Homework 4: Batteries

24-775 Robot Design & Experimentation

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Consider the battery and power supply selection for X-RHex. Be sure to show your work.

Introduction: Before beginning this homework, if you have not recently taken a circuits course, read the supplemental slides posted on the Canvas page for this assignment. In addition to these slides and the lecture notes, you may also find the following resource useful: https://rogershobbycenter.com/lipoguide/

a) The chosen battery is a 10S 3900mAh lithium polymer battery rated to 20C continuous discharge, or 40C peak discharge rate. What are the max (fully charged), nominal, and minimum safe voltage for this battery?

b) Each of the six motors draw about 3A of current on average and a peak of 20A, while the other electronics draw around 2A. What are the continuous and peak current available from this battery, and are they enough to meet the demands for X-RHex? (The actual average power draw is less than this, but 3A represents a "worst case" usage pattern).

c) How long will the robot be able to run at this average continuous power draw?

d) The internal resistance of the battery is 40 mΩ. When X-RHex is drawing the average continuous current, what is the voltage drop from the internal resistance? When X-RHex is drawing the maximum peak current, what is the voltage drop from the internal resistance?

e) We now want to pick a 5V regulator to run the computer and other electronics. We will pick from DigiKey in the "DC DC Converter" category (as the input and output are both DC, direct current): https://www.digikey.com/products/en/power-supplies-board-mount/dc-dc-converters/922 The power supply package that we can fit is a "Sixteenth Brick" package[1]. Start by assuming the battery is always at its nominal voltage. We want a power supply that can provide 5V with at least 10A of current. What is the cheapest option available? Explain how you found this part. (Do not worry about what is in stock or minimum quantity for orders, though if you were to actually buy one those would matter).

f) The actual voltage of the battery will vary with state of charge, rate of discharge, temperature, etc. If we want a power supply that can handle the full voltage range we found in part a), what is the cheapest option available? Explain how you found this part.

[1] Power supplies are often sized in fractional units of a "brick". For background on the "brick" sizing, see e.g. https://www.sunpower-uk.com/glossary/power-brick/

g) In part b) we assumed 2A at the battery voltage for the electronics. But we only know the amount of current (10A) that the electronics draw at 5V. For these switching power supplies, the key equation is:

(Power out) = (Power in) * (Efficiency)

(And, of course, Power = Voltage * Current). Based on the efficiency of your chosen power supply, what is the peak current at the battery that the electronics will require? (Hint: Consider the full range of battery voltages).

(a) Max: 42V Nom: 37V Min: 30V

(b) Continuous $3 \times 6 + 2 = 20A$

Peak: $20 \times 6 + 2 = 122A$

$3900mAh = 3.9Ah$

Continuous: $3.9 \times 20 = 78A \geq 20A$ enough

Maximum: $3.9 \times 40 = 156A > 122A$ enough

(c) $3.9 \div 20 \times 60 = 11.7$ mins

(d) $40m\Omega = 40 \times 10^{-3}\Omega$

$I_{avg} = 20A$

$V = I_{avg}R = 20 \times 40 \times 10^{-3} = 0.8V$

$I_{max} = 122A$

$V = I_{max}R = 122 \times 40 \times 10^{-3} = 4.88V$

(e) Selection Creteria

Package type: sixteenth bricks

Max Allowed Input Voltage: ≥37V

Output voltage: = 5 V

Output Current: ≥ 10 A

PKU4611ASIP

$15.08

Spec: Min Input: 36V, Max Input: 60V

VoltageOutput: 5V, Current output: 12A

(f) Package type: sixteenth bricks

Min Allowed Input ≤30V

Max Allowed Input Voltage: ≥42V

Output voltage: = 5 V

Output Current: ≥ 10 A

PKU5511ESI

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Spec: Min Input: 18 V, Max Input: 75V

VoltageOutput: 5V, Current output: 10A

(g) $10 \times 5 \div 0.92 \div 30 = 1.81$ A