Magnetic Field Camera

Milestone 2

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Outline

1. Feedback from milestone 1
2. Project management plan and documentation
3. Progress updates
4. Block diagram and relevant analysis
5. Schematic and PCB layout
6. Preliminary tests and plan
7. Future plans

01 Feedback

Feedback from Milestone 1

Pictures of sensors → We added pictures of components to the presentation

Component choice → We explored the reviewer's suggestions, particularly for the FPGA, and settled on the current choice

Clearer schematics → We created a hierarchy within the schematic and labelled nets for easier readability

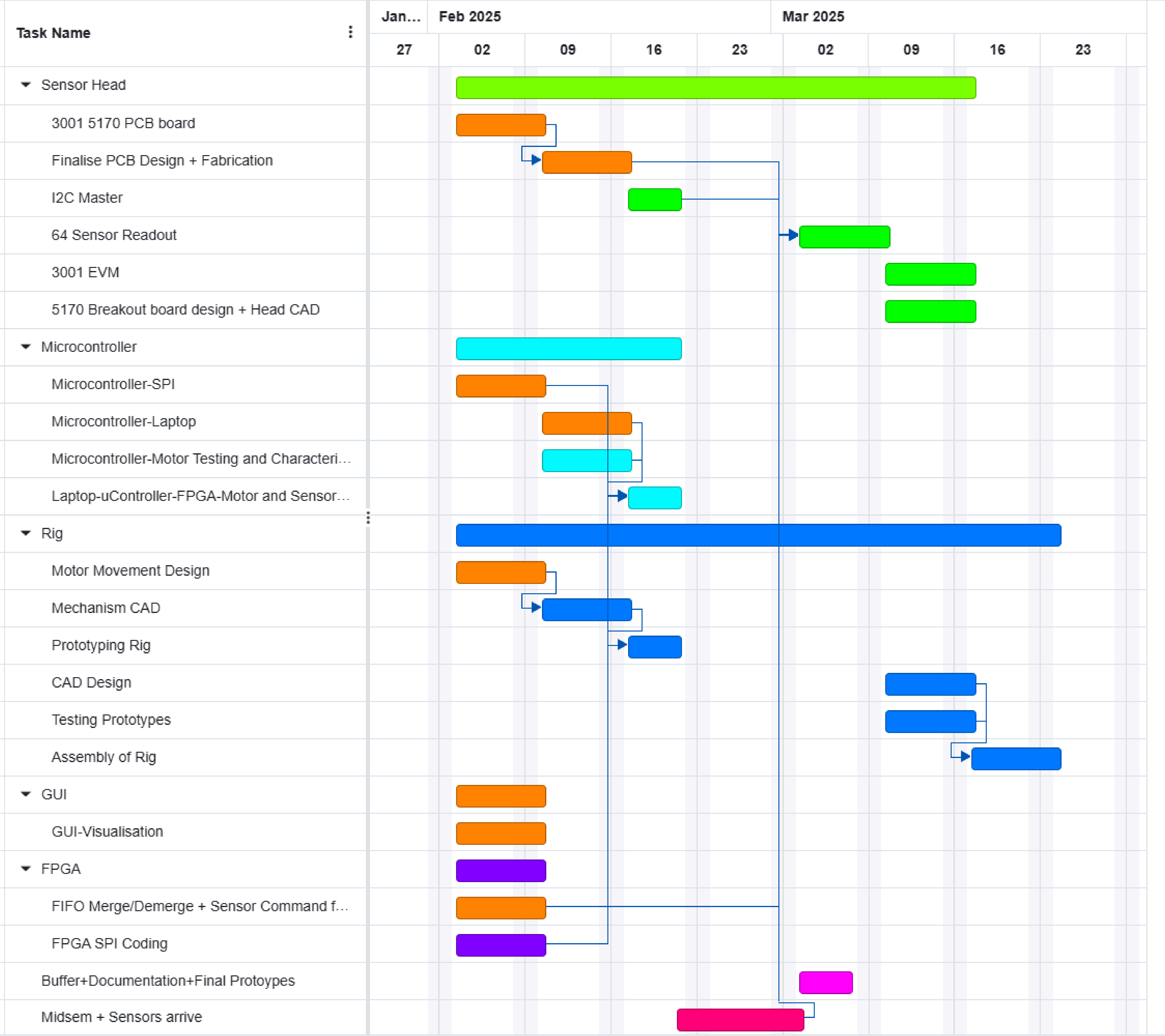
02
Project management

Work Division

- **CAD and motor design:** Designing the CAD files for the motor movement mechanism and the structure
    - *Ashwajit, Raunak, Aditya*
- **FPGA programming:** VHDL for communication and data processing
    - *Ashwajit, Suchet*
- **PCB Designing:** Designing the TMAG3001 board, in addition to the breakout board for the alternate magnetometer
    - *Navaneeth, Suchet*
- **Microcontroller and GUI:** Code to control the motors and FPGA, and to display the output on the laptop
    - *Raunak, Aditya*

Documentation

- **OneNote:**
  - We use OneNote to document and share our general progress, with attached schematic files
- **GitHub:**
  - All code used in our project is backed up on GitHub
  - The GitHub repository with all our code is available here


Task Name
Jan...
Feb 2025
Mar 2025
27
02
09
16
23
02
09
16
23
Sensor Head
3001 5170 PCB board
Finalise PCB Design + Fabrication
I2C Master
64 Sensor Readout
3001 EVM
5170 Breakout board design + Head CAD
Microcontroller
Microcontroller-SPI
Microcontroller-Laptop
Microcontroller-Motor Testing and Characteri...
Laptop-uController-FPGA-Motor and Sensor...
Rig
Motor Movement Design
Mechanism CAD
Prototyping Rig
CAD Design
Testing Prototypes
Assembly of Rig
GUI
GUI-Visualisation
FPGA
FIFO Merge/Demerge + Sensor Command f...
FPGA SPI Coding
Buffer+Documentation+Final Protoypes
Midsem + Sensors arrive

Deviations from original plan

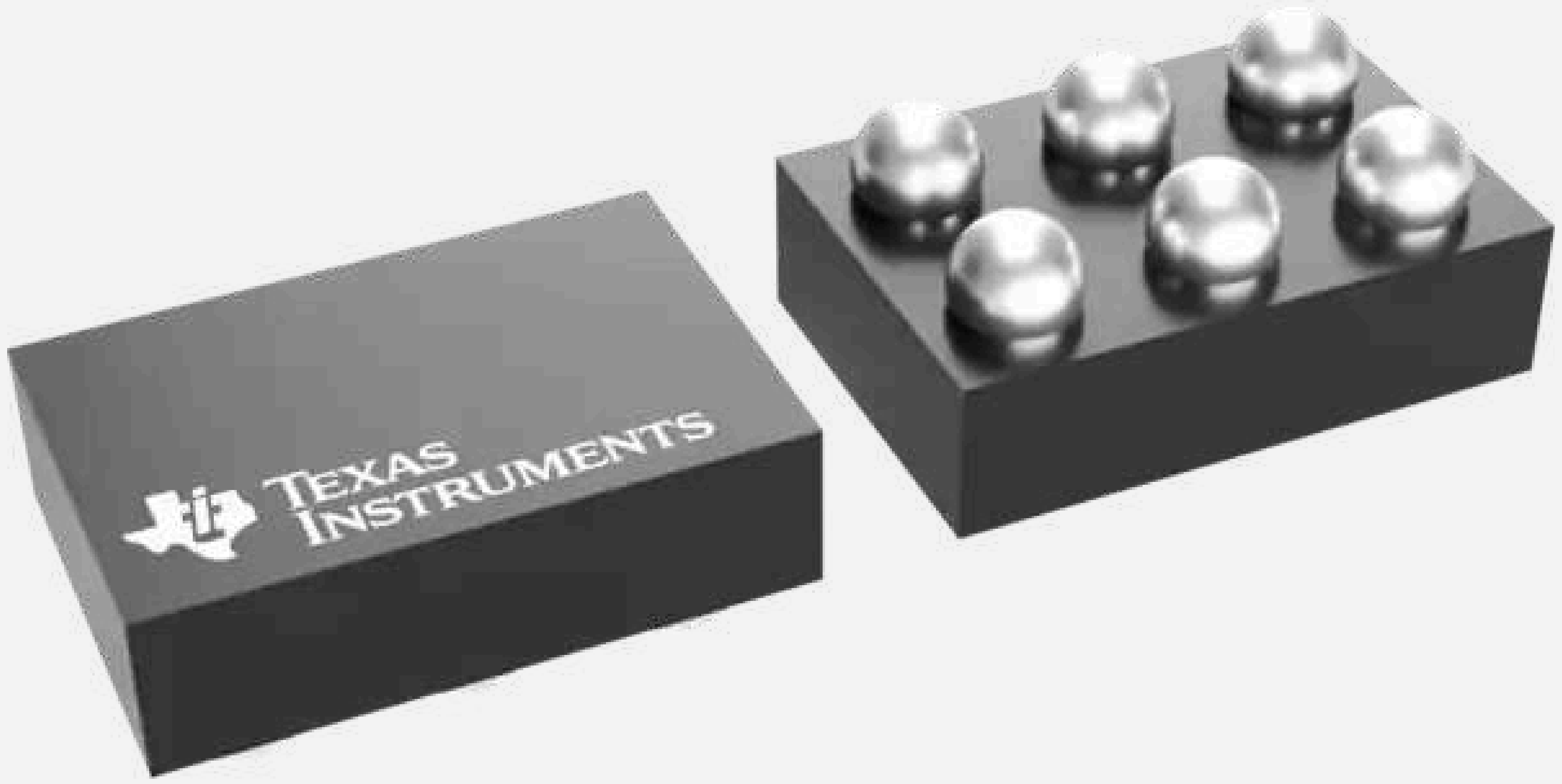
- The VHDL code for the I2C master and the SPI slave was delayed as iterating the PCB design took longer than originally expected
- We could not test the functioning of the motor using the microcontroller due to non-arrival of parts
- The CAD design is currently in progress, as finalising the top-level design of the mechanism took longer than expected

03
Progress Updates

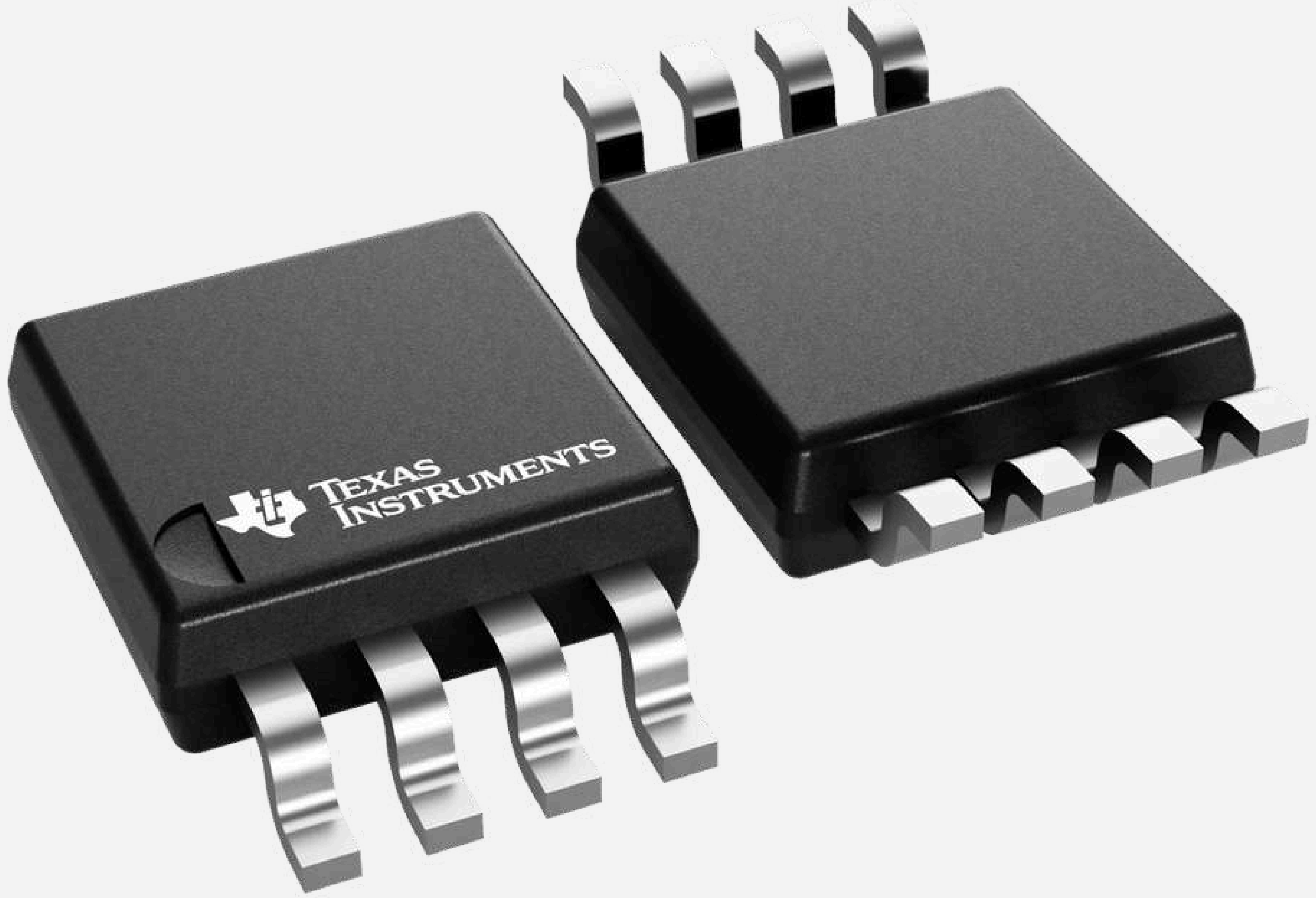
PCB Design

- **TMAG3001 64 sensor array**
  - Designed a high-density, four-layer PCB integrating a 64-sensor array of TMAG3001 magnetometers.
  - Developed a space-efficient layout for a 4-sensor I2C bus architecture to optimize signal integrity and maximize resolution.
  - Carefully selected pull-up resistor values and decoupling capacitor placements to ensure robust sensor operation.
- **TMAG5170 breakout board**
  - Designed a breakout board consisting of 2 TMAG5170 to be used for testing of the sensors.

Sensors Used



TMAG3001



TMAG5170

FPGA Programming

- The packet formats and communication protocol between the FPGA and the microcontroller were decided
- The associated VHDL to unpack data from the sensor array and commands from the microcontroller and validate it were completed
- The code to add error detection and timestamps (to allow AC field detection) was also completed

Microcontroller and GUI

- The microcontroller SPI master was tested and was able to communicate with the CMOD-A7 FPGA
- Additionally, the WiFi communication between the microcontroller and the laptop was tested
- We finalised the GUI available on the laptop to visualise the fields

Rig Design

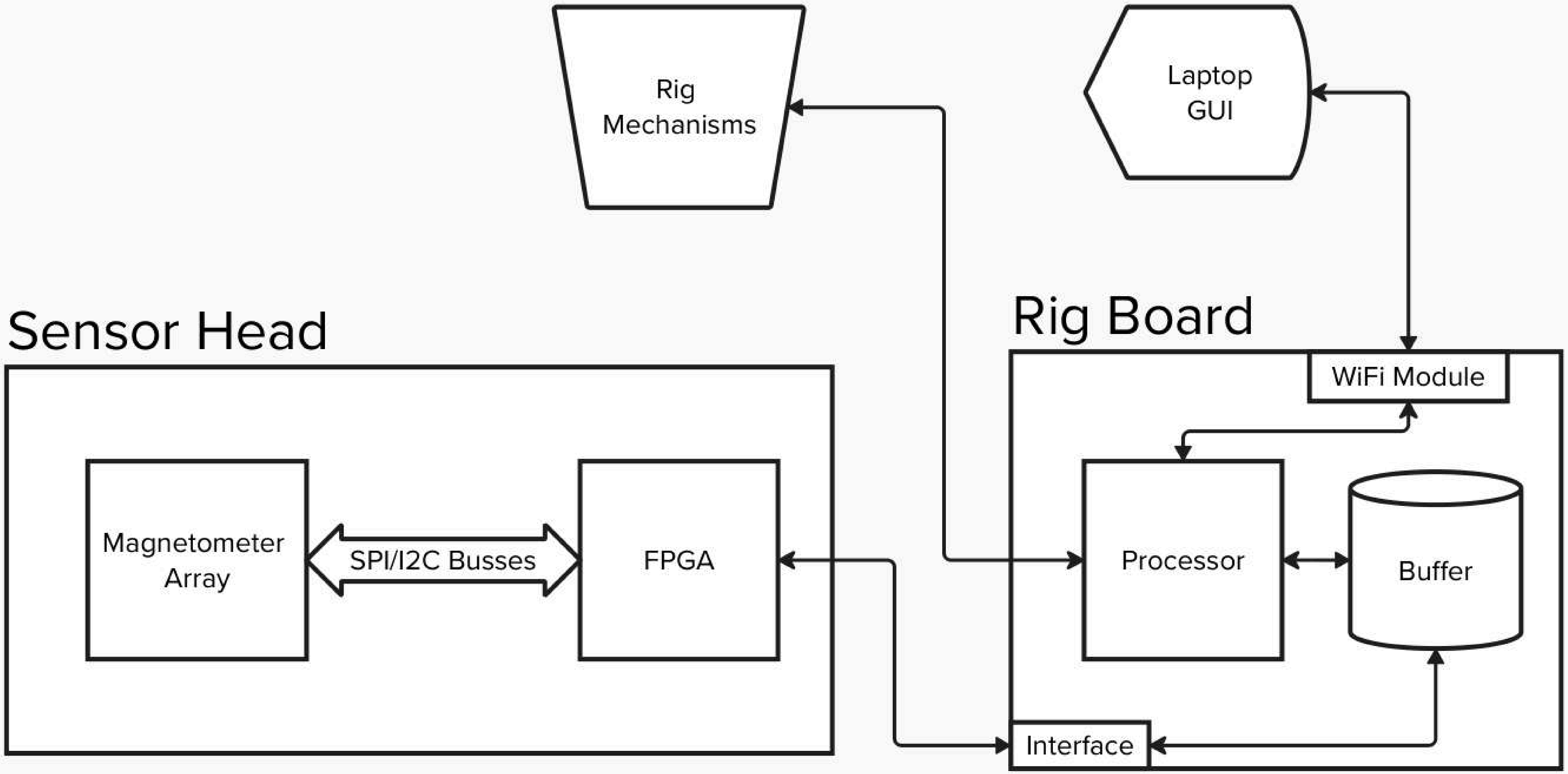
- **Mechanism**
  - We are continuing with the r-theta-z coordinate system to move the sensor head, since most
  - The sensor head will face in the theta direction as this allows us to cover the maximum area, since the theta-controlling motor will be moving the fastest
  - We are also using linear actuators instead of our original plan to use belts, as they require precise control over the tension to function
  - Materials
  - The initial prototype will be 3D printed, as it allows us to quickly test the design, and does not interfere magnetically

Rig Design

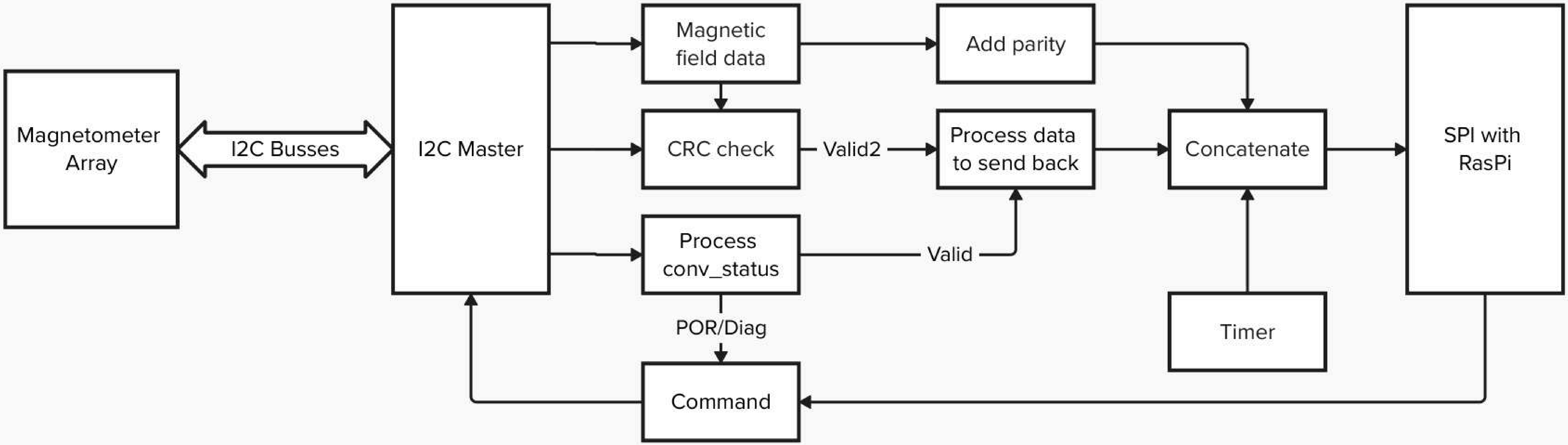
- **Materials**
  - The initial prototype is 3D printed, as it allows us to quickly test the design, and does not interfere magnetically
  - We will be using nylon rods for support, as they are standard and will not interfere, and are planning to 3D print and laser cut custom linear actuators

04
Block Diagrams

Overall block diagram

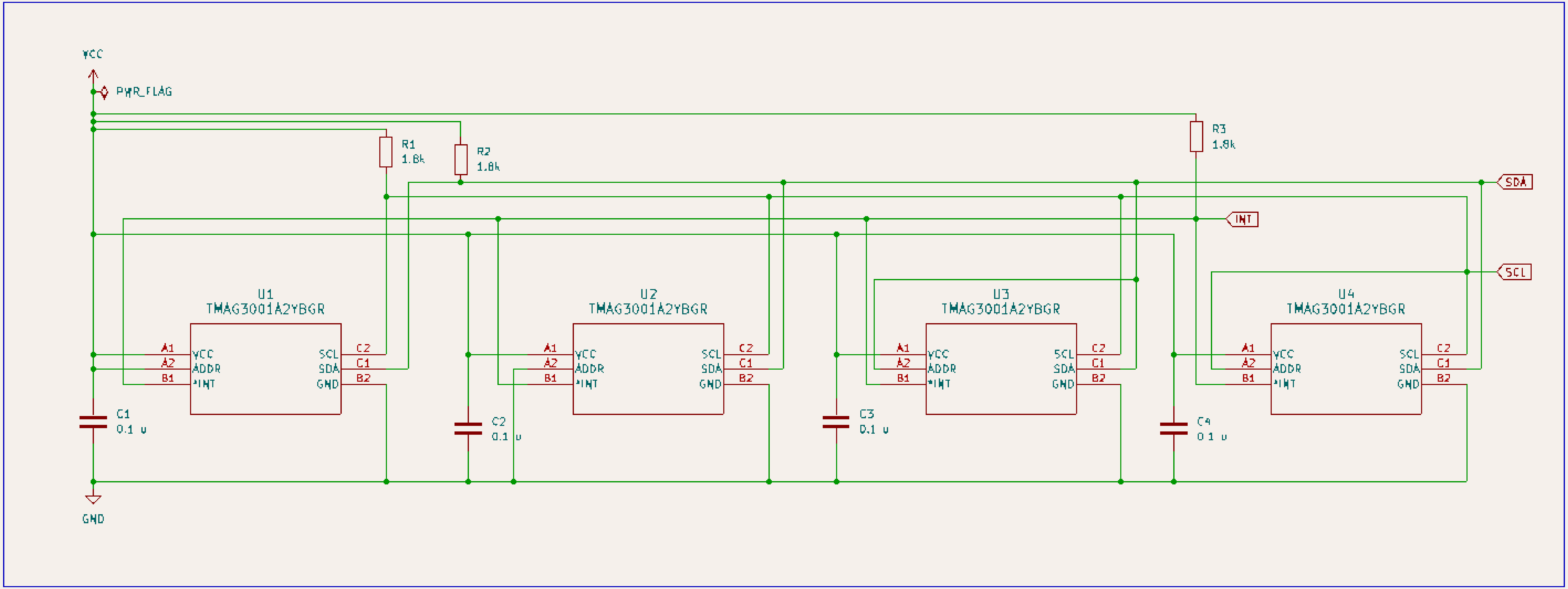


FPGA Code Structure



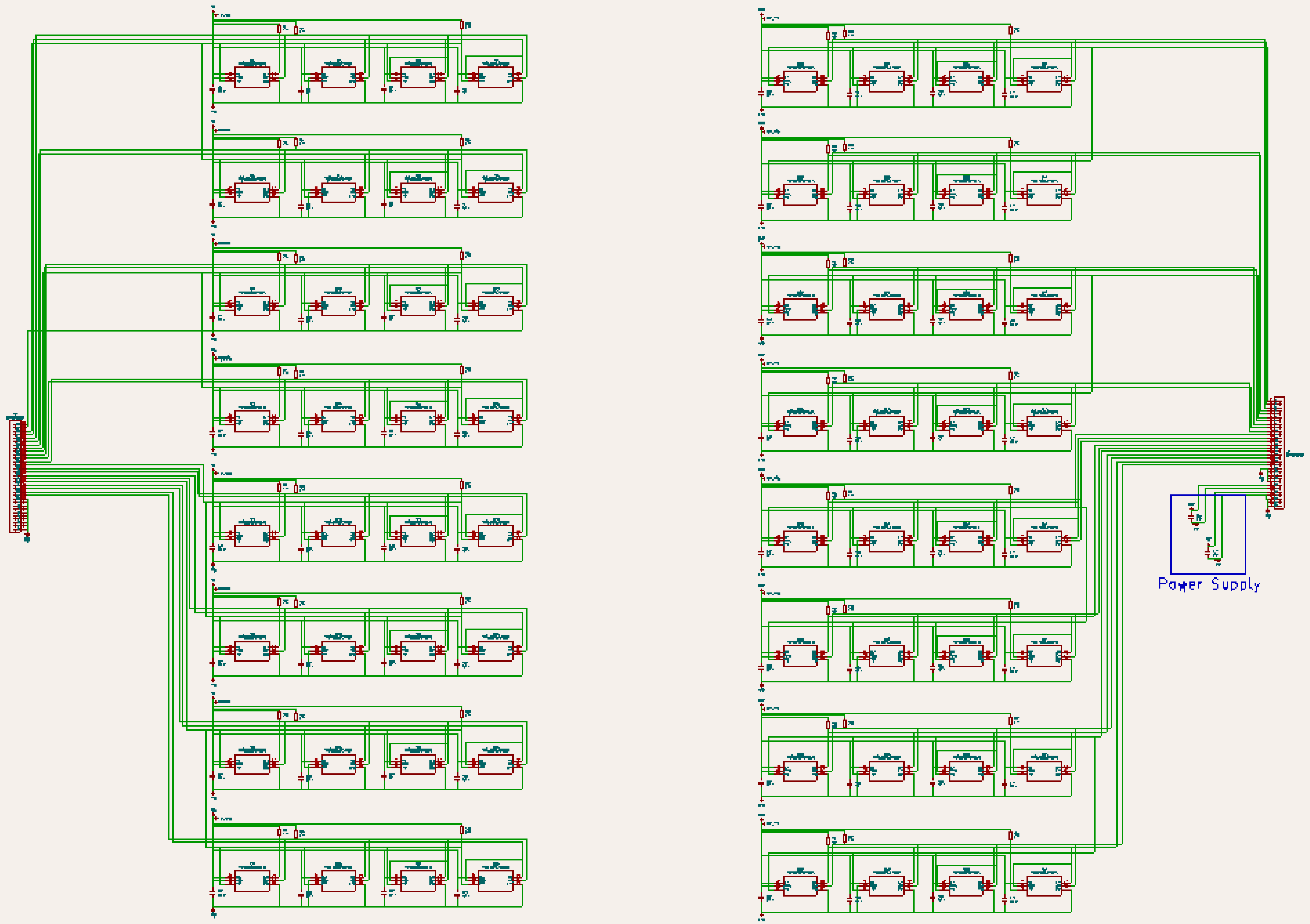
05
Schematics

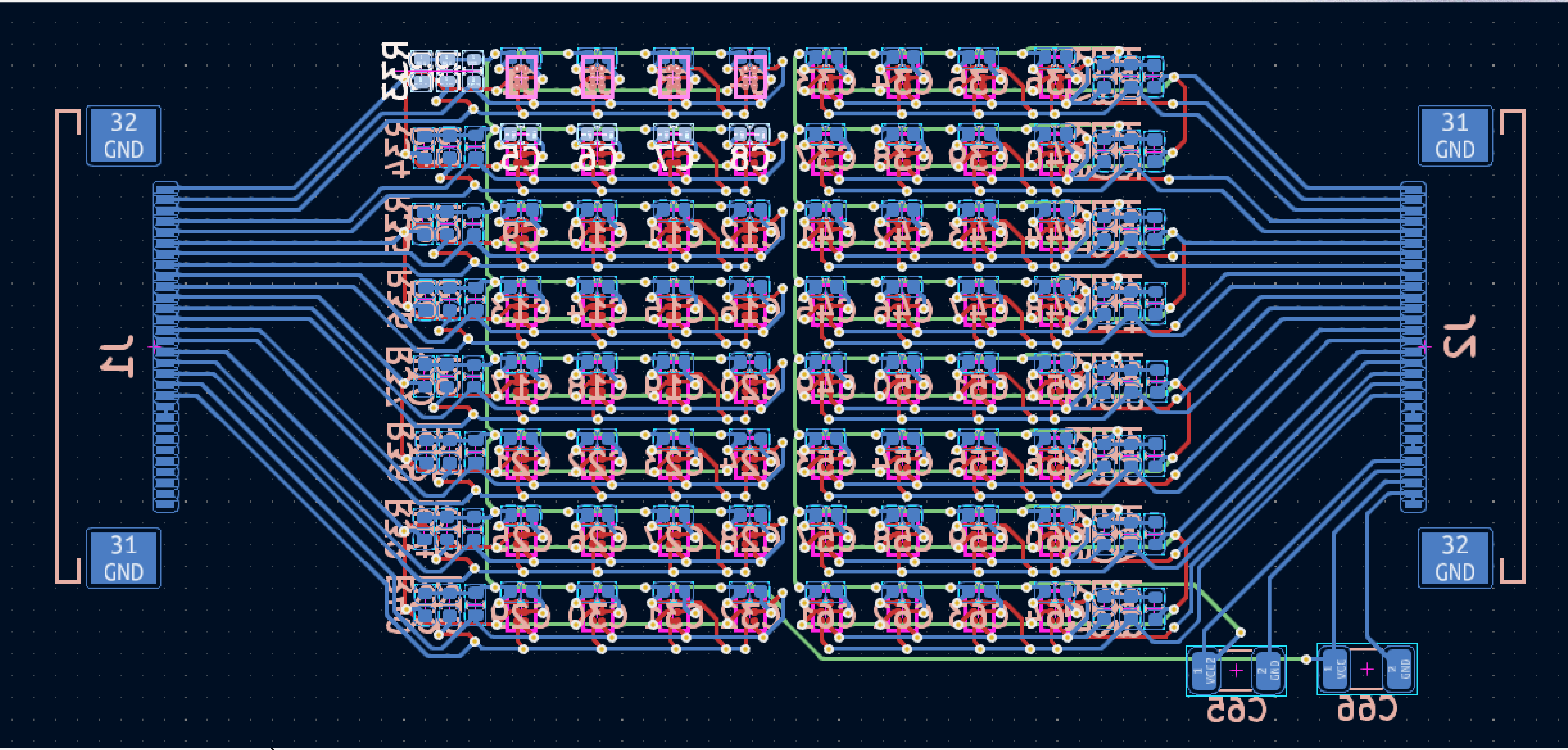
4 SENSOR BUS



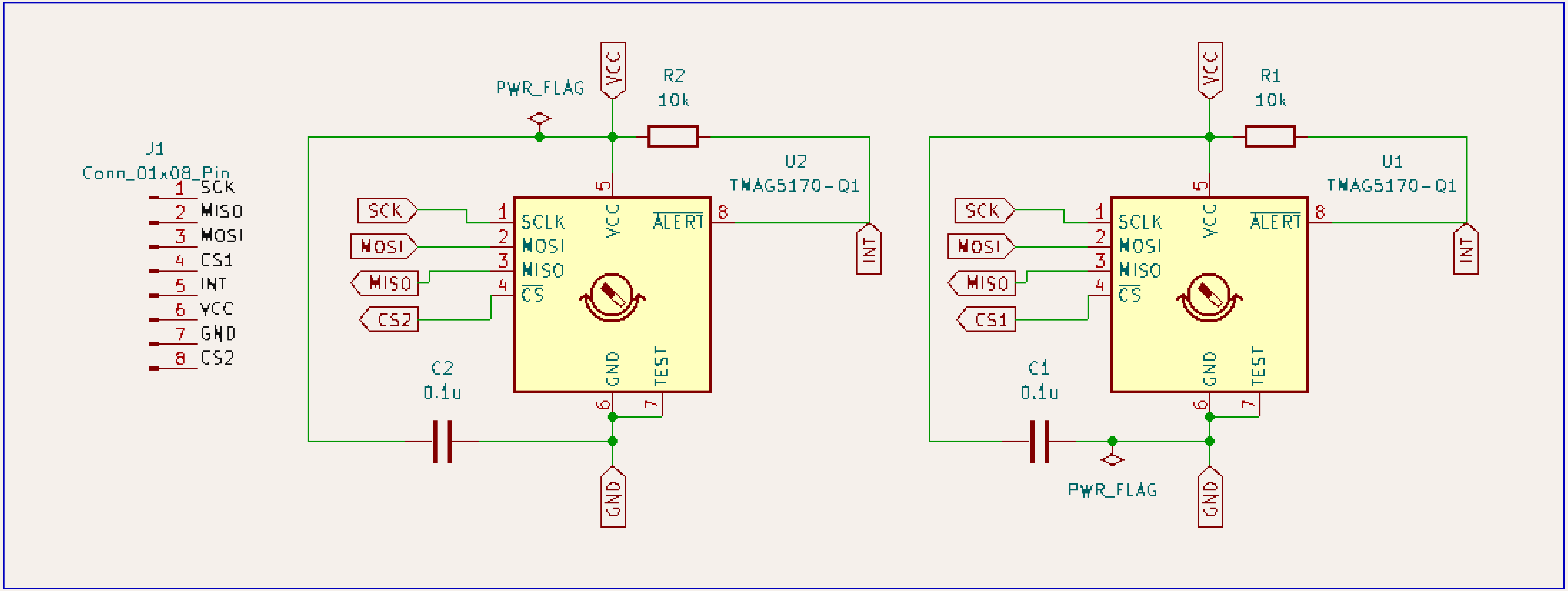
VCC
PWR_FLAG
R1
1.8k
R2
1.8k
R3
1.8k
SDA
INT
SCL
U1
TMAG3001A2YBGR
U2
TMAG3001A2YBGR
U3
TMAG3001A2YBGR
U4
TMAG3001A2YBGR
A1
A2
B1
VCC
ADDR
*INT
SCL
SDA
GND
C2
C1
B2
C1
0.1 u
C2
0.1 u
C3
0.1 u
C4
0.1 u
GND

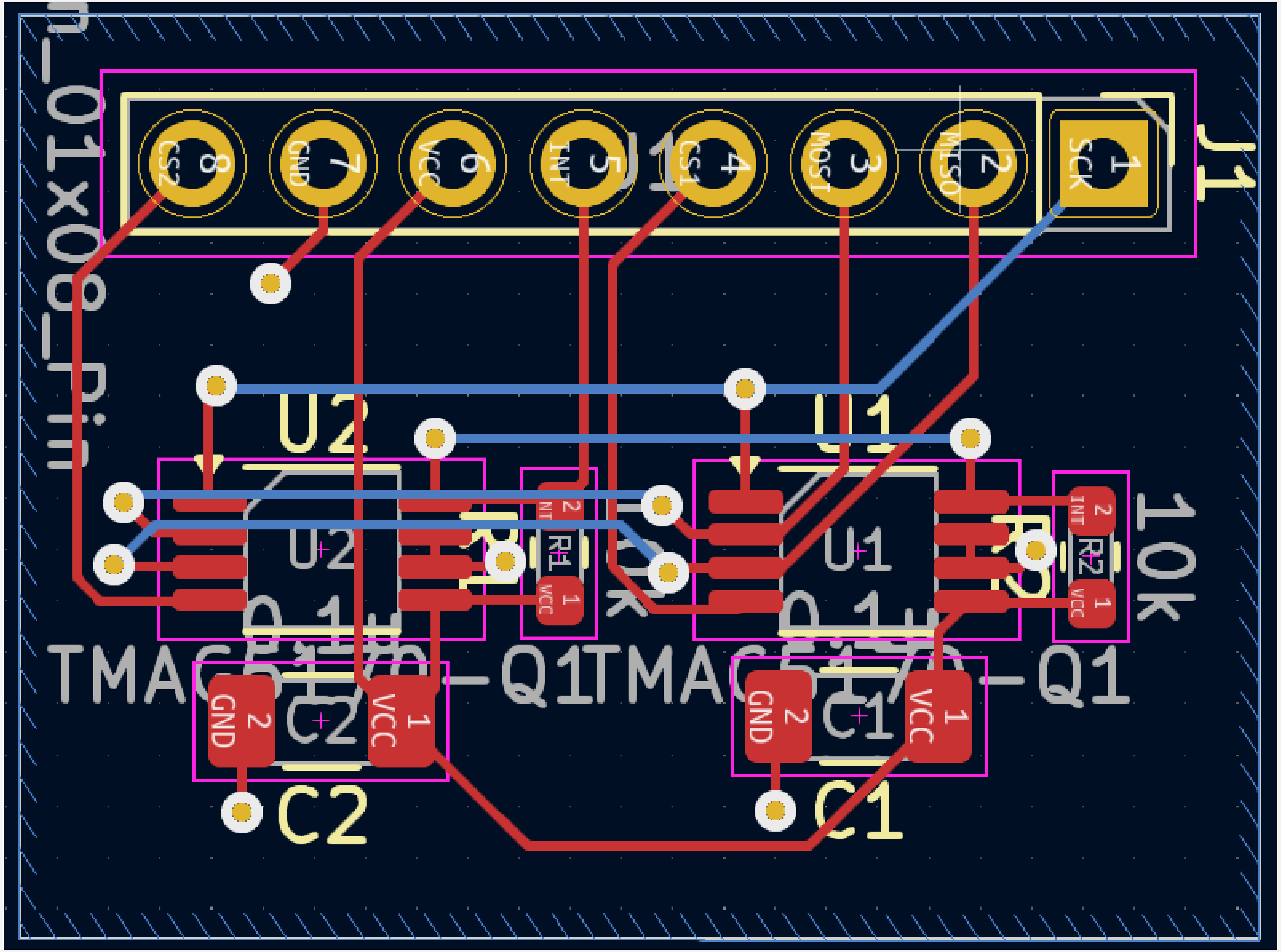
MAGNETOMETER ARRAY (8X8)



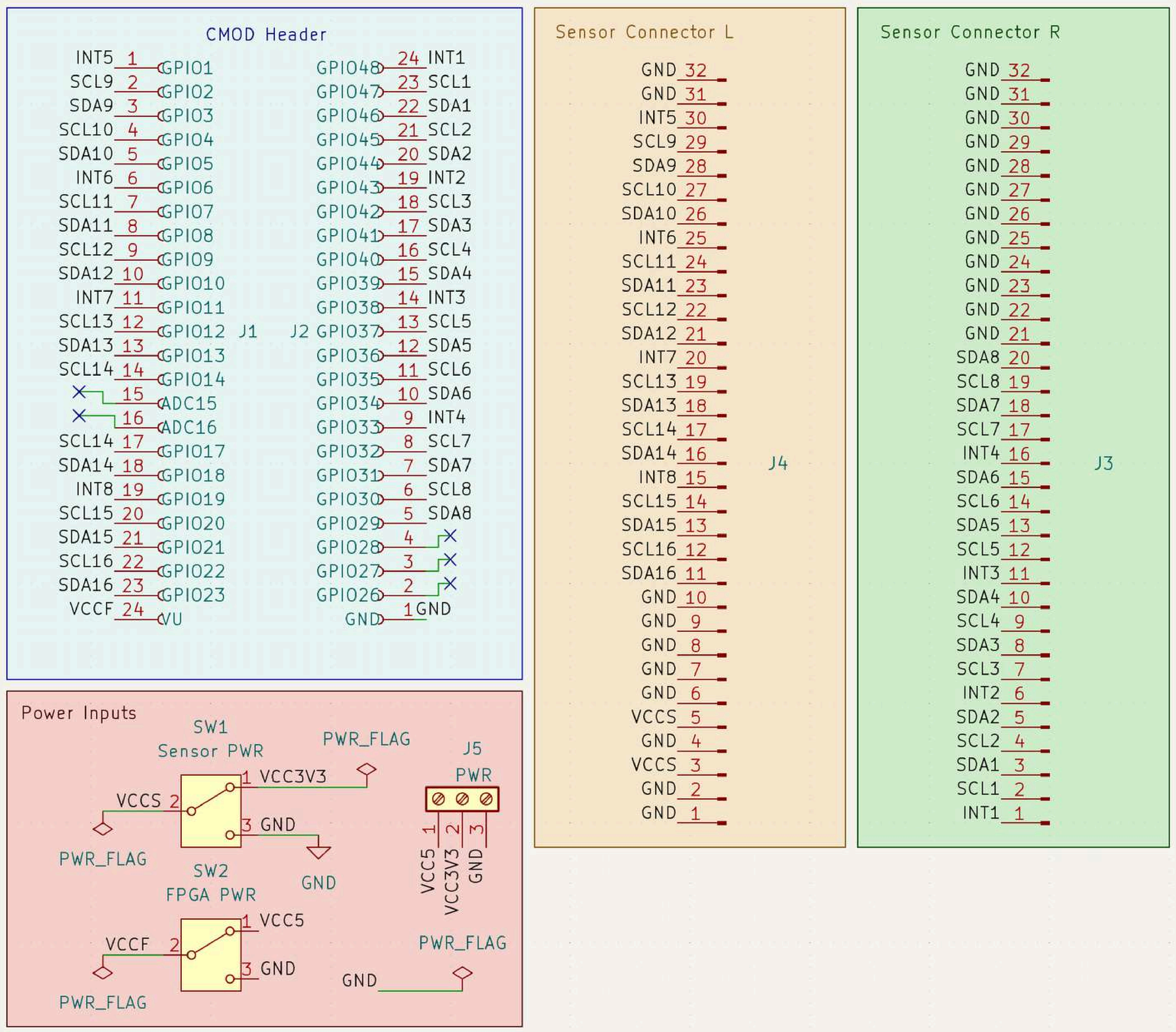

32
GND
31
GND
31
GND
32
GND

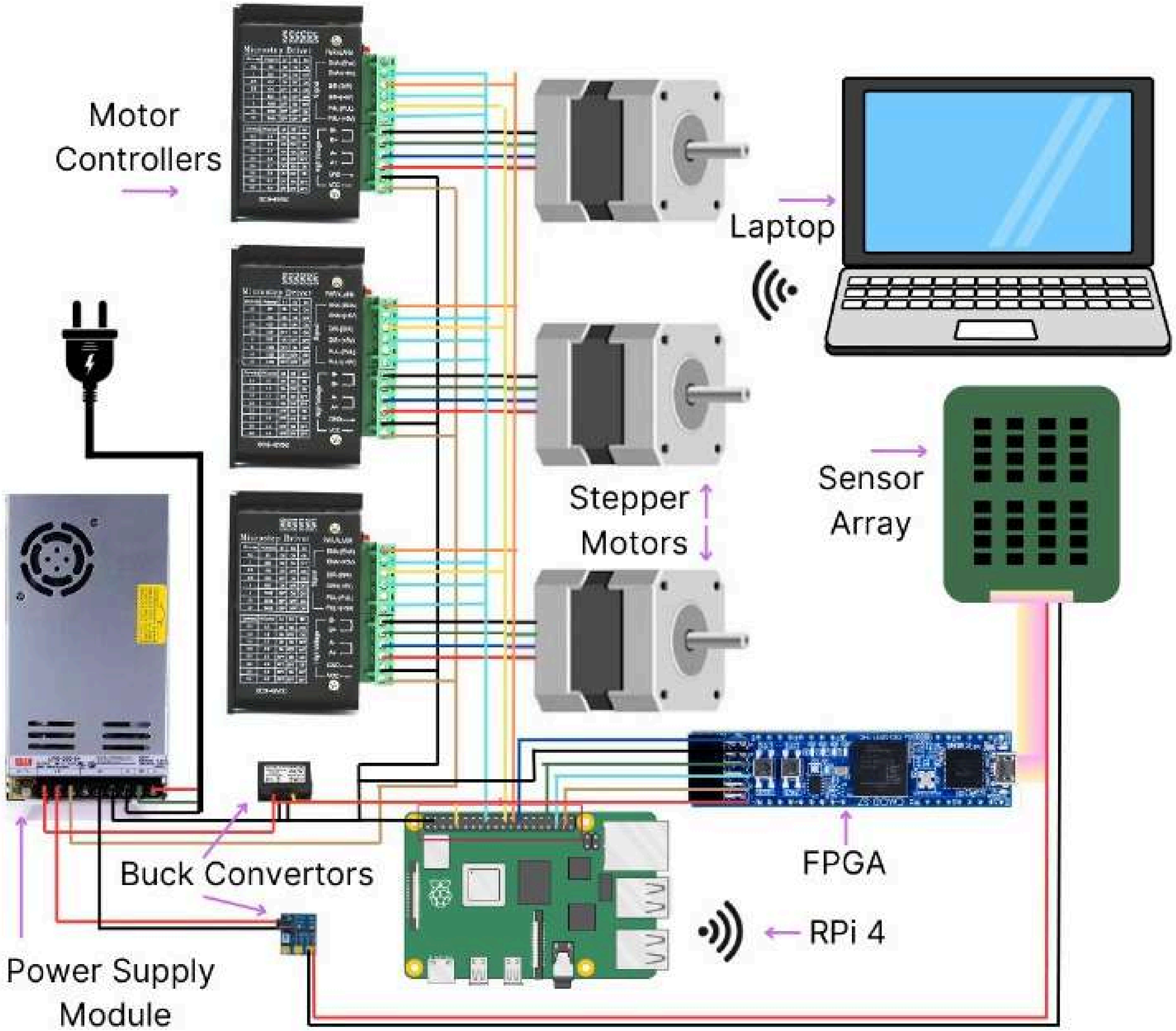
TMAG5170 Breakout Board




J1
SCK
MISO
MOSI
CS1
INT
VCC
GND
CS2
U2
U1
R1
R2
10k
TMAG5170-Q1
TMAG5170-Q1
C2
C1

FPGA-Sensor Bridge Schematic

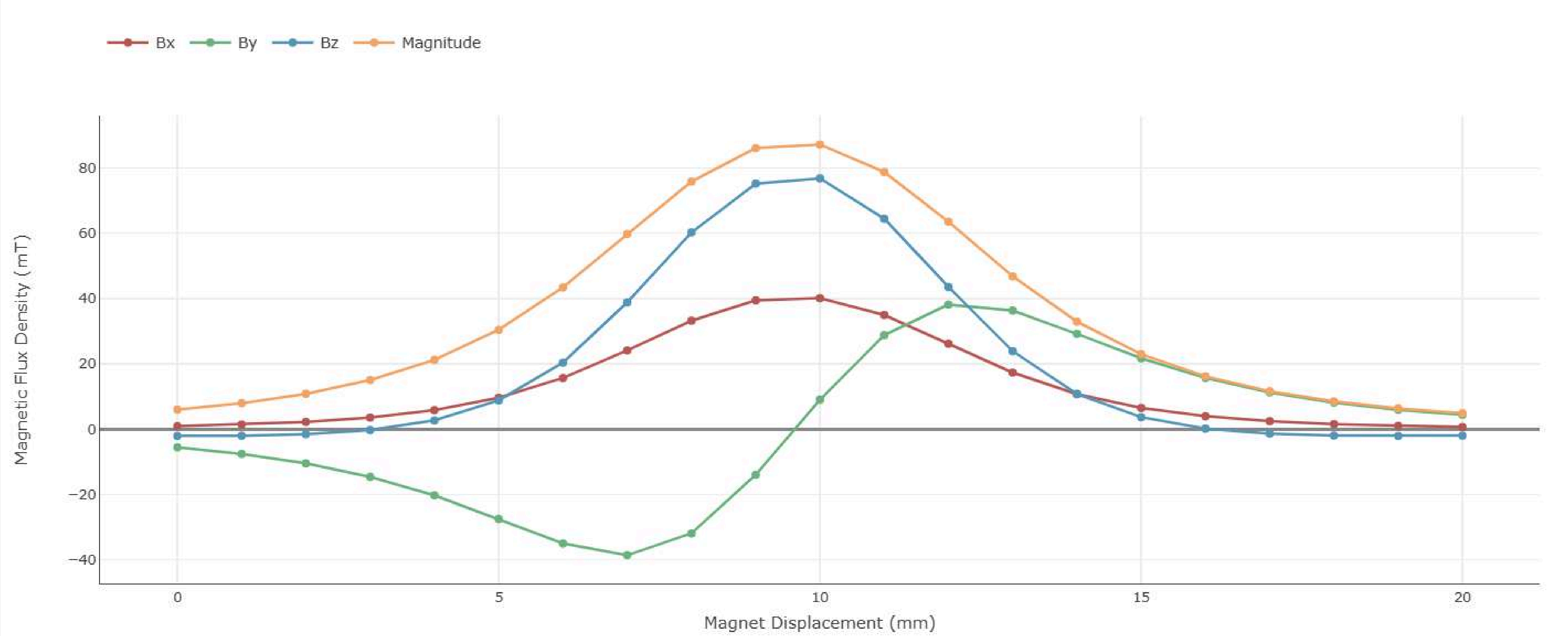



Motor
Controllers
Laptop
Stepper
Motors
Sensor
Array
FPGA
Buck Convertors
RPi 4
Power Supply
Module

06
Preliminary Tests

TI Simulation

- To determine the range of magnets that we could test, we used a Texas Instruments tool to simulate the a sensor array sweeping across magnets of different strengths
- This allows us to fix the minimum distance away from the magnet we will sweep at, to prevent damaging the sensors, and also makes the use cases for the product clearer



FPGA-uC SPI

Setup → We made connections from the FPGA's PMOD header using simple jumper wires to an RPi Pico

Speed → We were successfully able to test SPI Communication up to 12 MHz, which is above spec.

Software Delay → We have a software delay of about 60us per 128 bits using MicroPython, which is within spec. This can be further reduced using C++ if necessary.

WiFi Test

Connection

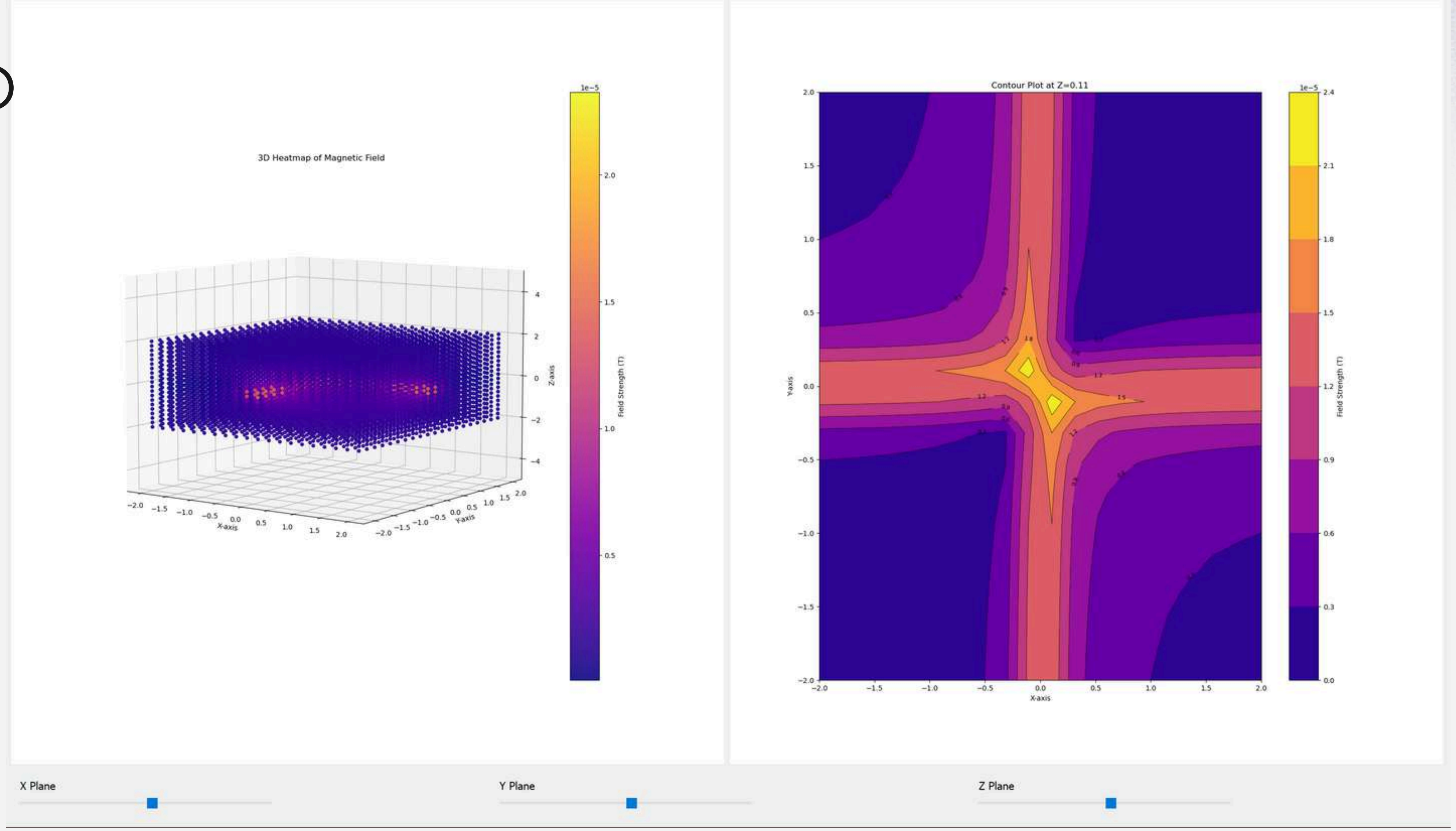
A WiFi connection was successfully implemented and tested using an Raspberry Pi Pico W and an Asus laptop over a supplied hotspot.

Data Transfer

Data was then sent from the Raspberry Pi Pico W to the laptop using Internet Protocol. The data sent was a basic html page that was received and correctly displayed on the laptop demonstrating real time transfer capabilities.

GUI Test

- Implemented several techniques of visualisation available on matplotlib including 2D and 3D quiver plots, heat maps and contour plots.
- Finalised the design to be a 3D zoomable and rotatable heat map along with a 2D heat map of any plane specified by user
- Aim to implement a 2D heat map cum quiver plot of the plane parellel to the current orientation of the 3D heat map as default



07
Future Plans

Mechanical Design

- We prioritised electronic design initially to ensure we could send our PCBs for printing as soon as possible
- The priority in the near future is to focus on mechanical design, and create an initial 3D printed prototype to test the accuracy of the linear actuators and rigidity of the design
- We aim to complete and test the first prototype in the first week of March
- Following this, we will place an order for the necessary mechanical components and build the final version

Motor testing

- We initially planned to test the motors and their accuracy this week, but due to a delay in procuring the components we were unable to
- This is a priority as it determines the resolution of our camera, and the microcontroller code will have to be tweaked accordingly
- Getting a better idea of the dimensions also allows us to design the case for the motors