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E344 Assignment 3

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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 30, 2021

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Nomenclature

Variables and functions

V_{GS}	Gate to source voltage
$V_{GS(th)}$	Gate to source thevenin voltage
V_{DS}	Drain to source voltage
R	Resistor
V_{CM}	Common mode voltage
V_{DIFF}	Difference Input Voltage
V_{IN}	Input Voltage
V_{REF}	Reference voltage
V_{OUT}	Output voltage
I_D	Drain current

Acronyms and abbreviations

OP-AMP	Operational Amplifier
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor

Chapter 1

Fuse

1.1. Literature

A fuse is a electric component that is design with the intention of protecting other components, especially against overcurrent conditions. A fuse has a conductive strip build into it that is designed to melt at a specific current value. This stops all current flowing through the fuse and the components on the other side. To allow the electic circuit to fuction again the fuse would have to be replaced with a new one. Fuses are rated in the unit of current:amperes. They are also designed to no amount to any extra resistance in the circuit, until it breaks, then the fuse will function as a open circuit. One thing to note however is that if the fuse is broken and the voltage is high enough(depends on the circuit), a spark could jump the gap of the fuse allow some current to flow through the circuit. This effect could lead to damage to certain components and should be avoided. [1]

1.2. Design

When designing for a fuse to protect the battery [2] the recommended maximum charging current limit should be evaluated. This value for the lead acid battery is sited to be $I_{max} = 1.2A$. Our fuses Ampere rating should thus be lower than I_{max}. Design choice is made to have a fuse with a 1A rating.

As a student we are given 2 options to use RSPro fuses [**?**] or Littlefuses [**?**], but as RSPro fuses only consist of fuses rated higher than our required 1A a $Little_fuse$ will be used. The only little fuse with the correct rating is the black 1A 0287001 fuse. This fuse has a voltage drop of 176mV. This means that for calcultion purposes the fuse can be neglected.

Chapter 2

Undervoltage battery protection

2.1. Overview

The undervoltage protector circuit should start charging the Battery terminal when the voltage at the battery becomes to low, this will protect the battery and increase the live span of it.The undervoltage circuit will consist of two operational amplifiers, one will function as a Schmidt trigger and will use hysteresis to avoid outputs that oscillate between states. The second operational amplifier will invert the Schmidt triggers output and will be fed into the high side switch design to allow the Battery to be charged or dissipate power, depending on the state of the Battery terminal. A 5V regulator will be designed and be used to supply a constant 5V to the circuit. Voltage division will be used at both of the operational amplifiers to avoid the inputs to them to hit the 5V rail. The high side switch will consist of a npn driver transistor and a pnp switch transistor.

2.2. 5V rail

The first design choice to be made when designing a voltage monitoring circuit out of MCP6241 [3] operational amplifiers is to the rail voltages. Under DC conditions $V_{ss} = 0V$ according to the data sheet [3] and the V_{DD} should be between 1.8V and 5.5V. When monitoring the voltage of the battery terminal, binary logic will be implemented where a 5V represents a 1 and 0V represents a binary value of 0. The middle value where a value of 1 and 0 splits is 2,5V. This value is the V_cm of the operational amplifier. Using the equation:

$$V_{cm} = \frac{V_{DD}}{2} \tag{2.1}$$

$$V_{DD} = 5V \tag{2.2}$$

2.3. 5V Voltage regulator

The 5V regulator was designed using the LM2940 1A low dropout regulator using the data sheet. [4] This regulator was chosen because it has a typical output voltage of 5V at $T_{amb} = 25°C$ when the input voltage is between 6.25 and 26V. The input voltage of the regulator should be connected to the battery terminal that will have the required output voltage for the voltage regulator to function properly.

2.4. High-side switch

The design should receive a 5V or a 0V from the voltage monitoring circuit that corresponds to a binary 1 or 0. When the switch receives a 1 the battery will have a voltage below 6V and should therefore be charged by the power supply. The switch should be turned on at this point. If the voltage monitoring circuit returns a 0, the battery will have a voltage larger than 6V and should thus be left to dissipate power. The swithc should off at this point. Because a 1 corresponds to 5V a npn should be used at the terminal of the voltage monitoring circuit. A 2N7000 npn mosfet is chosen for this design [5].The gate input voltage will be 5V and $V_{GS(th)=2.1V}$ typically with a maximum of $V_{GS(th)=3V}$.Therefore 5V will turn on the transistor sufficiently.But one of the design requirements are that we should use a high side switch, a pnp IRF9Z24N [6]. The npn 2N7000 will function as a driver transistor to the IRF9Z24NPBF.The IRF9Z24NPBF $V_{GS} > V_{GS(th)}$ should thus be on when the 2N7000 is turned on. Considering that battery terminal is going to be below or above the 6V and when the 2N7000 npn is turned on $V_{GS} = -6V$ which is above $V_{GS(th)=-4}$ this requirement is met. A 82Kresistor is placed at the IRF9Z24NPBF pnp's gate and source to allow the voltage between the two nodes to differ.

2.5. Voltage monitoring with hysteresis design

Explain your design of the comparator with hysteresis, taking into account things like common mode voltages, differential voltages, input-to-rail voltages, hysteresis deadband, resistor values and current consumption, etc.

When designing a comparator the rail voltages are designed to be $V_{DD} = 5V$ and $V_{SS} = 0V$ as explained is section 2.3. A inverting comparator is designed. This design has a rail of 5V but this will not be a issue as will be seen the highest value possible is about 3.6, when the battery terminal is 7.2V. The battery terminal is compared with 6.2V. However our source voltage is 5V which is less than 6.2V. Voltage division is thus used to achieve appropriate voltage values. Design choice: 6V will be turned into 3V by making $R4 = 200k\Omega$ and R5 = 200kΩ. 6.2V will be turned into 3.1V.R2 = 100KΩis a design choice made. Using voltage division:

$$R1 = \frac{R2}{\frac{3.1}{5}} - R2 \tag{2.3}$$

$$R1 = 61.3k\Omega \tag{2.4}$$

This means:

$$V_{cm} = V_{DD}/2 \tag{2.5}$$

$$V_{cm} = 2.5V \tag{2.6}$$

This is less than $V_{cm(max)=2.75}$ The $V_{Diff(max)} = |V_{DD} - VSS|$:

$$V_{Diff(max)} = 5V \tag{2.7}$$

Our voltage difference is:

$$V_{diff} = 3.1V \tag{2.8}$$

at maximum difference.

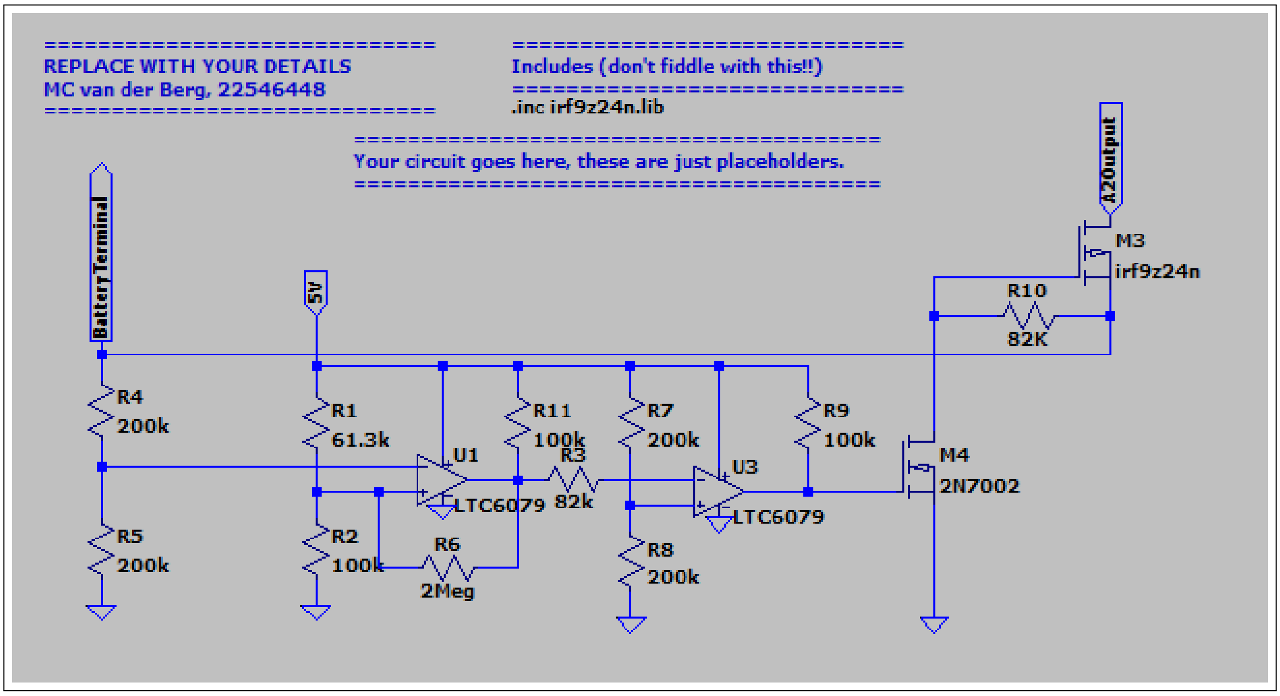
2.5.1. Hysteresis

When the input voltage comes really close to the reference voltage the output of a op amp can begin to oscillate between states. This is especially true when the input can be effected by noise. Hysteresis solves this issue by making use of a feedback resistor connected to the V_{ref} node called a hysteresis resistor. When the input voltage is low the output of the operation amplifier will be high. This voltage at the V_{ref} node is slightly higher than it would have been without hysteresis. For the same reason when the output voltage is low V_{ref} will be lower than it would've been without hysteresis. By changing the reference voltage when ever the input voltage is made a state creates a bigger difference between the two voltage not allowing oscillations in the output to occur.
For the design of this circuit the hysteresis resistor is calculated to be 2MΩ
The comparators output is pulled high through a 100kΩresistor connected from the operational amplifiers output to 5V.
The operational amplifier that has been designed so far is known as a Schmitt trigger. It switches at different voltages depending if the input voltage is moving from 0 to 1 or 1 to 0 [7].
A second operational amplifier is also used. This will be a inverting operational amplifier. Voltage division is used again to choose the reference voltage as $V_{REF} = 2.5V$.R7 =200kΩand R8 = 200kΩto satisfy this requirement. R9 =100kΩand functions as a pull up resistor to not leave the output hanging. The output terminal of this operational amplifier is then connected the 2N7002 npn transistor. The goal of this operational amplifier is to invert the Schmitt trigger.

2.6. Circuit diagram

2.7. Results

The results are as expected. The Battery terminal switches of at 6.2V as designed for. The current is limited and almost zero.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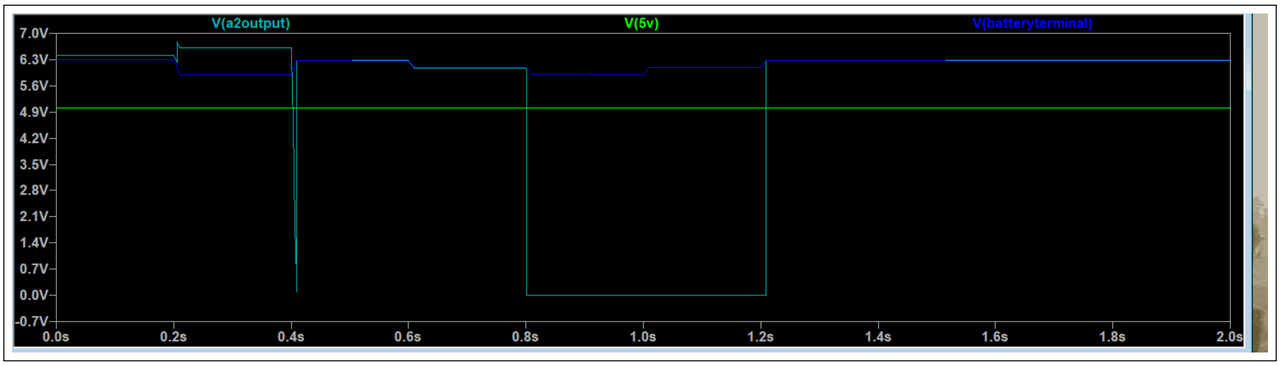
REPLACE WITH YOUR DETAILS
MC van der Berg, 22546448
==============================
==============================
Includes (don't fiddle with this!!)
==============================
.inc irf9z24n.lib
==
Your circuit goes here, these are just placeholders.
==
BatteryTerminal
5V
A2Output
M3
irf9z24n
R10
82K
R4
200k
R5
200k
R1
61.3k
R2
100k
R6
2Meg
U1
LTC6079
R11
100k
R3
82k
R7
200k
R8
200k
U3
LTC6079
R9
100k
M4
2N7002


V(a2output)
V(5v)
V(batteryterminal)
7.0V
6.3V
5.6V
4.9V
4.2V
3.5V
2.8V
2.1V
1.4V
0.7V
0.0V
-0.7V
0.0s
0.2s
0.4s
0.6s
0.8s
1.0s
1.2s
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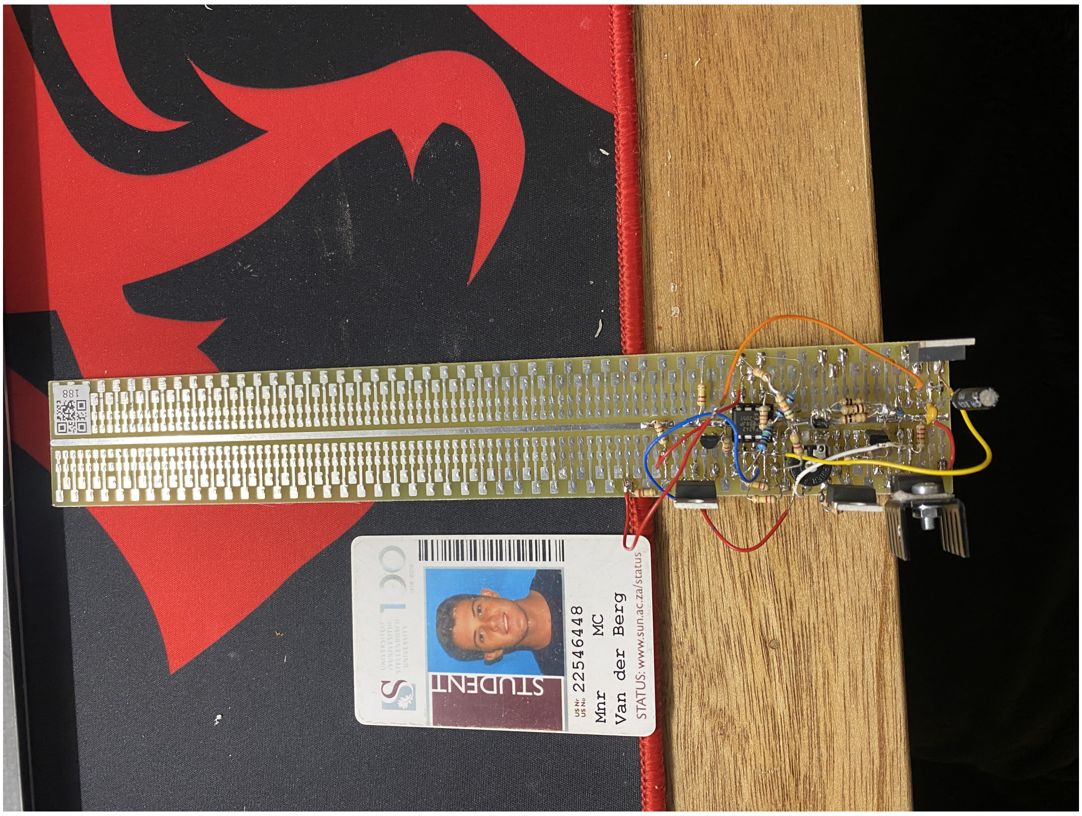
1.6s
1.8s
2.0s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STATUS: www.sun.ac.za/status

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Appendix A

GitHub Activity Heatmap

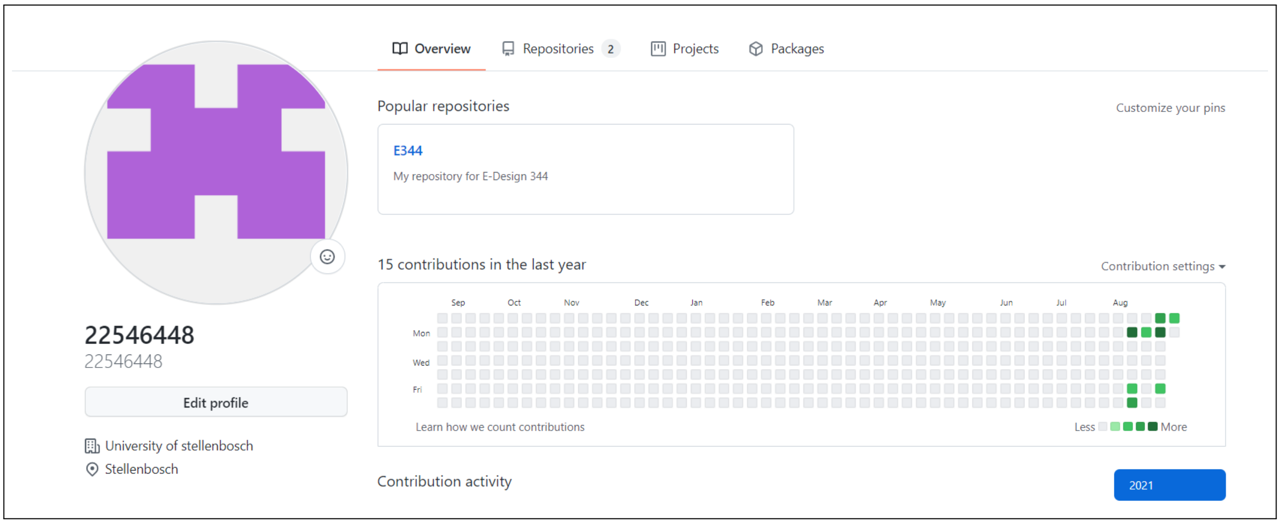

Figure A.1: Heatmap of Github activity

Appendix B

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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, MC van der Berg ..... 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

Signature: Digitally signed by MJ BOOYSEN Date: 2021.08.04 22:12:45 +02'00'

Date: 4 Aug 2021

Student number: 22546448

Signature: Michiel Christiaan van der Berg Digitally signed by Michiel Christiaan van der Berg Date: 2021.08.16 00:28:10 +02'00'

Date: 15 Augustus 2021

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