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E344 Assignment 6

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Nomenclature

Variables and functions

V_O	The output voltage of the TSC213.
V_{swing}	The output swing of the TSC213.
V_{ref}	The reference voltage of the TSC213.
I_{range}	The current range that the TSC213 is designed for.
R_{shunt}	The resistor value that the TSC213 will measure a differential voltage across.
C	Capacitance used in lowpass circuit.

Acronyms and abbreviations

A	Ampere
µ	micro-
m	mili-
k	kilo-
V	Volts
NMOS	N-channel metal-oxide semiconductor
PMOS	P-channel metal-oxide semiconductor
op amp	Operational Amplifier
LED	Light emitting diode
Ω	Ohms- a measure of resistance
Hz	Hertz- a measure of frequency
F	Faret- a measuremnt of Capacitance

Chapter 1

Battery 0-5V

1.1. Literature

1.2. Design

I this design the battery voltage will be go through a signal conditioning process to make it readable from the perspective of an ADC. The ADC we are going to use requires a voltage between 0 and 5V. The battery voltage will vary between 6V and 7.2V if the complete system is working as designed. For the purpose of the design an additional 0.3V will be extended on to either side of the boundaries (5.7V to 7.5V) Using Op Amps the battery voltage will be designed to vary linearly with an output swing of 3.5V. This 3.5V will be equally spaced from the 0 and 5V boundaries of the ADC (0.75V to 4.25V), the output swing is chosen to be less than 5V in order to prevent possible damage to the ADC in the case that the reconditioned battery voltage exceeds 5V.

The immediate problems faced is that the lowest battery voltage is not 0V but rather 5.7V. This means that the battery voltage will require a shift in order for the design requirements above to be met. This is achieved with an inverting op amp with a reference voltage. The voltages as they are will have to to be divided down in order not to breach the differential voltage limits of the MCP op amps that are being used ($|V_{ss} - V_{dd}|$ [1]). This can be seen in the voltage following section of figure 1.1. A voltage follower is used to prevent the negative feedback of the inverting op amp from interfering with the divided battery voltage. The output of the non inverting amplifier is significantly smaller than the requirements. Therefore a non inverting amplifier is then used to amplify this output to required levels.
To calculate suitable values I worked backwards from the output to the input.

$$V_{out-invert} = 2 \times V_{invert-ref} + (-1) \times (\frac{R_{F1}}{R_{in1}}) \times V_{invert-in} \tag{1.1}$$

$$V_{noninvert-out} = (1 + \frac{R_{F2}}{R_x}) \times V_{out-invert} \tag{1.2}$$

The non inverting amplifier is chosen to have a gain of 15. This means that to achieve the output range ”0.75V to 4.25V” the non inverting amplifier requires 15 times less than the output ”50mV to 283.3mV”. Due to using an inverting amplifier the point at which the inverting output is 283.3mV the battery voltage will be 5.7V and when the inverting output is 50mV the battery voltage will be 7.5V. Using eq.1.1 and solving simultaneously for $V_{invert-in}$ ($V_{invert-in} = V_{bat} \times \frac{R_2}{R_2+R_1}$). The inverting amplifier is designed to have unity gain as it only serves the purpose of shifting the battery voltage down. The resistor values are then found to be , R_1=180kΩ and R_2=27kΩ. Detailed calculations can be found at appendix B. $V_{invert-ref}$ is calculated to be 511mV and is implemented by dividing the 5V regualtor voltage with R_3 and R_4 (refer to figure 1.1).

To achieve a gain of 15 for the non inverting amplifier ($1+\frac{R_{F2}}{R_x}$ from eq.1.2) must be equal to 15. R_{F2} is chosen to be 150kΩ and R_x is calculated to be 10.71kΩ. Two lab 22kΩ resistors in parallel are used to implement R_x (refer to 1.1).

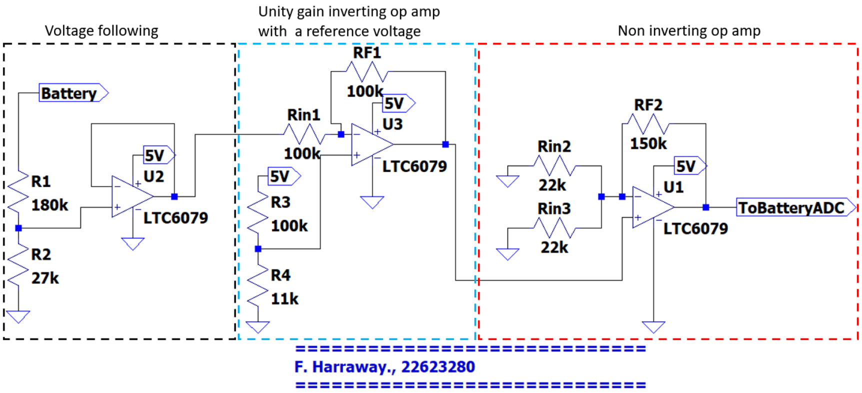


Figure 1.1: Battery Voltage Conditioning Circuit

1.3. Results

Chapter 2

Bidirectional current measurement

2.1. Overview

2.2. Literature

2.3. Design

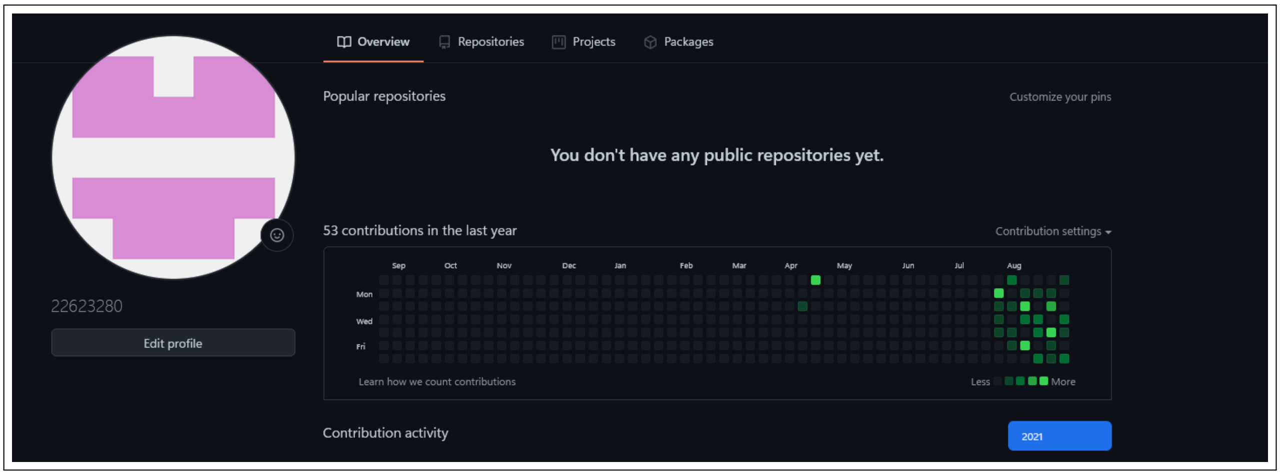
2.4. Results

Bibliography

[1] Microchip Technology, “Mcp6241/1r/1u/2/4,” 2008. [Online]. Available: https://learn.sun.ac.za/pluginfile.php/2893569/mod_resource/content/0/MCP6241.pdf

Appendix A

GitHub Activity Heatmap



Appendix B

Calculations

$$V_{out-invert} = 2 \times V_{invert-ref} + (-1) \times (\frac{R_{F1}}{R_{in1}}) \times V_{invert-in} \tag{B.1}$$

$$V_{invert-in} = \frac{R_2}{R_2 + R_1} \times V_{bat} \tag{B.2}$$

$$V_{noninvert-out} = (1 + \frac{R_{F2}}{R_x}) \times V_{out-invert} \tag{B.3}$$

Using eq.B.2 and B.1 the equation below is setup.

$\frac{R_2}{R_1+R_2} = \frac{2\times V_{invert-ref}-283.3mV}{5.7} = \frac{2\times V_{invert-ref}-50mV}{7.5}$

$V_{invert-ref} = 511mV$ R_1 chosen to be 180k and $R_2 = 26.8\text{k}\Omega$(lab resistor is 27kΩ)