TECHNICAL REPORT

TEAM LOXOPHOLIS

EE1-13 ENGINEERING DESIGN AND PRACTICE (2018-2019)

FIRST YEAR ELECTRICAL AND ELECTRONIC ENGINEERING

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WORD COUNT - 7961 WORDS

1.1 ABSTRACT

This report is about the design process and technical details related to the Loxopholis Rover Project. The aim of the project is to build a remote-controlled rover that can perform two core functions: A 360° two-dimensional maneuverability range, and process all possible signals received from its environment. This report will focus on how these core functions have been satisfied but will also explain further optimizations which allow the rover to perform its core functions more efficiently, and to include application-specific features.

1.2 INTRODUCTION

The project brief outlines that the purpose of the rover is to navigate a sensitive forest environment and identify lizards which have evolved to communicate with electromagnetic and acoustic signals – making the lizards into signal sources. in this environment. A list of the signals emitted by each type of lizard in the test environment can be seen on figure 1. The purpose of the optimization elements in the rover is to allow it to move and sense as quickly as possible, and to fulfil as many of the qualitative aspects specific to the application as is possible. There are two constraints on the project: A maximum total budget of £50, and a weight limit of 700g. The top priority when designing the rover is to keep within the constraints, because otherwise the rover will be disqualified. The next priority is to ensure that the core functions of the rover – specified in the abstract - function efficiently and reliably. The lowest priority design factors are the qualitative elements specific to the application that the rover will be used in. Qualitative factors include waterproofing the rover and ensuring it is composed of less environmentally harmful materials. Approaching the EERover group project in this logical and strategic manner has made setting priorities easier and will hopefully allow us to develop the best possible final project that we can produce.

Species	Property 1	Property 2
Gaborus	61kHz radio modulated '#GAB'	Acoustic signal at 40.0kHz
Nucinkius	61kHz radio modulated '#NUC'	None
Durranis	89kHz radio modulated '#DUR'	Magnetic field up
Pereai	89kHz radio modulated '#PER'	Magnetic field down
Cheungus	Infrared pulses at 353Hz	None
Yeatmana	Infrared pulses at 571Hz	Acoustic signal at 40.0kHz

Radio signals are on-off modulated with a UART coding at 300 bits per second

Figure 1: signals emitted by the lizards (EERover Brief)

1.3 CONTENTS

2 CONTENTS

2.1 SENSOR BLOCK

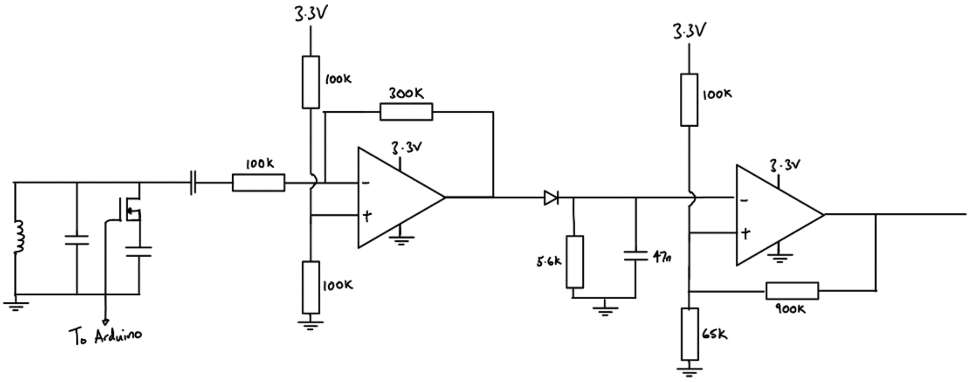
2.1.1 RADIO BLOCK

2.1.1.1 INTRODUCTION

The lizards emit two different types of carrier frequencies (61kHz and 89kHz), however they have different messages encoded on them. The final goal of the radio sensor is to have a clean UART signal that can be detected from 10cm away. This is done in a series of stages:

Antenna → Tuning Circuit → Amplification → Envelope detector → **Schmitt trigger**

The current circuit is shown below:



For each stage; its functioning, its role and the design process will be examined.

2.1.1.1.1 THE ANTENNA

The coil antenna acts as an inductor with inductance[1] (L) (Spazztech.net, 2017):

$$L = \frac{\mu N^2 A}{l} \qquad [1]$$

μ = permeability (Wb/Am)

N = number of turns in coil

A= area encircled by the coil (m^2)

l= length of coil (m)

[1] (Spazztech.net, 2017)

A “good” antenna is one that can provide a high gain and high resolution and still respect the design criteria. To maximizes those conditions, the following consideration were done:

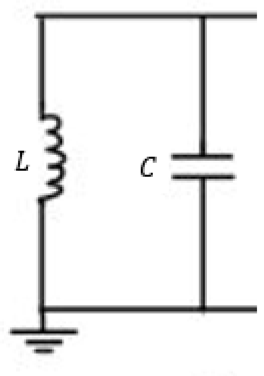
- Multiple layers of loops, to increase the number of turns, but remain at a convenient size.
- The area encircled by the coil is as big as the design criteria allows
- Thick wire is used to reduce resistance.

The inductance of the coil antenna was measured to be 432.6x10µH.

2.1.1.1.2 TUNING CIRCUIT

The role of the tuning circuit is to isolate a certain bandwidth of frequencies. The latter done by creating a band pass filter using inductors and capacitors (see figure(1)). This type of circuit should ideally filter out all the frequencies except for the corner frequency. The equation for the corner frequency is given by:

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad [2]$$



Knowing the value of L to be 432.6x10^{-6}H and wanting to isolate either 61kHz **or** 89kHz, eq.[1] ca be rearranged to find the corresponding value of C:

$$C = \frac{1}{4\pi^2 Lf} \qquad [3]$$

To switch between isolating a signal of 61kHz or 89kHz, the following options were considered in the design process:

1. Two entirely different circuits
2. Two capacitors in parallel, with two MOSFET controlled by the Arduino
3. Two capacitors in parallel, with one MOSFET controlled by the Arduino

The table gives a numerical value to the efficiency of each circuit based on tree design criterias : weight, size, cost, points of failure:

Design criteria	importance	Design 1	Design 1 weighted	Design 2	Design 2 weighted	Design 3	Design 3 weighted
Weight	35%	2	0.7	8	2.8	9	3.15
size	35%	2	0.7	8	2.8	9	3.15
cost	10%	4	0.4	6	0.6	8	0.8
Points of failure	20%	8	1.6	5	1	7	1.4
total	100%		3.4		7.2		8.5

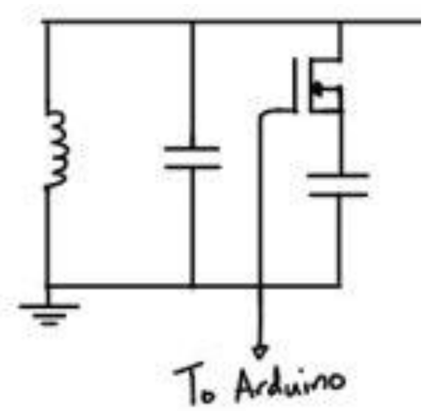
Table 1

The chosen design (design 3) consists of a simple bandpass filter as the one explained in figure(1), in parallel with a MOSFET (controlled by the Arduino) and a capacitor in series. The circuit can be seen above. When the MOSFET is “off” the circuit acts as a normal bandpass filter with corner frequency: eq[2]:

$$f = \frac{1}{2\pi\sqrt{LC_1}}$$

When the MOSFET is “on” the circuit becomes a bandpass filter with corner frequency:

$$f = \frac{1}{2\pi\sqrt{L(C_1+C_2)}} \qquad [4]$$



Since $f_c \propto {}^{1}/_{\sqrt{c}}$ it makes sense to use the circuit 1 to detect the 89kHz signal and circuit 2 to detect the 61kHz signal.

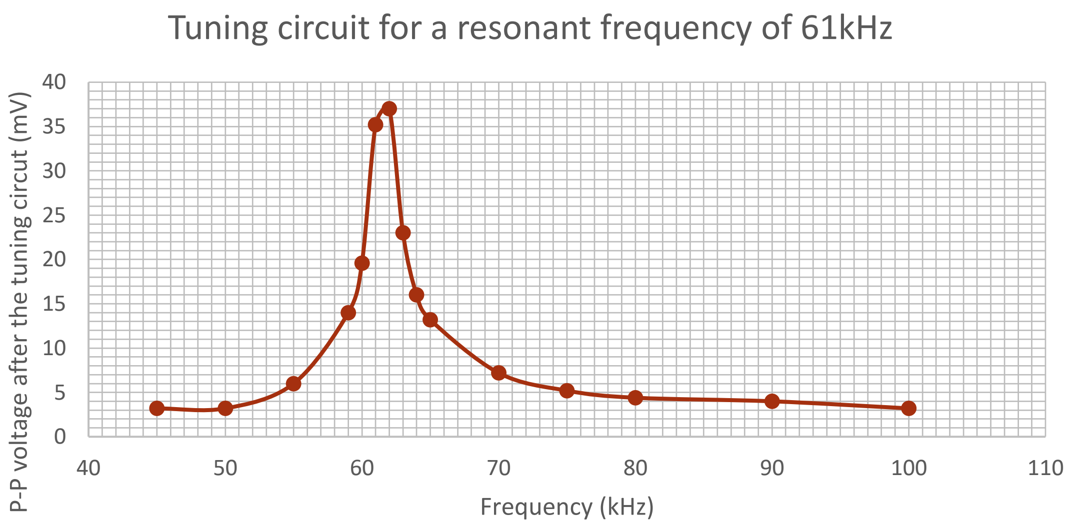
Using eq.[3] : C_1 was found to be 7.4nF

Using eq.[4]: $C_1 + C_2$ was found to be 15.7nF

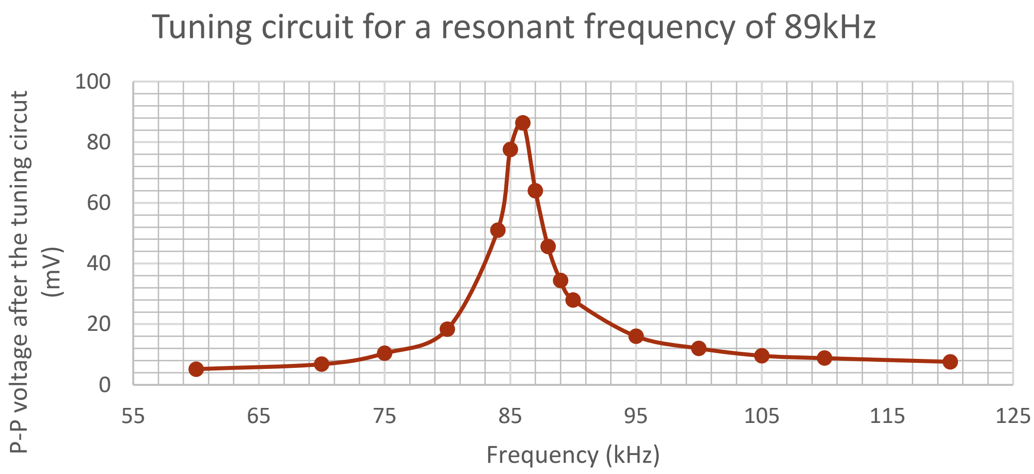
Hence, for C_1 a 6.8nF and a 560pF capacitor in parallel were used,

and for $C_2 = 15.7 - 7.4$ =8.3nF a 5.6nF and a 2.7nF capacitor in parallel were used.

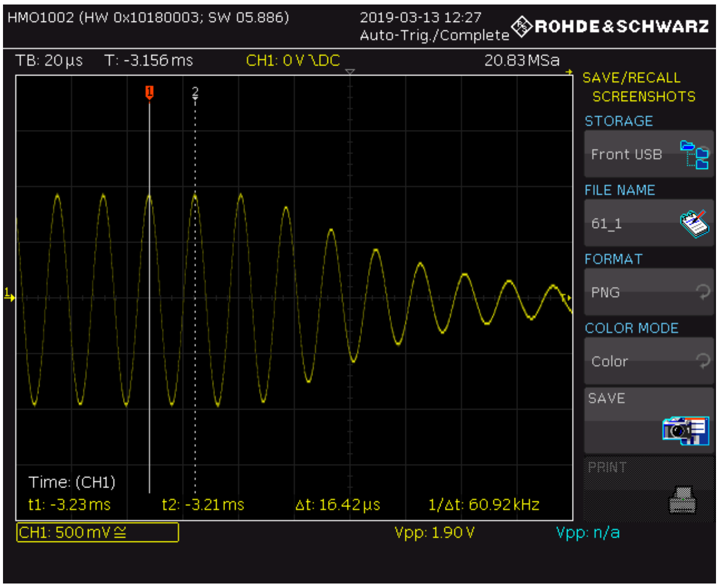
The effectiveness of the tuning circuit can be see in graph(1) and graph(2):

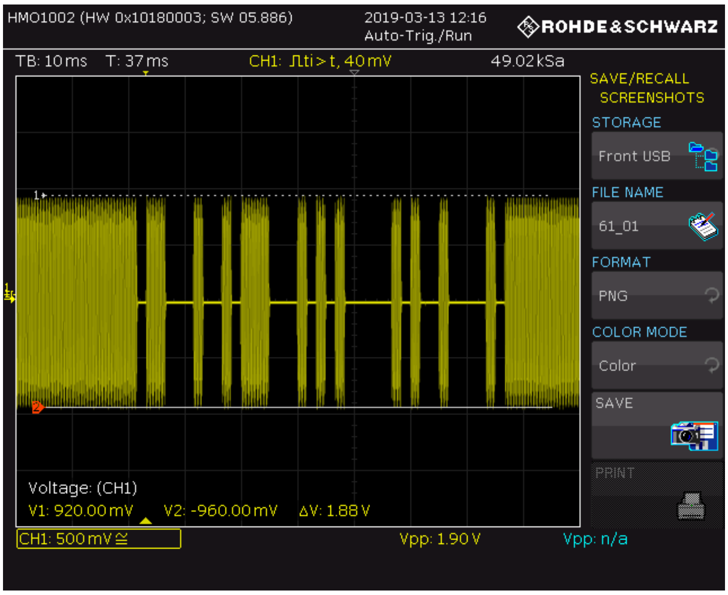


Graph 1: graph of tuning circuit for a resonant frequency of 61kHz

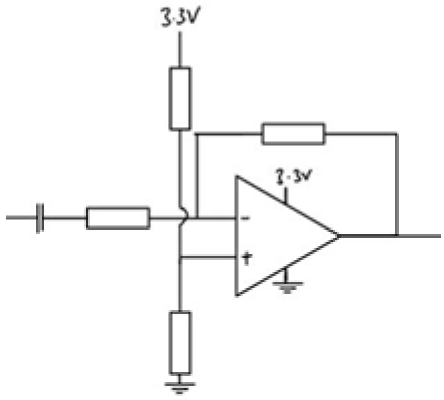


Graph 2: graph of tuning circuit for a resonant frequency of 89kHz





2.1.1.1.3 AMPLIFIER STAGE



The signal received from the antenna is strong enough that it does not need to be amplified, even when the circuit is loaded. However this only works when the antenna is relatively close to the lizard. In order to maximize the range of the sensor (hence increasing efficiency) the signals needs to be amplified.

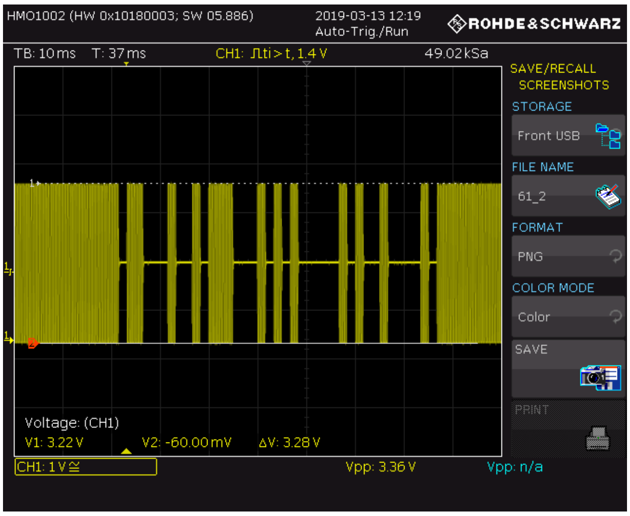
All the sensor amplifiers where designed using single supply inverting amplifiers. The latter was done to simplifying the design of the printed circuit board (PCB).

In an inverting amplifier the amplification is determined by $-\frac{R_2}{R_1}$.

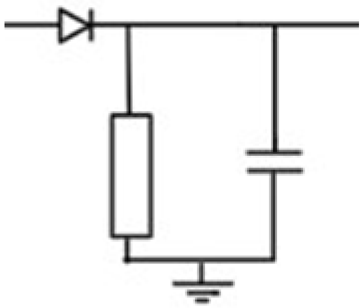
Amplifiers cannot amplify the signal more than the power supply (in the case 3.3 V_{PP}), but the signal amplitude drops with distance. So as long as a small signal is detected it should be able to amplify the signal enough such that it can be to fed it to the next step of the circuit. However, amplifying the signal, amplifies noise just as much. After several testing with different gain values, it was found that a gain of 10 is the compromise between having a decent range of detection and no error due to noise. Hence R_2 = 1MΩ and R_1 = 100kΩ:

Since this amplification design is using a single power supply, the ap-amp needs to be biased around 1.6v. The latter is done with a potential divider (R_{B1} and R_{B2}). Therefore, R_B = 100kΩ and R_{B2} = 100kΩ.

After the amplification, the signal can be seen in figure below:



2.1.2 ENVELOPE DETECTOR



At this point, the signal still contains both the carrier frequency and the baseband signal as seen in figure x . An envelope detector will tf_c) as input and, provides an output which is the envelope of the original signal (our baseband signal) (En.wikipedia.org, 2019)[2] The envelope detector is composed of a diode that acts as a half wave rectifier and a capacitor in parallel with a resistor that act as a low pass filter. $\tau = RC$) to remove the corner frequency without altering the baseband signal is when [3]:

$$RC = \frac{1}{2\pi f_m} \qquad [4]$$

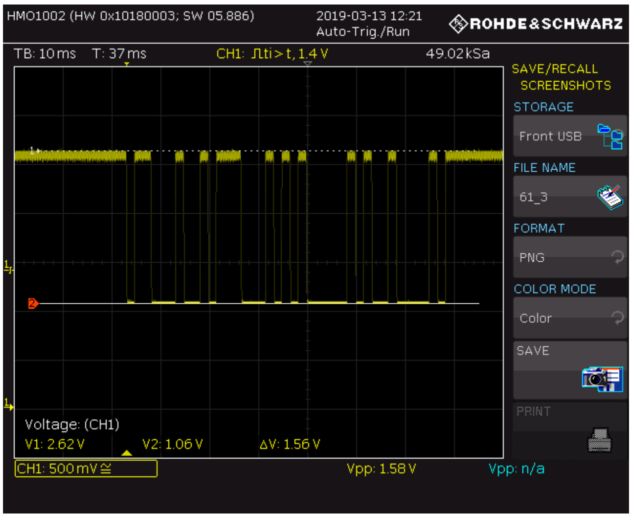
[2] https://en.wikipedia.org/wiki/Envelope_detector

[3] communication lab

f_m is the corner frequency and has value 600Hz

Setting R = 5.6kΩ, C Can be calculated to be 47nF.

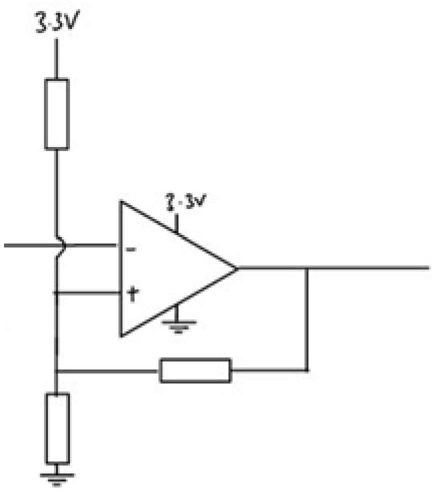
The effect of the envelope detector can be seen in figure X:



2.1.3 SCHMITT TRIGGER

"Digital inputs should be 0V for logic low and 3.3V for logic high."[4] Hence, for the Arduino to decode the UART, the signal needs to be convert from 1.56 v_{pp} to a 3.3 v_{pp}.

The circuit of the design that was used can be seen in figure below:



The Schmitt trigger allows to set High and Low Threshold Levels to any voltage desired[5] (Lazaridis, 2009): V_{high} and V_{low} respectively. V_{high} and V_{low} are the values of the positive input, where any values of V_{in} bellow V_{low}

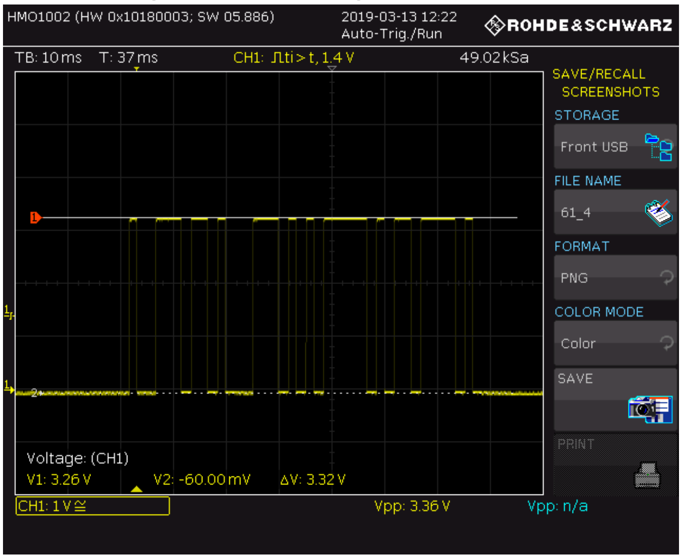
[4] https://intranet.ee.ic.ac.uk/intranet/labweb/pdf/tech-guide.pdf
[5] http://www.pcbheaven.com/wikipages/The_Schmitt_Trigger/?p=1

will be set to 0 v and any value of V_{in} above V_{hight} will be set to 3.3 v. Values between V_{hight} and V_{low} will cause no change.

From figure x, the values of V_{high} and V_{low} were decided to be 1.5v and 1.2v respectively. Those value are a compromise between maximizing range and avoiding error due to noise.

The values of R_1, R_2 and R_{FB} were calculated to be: R_1 = 12KΩ, R_2 = 8kΩ and R_{FB} = 51kΩ

After the Schmitt trigger circuit, the signal will look like figure X:



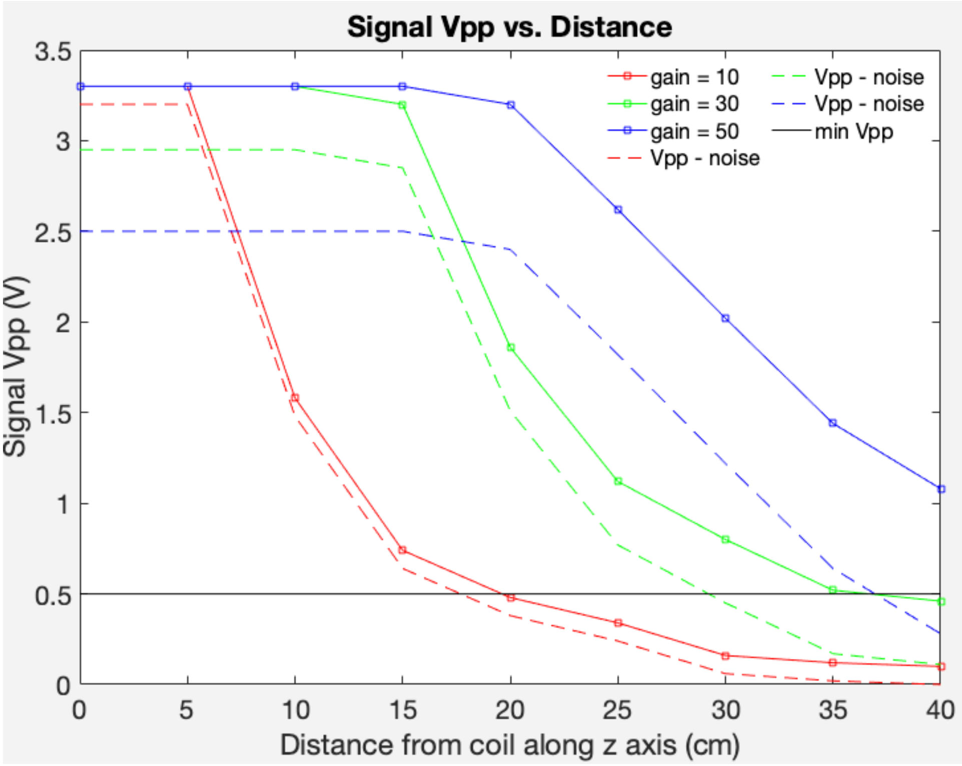
The signal is then read by the Arduino.

2.1.3.1 TECHNICAL CONCLUSION

This section on radio sensor has explained how the succession of the antenna, the tuning circuit, the amplifier, the envelope detector and the Schmitt trigger work together to detect and filter the information of a radio signal. Final circuit implementation of the sensor can be seen on figure X. Figures x-x, allow for a clear understanding of this process. When applicable, a brief explanation was given for the choice of design (especially when more than one option was available). However, most of the decisions where made to satisfy the design criterias imposed by the consumer (mainly: weight, size, cost and reliability).

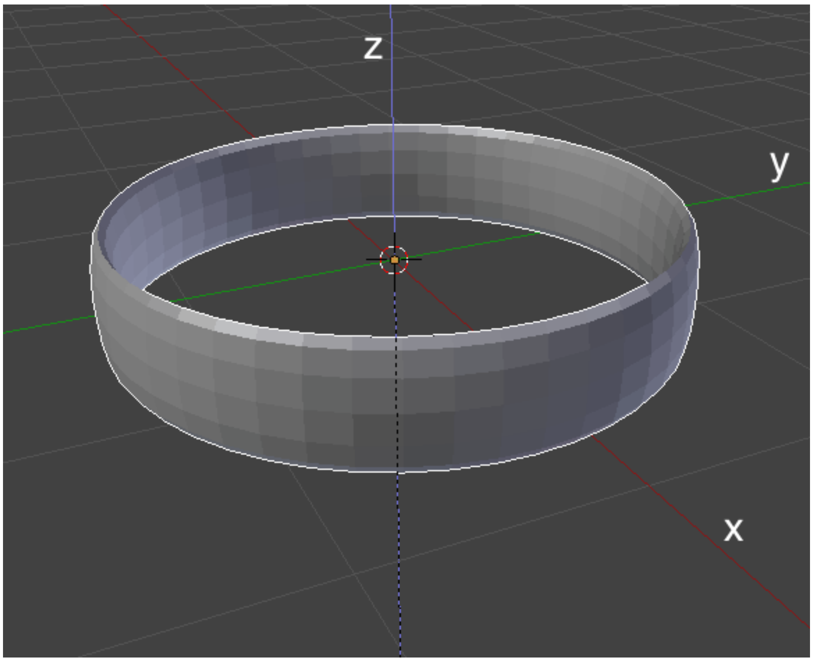
2.1.4 OPTIMISATION PROCESS EXAMPLE - OP AMP GAIN FOR RADIO SIGNAL DETECTION

THEORETICAL OPTIMISATION

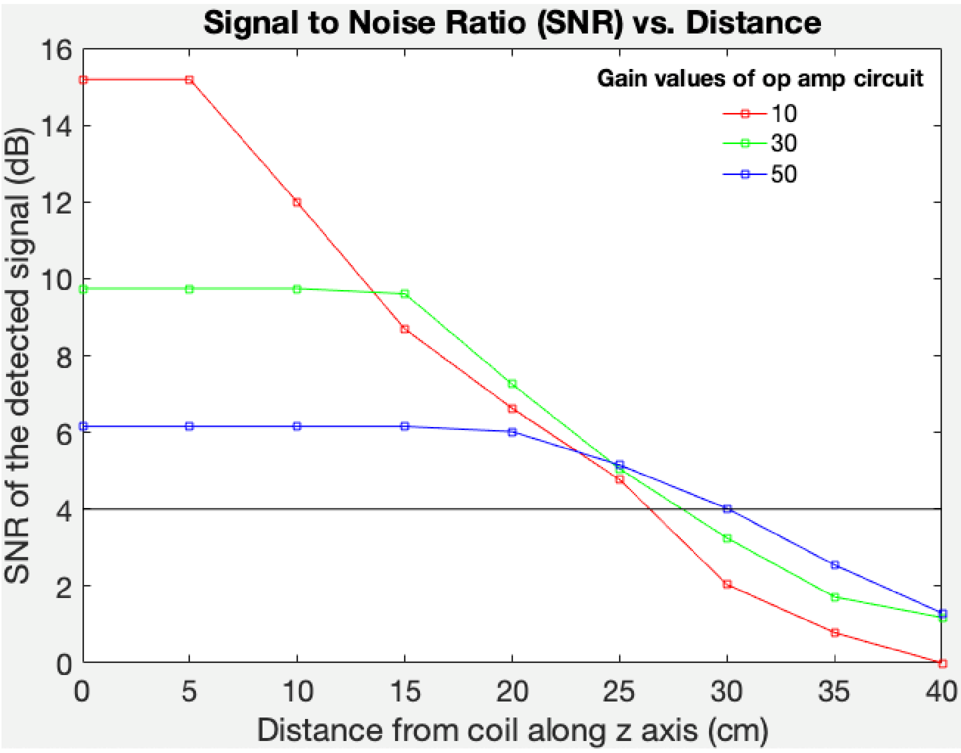


In order for the Schmitt trigger threshold voltages to function reliably, V_H-V_L (the Schmitt trigger high and low threshold voltages) needs to be larger than the noise peak to peak voltage. Experimentally, it was determined that for the noise to not affect the signal at any gain value, the signal must have an amplitude at least 0.25V greater than the noise. In total, the signal Vpp must be 0.5V greater. This is demonstrated on the graph to the left, showing that an op amp gain circuit with values of 10, 30 and 50 have a maximum theoretical detection range of 18, 29 and 37cm respectively, assuming that the noise and signal amplitudes are perfectly detected. It is evident that theoretical detection range doubles when the gain increases from 10 to 50. However, it must be taken into account that the inductor is a directional sensor, and that these measurements have been taken with the signal source perfectly aligned along the z-axis of the coil. Clearly, the signal Vpp will realistically never be this high.

DIRECTIONALITY OF THE INDUCTOR AS A SENSOR



The curved plane formed by the angular bisectors between the x-y plane and the z-axis (both in positive and



negative z directions) represents the range of positions in which the radio frequency magnetic field lies on the x-y plane, or at a 90° angle to the z-axis. Here, according to Faraday's law, BAcosTHETA = 0 since cos(90°) = 0 [1]. **REALISTIC DETECTION**

To ensure that the resonant circuit will be able to both accurately and reliably detect the signal, the signal Vpp should be at least 2.5 times greater than the peak to peak noise. The industrial standard signal sensing is to have a SNR of at least 18dB [2], but for our application, it does not matter if some of the carrier frequency goes undetected, since we are only interested in detecting the baseband signal. Also, taking our equipment and experimentation into account, this is an acceptable value. The corresponding signal to noise ratio must be greater than 4dB, due to SNR being 10*log(Signal/Noise) for voltage signals (for power signals it's 20log(S/N)).

From these results, it is clear that a lower gain is by far favourable at closer distances, since the SNR of gain 10 is 250% of the SNR of gain 50 at a 5cm range. and that at the defined minimum SNR of 4dB, the difference in the range of detection (27 to 30cm) is 11%, so the gain of the op amp makes a negligible difference at this SNR value.

2.1.4.1 OPTIMISATION CONCLUSION

Theoretically, a higher gain value of 50 increases the range of detection dramatically when only considering Schmitt trigger threshold voltage precision (Figure 1). However, when simulating a realistic scenario, it is clear that the directionality of the inductor as a sensor must be considered, causing the SNR to influence the decision of the optimum gain value (Figure 2). From the SNR, it is clear that a lower gain of 10 is very much favourable (Figure 3). Therefore, to retain both a reasonable theoretical range between Schmitt trigger threshold values, and also a good SNR, the middle gain value of 30 gives the best results.

2.1.5 INFRARED BLOCK

This sensor block was designed to do the following tasks after having discussed and confirmed as a group its main aim:

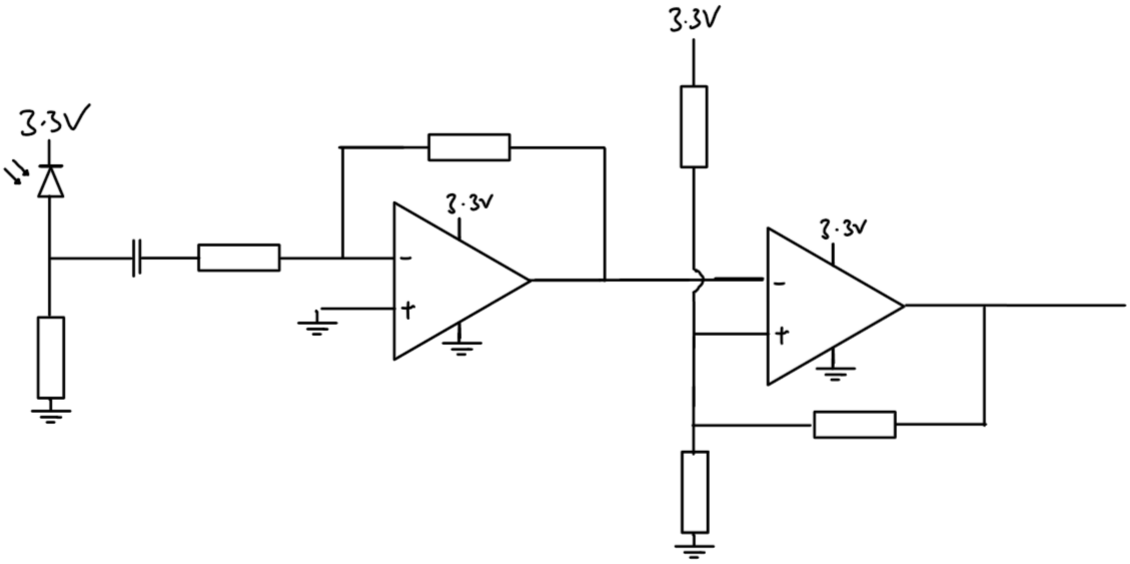
- Detect incident infrared rays
- Produce a large peak-peak voltage as an output
- Implement a band pass filter

2.1.5.1 INTRODUCTION

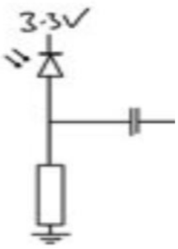
This sensor block is well understood in terms of the desired output, but there are many design restrictions which must be incorporated in the final design. While in the challenge there will be two different infrared pulses (353 Hz, 571 Hz), we discovered that our design won't need to detect these signals individually in order to differentiate, due to the pulse nature of the rays. This means that we can drastically reduce the number of components in our sensor block, simplifying our circuit nicely. This process of optimization before going forward with assembly is a key part of our design process. For our design process we followed the usual process of searching for optimization before any implementation.

The block diagram is shown below:

The final circuit is shown below:



2.1.5.2 INFRARED DIODE BLOCK



The first block of the infrared sensor is the detecting block. This consists of an **infrared sensor**, **resistor** and **capacitor.**

The infrared sensor here is connected to our 3.3V power rail which is the voltage required to create a high input to our Arduino board. The infrared sensor works on Einstein's Photoelectric effect and consists of a cathode and an anode.

$$K_{\max} = h\,f - \varphi,$$

Here the maximum kinetic energy of a released electron is the product of *h (Planck's Constant)* and *f (the frequency of the incident light ray)* minus *gamma (this is the work function which is equal to threshold frequency of the material multiplied by Planck's constant).*

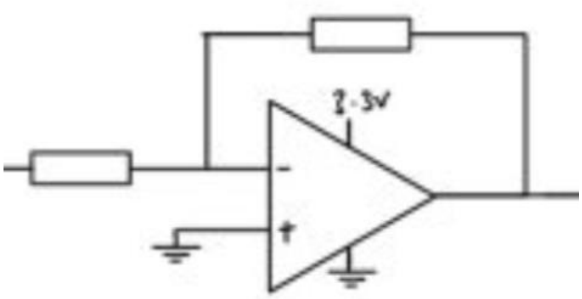
$$\varphi = h\, f_0,$$

This equation tells us that current will only flow in the device when the frequency of the incident ray is greater than the threshold frequency of the cathode in the device. The incident ray will excite electrons on the outer energy band of the cathode which are then attracted to the anode, thus creating a flow of current.

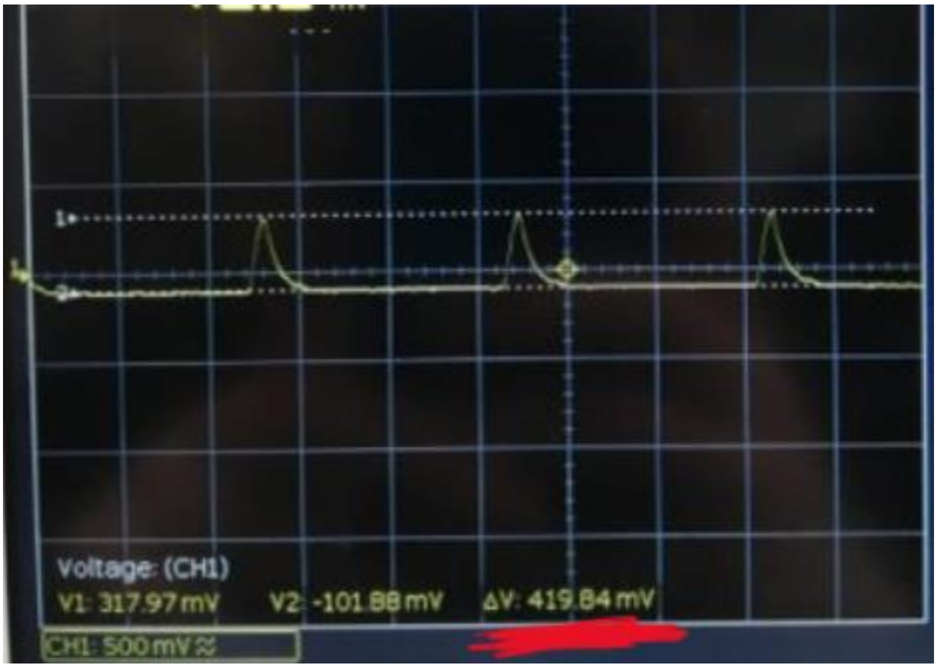
This principle is manipulated by the infrared sensor which will allow only current to flow when the frequency of the incident ray is that of an infrared ray. This, however, will allow a ray of any frequency greater than that of the lowest infrared frequency to create a current in the device, which means we will have to use our next block to distinguish/amplify the desired incident frequency.

The resistor in the first block prevents the creation of a floating voltage between the sensor and ground. The capacitor, meanwhile, draws the quiescent voltage to zero by preventing the inherent DC voltage from the diode.

2.1.5.3 INVERTING AMPLIFIER



The second block in this circuit is an inverting amplifier, which amplifies the signal from the first block. This is done by the combination of the voltage divider circuit between the negative feedback of the amplifier which allows us to manipulate the gain to a desired value. Our diode and amplifier block created a peak-peak voltage of 495 mV, this should be easily high enough to be detected by our Arduino board.



Refer to earlier sections for explanation on Schmitt trigger.

2.1.6 ACOUSTIC BLOCK

2.1.6.1 INTRODUCTION

The aim of the following block is to detect an ultrasound signal at a frequency of 40,000Hz, and outputs a ‘high’ pulse voltage if the frequency is detected, and a ‘low’ pulse voltage if no frequency is detected.

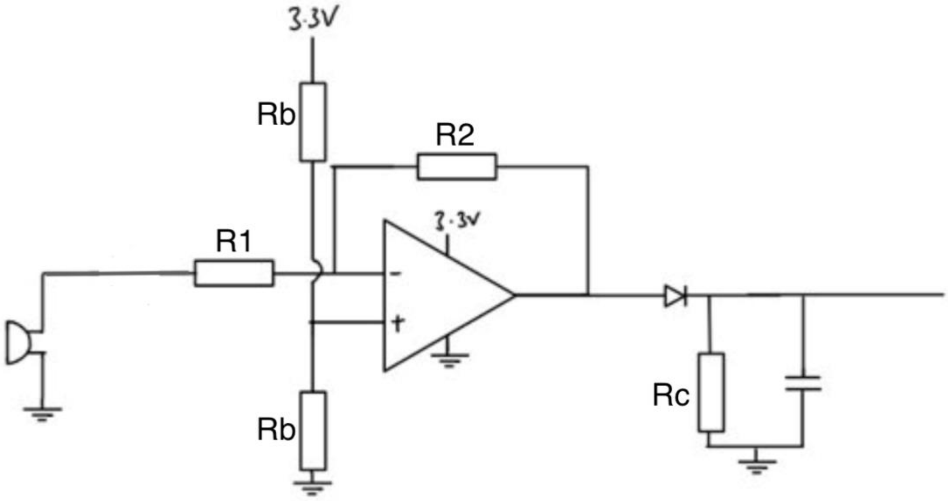
Block diagram to clarify how we would implement this

:

The sinusoidal output of the acoustic sensor was given a DC offset in the positive terminal of the op amp, and the amplified signal was rectified using a diode, and passed through an envelope detector (see radio signal circuit section).

An inverting amplifier is used here, since the phase of the voltage output is irrelevant to detecting the value of the signal, and we obtained slightly higher amplification results with an inverting amplifier than a non-inverting one for the same theoretical gain values. Also, keeping the common mode bias voltage fixed in the positive input terminal also ensures that there will be minimal disturbance in the output when the circuit is switched on (when ultrasound detection is required).

Final circuit implementation of the sensor:



Since the ultrasonic transducer behaves like a capacitor is biased relative to ground, there is no need to apply a filter (e.g. a capacitor to reduce noise) between the sensor output and the amplifier negative input terminal.

The model of ultrasound transducer we chose is the 400STR160, which has centre frequency 40kHz ± 1kHz [1]. This is a narrow range of frequencies, so no sensitivity adjustment or band pass filter were required to filter the input of the filter. The sensor has a capacitance of 2.4 µF, but this will not affect the circuit due to the sensor being grounded. Additionally, the sensor will output a 10Vrms signal for 0.2nbar = 0.02Pa [1] of pressure produced by the sound source at a distance of 30cm away. This is a very long range, outperforming the sensitivity of all of the other sensors. However, it is highly directional, as shown in a diagram later. This will present mechanical and positioning challenges, to ensure that a range of orientations of lizard can be detected.

The gain equation for this inverting amplifier setup is Av = -R2/R1. The voltage output of the acoustic sensor at a range of 10cm away from the lizard was measured to be an average of around 200mV, so amplification by a factor of 10 was decided to be suitable for this application. R1 = 130kΩ and R2 = 1.3MΩ were used to achieve the desired amplification level.

The voltage biasing resistors, Rb, were set to 100kΩ each to bias the voltage halfway through the 3.3V output range, so at 1.65V, allowing a sinusoid with an amplitude of 1.65V to be detected without the signal being capped. High resistance values also help to reduce the current required by the system (since voltage is fixed at 3.3V). Using Ohm's law, the theoretical current intake of the circuit (assuming infinite resistance of an op amp) is $I = 3.3/2\times10^{-5}$ = 16.5µA. This was confirmed to be around 20µA by the reading on the power supply of the connected circuit.

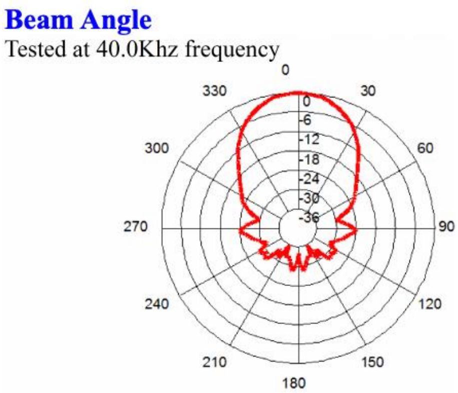
This meets our initial requirements for the circuit, so the successful design process is complete.

2.1.6.2 FURTHER TECHNICAL DETAILS:

The most significant problem we experienced when sensing with the ultrasonic transducer was that it is highly directional, with a 55° beam angle (typical for ultrasonic sensors) [1]. Within a 30° angle of the principal axis in front of the sensor, the detected voltage is at least –7db of the signal detected along the principal axis. As a percentage, this is calculated by:

-7 = 20log(v2/v1), log(v2/v1) = -7/20, v2/v1 = 10^(-7/20) = 0.447

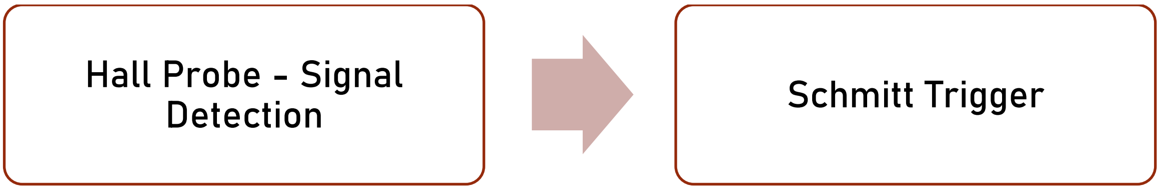
0.447 * 100 = 44.7%. This means that 44.7% of the maximum possible detected signal will be detected at a 30° angle to the principal axis. One way of reducing the issue is by using the second acoustic sensor we have and arranging them such that detection works over a larger range



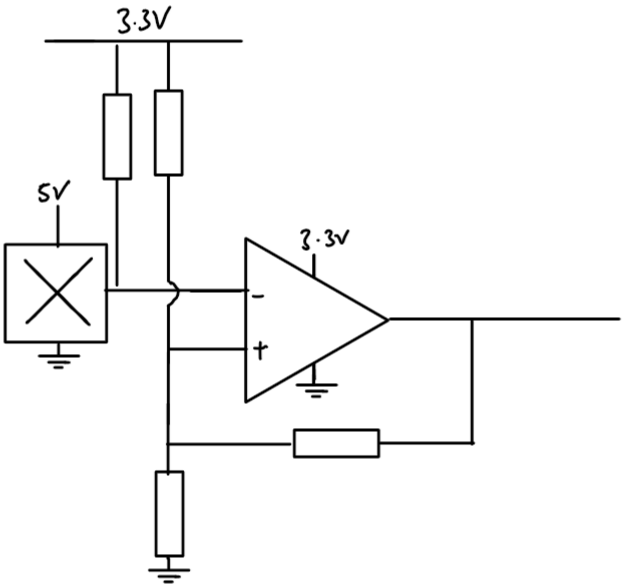
2.1.7 MAGNETIC BLOCK

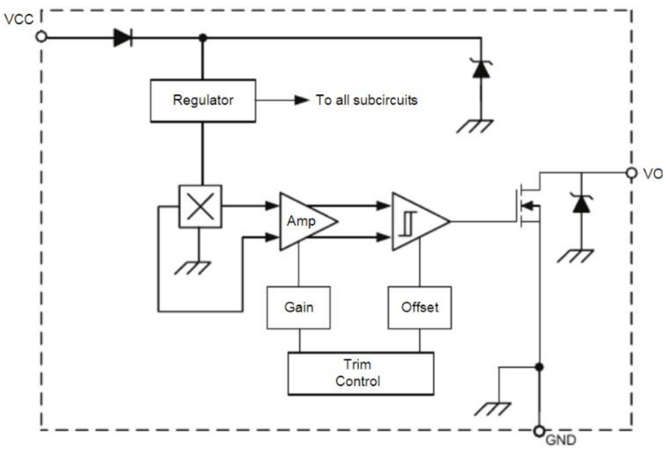
2.1.7.1 INTRODUCTION

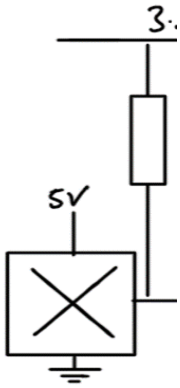
The lizards emit a magnetic field with the fields going in two different directions, up and down. The final goal of the magnetic sensor is to detect and differentiate between the two signals from 5cm apart.



The circuit currently being used is shown below:







Functional Block Diagram

SIGNAL DETECTION – HALL PROBE & SCHMITT TRIGGER

To detect a magnetic field, a unipolar hall probe will be used, with one being used to detect the "up" direction and the other going used to detect "down". This was done by simply changing their respective orientation. When no signal is being detected, the hall probe outputs no voltage from its output pin. Because there is a MOSFET present in the output, when the probe is switched off the equivalent resistance incredibly high. This means the voltage output is 3.3V when the probe is switched out due to pull up resistor.

When the field is detected, the output of the probe is provided at a constant 200mV due to the Schmitt trigger and MOSFET. This then results in the output of the initial stage to drop to 200mV. This is intended, as the Schmitt trigger will then invert this signal, resulting in the digital signal which will then be fed into the Arduino.

2.1.7.2 NEW CIRCUIT DESIGN/FUTURE PLANS

The sensor did detect the signal and worked as expected. However, the threshold Gauss value present in the hall probe is simply too high, and so the probe will only detect a signal when very close to the magnet. This does not meet our initial specification. The specification initially stated a minimum distance of 10cm, and was revised to 5cm once this was discovered.

Our solution for this was to use an analogue hall probe, also known as a linear hall probe, which has a quiescent voltage output of 2.5V. If an upward facing field is detected, the voltage output will increase, and if a downwards facing field is detected, the voltage output will decrease. The voltage change is proportional to the strength of the field. This is a better solution as the linear hall probe has a much greater resolution and no minimum Gauss value. The block diagram is shown below:

The linear hall probe has already been purchased and delivered, and the whole block will be worked on over the Easter break.

2.2 INTELLIGENCE BLOCK

This block is aimed to do the following tasks after a group discussion session:

- Provide a gateway for remote controller to the rover itself through the use of Wi-Fi Shield that is provided by the client
- Become the centre unit for all logic operations
- Move the rover using sub-block 'Actuator Block'
- Process the signal inputs accordingly and send it to the remote controller

2.2.1 INTRODUCTION

This block revolves around the Arduino microcontroller board which boasts a powerful Atmel 48MHz microprocessor and a myriad of capabilities of the Arduino library package. The Arduino board used in this project is from Adafruit Metro M0 Express. The relevant information and datasheet regarding the board can be found on the Adafruit website. The intelligence block also includes a Wi-Fi shield that enables the communication between Wi-Fi-capable devices and support connection with a wireless network with WEP and WPA encryption scheme. This block also includes Actuator Block and handles output connection from the sensors block as the input of this block. The code is well commented and can be read in the Appendix A at the end of this document.

All the source code for Arduino can be found online on GitHub:

https://github.com/NadzrinAzilan/EEEProject-Rover-2018-9

2.2.2 DESIGN PROCESS

The programming of the board involves a few stages as illustrated in Figure Error! **Reference source not found.**.1. The flowchart of the execution of the whole program can be seen in Section **Error! Reference source not found.** User Interface.

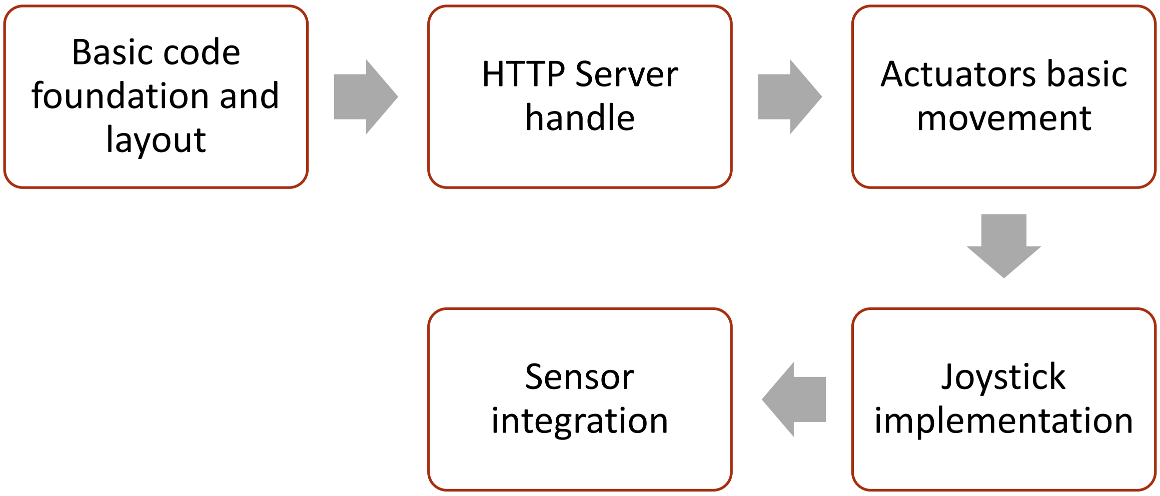


Figure Error! Reference source not found.**.1: Stages of programming of Arduino board**

2.2.2.1 BASIC CODE LAYOUT

The first part of writing the code is to write the core functionality of the program which will define the workflow of the program. This involves separation and definition of the tasks into several files or sections. At this stage, the overall layout is declared as the skeleton of the program and will be written at the next stage of the process.

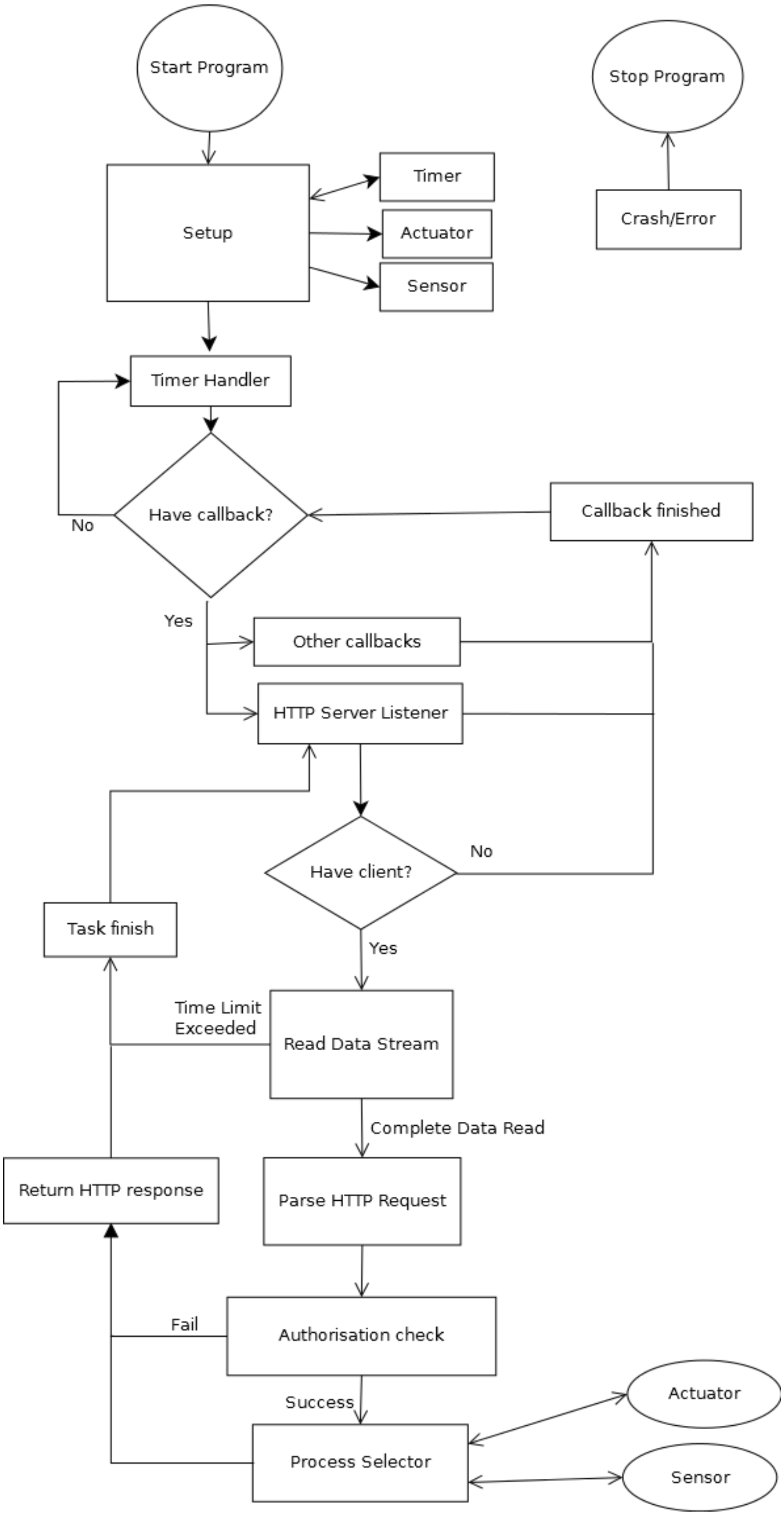


Figure Error! Reference source not found.**.2: F low chart of the main program**

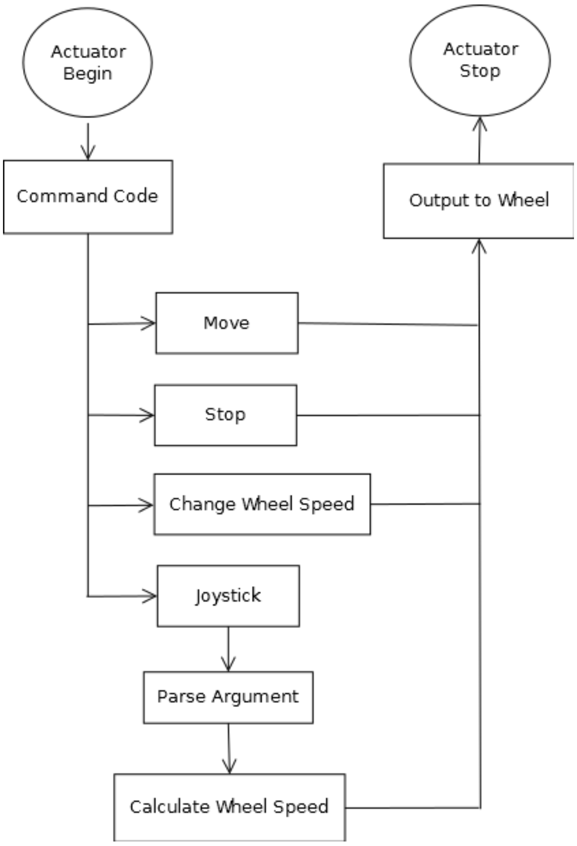


Figure Error! Reference source not found.**.3: Flowchart of the actuator control**

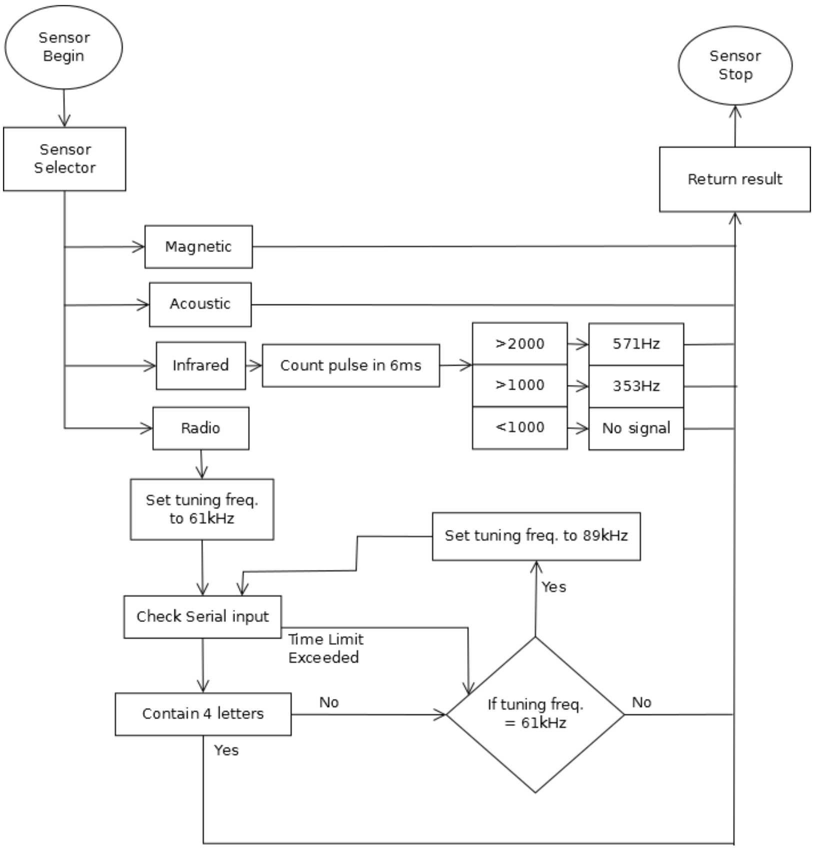


Figure Error! Reference source not found.**.4: F**

2.2.3 USER INTERFACE

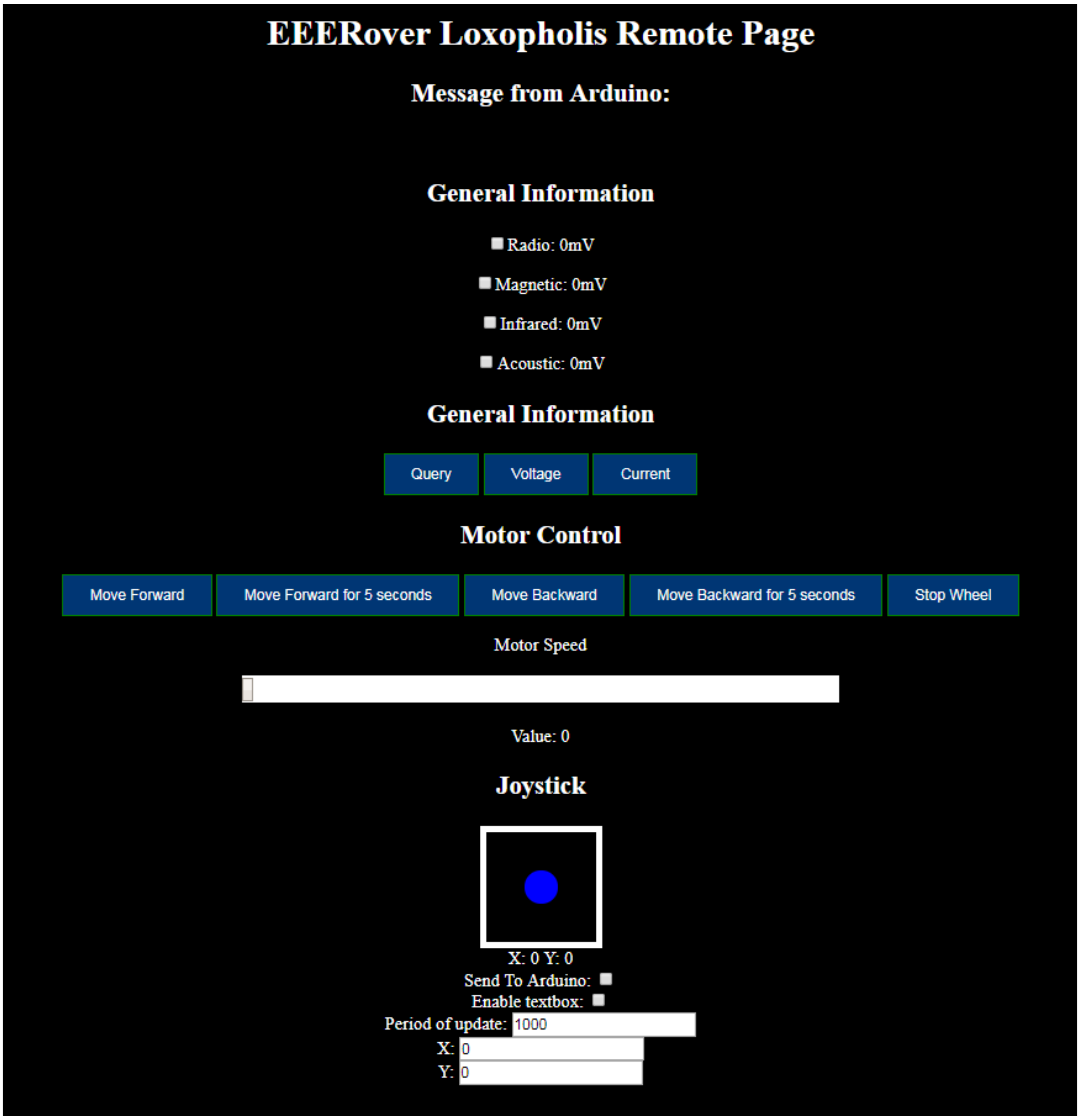


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Figure 5: Website hosted on the Arduino

The control element of the rover is the website hosted by the Arduino by sending a HTTP request on the IP address of the rover at port 80. The user will need to connect to the same netwrok as the Arduino and access the website through a web browser. The website hosted is as shown in Figure 4.5.

The website is written from scratch except for an element which is the joystick element, where it was taken from an online source (https://jsfiddle.net/aa0et7tr/5/).

The website works by sending a HTTP GET request where the URL path is the command and argument th segment = 10), the process will repeat for 4 times only.

2.2.4 ACTUATOR/MOVEMENT PROCESSING BLOCK

This block is aimed to do the following tasks:

- Controlling the output pins to H-bridge module
- Calculating the correct speed for each wheel in the event of changing the direction

2.2.4.1 INTRODUCTION

The actuator block is put under the Intelligence Block due to close relationship between these 2 blocks and the fact that the whole operation of actuator block is defined by the implementation of Intelligence Block. This block involves the connection from Arduino to the H-Bridge module, and the considerations taken in affecting the performance of the motor.

2.2.4.2 DESIGN PROCESS

The code writing of this section involves a few stages based on the iterative and incremental development in software engineering. At each stage, a stable code is written and be ready for deployment but will branch off to a new experimental stage (alpha or beta version) where there will be bugs and errors trying to be found and fixed. The fixed code will then merge with the stable code and become the next stage in an iterative process. The difference of each stage will be either a small or large increment. The flow can be illustrated in Error! **Reference source not found..**

Figure 6.

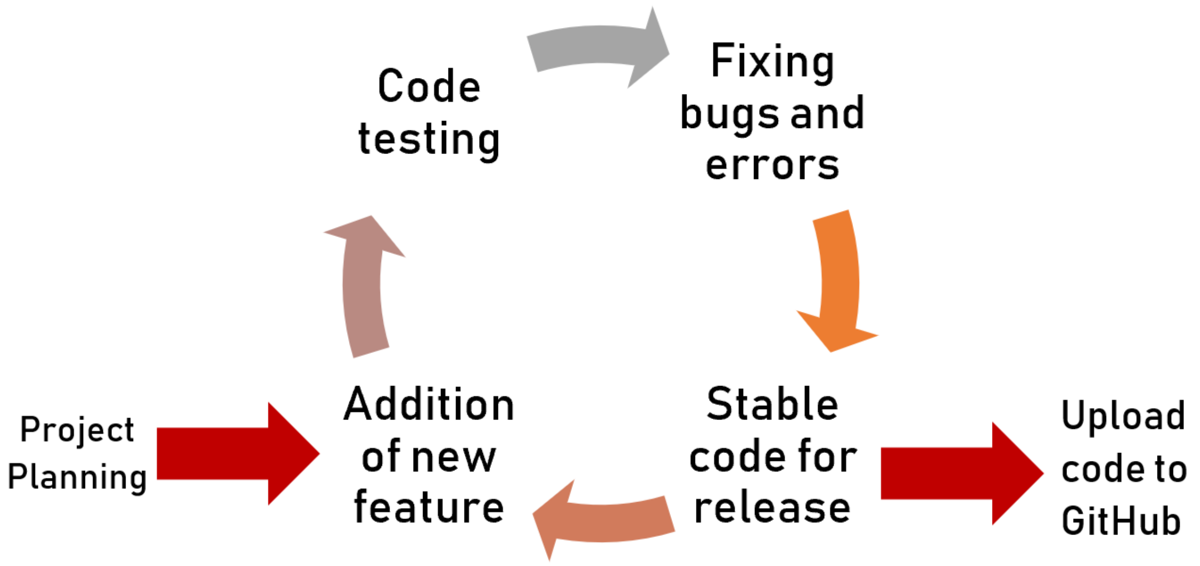

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Figure 6: Stage cycle of writing actuator block

2.2.4.3 OPERATION OF JOYSTICK

The implementation of joystick into the control interface presents a great challenge to the group. First, the system used in the joystick control interface, which is Cartesian 2-ordinates system, is different from the system used to drive the wheels, which is a 1-D bidirectional for each wheel for a total of 2 wheels. The derivation and justification on how to achieve the control system is discussed in the following.

First of all, the joystick XY coordinate (Cartesian) system is converted to 2-D polar system as the parameter is more meaningful compared to the Cartesian system.

Given that x is the horizontal axis of the joystick where a positive value refers to 0 translational speed and positive rotational speed (clockwise), and y is the vertical axis of the joystick where a positive value refers to 0 rotational speed and positive translational speed (forward),

$$r = \sqrt{x^2 + y^2}$$

$$\theta = \tan^{-1}\left(\frac{y}{x}\right)$$

Hence, the variable r is represented as the magnitude of the speed vector of the rover. The variable θ is responsible for the direction of the rover speed vector. Note that θ is the angle from the positive x-axis going counter-clockwise.

To convert to the wheel 1-D bidirectional system, the variable r can be set as the scaler for the speed of the wheel, while variable θ represents the input for the function $f(\theta)$ where the function represents the mapping of input θ to the normalised speed of the wheel. Due to the usage of angle in the system, the use of trigonometry is unavoidable and hence the function $f(\theta)$ must consist of trigonometry function. But, to simplify the calculation, the boundary conditions for the functions can be set and shown in the Table 2.

Before going to the table, some variables need to be defined first. First of all, split the speed of each wheel to 2 components, which is translational and rotational components. Below is the list of new variables:

$v_{t \cdot L}$: Translational speed of left wheel

$v_{t \cdot R}$: Translational speed of right wheel

$v_{r \cdot L}$: Rotational speed of left wheel

$v_{r \cdot R}$: Rotational speed of right wheel

Note that total speed variables are normalised. All the 4 components are the range/output of the function $f(\theta)$. Because the 4 variables are components of the 2-wheel speed, the relation between each pair of translational and rotational speed pair is as follows:

$$v_L = k(v_{t \cdot L} + v_{r \cdot L})$$

$$v_R = k(v_{t\cdot R} + v_{r\cdot R})$$

where k is the normalising factor which will be calculated later.

θ/rad	$v_{t\cdot L}$	$v_{t\cdot R}$	$v_{r\cdot L}$	$v_{r\cdot R}$	Explanation
0	1	1	0	0	Move forward, no rotational component
$\frac{\pi}{2}$	0	0	1	-1	Rotate clockwise on same spot, no translational component
$-\frac{\pi}{2}$	0	0	-1	1	Rotate anti-clockwise on same spot, no translational component
π	-1	-1	0	0	Move backward, no rotational component
$-\pi$	-1	-1	0	0	Same as $\theta = \pi$

Table Error! Reference source not found.**2: Boundary conditions of the functions** $f(\theta)$

From Table Error! Reference source not found.**2**, each of the variable can be represented as a shifted cosine function. Hence, the $f(\theta)$ that represents the 4 variables can be set as:

$$\begin{aligned} v_{t\cdot L} &= \cos(\theta) \\ v_{t\cdot R} &= \cos(\theta) \\ v_{r\cdot L} &= \cos\left(\theta - \frac{\pi}{2}\right) \\ v_{r\cdot R} &= -\cos\left(\theta - \frac{\pi}{2}\right) \end{aligned}$$

The following graphs in **Error! Reference source not found.** shows all 4 of the speed components with varying θ.

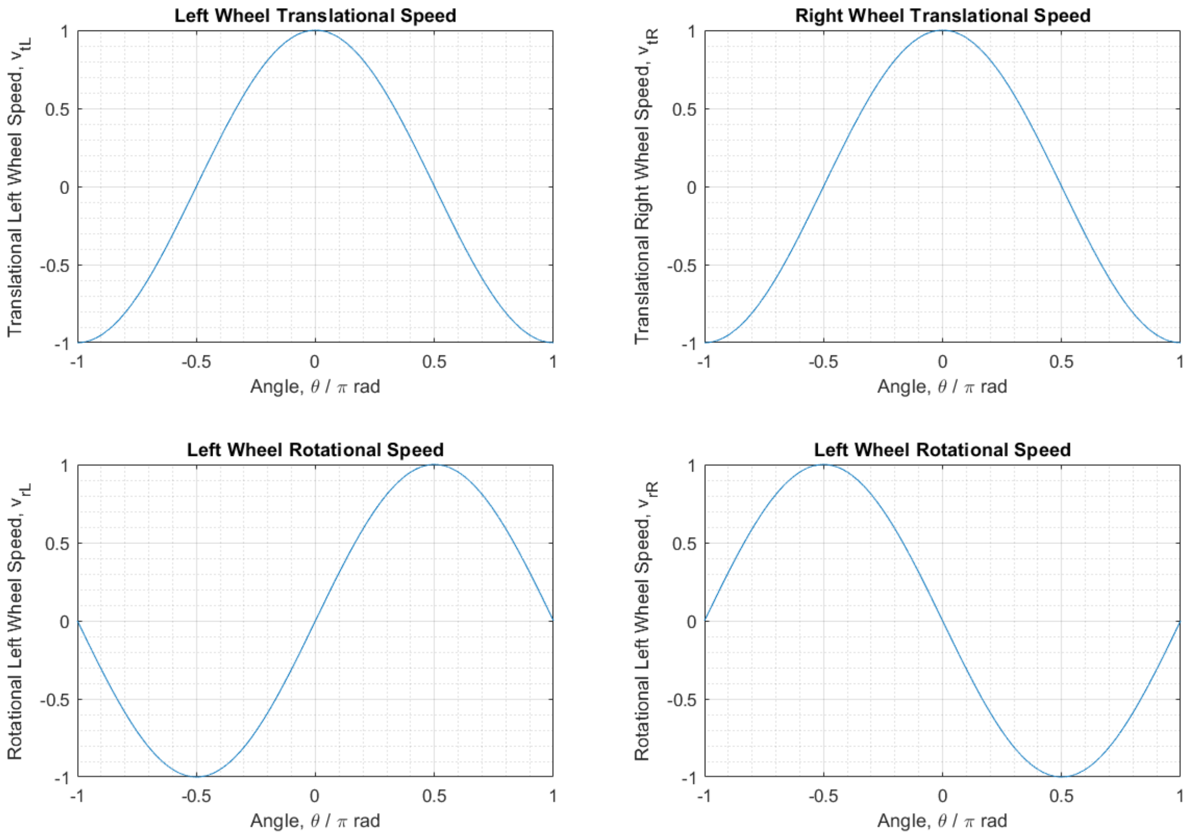

Figure Error! Reference source not found.**.7: Graphs of the 4 speed components**

Thus, the speed of each wheel is given as the sum of its components:

$$v_L = k\left(\cos(\theta) + \cos\left(\theta - \frac{\pi}{2}\right)\right)$$

$$= k\sqrt{2}\cos\left(\theta - \frac{\pi}{4}\right)$$

$$v_R = k\left(\cos(\theta) - \cos\left(\theta - \frac{\pi}{2}\right)\right)$$

$$= k\sqrt{2}\cos\left(\theta + \frac{\pi}{4}\right)$$

Hence, because the variable v_L and v_R is normalised, the variable k is set to $\frac{1}{\sqrt{2}}$. The speed of each wheel then is found to be:

$$v_L = \cos\left(\theta - \frac{\pi}{4}\right)$$

$$v_R = \cos\left(\theta + \frac{\pi}{4}\right)$$

The speed for each wheel is graphed in the following Figure Error! Reference source not found..8.

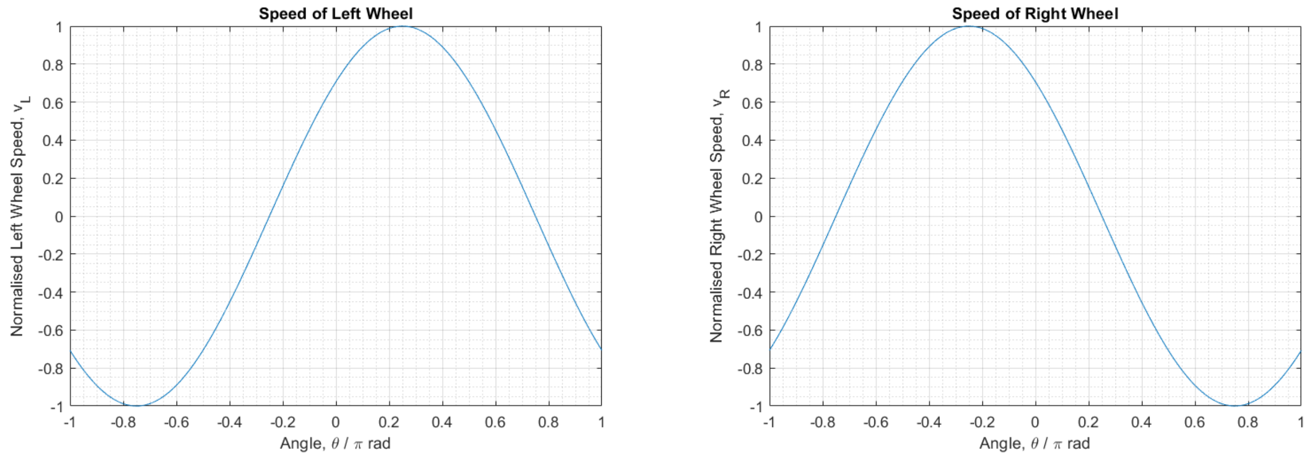

Figure Error! Reference source not found.**.8: Graph of speed of each wheel**

To further illustrate the rover movement due to the contribution of each wheel, the translational speed ($v_t = v_L + v_R$) and rotational speed ($v_r = v_L - v_R$) is shown in the following graph in Figure Error! Reference source

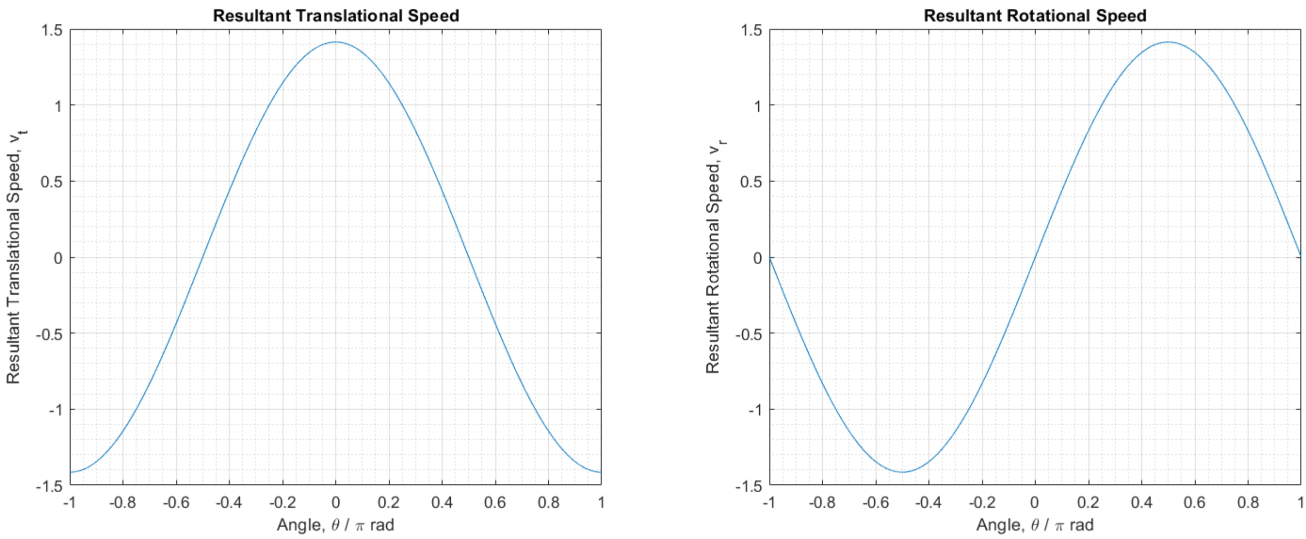

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Figure Error! Reference source not found.**.9: Graph of translational and rotational speed of the rover**

2.2.4.4 CONNECTION TO H-BRIDGE

There are 4 output pins from Arduino connected to the H-Bridge module. The module is consisted of 2 H-Bridges with each of their own decoder which converts 2 control pins to 4 pins used to drive the H-Bridge. Thus, 2 control pins will be used to drive 1 motor and there is a total of 4 control pins to drive 2 motor. The 2 control pins are characterised as:

- Direction pin, digital
- Speed pin, digital with PWM modulation (duty cycle+ represents the speed)

The connection of H-Bridge module to the motor is a part of the design of EEBug lab experiment and hence is already finished during building of the EEBug. The circuit for the EEBug PCB responsible for the connections with the batteries, motors, and H-Bridge module can be read in Appendix B(i), which is just the exact copy from the lab handbook. The table for the type of input expected at the control pins is given in Appendix B(ii) which is also a copy from the technical guide given in Spring Term.

2.2.4.5 POWER SUPPLY OF MOTOR

The DC motor draws a significant current from the battery in magnitude of 1/10 Amperes. This is significant as it can degrade the battery which is also the power source for the whole Arduino and sensor circuit. Hence, a different power supply is needed for driving the motor and there will be a need to separate the power supply of the motor with the rest of the circuit. But this requires a different control PCB from the one used from the EEBug. Hence, this idea is supported by the group but will not be implemented for now due to lack of time. One of the implementations of the idea is to use a 2 parallel-connected 9V batteries to provide a larger voltage hence less current draw to the motor so that the motor can maintain high performance while not degrading/draining the battery quickly.

2.2.5 SENSOR PROCESSING BLOCK

The aim of this block is to:

- Process the signal inputs on the pins and determines the state/message detected by the sensors
- Provides an easy calibration on the parameters involve in processing the signal
- Provides the functions to set/clear output pins to the sensor circuit in order to change the characteristic values of some circuits, e.g. resonant frequency in tuning circuit of radio

2.2.5.1 INTRODUCTION

The sensor processing block deals with the processing of the output of sensor circuits as described in the Sensor Block. The outputs of Sensor Block are connected to the analogue pins of the Arduino. The Arduino performs some logic and arithmetic operations to determine what kind of signals are detected in the Sensor Block. Hence, this block heavily depends on the implementation of the Sensor Block in terms of making sense of the output signal from the Sensor Block and partly depends on the Intelligence Block in terms of the way how the data is formatted and transmitted to remote controller.

2.2.5.2 RADIO SIGNAL

The processing of radio signal is the most complex compared to the type of signal. This is due to 2 different frequencies at which the radio signal is modulated and hence there is a need to check both of the frequency for any kind of meaningful data. An output pin is dedicated to act as a switch to change the frequency. The radio signal, of which the data is modulated in UART format, is fed to the input of hardware UART pin (pin 0, RX pin) where the microprocessor will process the UART signal independent of the main processor using built-in hardware or specifically peripheral. The data from the UART peripheral can be fetch in the program using Serial class.

The operation of the reading the signal is as follows. The class's buffer is cleared first to remove any previous data and the program will listen for any incoming data for a fixed period of time, which is set to 300ms, in which the program will block the execution until a complete set of data (4 letter UART signal) is received or the time limit had passed. If the time limit had passed, then the program will change the resonant frequency of the sensor and listen again for any incoming valid and complete signal. If there is still no signal received, then the program will conclude that no data is captured by the sensor at both interested frequencies. If there is data, then the program will immediately return the data to the remote controller.

2.2.5.3 MAGNETIC SIGNAL

Magnetic sensor circuit will output a linear voltage ranging from [0,3.3] which will be connected to the analogue input of the Arduino. The analogue input will give a reading in the range of [0,1023] due to the fact that the ADC module in Arduino has a 10-bit resolution. The magnetic sensor will detect from magnetic field in 2 orientations: south or north. Hence, the sensor will be centered at 1.65V and will decrease or increase if it detects a magnetic signal. Thus, the Arduino will use a comparison table as shown in the Table 4.3. Let V be the analogue value read by the Arduino.

Condition	Result
$V < 500$	South-pointing magnetic field detected
$500 < V < 600$	No magnetic field detected
$V > 600$	North-pointing magnetic field detected

Table 4.3: Comparison table for processing the magnetic circuit

The result is then transmitted to the remote controller/user to be displayed.

2.2.5.4 INFRARED SIGNAL

The infrared sensor circuit will output a cleaned and amplified signal detected by the photodiode within certain voltage difference between 'HIGH' state value from 'LOW' idle state value. Refer to the Section 2: Sensor Block for more detail. The output signal will be fed to one of the analogue pins and the signal will have a form of 'LOW' value for a period followed by 'HIGH' value for a certain period. The total period of 'HIGH' and 'LOW' state will be the period of the infrared signal modulation. Assuming the modulation frequency is f_m and the positive duty cycle is D^+, then the period for the 'HIGH' state is given as:

$$T^+ = \frac{D^+}{f_m}$$

The positive duty cycle for the 2 interested frequency is measured using the oscilloscope in the following Table 4.4:

Modulating frequency, f_m / Hz	Positive Duty Cycle, D^+ / $no\ unit$
353	0.90
571	0.95

Table 4.4: Measured positive duty cycle of the modulated signal

From the equation, the period for 'HIGH' state for the 2 modulating frequencies is given in the following Table 4.5:

Modulating frequency, f_m / Hz	Period of 'HIGH' state, T^+ / μs
353	2550
571	1664

Table 4.5: Calculated period of 'HGH' state in the infrared signal

From the period of 'HIGH' state, the frequency of the modulated signal can now be found using an Arduino function pulseIn(pin, measuredState, timeout). The function takes the pin number to be read, the state of which it will measure, and the timeout where it will terminate if no signal is detected to avoid blocking the program indefinitely. The timeout is set to 2 times the period of the highest modulation period ($t = \frac{2}{353} = 5667\mu s \approx 6000\mu s$) and the measured state is set to 'HIGH'. The function will return the period (in μs) of 'HIGH' state. Since there will be some error in the measurement, the following Table 4.6 is used to determine the frequency of the modulating signal.

Output of `pulseIn`, T / μs	Modulating frequency, f_m / Hz	Data Value
2000 < T < 6000	353	1
1000 < T < 2000	571	2
0 < T < 1000	Invalid frequency	0

Table 4.6: Logic table for determining the modulating frequency f_m and the output data representation

The data value will be the one sent to the remote controller and will be mapped on the controller side for the correct value.

2.2.5.5 ACOUSTIC SIGNAL

Acoustic sensor circuit will output a linear voltage ranges from 0V to 3.3V depending on the strength of the signal detected by the sensors. The voltage is connected to the analogue output of the Arduino where the program will determine whether there is a signal detected by the sensor. The logic to process the input voltage is by comparing the input against a fixed value. The Arduino will automatically convert the input voltage by mapping the range from [0,3.3] to [0,1023] since the ADC module has 10-bit resolution. From the value, the following Table 4.7 describe the output to the remote controller. Let the digitalized voltage detected to be denoted as V.

Condition	Results
$V < 30$	There is no signal detected
$V \geq 30$	There is a signal detected

Table 4.7: The comparison logic in processing the acoustic sensor output

The value of 30 is found experimentally by taking into account the noise produced by the sensor. The Boolean value is then sent to the remote controller/user to be displayed.

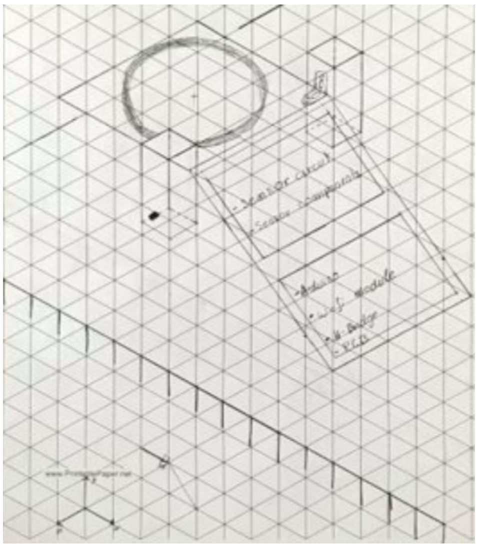
2.3 MECHANICS

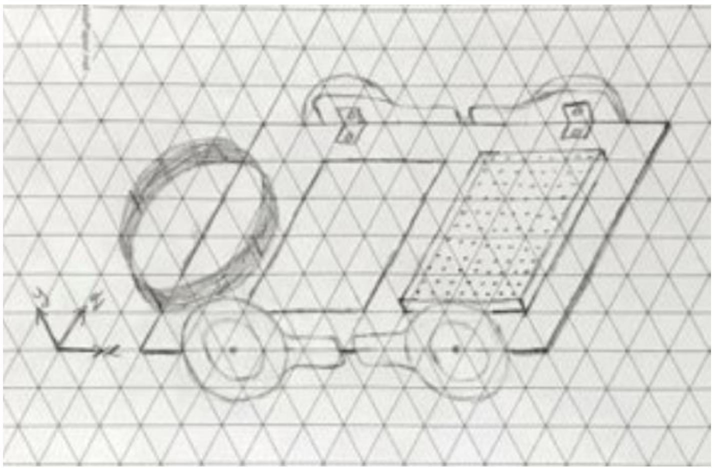
2.3.1 CHASSIS DESIGN

The basic chassis we chose to use is the one from the EERover. The final aim is to 3D print this is biodegradable filament if we have the budget left at the end. This basic rectangular structure is adequate to successfully implement all of the core functions of the rover. Since the only real benefit of changing the chassis is to make it more camouflaged in a forest environment, and possibly make the rover slightly lighter and more compact, this was given a low priority in the design process. The design of the chassis will be further optimized once the other elements of the design process are complete.

The positioning of the chassis is important to ensure that all sensors can fit on it. The inductor coil is by far the largest sensor, so it has been shown in the diagrams below. The first design assumes that no structural changes happen to the EERover, and space clearly exists in which to place the other sensors. The lack of forward-pointing space does mean that efficiency of detection will be low with both designs, since the rover would need to be rotated so that the principal axis of detection for each sensor is pointed directly at the signal source.

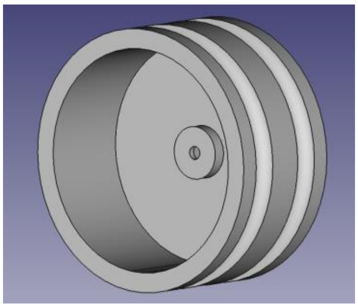
The advantage of the second design is that there is a platform oriented at a 45° angle, which allows the coil to function optimally (see radio circuit section).

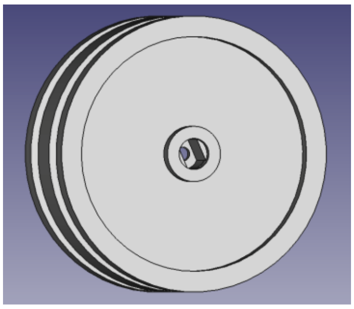




2.3.2 WHEEL DESIGN

The original 18mm wheel radius was increased to 22mm to help overcome obstacles and increase the speed of the rover by 22.2% (22/18 = 1.222 since the increase is linear because it depends on the circumference, which is given by 2*π*r). The increased width of the wheel allowed a overlapping arrangement of elastic bands over the wheel, increasing friction between the surface, and allowing the rover to move up steeper slopes. Uneven surfaces are also easier to move on, since the elastic bands are compressible, effectively evening out the surface.





2.3.2.1 CIRCUIT INTEGRATION

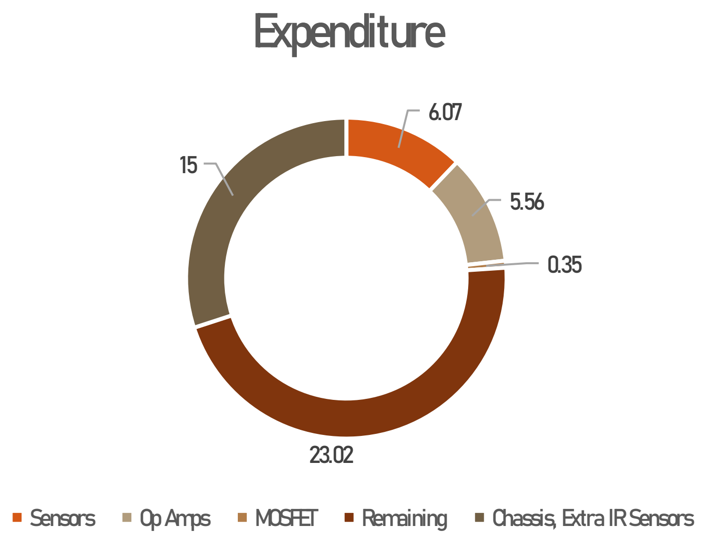
In the final chassis, we want to use a PCB in order to reduce the space taken up by the breadboards in the current rover. We plan to do this using 'PCB etching via UV light'. This method is perhaps the easiest and most cost-effective way of printing out a PCB. A copper clad laminate (such as FR4 or FR2) has the PCB design printed onto a piece of tracing paper that is then stuck onto it. This is treated in an acid bath whilst being exposed to UV light. After this, any holes in the circuit will be drilled out resulting in a complete circuit board. The equipment required for this is easily accessible to us (for example at Hackspace). This solution would be optimal, as it would allow us to have all the benefits of a regular PCB whilst still being reasonably priced. It would be considerably smaller than our current breadboard solution. Designing the PCB will be tedious and would require us to have finalised all our sensor circuitry as it would most likely all have to be printed at once. Once a PCB has been designed it is also relatively quick to print out (roughly taking half an hour), and so any adjustments can be made with relative ease. Our group has previous experience with this process and it will not be very hard to do.

2.4 BUDGETING AND COSTING

Table 5.1 and graph 5.2 below shows the list of all components ordered. The components are mostly sensors and operational amplifier.

Component model	Quantity	Price (£)
Hall Probe(Latch)- A1104EUA-T	2	1.46
Ultrasound Receiver -400SR160	2	2.06
TLC2274ACN - Operational Amplifier, Quad, 4 Amplifier,2.18 MHz	2	3.50
MCP6022-E/P - Operational Amplifier, Dual, 2 Amplifier, 10 MHz	2	2.06
MOSFET PNP – 2N7000	5	0.35
IR Photodiode – SFH213-FA	1	0.45
Hall Probe – Analogue	2	2.10
TOTAL:		£11.98

Table 5.1: List of all components ordered with their price



Graph 5.2: Expenditure with forecast prediction

The op-amps used in the project are the TLC2274ACN due to its quad-channel feature in 1 chip whereas MCP6022-E/P is used due to its high gain bandwidth product which is 10MHz. The high GBP is used in the radio sensor circuit where a high frequency AC signal is processed hence require a high GBP. MOSFET 2N7000 is an enhancement mode N-channel MOSFET where it was selected due to its availability and its general purpose where it can be used in normal operating condition. In this project, a MOSFET is used to change the resonant frequency of the radio tuning circuit in order to select between 2 frequency that are needed to be detected. Other MOSFETs are planned to be used to switch the sensor circuits and motor to either on or off in order to save batteries' energy.

The budget of £50 is still far from the current expenditure. The remaining budget will be used to reduce the rover size by using a stripboard and to create a new proper chassis for the rover. The new chassis will be built with focus on maximising the mobility of the rover.

2.5 PROJECT MANAGEMENT

As a functioning team, each group members are given roles which indicates the area of responsibility that they had to do for the completion of the project. The roles are selected at the first group meeting in Autumn Term 2018. The allocation is based on the preference of each of the group member and the final roles are agreed by the group. The roles are shown in Table Error! **Reference source not found.**.

Members	Role	Area of responsibility
Sushanth Kolluru	Team Leader	Ensuring that progress is consistent with Gannt Chart
Muhammad Nadzrin Nor Azilan	The Principle Software Engineer	All software components of the rover
Matteo Spinola	Head of Radio Circuit	Ensuring that the radio block is functioning
Edward Schamp	Head of Magnetic Circuits	Ensuring that the magnetic block is functioning
Eoin Quigley	Head of Infrared Circuit	Ensuring that the infrared block is functioning
Seth Omoke-Enyi	Head of Magnetic Circuit & Treasurer	Ensuring that the magnetic block is functioning

Table Error! Reference source not found.**.1**: Roles and responsibility of each members

The group also realizes the importance of doing a risk analysis on the project so that most of the failure can prevented or at least detected at an early stage. The risk analysis that is done for this project is the Failure Mode and Effect Analysis (FMEA). The FMEA table is shown in the Appendix I.

A further take on making our team works more effective and coherent, we made a Gantt Chart to indicate our past achievement/milestones and also out future planning. The chart is really important in making sure that the group is on track and did not go over the deadline. A copy of the project's Gantt Chart can be found in the Appendix II of this report.

To further simplify the group's internal communication, a shared folder is setup on OneDrive™ where all of the project-related files are stored. This ensures that every group member is able to access the files at all time. The online shared folder also enables the group members to work on a same file at the same time. This makes it easier to merge works together and enables quick access to the current data from other members in real-time. The usage of online storage OneDrive™ also ensures that no important files will be missing and easier to be searched when needed. This is because it is far harder to accidentally delete the files stored online and even then the files can be easily restored from deletion. Moreover, working online prevents loss of data when the physical storage devices were to be lost or stolen. Hence, the group decides unanimously to use a shared online storage to store all of the project-related materials.

Moreover, the group also setup a Whatsapp™ group which includes every group member. The Whatsapp™ messaging platform is used because of its simplicity and the availability on every group member's phone. This enables the group to have an online discussion at anytime and anywhere in the world as long as there is an Internet connection. So, information is able to be broadcasted to group members in a short time and small discussion and minor decision-making process can took place in the chat before the weekly group meeting. This simplify the amount of time it need for the weekly group meeting as only major decision are discussed whereas minor decision and problems can be resolved through the use of group chat.

2.6 PERFORMACE EVALUATION

All of the circuits that were made work really well in isolation. Although some of the circuits uses a same op-amp chip, they are not in contact with each other directly. The approach of making each circuits into sub-unit/blocks makes the project handling much easier. This is because each block is only responsible for a task which enables a work to be focused. This also speeds up works as each group members did one block at one time making the tasks parallelized. Hence, the group is able to take advantage of this concurrent tasks to speed up the work.

Fortunately, the integration of the blocks works without any problem. The circuits work as expected without interfering with each other. This is all thanks to the careful and detailed planning done prior to the circuit-building, in which everything is taken in to consideration. The FMEA also helps a lot in detecting many errors and failed design concepts.

One of the errors that the group has is the type of component for the magnetic sensor. Initially, the group decided to buy a Hall Probe sensor but the operating behaviour of the probe is found to be digital instead of linear. This limits the range of magnetic detection and hence a new type of magnetic sensor is needed.

The radio coil used to detect radio signal works without any problem. The coil is made to have up to hundreds of micro Henry and the resonance effect of the tuning circuit is able to produce radio signals up to 1V for very short distance. This causes the range of detection to be far up to tens of cm.

The acoustic and infrared sensor circuits are designed to clean the signal to square wave by using Schmitt trigger. The range of acoustic and infrared sensors are quite far but they are highly directional.

2.7 CONCLUSION

The top priority when designing the rover was to keep within the constraints specified in the brief. Our current working design does not require more than the allocated budget, and also does not exceed the specified weight limit, so this objective has been achieved. The next priority was defined as ensuring that all the core functions work reliably and efficiently. All of these functions can now be performed by the rover, so this objective has also been achieved. Specifically, the rover now has full 360° maneuverability, and it can detect all signals that are sent towards it. This can all be done remotely by the local web page interface that was created, using the Wi-Fi shield.

Now that all core functions work well, the optimisation of components and signal detection circuits is the next element of the design by priority. A level of optimisation has been achieved where all of the signal sensor circuits have a suitable gain to allow them to sense the signal from at least 10cm away. The only exception to this is the magnetic sensor, which has a current range of only 2cm, only 20% of the 10cm range belonging to the radio signal detection circuit's realistic range after the directionality of the inductor is considered. Additionally, the chassis design could be optimised further, and the speed of the rover could be increased by utilising all power provided by the motors.

In the future, according to the priorities that we defined for this project, we will complete the optimisations of all components of the rover, and then move on to focusing on qualitative factors specific to the application. The final product will ideally have several qualitative features integrated in the design such as full waterproofing, a camouflaged colour scheme, and be constructed from biodegradable materials where possible. We are satisfied with our current progress on the rover, since it is on track with the Gantt chart that we updated on the 15th January after returning from the winter break. We have a clear plan for the stages which need our attention next, and we are confident that this project will reflect our best possible work because of this.

2.8 APPENDIX

FMEA

System	EERover		
Subsystem	Sensor		
Design Lead	Matteo Spinola		
Core Team	Loxopholis		

Potential
Failure Mode and Effects Analysis
(Design FMEA)

Key Date 2/15/2019

FMEA Number	
Prepared By	Nadzrin Azilan
FMEA Date	
Revision Date	3/22/2019
Page	2 of 5

Item / Function	Potential Failure Mode(s)	Potential Effect(s) of Failure	Severity	Potential Cause(s)/ Mechanism(s) of Failure	Probability	Current Design Controls	Detection	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	New Sev	New Occ	New Det	New RPN
All sensing components	Sensing component cannot detect asignal	No signal detected even when a signal is detected	5	Components requires a certain orientation/angle in order to detect a signal	10	No detection mechanism	10	**500**	Make a motor to rotate the sensing components	Matteo, 05/05/2019					
All sensing components	Interference from stronger external signal	Error signal picked up	3	Nearby lizard might interfere, noise level is too high	3	Sensor output appear gibberish	1	**9**	Amplify and filter signal	Edward, 14/03/2019	Schmitt Trigger with narrow thershold value, capacitance of envelope detector increased	1	0	1	**0**

System	EERover	**Potential Failure Mode and Effects Analysis (Design FMEA)**	FMEA Number
Subsystem	Power		Prepared By Nadzrin Azilan
Design Lead	Edward Schamp		FMEA Date
Core Team	Loxopholis	Key Date 2/15/2019	Revision Date 3/22/2019
			Page 1 of 5

											Action Results				
Item / Function	Potential Failure Mode(s)	Potential Effect(s) of Failure	Severity	Potential Cause(s)/ Mechanism(s) of Failure	Probability	Current Design Controls	Detection	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Actions Taken	New Sev	New Occ	New Det	New RPN
Battery	Drained battery provides low output voltage (high output impedance)	Circuit components and Arduino board will not be turned on properly	5	Continous operation of motor	5	Rover's LED not lighting up, sensor processing circuit will output nonsense	4	**100**	Change batteries periodically, measure battery voltage and current, and use a separate battery for powering up motors	Edward, 05/05/2019					
Motor	Large reverse current from motor coil	Connected components will stopped working after a current surge	7	Sudden change in polarity of motor's coil	7	No detection mechanism	10	**490**	Add a flyback diode in parallel to motor connection	Eoin, 12/03/2019	Diode added to the motor	0	0	0	**0**
Fuse	Blown fuse require manual replacement	Rover power supply cutoff until replacement is made	5	Short-circuit in design	1	Rover will not power up, and fuse appears to be blown	1	**5**	Use a current-limiting circuit using BJT	Seth, 03/05/2019					

System	EERover	**Potential Failure Mode and Effects Analysis (Design FMEA)**	FMEA Number
Subsystem	Intelligence		Prepared By Nadzrin Azilan
Design Lead	Nadzrin Azilan		FMEA Date
Core Team	Loxopholis	Key Date 2/15/2019	Revision Date 3/22/2019
			Page 3 of 5

											Action Results				
Item / Function	Potential Failure Mode(s)	Potential Effect(s) of Failure	Severity	Potential Cause(s)/ Mechanism(s) of Failure	Probability	Current Design Controls	Detection	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Actions Taken	New Sev	New Occ	New Det	New RPN
Processor	Single-threaded process	Tasks are out of sync with time	3	Unable to run tasks in interval effectively	7	A significant 'time-lag' between tasks	2	**42**	Create a timer library to handle all functions that require a timer with callback capability	Nadzrin, 17/02/2019	Timer library created	2	1	0	**0**
HTTP File	Arduino program capability limited	Program will run out of memory, client might trigger a timeout	2	HTTP File is too big	5	Program might not be working as intended due to lack of memory	3	**30**	Use the internal flash memory to store all big files, and read them on demand	Nadzrin, 15/05/2019					

System	EERover	**Potential Failure Mode and Effects Analysis (Design FMEA)**	FMEA Number
Subsystem	Communication		Prepared By Nadzrin Azilan
Design Lead	Nadzrin Azilan		FMEA Date
Core Team	Loxopholis	Key Date 2/15/2019	Revision Date 3/22/2019
			Page 4 of 5

											Action Results				
Item / Function	Potential Failure Mode(s)	Potential Effect(s) of Failure	Severity	Potential Cause(s)/ Mechanism(s) of Failure	Probability	Current Design Controls	Detection	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Actions Taken	New Sev	New Occ	New Det	New RPN
WiFi Shield	Client buffer full	Disconnected with the EEERover	5	Processor unable to handle all requests, or too many request received	3	Client app timeout after server has no response	1	**15**	Limit HTTP request in client app, and clear client buffer after limit reached	Nadzrin, 23/02/2019	Limit set in the Arduino code	0	0	1	**0**
Connection Strength	Connection to existing WiFi is too weak	Communication with rover is not possible	5	Distance is too far, physical blocking between rover and router	2	Client app timeout after server has no response	1	**10**	Connect to a network with large coverage area	Nadzrin, 21/02/2019	Connect to EERover WiFi	0	0	1	**0**
Security	Unauthorised connection made to the rover	Rover could be hijacked, operation interrupted	10	HTTP connection is not encrypted	10	Rover will appear to move by its own	8	**800**	Implement an encryption or authentication scheme, connect to a private WiFi with password	Nadzrin, 21/03/2019	All command require a password, wrong password cause request to be discarded	10	0	8	**0**

System: EERover
Subsystem: Actuators
Design Lead: Sushanth Kolluru
Core Team: Loxopholis

Potential
Failure Mode and Effects Analysis
(Design FMEA)

Key Date: 2/15/2019

FMEA Number:
Prepared By: Nadzrin Azilan
FMEA Date:
Revision Date: 3/22/2019
Page: 5 of 5

Item / Function	Potential Failure Mode(s)	Potential Effect(s) of Failure	Severity	Potential Cause(s)/ Mechanism(s) of Failure	Probability	Current Design Controls	Detection	RPN	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	New Sev	New Occ	New Det	New RPN
Wheel Motor	Unable to move in a steep slope	Rover will not be able to access certain places, continous high current draw might occur causing battery degradation	6	Motor not enough torque to counter the grav. force	6	Rover will be observed to not move at steep slope	1	**36**	Use 2 parallel-connected 9V battery to provide more power with less current per battery	Sushanth, 03/05/2019					

<u>Sensors Used(n.b. these were not necessarily purchased from their respective website, but are the same model):</u>

https://uk.farnell.com/allegro-microsystems/a1104eua-t/ic-hall-effect-switch-sip-3/dp/1521705?gclid=CjwKCAjwstfkBRBoEiwADTmnELXB2RUo4WpFxvX_SOMPTmSoI8rfCTKLL3WdyXmaIuPwjwksJYEmLxoCMpgQAvD_BwE&mckv=sHTKukR5Y_dc|pcrid|99269630048|kword|a1104eua-t|match|p|plid||slid||product||pgrid|5271656048|ptaid|kwd-10786282317|&CMP=KNC-GUK-GEN-SKU-MDC

https://www.mouser.co.uk/ProductDetail/Microchip-Technology/MCP6022-E-P?qs=R9WqqQqCiv4H%252BZAZtbPwyQ==

https://www.onsemi.com/pub/Collateral/2N7000-D.PDF

http://www.farnell.com/datasheets/1672048.pdf

https://uk.farnell.com/prowave/400sr160/receiver-ultrasonic-40khz-16mm/dp/1007333

Gantt Chart

GANTT CHART

TASK NAME	START DATE	END DATE	DURATION (WORK DAYS)	PERCENT COMPLETE
Project Planning Phase				
Project Briefing	16/11	16/11	1	100%
Group Roles Allocation	16/11	23/11	8	100%
PDS Writing	23/11	29/11	7	100%
Rover Design and Preparation				
Design and Modification Planning	29/11	05/12	7	100%
Client Meeting	04/12	08/12	5	100%
Product Reseacrh	08/12	06/01	30	100%
Building and Testing				
Designing High-Level Circuits	07/01	06/02	31	100%
Choosing the Components	14/01	04/02	22	100%
Mechanical Designing	04/02	11/02	8	100%
Testing and Calibrating the Sensors	11/02	18/02	8	60%
Programming Arduino & Building the Circuit	14/02	20/02	7	100%
Final Presentation	18/02	22/02	5	0%
Documentation and Competition				
Final Testing/Changes	22/02	11/03	18	0%
Project Report	11/03	15/03	5	0%
Spring Break	16/03	28/04	44	0%
Final Changes to Rover	29/04	20/05	22	0%
Demo & Competition	20/05	24/05	5	0%