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E344 Assignment 4

Willem Viljoen

22877169

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.

2 September 2021

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22877169 Studentenommer / *Student number*	Handtekening / *Signature*
W. Viljoen Voorletters en van / *Initials and surname*	2 September 2021 Datum / *Date*

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Nomenclature

Variables and functions

J	Joules
P	Power
W	Watt
V	Voltage/Volts
I	Current
A	Ampere
R	Resistance
Ω	Ohms
Q	Charge
C	Coulomb
t	time
$F.V$	Full Voltage
V_{OC}	Open circuit voltage
I_{SC}	Short circuit current
T_{amb}	Ambient Temperature
T_j	Junction Temperature
V_{sg}	Source to gate voltage
V_{gs}	Gate to source voltage
V_T	Threshold voltage
V_{Supp}	Supply voltage
V_{cc^+}	Positive voltage rail of an op-amp
V_{cc^-}	Negative voltage rail of an op-amp
V_{ref}	Reference voltage of an op-amp
V	Inverting input of an op-amp
V^+	Non-inverting input of an op-amp
R_s	Sense resistance

Acronyms and abbreviations

s.	seconds
e.g.	for example
LED	Light-Emitting Diode
mV	milli Volts
mA	milli Ampere
NMOS	Negative-channel Metal-Oxide Semiconductor
PMOS	Positive-channel Metal-Oxide Semiconductor
MOSFET	Metal–Oxide–Semiconductor Field-Effect Transistor
Temp	temperature
AC	Alternating current
DC	Direct current
op-amp	Operational Amplifier
LTspice	Circuit Simulation Software

Chapter 1

Literature

1.1. Low-side Switch

The low side switch will be used to switch the supply to the load on and off.

1.2. Current Sense

Bidirectional current sensor is connected over a resistor called Rsense. This resistor is placed in series between to battery and the load. It has a very small resistance such that its power dissipation can be neglected, and its tolerance is also very small so that the resistance value is accurate enough to give a more precise current reading through it. Then an op-amp is connected in parallel over the sense resistor with the inverting and non-inverting input terminals of the op-amp. The op-amp produces an amplified voltage signal of the potential difference over the resistor because of the high gain of the op-amp. This voltage signal is proportional to the voltage over the resistor and according to ohms low it is also directly proportional to the current through the resistor. Therefor output of the op-amp now follows the current flowing between the battery and the load and is scaled to represent the current level as an analog signal.

Chapter 2

Design

2.1. Low-side Switch

The given design requires a low-side load control that will help it to manage the current flow to 5 displayed indistinguishable bright LEDs. The low-side load control will be embodied out of a NMOS which will act as a switch to the LEDs and when it receives a control signal of 0V and 5V it will be able to turn on and off. Every one of the LEDs will be drawing 20mA of current, with a battery voltage of V_{bat}=7.2V, this will then lead to total current drawn by the load of 100mA. To be able to successfully meet this present requirement, each LED will need to consist of a current limiting resistor that is connected in series and needs to be designed to limit the current to meet the desired amount for the LED. The mentioned 5 ultra-bright LEDs will be drawing 20mA(each) which we will call, I_{LED}. The LEDs have voltage aimed forward of 3.2V which we will label V_F and the value of the current limiting resistor, R_{lim}, will be calculated by making use of the equation: "$R_{lim} = \frac{V_{bat}-V_F}{I_{LED}}$", and as a result we will get $R_{lim} = 200\Omega$. For the NMOS that preforms the switching we will need a pull down resistor of $10k\Omega$ to get to correct V_{gs} voltage from the 5V rail voltage available to us. See Figure3.1.

2.2. Current Sense

We use the "TSC213" op-amp because it has a large enough gain to amplify to small voltage across Rsense. When the battery is charging 150 mA flows through Rsense which has a resistance of 0.1Ω and 450 mA will flow through Rsense in the opposite direction when the battery dis-charges to full-load. Because of the bidirectional current flow, a zero-reference voltage is required for the op-amp to determine the direction of the current in terms of its voltage output analog signal. a Reference voltage, V_{ref}, is designed for maximum swing while staying in range of the rail voltages of the op-amp. We determine this V_{ref} using the following equations provided by the datasheet op the TSC213 op-amp: "$\Delta V_{out} = \Delta V_{out(charge)} + \Delta V_{out(discharge)} = 3V$" and "$V_{ref} = \frac{5-3}{2} + \Delta V_{out(charge)} = 1.75V$". Furthermore two resistors is designed to apply voltage division to the 5V rail voltage, available for the circuit, to produce the V_{ref} voltage for the op-amp. Thus R1 and R2 is determined with a simple voltage division calculation and then scaled up to prevent unnecessary power dissipation in the resistors, to get the values of $R1 = 13k\Omega$ and $R2 = 7k\Omega$. Lastly the capacitor is placed at the output of the op-amp to filter out the signal, a 47μF capacitor is chosen, it's capacitance is high enough so that the signal is filtered good but not too high otherwise the output will become sluggish.

Chapter 3

Results

3.1. Low-side Switch

The circuit I built and measured is shown Figure3.1, the measurements confirmed the results seen in the simulation shown by Figure3.2.

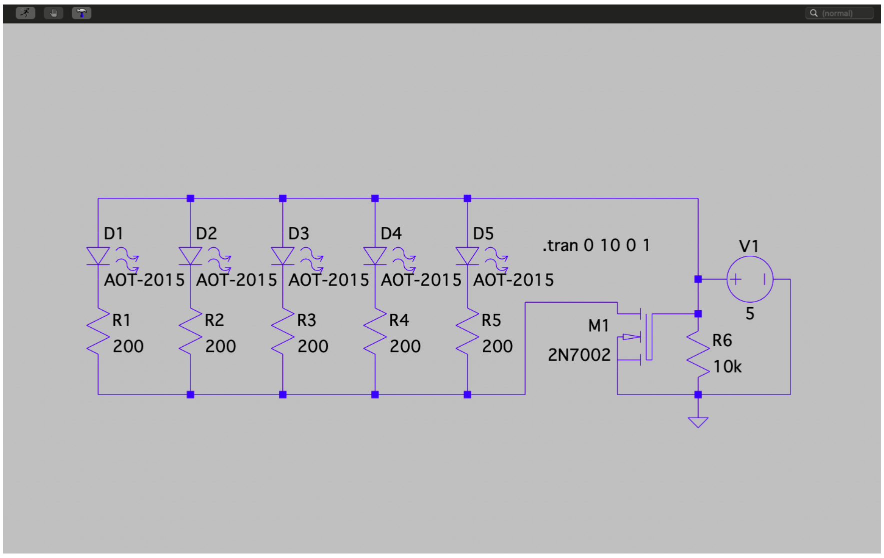


Figure 3.1: Low-side Switch and LED load circuit.

Figure 3.2: Low-side Switch and LED load circuit Simulation.

3.2. Current Sense

The circuit I built and measured is shown Figure3.3, the measurements confirmed the results seen in the simulation shown by Figure3.4.

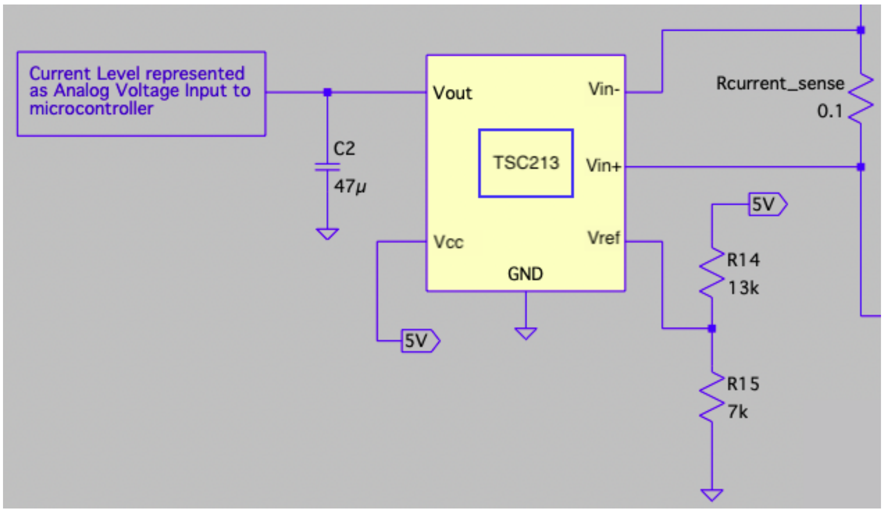


Figure 3.3: Current sense circuit.

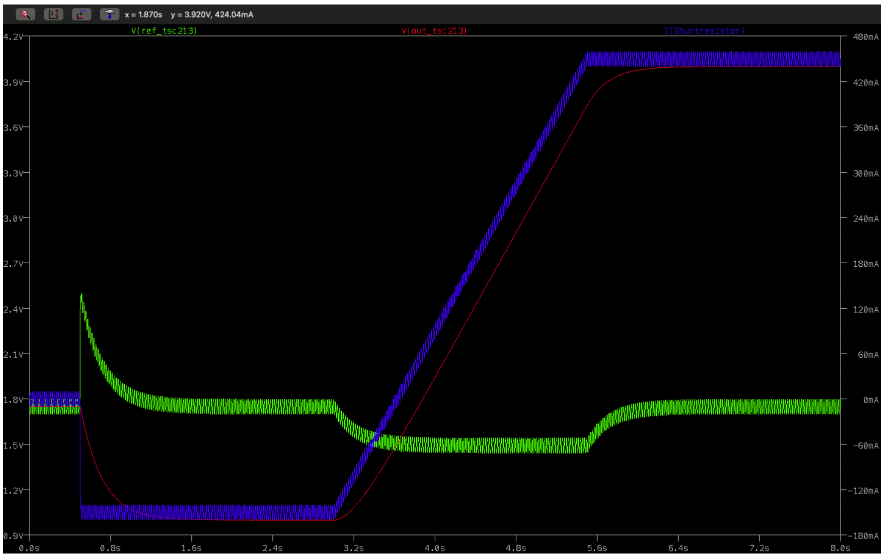
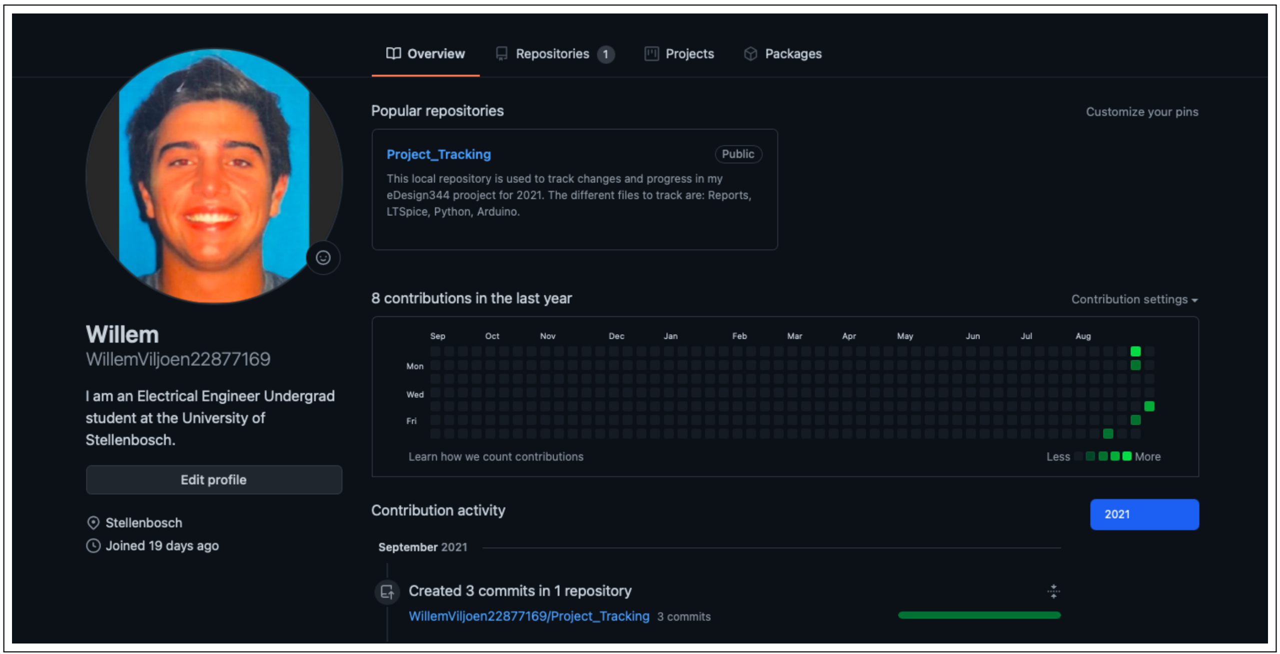


Figure 3.4: Current sense circuit Simulation.

Bibliography

Appendix A

GitHub Activity Heatmap



Appendix B

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, ...Willem Viljoen...................... 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: ....22877169................

Signature: ....

Date: ....16 Aug 2021..........................

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