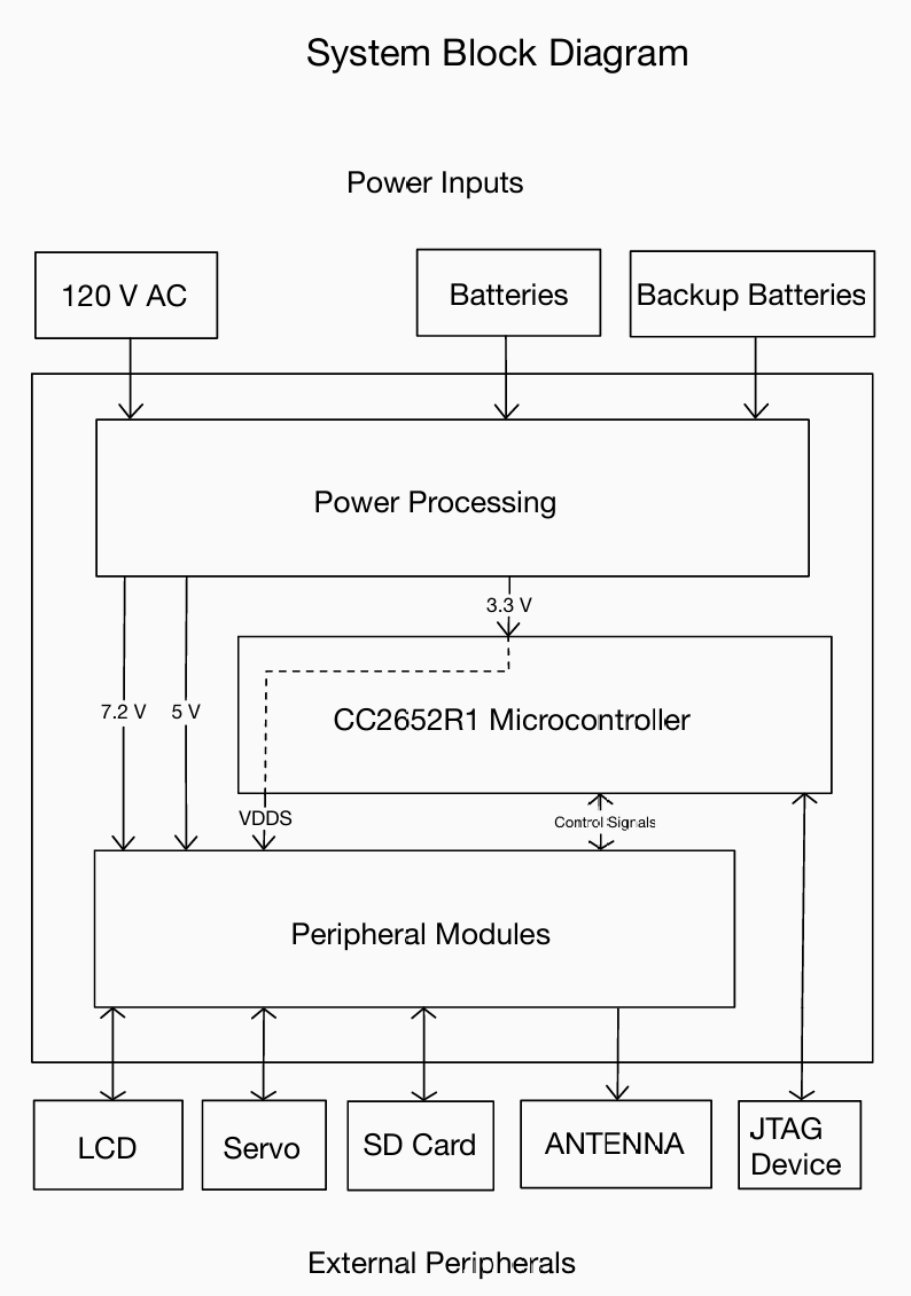
Project Summary and Capabilities

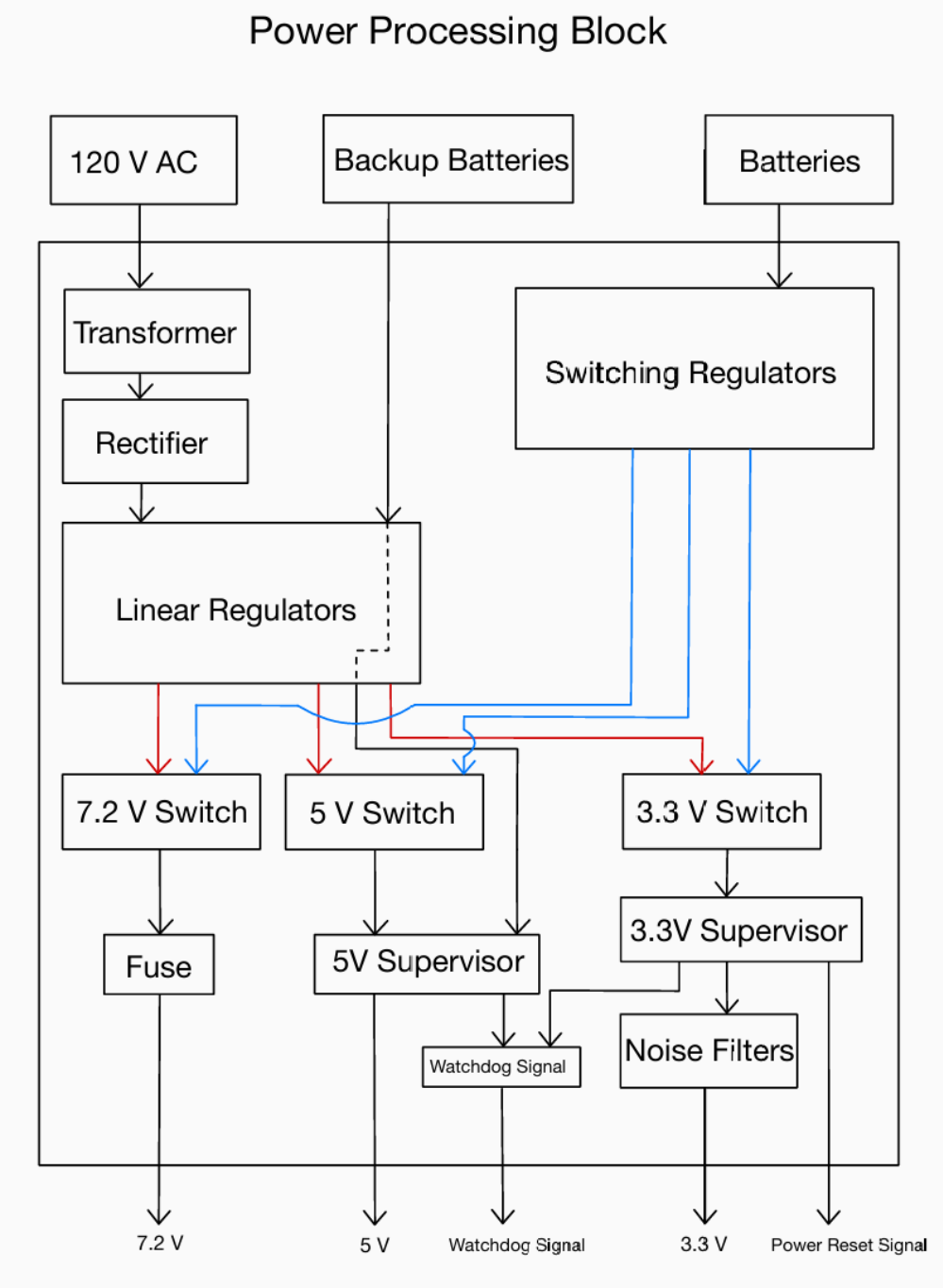
This project is a prototype test board that contains all the required systems for testing the systems for a wireless servo controlled robot and its control board. Here is a list of its features

- Three level power generation from both AC and battery power
    - 7.2 V
    - 5 V
        - Supervision IC
        - Backup battery source
    - 3.3 V
        - Supervision IC
- JTAG programmable TI CC2652R1 microcontroller
    - 10 pin JTAG connector
- Button, supervisor, and JTAG reset system
- Watchdog timer compatibility
- 7.2 V powered servo motor with feedback system
    - Fuse included for current protection
    - Proof of concept for wireless robot
- 5 V powered servo motor signal opamp
- 5 V powered LCD system
    - Potentiometer controlled contrast
- 5 V powered 4x4 LED keypad
- 5 V powered audio system with speaker and mic
    - Volume potentiometer
- 3.3 V powered SPI IMU
- 3.3 V powered SPI SD card
- RF system with PCB or external antenna selection
    - Contains balun and matching network
    - MF4 standard antenna port

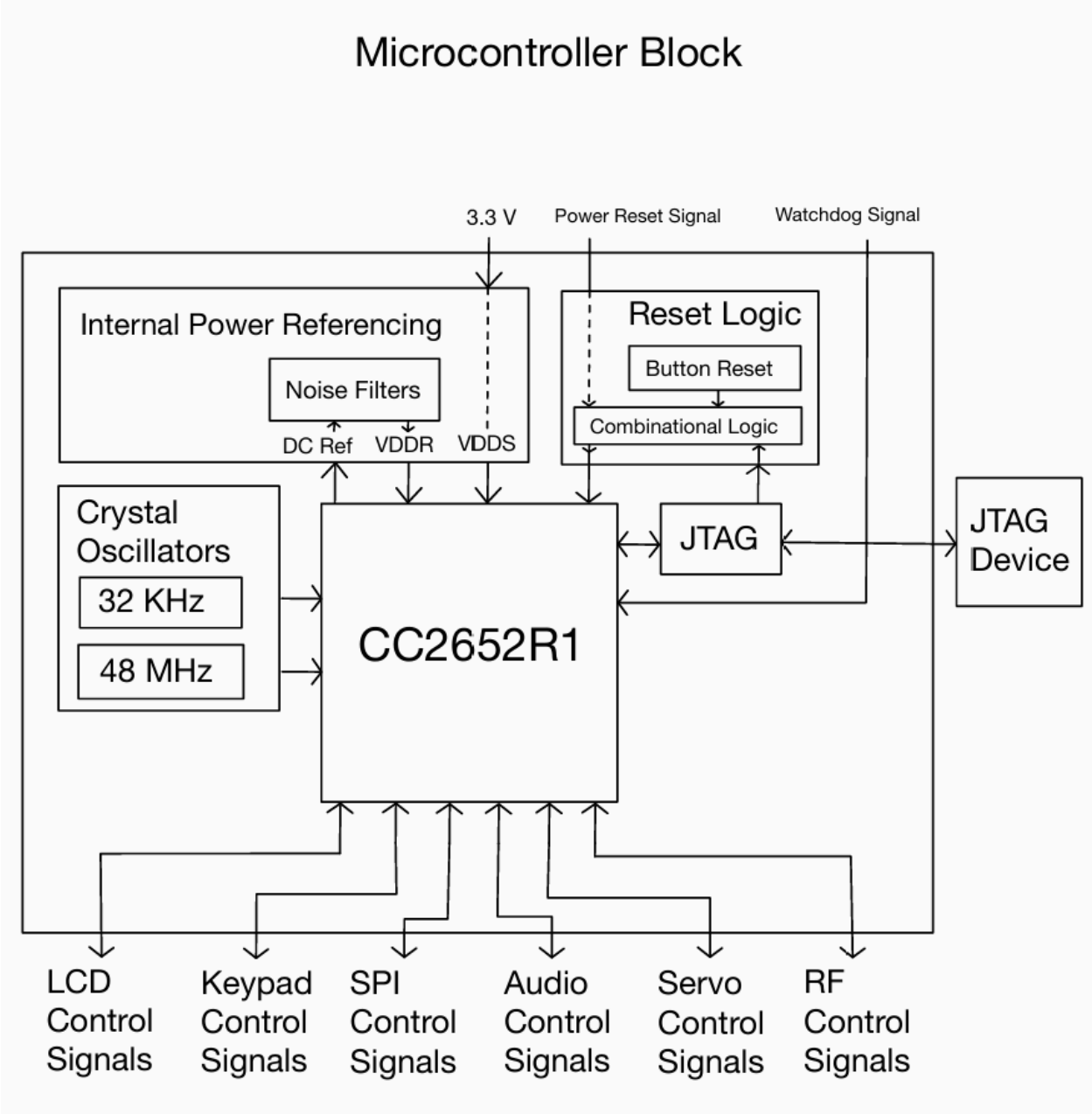
Block Diagrams



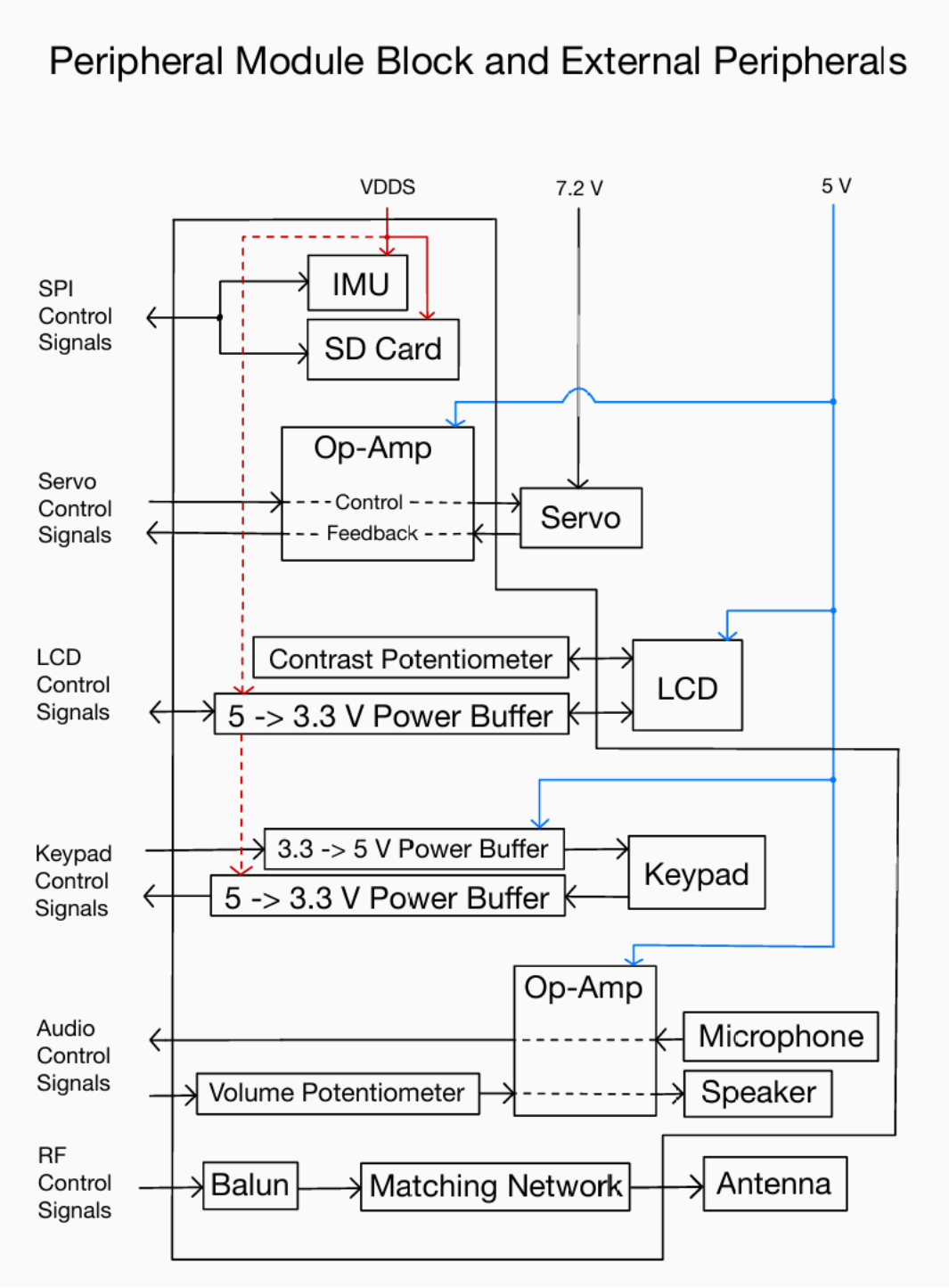
The system requires three power sources to function properly. This includes 120 V AC through a C13 power connector, and six 18650 lithium batteries. Three are for standard power and the other three are for backup power. The external peripherals include a 2x16 14 pin LCD, a feedback modified servo motor, a microSD card, and a JTAG programmer. The internal system can be simplified into three subsystems.



The power processing block processes the AC power into the three voltage levels via transformer, rectifier, and linear regulators. The backup battery power is also put through a linear regulator. The battery powered voltages are generated through switching regulators for increased power efficiency. Each power level has a switch that can be used to toggle between the two source types. The selected 7.2 V output is run through a fuse for overcurrent protection. The selected 5 and 3.3 V outputs each have supervisors that can generate a watchdog signal. The selected 3.3 V line also had noise filters to protect sensitive signals.



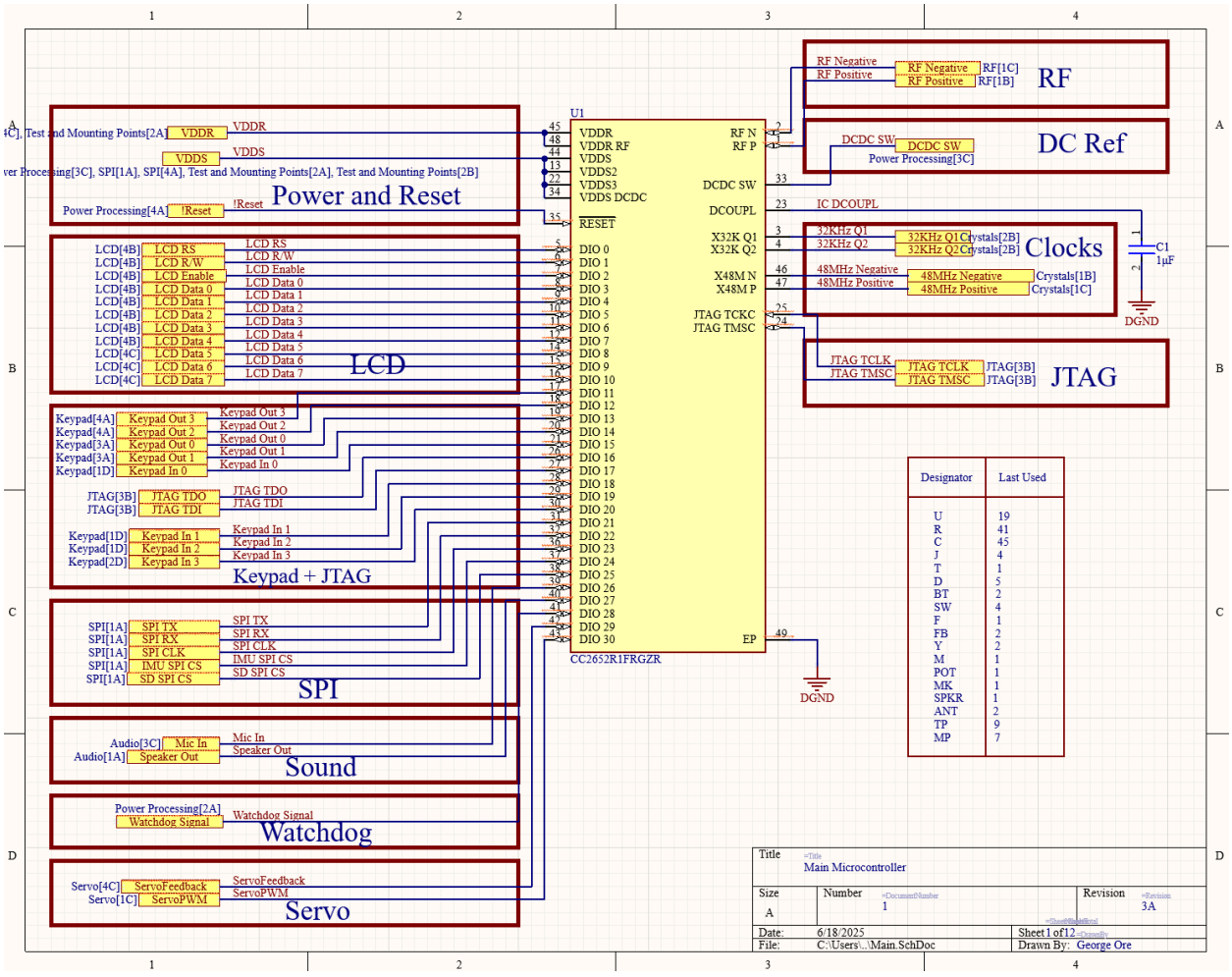
The microcontroller block contains the bare minimum operational requirements for the CC2652R1 microcontroller. This includes a 32 KHz and 48 MHz crystal oscillator source as well as a voltage reference system and a JTAG interface. The JTAG system is connected to some reset logic that can also be triggered via push button or power supervisor. All signal lines are routed in/out of this block.



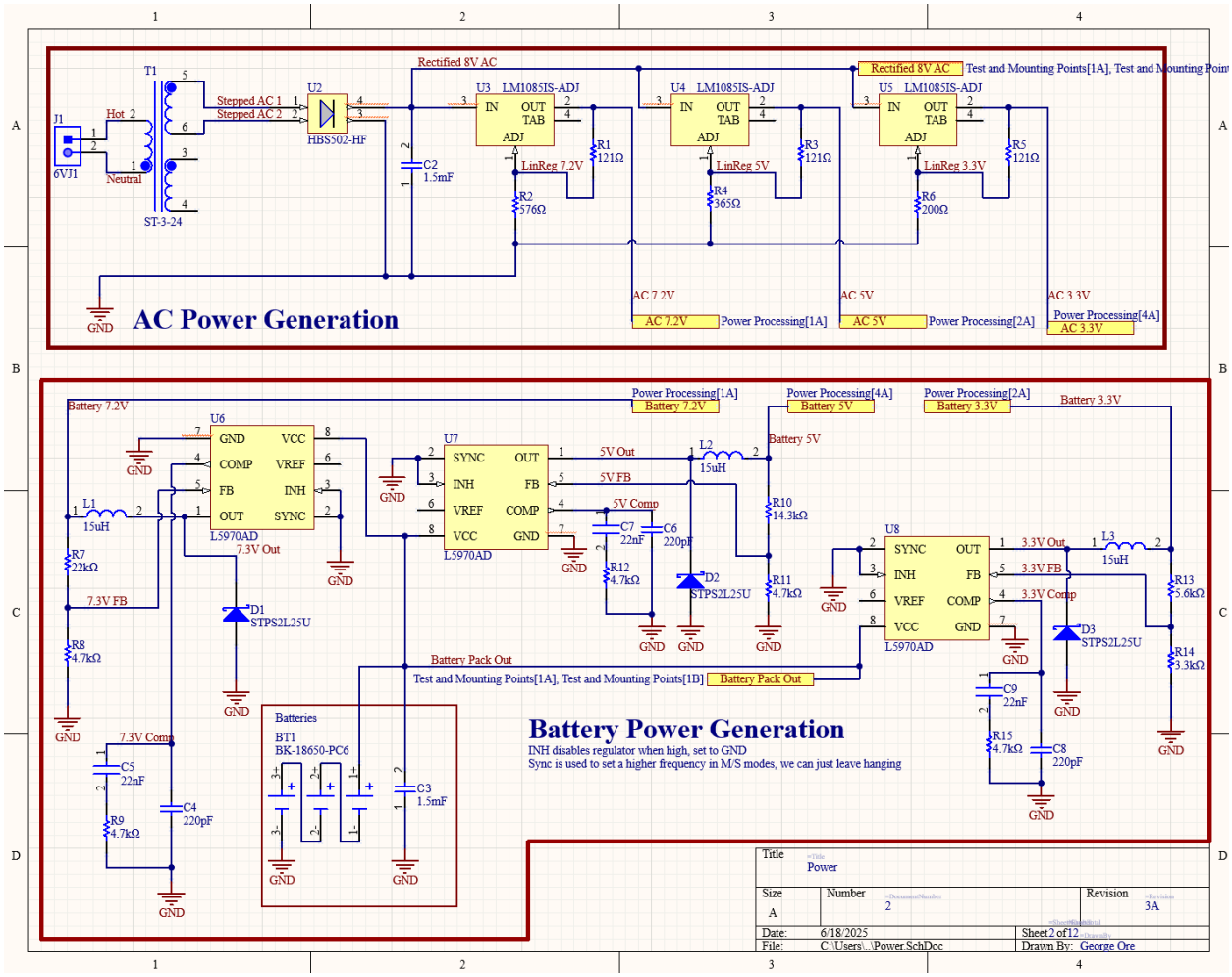
The black boxed section is the internal peripheral module block while the outside blocks are external. Each peripheral module requires a specific power source. Both the IMU and SD card share the same SPI signals. All signals to and from the servo and audio system go to an Op-Amp for signal processing. The LCD and keypad systems have voltage buffers to interface between the 5-3.3 V power levels. The RF signals pass through a balun and matching network before arriving at the antenna.

Schematics

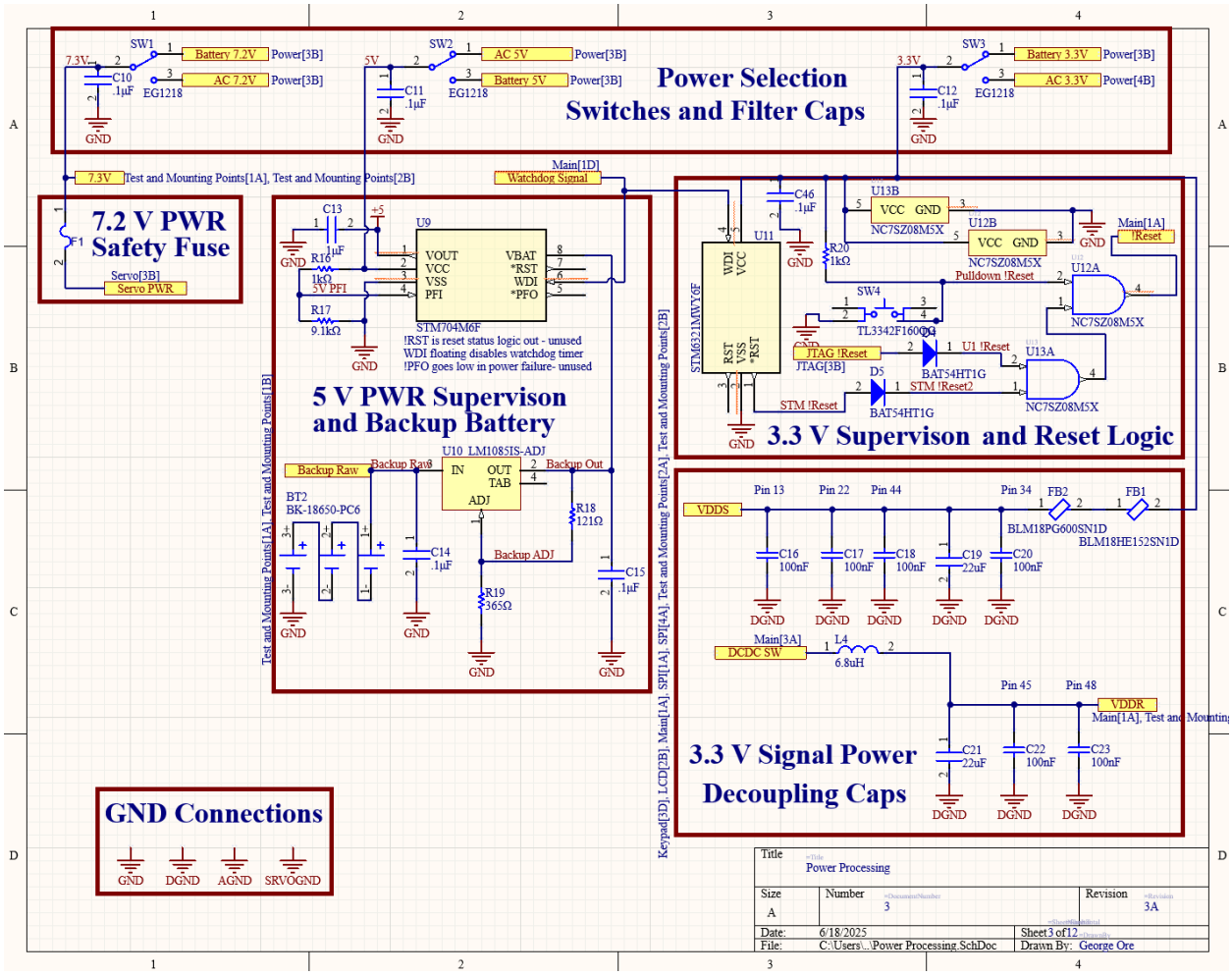
Microcontroller



Power Generation



Power Processing



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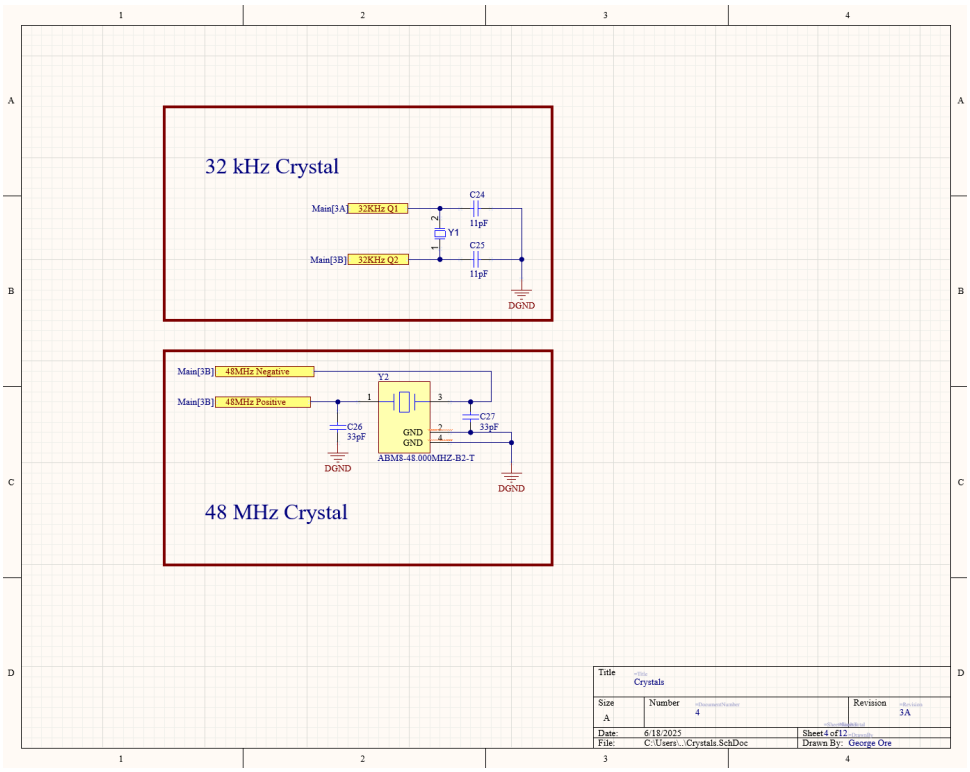
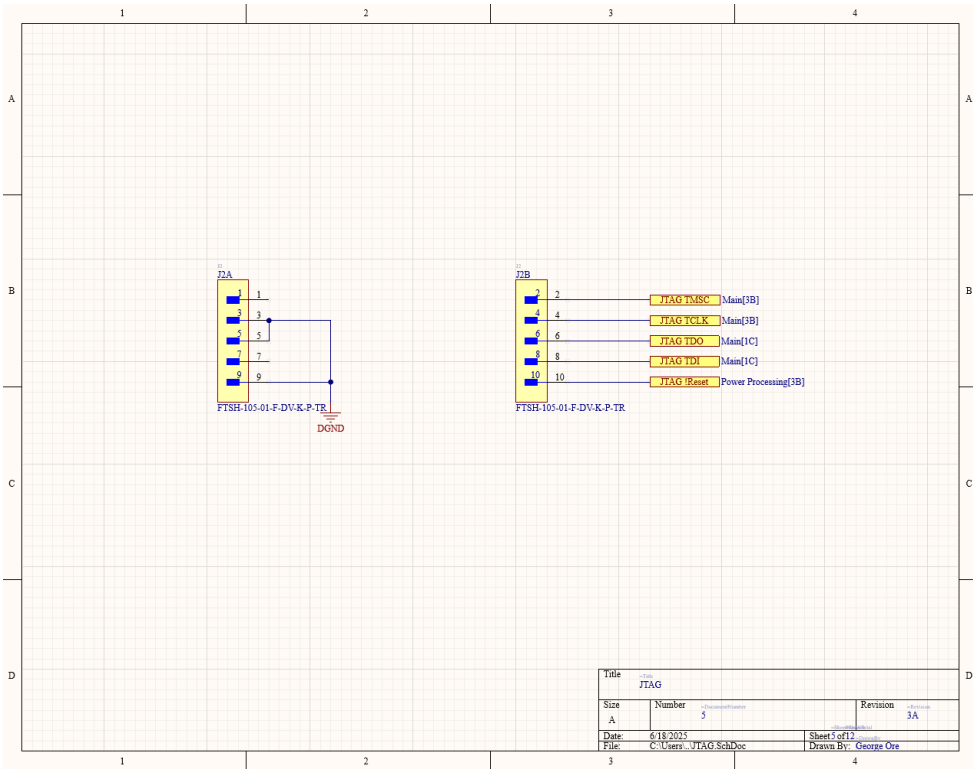
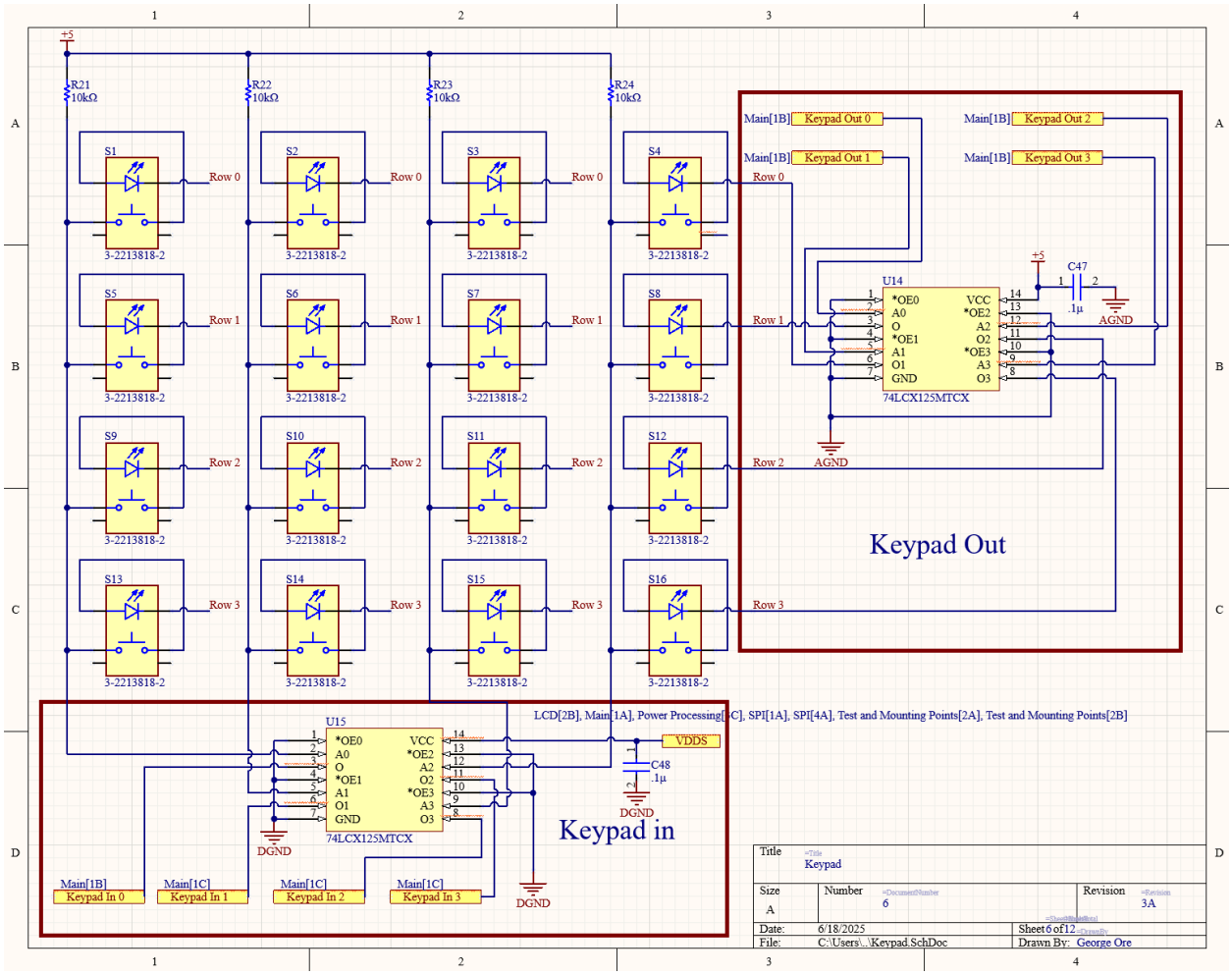
Crystal Oscillators and JTAG

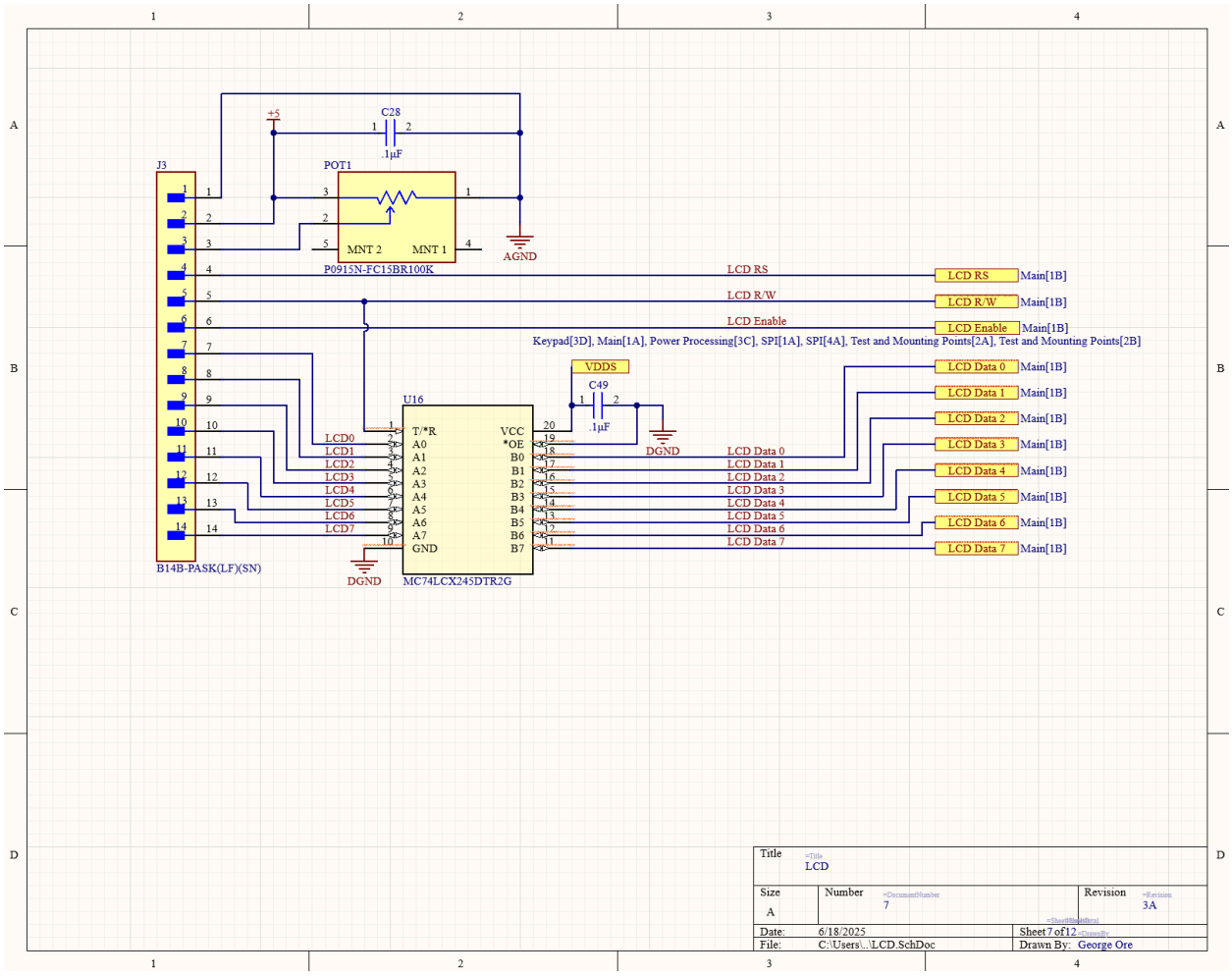




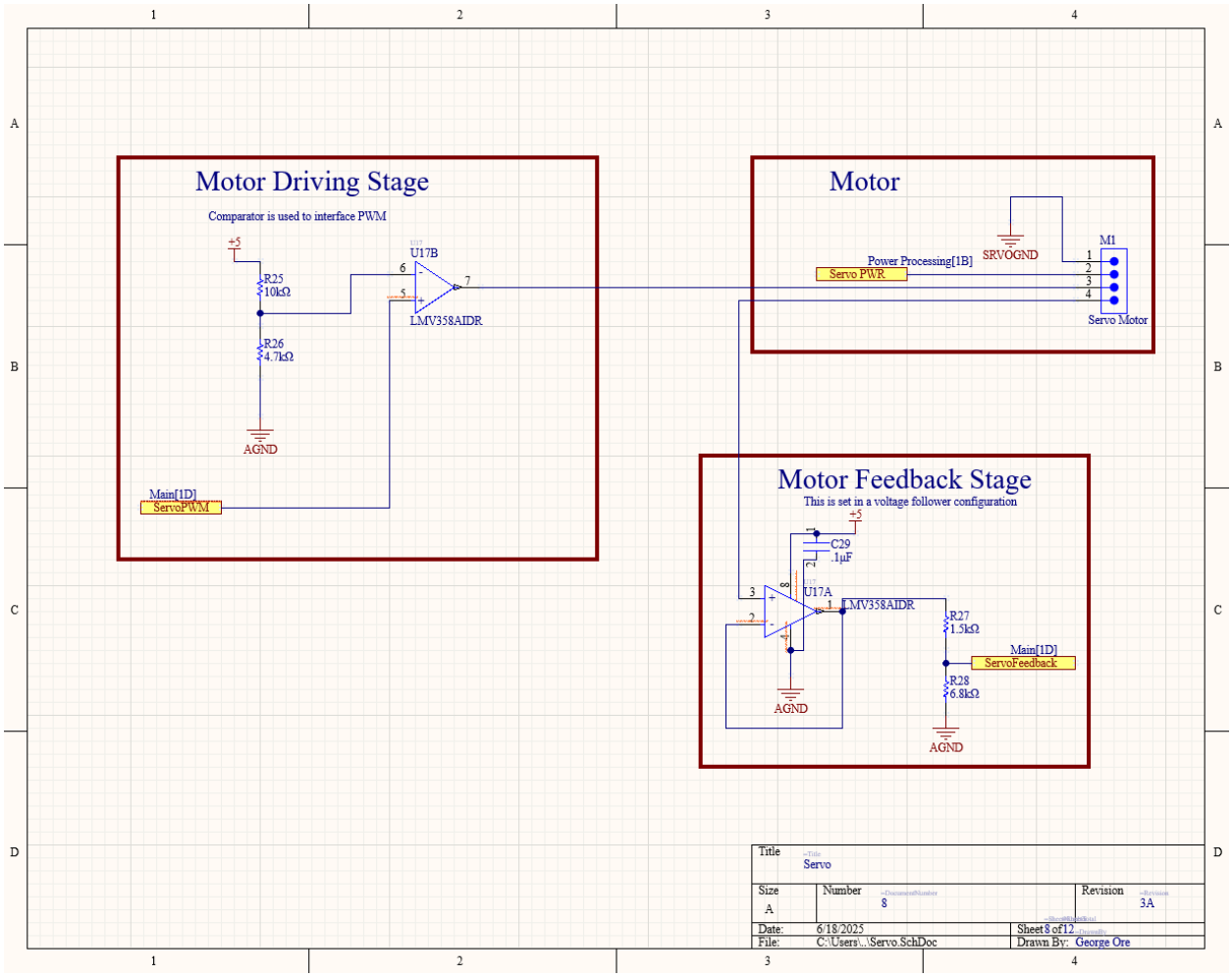
Keypad


+5
R21 10kΩ
R22 10kΩ
R23 10kΩ
R24 10kΩ
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
S12
S13
S14
S15
S16
3-2213818-2
Row 0
Row 1
Row 2
Row 3
Main[1B] Keypad Out 0
Main[1B] Keypad Out 1
Main[1B] Keypad Out 2
Main[1B] Keypad Out 3
U14
*OE0
A0
O
*OE1
A1
O1
GND
VCC
*OE2
A2
O2
*OE3
A3
O3
74LCX125MTCX
C47
.1µ
AGND
Keypad Out
LCD[2B], Main[1A], Power Processing[1C], SPI[1A], SPI[4A], Test and Mounting Points[2A], Test and Mounting Points[2B]
U15
VDDS
C48
.1µ
DGND
Keypad in
Main[1B] Keypad In 0
Main[1C] Keypad In 1
Main[1C] Keypad In 2
Main[1C] Keypad In 3
Title
Keypad
Size
A
Number
6
Revision
3A
Date: 6/18/2025
Sheet 6 of 12
File: C:\Users\...\Keypad.SchDoc
Drawn By: George Ore

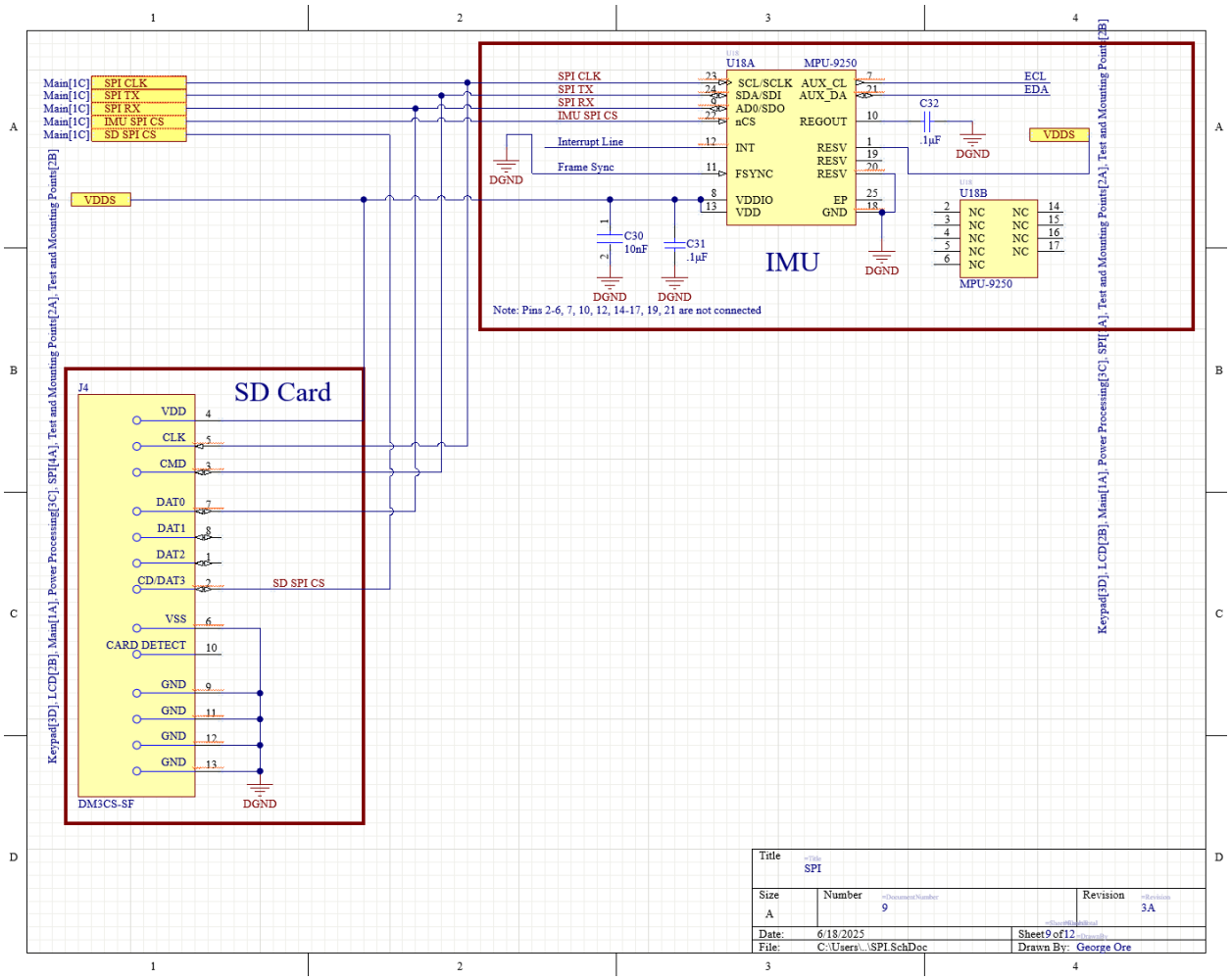
LCD


+5
C28
.1µF
POT1
J3
MNT 2
MNT 1
AGND
P0915N-FC15BR100K
LCD RS
LCD R/W
LCD Enable
Keypad[3D], Main[1A], Power Processing[3C], SPI[1A], SPI[4A], Test and Mounting Points[2A], Test and Mounting Points[2B]
VDDS
C49
.1µF
U16
T/*R
A0
A1
A2
A3
A4
A5
A6
A7
GND
VCC
*OE
B0
B1
B2
B3
B4
B5
B6
B7
LCD0
LCD1
LCD2
LCD3
LCD4
LCD5
LCD6
LCD7
DGND
DGND
LCD Data 0
LCD Data 1
LCD Data 2
LCD Data 3
LCD Data 4
LCD Data 5
LCD Data 6
LCD Data 7
Main[1B]
B14B-PASK(LF)(SN)
MC74LCX245DTR2G
Title
LCD
Size
A
Number
7
Revision
3A
Date: 6/18/2025
Sheet 7 of 12
File: C:\Users\...\LCD.SchDoc
Drawn By: George Ore

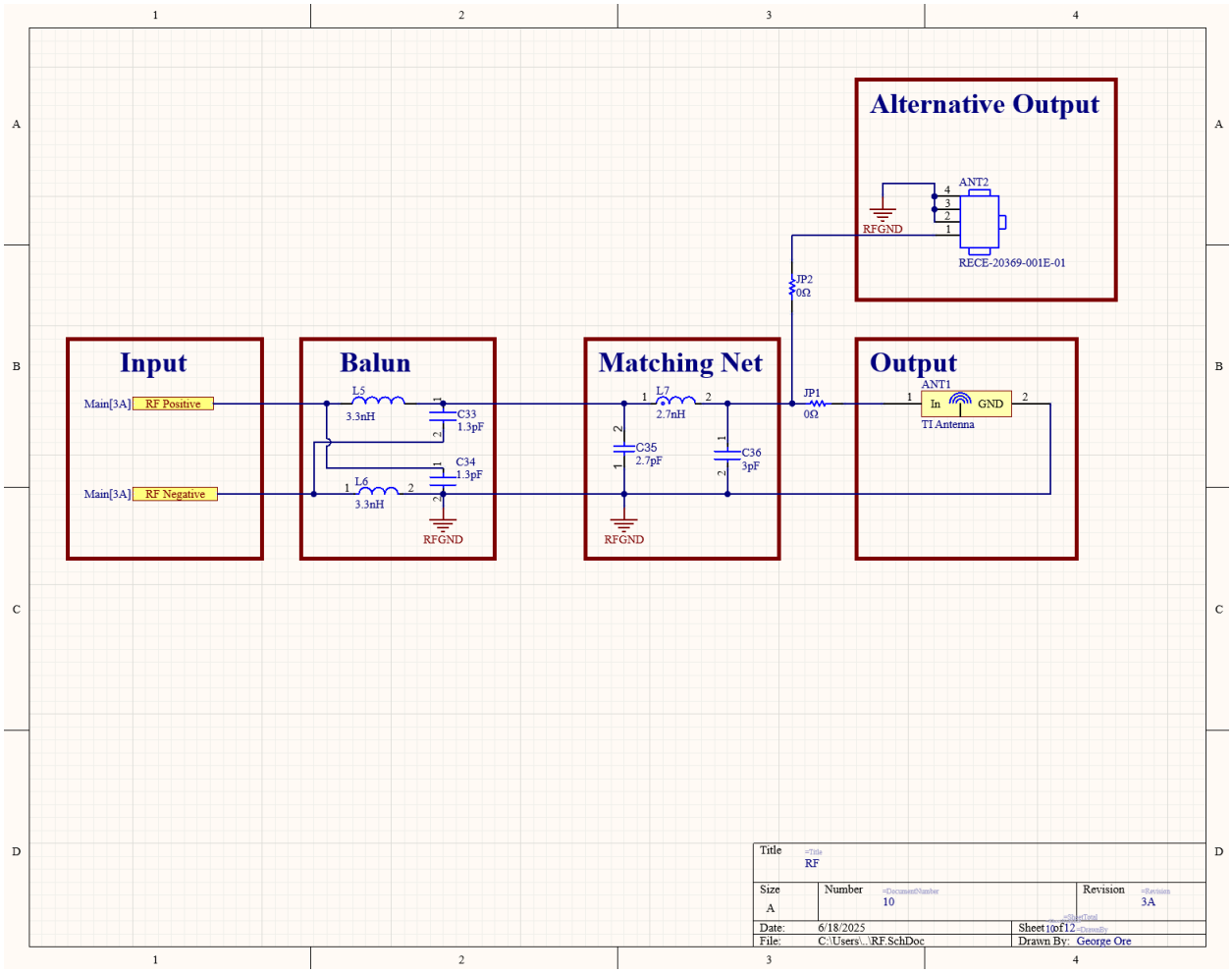
Servo Motor


Motor Driving Stage
Comparator is used to interface PWM
+5
R25
10kΩ
R26
4.7kΩ
AGND
U17B
LMV358AIDR
Main[1D]
ServoPWM
Motor
SRVOGND
Power Processing[1B]
Servo PWR
M1
Servo Motor
Motor Feedback Stage
This is set in a voltage follower configuration
C29
.1µF
U17A
LMV358AIDR
R27
1.5kΩ
R28
6.8kΩ
Main[1D]
ServoFeedback
Title
Servo
Size
A
Number
8
Revision
3A
Date: 6/18/2025
File: C:\Users\...\Servo.SchDoc
Sheet 8 of 12
Drawn By: George Ore

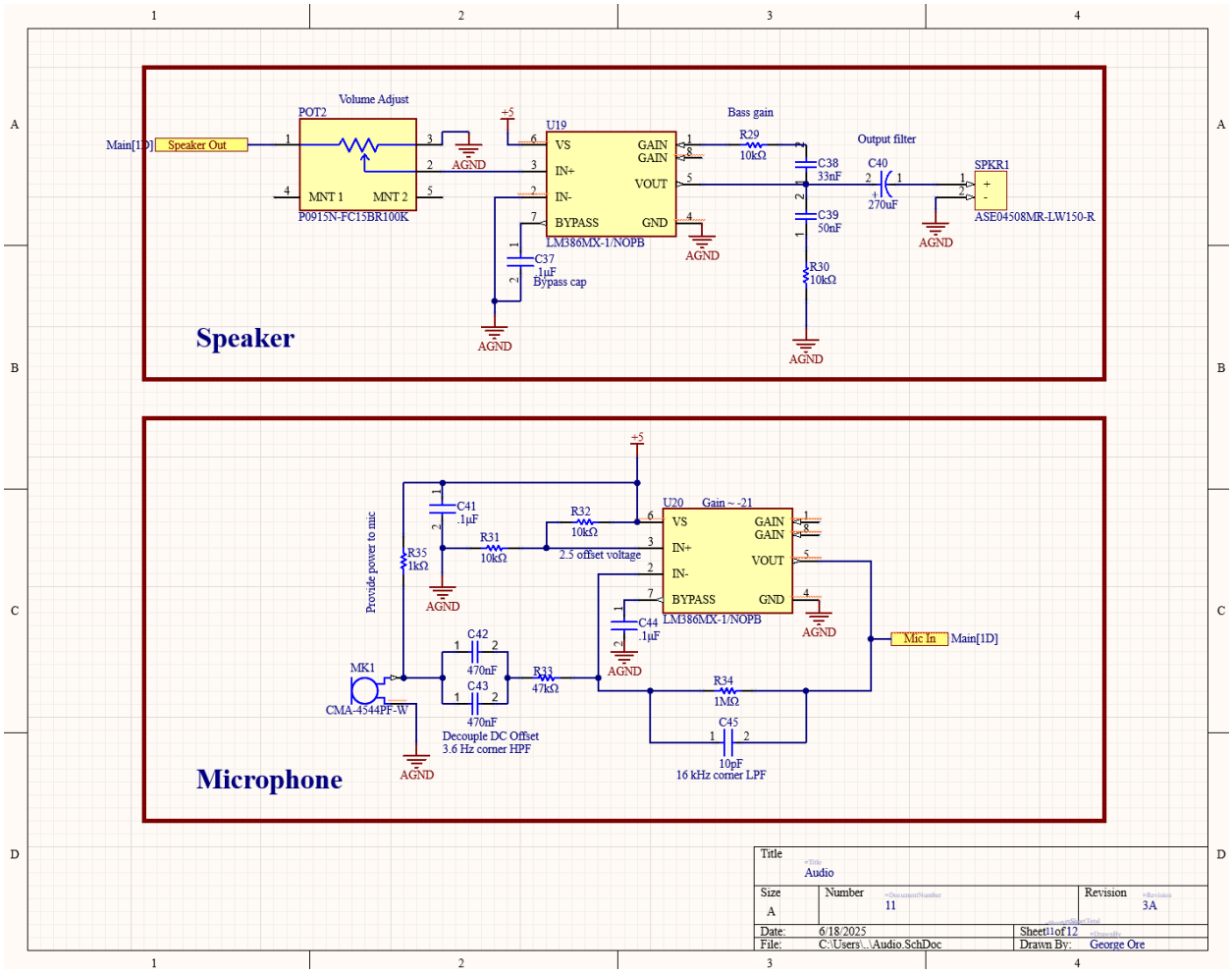
SPI Interface



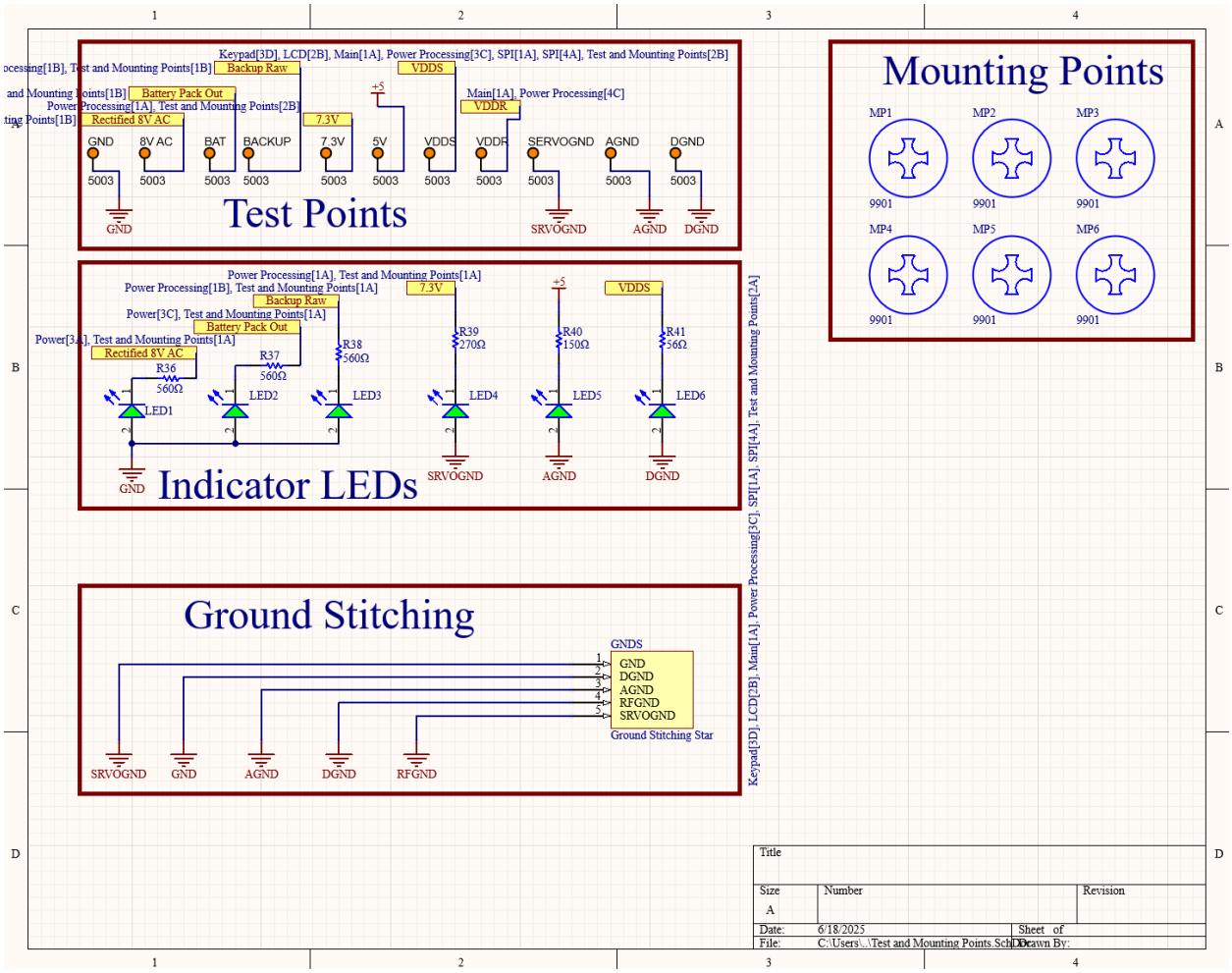
RF Waveguide Path



Audio System

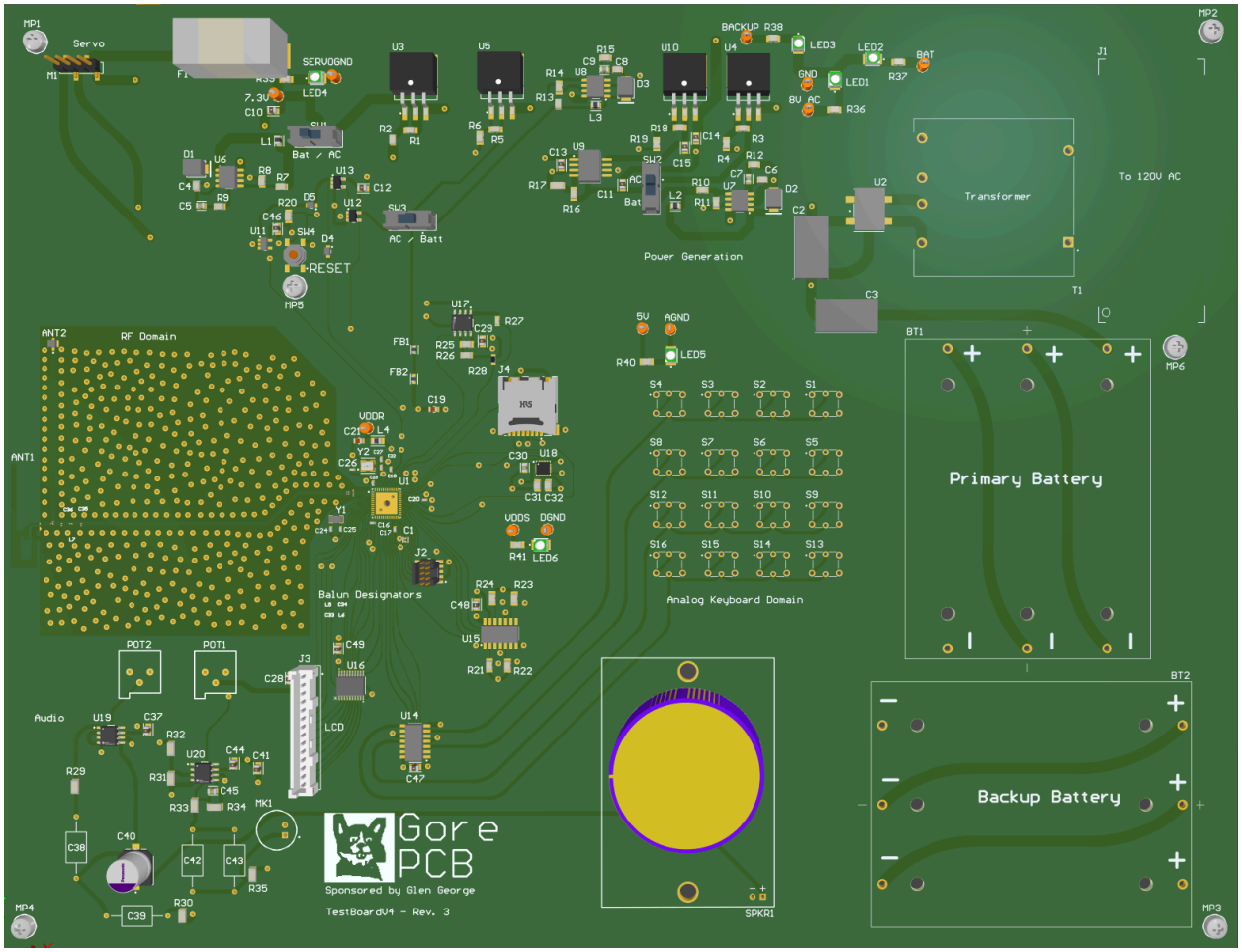


Test Points, Mounting Points, Indicator LEDs and Ground Stitching

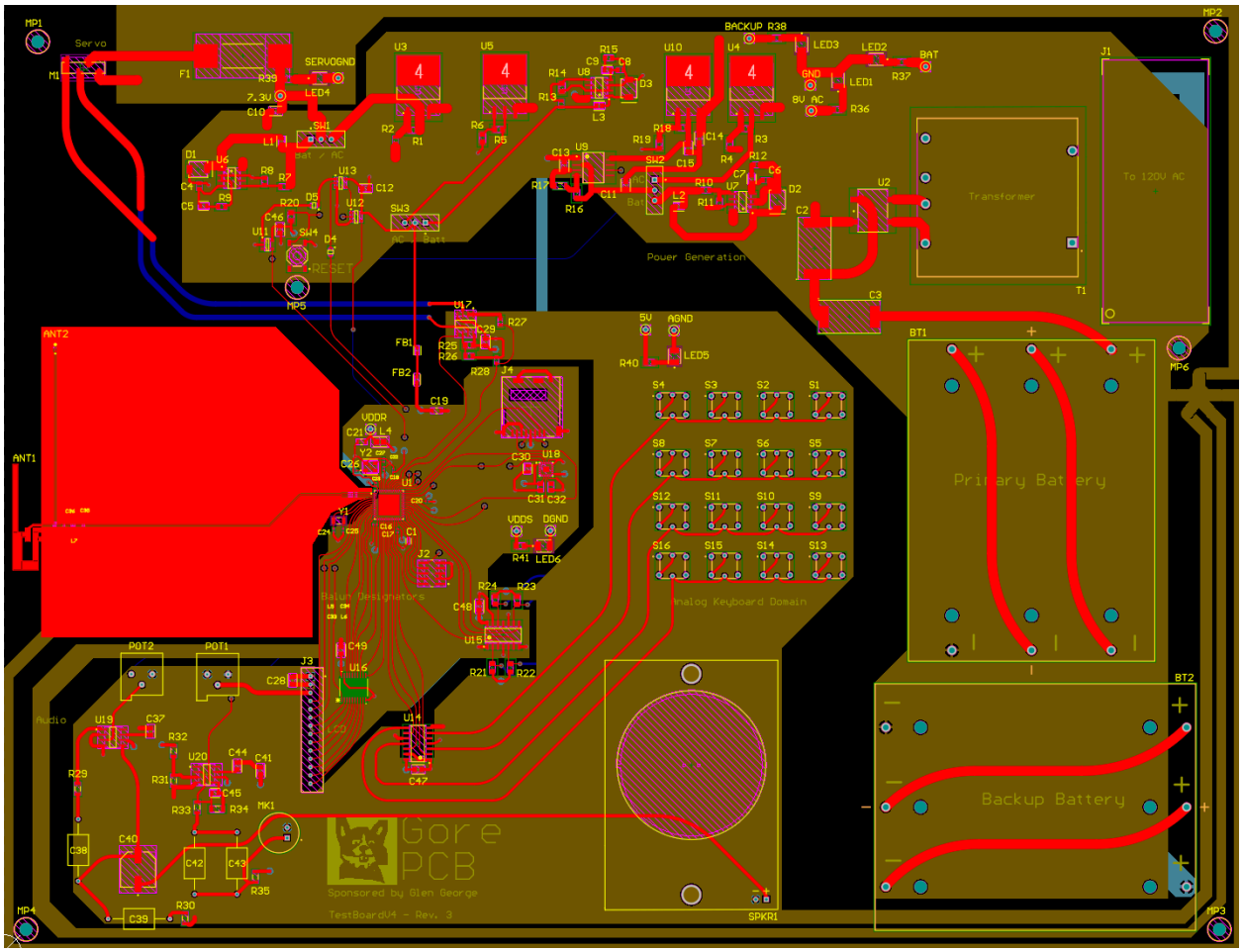


PCB Layout

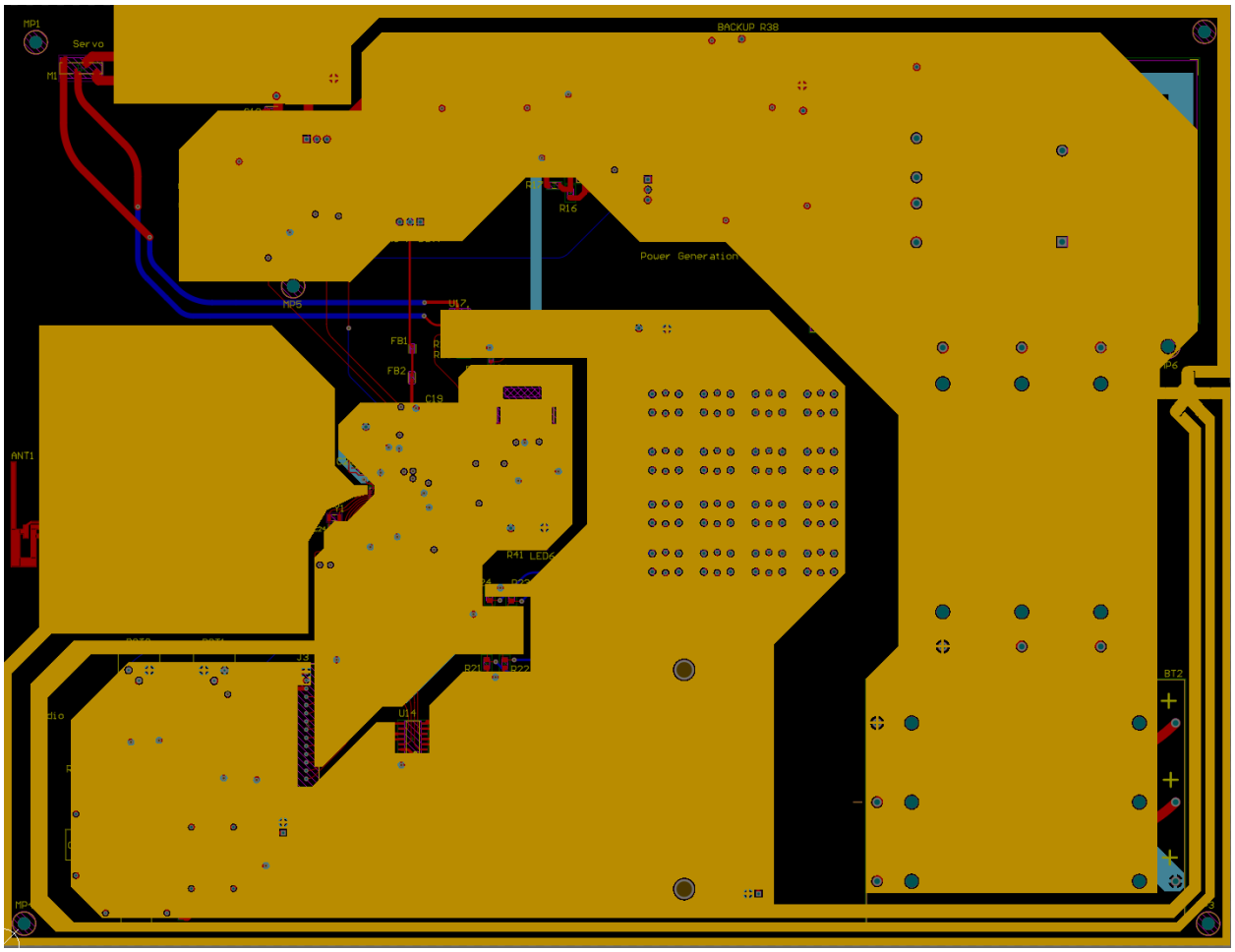
3D Preview



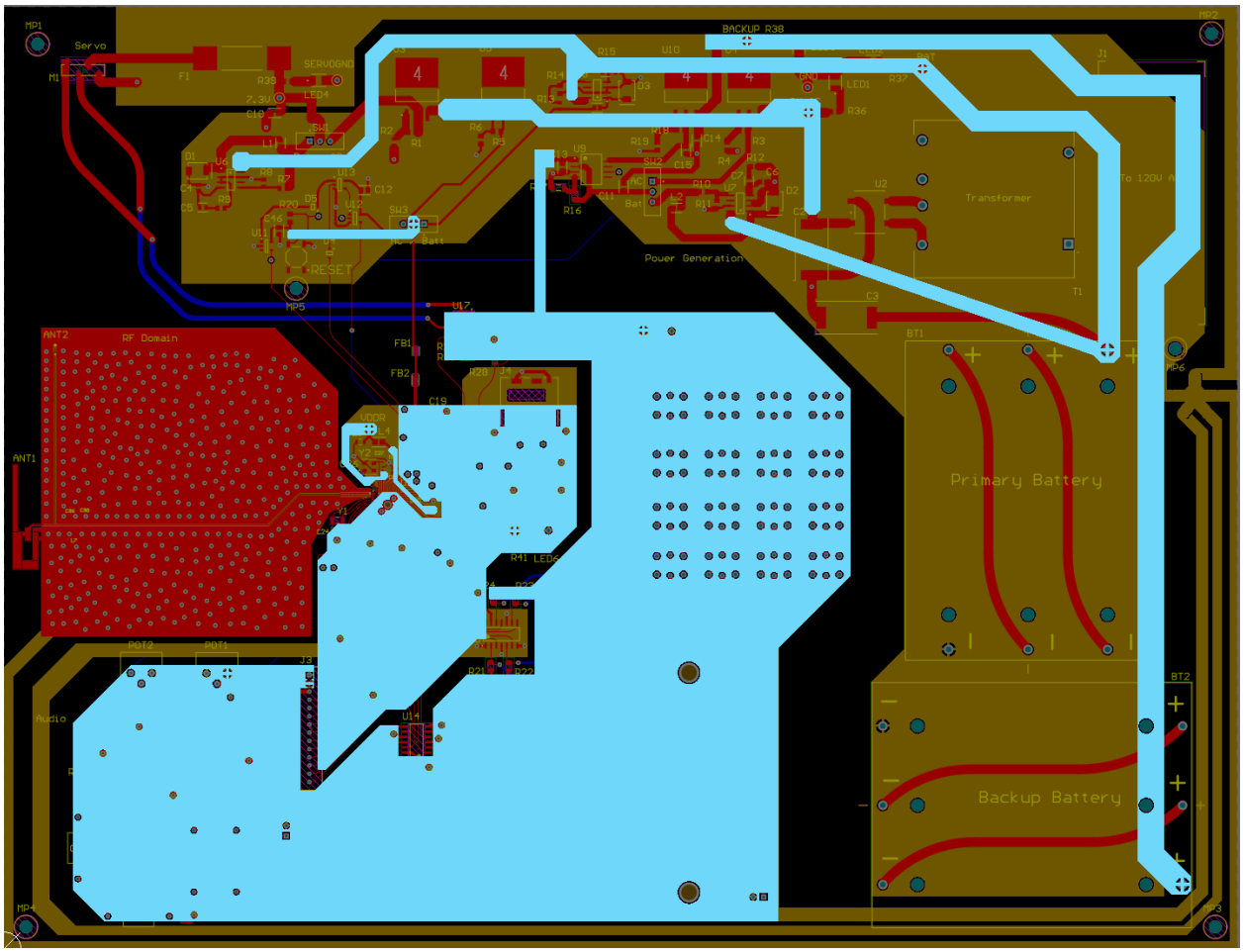
Top Signal Layer



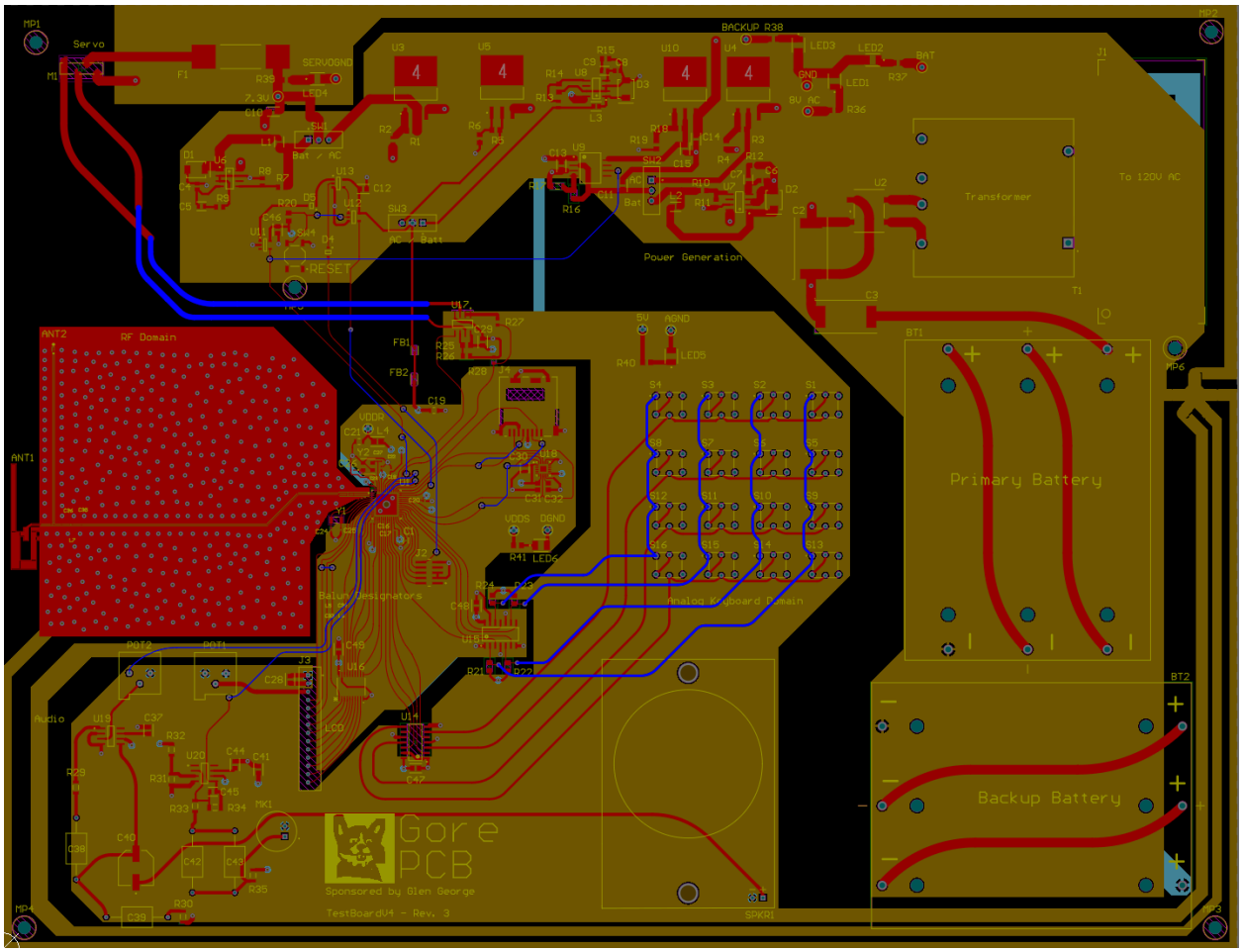
Ground Layer (Layer 2)



Power Layer (Layer 3)



Bottom Signal Layer



Example Programs

An ever-growing set of reference and demo projects are available on GitHub at https://github.com/GeorgeOre/EE110. The repository is organized so that each demo resides in its own Code Composer Studio (CCS) workspace. After downloading CSS and cloning the repo, you can choose File → Import → Existing CCS Project, where the desired demo can be built and loaded onto the system using the 10-pin JTAG interface.

Some notable example programs include the keypad demo which scans the 4x4 button matrix with interrupt-driven GPIO and records button presses in a memory buffer. The LCD demo drives the 2x16 character module in eight-bit mode which cycles through several messages defined on data tables. The servo demo produces various PWM signals that step the motor through several angles. Those angles are read through the feedback line and displayed onto the LCD. After looping through all the angles in the data table, the servo will enter free mode where the user may adjust the angle and observe the angle display on the LCD. The audio demo simply plays the popular song Diamonds by Rihannah. The BLE demo allows you to connect to the device with any smartphone and adjust characteristic values. Finally, the complete system demo stitches every subsystem together.

Additional information will be added in the github READMEs. All of the code is customizable for your specific needs.

User Reference Manual

Ordering Materials

To build your own test board, you must order the bare PCB and the parts. Gerber and pick-and-place files are in the hardware folder of the GitHub repository ready to upload to any mainstream fabricator such as JLCPCB, PCBWay, OSH Park, and others. The accompanying BOM includes all the required Digi-Key part numbers. Specific parts are replaceable such as the C14 receptacle or transformer but others will require special orders such as the CC2652R1 from TI. It is a good idea to order many extras off small components such as the 0201 capacitors and inductors. The MF4 receptacle also allows for more freedom in choosing an antenna.

Assembly

Assembly is fastest with a small reflow oven or hot-plate rather than an iron. Type-4 solder paste contains small enough grains and melts at a low temperature. If using an oven, a stencil would be useful. The oven profile should be about 235 °C for about 45 s. Make sure to check all of the CC2652R1's connections to avoid damaging it when connecting to power.

Possible Future Enhancements

While this board provides a complete all-in-one test platform, the project is designed to be split into two separate PCBs. One would be a servo board dedicated to high-current motor control, powered from a dedicated AC power adapter. It would include multiple motor arbitration, fuse protection, and a BLE server to store all the robot information. It would also mount directly to the robot frame. The second board would be a control board, which would handle low-voltage digital logic and sensor processing, powered from an onboard battery. All the non-motor peripherals would be included here. This board would run a server to connect and control to the servo board.