

Smart Auto-Equalization Sound System

Final Presentation

Group 31



The Team



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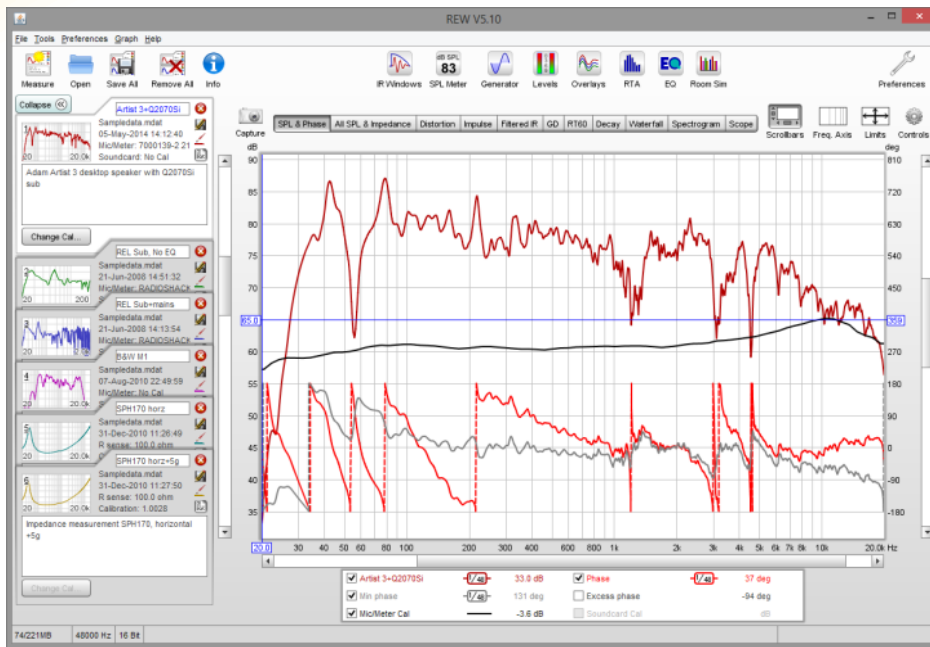
Computer Engineering



Motivation & Background



- Manual EQ is time-consuming
- Room acoustics change sound drastically
- Existing solutions require external tools or audio expertise
- To create an ecosystem between the speaker and audio adjustment software, removing the need for 3rd party services.
- Our goal: provide an easy-to-use system that automatically measures the room and corrects itself





Goals & Objectives

- Basic Goals
 - 2.1 System
 - Auto-EQ
 - Web App
- Advanced Goals
 - DSP
 - Adaptive Filtering
 - Noise Sweeps
- Stretch Goals
 - Bluetooth Streaming
 - Distortion Prevention
- Basic Objectives
 - Create an EQ algorithm that is fast, and reliable.
 - Implement correct amplification factor to achieve sufficient power.
 - Achieve a base equalization setting, to help the algorithm figure out a starting point
- Advanced Objectives
 - Provide a fast and reliable connection between the app and the system.
- Stretch Objectives
 - Achieve a runtime of $N \cdot \log(N)$ N where the number of samples.
 - Provide the user with real-time data including histograms and charts.





3D Illustration of System

- Fully integrated 2.1 audio system
- Central processing & control enclosure
- Dedicated mid/high speakers and subwoofer
- Custom amplification and DSP control

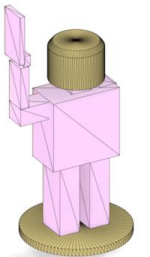
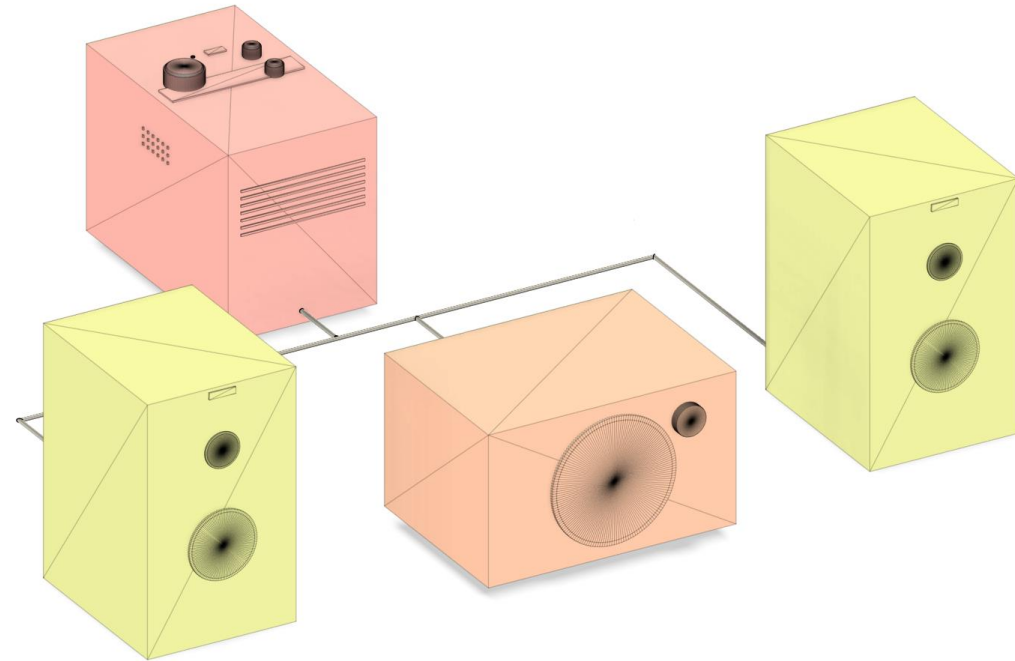




Table of Engineering Specifications

Specification	Target Value	Notes
Frequency Response Range	20 Hz – 20 kHz	Full audio spectrum
Total Harmonic Distortion (THD)	$\leq 0.5\%$	At rated power
Amplifier Output Power	50W RMS (subwoofer), 25W RMS (mid/high)	Per channel
MCU Processing	≥ 240 MHz dual-core with FPU/DSP	ESP32-S3 candidate
Microphone Accuracy	$\leq \pm 1$ dB	Acoustic measurements
Power Supply	$\pm 12\text{V}$ to $\pm 24\text{V}$ (audio), $+5\text{V}/+3.3\text{V}$ (logic)	Linear + switching regulation
Latency (Mic-to-DSP-EQ)	≤ 20 ms	Real-time correction



Processor Technologies Comparison

Specification	SBC	FPGA	MCU
Processing Power	High	High	Moderate – Low
Throughput	High	High	Low
Programming (Difficulty)	Moderate - High	High	Moderate – Low
Project Fit	Moderate	Good	Very Good
Price	Moderate	High	Low



MCUs Comparison

Specification	ESP32-S3-N16R8	STM32H735ZGT6	i.MX NXP RT1170
Processor	Xtensa LX7	Arm Cortex-M7	Arm Cortex-M7, Arm Cortex-M4
Frequency (max.)	240 MHz	550 MHz	1 GHz, 400 MHz
Bluetooth (BLE)	✓	✗	✗
DSP	ESP-DSP Library	CORDIC, FMAC, CMSIS Library	CMSIS Library
ADC	2 x 12-bit	2 x 16-bit, 1 x 12-bit	2 x 12-bit
DAC	✗	2 x 12-bit	1 x 12-bit
Price (Approx.)	\$ 6.00	\$ 13	\$ 26





DAC vs CODEC

- The DAC is the only component missing in the MCU.
- A CODEC would amplify the performance of the design.
- CODECs often offer better resolution → but more connections (software & hardware) would need to be done.

DAC Comparison

Specification	DAC8555IPW	AD1934WBSTZ-RL	AD5664ARMZ-REEL7	PCM5122
Resolution (bits)	16	24	16	32 (max)
Channels	4	8	4	1
SNR (dB)	95	108	N/A	112
THD (dB)	-85	-94	-80	-93
Operating Freq. (Max.)	50 MHz	27.6 MHz	50 MHz	50 MHz
Interface	SPI, DSP	SPI, I2S	SPI, DSP	I2C, SPI, I2S
Price (Approx.)	\$ 15	\$ 11	\$ 18	\$ 7.28



ADC



- ESP32 has a 12-bit ADC onboard, but is nonlinear and is said that 3 bits are noise
- Original plan was to use the ESP32 ADC
- To minimize potential issues, an external ADC was introduced to the design during the early stages of SD2
- The ADC is the ADS8320 by TI
- ADC is 16-bit, utilizes minimal connections, and has SPI communication
- SPI chosen for speed and simple operation



Amplifier Topologies



- Multiple amplifier classifications to choose from
- The main topologies used for audio electronics are Class AB and Class D
- Class A is also used but is highly inefficient so use is minimal
- Amplifiers can be integrated on an IC, perfect for simple integration for our project

Class	A	B	AB	D
Efficiency	Very Low	High	Medium	Very High
THD	Low	Very High	Low-Medium	Low-Medium
Footprint	Large	Medium	Large	Small
Heatsink	Large	Medium	Large	Small
Cost	High	Medium	High	Medium





Mids and Highs Amplifier

- Most considerations were for Class D amplifiers for efficiency
- TPA3116 was chosen to for THD and power output
- LM3886 is a backup choice as we have been warned of issues with TPA amplifiers

Device	Topology	Power	THD	Efficiency	Price
TPA3116D2DADR	Class D	2x50W @ 4Ω	<0.1%	~90%	\$3.10
TPA3112D1QPWPRQ1	Class D	1x25W @ 8Ω	0.1%	94%	\$2.84
		1x20W @ 4Ω	10%	Not Considered	
MAX9709ETN+D	Class D	2x25W @ 8Ω	10%	Not Considered	\$21.80
		1x35W @ 4Ω	0.5%	~85%	
LM3886	Class AB	2x38W @ 8Ω	<0.1%	~50%	\$7.01
		1x68W @ 4Ω	<0.1%	<50%	



Subwoofer Amplifier



- TPA3251 chosen for multitude of options, and THD
- Other options border our THD specification, offering no room for error in board layout or audio processing

Device	Topology	Power	THD	Efficiency	Price
TPA3251D2DDVR	Class D	2x55W @ 8Ω	0.5%	90%	\$7.81
		2x100W @ 4Ω	0.01%	90%	
		2x100W @ 3Ω	0.01%	85%	
		1x60W @ 8Ω	0.5%	N/A	
		1x125W @ 4Ω	0.01%	N/A	
		1x200W @ 2Ω	0.01%	N/A	
TDA7293	Class AB	1x90W @ 8Ω	0.5%	N/A	\$8.49
		1x70W @ 4Ω	0.5%	N/A	
TPA3221DDVR	Class D	1x45W @ 8Ω	0.5%	90%	\$4.39
		1x80W @ 4Ω	0.5%	80%	
		1x100W @ 3Ω	0.5%	80%	
		1x100W @ 4Ω	0.5%	90%	
		1x100W @ 2Ω	<0.1%	85%	



Microphone

- The ECM99 is the cheapest choice even with having an attractive SNR decibel level compared to the UMIK-1
- The UMIK-1 although the most expensive option, does have the highest SNR decibel level
- The EMM-6 has the highest sensitivity and a close SNR to both the ECM99 and UMIK

Microphone	Cost	Sensitivity	SNR	Frequency Range
Superflux ECM99	\$49.99	37dB	77dB	20kHz
miniDSP UMIK-1	\$128.95	39dB	78dB	20kHz
Dayton Audio EMM-6	\$59.98	40dB	70dB	20kHz



Power Supply Unit (PSU)



	LRS-600-48	LRS-600N2-36	LAD-600C	LAD-600CU
Output Voltage (V)	48	36	41.5	41.5
Output Current (A)	12.5	16.6	11.45	11.45
Efficiency (%)	92	92	91	91
Temp Range (C)	-20 to +65	-20 to +65	-20 to +60	-20 to +60
Distinguishing Features	Fan	Fan and 200% peak power capability	Battery Charger	UART and Battery Charger
Price	\$59.90	\$64	\$77.90	\$89.30



Component Comparison (Tweeter)



Speaker Consideration	Frequency Range	Power Handling	Sensitivity
Peerless by Tympany BC255C08-04	2,500 Hz – 20,000 Hz	100 W	98 dB
Peerless by Tympany XT25SC40-04	2,500 Hz – 20,000 Hz	100 W	91.1 dB
Mr. DJ HDT5005	???	100 W	109 dB



Component Comparison (Subwoofer)



Speaker Consideration	Frequency Range	Power Handling	Sensitivity
Kicker 43CVT102	25 Hz – 500 Hz	350 W – 700 W	87.2 dB
Goldwood GW-212/4	28 Hz – 4,000 Hz	120 W – 240 W	92.3 dB
Goldwood GW-10PC-4	25 Hz – 3,000 Hz	200 W – 400 W	92.7 dB



Component Comparison (Mid-Gain Speaker)



Speaker Consideration	Frequency Range	Power Handling	Sensitivity
Dayton Audio DC130B-4	50 Hz – 5000 Hz	40 W – 80 W	92.1 dB
Goldwood GM-65/4	550 Hz – 15,000 Hz	50 W – 100 W	92 dB
Goldwood GM-85/4	500 Hz – 15,000 Hz	60 W – 120 W	92 dB



Bluetooth Module

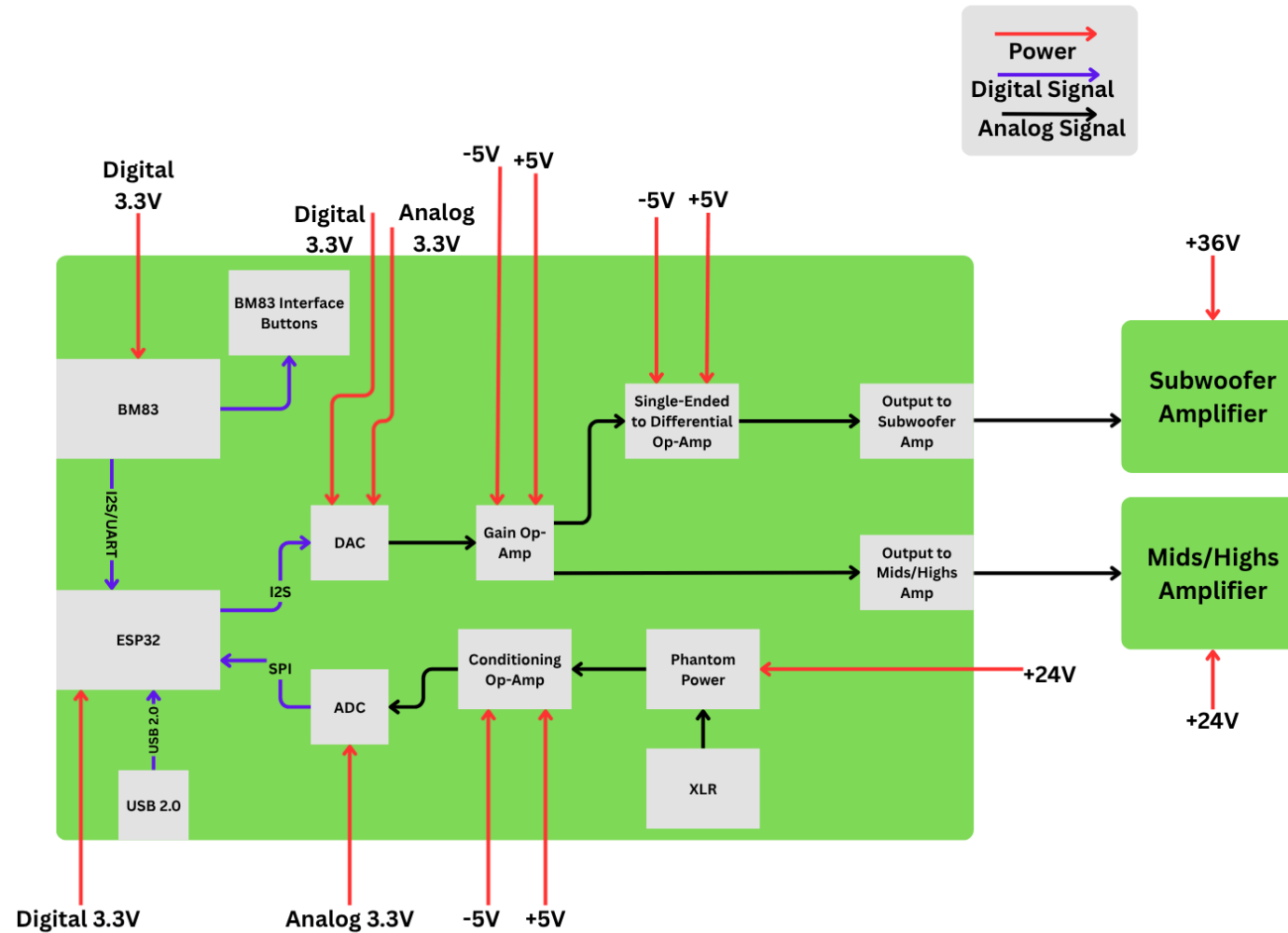


- Bluetooth module needed for A2DP communication protocol
- FSC-BT1026 has many features unnecessary to our design
- BM83 was chosen for its price and ease of integration

Device	BM83	BM64	FSC-BT1026
Transmission Power (dBm)	+11	+15	+9
Receiver Sensitivity (dBm)	-90	-90	-100
Transfer Rate	2	2	3
Antenna	PCB	PCB	PCB or External
Price	\$12.20	\$18.13	\$14.46



Hardware Block Diagram

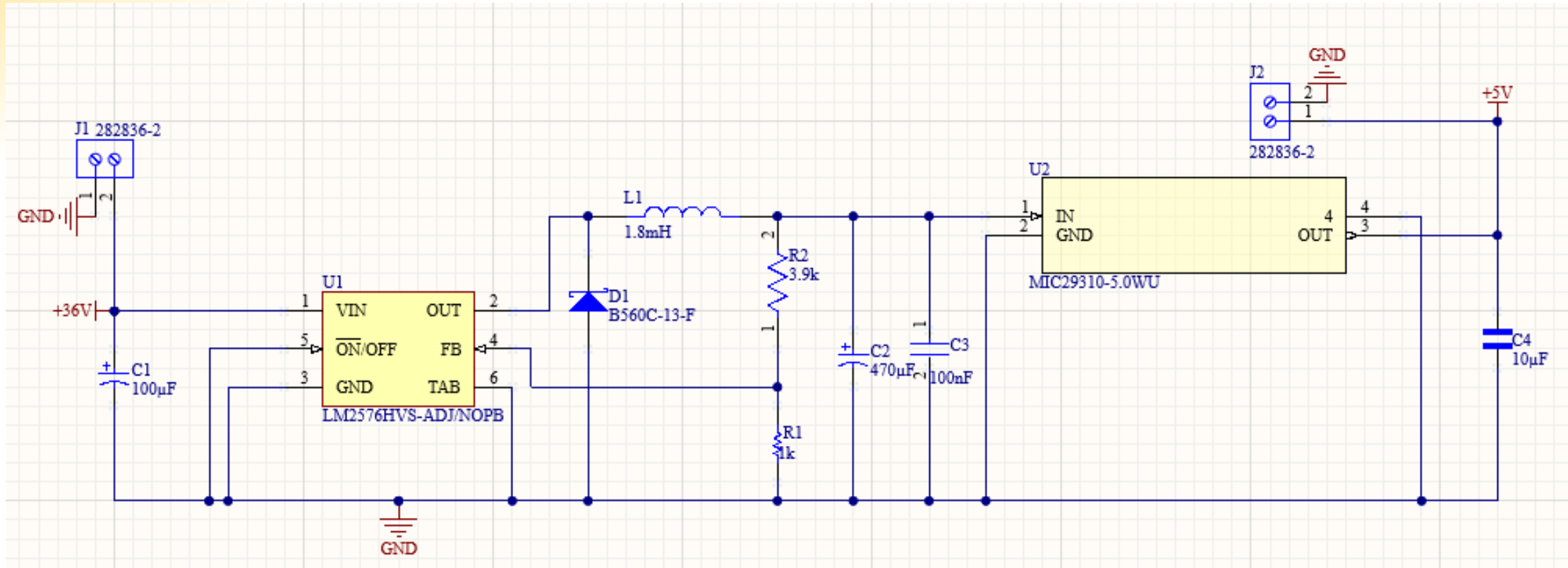




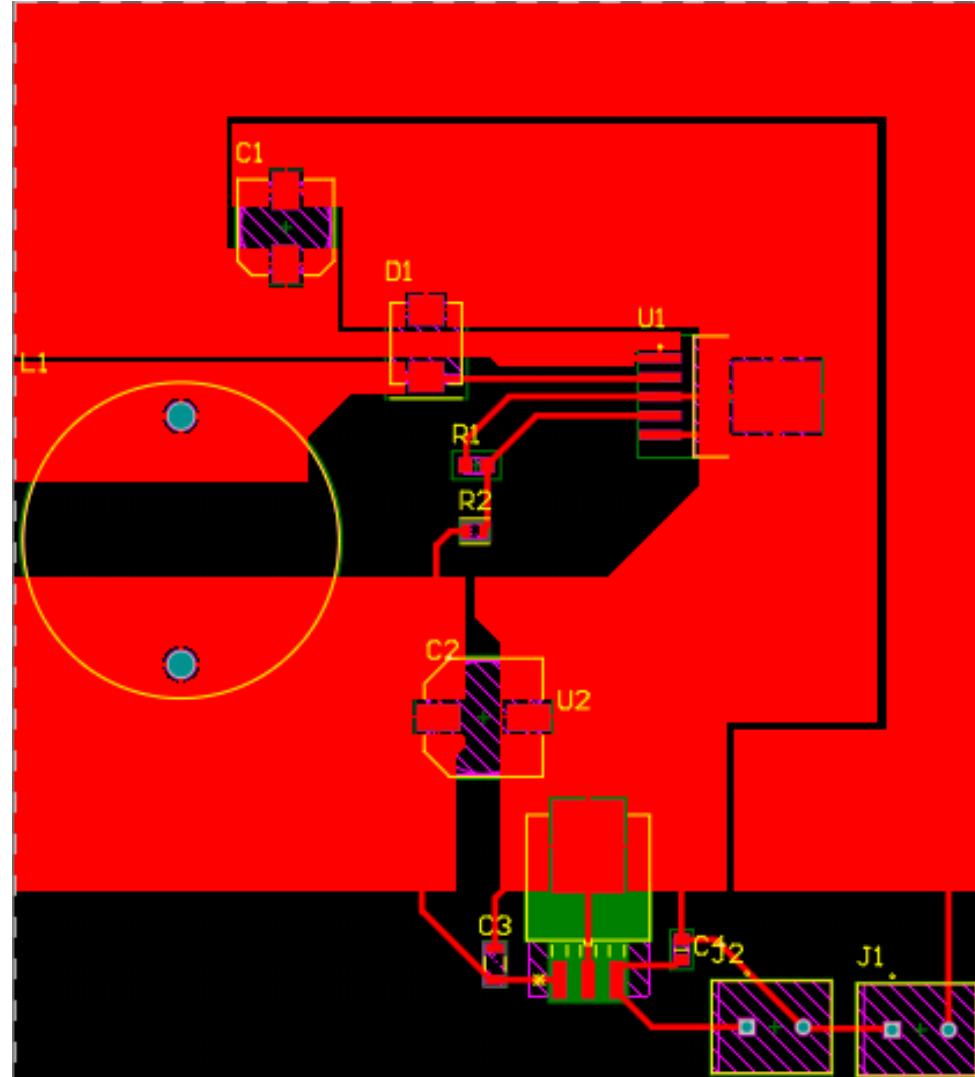
Regulators



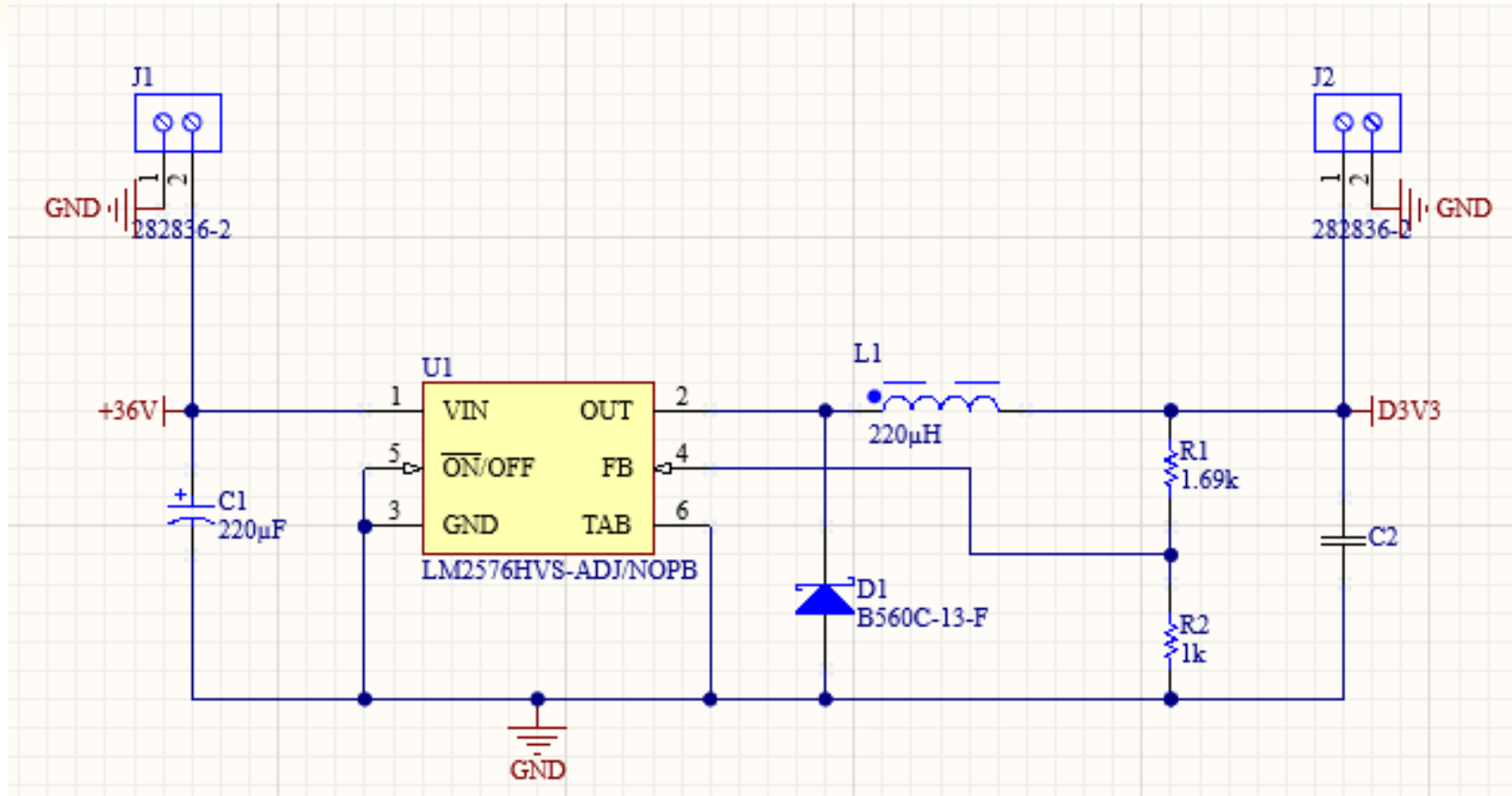
+5V Regulator Schematic



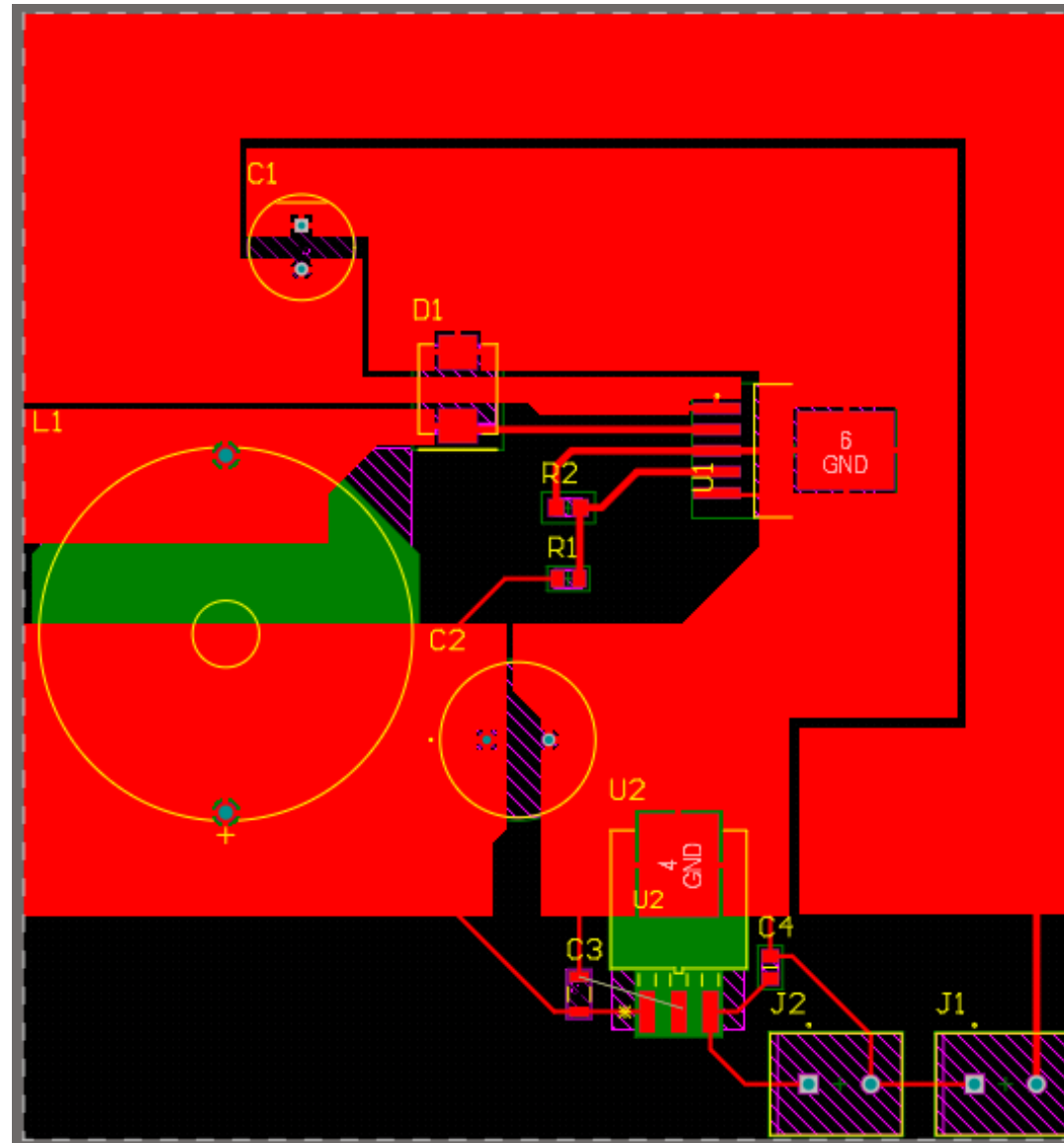
+5V Regulator PCB Design



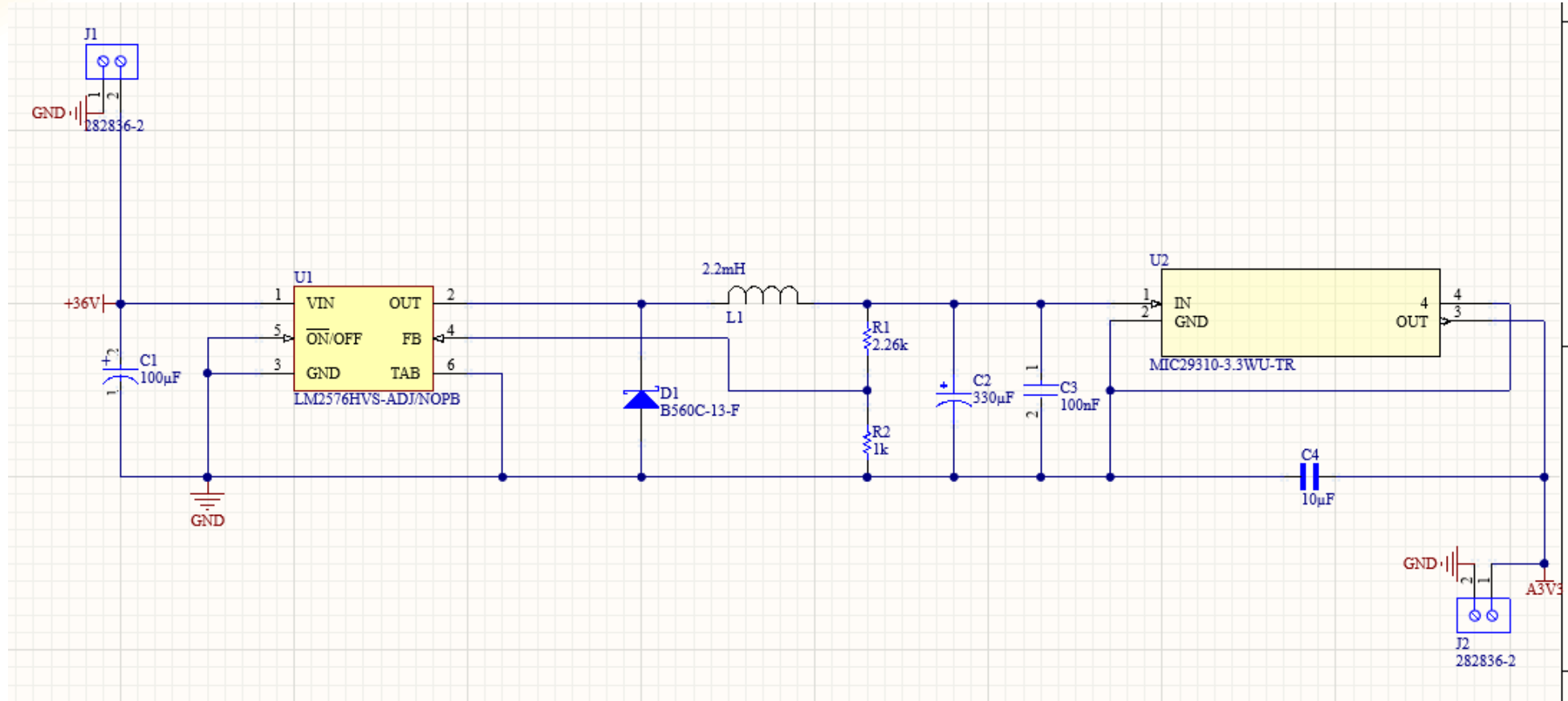
Digital 3.3V Regulator Schematic



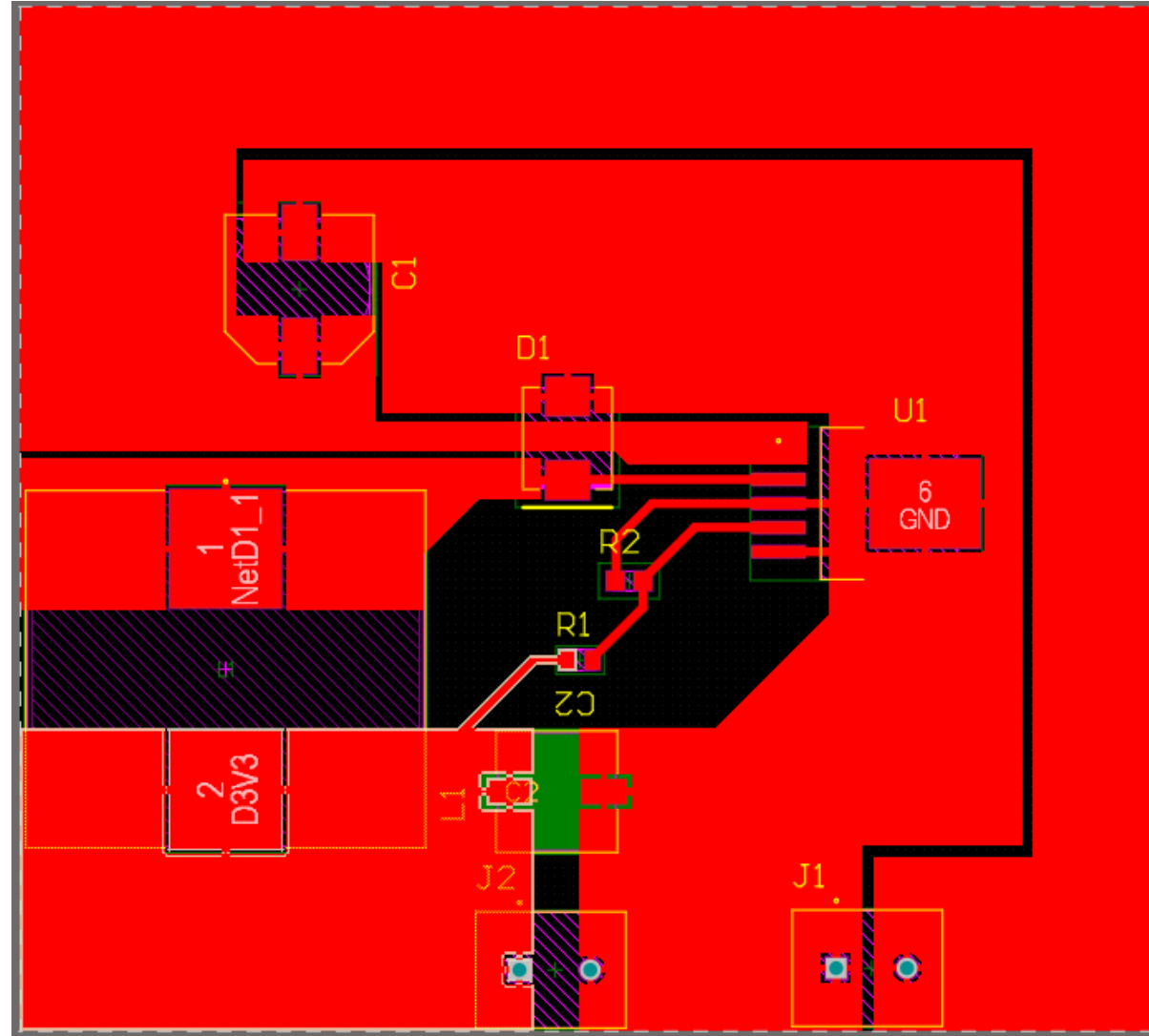
Digital 3.3V Regulator PCB Design



Analog 3.3V Regulator

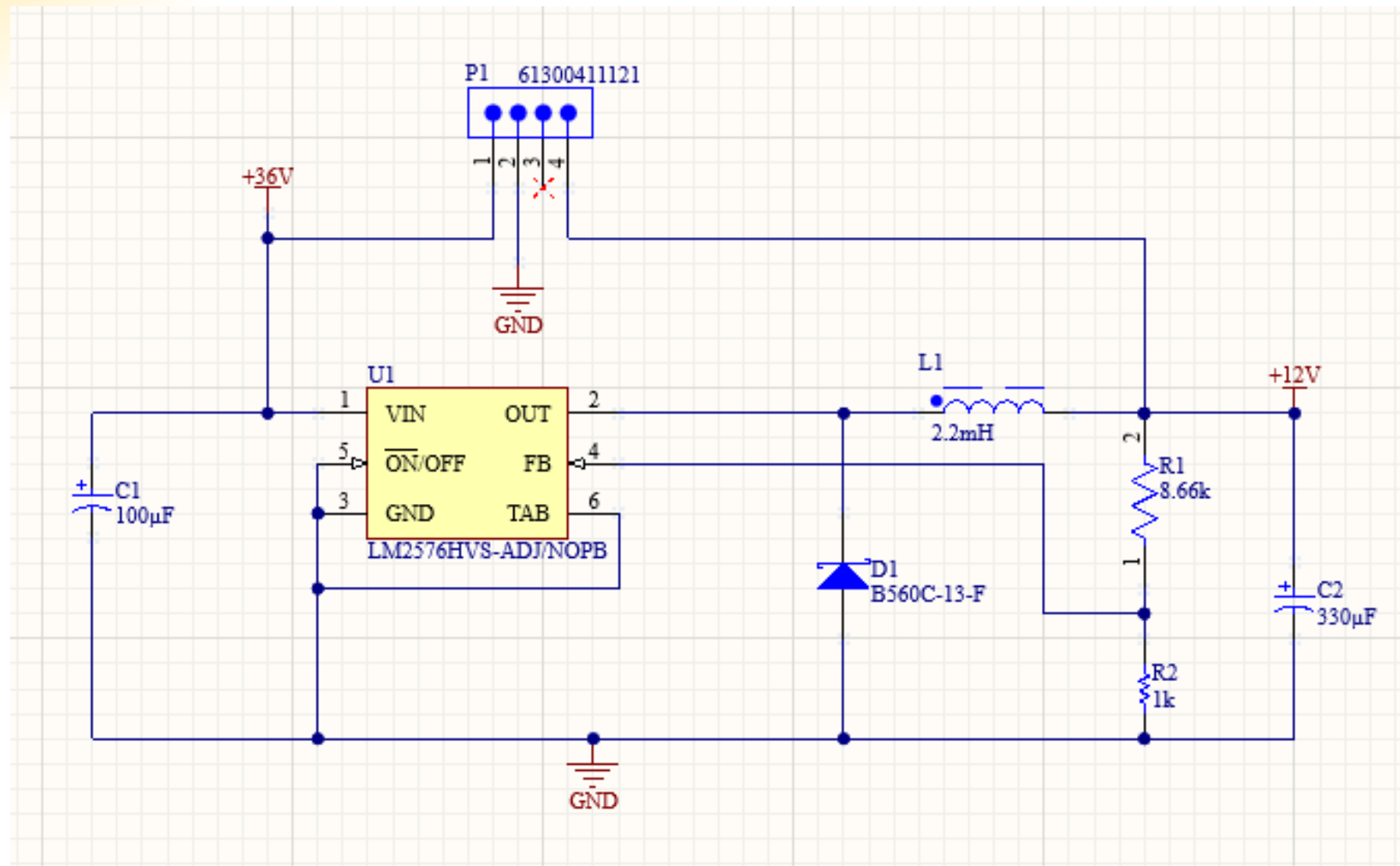


Analog 3.3V Regulator PCB Design

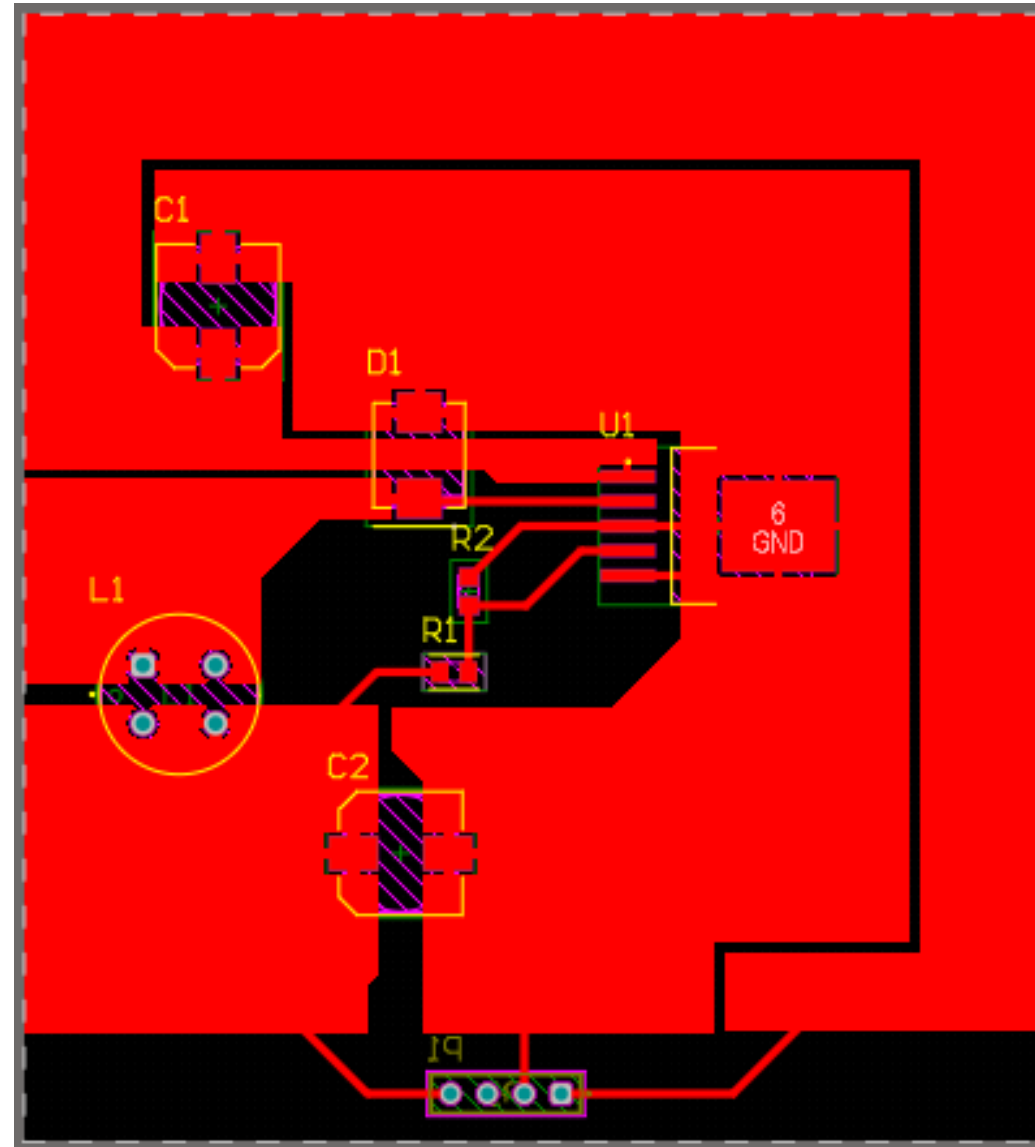


A portrait of a young man with dark, wavy hair, smiling. He is wearing a blue suit jacket, a white shirt, and a blue tie. A small floral boutonniere is pinned to his lapel. The background is a light-colored, textured wall.

+12V Regulator Schematic

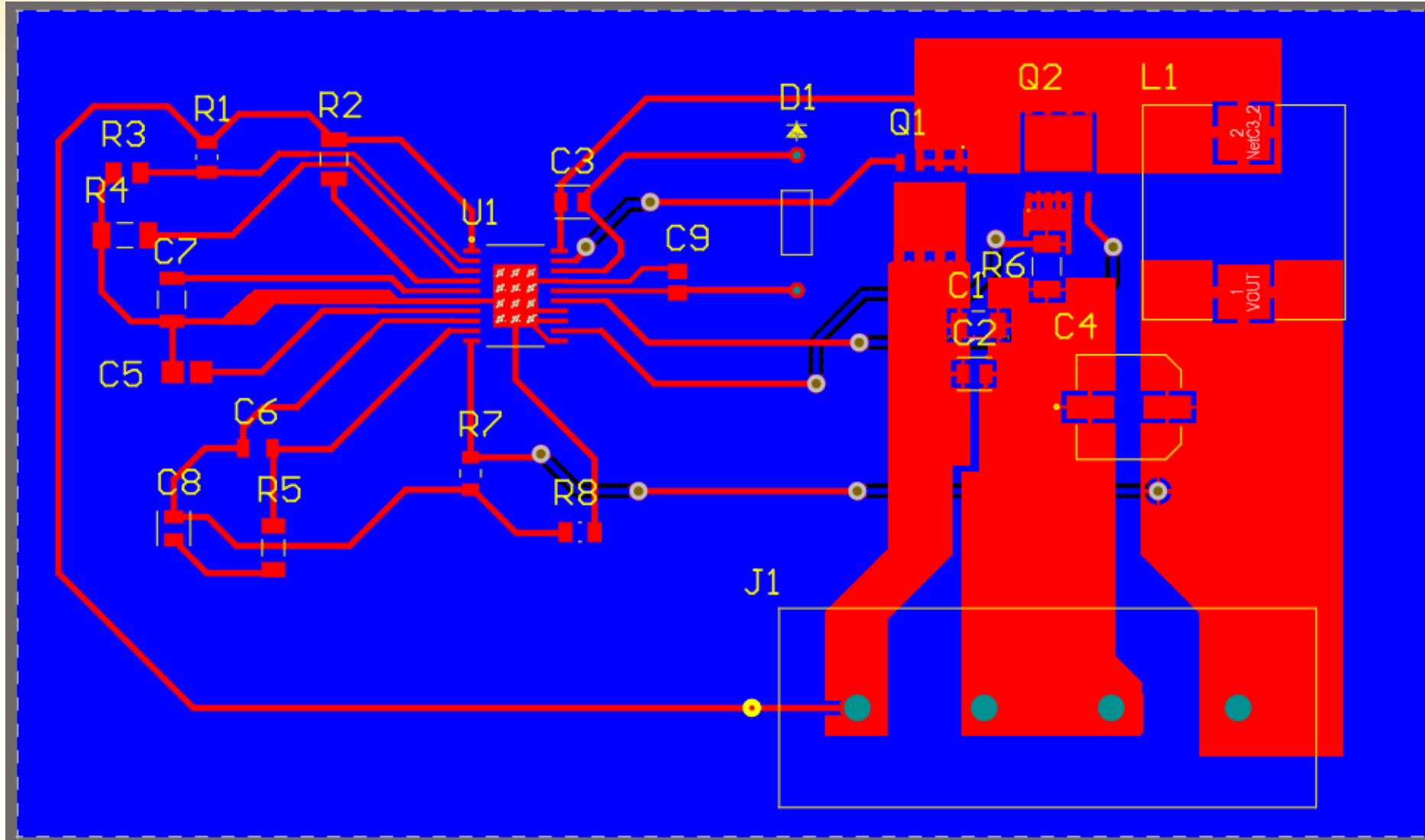


+12V Regulator PCB Design





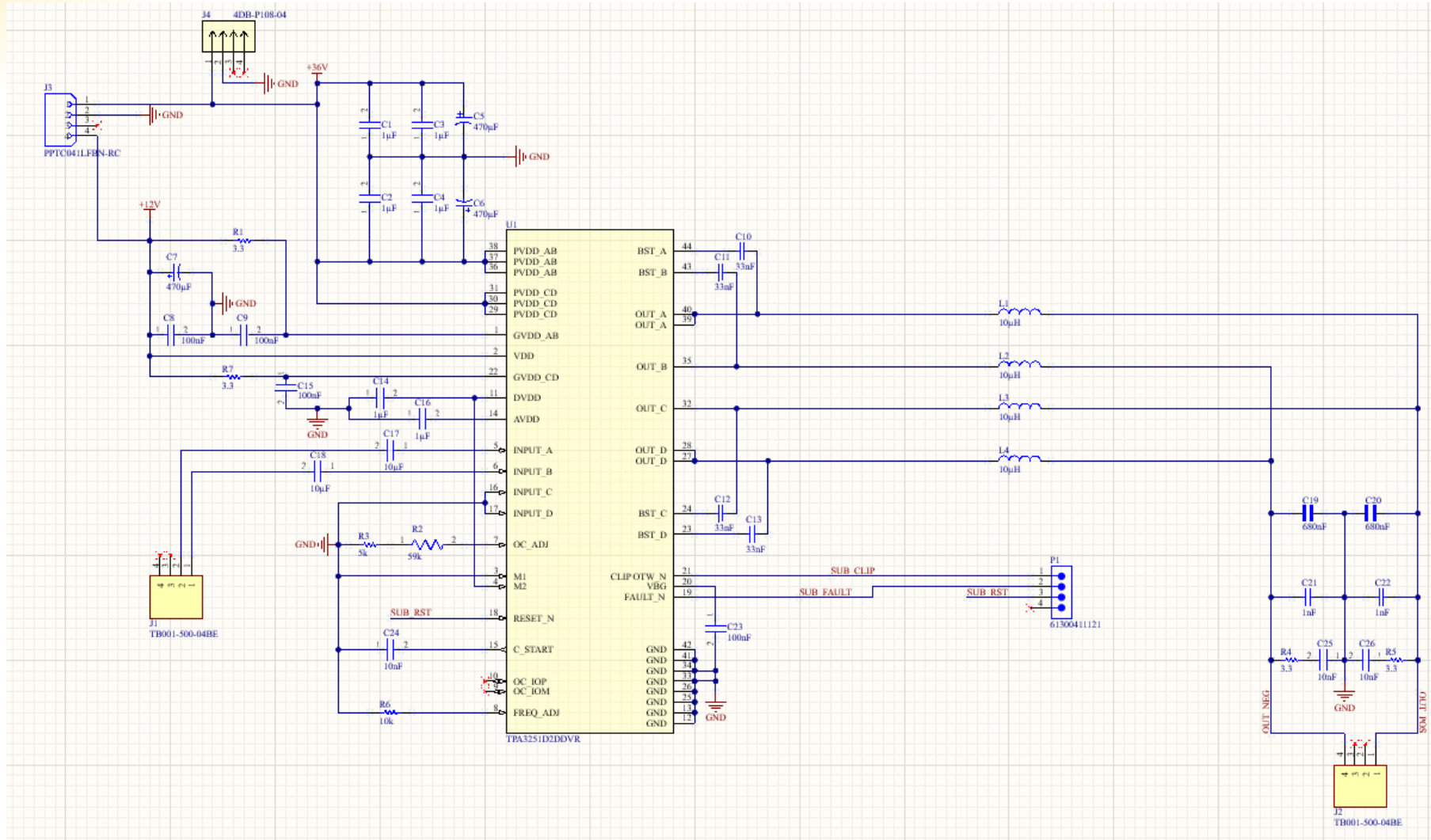
+24V Regulator PCB Design



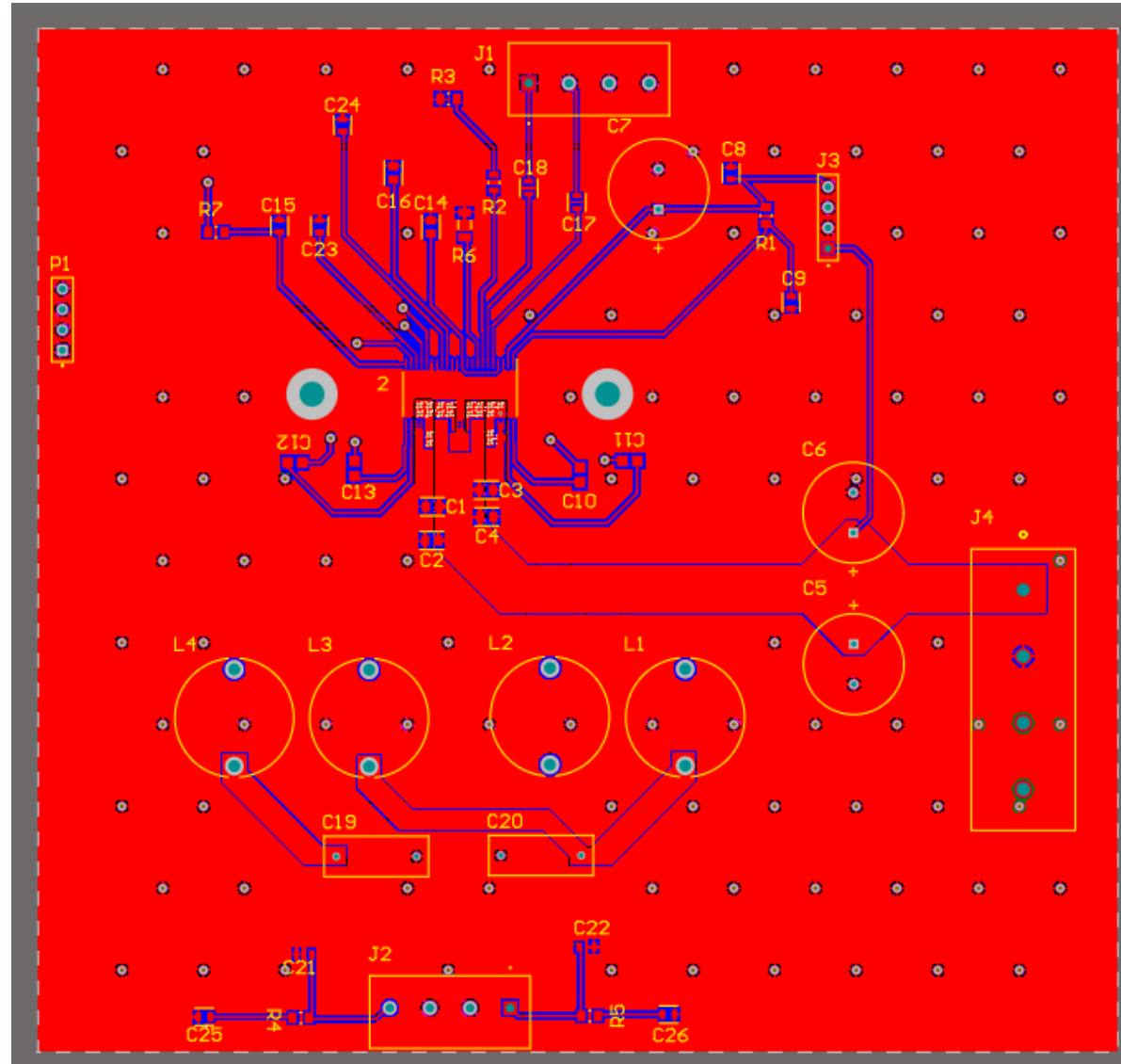
Amplifiers



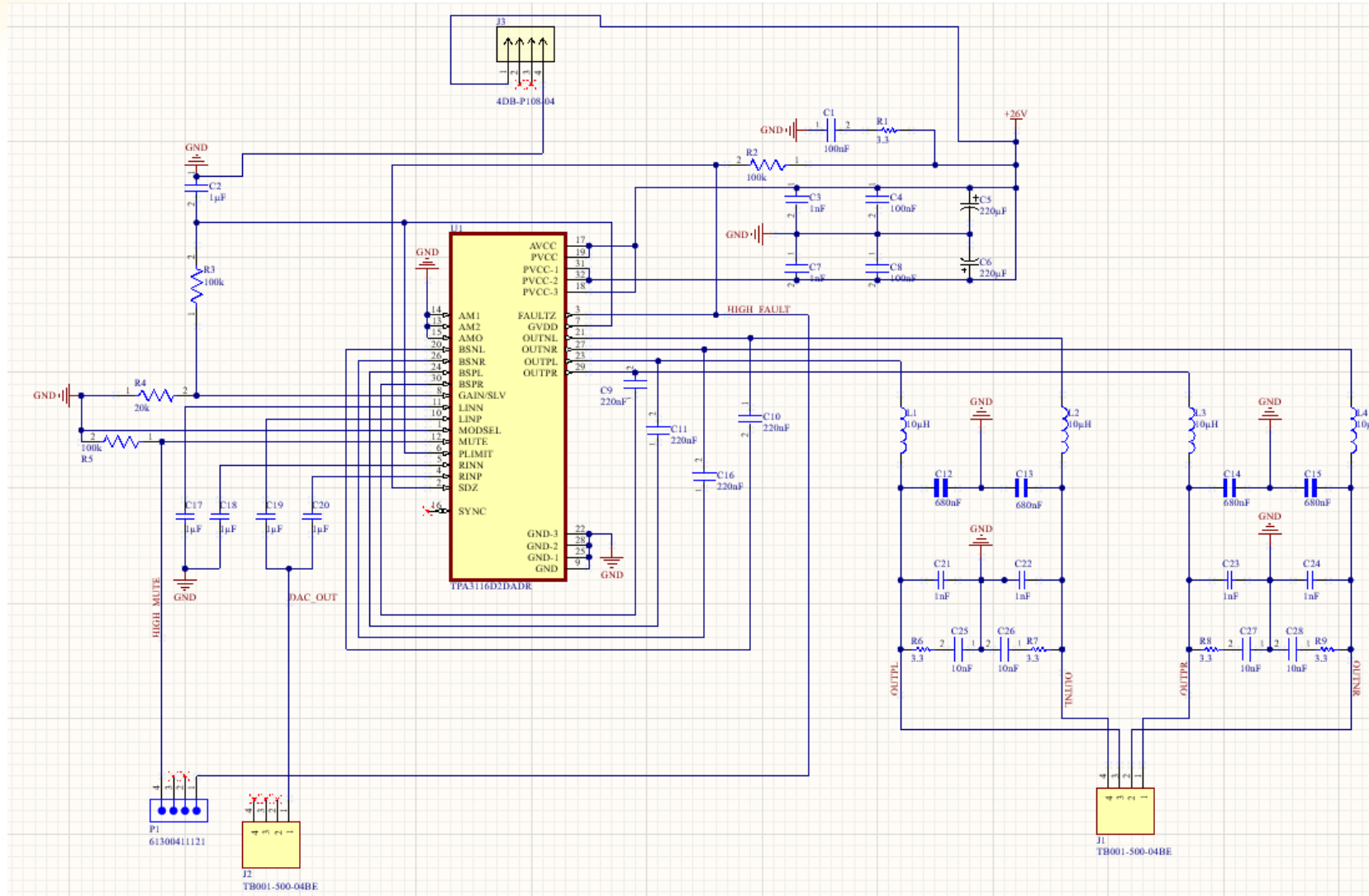
Subwoofer Amplifier Schematic



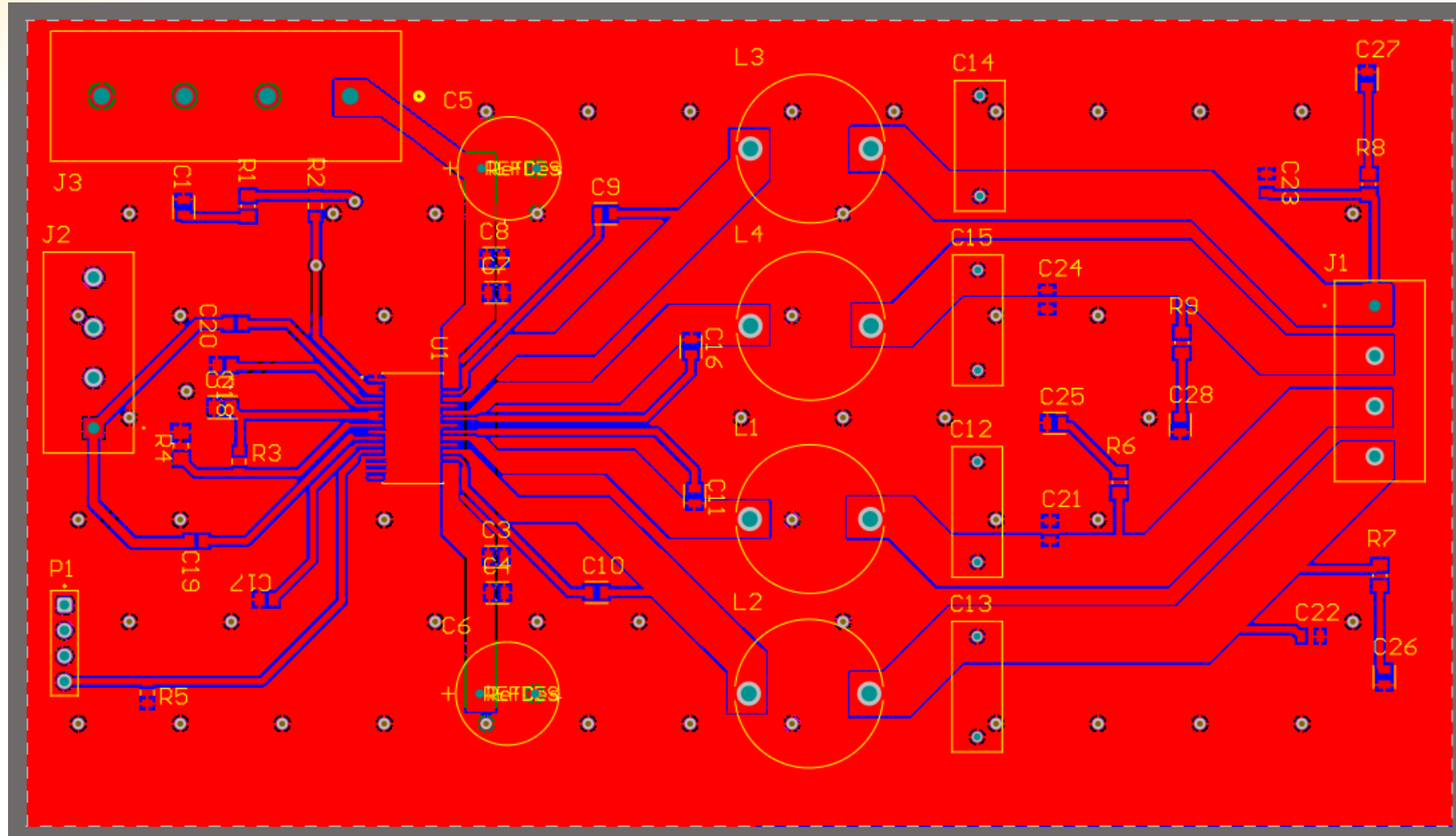
Subwoofer Amplifier PCB Design



Mid/High Amplifier Schematic Design



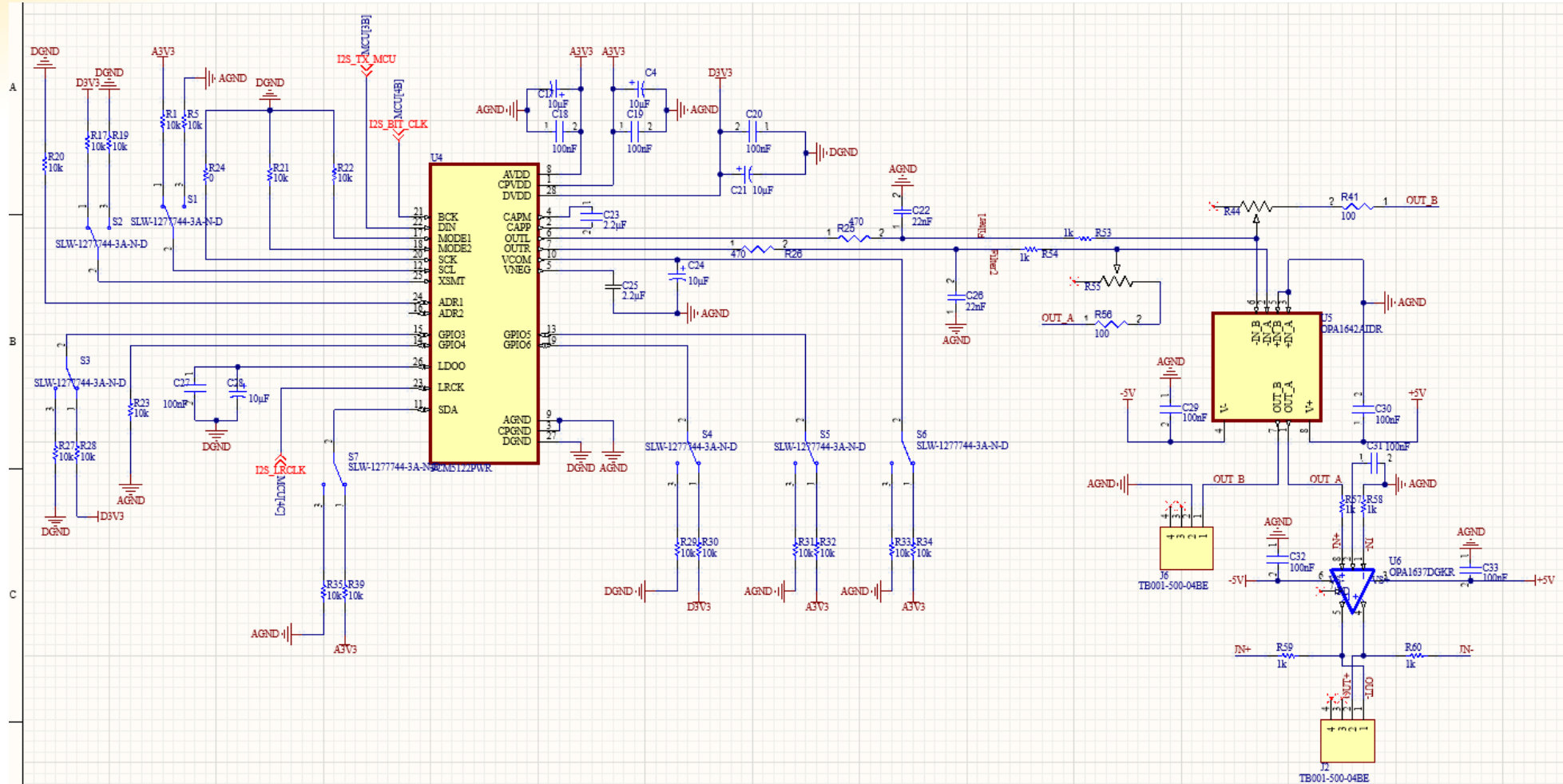
Mid/High Amplifier PCB Design



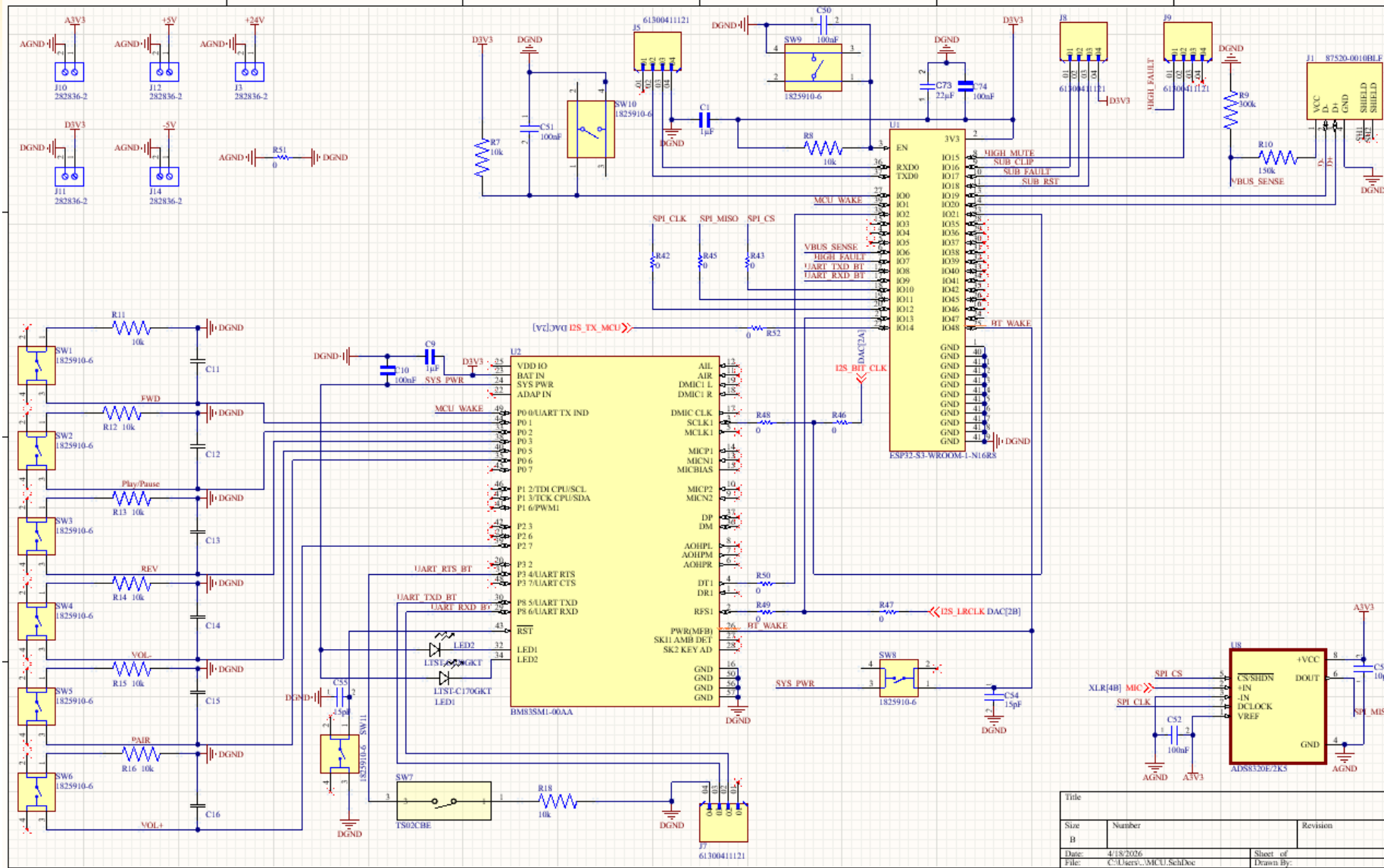
Main PCB



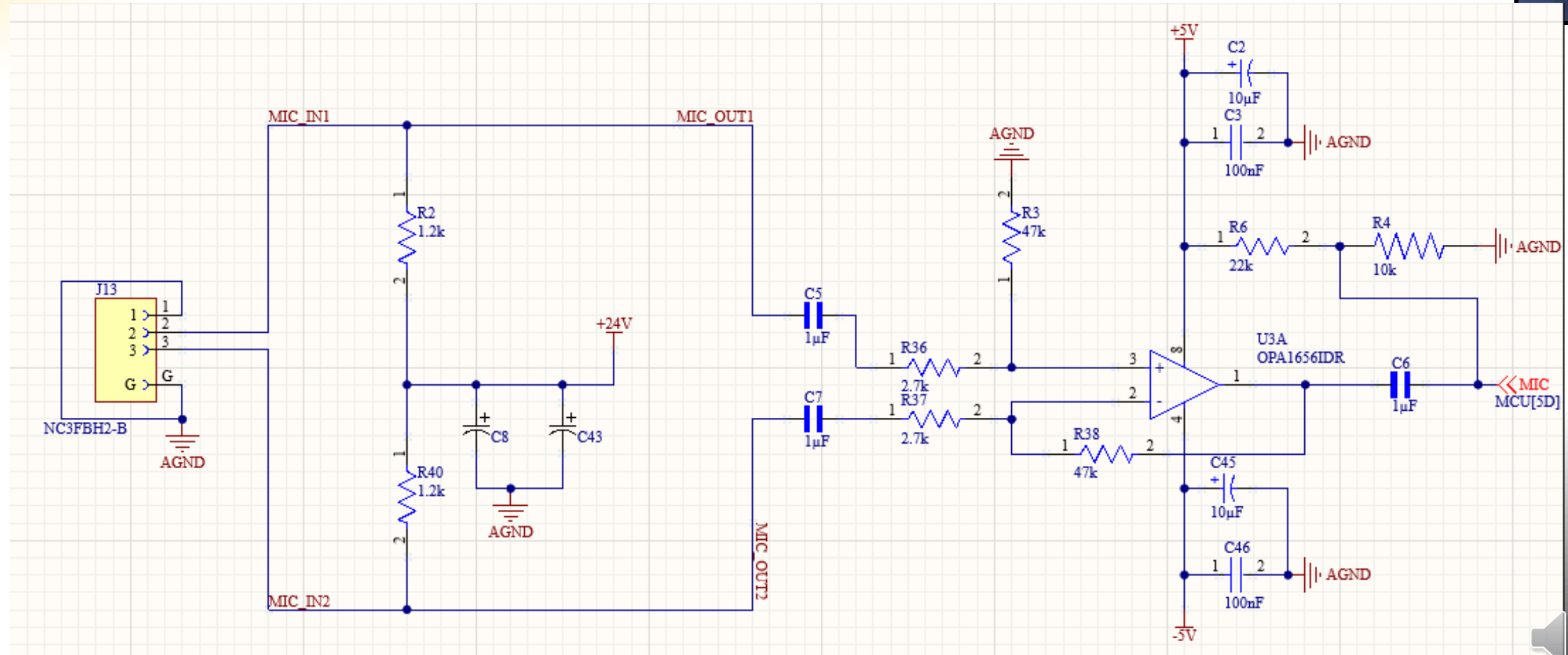
Main Board DAC Schematic



Main Board Digital Schematic

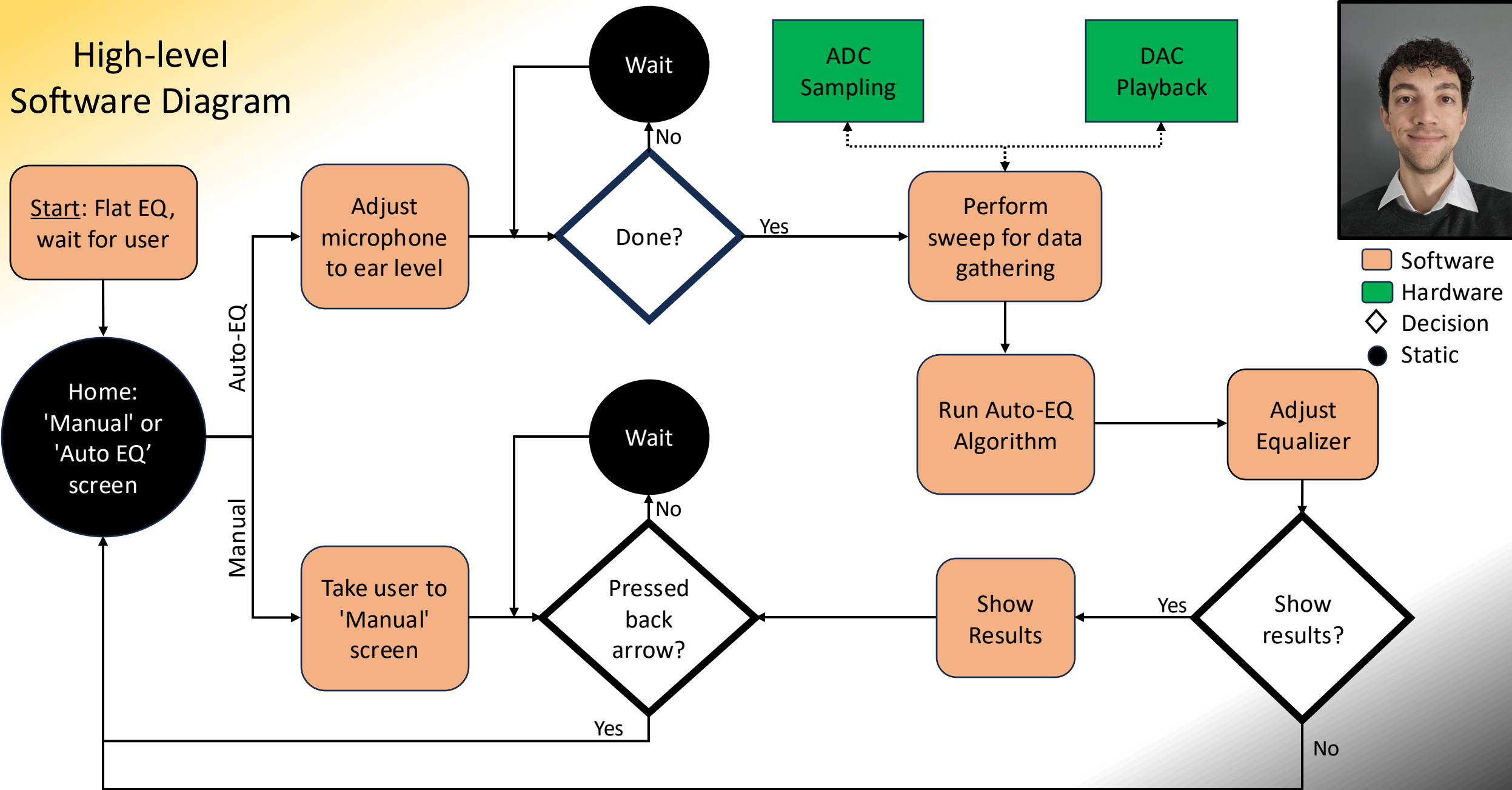


Main Board XLR Schematic





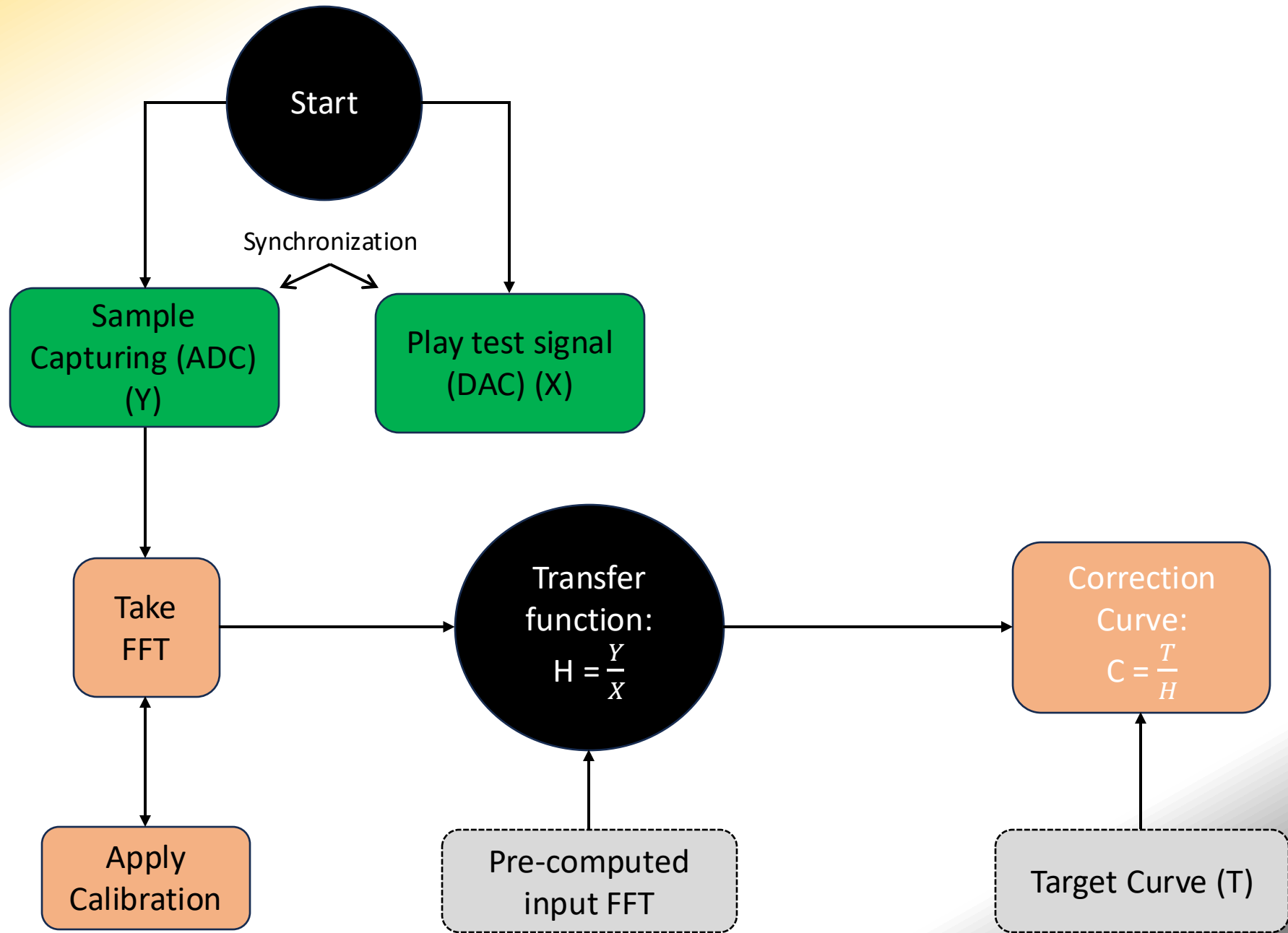
High-level Software Diagram



Auto-EQ Algorithm



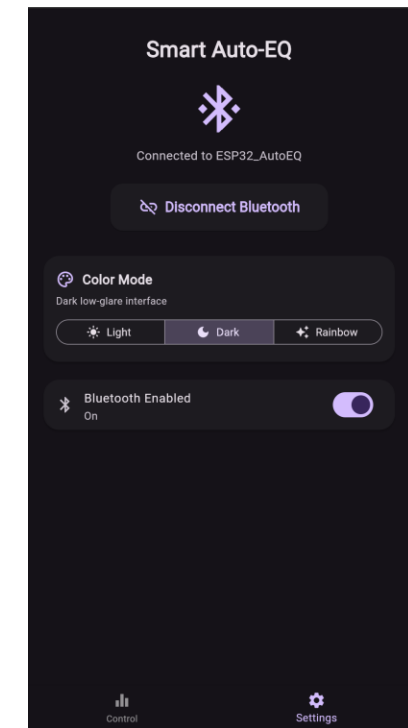
Software
Hardware





Web Application

- **App Framework – Comparison**
 - Flutter (selected)
 - Single codebase for OS
- High-performance UI rendering
- Strong support for:
 - Socket / serial-style communication
 - Real-time UI updates
 - Custom controls and visualization
- Rapid iteration during development
- **Alternatives Considered**
- React Native
 - JS bridge overhead
- Native iOS / Android
 - Duplicate codebases
 - Increased development time



- **Why Flutter Fits This Project**
- Clear separation between:
 - UI layer
 - Control logic
 - Data handling
- Handles:
 - Auto-EQ execution control
 - Manual EQ parameter updates
 - System telemetry and status
- Clean integration with ESP32 communication stack
- **App Deployment & Backend Design**
- Local deployment (APK / iOS build)
- No cloud backend
- ESP32-S3 acts as backend
 - Handles:
 - DSP processing
 - Audio routing
 - Control command parsing
 - Status reporting



Work Distribution



Noah

MCU Board

Regulator Design

Microphone Integration

Speaker Drivers Selection

Jordan

Amplifiers Boards

Bluetooth Hardware

Enclosure Design

Power Supply

Xander

GUI (App) Design

UI/UX Design

Bluetooth (BLE) Integration

Matias

Auto-EQ Algorithm

Embedded Design & Programming



Bill of Materials



Component	Name	Price	Quantity
MCU	ESP32-S3-WROOM-1-N16R8	\$6.56	1
Mids/Highs Amp	TPA3116D2DADR	\$3.10	1
Subwoofer Amp	TPA3251D2DDVR	\$7.81	1
BT Module	BM83	\$13.18	1
DAC	AD1934WBSTZ-RL	\$7.81	1
ADC	ADS8320	\$13.13	1
Microphone	Dayton Audio EMM-6	\$59.98	1
Power Supply	LRS-600N2-36	\$64	1
Regulators	LM2576HSV-ADJ/NOPB	\$8.48	5
24V Regulator	LM5116MH/NOPB	\$6.67	1
XLR Connector	IO-XLR3-F-EH	\$2.63	1
USB-A Connector	87520-0010BLF	\$0.91	1
Tweeters	BC255C08-04	\$23.95	2
Midrange Drivers	Goldwood GM-85/4	\$15.98	2
Subwoofer	Goldwood GW-10PC4	\$79.98	1
PCBs	N/A	\$479.41	N/A
Miscellaneous	Capacitors, Resistors, etc.	\$150.77	N/A
Total Row	N/A	\$1034.09	N/A



Problems faced



- 24V regulator MOSFET broke day before demo
- -5V regulator went through 3 designs before finding one that worked
- Original DAC we chose did not work
- Multiple boards were manufactured with all THT components shorted to ground
- XLR circuitry introduced noise to the microphone

