Engineering Project Portfolio

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Featured Projects:

Chemical Dilution & Dispensing System (in progress)

> A complete mechatronic system with a custom PCB, firmware, and GUI.

DCIR Plotter & Battery Monitor

> A precision data acquisition tool developed for the WWU Formula SAE team.

RGB FFT Music Matrix

> An audio-reactive display featuring digital signal processing.

Formula SAE

>Primary work on safety shutdown loop and Battery Management System (BMS).

Digital Audio Synthesizer

> A bare-metal firmware project focused on real-time waveform generation.

Summary of Core Competencies

Hardware & PCB Design:
Proficient in Altium Designer / KiCad for schematic capture and multi-layer PCB layout. Experienced in full-system hardware design, including component selection, power supply design (LDOs, ferrite beads), and modular driver circuits.

Embedded C/C++ Programming:
Extensive experience with STM32 (ARM Cortex-M) and ESP32 microcontrollers. Skilled in both high-level abstraction (STM32 HAL, TouchGFX on MVP architecture) and low-level, bare-metal register manipulation.

Firmware Architecture & DSP:
Implementation of robust state machine architectures for complex process control. Experience with real-time digital signal processing (FFT) using the ARM CMSIS-DSP library. Designed and implemented persistent storage systems using internal Flash with CRC32 checksums for data integrity.

Communication Protocols & Peripherals :
Proficient with SPI, I2C, UART, and advanced peripheral configuration including DMA, ADC, DAC, and Timers (PWM, Triggers).

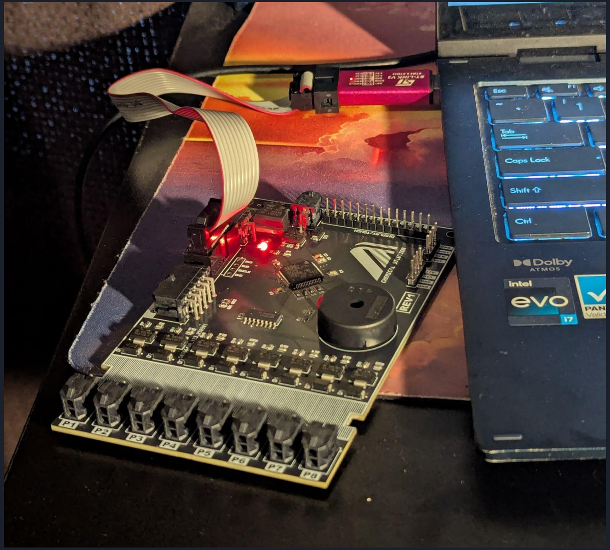
PC Interfacing & Software:
Experience interfacing embedded systems with PCs for data acquisition and visualization using MATLAB. Primarily using Fusion 360 for CAD work. Programs are usually written on STM32CubeIDE.

Prototyping, Fabrication & Debugging:
Skilled in hands-on prototyping, including SMD and Through-Hole soldering, reflow, and 3D printing for enclosures.Proficient with lab equipment including multimeters, oscilloscopes, and logic analyzers for debugging and validation.

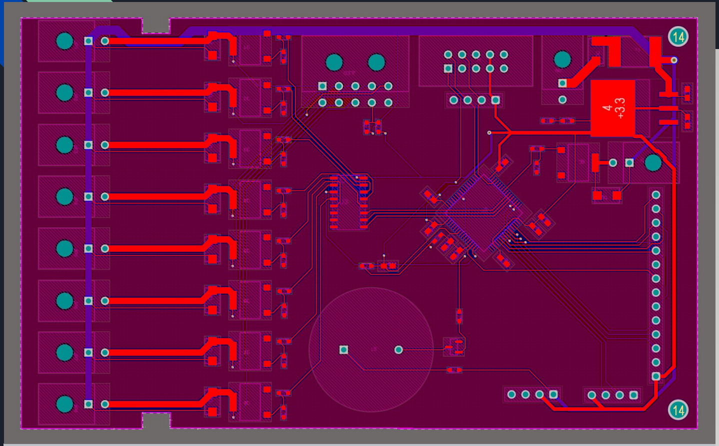
Project 1: Chemical Dilution & Dispensing System

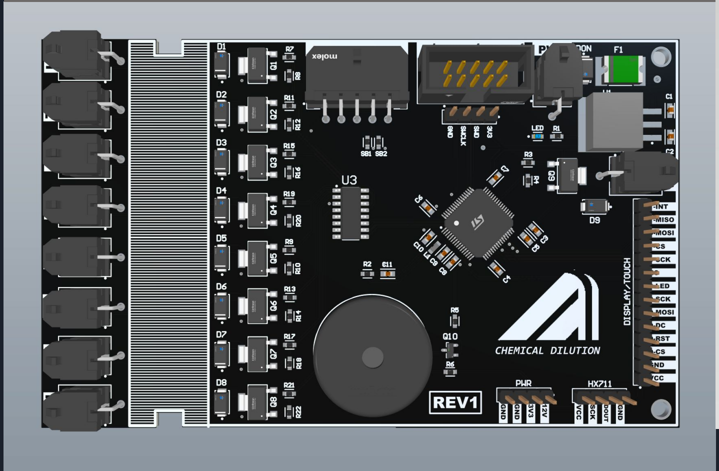
(in progress)

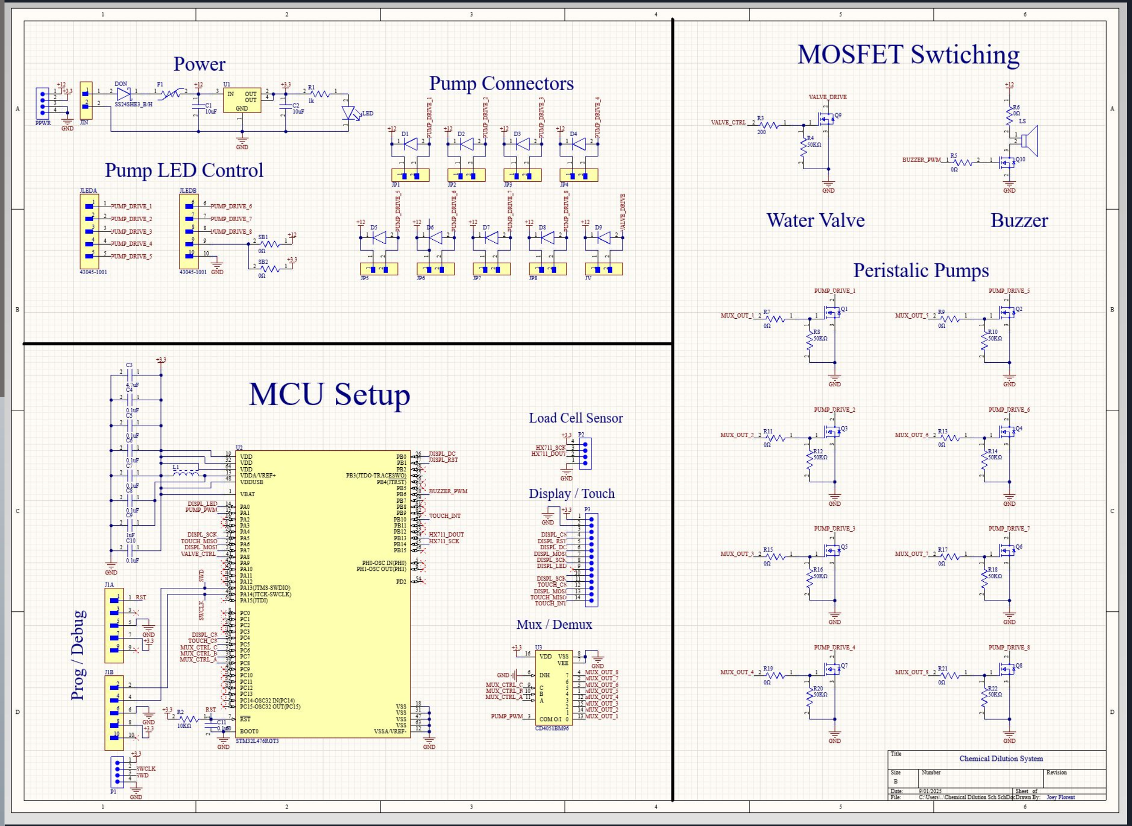
Summary: A standalone, microcontroller-based system designed to accurately dispense user-defined chemical recipes by weight, featuring a custom PCB, modular firmware, and a full graphical user interface



Project 1: Chemical Dilution & Dispensing System







Project 1: Chemical Dilution & Dispensing System

Key Features & Technical Specifications:

Hardware:

>MCU: STMicroelectronics STM32L476RG (ARM Cortex-M4)
>Power: 12V DC input with on-board AMS1117-3.3 LDO regulation. Isolated analog power rail (VDDA) using a ferrite bead.
>Outputs: 8x pump channels and 1x solenoid valve channel, driven by N-Channel MOSFETs with flyback diode protection.
>Sensing: HX711 load cell amplifier with a 5kg load cell for precision weight measurement.
>Interface: 2.8" ILI9341 LCD with an XPT2046 resistive touch panel, driven via SPI.

Firmware:

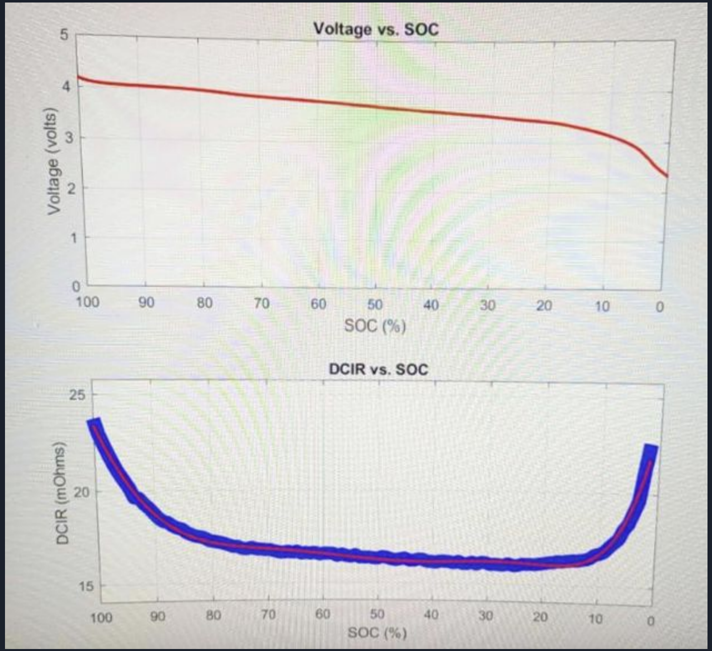
>Developed in C using STM32CubeIDE.
>Robust, non-blocking state-machine architecture manages the entire dispensing workflow.
>Persistent storage of all system settings and recipes to internal Flash memory, validated with a CRC32 checksum for data integrity >PWM control for pump speed (two-stage fast/slow dispense) and buzzer feedback.

Graphical User Interface (GUI):

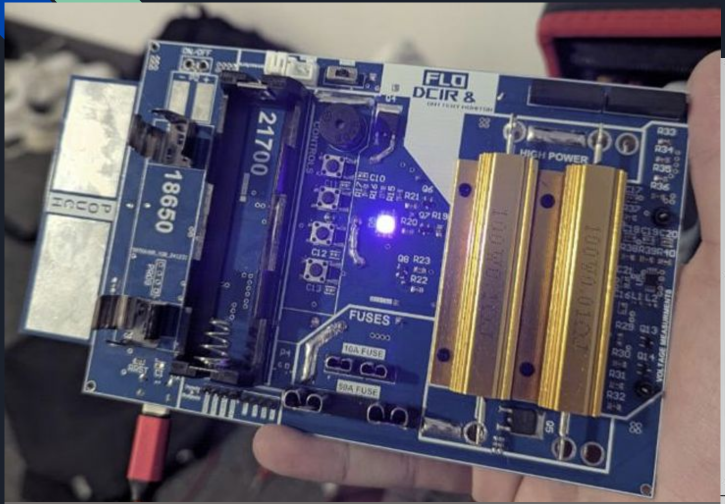
>Developed in C++ with TouchGFX, built on the Model-View-Presenter (MVP) architecture.
>Features a comprehensive suite of 8 screens for dispensing, in-depth recipe creation, pump setup, and system calibration.
>Cleanly bridges the C++ UI and C firmware layers via the Model class.

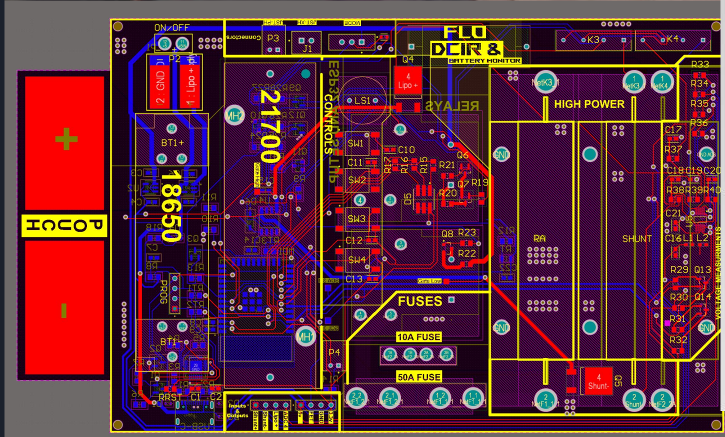
Project 2: DCIR Plotter

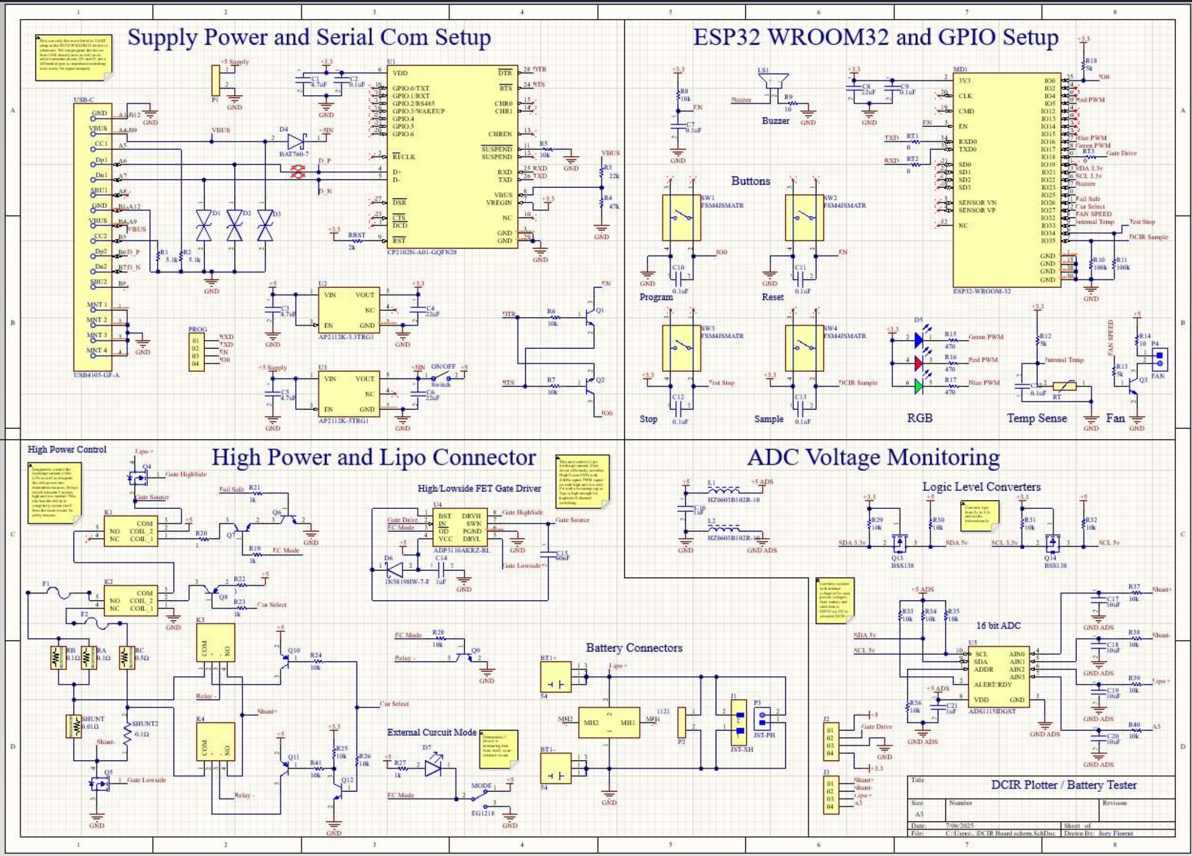
Summary: A custom-built battery diagnostic tool designed to discharge lithium-ion cells at a constant current while measuring voltage and Direct Current Internal Resistance (DCIR) with high precision, interfacing with MATLAB for data visualization.



Project 2: DCIR Plotter







Project 2: DCIR Plotter

Hardware:

>MCU: ESP32 for processing and USB-to-UART communication.
>ADC: Texas Instruments ADS1115 16-bit external ADC for high-resolution measurement, communicating via I2C.
>Current Sensing: Precision low-value shunt resistor for accurate current measurement.
>Load: High-power aluminum-housed resistors to dissipate energy from the battery.
>Thermal Management: Active cooling system with fans to manage heat generated by the load resistors during high-current discharge

Performance:

>Discharge Current: Constant-current discharge, programmable up to 15A.
>Voltage Measurement Tolerance: Within 0.2 millivolts.
>Impedance Calculation Accuracy: Within 0.5 milliohm.
>Data Interface: Transmits measurement data over a serial connection (USB-to-UART) to a host PC.

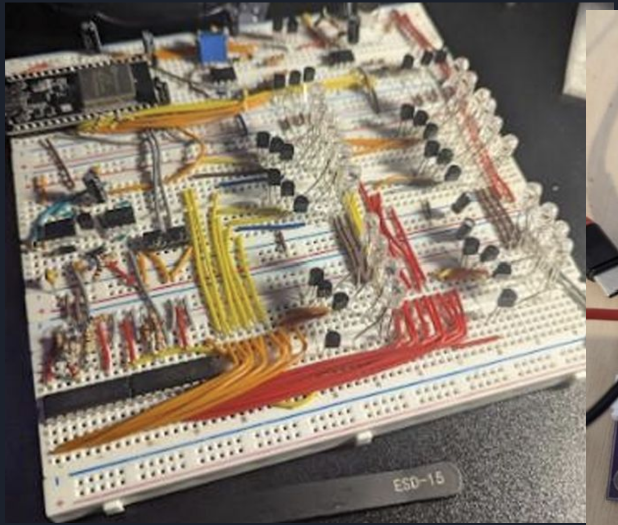
PC Software:

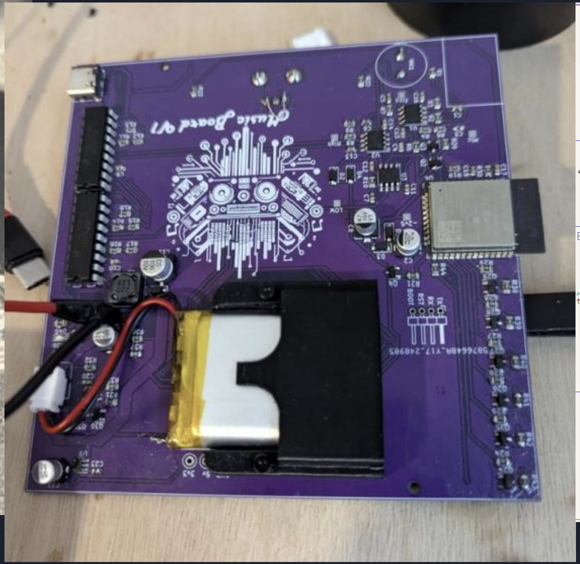
>A custom MATLAB script was developed to receive the serial data, process it, and automatically plot key battery parameters, such as DCIR as a function of the cell's State of Charge (SOC).

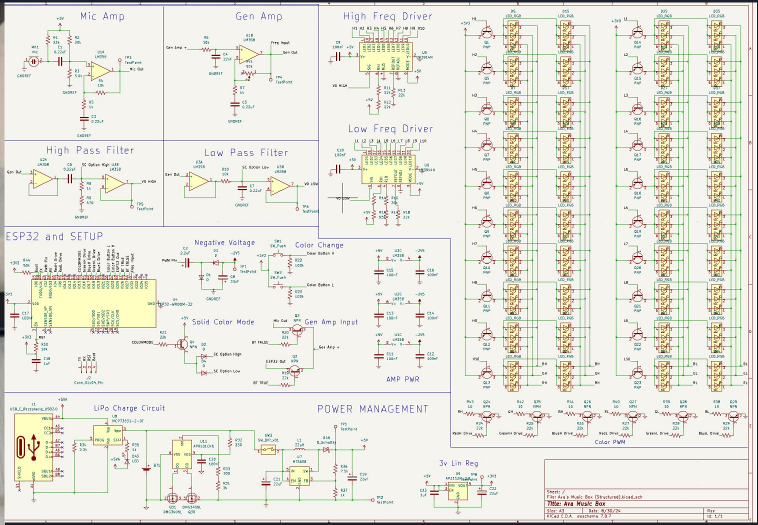
Project 3: RGB FFT Music Matrix

Summary: A dual 10x3 RGB LED matrix that processes audio from a microphone or Bluetooth source. An ESP32 microcontroller performs a Fast Fourier Transform (FFT) to map frequency bands to LED colors, while an LM3915 driver maps audio amplitude to the height of the display.

Project 3: RGB FFT Music Matrix







Project 3: RGB FFT Music Matrix

Hardware:

>MCU: ESP32 for its processing power and integrated Bluetooth Classic capabilities.
>Audio Input: Dual-mode input via an onboard microphone or a Bluetooth A2DP audio sink.
>Display: Two custom 10x3 RGB LED matrices.
>Amplitude Driver: LM3915 Dot/Bar Display Driver for analog-driven row illumination.

Power System:

>Powered by a single-cell Lithium-ion battery.
>Onboard TP4056 for Constant Current/Constant Voltage cell charging. >MT3608 boost converter to provide a stable 5V rail for the system from the battery. >Custom negative voltage charge pump circuit to provide a true ground reference for the audio op-amp.

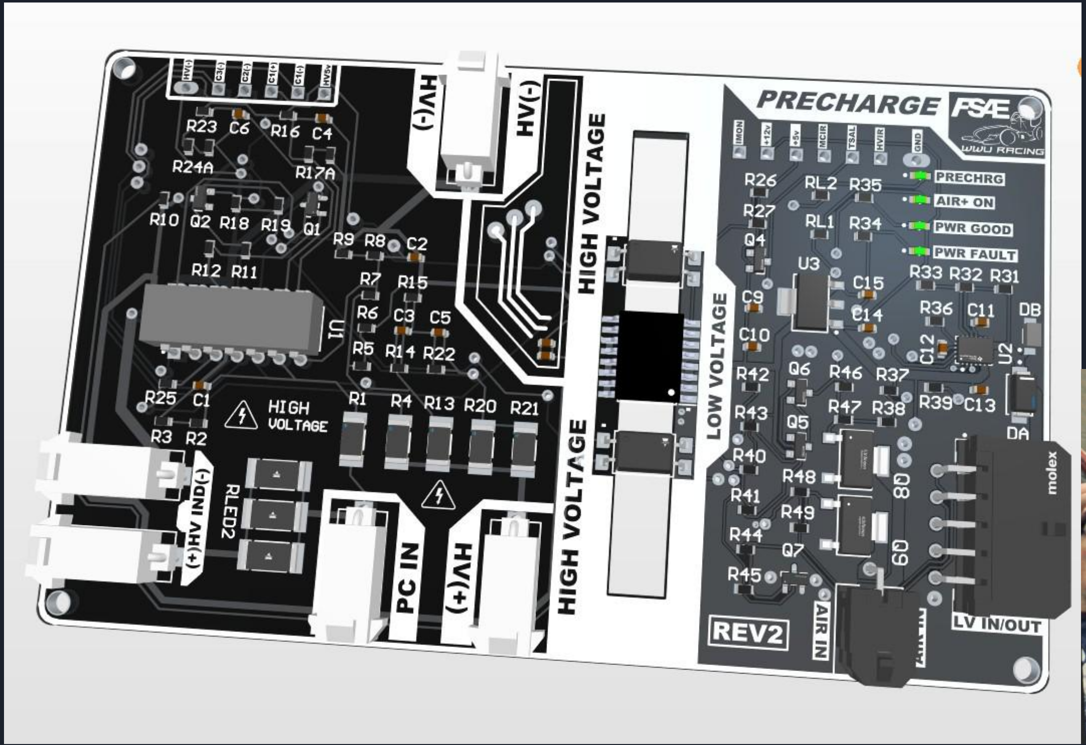
Firmware & Signal Processing:

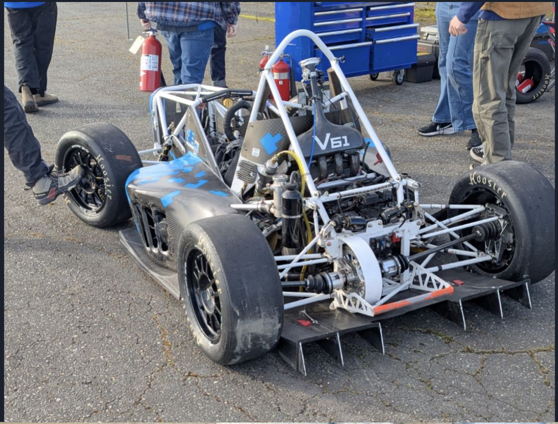
>Developed in C using the Arduino IDE and ESP-IDF components.
>Implementation of a C-based Fast Fourier Transform (FFT) library to analyze audio in real-time.
>Frequency bands (bass, mid, treble) are extracted from the FFT output bins.
>PWM control is used to mix the RGB colors of the LED columns based on the energy in each frequency band. >Also features non-audio-reactive modes for displaying solid or changing colors.

Project 4: Formula SAE: Accumulator & Shutdown Systems

Summary: As a member of the electrical engineering team, I designed safety-critical PCBs for the high-voltage (HV) battery accumulator's shutdown loop, ensuring compliance with rigorous FSAE safety rules. (LV) I designed High and Low voltage interface circuits and the teams standard PCB safety circuits.

Project 4: Formula SAE: Accumulator & Shutdown Systems





Project 4: Formula SAE: Accumulator & Shutdown Systems

System Focus: The Accumulator Shutdown Loop >The shutdown loop is a series of safety circuits designed to instantly and safely disconnect the high-voltage battery pack from the rest of the vehicle in the event of a fault. My work was focused on designing the custom PCBs that monitor the system and control the main isolation relays.

My Contributions:

>Schematic Capture & PCB Layout (Altium Designer): Designed multiple PCBs for the shutdown circuit, focusing on high reliability and clear separation between high-voltage and low-voltage (12V) domains.

>Tractive System Active (TSA) Detection: Designed the circuit that physically illuminates a light when the high-voltage system is active (>60V), a key safety requirement.

>Isolation Relay Control: Designed the MOSFET-based driver circuits to reliably switch the large contactors that control the flow of current from the battery pack.

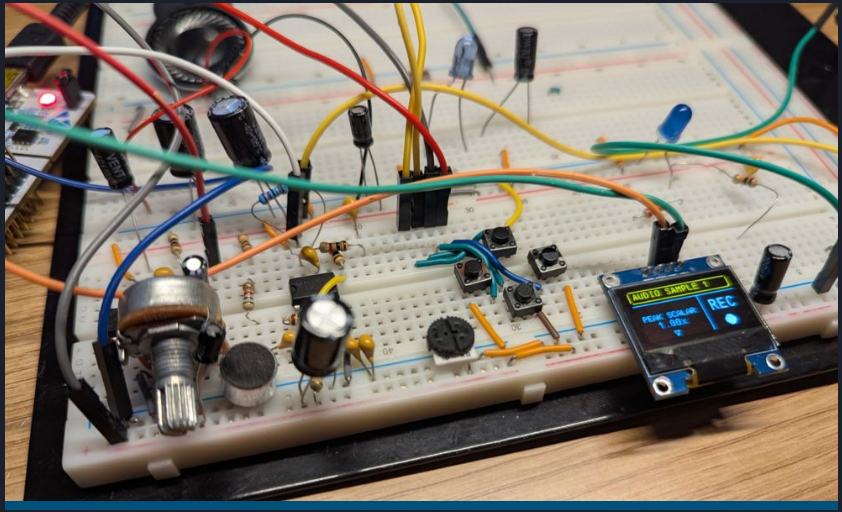
>Battery Management System (BMS) Support: Worked with the BMS, a critical component that monitors the health of individual cells and can trigger the shutdown circuit.

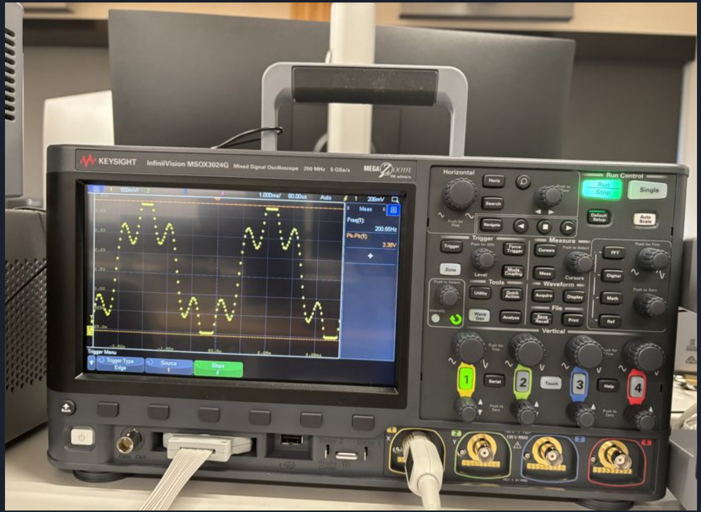
>Data Acquisition Tooling: Developed the DCIR Plotter (detailed in the next section) to provide essential cell characterization data for the accumulator design team.

Project 5: Digital Audio Synthesizer

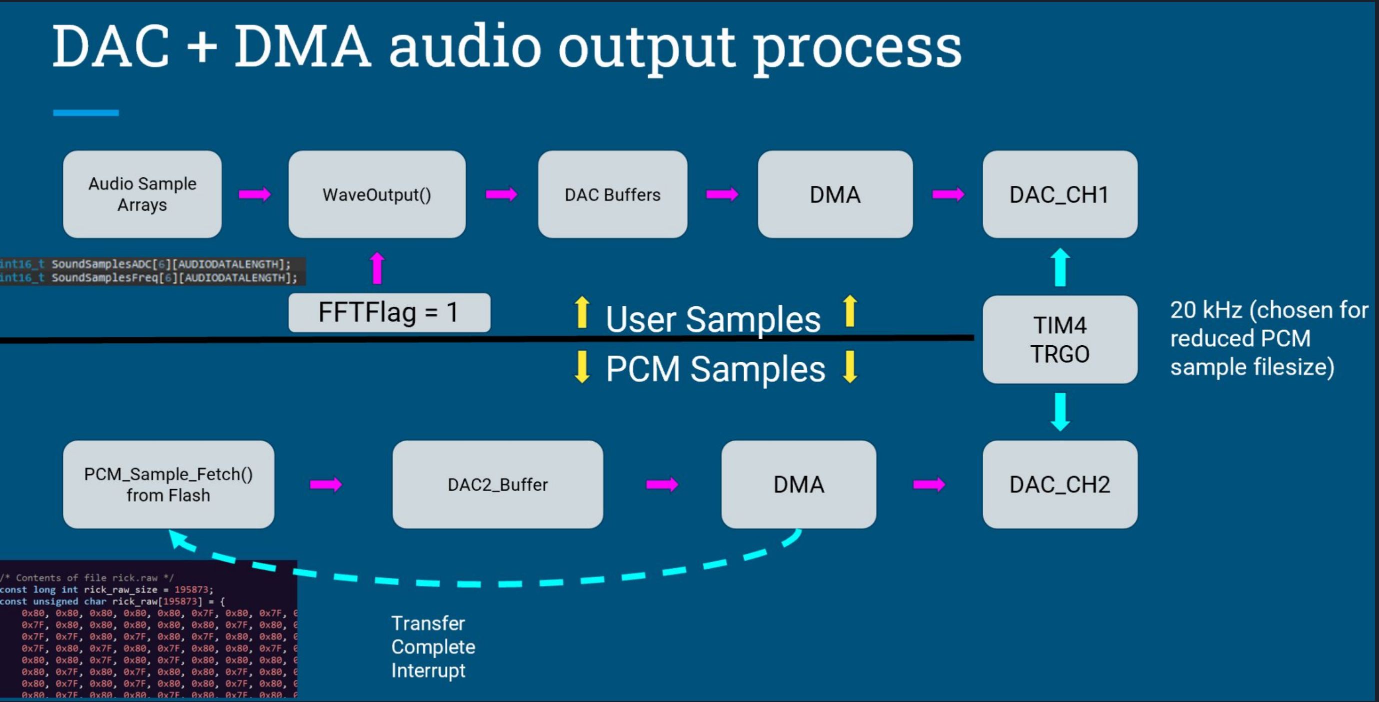
(This project was not finalized past breadboard (No PCB or schematic)

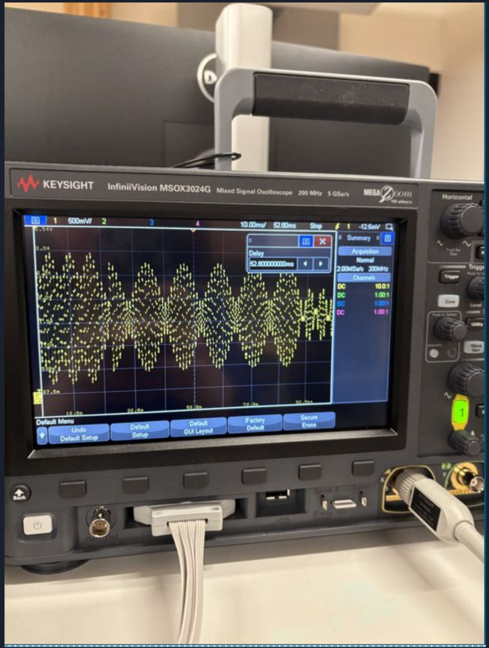
Summary: A complete monophonic synthesizer built on an STM32 microcontroller. The firmware was written using low-level register manipulation to generate multiple classic waveforms and process them through a digital filter and envelope, all in real-time.





Project 5: Digital Audio Synthesizer





Project 5: Digital Audio Synthesizer

Firmware Architecture:

>Developed entirely in C using bare-metal register manipulation (no HAL library).
>Utilizes a dual-DMA architecture: DMA2 for ADC sampling and DMA1 for continuous, glitch-free waveform output to the DAC.
>A high-frequency timer (TIM4) acts as the master audio clock, triggering the DAC via DMA to ensure a stable sample rate (e.g., 44.1kHz).

Synthesizer Engine:

Oscillators (VCO): Real-time generation of multiple waveforms:
>Sine: High-resolution, generated from a 1024-point lookup table.
>Sawtooth: Band-limited, generated using a digital accumulator.
>Square: Generated using the microcontroller's PWM hardware.
>Triangle: Generated by integrating the square wave.

Hardware:

>MCU: STMicroelectronics STM32L476RG.
>Output: 12-bit Digital-to-Analog Converter (DAC) for audio output.
>Interface: User control via push-buttons (managed by EXTI interrupts) and an I2C-based SSD1306 OLED display for parameter feedback.
>LM386 Power amplifier for the speakers
>LM358 Dual Op Amp for microphone amplification.