E344 Assignment 4

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Nomenclature

Variables and functions

V_{BAT}	Voltage battery source
I_{LED}	Current through LED
$VLED$	Voltage over the LED
$V_{GS(th)}$	Gate Threshold Voltage
V_{cc}	Voltage source
V_{out}	Output voltage
I_{LOAD}	Current through the load
R_sence	Current sense resistor value
V_{ref}	Reference voltage
R	Resistor

Acronyms and abbreviations

NPN Negative positive negative

MOSFET Metal–oxide–semiconductor field-effect transistor

LED Light emitting diode mV_{pk} milliVolt peak

Chapter 1

Low-side load control

1.1. Literature

A load will be connected to the battery, this will allow the battery to discharge over the load. We want to be able to control this behaviour and thus need a switch. A low side switch will be build by only using a NPN MOSFET to control the discharge over the load.

1.2. Design

The load consists of 5 ultra bright LEDs connected in parallel with each other. The LEDs will be connected to the 7.2V source and the switch. The ultra bright LEDs datasheet [1] specifies a forward voltage drop of 3.2V.The maximum current that will flow through the load is 150mA, if 150mA flows through the load, each LED will receive a current of 30mA. This is the maximum rated forward current for the ultra bright LEDs according to the datasheet [1] this shouldn't damage the LEDs. The typical current of 100mA(20mA per LED)The NPN that will be used has a $V_{GS(th)} = 2.1V$. 5V will thus be sufficient to turn on the transistor [2].

Designing for one LED we thus use circuit analysis to do the following calculations:

$$Vcc = I_{LED} * R + V_(LED) \tag{1.1}$$

$$7.2 = (20m) * R + 3.2 \tag{1.2}$$

$$R = 200\Omega \tag{1.3}$$

I decided to use R = 220 for safety and labs restrictions.

1.3. Results

The circuit worked as intended. The load could be controlled by the signele NPN MOSFET, but because of resistor tolerance the voltage drop over the LEDs where not exact as the equation anticipated. For the following conditions: Vcc = 7.3V;I = 100mA; R = 220Ω; the led vlotage was 2.91V. This is less than the typical forward volatge. This means that the LED would be as bright as they could be. But also means that the LED are more protected against higher currents.

Chapter 2

Bidirectional current measurement

2.1. Introduction

The RS -4Ah battery [3] has 4 different phases of charging, it should also be allowed to discharge over a load. The battery therefore has many modes it goes through and these modes need to be tracked to determine how the battery is behaving and how other components should behave according to the battery and users desires. A bidirectional current circuit is a circuit that measures the current flowing through a current sense resistor, a resistor so small that the voltage drop over it can be neglected, amplifies the voltage drop by using a amplifier and then sending out a output voltage that correlates to the current flowing through the sense resistor.

2.2. Design

The TLC213 [4] and current sensing resistor [5] was used to design a current sensing resistor. The TLC213 is selected because it has n build in gain of 50V. The TLC213 amplified the voltage difference over the current sensing current would output a voltage output V_{out} between 5V and 0V to determine if the battery is charging or discharging. The TLC213 has a gain of 50V/V and the following resistors where build into the component we received: R1=R2=1MΩ, R3=R4=20kΩ. The reason these components have the same values are to minimize errors such as noise.

The current over the current sensing resistor(1mΩ) will range from -150mA to 450mA and thus the center current (150mA) has to be at the center of the Voltage range. This will allow the best output swing. The following equations are used to determine the reference voltage(V_{ref}) to achieve the goal above:

$$V_{out} = I_{LOAD} * V_{diff} * gain + V_{ref} \tag{2.1}$$

Because we want the center current at the center voltage:

$$V_{out} = I_{LOAD} * R_{sense} + V_{ref} \tag{2.2}$$

$$2.5 = (0.1) * (0.15) * (50) + V_{ref} \tag{2.3}$$

$$V_{ref} = 1.75V \tag{2.4}$$

Because a $Vcc = 5V$, voltage division will be used to achieve the desired reference voltage.This means:

$$V_{ref} = Vcc * \frac{R6}{R6 + R5} \tag{2.5}$$

$$\frac{R6}{R6 + R5} = 0.35 \tag{2.6}$$

Choose R6 = 100kΩ. This value is large enough to minimize current through the resistor and therefore minimizing power dissipation over the resistor as well.

$$R5 = \frac{R6}{0.35} - R6 \tag{2.7}$$

$$R5 = 185.7k\Omega \tag{2.8}$$

The output should be connected to a capacitor that will filter out the high frequency noise, however this capacitor should also be small enough as to not effect the transient response of the TLC213 to much. By running through many simulations in spice and seeing what is available in the labs, a capacitor of 4.7u has been chosen.

2.3. Results

The design requirement state the following:
1. The output voltage must be less than $2mV_{pk}$: The 4.7u capacitor is large enough to filter out high frequency noise the TLC213 might face. The maximum noise measured and seen on spice is 1,6mV which is less than $2mV_{pk}$
2. The circuit response should respond to a change of 150mA in 2 seconds: The capacitor is small enough to achieve this requirement. The measured response is 1.79s, this is less than 2s.
3. Output voltage should be 3V for the given current range: The highest $V_{out} = 4V$ and the lowest $V_{out} = 1V$, this means the output swing is 3V.
4. The voltage range must be 5V to 0V: This range was designed for as indicated above. V_{out} will never achieve 5V or 0V as the output swing does not allow it and this is also undesirable as this would hit the TLC213 Rail voltages.

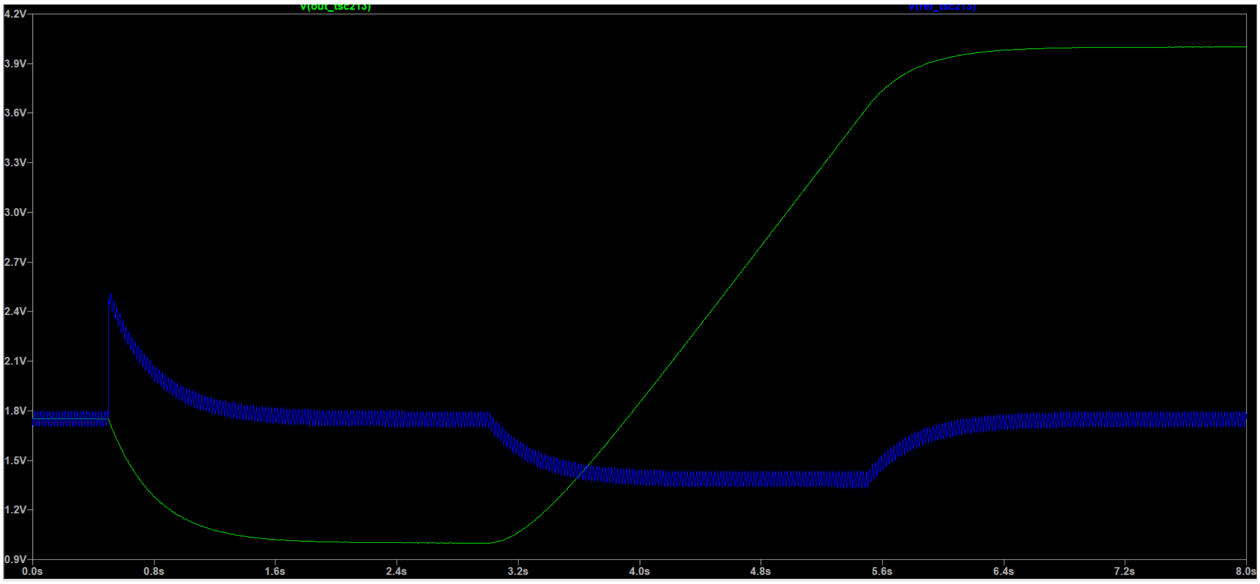

Figure 2.1: LTSPice output simulation graph

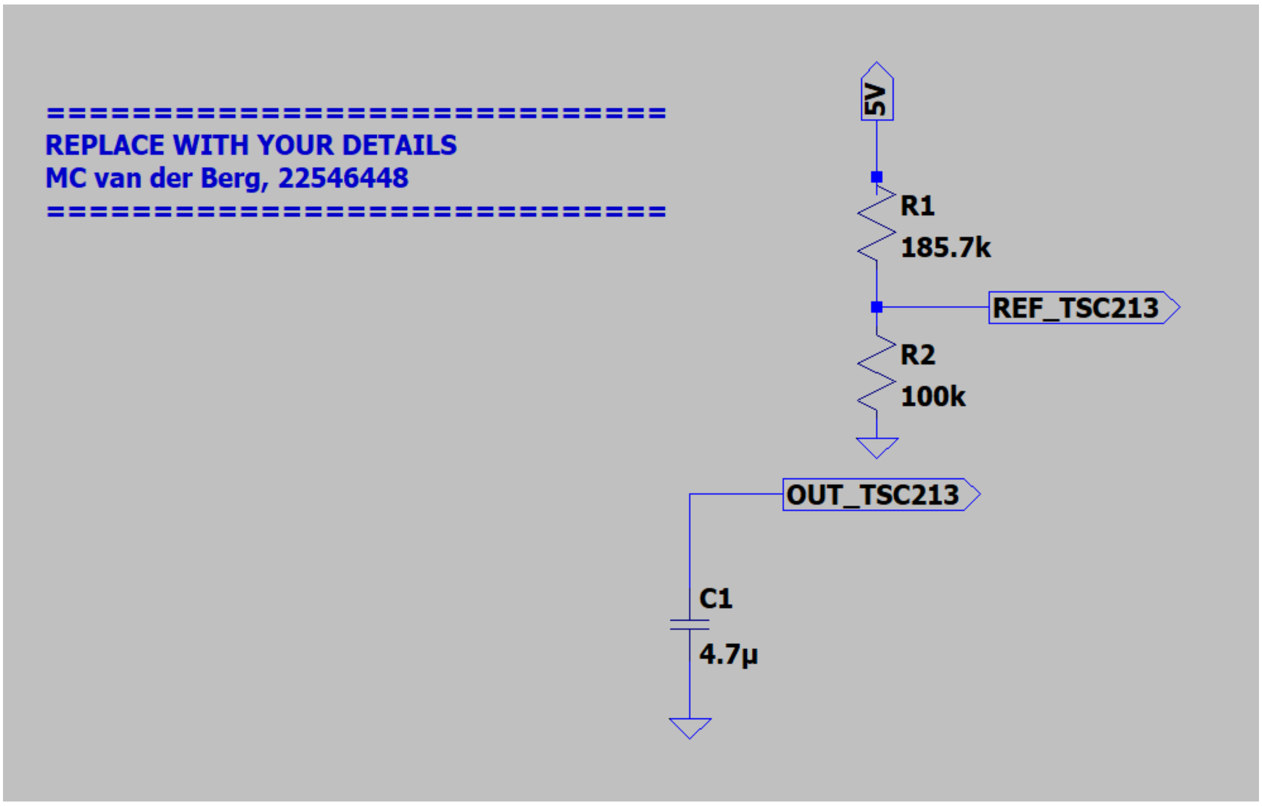

Figure 2.2: LTSpice design schematic

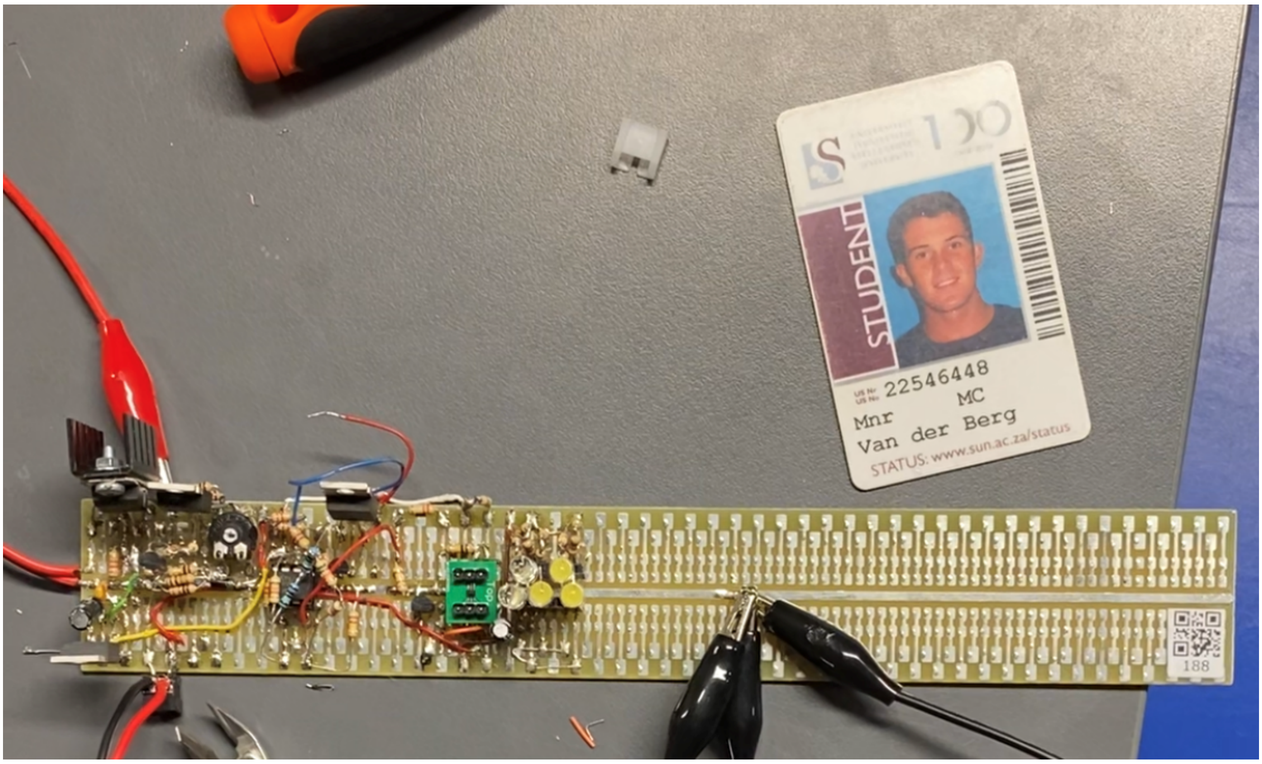

Figure 2.3: MY design and student number

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[3] R. Pro, "Battery:2021," 2021. [Online]. Available: https://learn.sun.ac.za/pluginfile.php/2876542/mod_resource/content/0/battery.pdf

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[5] RSPro, "Datasheet : Metal film resistor," 2021. [Online]. Available: https://learn.sun.ac.za/pluginfile.php/2893570/mod_resource/content/0/Current%20Sense%20Resistor.pdf

Appendix A

GitHub Activity Heatmap

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