Portfolio

Jackson Russell

Email: jackrussell772@gmail.com
Phone: 0434 421 611
LinkedIn: LinkedIn
GitHub: GitHub

Contents

Introduction

This is my portfolio showcasing many projects I have completed via work experience or course work throughout my degree which I'm still completing. This entire protfolio is written in LaTeX because it's far superior to word (except formatting.. that sucks). You can find the codebase for this portolio here. I've tried to keep this portfolio as brief as possible so you don't have to end up reading too many pages. If what I've done seems of interest you're more than welcome to contact me using the contact details on the title page and check out my LinkedIn and GitHub.

1 RIMA1 and RIMA2: Conditianal Assessment Robotic Tools for Sewer Pipes

Brief: RIMA1 [1] and RIMA2 [2] are two robotic tools developed by the UTS Robotics Institute in collaboration with Sydney Water. They are designed to conditially assess the pipe walls of sewer pipes using Pulse Eddy Current (PEC) Sensors. Both robots operate in the ROS1 framework and are equipped with various sensors and cameras such as IMU and RGB-D cameras. Both robots communicate with the base station using VDSL via a kevlar braided cable. The subsections will go over more specific tasks I did on RIMA1 and RIMA2 meaning it will excluide things such as general maintenance and repair which was definitely done given these robtots are prototypes.

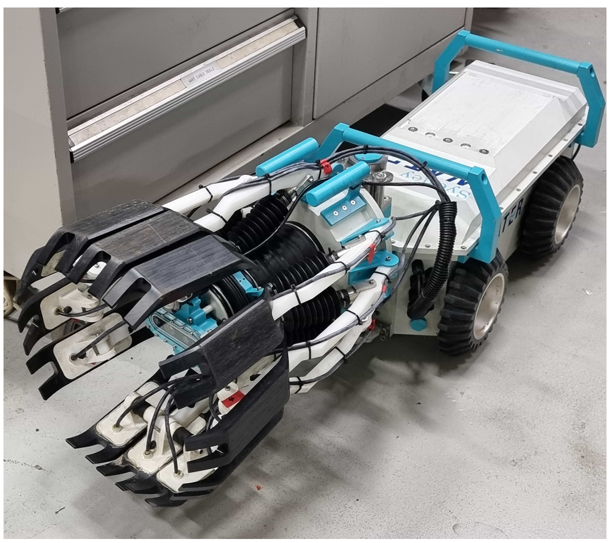


Figure 1: RIMA1

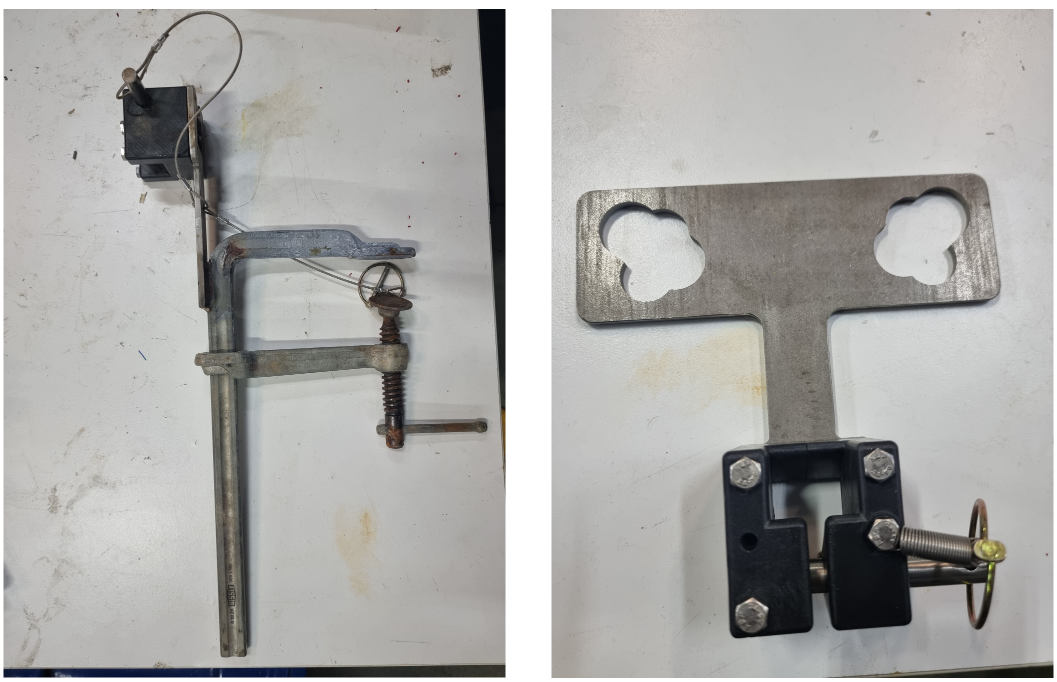
Figure 2: RIMA2

1.1 Mechanical Work

1.1.1 Utilities for RIMA1 and RIMA2 Field Trials:

I designed a number of utilities to assist with field trial deployments to prevent damage to equipment and site. Using solidworks I designed tether protection for flangless and flanged pipes [3] which were later manufactured to be used in deployments. The tether protection units are designed with the following intent:

- Ease of use for Sydney Water personnel
- Prevent damage to the tether and pipe wall at entrance where edge is sharp
- Adjustability for different pipe diameters (250mm to 750mm)
- Stainless steel for Chemical and Weather resitance and durability
- Simple lock-pin mechanism to ensure ease of use when wearing gloves
- Teflon block with internal radius matched to the bend radius of tether cable connected from base station to the robot
- Simple, low cost design



(a) Flangless Tether Protection

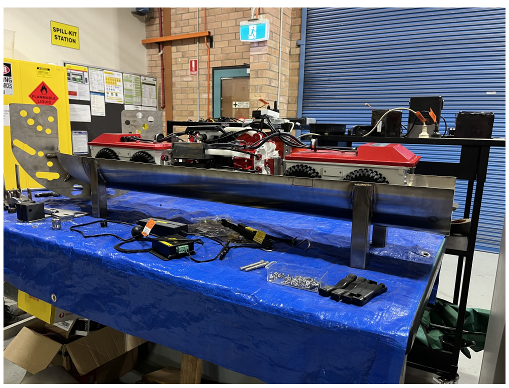
(b) Flanged tether protection

Figure 3: Tether Protection

1.1.2 RIMA2 Deployment Cradle:

The next utility I designed was a debloyment cradle for RIMA2 [4]. Often, due to safety constraints only one person is allowed into the sewer pit. This does not favour the handling of RIMA2 which is a 3-body system best carried and inserted into pipes safely by two people. After an incident in a previous deployment before I started where RIMA2 was dropped, I was assigned with designing a cradle. The advantage of the cradle to safely lower and deploy RIMA2. The final deisgn has the following features:

- Can be lowered using block-and-chain or cranes (varies with resource availability on site)
- Lightweight to ensure weight requirements are met as per agreement with Sydney Water
- Simple, intuitive locking mechanisms to ensure ease of use for Sydney Water personnel
- Custom flange design to adapt to various flanged pipe diameters (250mm to 450mm) if additional support is required



(a) RIMA2 Cradle in lab

(b) Cradle in use on field trial

Figure 4: RIMA2 Cradle

1.1.3 RIMA1 Rollover Assist:

I designed a set of rollover assist devices for RIMA1 after an incident in one of the first trial runs with Sydney Water having full control in our robot when unfortuntaely a software bug caused the robot to drive autonomously up the pipe wall causing in to invert. The aim of the rollover assist is to assist in manually having to pull the robot out the pipe when it inverts, as using mchinery to dig up the robot can be costly, time-consuming and potentially impossible depending on location.The inital inspiration [5] actually came from when I pulled apart my skateboard and attached it to RIMA1. The final design [6] after a few iterations is quite different from this and is simply a modification of the Sensor Pad on the sensor head with a custom bracket that could be fitted to RIMA1 with a simple modification to the handles.

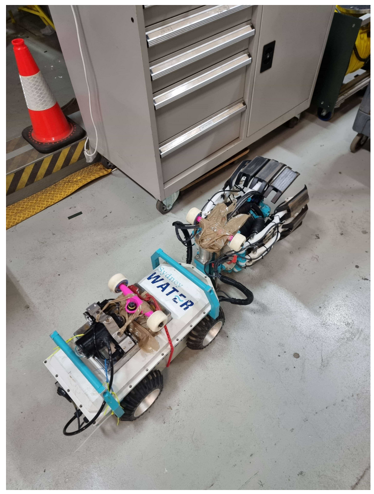


Figure 5: Rollover Prototype

(a) Rollover Assist Rear View

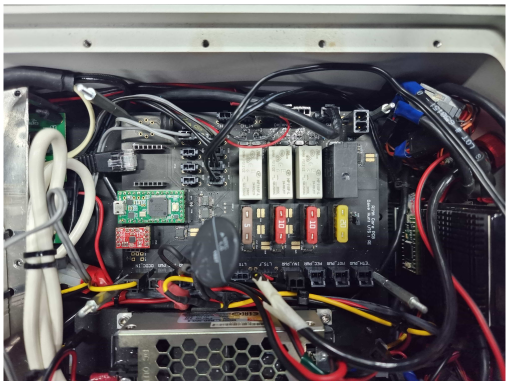
(b) Rollover Side View

Figure 6: Final Design Rollover Assist

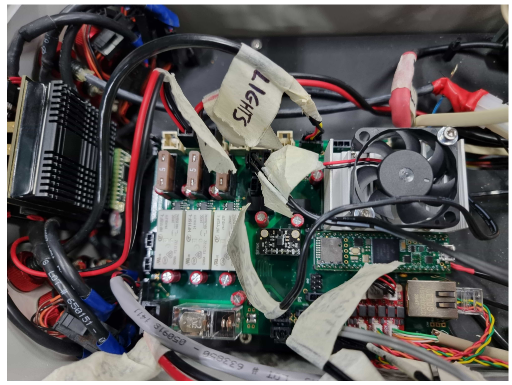
1.2 Electrical Work

1.2.1 RIMA1 System Board Installation:

RIMA1 had a new system board [7] installed to fix in-rush current issues when turned on which caused the battery BMS to kick in and turn off for safety and could not be reset without removing the top of RIMA1 and unplugging the battery directly to reset. It also featured a new IMU which I simple vector normalisation algorithm to ensure data was correct. The installation also required simple probing and electrical tests to ensure it was working properly.



(a) Old System Board



(b) New System Board

Figure 7: System Board Installation

1.2.2 RIMA2 New PEC Board Test Rig:

RIMA2 was to be fitted with a new PCB circuit which used Darlington Mosfets to drive the sensors instead op-amps used on its predessor. This was to allow for stronger signal amplification which would allow reasonable signals to be picked up on pipe walls with thick concrete lining (> 20mm). To validate the Darlington Mosfet, I created a test rig for the chip which could be attached to the predessor board.

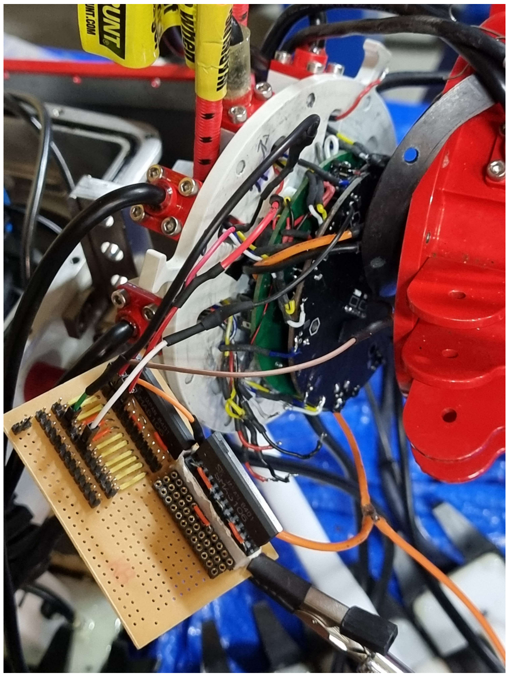
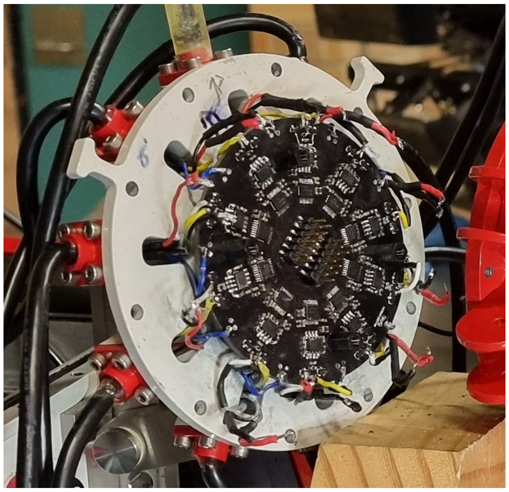


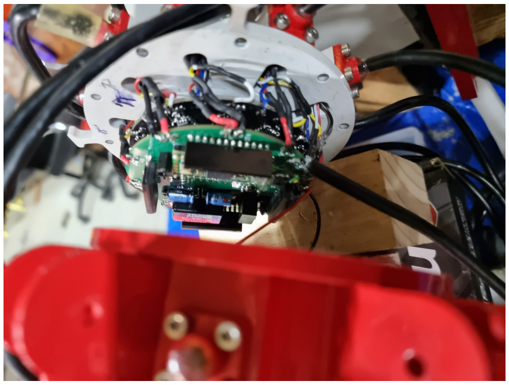
Figure 8: Darlington Mosfet Perf Board Setup

1.2.3 RIMA2 New PEC Board Installation:

Once tests were validated. The teams senior engineer who works remotely designed the new PEC board and it was my task to install it [9]. This wasn't a simple installation as the receiver board (black PCB) had to be removed and the new board had remounted to the sensor head base where the old PEC board was mounted. This is becasue the Mosfets of the new board are quite large and clearence is needed to ensure it fits within the sensor head. Installing the board required hand soldering extremely small wires and SMD components that were damaged or fell off the recevier board when relocating. It also required soldering USB data lines to the new PEC board.



(a) New Pec to be installed ontop of Receiver Board



(b) New PEC PCB

Figure 9: New PEC System Installed

1.2.4 RIMA2 Electrical Debugging:

RIMA2 is a very small, compact robot and with that came many issues. Especially after the new PEC board was installed. Various debugging was completed on RIMA2 to ensure everything was working as intended and to fix any issued. Debugging and fixes include:

- Replacing PEC USB cable which became faulty due to strain during installation and earlier testing with the Sensor Head open
- USB voltage testing for rear cart camera which was no longer being detected. Other software based diagnosis such as dmesg was done for this issue as well. Camera cable was eventually replaced
- RIMA2 ran off and NVIDIA Jetson Xavier AGX. Port health was checked for PEC and Cameras.
- Probing of RIMA2 PEC and System Boards for debugging and diagnosis when PEC would arbitrarily stop working.
- Further PCB debugging to identify and replace faulty components such as regulators.

1.3 Software Work

1.3.1 Software Brief:

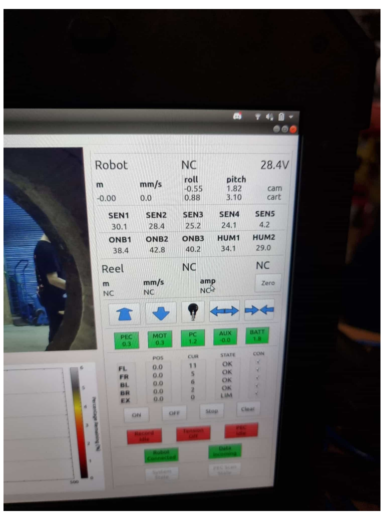
RIMA1 and RIMA2 ran off the ROS1 Melodic framework. They utilised custom messages and customised ROS packages to function. All code for the robot was written in C++ and analysis scripts used for PEC are written in Python. Unfortunately the codebases for these robots cannot be shared as it is property of UTS and Sydney Water. The robots processes and GUI's are all run/launched ushing shell scripts in the linux CL.

1.3.2 RIMA1 System Board Software Update:

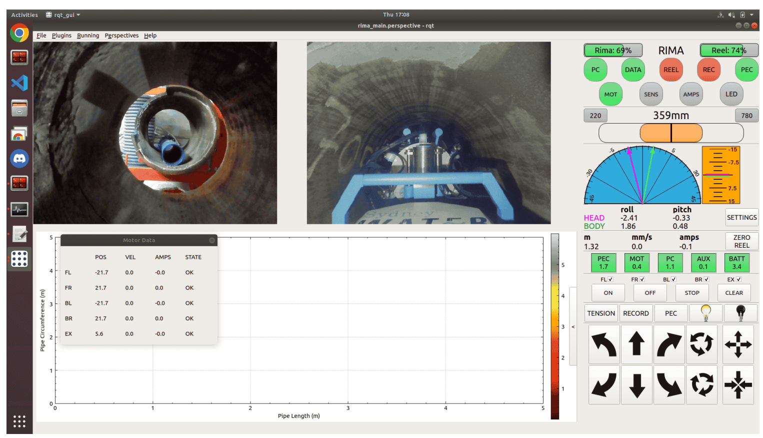
The new system board required some minor software updates. This primarily consisted of changes to message data types and names. This change also required small modification to RIMA1's core.cpp file which was resposible for ROS handling (i.e. setting up subscribers, publishers, etc.).

1.3.3 RIMA1 GUI Update:

The old GUI of RIMA was outdated and not greatly designed and doing something simple such as turning required going into settings and modifying rotation setpoints which is clearly not ideal or user friendly. I updated the GUI [10] to have more intuitive control, I also installed rear cameras at the time for rear view and visual view of the sensor to have a better cue of full expansion rather than basing it off the current reading. Basic IMU visualisation was also added to the GUI to allow for better understanding of the robot's orientation in the pipe. The GUI was written in C++ using Qt Designer.



(a) Old RIMA1 interface



(b) New RIMA1 interface

Figure 10: Comparison of RIMA1 GUI's

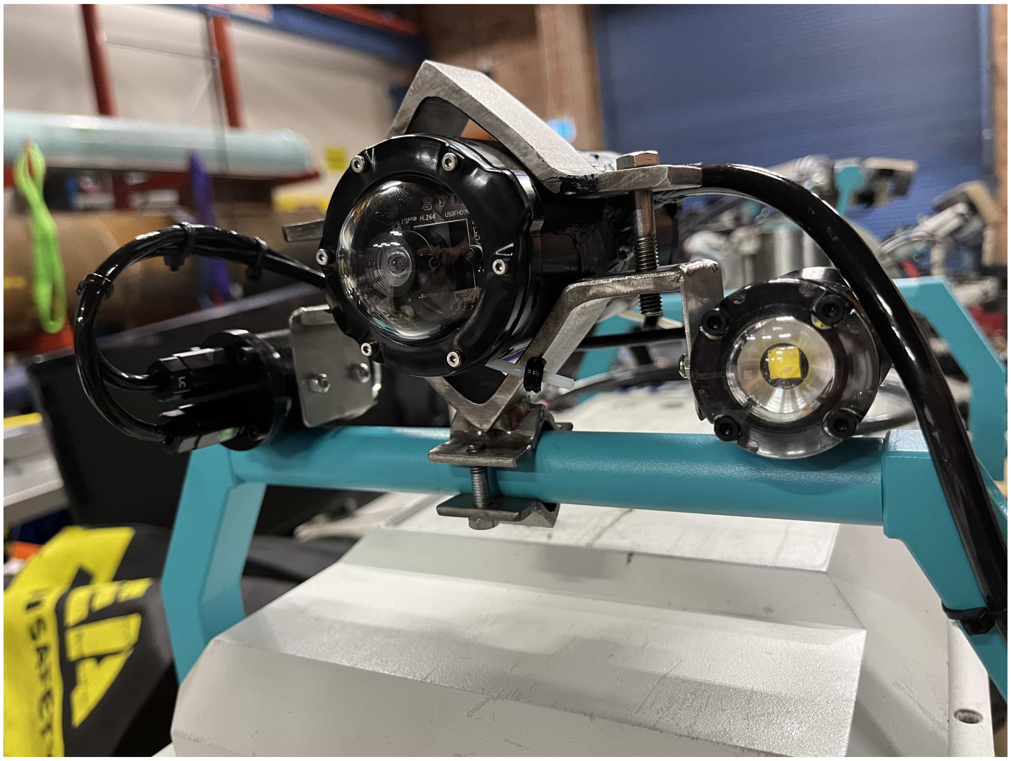


Figure 11: RIMA1 Rear Camera rear View

1.3.4 RIMA2 PEC Embedded Software Debugging:

When RIMA2's PEC Board was installed, its microcontroller onboard the PCD was also upgraded and used slightly different libraries compared to the old PCB for SPI communication. The way the Sensor Head has 10 PEC channels that each have an ADC daisy-chained together. From a software standpoint the channels buffer through in a loop so all 10 channels are obtained and transferred via SPI. With the new MCU, Libary and PEC board, 10 inidvidual channels of data did not come through. Instead the 1st channel appeared to override all channels and there were 10 identical plots of data. After logic analysing and electrical debugging, if was found that the Chip Select was a consant and as a result, would not allow proper buffering through the ADCs. Once this was changed, PEC worked as expected.

1.3.5 RIMA PEC Calibration:

PEC was regularly calibrated before field trials to ensure that sensors were fully functional. PEC curves could be extracted and analysed [12] [13] using Python Scripts.

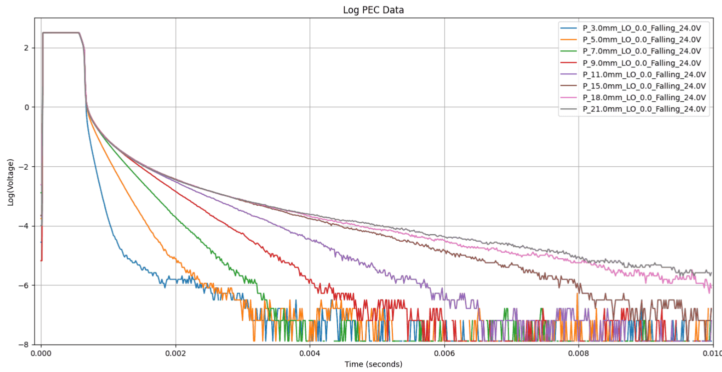


Figure 12: PEC data RIMA2 no concrete lining results

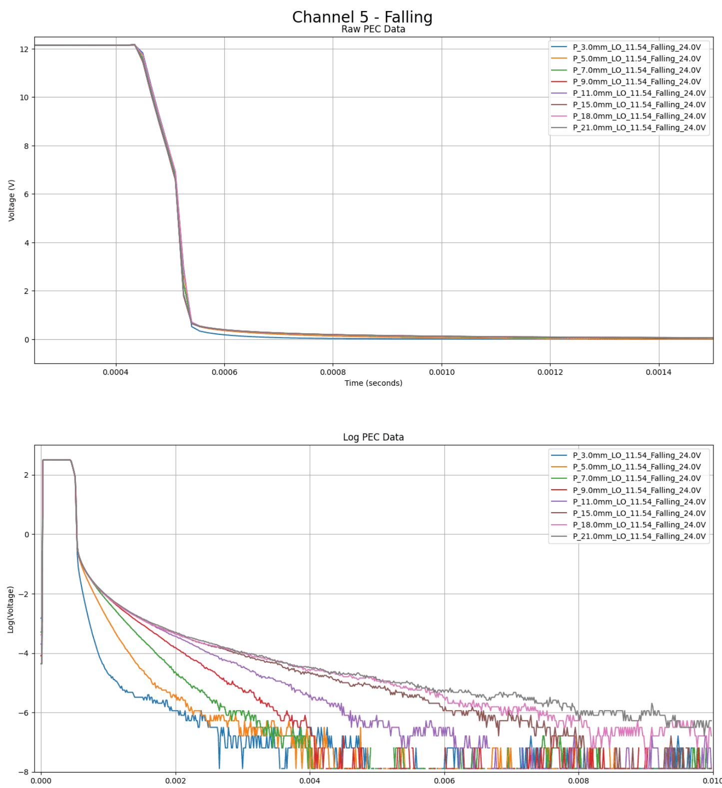


Figure 13: PEC data RIMA2 11.54mm concrete lining results

1.3.6 Other Software Work:

There were a few other software tasks I did such as creating new shell scripts for QOL such as easier data transfer between robot and base station. This made it more intuitve for anyone using to command line rather than having to memorise shell copy commands. I was also in the process of creating a Master GUI in collaboration with our Senior Engineer. This was to make everything more user firendly for Sydney Water to grant them capability in having non-technical staff operate the robots. However, due to project timeline constraints, whilst built, it was never tested fully.

2 S100: Demonstartion robot for the UTS Robotics Institute

The S100 demonstration robot [14] is an incomplete project before my departure from the UTS Robotics Institute. It was a robotic platform smaller than RIMA2 intented to do similar tasks to the RIMABOT Project. The robot was desiged with the following featrures:

- Single Teensy MCU for control
- Communicated with base station using an MQTT broker over ethernet to replicate similar communcation functionality to RIMA1 and RIMA2
- GUI with intuitive controls and a 3D real-time imu visualisation devolped using ReactJS [15]
- The ability to be used without ROS to make it more user friendly for non-technical users
- The GUI was also linux compatible and a ROS bridge could be used to also control the Robot in ROS amongst other things, making the robot versatile for both general and research use. The React application itself would generate all ROS topics using standard ROS packages if the ROS bridge was used.

Codebase: The repository for the S100 project can be found here

Figure 14: S100 Robot

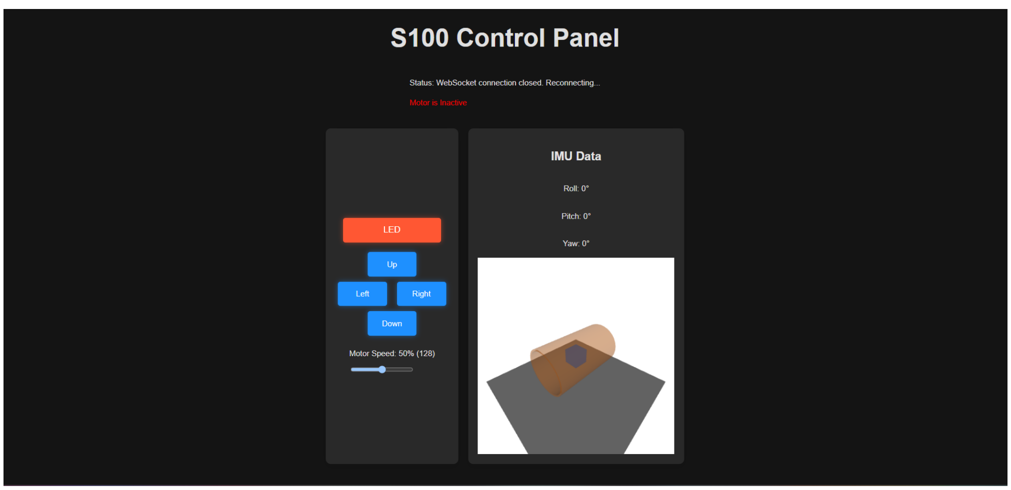


Figure 15: S100 GUI

3 Course Work

Brief: This section will go over the course work I have done throughout my degree throughout various subjects that I'm quite proud of and believe are industry relevant. The projects will go in chronological order of when I completed them.

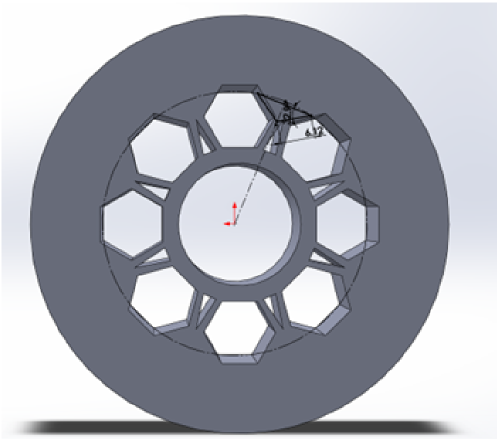
3.1 Mechanical/Mechatronic Work

3.1.1 MDFS Robot for Warman Challenge:

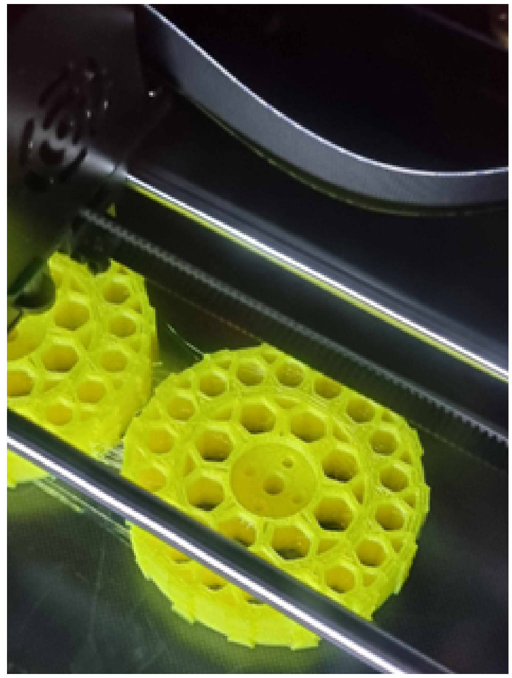
Subject: Mechhanical Design Fundamentals Studie 1 (Spring 2023)
Grade Achieved: Distinction
Project Overview: The goal of the assignment was to design an autonomous robot [20] that could traverse a track to collect tennis balls and deposit them into a Silo [19]. The final robot my team produced was successful in making the leaderboard. Below are my contributions to the final design of the project:

- Full electrical design [17] [18] with safety features fuses and properly rated components
- Custom designed 3D printed TPU Wheels [16]
- Chassis design and calculations
- Parrallel Manipulator design
- Software design and implementation
- Construction of the robot

Whilst this looks like I did everything, it's important to clarify that my group did contribute to different designs for various sub-systems however, the sub-systems didn't integrate together well and we had two members (it was a five person group including myself) not contribute for the semester. Because a last minute redesign was needed we agreed as a team that I would take over the entire design of the robot given my experience and they would focus on the group documentation and the presentation which was a large component along with the robot. Without their efforts in this, I would not have achieved the grade I did.



(a) CAD model of wheel



(b) Wheel being printed with TPU

Figure 16: Wheel Design

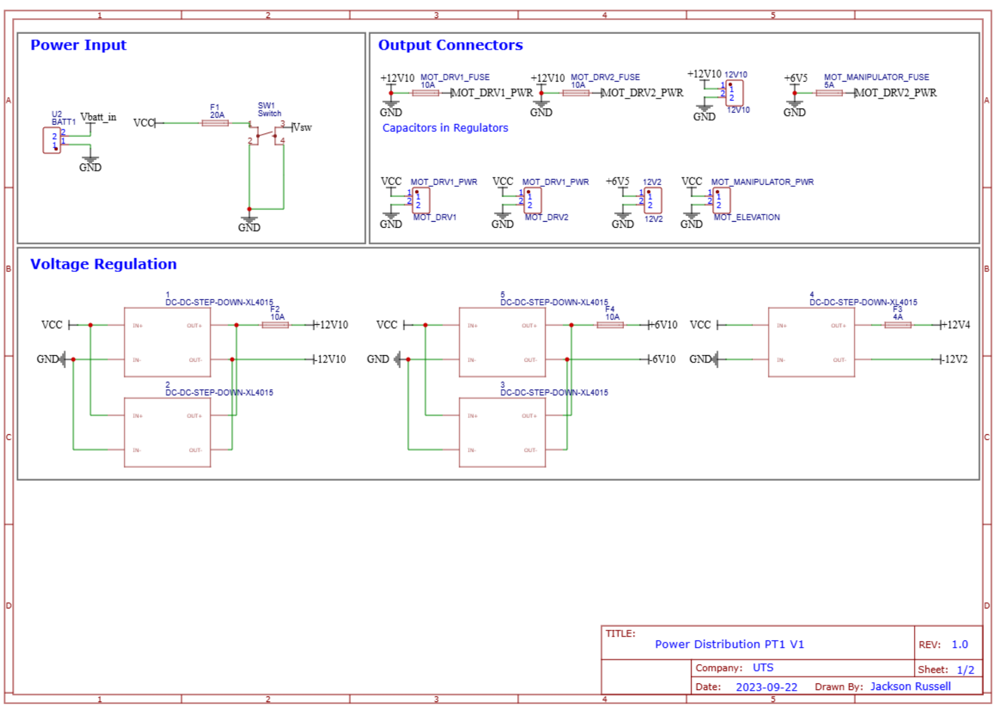


Figure 17: Power distribution Circuit

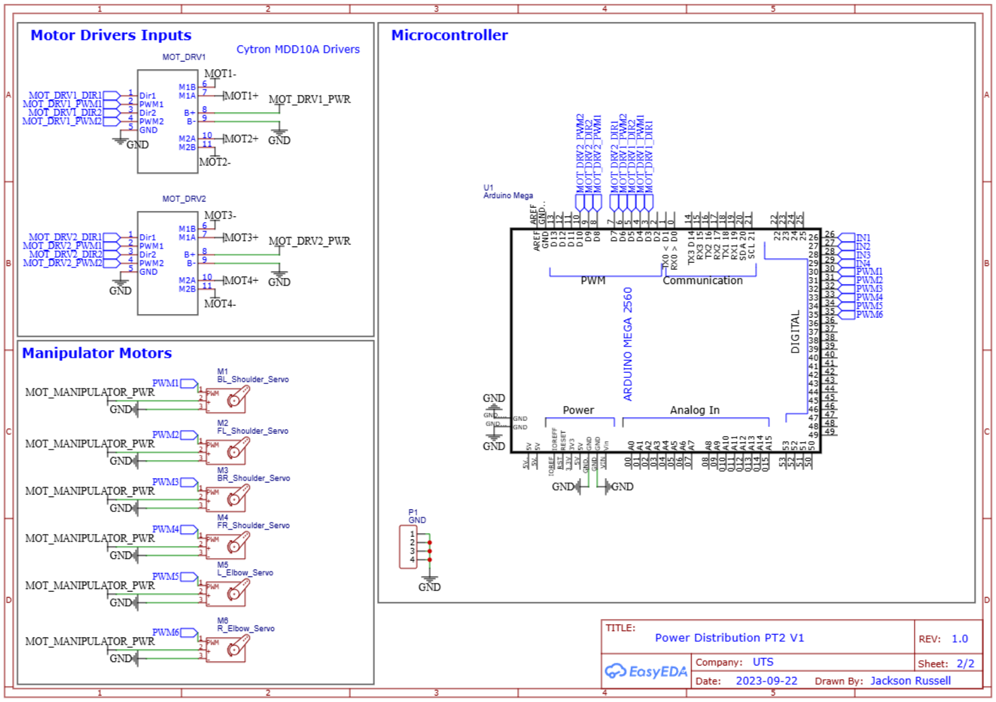


Figure 18: MCU circuit

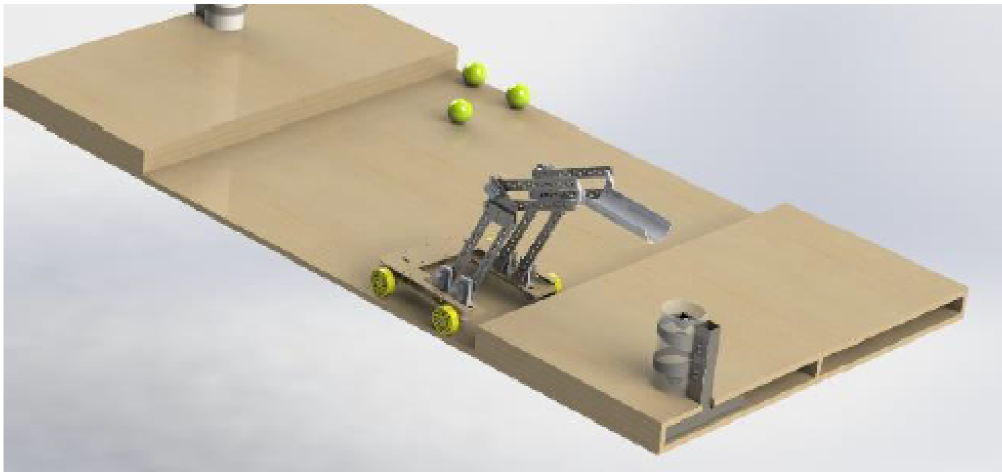


Figure 19: Robot Render

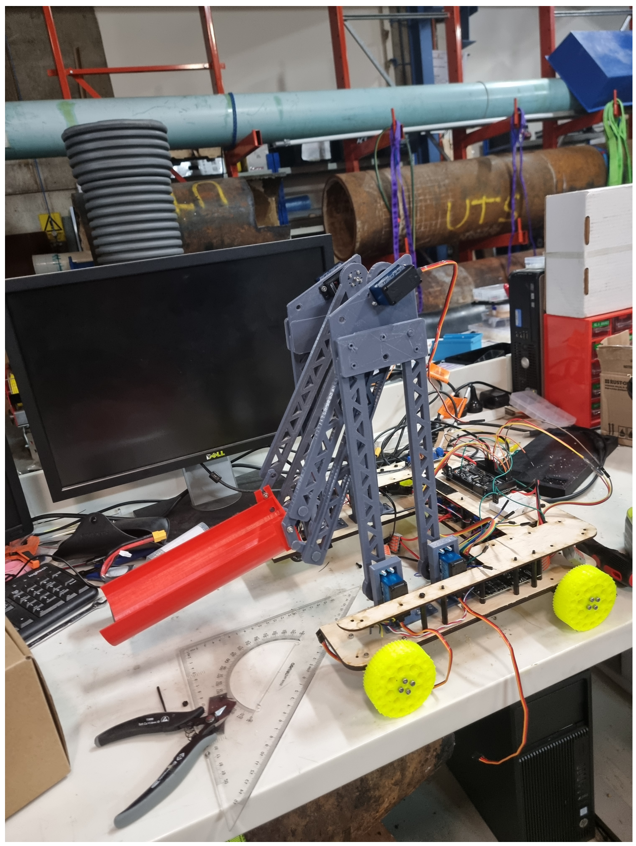


Figure 20: Final Robot

3.2 Electrical Work

3.2.1 Low Level Circuit Design using Keysight ADS:

Subject: Microelectronics (Autumn 2025)
Grade Achieved: TBA
Project Overview: Over the semester, I designed three low level circuits that had to meet certain specifications. I designed a Low Pass Filter (LPF), A Balun Circuit and a Low Noise Amplifier (LNA). This type of circuit design differs from standard circuit design as it uses unideal components where noise and resonance effects are taken into account. All components are tuned at a low level. For example, an inductor is not assigned an inductance value, instead its parameters such as coil lenght, spacing, number of turns, etc. are set instead. This is necessary for high speed circuit design where the slightest change in just one of these parameters can effect the entire circuit.

3.2.2 LPF:

Benchmark Specifications:

Parameter	Symbol	Value
Centre frequency	f_0	2.5 GHz
Insertion loss	IL	< 2 dB
Return loss (both ports)	RL	> 10 dB
Bandwidth	FBW	30–50%
Out-of-band rejection	OoB	> 30 dB at $2f_0$

Table 1: Filter Design Specification

Result Delivered:

Specification parameter	Result delivered	Spec met?
Centre Frequency (2.5 GHz)	2.75 GHz	✓
Insertion Loss	< 2 GHz	✓
Return Loss (Both Ports)	> 10 dB	✓
Fractional Bandwidth	61%	✗
Out-of-band rejection	15/18 dB (assignment/actual f_c)	✗

Table 2: Benchmark Results

Circuit Design:

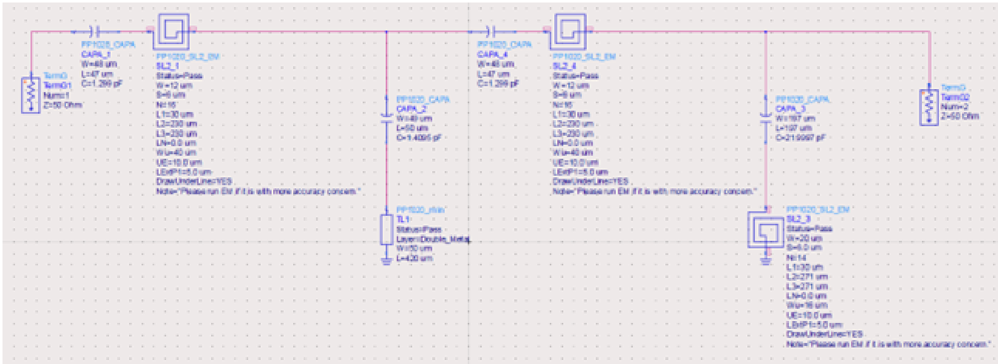


Figure 21: Low Pass Filter Circuit Design

Simulation Results:

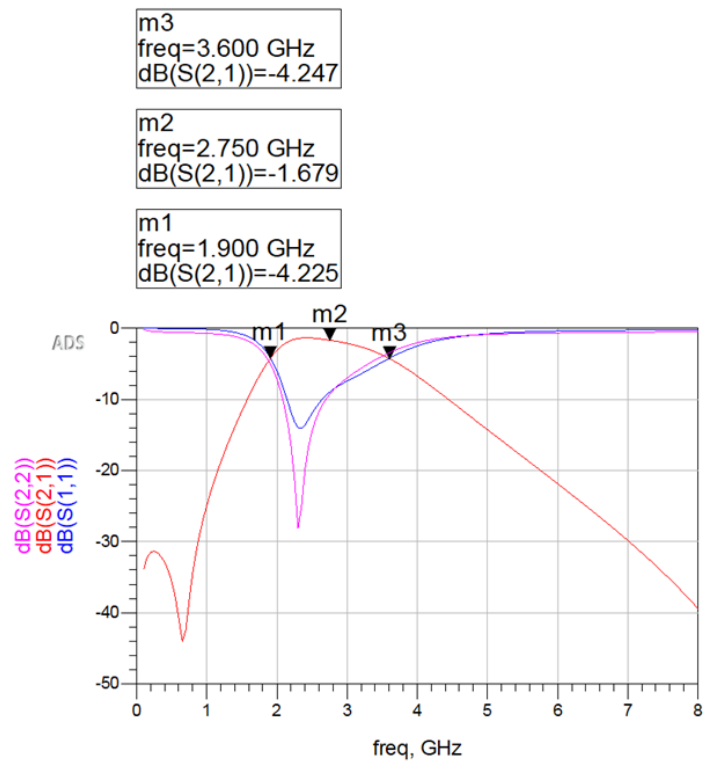


Figure 22: Low Pass Filter Simulation

3.2.3 Balun:

Benchmark Specifications:

Parameter	Symbol	Value
Centre frequency	f_0	15 GHz ($\pm$10%)
Balanced output load impedances	Z_L	According to Student ID[2]
Unbalanced source impedance	Z_s	50 Ω
Amplitude balance over FBW	AB	± 0.5 dB
Phase balance over FBW	PB	± 3°
Insertion loss (for both outputs)	IL	3 - 4 dB
Return loss (for input port)	RL	> 10 dB
Bandwidth	FBW	> 15%

Table 3: Design specifications for Balun

Result Delivered:

Specification parameter	Result delivered	Spec met?
Cf	54.25 GHz (target 55 GHz)	✓
AB	-0.495 – -0.221	✓
PB	-7.453, -9.180	✗
IL	-3.743, -3.998	✓
RL	-19.841 dB	✓
FBW	(66.25 – 39.75)/55 * 100 = 48.18%	✓

Table 4: Benchmark Results

Circuit Design:

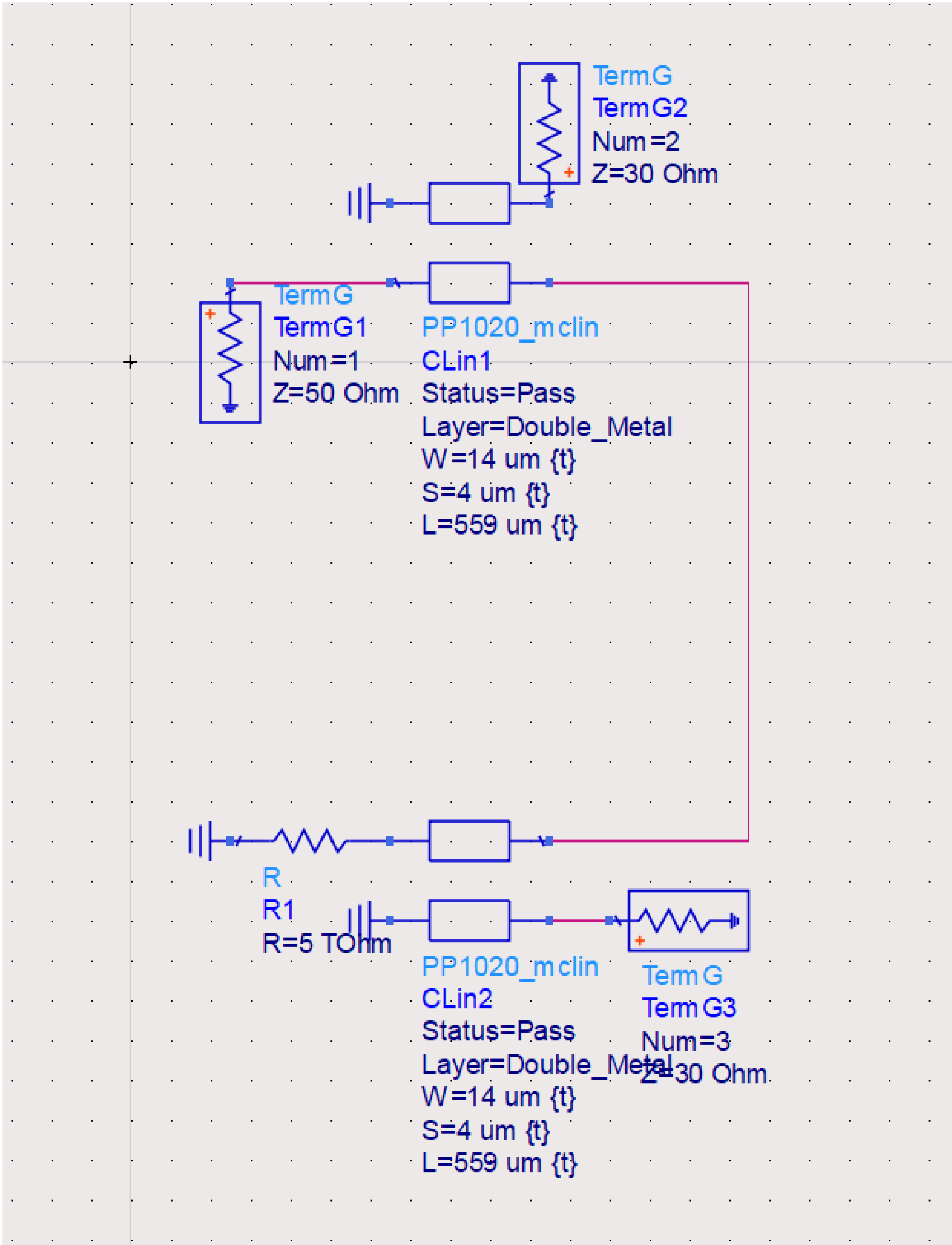


Figure 23: Balun Circuit Design

Simulation Results:

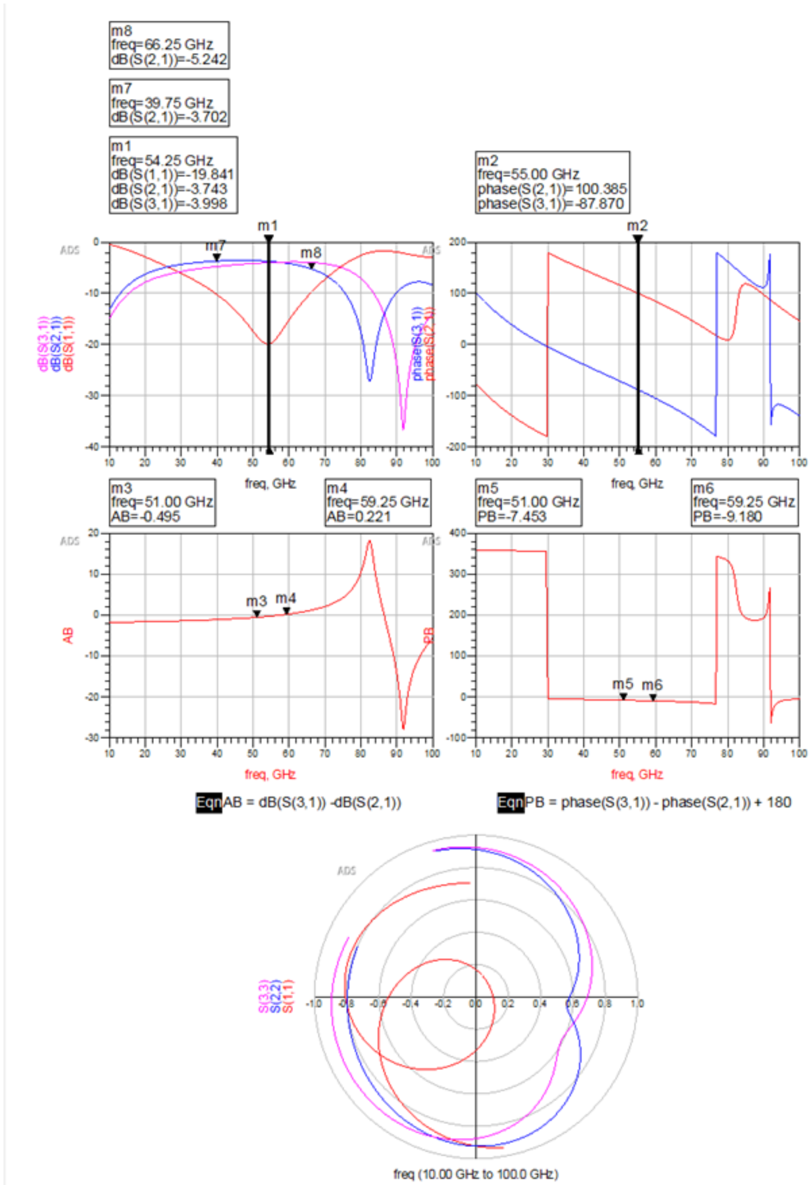


Figure 24: Balun Circuit Simulation

3.2.4 LNA:

Benchmark Specifications:

Parameter	**Symbol**	**Value**
Centre frequency	f_0	15GHz
Noise Figure	nf	< 1.2 dB
Transducer Power Gain	TPG	> 10 dB
Return Loss (Input and Output)	RL	> 10 dB
Quiescent DC Power Consumption	QDP	< 0.2W

Table 5: Design specifications for LNA

Result Delivered:

Specification parameter	**Result delivered**	**Spec met?**
Cf	15 GHz	✓
Nf	0.890 dB	✓
TPG	11.557 dB	✓
RL	11.336 dB, 11.693dB	✓
QDP	0.14385 W	✓

Table 6: Benchmark Results

Circuit Design:

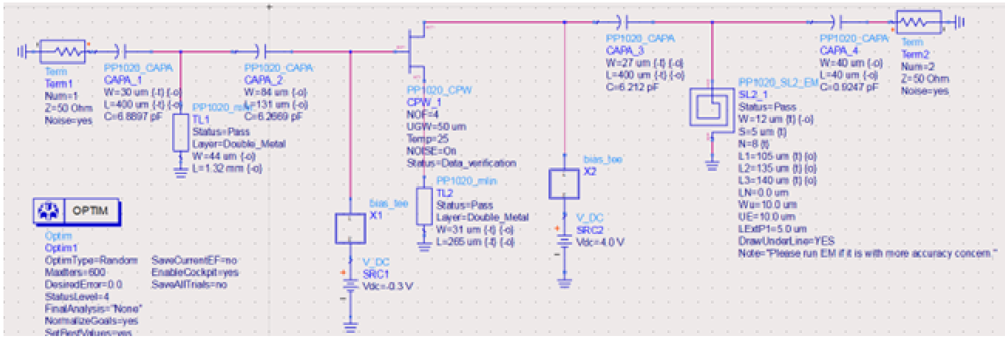


Figure 25: LNA Circuit Design

Simulation Results:

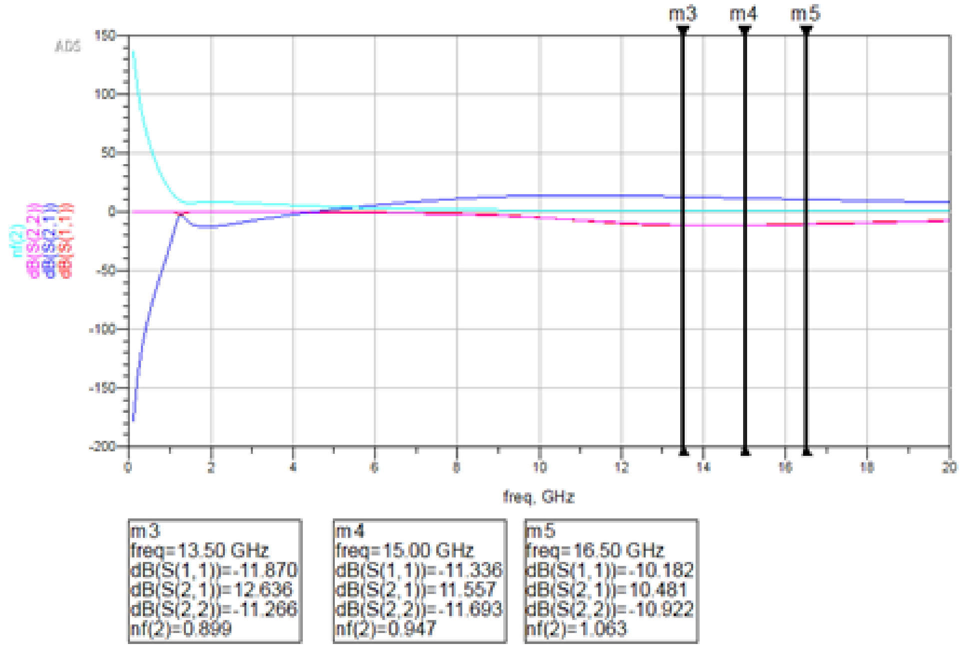


Figure 26: LNA Circuit Simulation

3.3 Software Work