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.

July 25, 2022

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23905093 Studentenommer / *Student number*	Handtekening / *Signature*
G. Allen Voorletters en van / *Initials and surname*	July 25, 2022 Datum / *Date*

Contents

List of Figures

List of Tables

Nomenclature

Update these lists to make it applicable to your project. It is in `/frontmatter/nomenclature.tex`

Variables and functions

Update this list to make it applicable to your project.

$p(x)$	Probability density function with respect to variable x.
$P(A)$	Probability of event A occurring.

Acronyms and abbreviations

Update this list to make it applicable to your project.

AE	Afrikaans English
AID	accent identification

Chapter 1

Literature review

The following study presents an overview of the current configurations and design techniques for both operational amplifier and current-sensing circuits. Operational amplifiers limitations are considered, as well as the system requirements. These findings are then discussed to ensure there is enough information to aid the design process, which is followed by simulations.

1.1. Operational amplifiers

Limitations

Often, it is applicable to design an amplifier using the ideal operational amplifier model, however this may be inadequate in low voltage, high current or high frequency environments. The following are common limitations of non-ideal op-amps [1]:

- Voltage supply saturation. For given k, output cannot go above $V_{ss} - k$ or below $V_{dd} + k$.
- Finite bandwidth. The signal starts to cut-off at high frequencies, which can be calculated using t he gain-bandwidth product equation.
- Offset voltage/bias current. Even with no input, there exists a small ”offset voltage” and ”bias current” into the amplifier. This results in unwanted voltage at the output.
- Finite slew rate. The output cannot change quicker than a specific rate. This is different to the high-cutoff, but has a similar limiting effect.
- Finite common-mode rejection ratio (CMRR). An op-amp should only amplify $V_+ - V_-$, but also amplifies the unwanted common signal (e.g. noise) on both inputs.

Considerations

System requirements should first be considered in order to attain an overview of the specifications:

- The output range of the circuit should be from 0.1 to 3 V. Since a low-side current-sense resistor will be used, this means initial measurements will be at a lower voltage initially.
- The step response of the circuit should reach 90% of its output in less than 100 ms. The op-amps slew rate should be analyzed to ensure this condition is met.

- Noise above 1 kHz should be filtered out such that a 10 mV, 1 kHz signal at the input is less than 250 mV at the output. Filter options should therefore be researched.

It is clear that voltage supply saturation, slew rate and CMRR are the main parameters to be considered. A filter circuit should also be designed for noise specifications.

MCP6242

The op-amp used in this project is the MCP6242. Listed below are its notable parameters [2]:

- Typical CMMR of 75 dB (DC) to 65 dB (1 kHz).
- Ability to output between 0.035 and 5.465 V if $V_{ss} = 6$ V and $V_{dd} = 0$ V
- Slew rate of 0.3 V/uS.

Configurations

A number of well-known op-amp configurations exist that all achieve slightly different amplification goals. The following list compares common configurations [3] which may achieve this project's goal of amplifying a small-signal voltage across a resistor:

Type	Advantages	Disadvantages
Non-inverting	- Simple to design and build - High input impedance due to negative feedback	- Relatively large input bias currents - Amplifies noise from input
Differential	- Good noise rejection - Flexible	- Complex design - Low input impedance due to virtual ground
Instrumentation	- Good noise rejection - Flexible - Very high input impedance	- Complex and expensive design

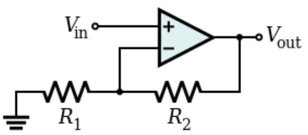


Figure 1.1: Non-inverting amplifier

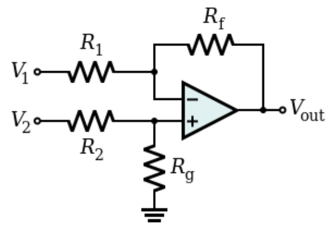


Figure 1.2: Differential amplifier

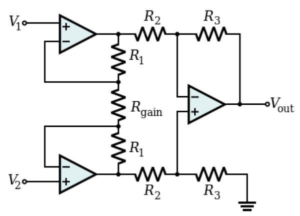


Figure 1.3: Instrumentation amplifier

1.2. Current sensing

Chapter 2

Detail design

This process details the design process and calculations for the current sensor/amplifier circuit. It provides insight into what decisions were made and the justification behind these decisions.

2.1. Current sensor

Configuration

The simple non-inverting amplifier configuration was decided on for this design. Although the differential amplifier provides explicit noise-rejection, its filter design would prove rather complex and may require a second buffer stage compared to the single additional capacitor for the non-inverting case. Overall, with proper filter design, the non-inverting amplifier should still ensure that there is little noise in the output signal.

The only addition to the researched configuration is that of an input resistor into the non-inverting input of the amplifier, followed by a capacitor from the non-inverting input to ground. This RC combination determines the high cut-off of the filter, which can be used to block out the noise.

Circuit diagram

The following figure details the circuit design for the sensor and amplifier combination.

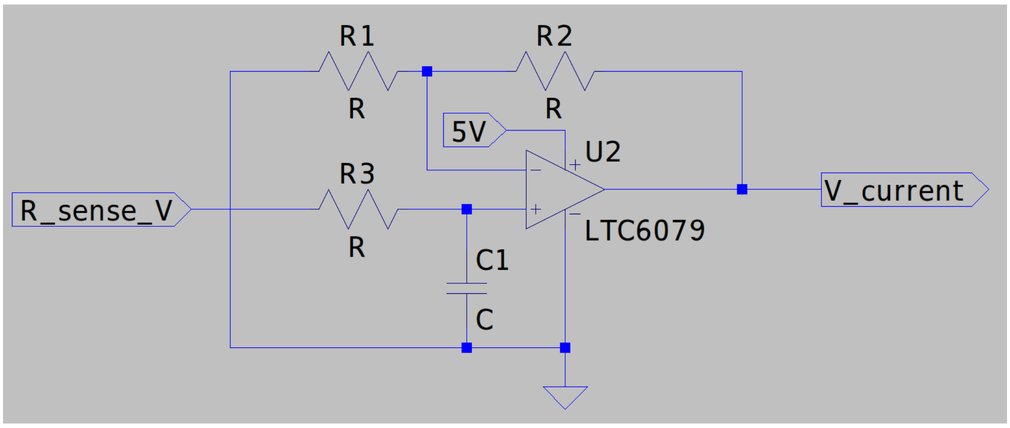


Figure 2.1: Circuit diagram of final configuration

As can be see, a single +5 V and 0 V supply will be used. Although there are benefits to a dual rail supply, that would prove impractical in the context of the larger system.

Since input current of the circuit needs to be limited below 150 uA, high resistance values should be chosen:

- Assuming $i_n = 0$, choose $\frac{V_{out(max)}}{(R_1+R_2)} << 150uA \therefore R_1 + R_2 >> 20\,\mathrm{k\Omega}$. Choose $R_1 = 100\,\mathrm{k\Omega}$.
- $G = 1 + \frac{R_2}{R_1}$
-

Chapter 3

Results

In this section, you want to demonstrate, by means of referring to simulation results, using the designed circuit, how your circuit behaves as you designed it in Section 2.1. Present and report on your simulated results in Figure 3.1. Be absolutely sure that the text and information in your report are readable.

You can use screengrabs or photos of the oscilloscope, or download the CSVs and plot them as PDFs using Matlab, Excel or similar. You can also use tables, example of which are presented in Tables 3.1 and 3.2.

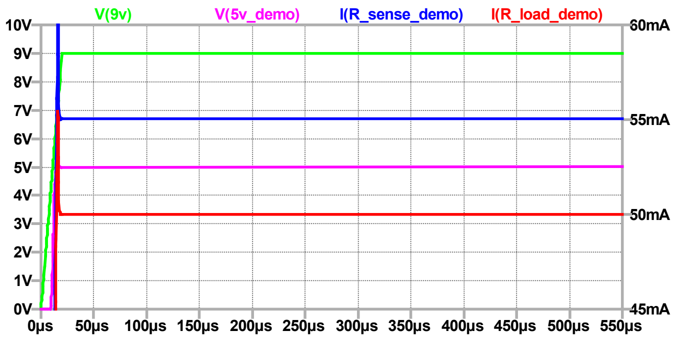
Table 3.1: Example of a simple table.

	2017	2018	Δ_{Abs}	Δ_{DiD}
A	9,868	10,399	+5	-11
B	10,191	10,590	+4	-12

Table 3.2: Example of another table.

Schools	Total energy used		Change	
	2017 [kWh]	2018 [kWh]	Δ_{Abs} [%]	Δ_{DiD} [%]
A	9,868	10,399	+5	-11
B	10,191	10,590	+4	-12

3.1. Current sensor



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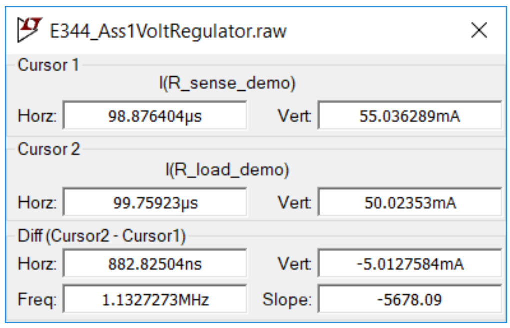

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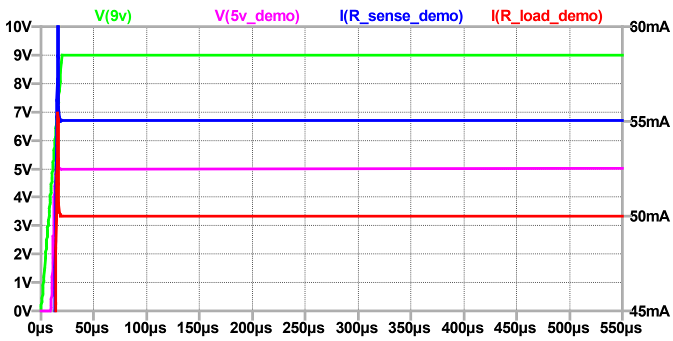

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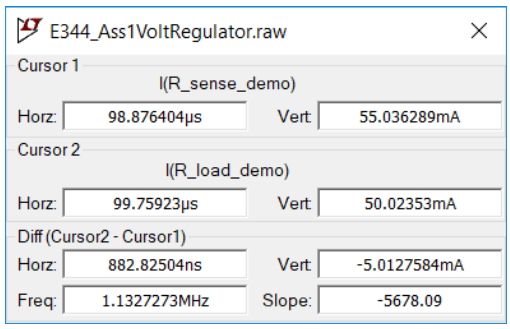

(d)

Figure 3.1: Voltage regulation, comparing the linear and switchmode regulators... (a) Blah blah. (b) Blah blah. (c) Blah blah. (d) Blah blah. As far as possible, please put input(s) and output(s) on the same plot rather than on separate plots. Based on the datasheet of XXXX in [**?**].

Bibliography

Appendix A

Social contract

Download copy from SUNLearn, sign and include here (replace this one).

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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, ... 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: ....
Signature:	Signature: ....
Date: 29 July 2021	Date: ....

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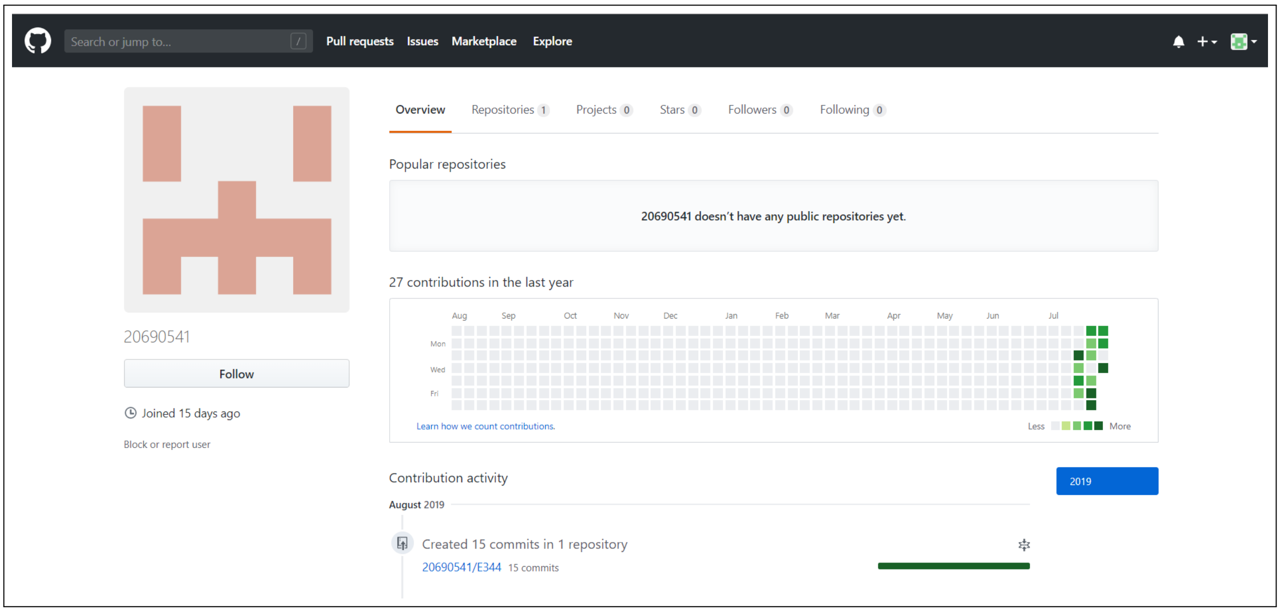
Appendix B

GitHub Activity Heatmap

Take a screenshot of your github version control activity heatmap and insert here.



Appendix C

Stuff you want to include

remove this if not needed!!

You can remove this chapter by deleting the "\include{App-C }" line in the e344_A1_report.tex file.

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