STM-Based DAQ

Automation Solutions

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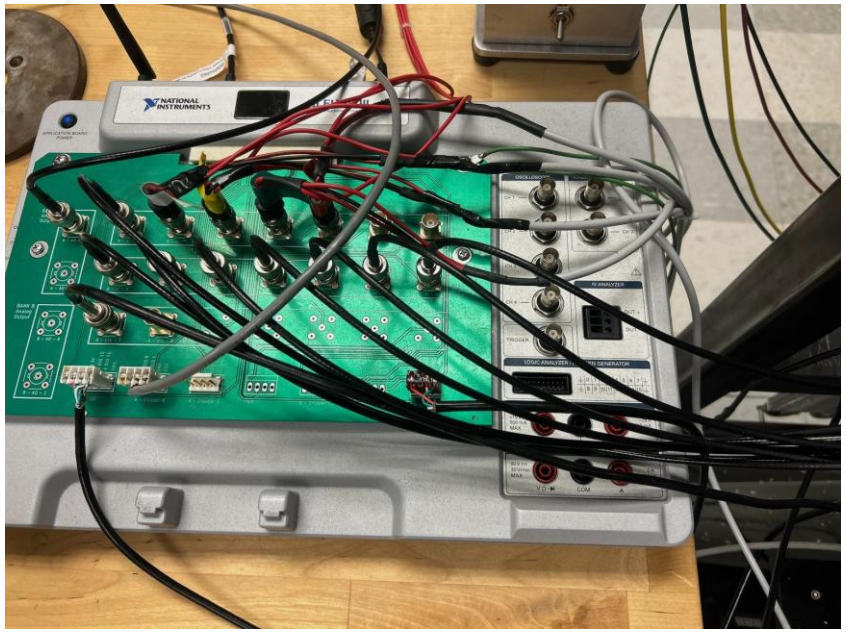
The Problem



Old DAQ System

- ME 4056's DAQ System has **high-cost** (~$3000)
- Currently being **phased out** by NI

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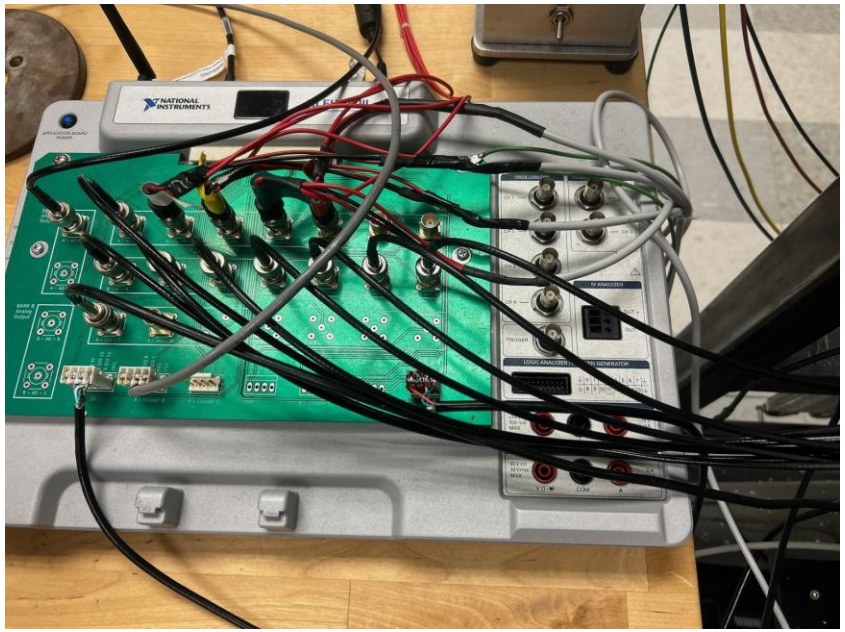
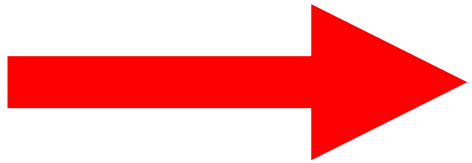
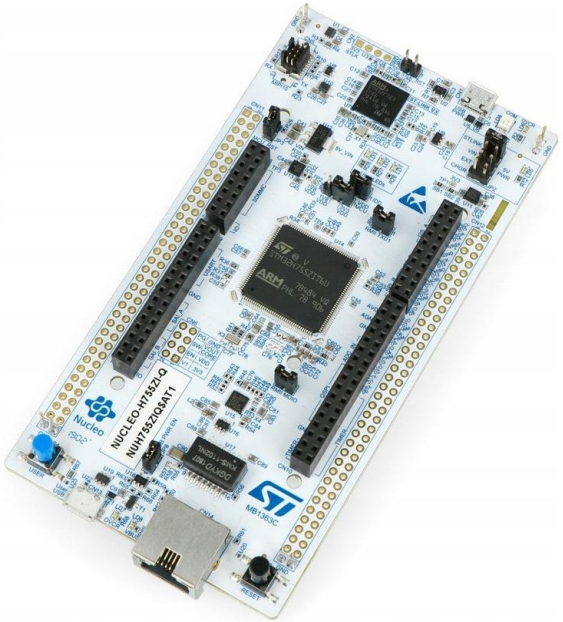
Our Project

Develop Data Acquisition System Compatible with Current ME 4056 Experimental Setup and with Cloud based GUI. Verify system with function generator and physical system (RC Car).



Old DAQ *($3000)*





New DAQ *($300)*

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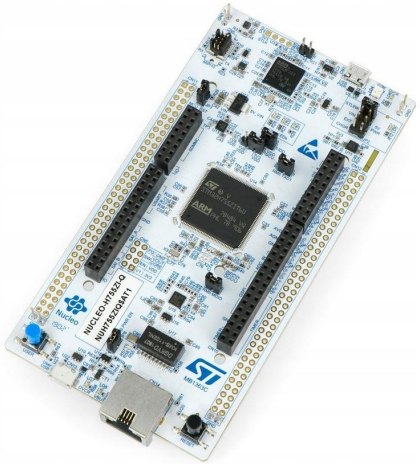
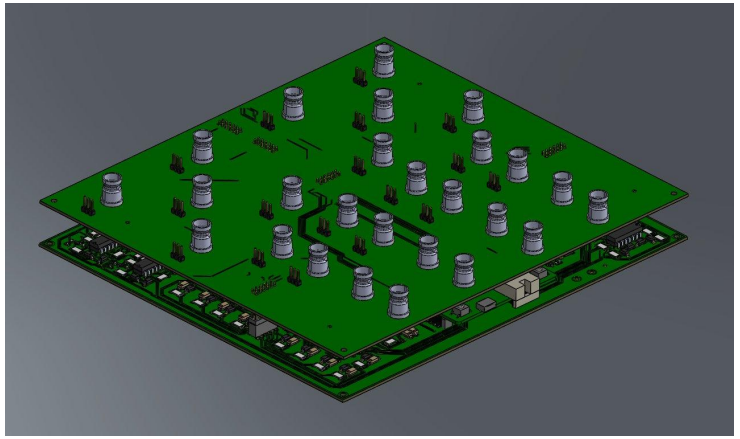
Subsystems

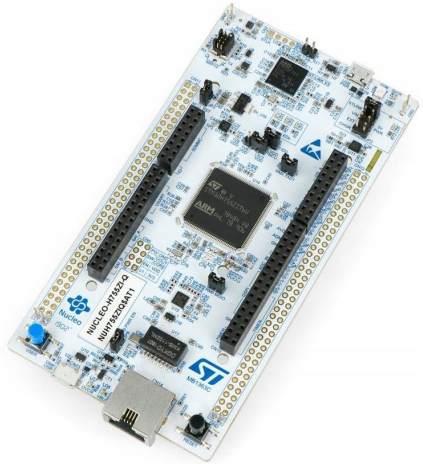


Microcontroller

Subsystems

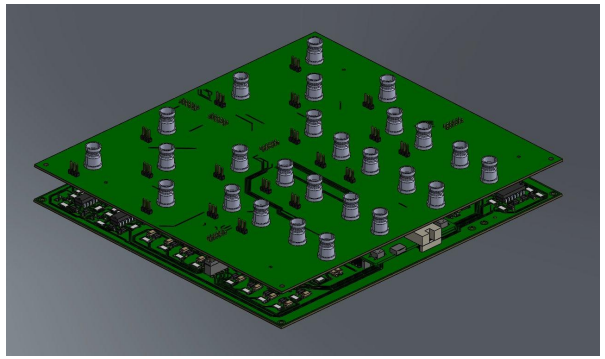


Interface Board

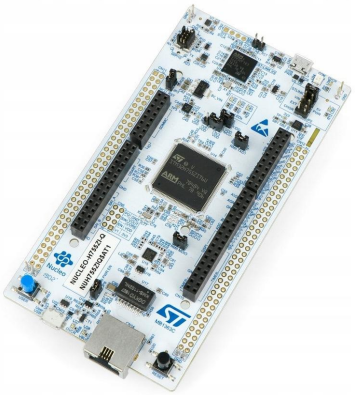


Microcontroller

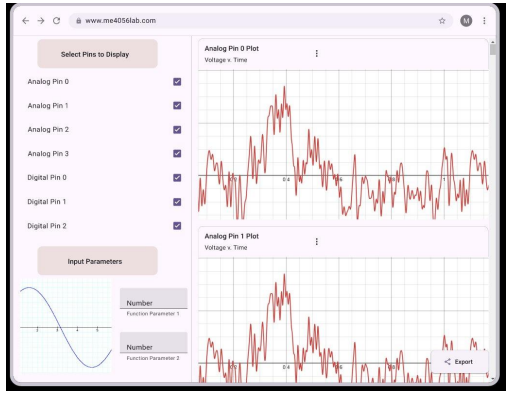
Subsystems



Interface Board



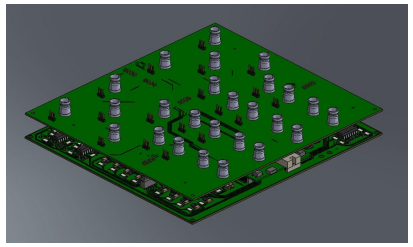
Microcontroller



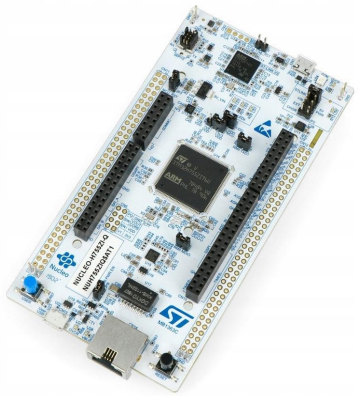
Cloud GUI

Subsystems

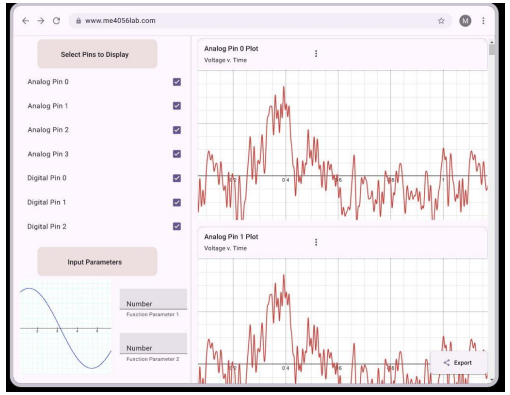
Test Bed (F1tenth)



Interface Board



Microcontroller



Cloud GUI

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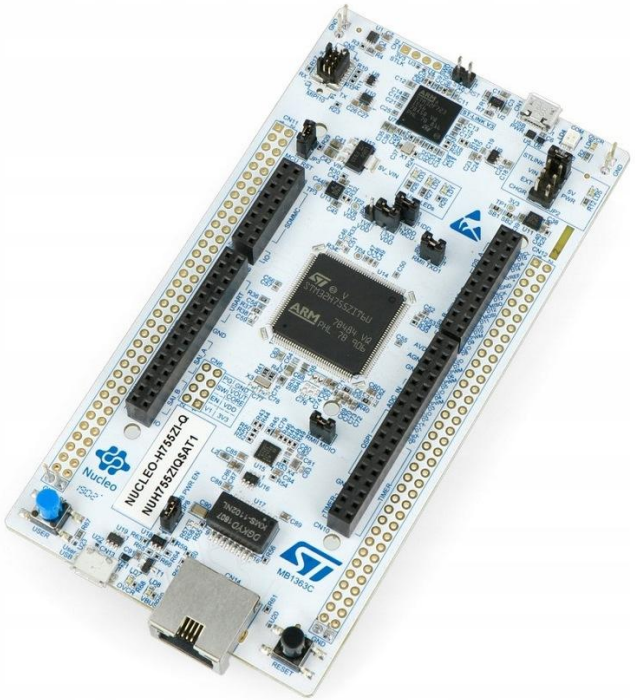
Microcontroller Requirements

- 10x Analog inputs
- 8x Digital inputs
- 2x I2C channels
- 2x Digital Frequency Monitors
- 2x PWM output channels
- 2x Function generator channels
- Communicate to cloud via USB



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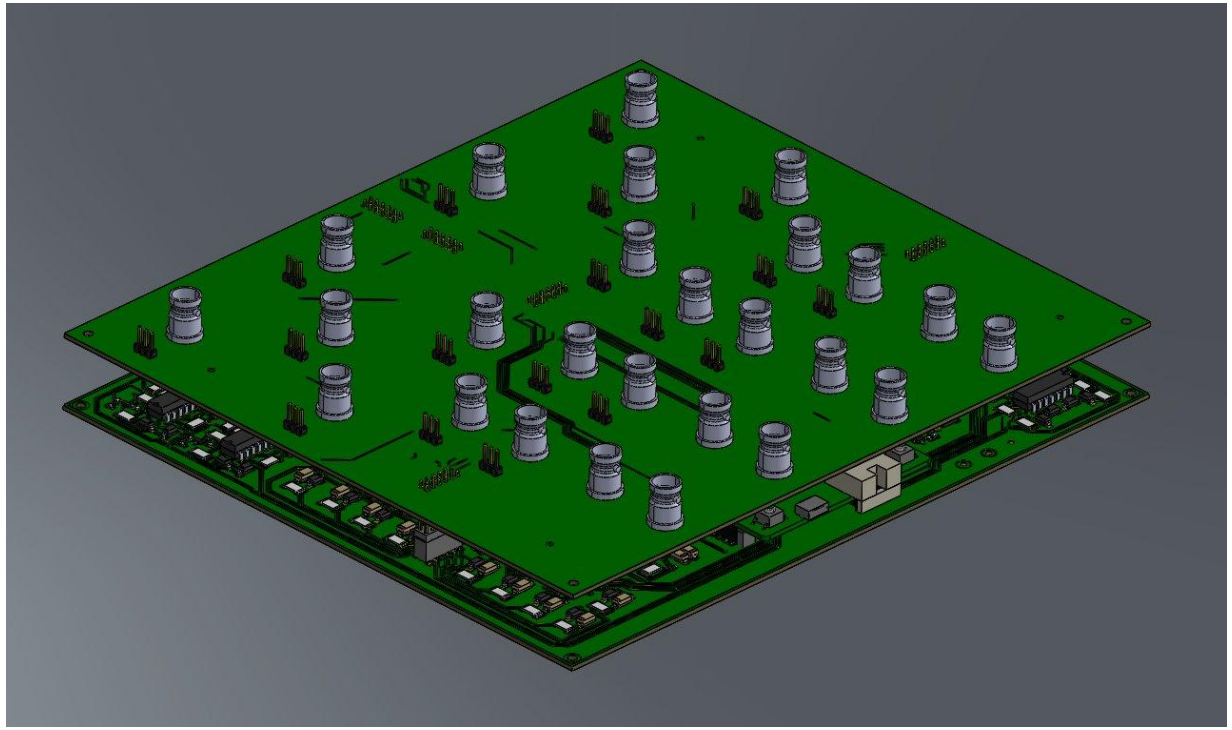
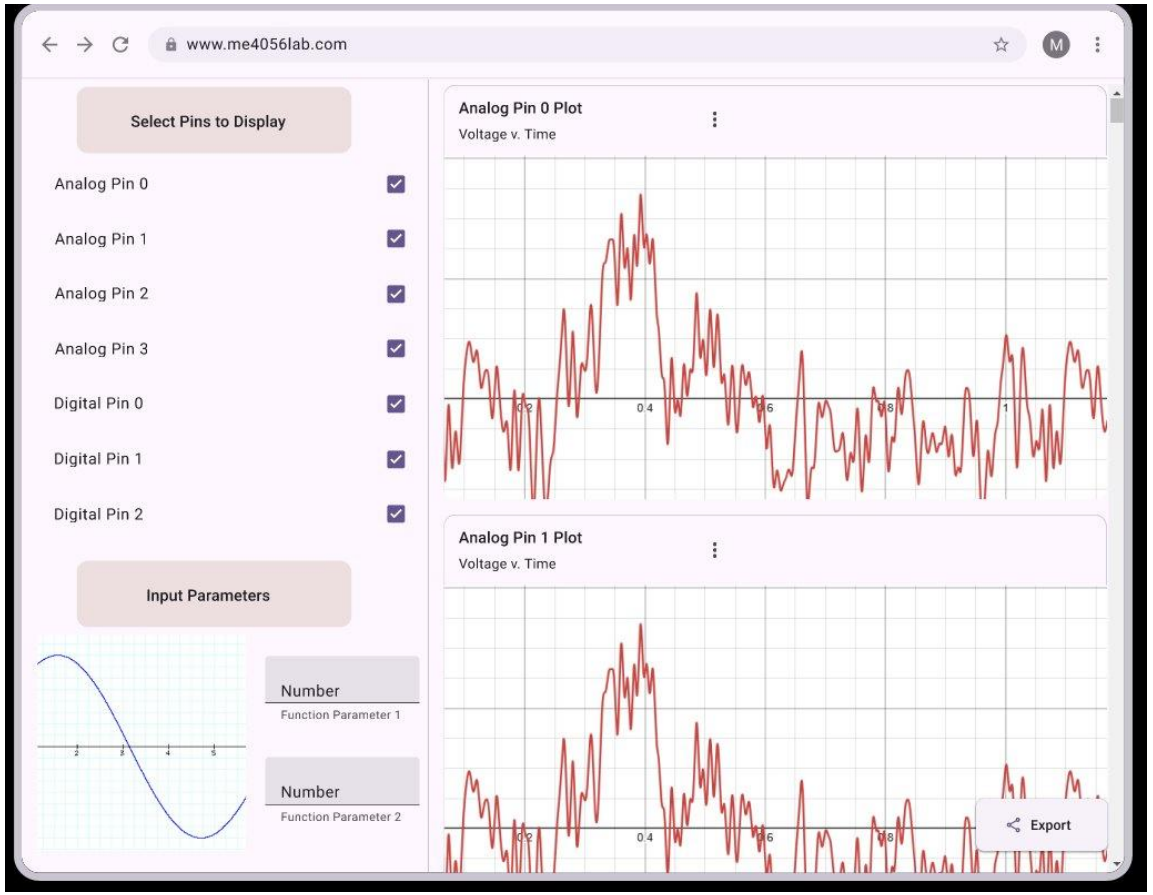
Interface Board Requirements

- Easy DAQ interface
- Protect against controller overvoltage
- Protect against controller overcurrent
- Remove background noise



Cloud GUI Requirements

- **Collect**, **Store**, & **Visualize** data from DAQ
- **Facilitate Communication** between User and DAQ
- **Intuitive Interface** to modify visualizations, creating adaptable dashboards for the labs



Validation Requirements

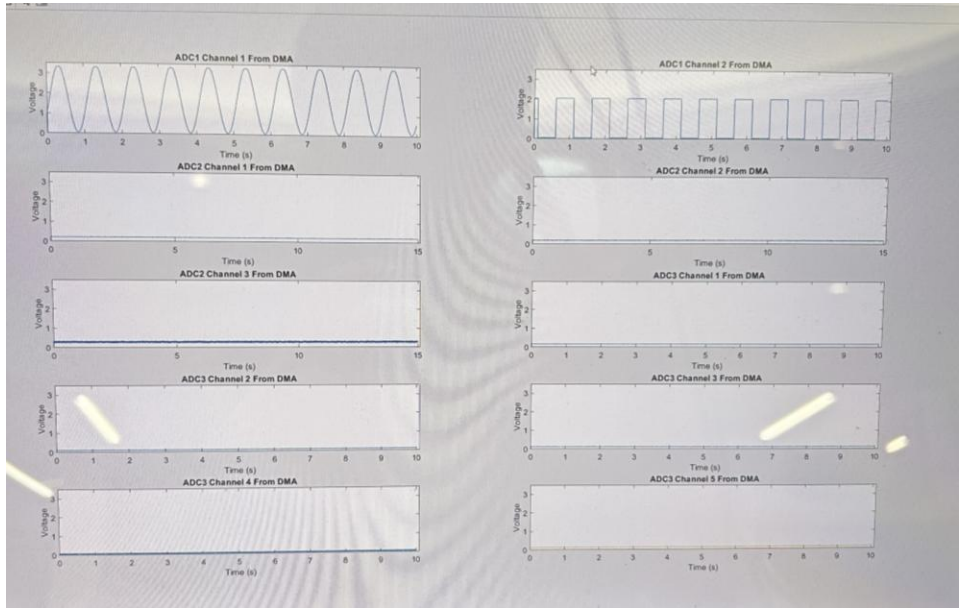
- Simulate all potential inputs/outputs
  - Analog, digital, I2C, PWM, function generator
- Simulate lab experiments
  - Optimize lap time
- Portable testbench

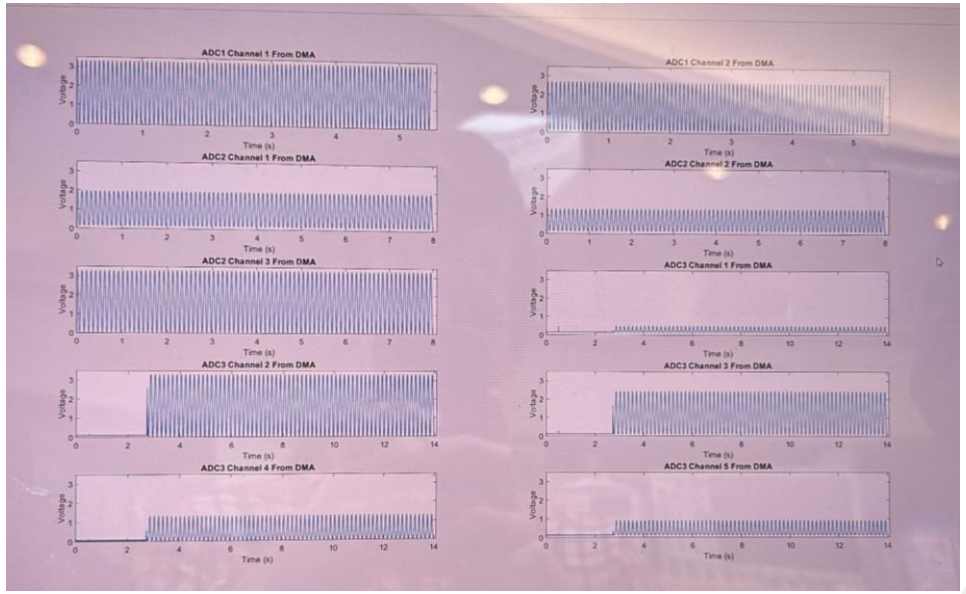
Microcontroller

STM Software Progress

Achievements to date

- RTOS
  - Multi-Threading
- ADC
  - Analog-to-Digital-Conversion with DMA
- Cross-Core Communication
  - Can send information from M4 to M7
- Output Peripherals Tests
- UART Communication Tests





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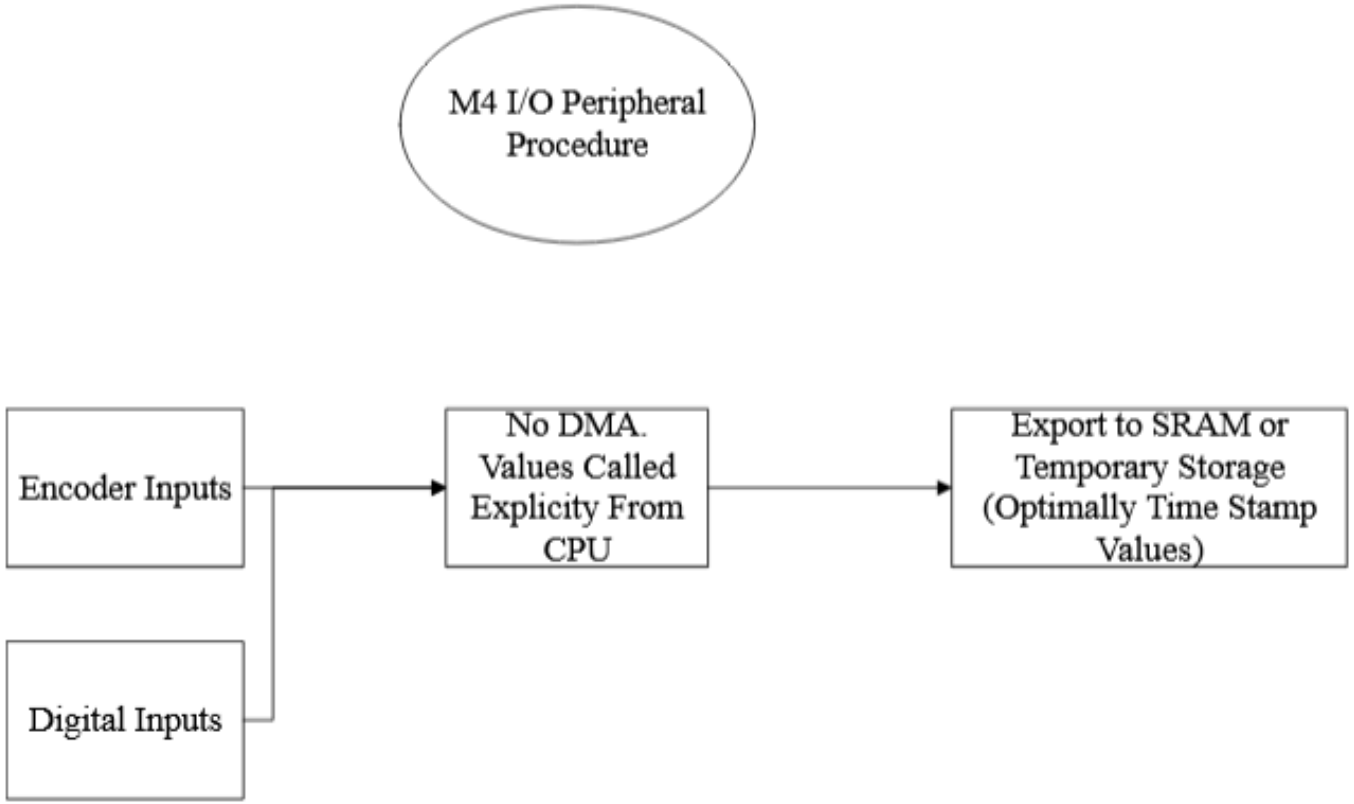
M4 State Diagram



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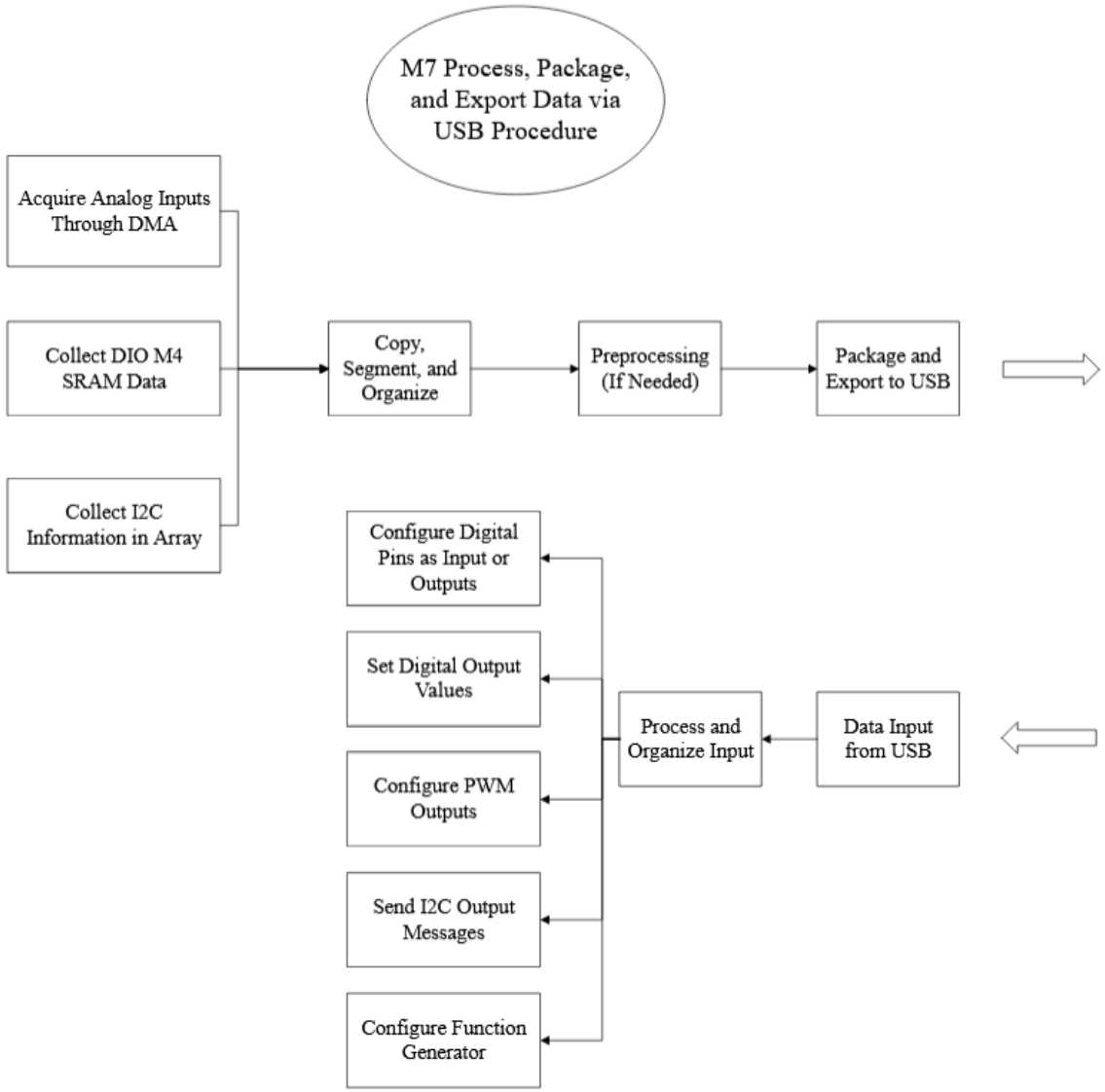
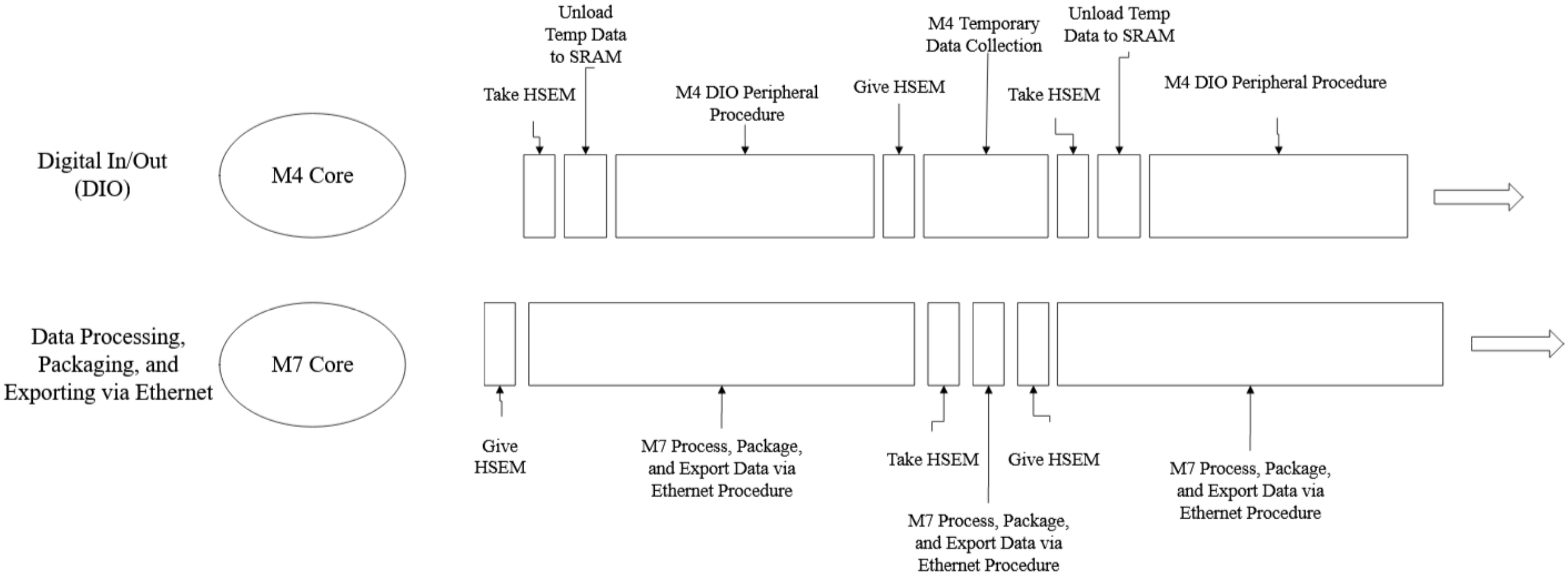
M7 State Diagram



HSEM Cross Core Communication – High-Level

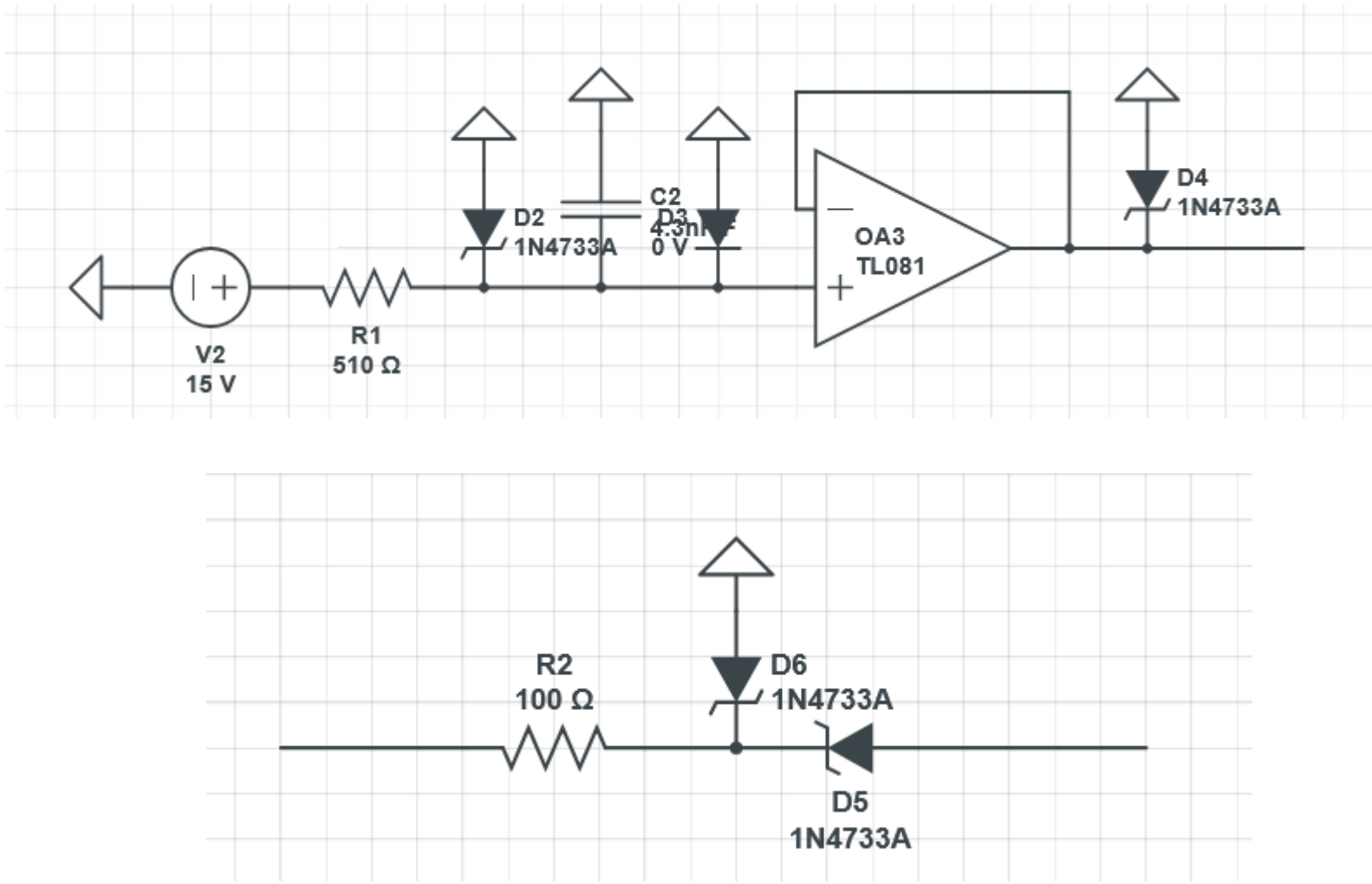


Microcontroller: Next Steps

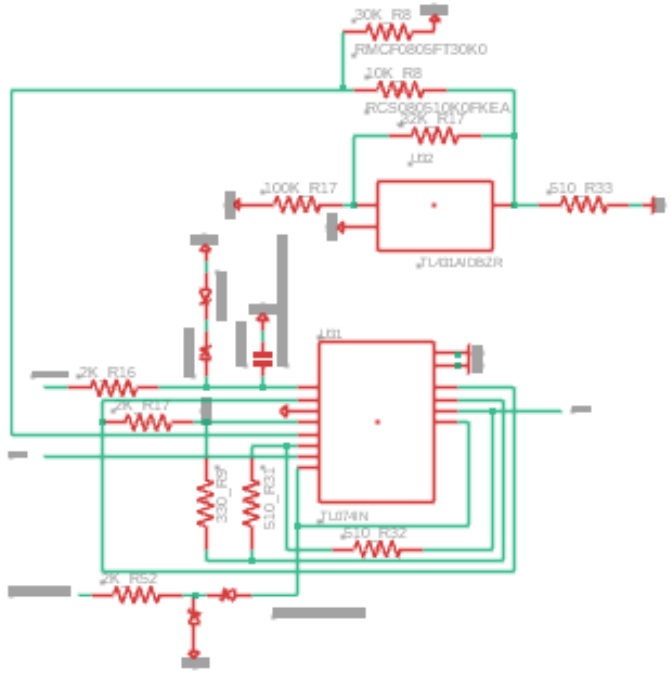
- Complete M4 Digital I/O Collection and Cross Core Communication
- Complete M7 ADC to Optimal Sampling Speed
- Implement M7 Peripheral Code
- Setup RTOS for Data Sending/Receiving Data

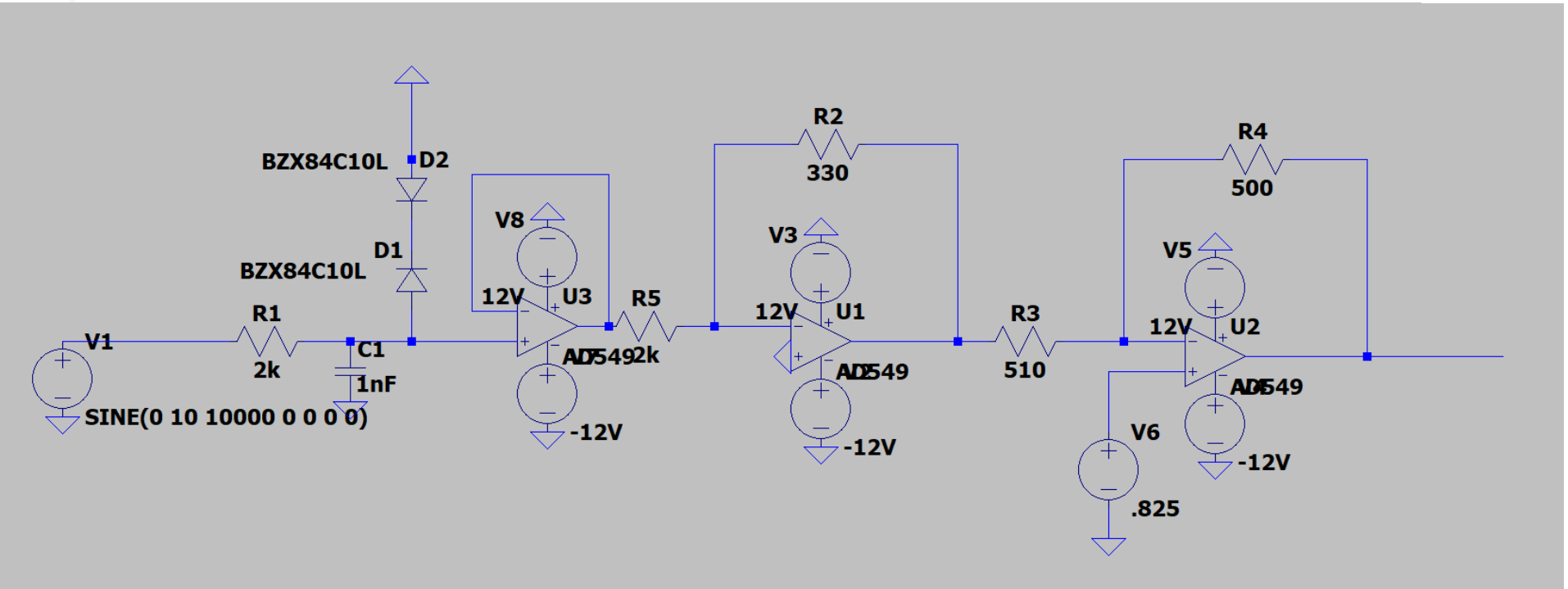
Interface Boards

0-3.3V Input Range



-10 to 10V Input Range





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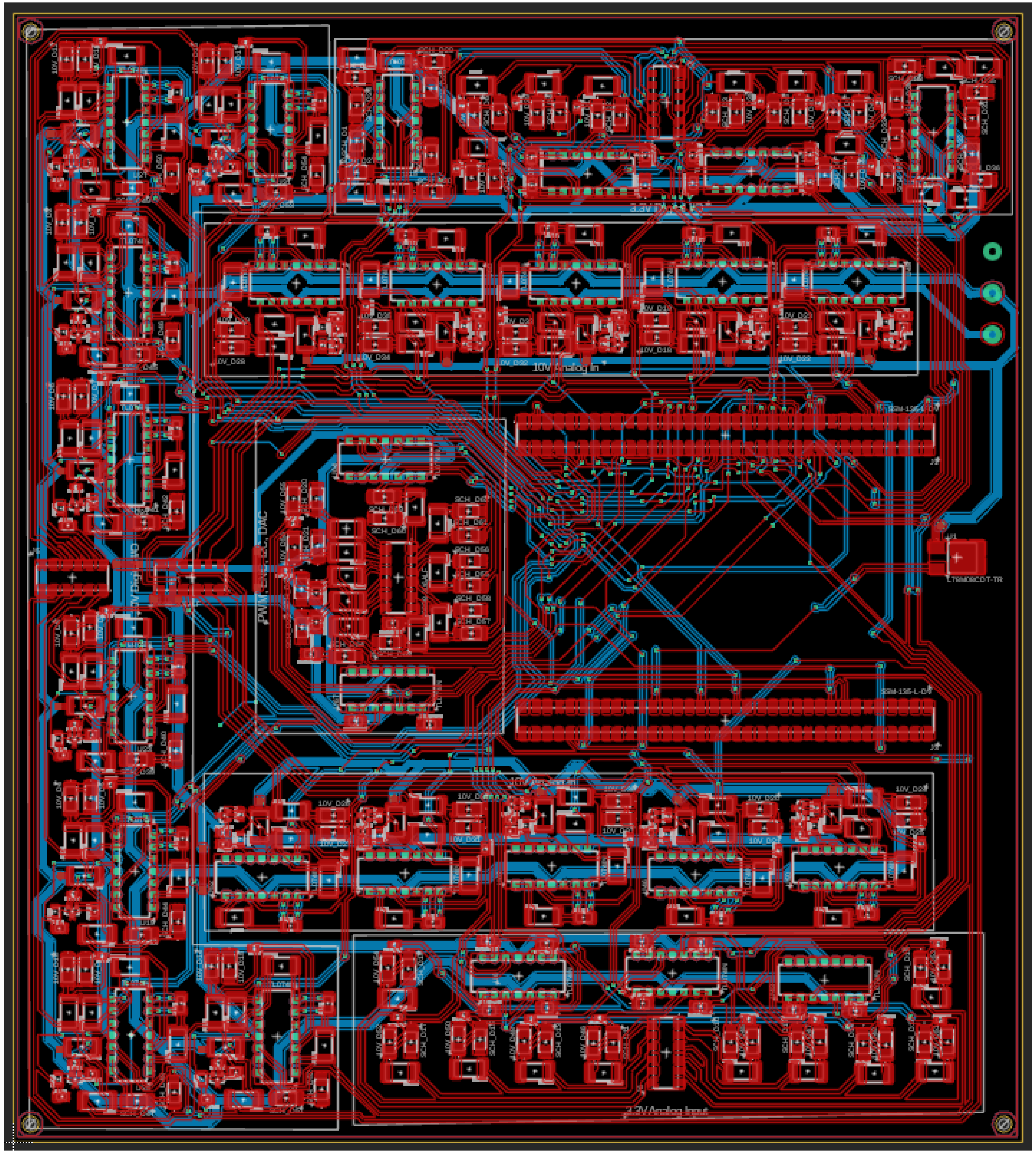
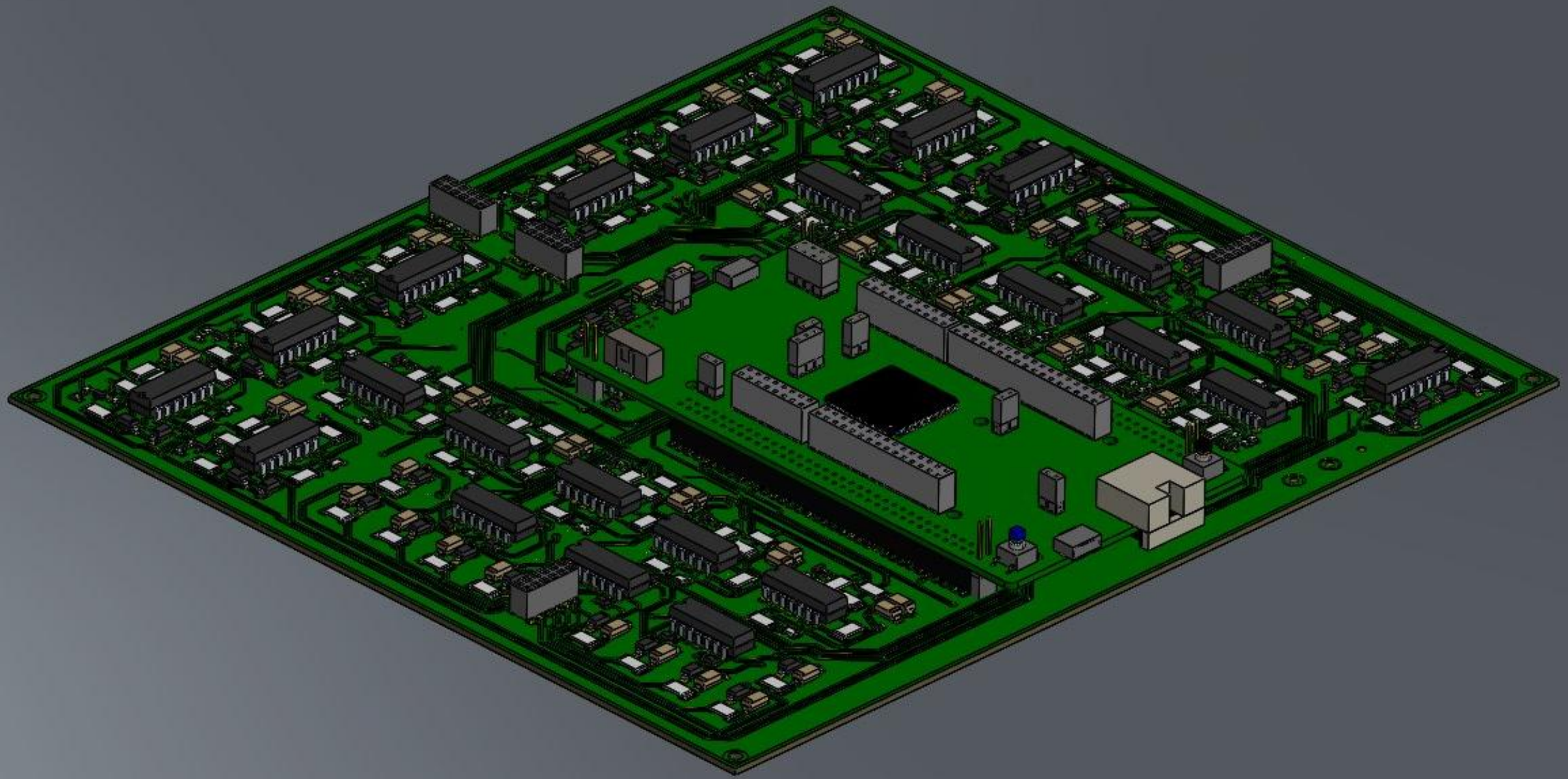
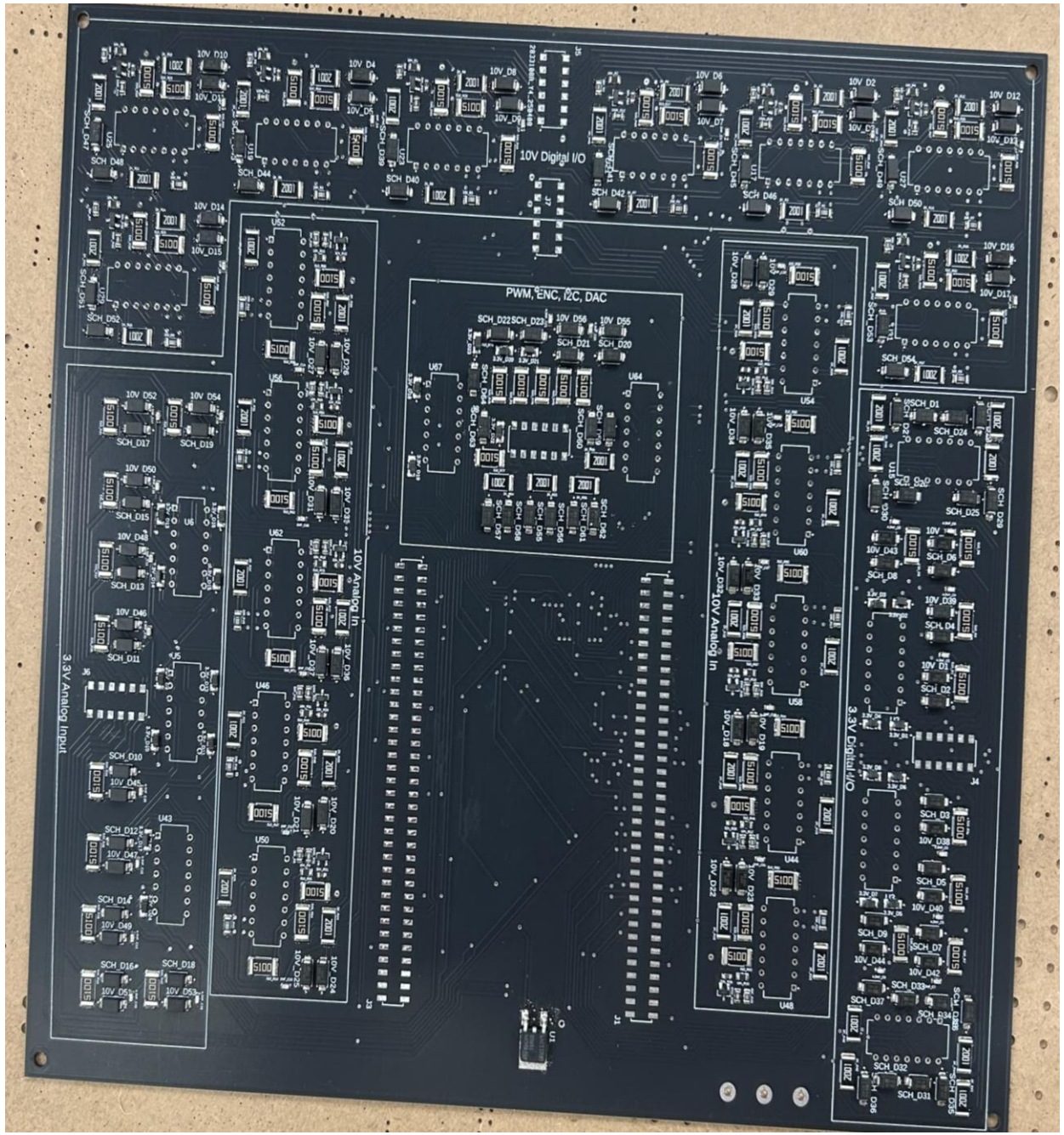
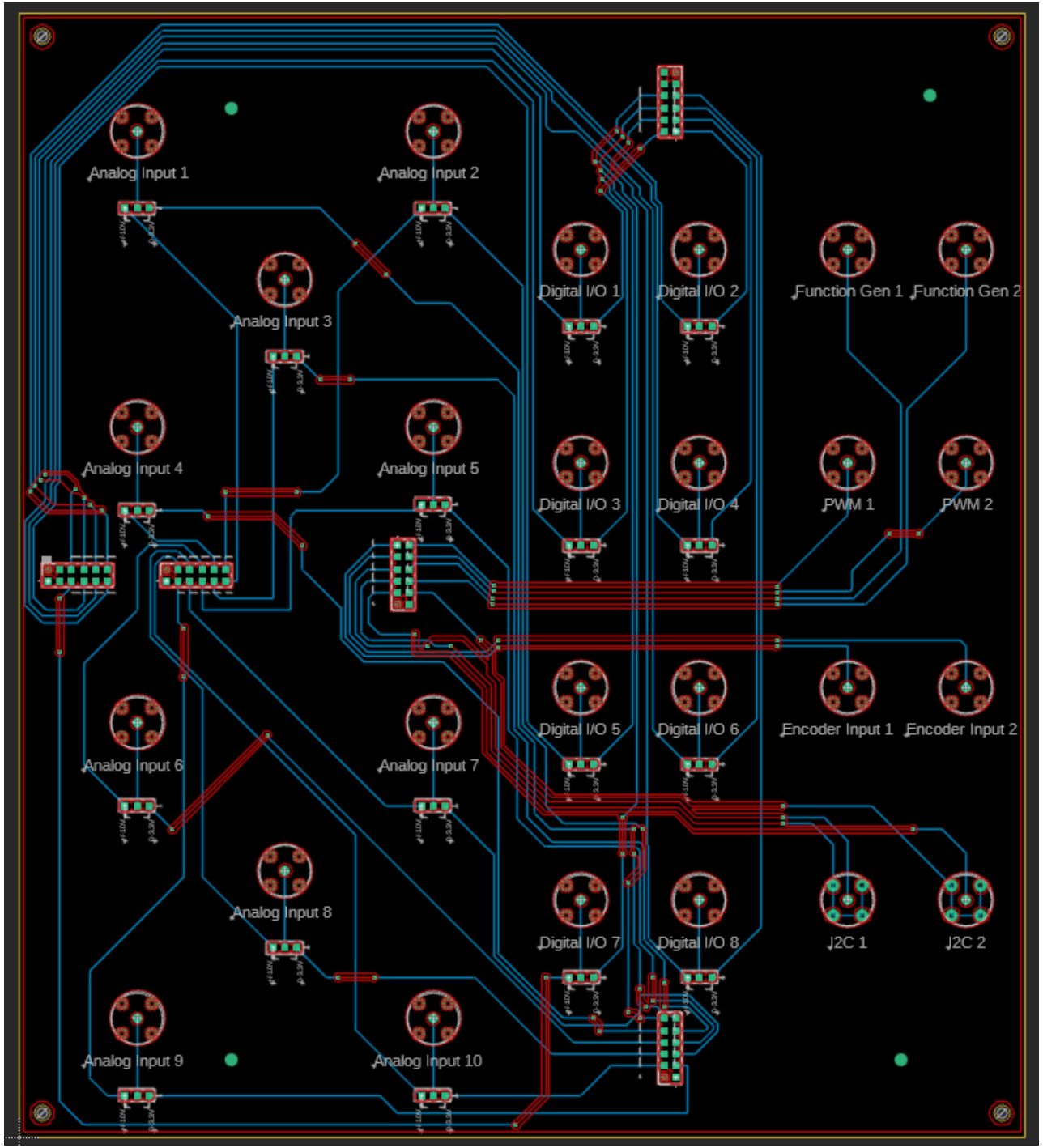





10V Digital I/O
PWM, ENC, I2C, DAC
10V Analog In
10V Analog In
3.3V Analog Input
3.3V Digital I/O



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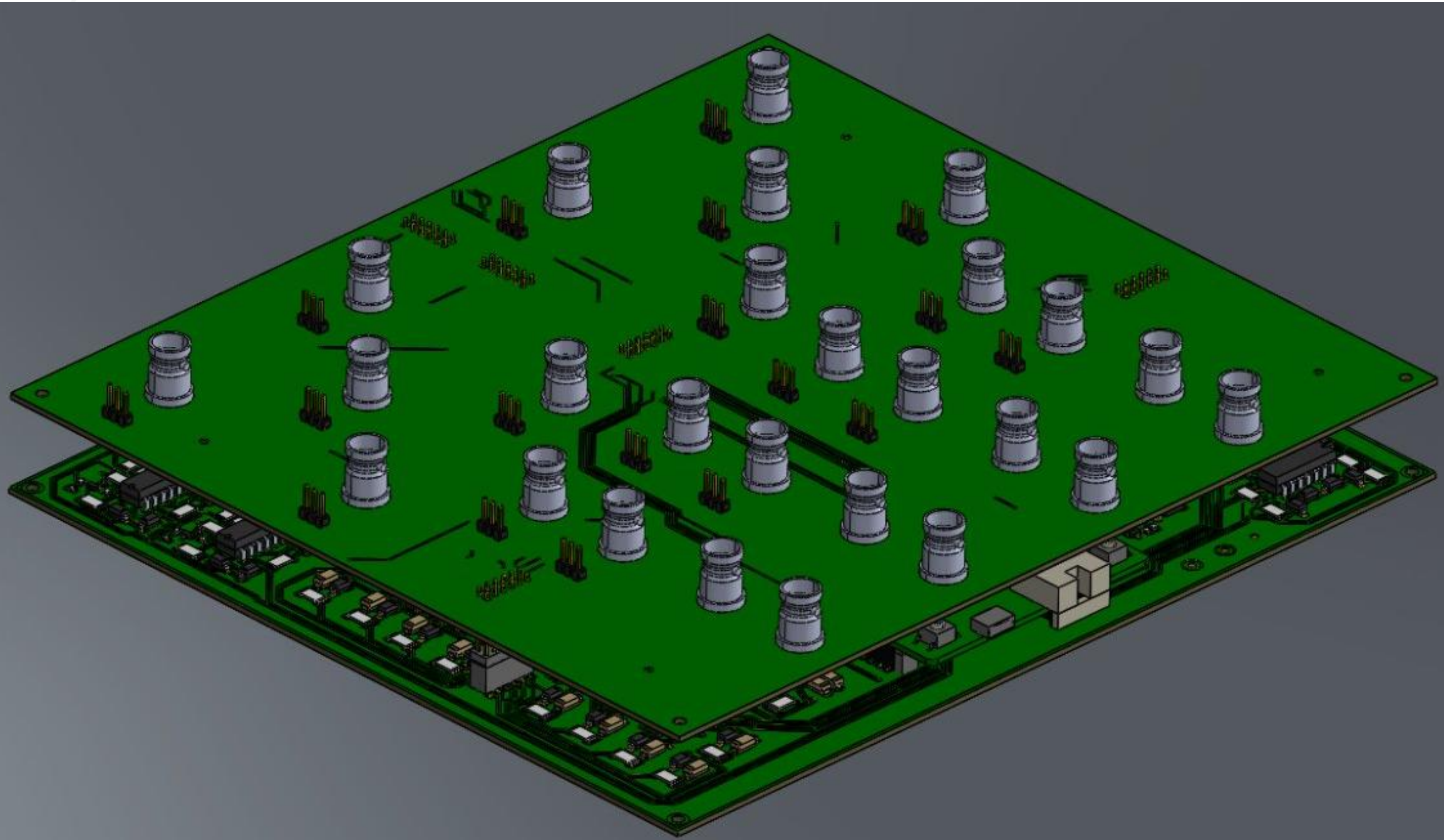
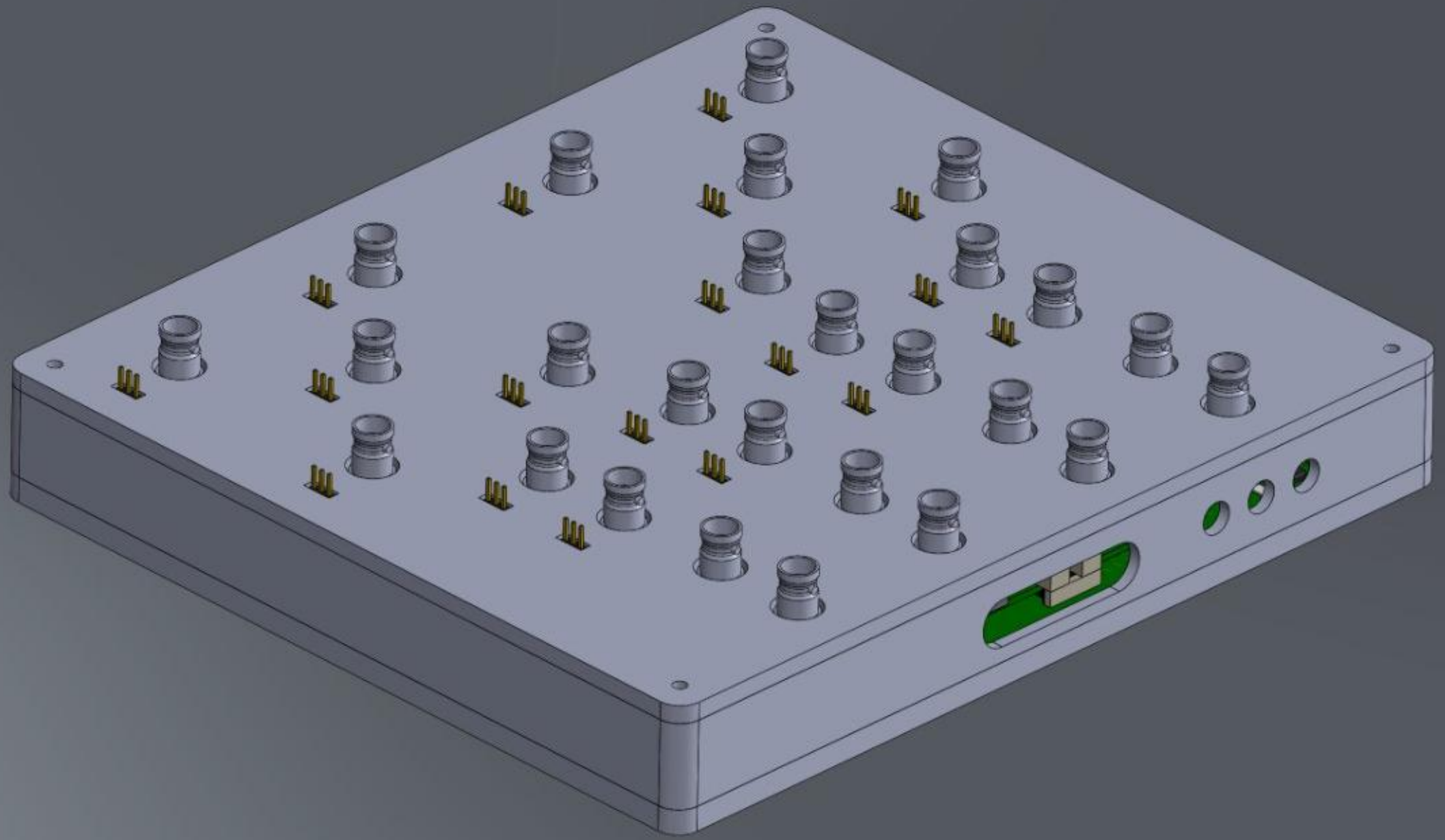



Analog Input 1
Analog Input 2
Analog Input 3
Analog Input 4
Analog Input 5
Analog Input 6
Analog Input 7
Analog Input 8
Analog Input 9
Analog Input 10
Digital I/O 1
Digital I/O 2
Digital I/O 3
Digital I/O 4
Digital I/O 5
Digital I/O 6
Digital I/O 7
Digital I/O 8
Function Gen 1
Function Gen 2
PWM 1
PWM 2
Encoder Input 1
Encoder Input 2
I2C 1
I2C 2
+/-10V
0-3.3V



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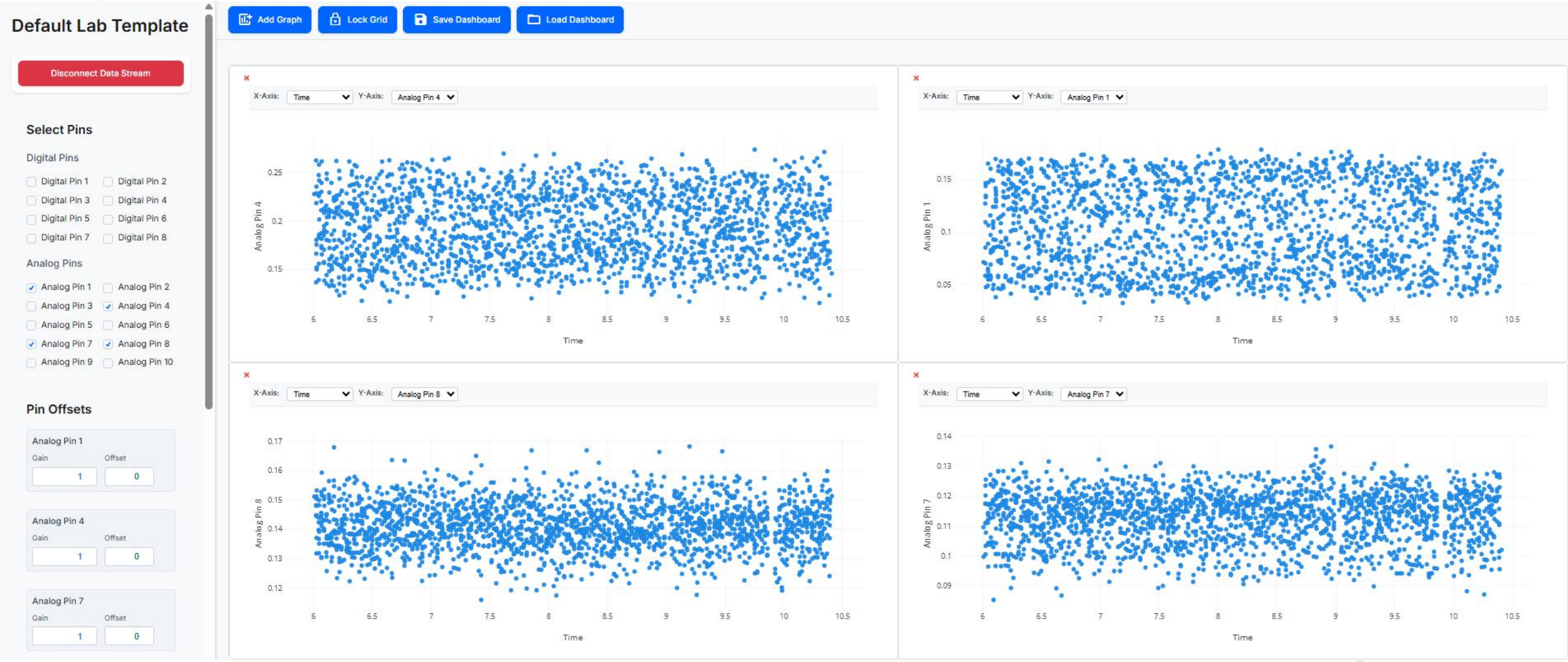
Interface Boards: Next Steps

- Complete Signal Processing Board
- Debug if Necessary
- Test and Record Capabilities

Cloud GUI

Implemented Features



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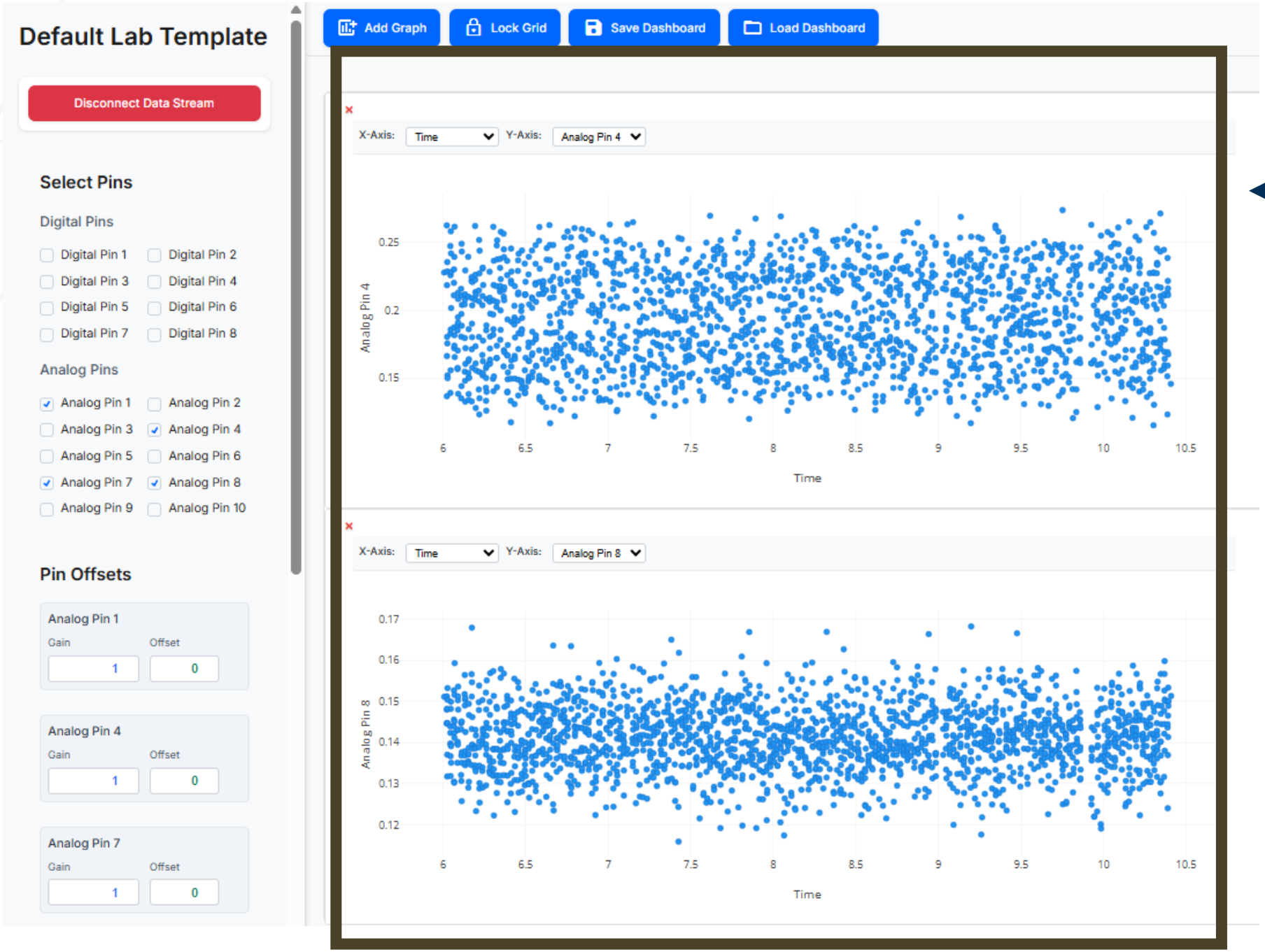

Interactive Analog & Digital Sensor Plots that update in Real-Time

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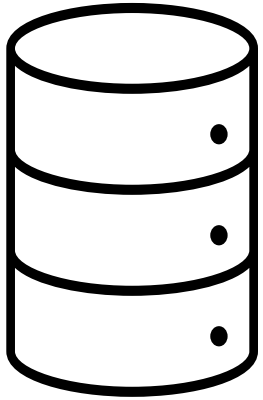
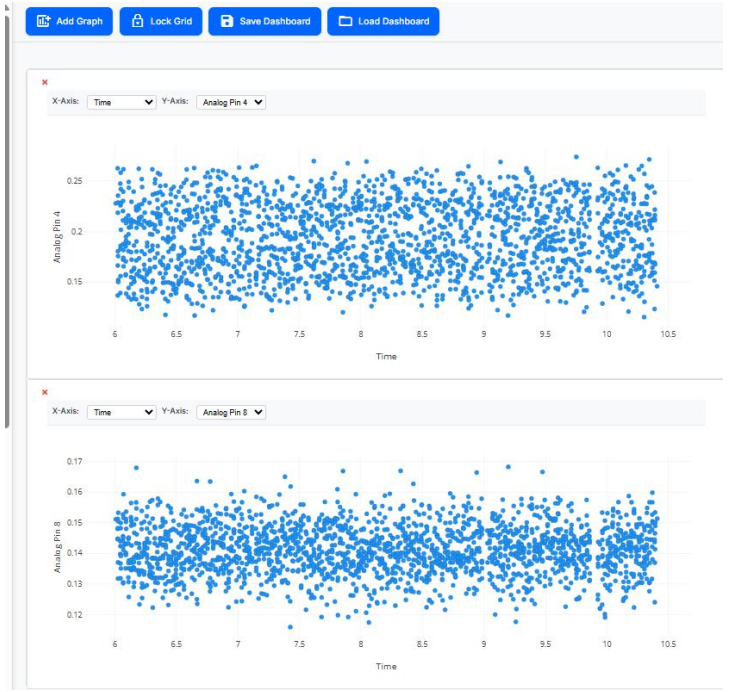
Live Plotting

UART (Serial USB)





Microcontroller

Database

Live Plots

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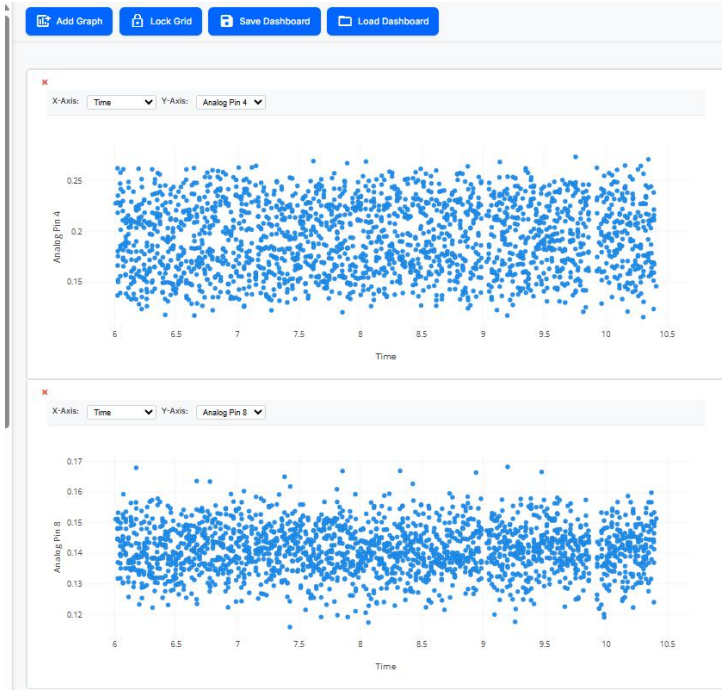
Live Plotting

Instructors Can Verify Authenticity

UART (Serial USB)



Microcontroller

Database

Live Plots

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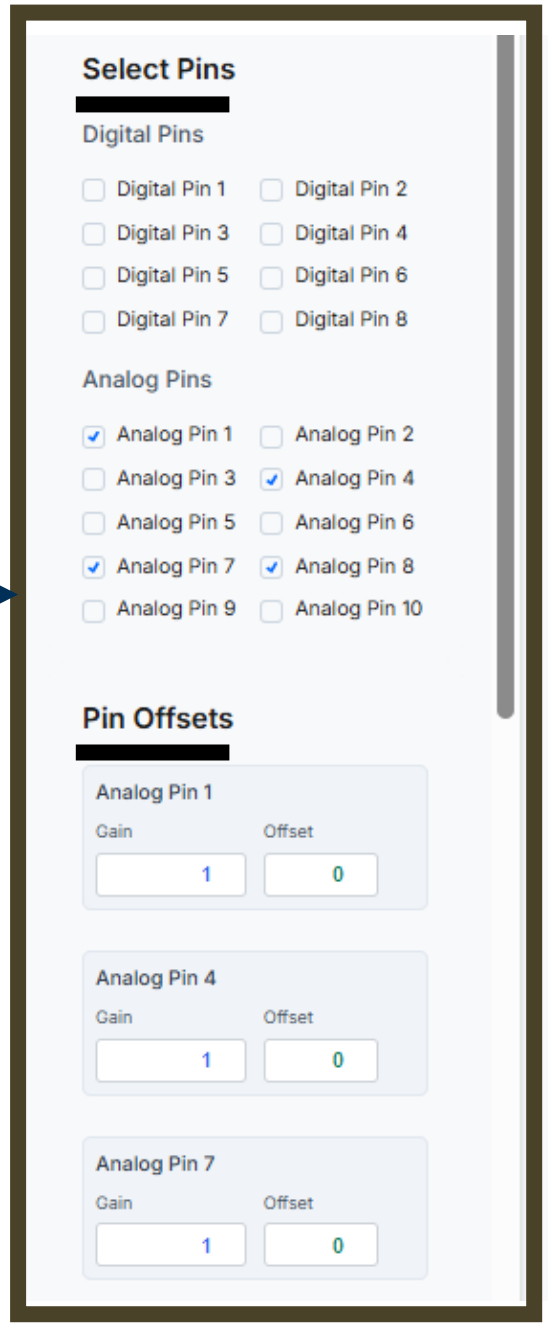
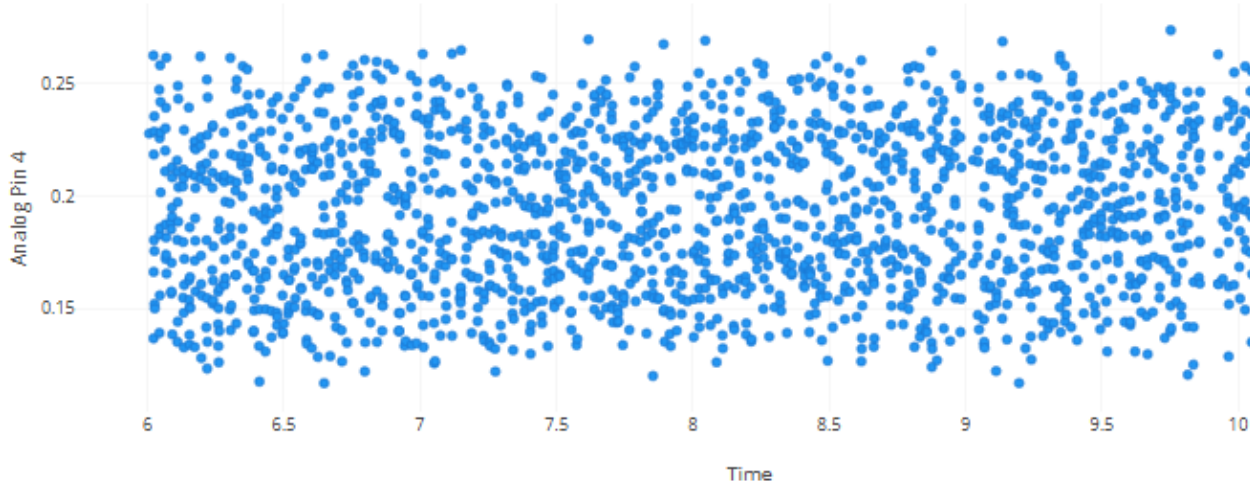
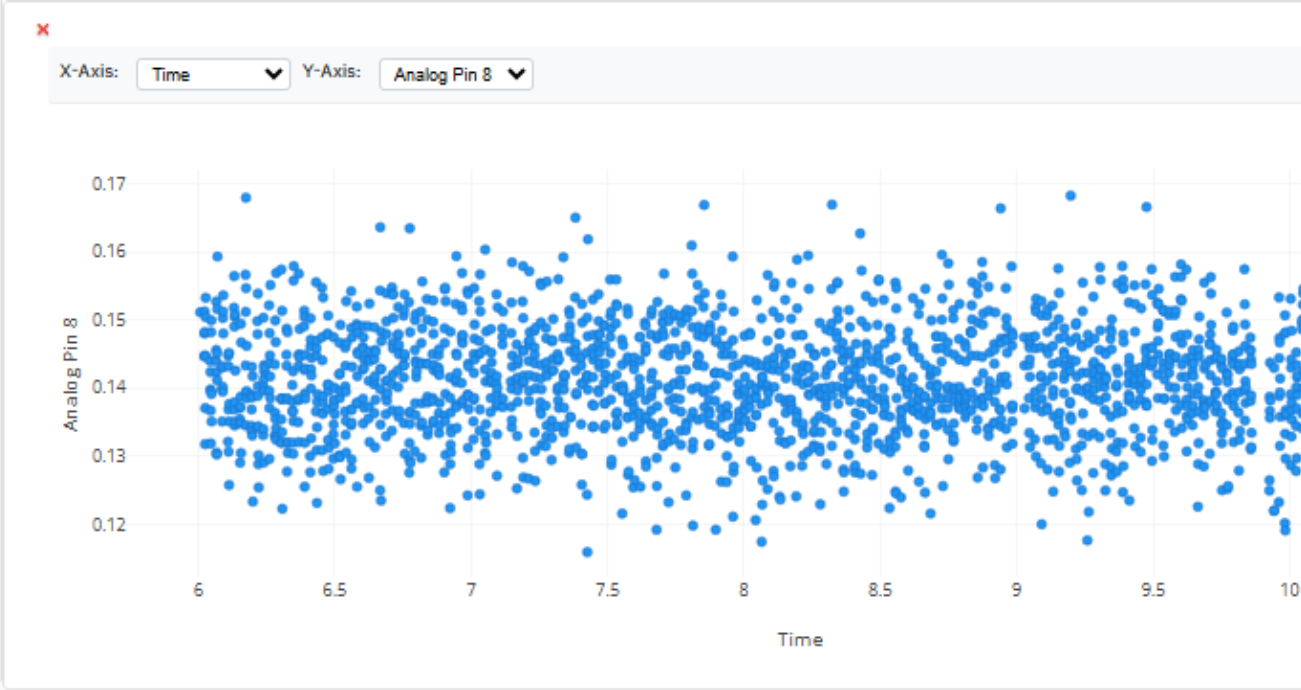
User Interface

Users Can Easily Select Desired Sensors & Set Analog Gain/Offsets for Calibration

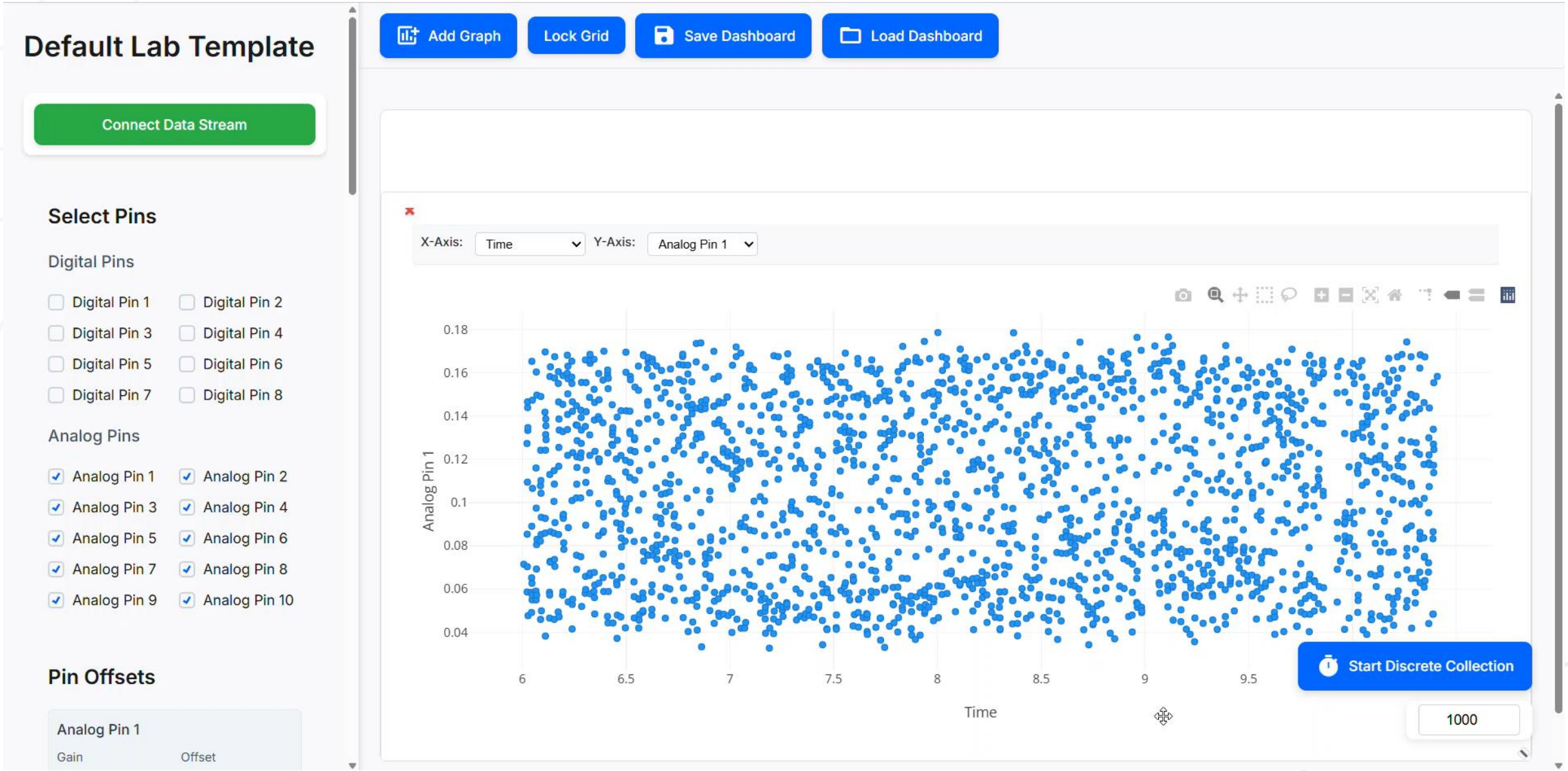






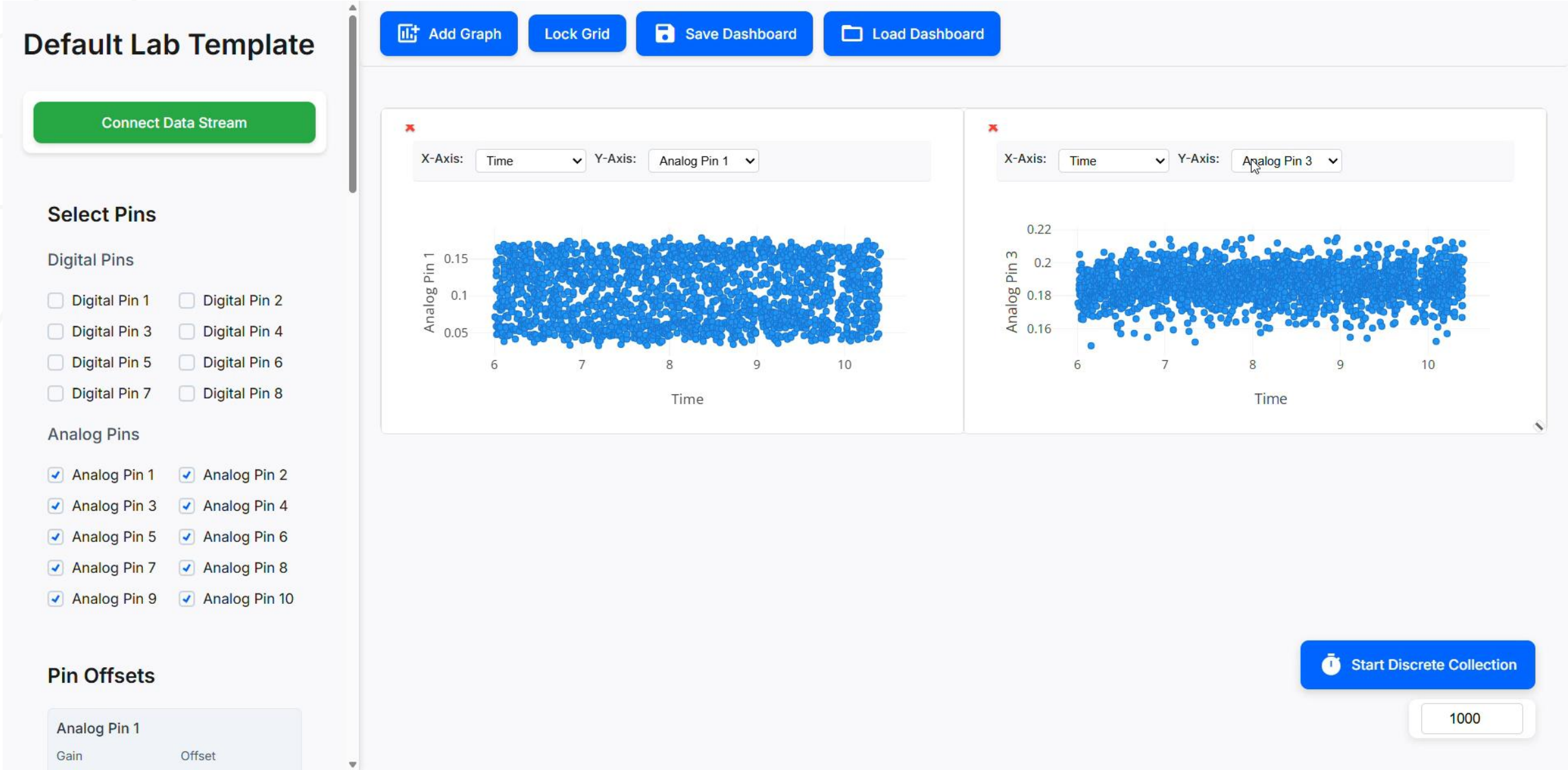
Powerful Dashboarding

Fully Customizable Graph Layouts (Size, Placement, and Number)



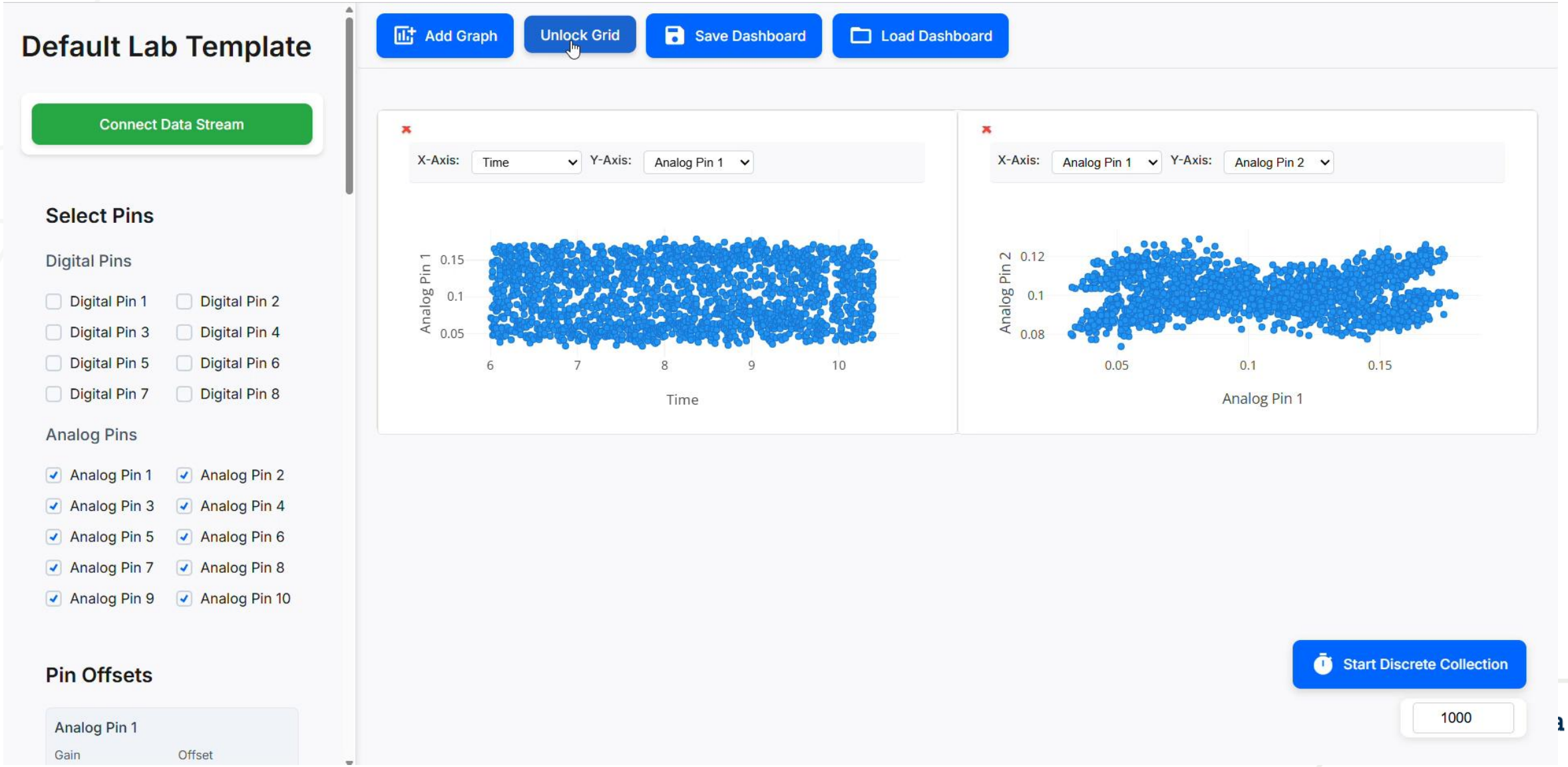
Selectable Plotting Axes for each Graph

- Sensor vs. Sensor or Sensor vs. Time



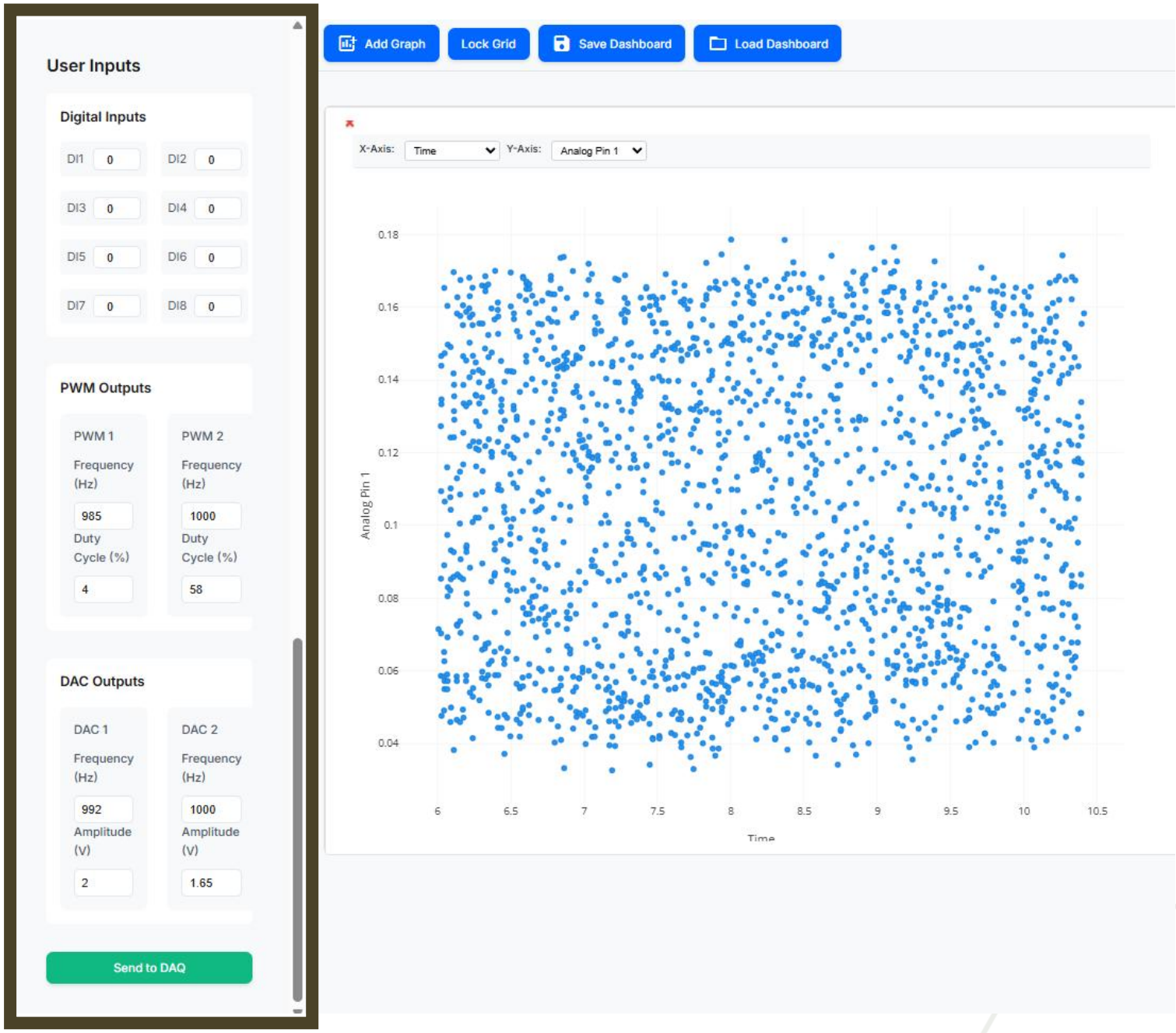
Save Dashboard Configs

- Allows Instructors to easily create & distribute dashboards for



Communication to DAQ

Users Can Also Communicate PWM, DAC, DI Settings to the DAQ



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Testing

Final Design Characterization

Analog Pins Testing (0-3.3V)	DC Voltage (0 Hz)	Low Frequency (100 Hz)	High Frequency (35 kHz)
Low Voltage (200 mV Amplitude)	Pass/Fail	Pass/Fail	Pass/Fail
Medium Voltage (3.3V Amplitude)	Pass/Fail	Pass/Fail	Pass/Fail
High Voltage (15V Amplitude)	Pass/Fail	Pass/Fail	Pass/Fail
Pass: Voltage Input RMSE < .05V/period			

Digital Pin Testing (0-3.3V)	DC Voltage (0 Hz)	Low Frequency (50 Hz)	High Frequency (2 kHz)
Low Voltage (LV)	Pass/Fail	Pass/Fail	Pass/Fail
High Voltage (HV)	Pass/Fail	Pass/Fail	Pass/Fail
Pass: LV Range within [0, 1.7] V			
Pass: HV Range within [1.6, 3.3] V			

PWM Signal Testing	Low Frequency (100 Hz)	High Frequency (50 kHz)
Low Duty Cycle (10%)	Pass/Fail	Pass/Fail
Medium Duty Cycle (50%)	Pass/Fail	Pass/Fail
High Duty Cycle (90%)	Pass/Fail	Pass/Fail
Pass: Duty Cycles within 2% Accuracy		
Pass: Frequencies within 2% Accuracy		

Function Generator Testing	DC Voltage (0 Hz)	Low Frequency (100 Hz)	High Frequency (50 kHz)
Low Voltage (0-1.65V)	Pass/Fail	Pass/Fail	Pass/Fail
Medium Voltage (0-3.3V)	Pass/Fail	Pass/Fail	Pass/Fail
Pass: Voltage Output RMSE < .05V/period			

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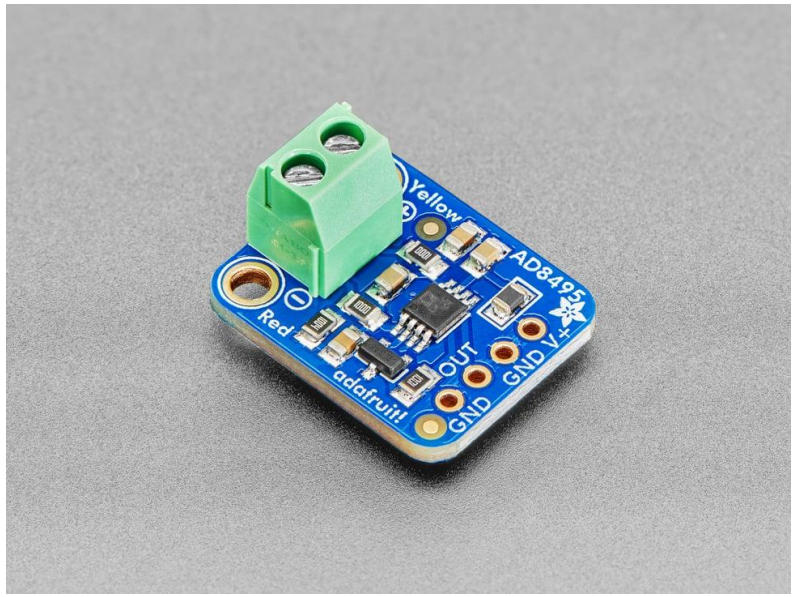
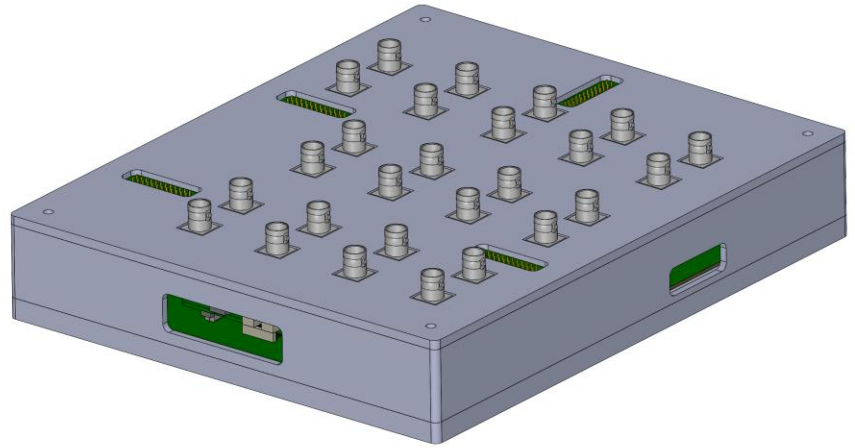
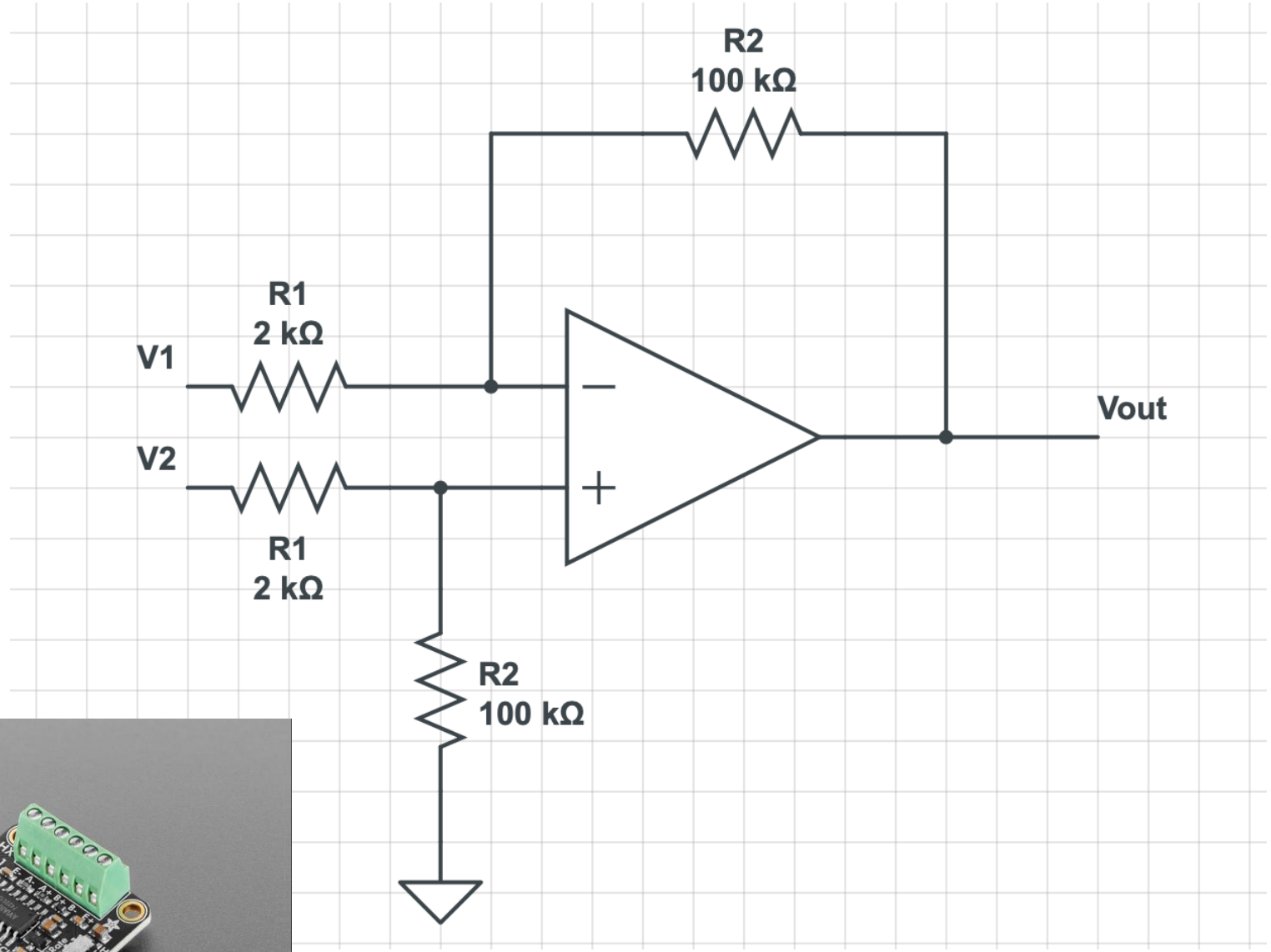
Analog

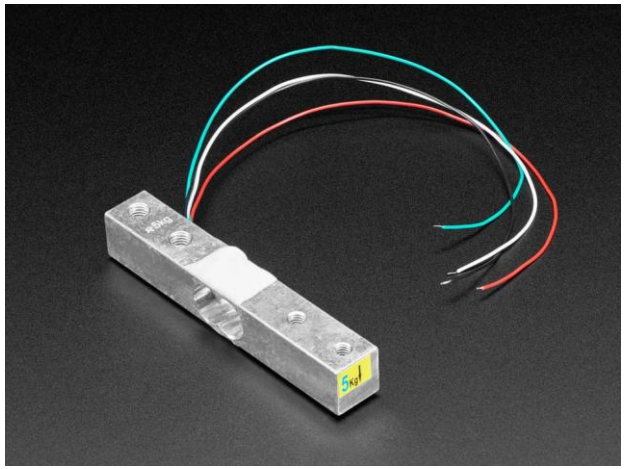


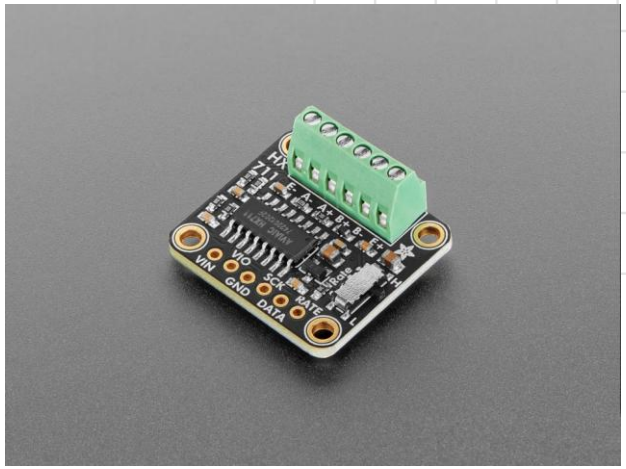


Potential Strain Gauge Circuitry

- Difference Amplifier







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Overall Test Bed

- 4 Digital Input Pins
  - Force Transducers
- 2 Analog Input Pins
  - Temperature Sensors
- 1 I2C
  - IMU
- 1 Digital or Analog Output
  - Fan Speed Control
- 3 Digital Inputs
  - Encoder PWM Input
  - Steering PWM Input
  - Throttle PWM Input

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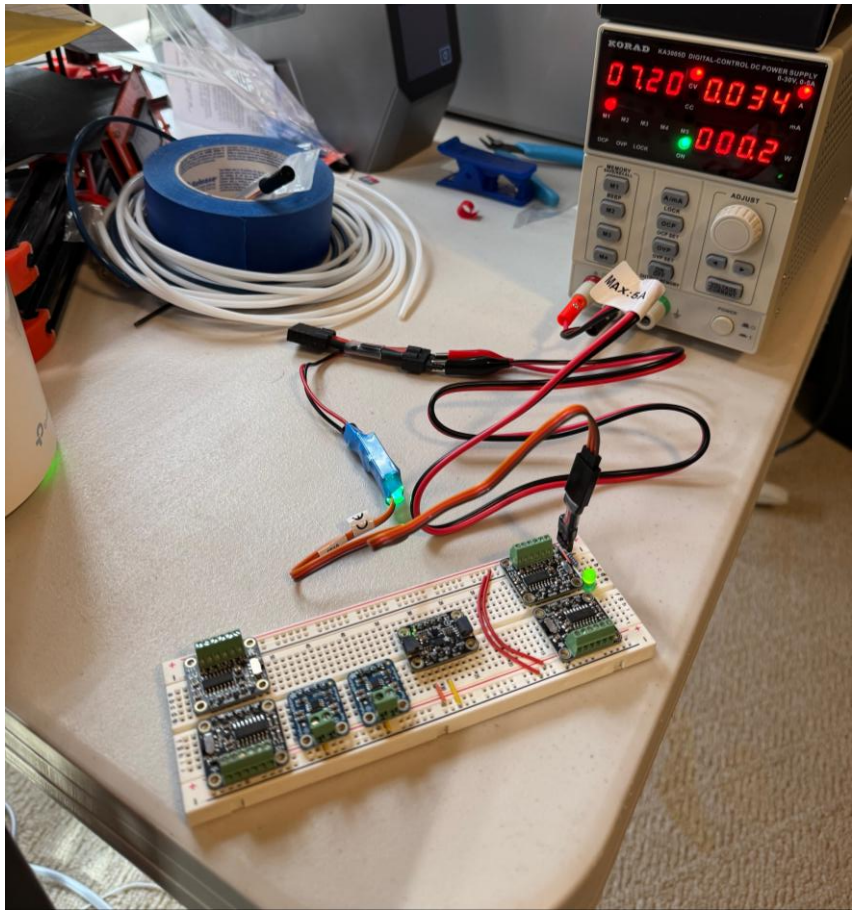

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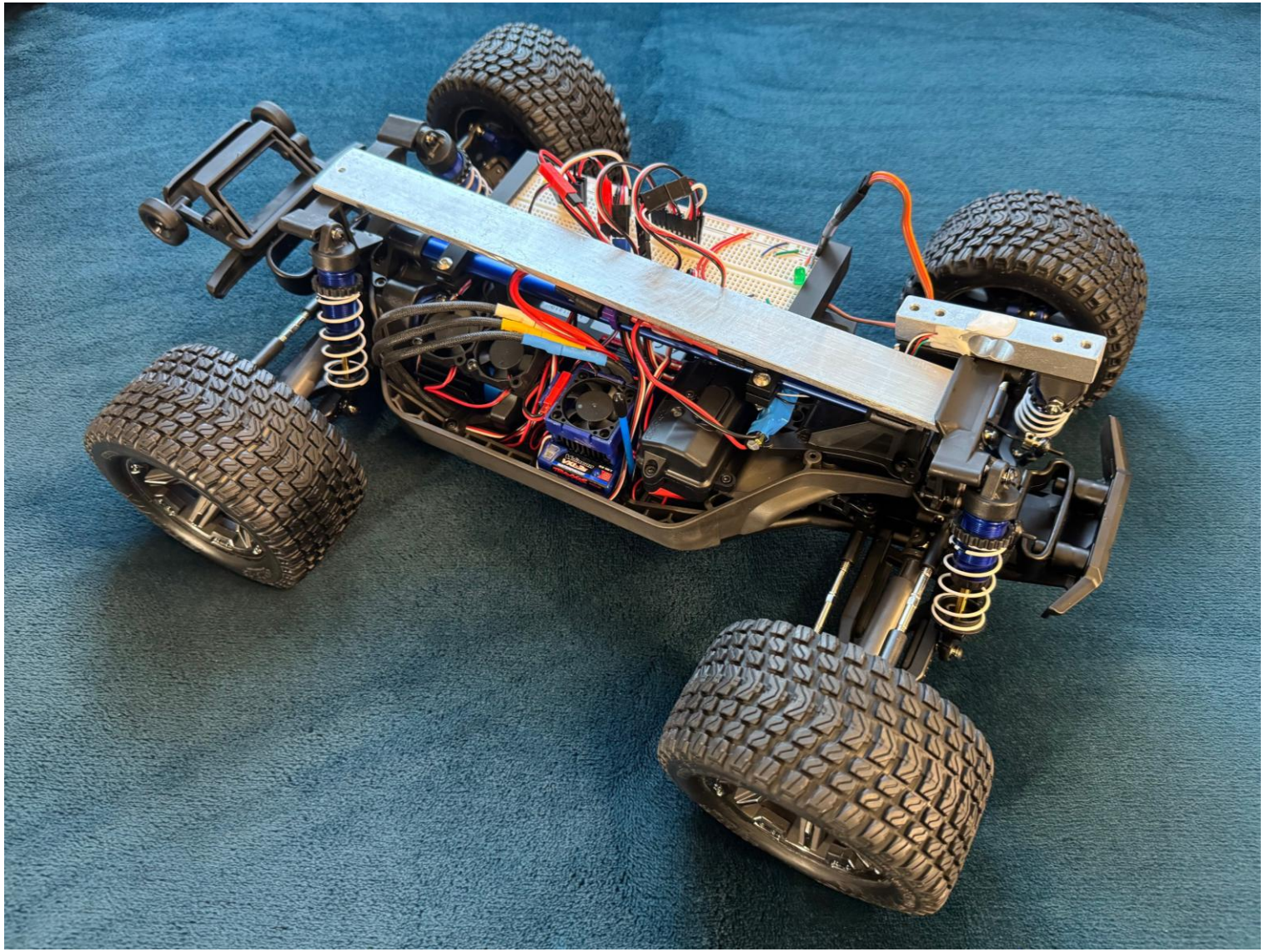
Validation: Next Steps

- Install DAQ
- Test



Future Developments

- Microcontroller
  - Using I/O Port Expander so that Digital Input Pins can be used with DMA
- Hardware
  - Using a 4+ Layer PCB to reduce vias and size
  - Adding in a Breaker for Additional MCU Protection
- Software
  - Full Integration of Docker Containers with Cloud with the Database
  - User Selection & Authentication
  - Facilitate simultaneous users on the cloud
- Validation
  - Integration with existing ME Lab Setups