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E344 Assignment 2

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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 15, 2022

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22569650 Studentenommer / *Student number*	Handtekening / *Signature*
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Nomenclature

Variables and functions

V	Voltage
I	Current
A	Ampere
V_{ref}	Reference Voltage
f_o	roll off frequency

Acronyms and abbreviations

KVL	Kirchhoff's voltage law
ESP	Espressif Systems
Op amp	Operational Amplifier
VCVS	Voltage-controlled voltage-source
RC	Resistor-Capacitor
temp	Temperature
PWM	Pulse width modulation
DAC	Digital to Analogue converter
FFT	Fast Fourier transform

Chapter 1

Literature survey

1.1. Converting PWM signals to analogue

PWM is changed to DAC voltage. DAC output is generate by the pulses that is used as an input into the Sallen-key filter. The duty cycle was varied by the application of the following equation.

$$DAC = (DutyCylcle) \times (A) \tag{1.1}$$

A pulse signal is received that has very prominent DC value as well as noise. The DC value is used by applying a low-pass filter that has the ability to filter out the noise that exceeds a certain frequency. To make sure that the best possible amount of noise is being filtered out the a value for the frequency is chosen. This value is usually very low to ensure the best results are achieved falling in between $1.5Hz$ and $10Hz$.

A second order Sallen-Key low pass filter is an active filter that was used because this filter has the ability to effectively rejects noise as well as apply a non-inverting gain. A VCVS design is created due to the use of 2 resistors and a non-inverting op-amp providing a Sallen-key filter with the ability the be cascaded due to the the high input impedance, stability and the low output impedance.

1.2. Fundamental operation of the range sensor

An ultrasonic sensor produces a "chirp" that is used to measure the distance of an object by measuring the amount of time that passes until the sound produced by the sensor has bounces off an object and been received by the sensor again.

$$x = \frac{t \times 343}{2} \tag{1.2}$$

Where t is rime in seconds, x is the distance and 343 represents the speed of sound at room temp.

The sensor used in the physical build is the HC-SR04. This means that there are a few values that should be taken into account. The working sensor works at the following values $5V$, 15mA, $40Hz$. The maximum range that the sensor works at is $4m$ and the smallest range the the filter can function at is $2cm$. The sensors accuracy can range to $3mm$.

[2] The sensor the 4 pins that can be used. The V_{cc} is the pin that is used to give power to

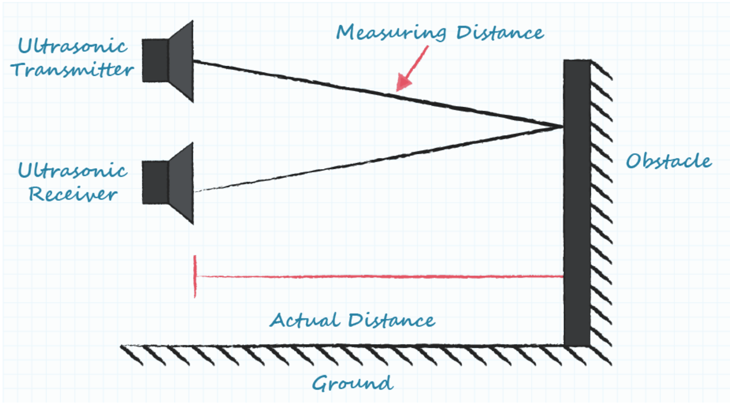

Figure 1.1: Movement of sound from and to the sensor. [1]

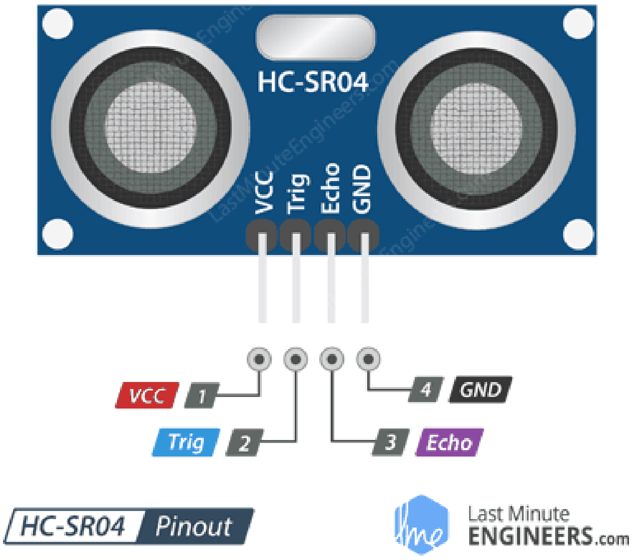

Figure 1.2: Ultrasonic sensor HC-SR04

the ultrasonic sensor. This is where the $5V$ input will be connected from the Arduino board. The Trig pin is where the sound pulse will be triggered from providing the ultrasonic sound chirps to be able to find the object in range when it is set as a high. The Echo pin will fall to a "low" when the sensor receives an echo after it bounced off of an object. The Echo pin will go high as soon as a sound "chirps" is transmitted and will go low if an echo is received. The GND is will be connect to the ground of the Arduino.

The sensor produces 8 pulses at 40KHz when the trigger pin has been set as high of $10\mu s$ and the Echo pin is set High. The only reason why 8 pulses it transmitted is to ensure that the sensor can correctly identify the echo of the signal and not just pic up other external ultrasonic sounds. When there is no pulse that is received after is bounced off an object in range the echo signal will go back to low after $38ms$. In the case that the 8 pulses are received back to echo pin will go back to low at the moment that the signal has been received. The echo pin will then generate a pulse that can have a pulse width anywhere between $150\mu s$ and $25ms$.

The distance can then be determined by the period of the signal that has been received by the echo pin. The larger the width of the wave the larger the distance from the sensor and the higher the voltage of the circuit. In the practical the trigger transmits every $60ms$ and produces a $10\mu s$ wave.

1.3. Converting digital values to analogue equivalents

A summing amplifier is used to convert the given digital signals to analogue signals. An inverting and non-inverting amplifier has a very big impact on the system. [2]

Inputs	0000	1111
Expected outputs	$>3V$	$<0.5V$

Table 1.1: Different results expected to at different inputs

When we take these results into consideration it can be seen that the best option is to make use of seeing as the high inputs produces lower input. [3]

The amplifier supplied by an average voltage. The average voltage is the common mode voltage to the op-amp. The input voltages of the operational amplifier is limited seeing as the rail-to-rail element of the op-amp limited to the supplied voltage. The operational amplifier can be damaged if the input voltage is not limited by the supplied voltage.

All the inputs produces an output that can range from $0V$ and $3.3V$. R_f is used as the feedback resistor that bias at a zero-potential the inverting operational amplifier.

A 4-bit binary number can produce number that range between $0 - 15$. A binary code $8 - 4 - 2 - 1$ will receive a result of 2^0, 2^1, 2^2 and 2^3.

Chapter 2

Detail design

2.1. Digital to Analogue converter

A digital to analogue converter is designed to convert the digital input signals that is received to analogue output signals. The DAC is very sensitive to when it comes to input impedance and the circuit has to be protected against it. [2]

The operational amplifier that is used implements rail-to-rail that means that is supply voltage will always be limited to 5.5V and have a minimum of 1.8V. This makes it possible for the common-mode voltage to become bigger than the supply voltage while illuminating the possibility that the operational amplifier will be harmed.

A potentiometers is implementer in order to apply further turning to achieve the wanted results.

The source has an output impedance that could if it is not considered have a very big impact on the system.

The input voltages can range between 3.3V and 0V. This is made possible when the DIP-switch is implemented making it easier to apply inputs. 0.5V should be the maximum voltage for an input of 1111 and 3V should be the minimum voltage for a input of 0000.

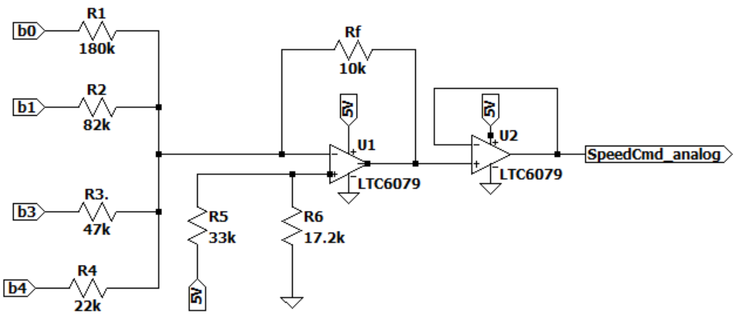

Figure 2.1: DAC simulated circuit

$$V_{out} = \frac{R_f \times V_{b3}}{R_1} + \frac{R_f \times V_{b2}}{R_2} + \frac{R_f \times V_{b1}}{R_3} + \frac{R_f \times V_{b0}}{R_4} \quad (2.1)$$

The resistor values are chosen for $R1$, $R2$, $R3$ and $R4$.

For the input of 1111 a V_{out} is picked to be $3.3V$. R_f is calculated:

$$R_f = 11733.33\Omega \quad (2.2)$$

Resistor values used	
$R1$	$22k\Omega$
$R2$	$47k\Omega$
$R3$.	$82k\Omega$
$R4$	$82k\Omega$
$R5$	$17.2k\Omega$
$R6$	$33k\Omega$
R_f	$10k\Omega$

Table 2.1: Different results expected to at different inputs

To be able to achieve the best output the values are tuned in the simulation but also in the build by implementing a potentiometers. R_f and R_5.

Chapter 3

Results

3.1. DAC(Digital to analogue converter

3.1.1. Simulated results

To be able to compensate for the offset of the amplifier an inverting summing amplifier is used with a voltage regulator.

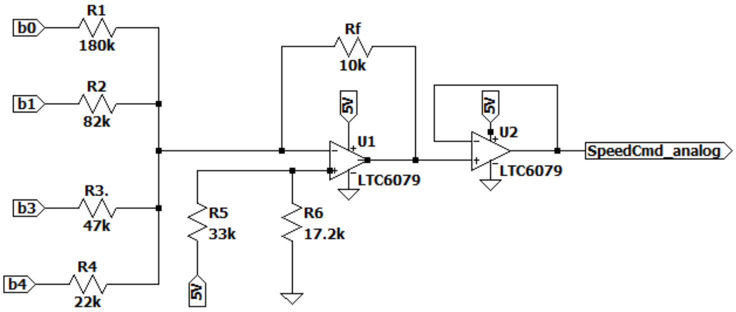

Figure 3.1: DAC simulated circuit

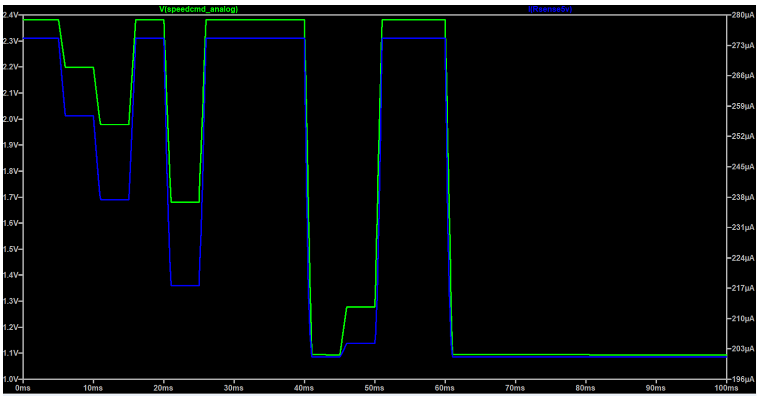

Figure 3.2: Output with different voltage inputs

The current has a range between $356\mu A$ and $194\mu A$. The voltage output can be seen to fluctuate depending on the input that is given.

3.1.2. Measured results

As expected the different voltage inputs will deliver different outputs.

Inputs	0000	0001	0011	0111	1111	1110
Multiple row	$3.70V$	$1.47V$	$0.41V$	$0.01V$	$0.00V$	$1.78V$

Table 3.1: Different results measured at different inputs

Chapter 4

Physical implementation

Figure 4.1: Picture of circuit and Student card

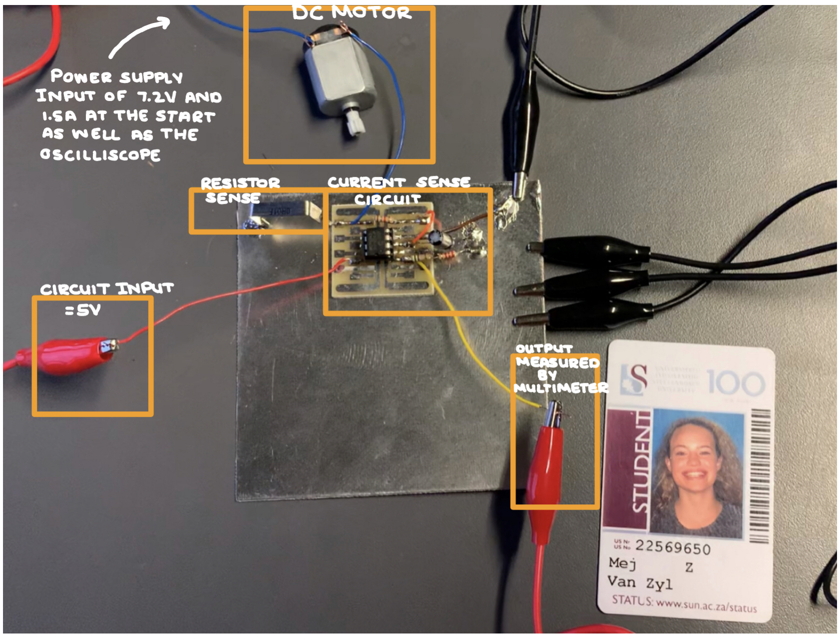

Figure 4.2: Picture of circuit and set-up in the labs

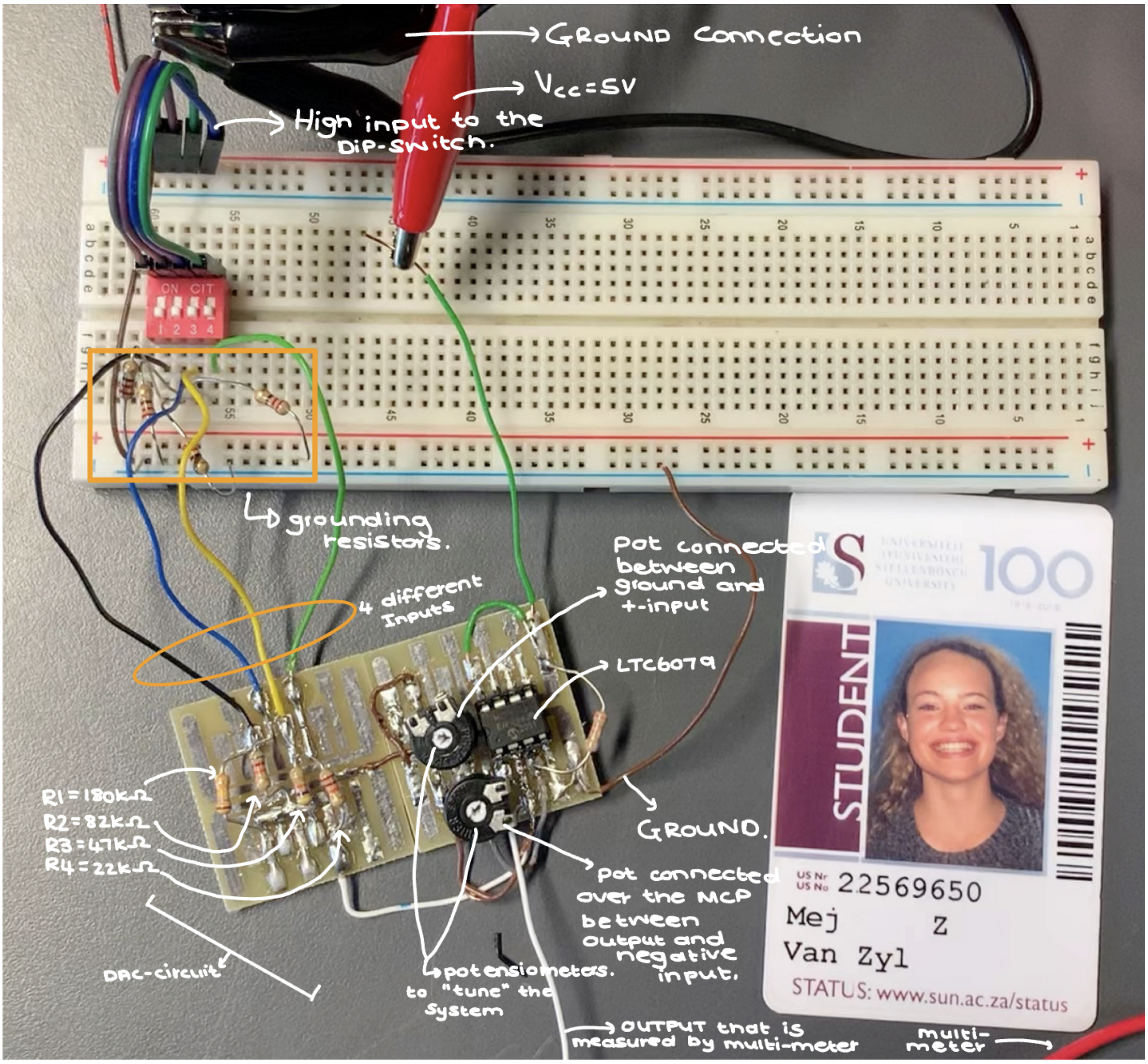

Figure 4.3: Student card and DAC Circuit

Bibliography

[1]

[2] BBC, "How to make opamps amp op," 2018. [Online]. Available: www.electronics-tutorials.ws

[3] Mircochip Technology Inc., "Microchip mcp6241/1r/1u/2/4," 2008. [Online]. Available: https://ww1.microchip.com/downloads/aemDocuments/documents/OTH/ProductDocuments/DataSheets/21882d.pdf

Appendix A

Social contract

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E-design 344 Social Contract

2021

The purpose of this document is to establish commitment between the student and the organisers of E344. Beyond the commitment made here, it is not binding.

In the months preceeding the term, the lecturer (Thinus Booysen) and the Teaching Assistant (Kurt Coetzer) spent countless hours to prepare for E344 to ensure that you get your money's worth and 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 tests and 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, Zaskia Van Zyl .... 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 Booysen	Student number: 22569650
Signature: Digitally signed by MJ BOOYSEN Date: 2021.07.29 16:46:05 +02'00'	Signature:
Date: 29 July 2021	Date: 22/07/2022

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Appendix B

GitHub Activity Heatmap