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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 31, 2022

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forward together
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I declare that the work contained in this assignment, except where otherwise stated, is my original work and that I have not previously (in its entirety or in part) submitted it for grading in this module/assignment or another module/assignment.

22660003 Studentenommer / *Student number*	Handtekening / *Signature*
M Roos Voorletters en van / *Initials and surname*	July 31, 2022 Datum / *Date*

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Nomenclature

Variables and functions

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

Acronyms and abbreviations

Hz Hertz

Op-Amp Operational amplifier

dB Decibel

AC Alternating current

DC Direct current

BW Bandwidth

Chapter 1

Literature survey

When measuring the current going through a motor, a current sense is used. This is a small resistor in series with the motor. This resistor has a voltage over it which can be amplified and measured. Most current sensing circuits are composed of an amplifier and some sort of filtering circuitry. Operational amplifiers are the ideal choice for the amplification and will be examined in this document.

1.1. Operational amplifiers

Operational amplifiers: limitations and considerations

There are many advantages to using an operational amplifier. They are widely available in the form of integrated circuits. They have a broad range of uses and are a key component in many analog applications. Practical amplifiers have its own complications versus ideal op amps. Practical op Amps don't have infinite

Operational amplifier configurations

- Inverting amplifier. The inverting amplifier amplifies the inverse of the signal on the inverting input pin of the amplifier.
- Non-Inverting. The Non-inverting amplifier amplifies the signal on the non inverting pin of the amplifier.
- Voltage follower amplifier. Because the input impedance is high and the output impedance is low, the voltage follower makes a useful buffer. This mean changes to the input produce equivalent cahnges to the output.
- Voltage comparator. Voltage comparators compare the voltages on both input pins of the amplifier and derives the output to the supply rail of the higher input. Voltage comparators are also open loop because there is no feedback loop.
- Differential amplifier. Differential amplifiers amplifies the difference between the the inputs on the pins. This is also the configuration that is used in the design of the low side current sense.
- Summing amplifier. The summing amplifier outputs the sum of all the signals on its input pins with regards to weighted resistances

- Integrating amplifier. The integrating amplifier outputs an amplified signal of the integrated signal on its input pin.

The configuration used in the low side current sense is a differential amplifier, together with a lowpass filter.

1.2. Current sensing

There are two ways of current sensing that will be examined in this section. Low side and high side.

Low side current sense

Low side current sensing is when the load resistor (Rsense) is placed between the load and ground. This means that the voltage over it is really low and close to ground. This is better in terms of power usage however it does mean that the system ground and supply ground is different.

High side current sense

High side current sensing is when the current sensing resistor is placed between the load and the source. In this configuration the system is more susceptible to noise over the load. When the resistor is between the load and source, the voltage is also much higher which means the system uses more power.

More current sensing methods:

- Hall effect.
- Inductive.
- Magnetoresistive.

Chapter 2

Detail design

Before designing the system the maximum power through the load must be found. This can be done by stalling the motor (which is the load) to find the maximum current it can draw. When stalling the motor it is working at its hardest and therefore draws the most current. The motor draws around 150mA when running freely with only the wheel attached. When stalled it draws around 1A. figure(2.1) shows two circuit designs for a low side current sensor.

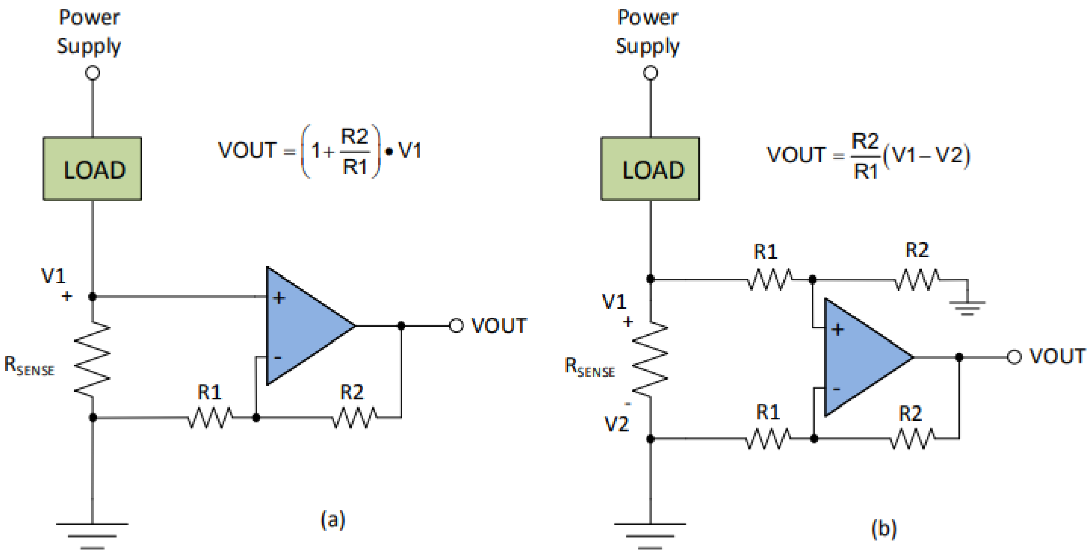


Figure 2.1: Low side current sensors

Figure 2.1(a) on the left, achieves current sensing with two external gain setting resistors. It uses fewer components than the one on the right but, for circuits with high ground currents it can be less accurate. Figure 2.1(b) Is a difference amplifier that senses the voltage drop directly over the sense resistor. This system is more accurate because the voltage drop from the resistor to the pcb is removed.

$$Rsense = \frac{Vsensemax}{Iloadmax} \tag{2.1}$$

$$Gain = \frac{VOmax}{Vsensemax} \tag{2.2}$$

With Rsense = 10 mΩ and Iloadmax = 1A we can find Vsensemax to be 10mV and the gain 300 since the maximum output voltage shold be 3V.

$$Vout = \frac{R2}{R1}(V1 - V2) \tag{2.3}$$

R1 is chosen as 300Ω and R2 is chosen as 100kΩ. These are chosen so that the circuit uses less than 150uA

Next the filter capacitors must be calculated.

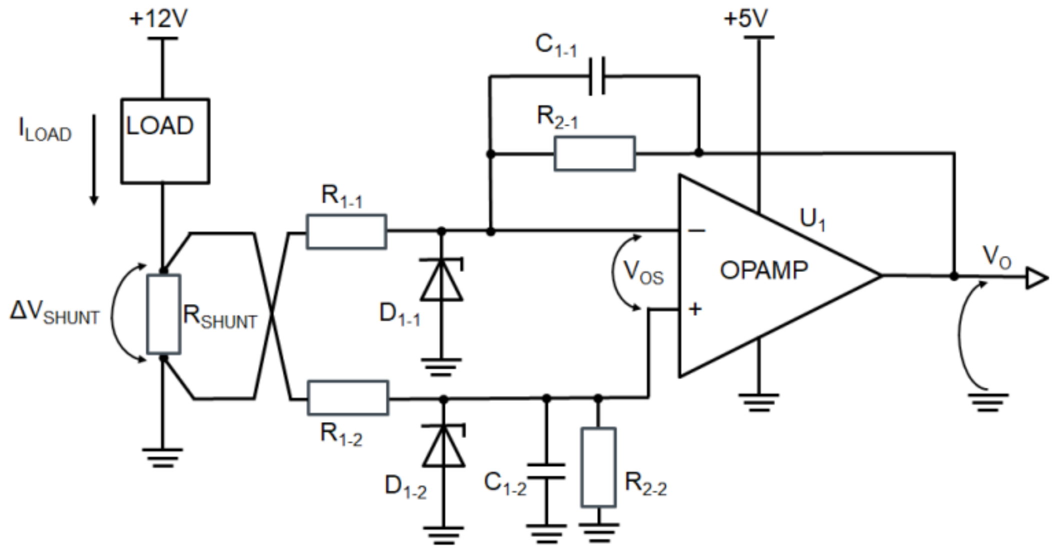


Figure 2.2: Lowpass filter incorporated with circuit.

$$C1 = \frac{1}{(2pi)(Fsense)(10)(R2)} \tag{2.4}$$

With the frequency of the sense resistor chosen as 10Hz the capacitor values can be calculated. initial calculations showed that capacitors of 5nF must be used but after tweaking the circuit in LtSpice it was found that 50 nF works better.

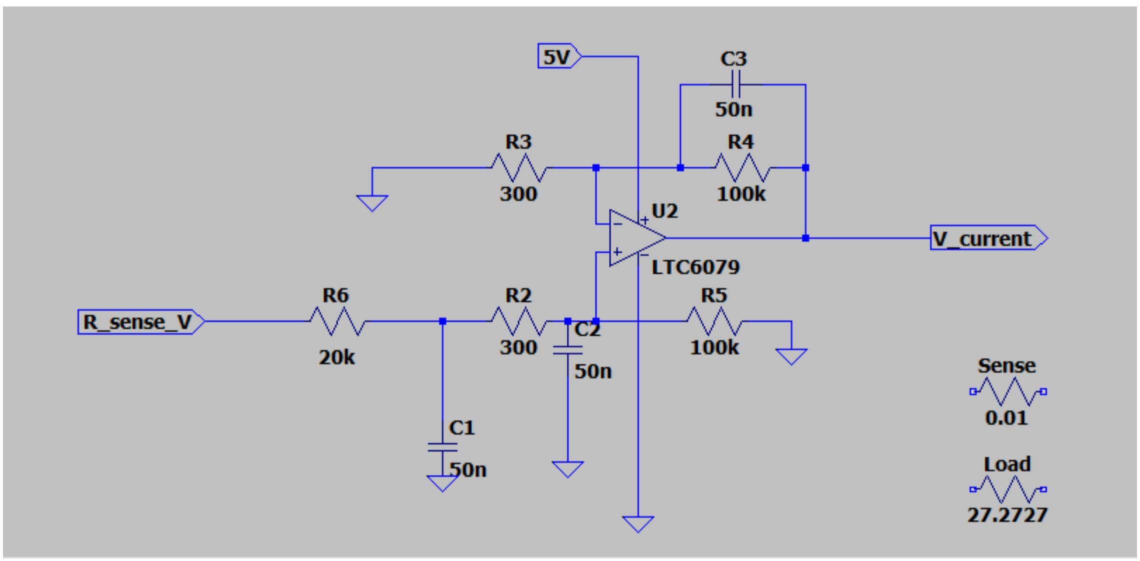


Figure 2.3: Final design.

Chapter 3

Results

The result of the circuit is satisfactory, the noise is filtered out and the signal gets within within the desired margins in less than 100ms.

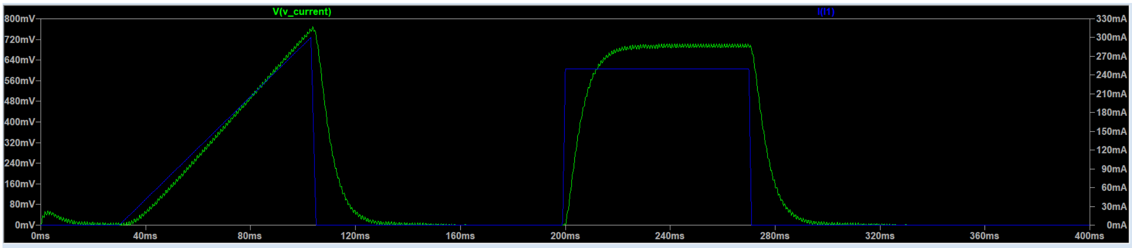


Figure 3.1: Response to ramp and step input.

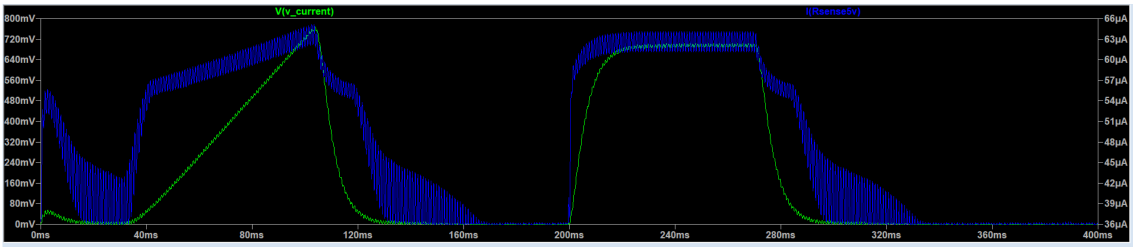


Figure 3.2: Circuit current draw.

3.1. Current sensor

Figure 3.3: Circuit and student card.

=====================Legend=========================

Green= Sense resistor.

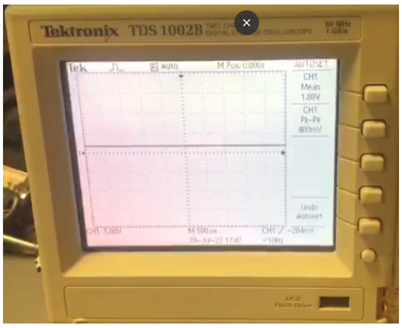
Blue= Input(This is where the motor is connected in series)

Red= VDD

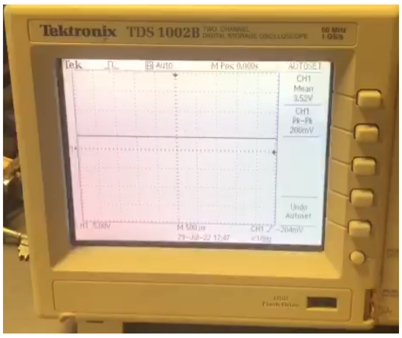
Brown= Output.

==

(a) Voltage output at freerun.



(b) Voltage output at slight load.



(c) Voltage output at stall.

Figure 3.4: Current sense circuit output at different loads.

Bibliography

Appendix A

Social contract

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jou kennisvennoot • your knowledge partner

E-design 344 Social Contract

2022

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 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, Marius Roos 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: 22660003
Signature: MJ Booysen Digitally signed by MJ Booysen Date: 2022.07.02 13:22:09 +02'00'	Signature:
Date: 1 July 2022	Date: 24/07/2022

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Appendix B

GitHub Activity Heatmap