E344 Assignment 1

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Report submitted in partial fulfilment of the requirements of the module Design (E) 344 for the degree Baccalaureus in Engineering in the Department of Electrical and Electronic Engineering at Stellenbosch University.

August 14, 2022

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Nomenclature

Variables and functions

Acronyms and abbreviations

PWM Pulse Width modulation DAC Digital analogue converter Op amp operational amplifier

A	ampere
s	seconds ms
milliseconds V	Voltage

Chapter 1

Literature survey

For the first assignment we had to design a current sensing circuit.A current sensing circuit is a circuit that can measure the current as the current is flowing through the circuit.We also had to use a circuit that can cancel all the noise,which is caused by an AC input.We had to amplify a certain signal by designing a circuit which consist of a operational amplifier,low current sensing circuit and a filter,which will be able to filter out all the noise of the signal.

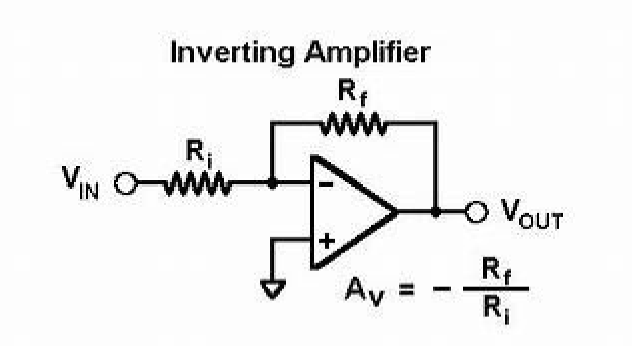
1.1. Operational amplifiers

Operational amplifiers: limitations and considerations

Operational amplifier configurations

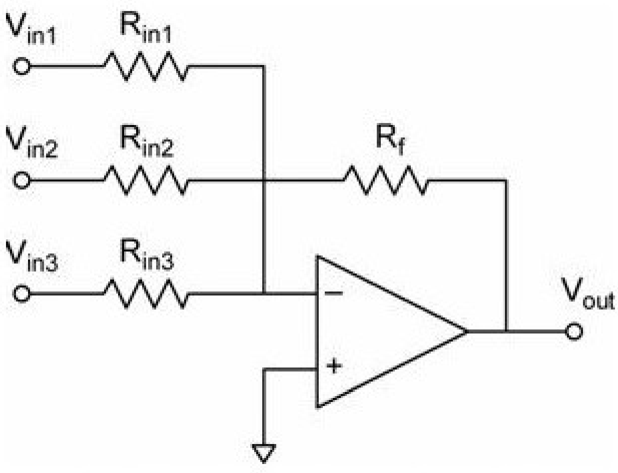
There are two main operational amplifiers that can be used to amplify signals.These two amplifiers are called: inverting amplifier and non-inverting amplifier.

Inverting amplifiers are used to amplify a signal where the output signal is fed back to the inverting input through a resistor R2.The input signal flow through R1 to the the inverting input.The positive pin is connected to ground.The gain of the circuit will be negative,because of the input being applied to the negative pin.This means that the output signal and the



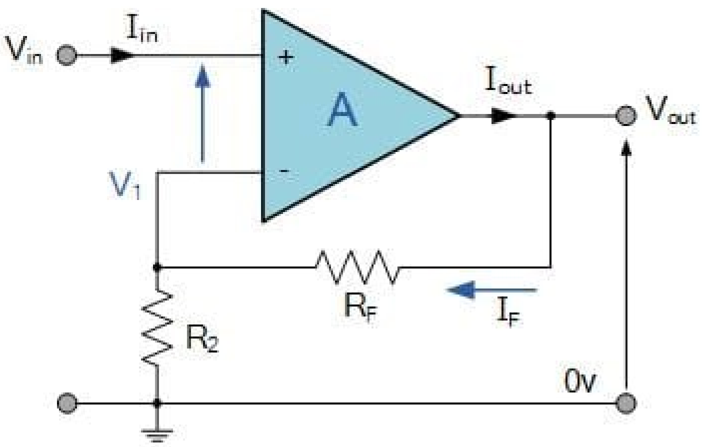
input signal will be out of phase.

An inverting summing amplifier will be an amplifier that has two resistor that will be added parallel to one another.These two resistors will then be connected to the inverting pin.

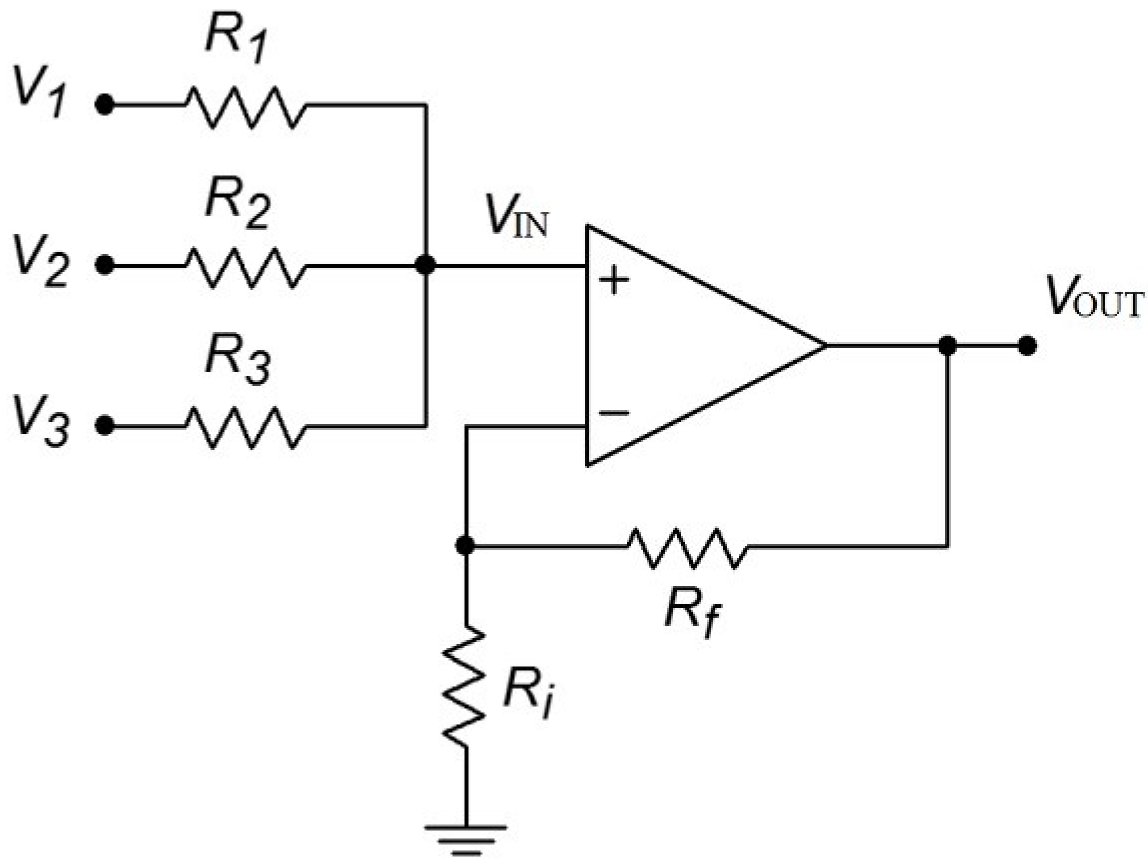


The Summing Amplifier Circuit Diagram

Non Inverting amplifier is very similar to the Inverting amplifier.The only main difference is that the voltage input will be connected to the non-inverting pin.The gain will be positive and the output signal and the input signal will be phase and therefore we will be using a non-inverting amplifier.



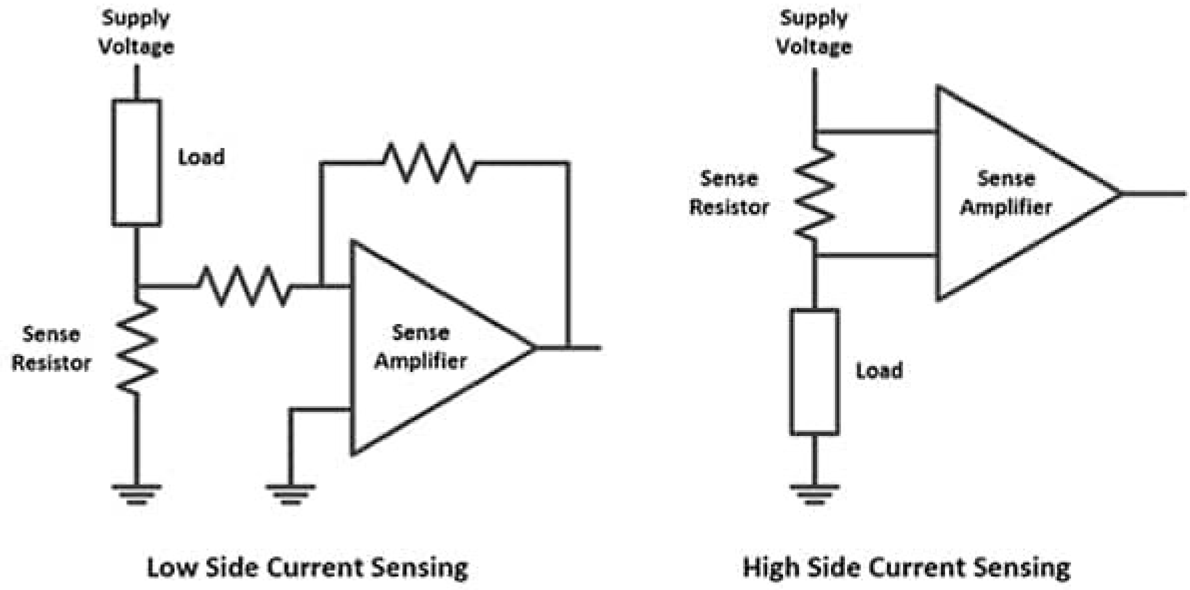
A non-inverting summing amplifier will be an amplifier that has two resistor that will be added parallel to one another.These two resistors will then be connected to the inverting pin.



An amplifier consist of a inverting input(-) ,a non inverting input,a voltage supply(+) and a negative voltage supply and a output.These components are then used to amplify a signal. The amplifier we will be using is the non-inverting amplifier.We don't want the input signal and the output signal to be out of phase. The gain we will be calculating will be Av=(1+Rf/R2). We will be using an LTC6079 op amp.This op amp doesn't have any range of common mode voltage.This op amp works with PMOS and NMOS pairs.A transition will happen when the common mode voltage is 0.9-1.3V.

1.2. Current sensing

A current sensing circuit is a circuit which is used to measure current.There are two different current sensing circuit called invasive and non invasive current sensing.A non invasive current senor can be placed around a supply line where it will be able to tell you how much current is present.Ac current sensor use a non invasive current sensor to measure alternative current.Dc current sensor would only be able to measure DC current.You will also find that there are two current sensing called high side current sensing and low side current sensing.Low side current sensing is when Rshunt is connected to ground and to the power supply. High side current sensing is when Rshunt is connected to the power supply and the load.



The maximum current flowing through the motor will be 1A.The voltage over the 10m ohm will be 10mV.The power over this particular resistor will then be p=IV,which is 10mW.

1.3. Ultrasonic sensors

Ultrasonic sensor are devices that measures distance by sending out ultrasonic signals and converts the reflected signals to electrical signals.Ultrasonic sensors has two main components namely:the transmitter and the receiver.The reason why the ultrasonic sensors send ultrasonic waves is mainly because ultrasonic waves travels faster than audible sound.

To calculate the distance the ultrasonic sensor takes the time the signal travels form the transmitter until the reflected signal is received by the receiver.The formula that is used is:

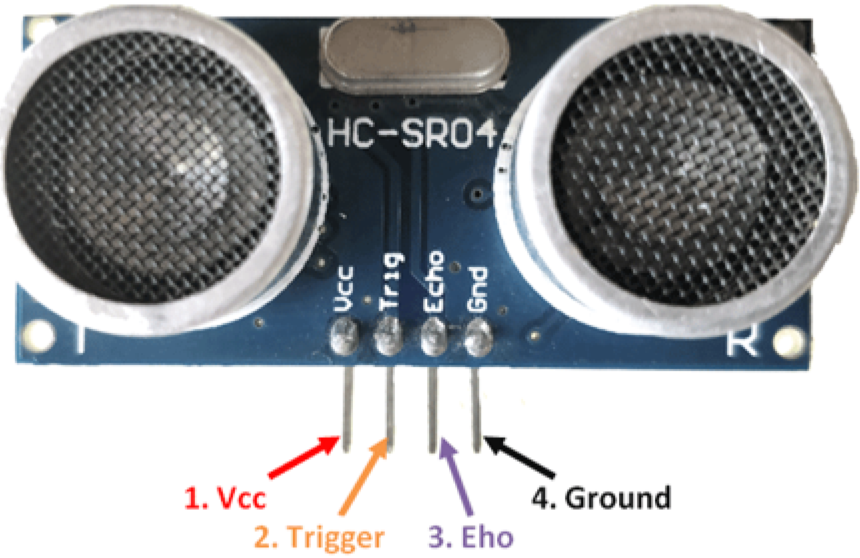
D=0.5T+C

D=Distance.

T=Time

C=Speed of sound(343 meters per second) The power specification of the ultrasonic sensor is the following:

Operating Voltage	Min range	Max range	Operating current	Raging accuracy
5V DC	3cm	4m	15mA	3mm



1.The Vcc pin will be supplied with 5V.

2.The trigger pin is used to trigger ultrasonic sound pulses.When this pin is set to HIGH for 10us, the system initiates an ultrasonic burst.

3.The echo pin goes High when ultrasonic burst is transmitted and remain HIGH until it receives an echo.It then goes low.The distance can then be calculated by looking at the time for which the the echo pin stays HIGH.

4.Is just connected to ground.

1.4. Converting PWM signals to analogue

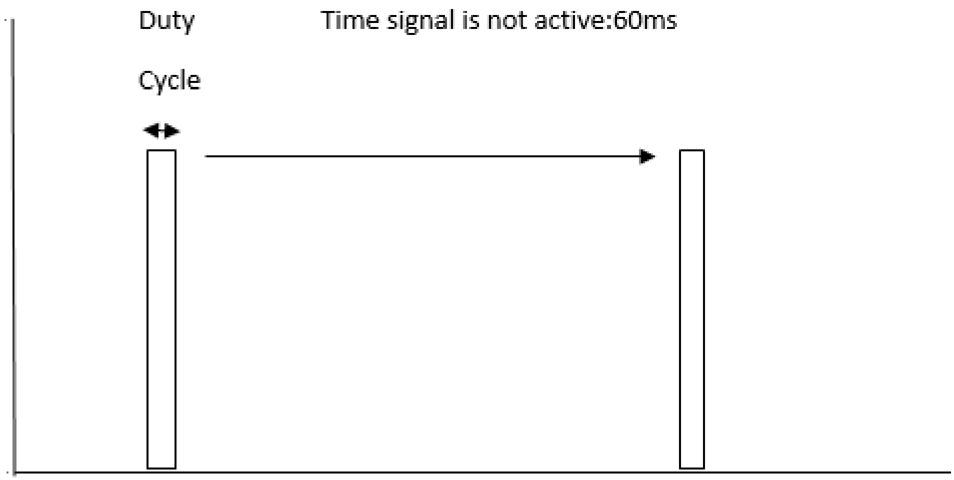


Figure 1: Duty cycle

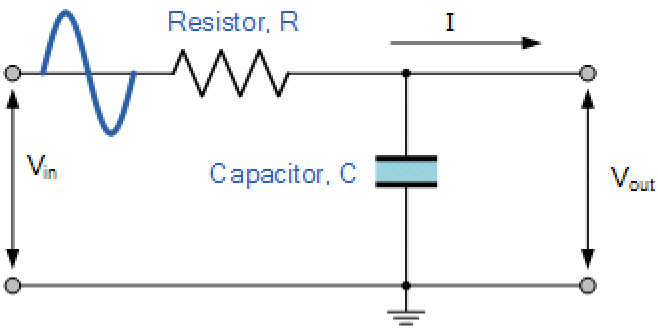
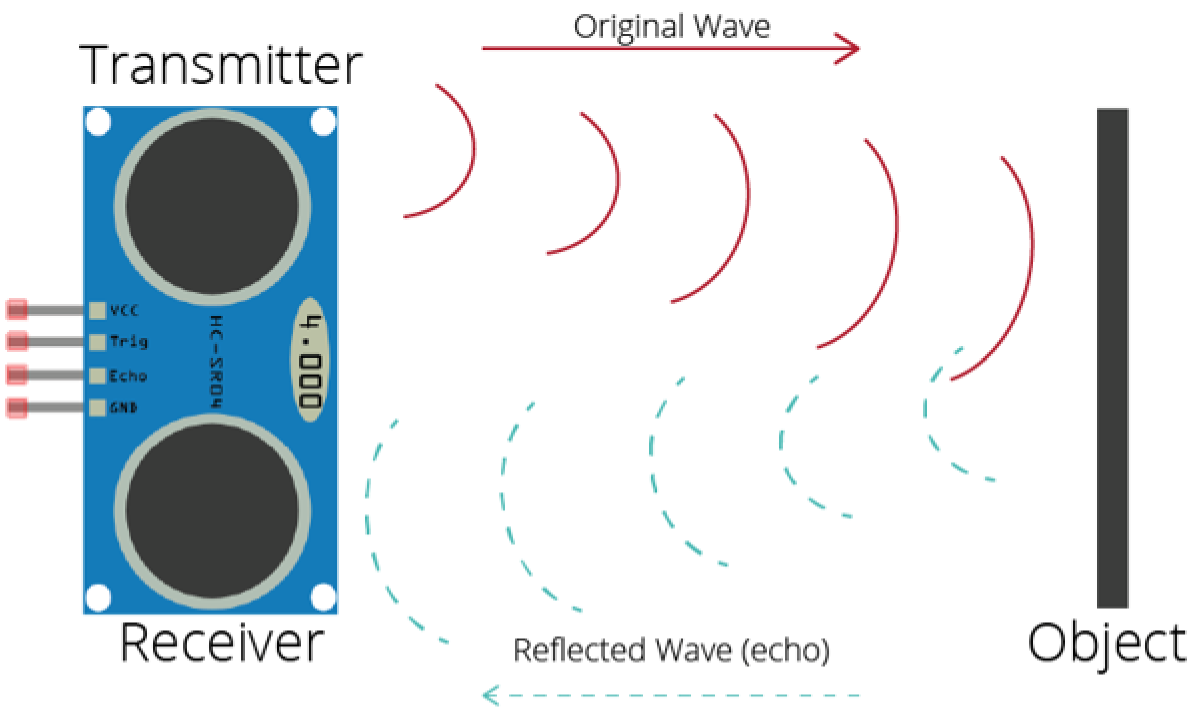


Figure 2: Low pass Filter

PWM signal is a modulation technique to generate different width wave pulses to represent the amplitude of an analog signal.

PWM signals can be transformed by only using a low-pass RC filter(Figure 2).This RC filter will then be directly proportional to the duty cycle of PWM.We want to get rid of the frequency where the signal is not active.In this case the frequency of the signal is 16Hz.The duty cycle of this wave is 0.017 percent.We can then use the time where the signal is not active and with that we can calculated our cut off frequency.We will also need to add an amplifier to amplify signal,because a low pass filter might lower the voltage.Only 0.707 of the voltage gain is able to pass the through the low pass filter.

1.5. Fundamental operation of the range sensor



The ultrasonic sensor consists of four pins.One of the pins,the trigger pin, is used to trigger a ultrasonic sound wave.This wave will then travel and the pin will stay be set on HIGH for 10us.This will then cause an ultrasonic burst of eight pulses at 40kHz.When this ultrasonic sound wave hits an object it will reflect a signal .This signal will then be received by the ultrasonic sensor which will set the echo pin back to LOW.After the reflected signal has been received the echo pin will then echo a pulse from 25us to 50ms dependent on the time it took for the signal to be received..The time it takes for the echo pin to stay high will then be used to determine the distance between the ultrasonic sensor and the object.

1.6. Converting digital values to analogue equivalents

We are going to look at a way to use a operational amplifier as an adder.We will be using a summing amplifier.There are two types of summing amplifiers namely an inverting and a non inverting amplifier. With a non inverting amplifier the amplifier will have a positive gain that an be calculated by this formula:

Vout=Vin(1+Rf/Rin)

All the inputs of the summing amplifier can bee added together to get the value of Vin.A inverting amplifier will work the same ,but the amplifier will have a negative gain.We will calculate the output with the following formula:

Vout=-Vin(1+Rf/Rin)

The output voltage of each channel can be calculated individually and then be added together to get your voltage input.I will be using an inverting amplifier,because I want the voltage to subtract from a DC offset,which will give me lower output for a higher input and visa versa. The common mode voltage will now also be equal to the non-inverting node of the operational amplifier.The output impedance for the operational will be dependent on the voltage input of the binary signals and the input resistances of the channels.The formula that will be used is the following:

Vout=-Vin(Rf/R1 +Rf/R2 +Rf/R3 +Rf/R4). Your Rf will be your gain resistor.This resistor value will be dependent on the inverting node voltage and what you want your output to be. Your input impedances will be a ladder of values which all differs from R to 2R to 4R to 8R.There are four bits which means there will be 2 to the power of 4 possibilities.So to counter that we will be using a 8,4,2,1 ratio of resistors.

Chapter 2

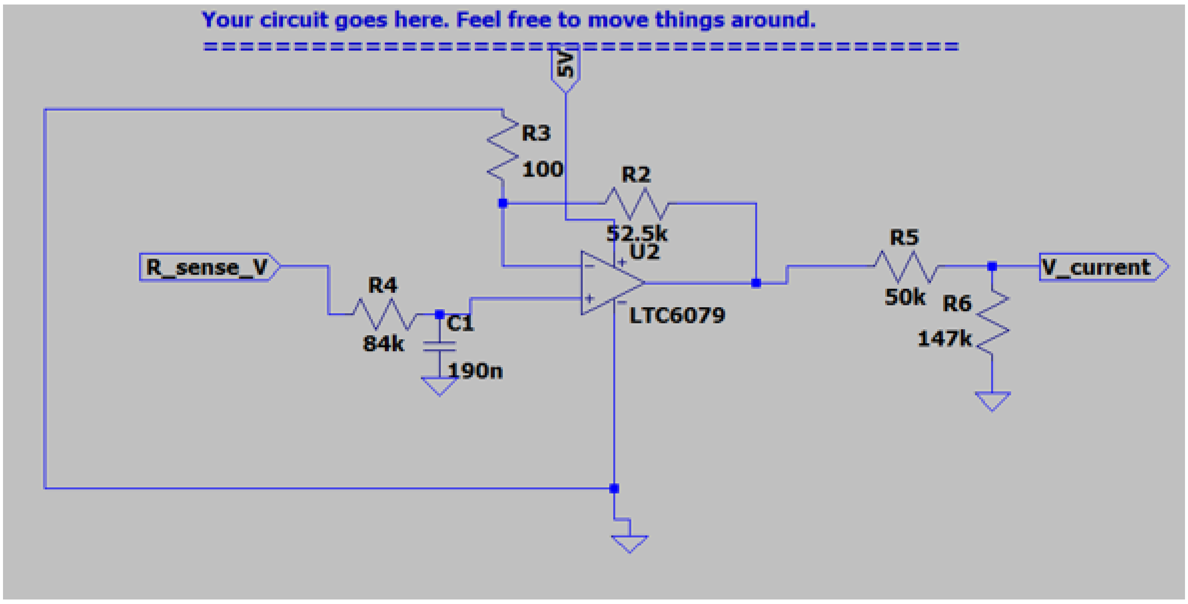
Detail design

I had to design an small signal amplifying op-amp,and a low current sensor with a lowpass filter which will then filter all the noise with a cut off frequency of 1kHz.

I used a cut off frequency of 10Hz to cancel all the noise bigger than 10Hz.I used 10HZ.because I said that f=1/T and then calculated the frequency to be 10hz.The lower your frequency is how lower your amount of noise will be.I will then use this frequency to create a low pass filter.I the used the following equation to calculate the resistance and the value of the capacitor.

numbered equation in Eq. 2.3.

$$fc = \frac{1}{2piCR}. \tag{2.1}$$



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The max current measured over the motor at 6V is 1A.I chose to choose my max current 0.95A.The max voltage that will be entering the op amp will then be 10m ohm multiplied by the max current.The max voltage will be then 9.5mV.I also chose the output voltage to be 5V at max current .This will then enable me to use voltage division to get my output 3.3V. The Gain will be calculated by this formula:

$$Av = 1 + \frac{R2}{R3}. \tag{2.2}$$

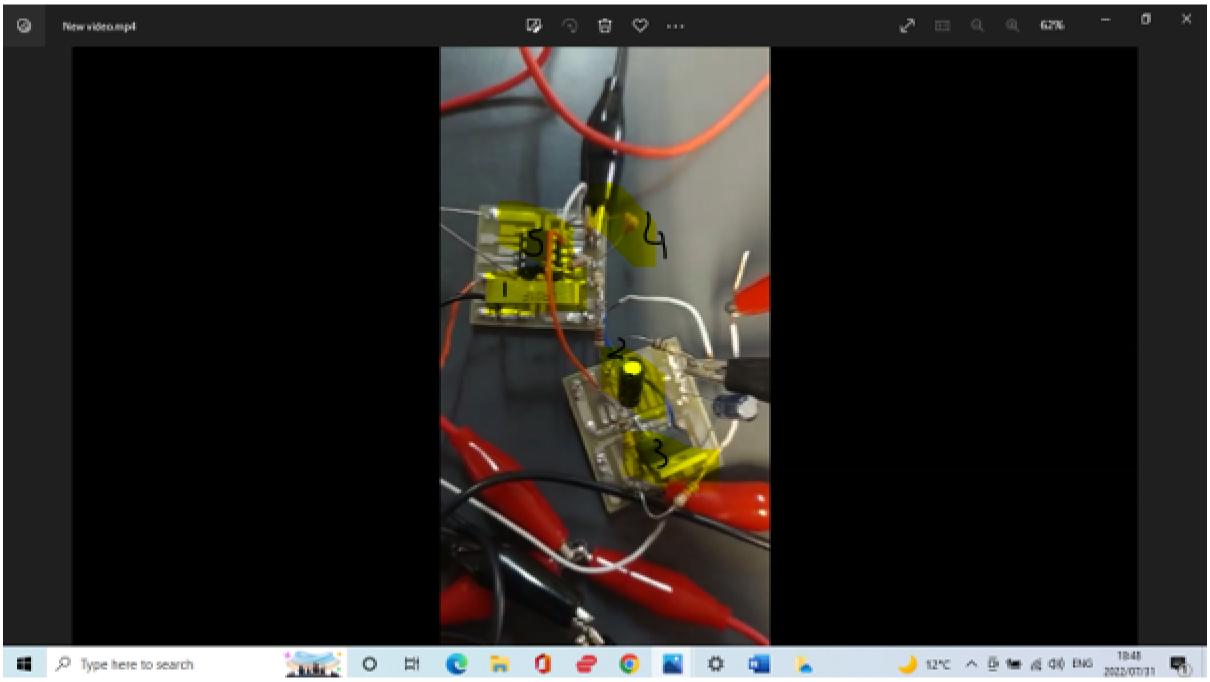
This table will show you the characteristics I needed to consider before designing the op amp

Common mode voltage	Rail voltage	Differential Mode voltage	Expected input voltage	Maximum allowable voltage
0-5V	5.5V	-	10mV	2.7-5.5V

The voltage input of the operational amplifier is 10mV.My rail voltage is 5V and ground which meets the specifications.My output voltage between 3V and 3.6V for that is the only voltages my microprocessor would be able to handle and that is why I made my out put voltage to be 3.3V. I used voltage division and calculated the voltage division in the following way:

$$3.3V = 5V(\frac{R6}{R5 + R6}). \tag{2.3}$$

. I used the following resistors: R4=84Kohm R3=100ohm R2=52.5kohm R5=50kohm R6=147kohm



1-Rsense(0.1 ohm)

2-Capacitors to help with oscillation.Make the voltage stable

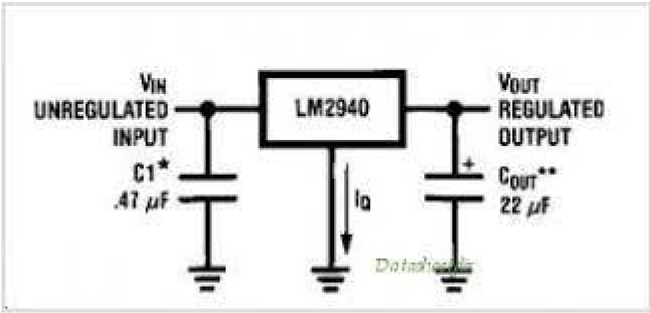
3-Voltage regulator(7.2V-5V)

4-Capacitor for low pass filter.

5-Operational amplifier.

2.1. Voltage regulator

My design is according to the datasheet.The Datasheet of the LM2940CT.This design is used to regulate the voltage form 7.2V to 5V.



2.2. Design for ultrasonic sensor

The first thing I had to do was to remove the unwanted signal in the PWM signal.The time where the signal was not active was 60ms.I had to cut out 60ms of the signal where it was not active.I used the following formula to calculate the cut off frequency.The op-amp I will be using in my design is MCP6242.This op-amp uses a common mode input voltage with the range of Vdd+350mV,Vss-300mV.

fc=1/(2 x pi x 60ms)

=2.653Hz

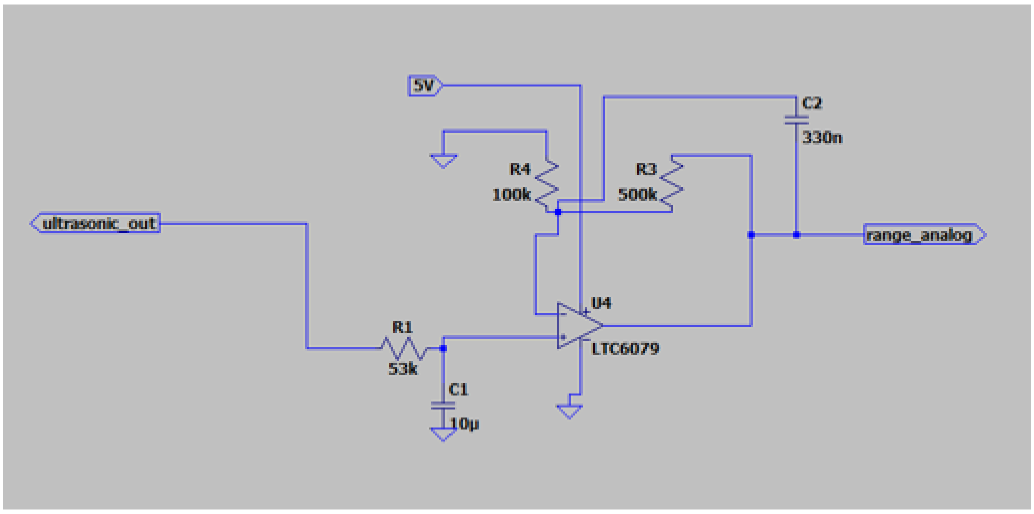
The cut off frequency had to be lower than 2.653Hz.When using this frequency ,my signal still had a lot of noise.I lowered my cut off frequency till I reached less noise.The cut off frequency I chose was 0.3Hz.I also chose resistance to be 53kohm. I calculated the capacitance by using the following formula:

fc=1/(2 x pi x R x C)

I calculated the capacitance to be 10uF.I then had to amplify the signal.The output of this signal was equal to 600mV and I wanted it to be 3.3V.To calculate the gain I used the following formula:

Av=R2/R1

I chose R1 to be equal to 100kohm.I then calculated the R2 to be 500kohm.To smooth out the noise on the signal even more I picked a 330nF capacitor.I used this capacitor to lower the noise on the signal down to 70mV peak to peak.In the building of my circuit I will be using 3.3V to power my op-amp,because when my distance measured on my ultrasonic sensor is more than 1 meter, my output voltage is more than 3.3V.



5V
C2
330n
R4
100k
R3
500k
ultrasonic_out
range_analog
U4
R1
53k
LTC6079
C1
10µ

2.3. : Digital to analogue converter design

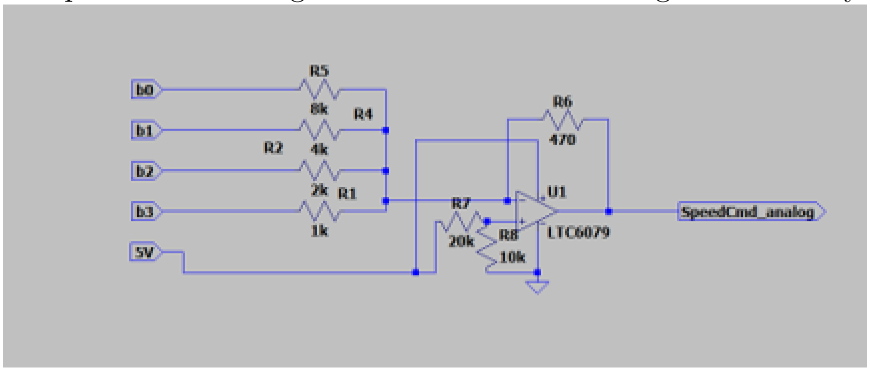
For my design I have decided to use a summing inverting amplifier.I will also be using a Dc offset that will be connected to my non-inverting node.With this offset I will be able to subtract my voltages from my offset.I will then be able to get lower outputs form higher inputs and visa versa.I will be using a gain of 0.5.With this gain I will use a voltage divider to get my 5V down to 1.67V.With a gain of 0.5 I will then be able to get a voltage of 3.2V for my output.

the output impedance of a DAC is a Thevenin equivalent circuit resistance.The higher the output resistance of the circuit the higher the output impedance of the DAC.The lower the output resistance the higher the current draw from the buffers and it will be inefficient in power.

Your Rf will be your gain resistor.This resistor value will be dependent on the inverting node voltage and what you want your output to be. Your input impedances will be a ladder of values which all differs from R to 2R to 4R to 8R.There are four bits which means there will be 2 to the power of 4 possibilities.So to counter that we will be using a 8,4,2,1 ratio of resistors.

The expected voltages from the source will be 3.3V.We can expect the following input voltages depending on the binary code: if binary code is 0001: Vin=3.3(0*1/R1+0*1/R2+0*/R3+1*1/R4)

The maximum allowable output of this circuit will be over 3V,but not higher than 3.3V. The output needs to range form 0 to 3.3V according to the binary signal that was send.



Chapter 3

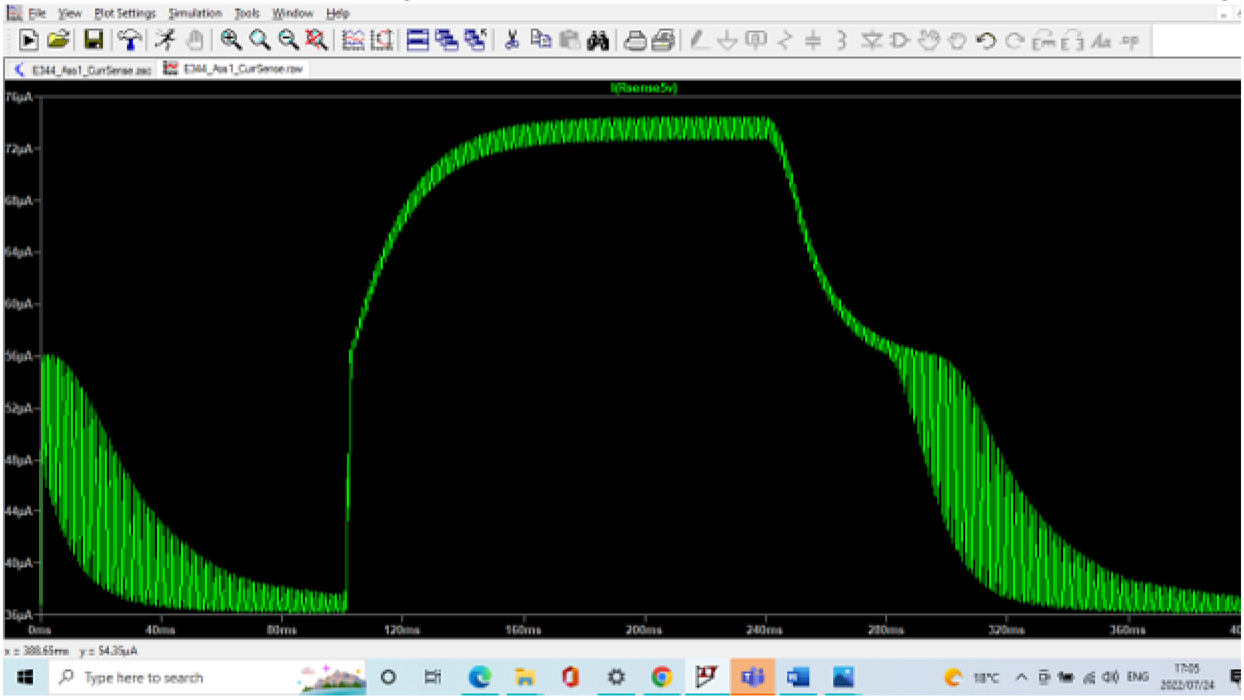
Results

In this section I will be showing my results by referring to my simulation results and will be showing how my designed circuit behaves.I will also be showing the current use of the DC motor according to it's condition.

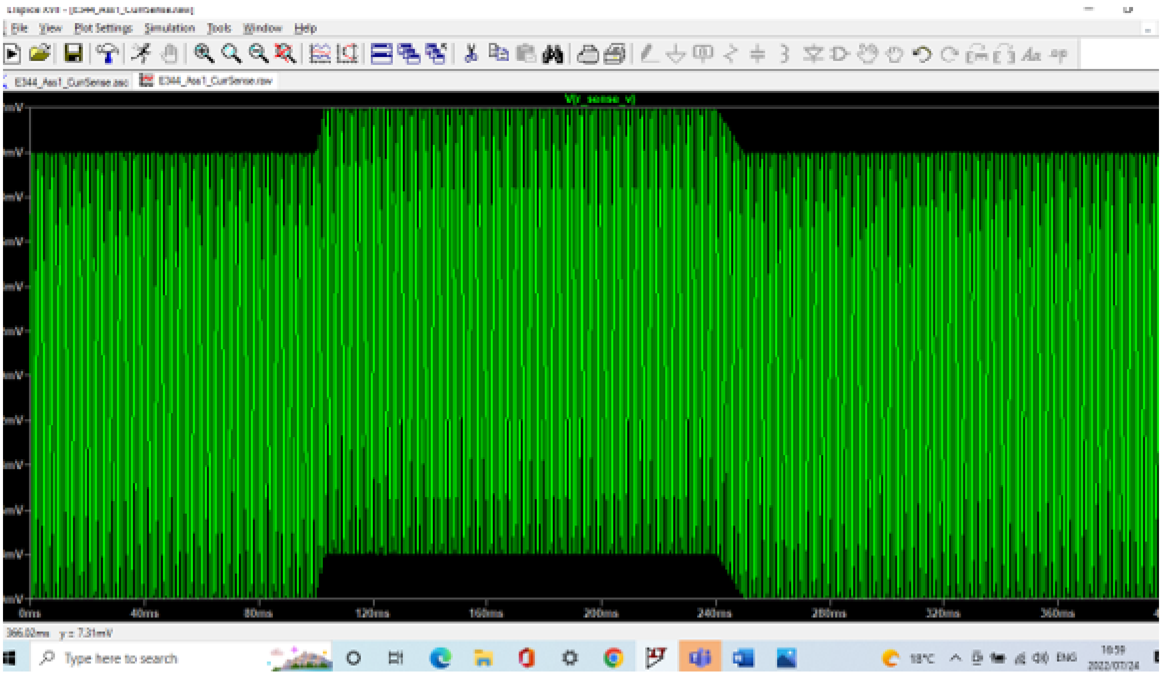
Table 3.1: voltage use of circuit when motor:.

stall	running	
3.2	0.45	V

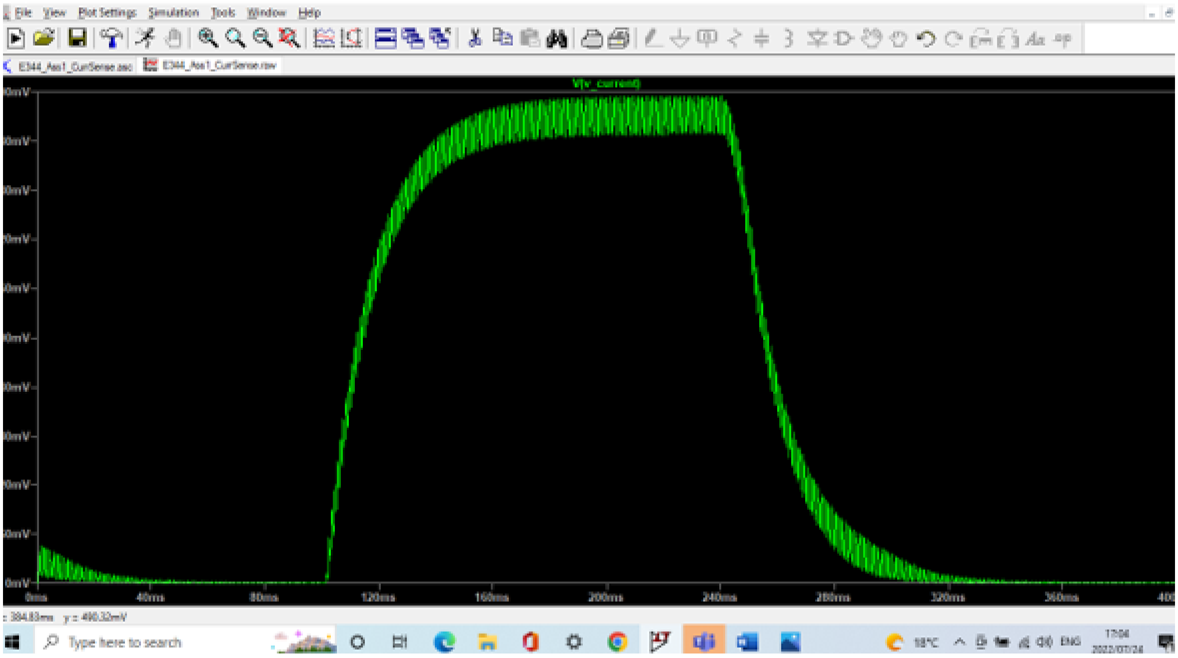
The current through Rsense is equal to the following:



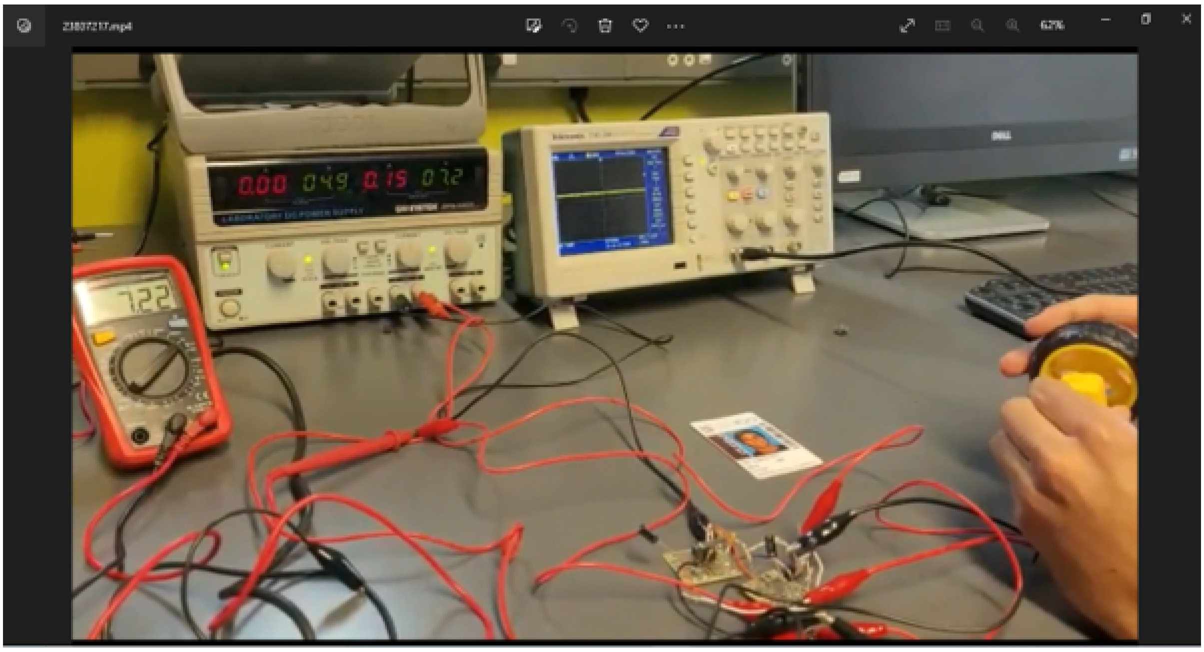
The input with the noise is :



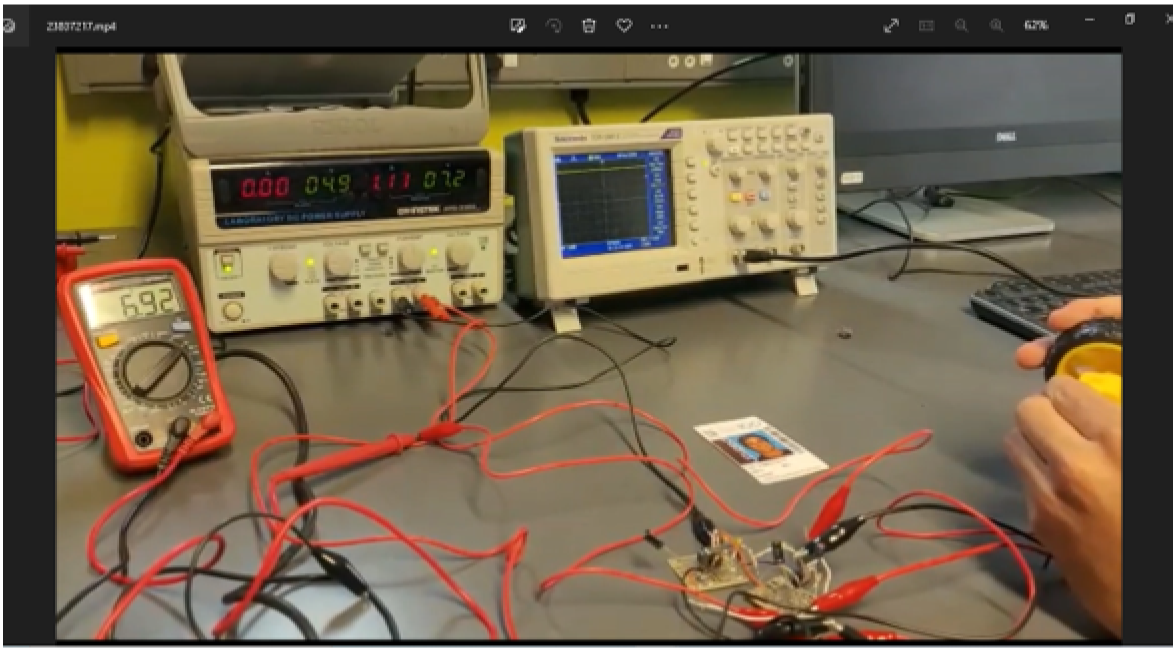
Output without any noise:



Results when 1.5A input and wheel is running:

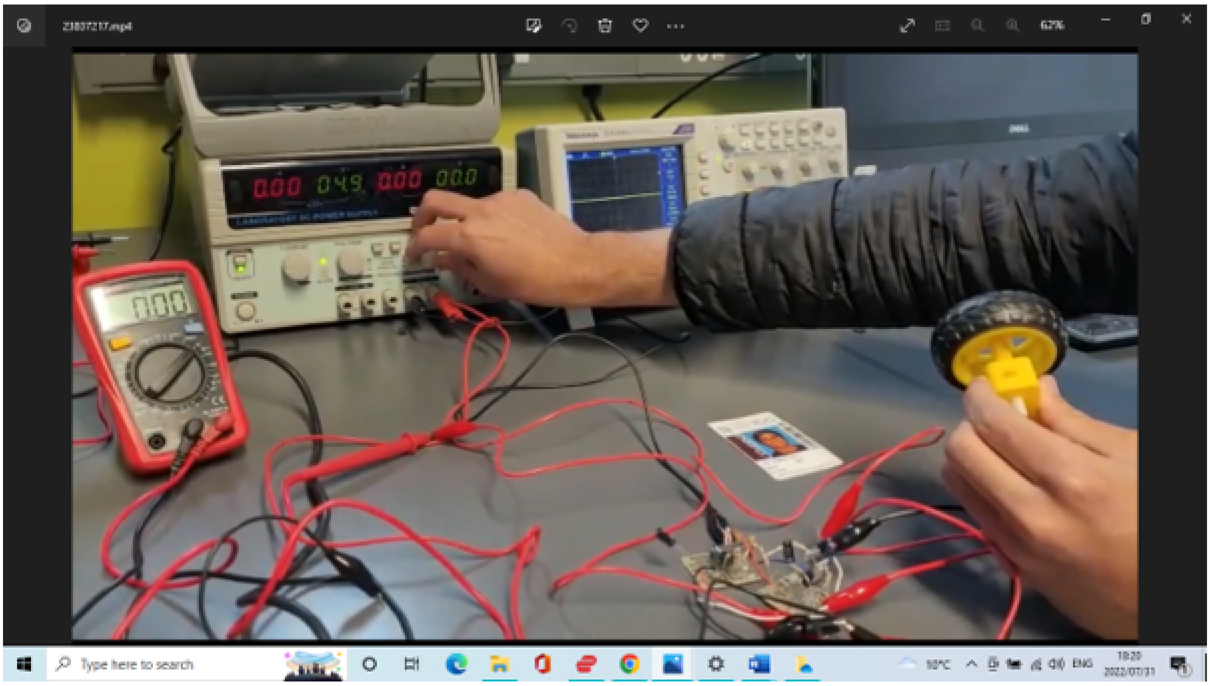


Results when 1.5A input and wheel is stalled:



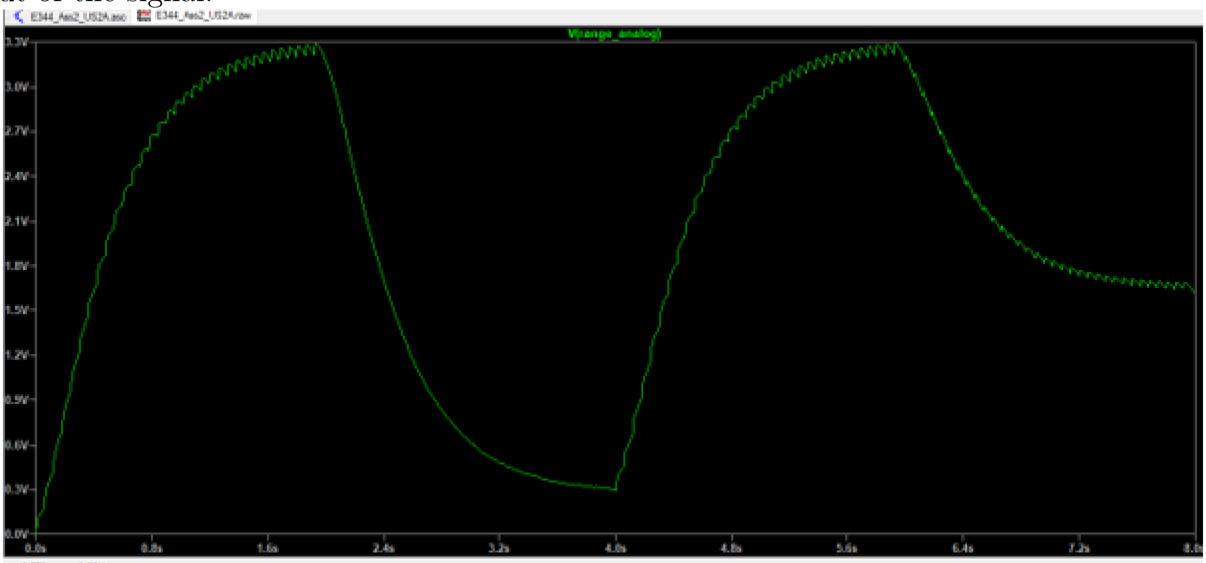
When the input current is 1.5A, the output voltage, when the wheel is stalled, is 3.2V.When current is 0.25A the results remain the same,but when the wheel is stalled the voltage go down to 0V.

When 0A or 0.05A is input:

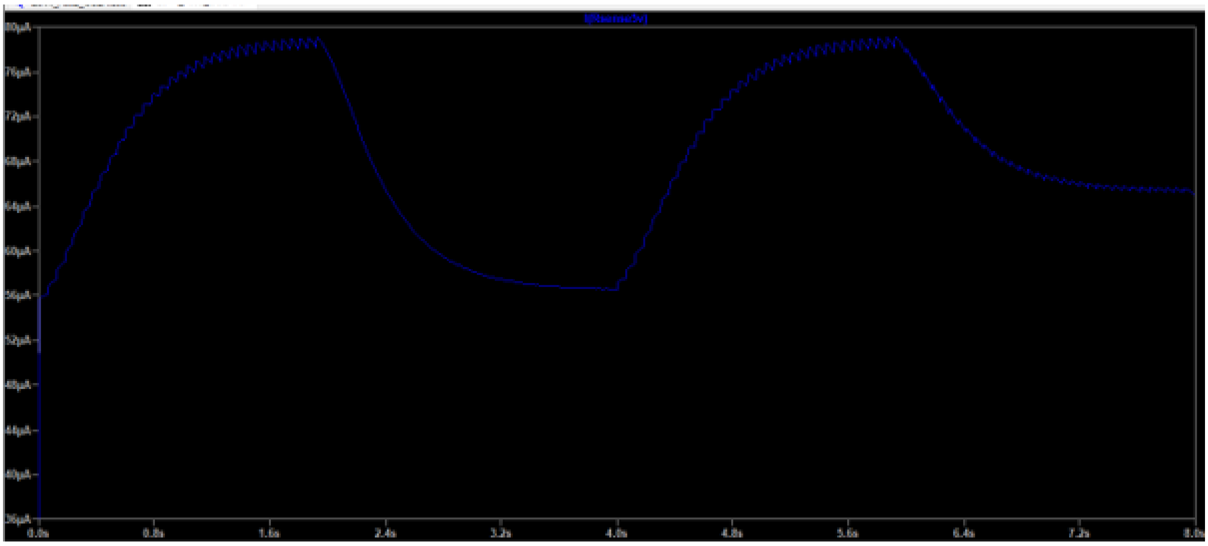


3.1. Ultrasonic sensor design

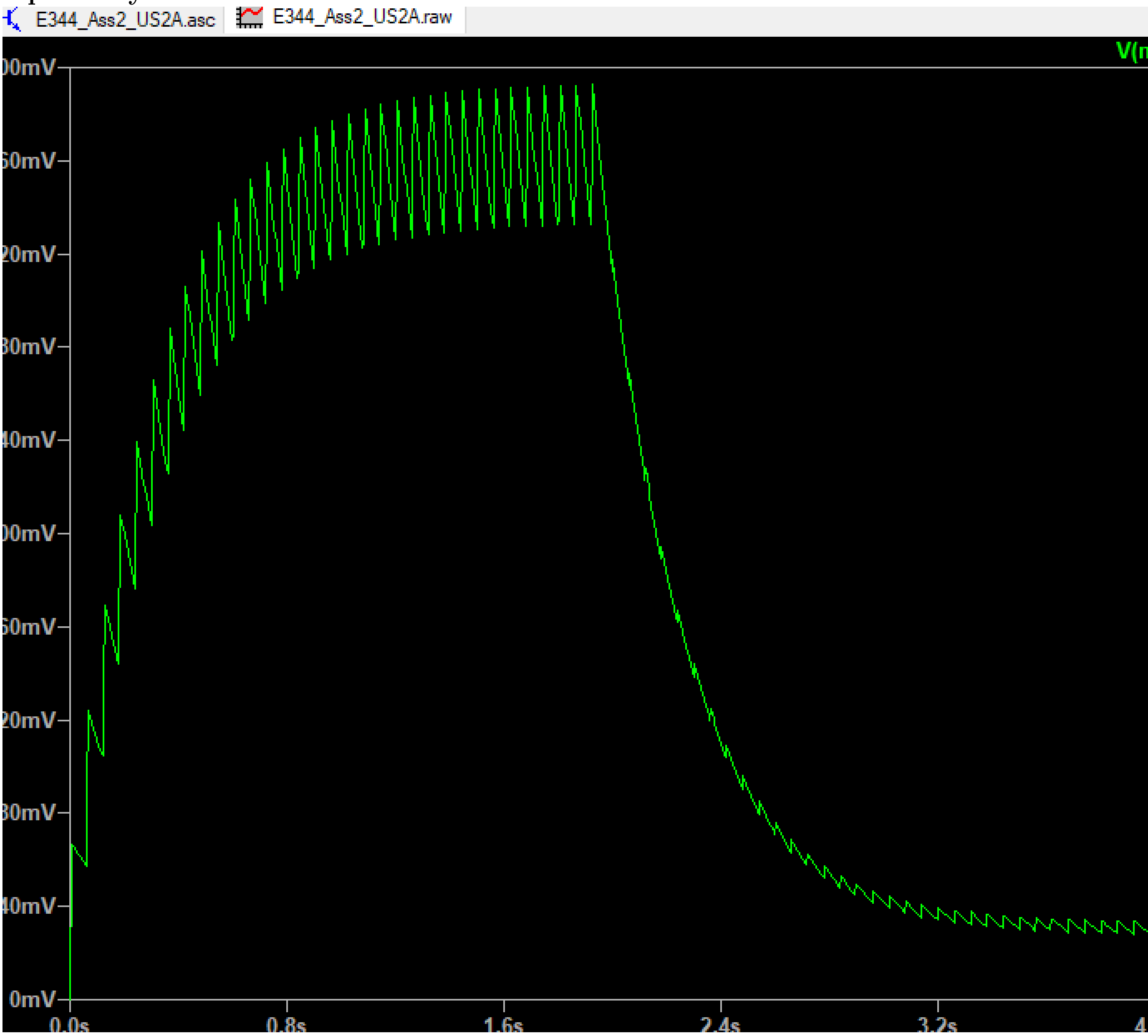
Output of the signal:



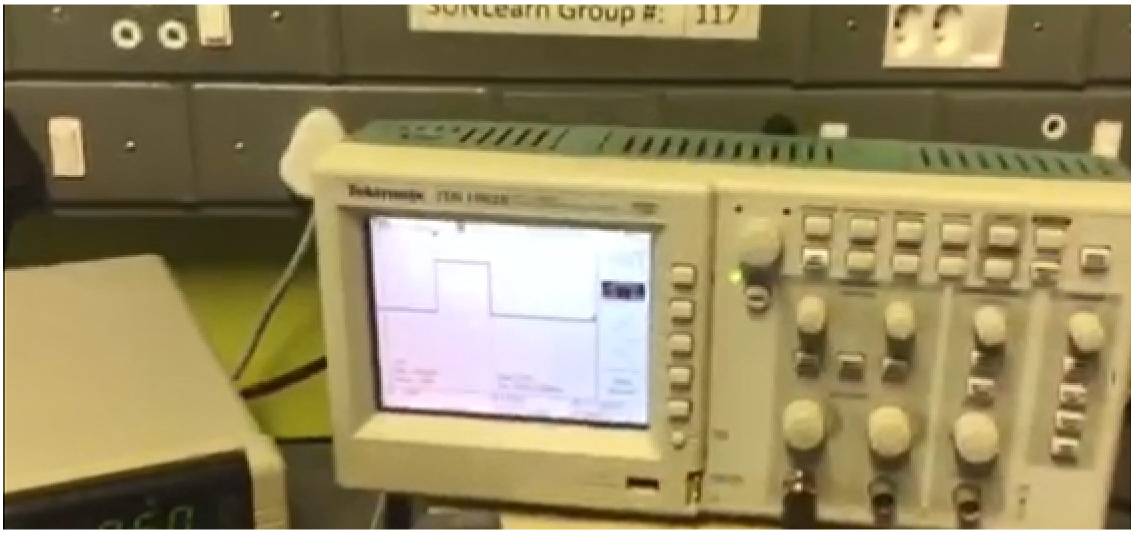
The amount of current going through Rsense:

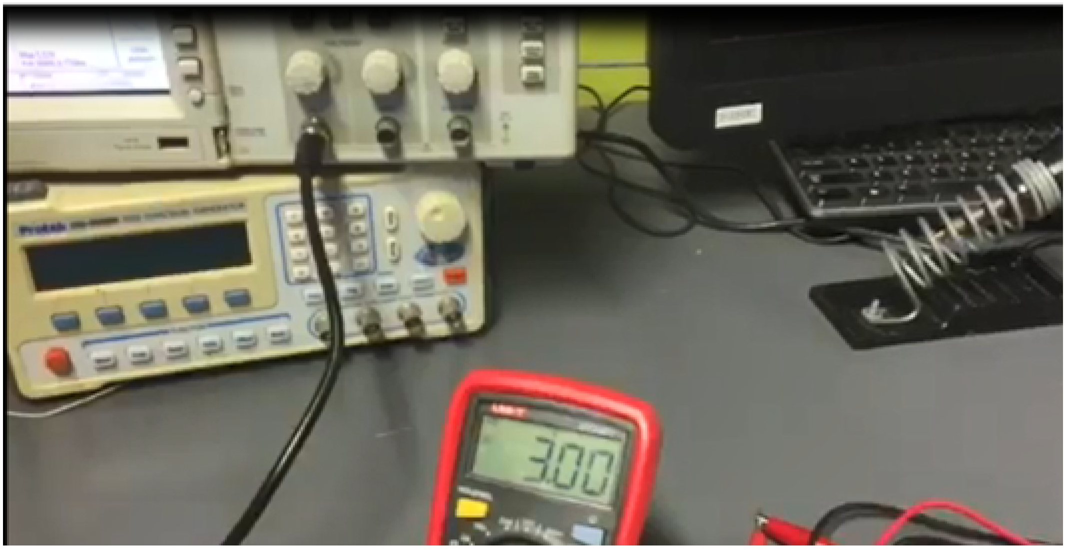


input of system

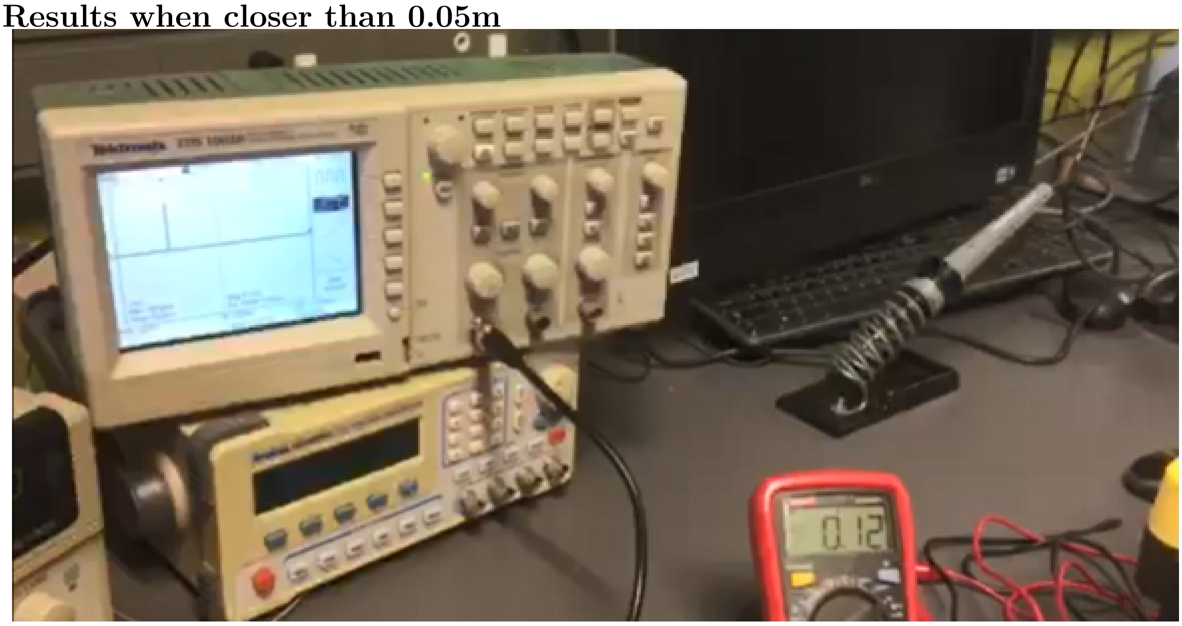


Results of practical circuit: Results when 1m away:



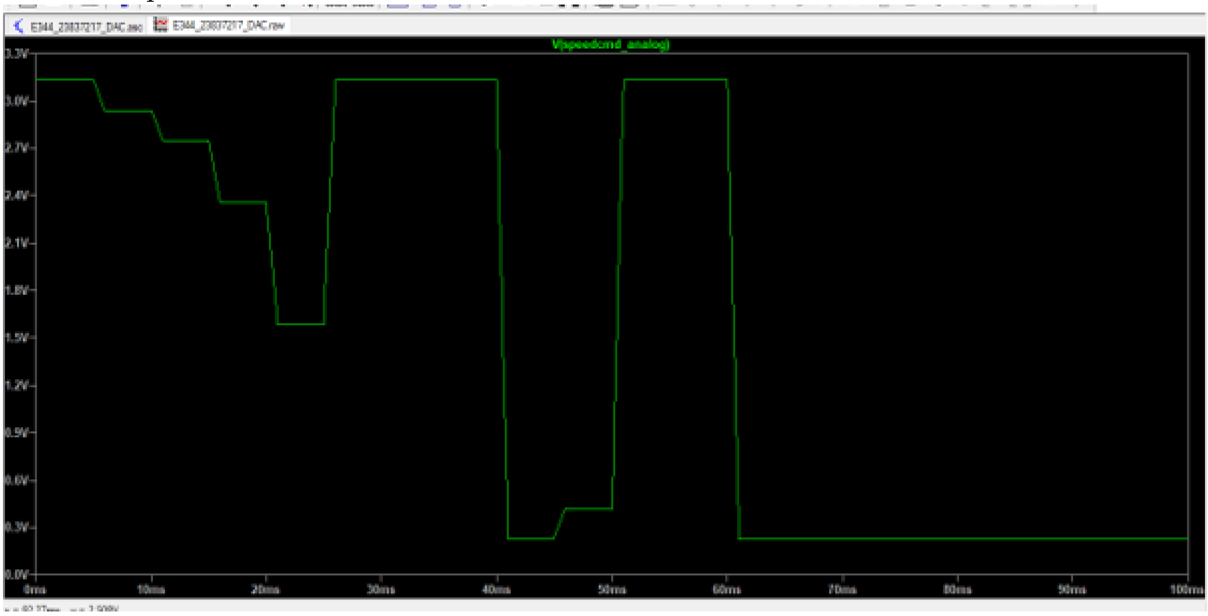


Results when closer than 0.05m

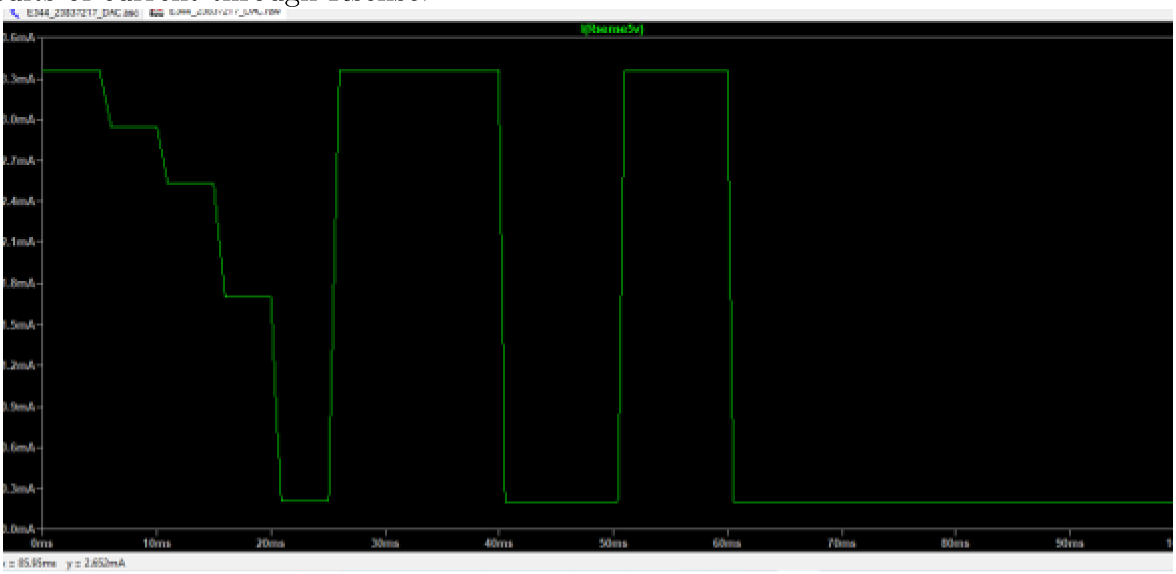


3.2. binary to analogue design

Results of Lt spice:



Results of current through Rsense:



Measurement for 0000:

measurement for 0001:

measurement for 1110:

measurement for 1111: 

Bibliography

https://www.allaboutcircuits.com/technical-articles/low-pass-filter-a-pwm-signal-into-an-analog-voltage/. [Accessed: 07- Aug- 2022].

HC-SR04 Ultrasonic Sensor", Components101, 2022. [Online]. Available: https://components101.com/sensors/ultrasonic-sensor-working-pinout-datasheet. [Accessed: 07- Aug- 2022].

"How HC-SR04 Ultrasonic Sensor Works and How to Interface It With Arduino", Last Minute Engineers, 2022. [Online]. Available: https://lastminuteengineers.com/arduino-sr04-ultrasonic-sensor-tutorial/. [Accessed: 07- Aug- 2022].

2022. [Online]. Available: https://www.allaboutcircuits.com/industry-articles/how-to-reduce-noise-in-low-voltage-amplifier-designs/. [Accessed: 07- Aug- 2022].

[2]2022. [Online]. Available: https://www.electronics-tutorials.ws/combination/digital-to-analogue-converter.html. [Accessed: 14- Aug- 2022].

[3]2022. [Online]. Available: https://www.electronicshub.org/summing-amplifier/. [Accessed: 14- Aug- 2022].

Appendix A

Social contract

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E-design 344 Social Contract

2022

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In the months preceeding the term, the lecturer (Thinus Booysen) and a few paid helpers (Rita van der Walt, Keegan Hull, and Michael Ritchie) spent countless hours to prepare for E344 to ensure that you get your money's worth, that you are enabled to learn from the module, and demonstrate and be assessed on your skills. We commit to prepare the assignments, to set the assessments fairly, to be reasonably available, and to provide feedback and support as best and fast we can. We will work hard to give you the best opportunity to learn from and pass analogue electronic design E344.

I, ...Henry Charles Louw..................... have registered for E344 of my own volition with the intention to learn of and be assessed on the principals of analogue electronic design. Despite the potential publication online of supplementary videos on specific topics, I acknowledge that I am expected to attend the scheduled lectures to make the most of these appointments and learning opportunities. Moreover, I realise I am expected to spend the additional requisite number of hours on E344 as specified in the yearbook.

I acknowledge that E344 is an important part of my journey to becoming a professional engineer, and that my conduct should be reflective thereof. This includes doing and submitting my own work, working hard, starting on time, and assimilating as much information as possible. It also includes showing respect towards the University's equipment, staff, and their time.

Prof. MJ (Thinus) Booysen   Student number: ....23837217....................

Signature: .... Signature: .... Date: ....

Date: ....22/07/24..........................

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Appendix B

GitHub Activity Heatmap