Calculation of Values of Components Required for DC-DC Converter

# Section 1: Objective

The objective of this calculation is to determine the values of the passive components used in tandem with the DC-DC converter required for the circuit to have 5 V available to certain components (the Jetson Nano, motor drivers, and limit switches).

# Section 2: References

The equation for calculating Rtrim is provided in the datasheet for the selected DC-DC converter, available at Digikey: <https://www.digikey.ca/en/products/detail/bel-fuse-inc/VRAE-10E1A0G/1754625>

# A file from Texas Instruments was consulted regarding capacitor calculations for DC-DC converters: <https://www.ti.com/lit/an/slta055/slta055.pdf?ts=1615409420996&ref_url=https%253A%252F%252Fwww.google.com%252F>

# Links and datasheets for other relevant information regarding components implemented in the electrical circuit are available in the Datasheets folder of Electrical Detail Design on Microsoft Teams for MTE 380 Project Group 13.

# Section 3: Design Inputs

It is known that the required output voltage is 5 V.

The steady state output current is, conservatively, 5.5 A. See Section 4: Assumptions for justification.

The TI document explaining capacitor calculations suggests a value of 75 mVpp as the maximum allowable input voltage fluctuation.

Provided an input voltage of 12 VDC, the desired output voltage is 5 VDC.

The switching frequency of the DC-DC converter is given in its datasheet as 500 kHz.

The efficiency of the DC-DC converter when outputting 5 V is given in the datasheet as somewhere between 91 % and 93 %.

# Section 4: Assumptions

The most current that the Jetson Nano will draw is 5 A, and the most current that a limit switch will draw is 0.01 A. Therefore, current drawn by the stepper motor drivers combined will not exceed the allowed 0.47 A per the design input steady state output current.

An output voltage between 4.9 V and 5.1 V is permissible (i.e. components of the circuit will continue to operate safely within this range). In fact, this range is conservative compared to the values listed in datasheets as damaging to the components.

As a conservative factor, the efficiency of the DC-DC converter is assumed to be 91 %.

# Section 5: Analytical Method and Computations

A single equation for each necessary component is available.

For the trim resistor that controls the output voltage of the DC-DC converter, the following equation is pulled from the datasheet:

(1)

For the capacitor on the input (12 V) line to the DC-DC converter, the following equation is found in the TE document:

(2)

Where *dc* is the duty cycle,

(3)

Calculations for the capacitor on the output (5 V) line from the DC-DC converter are significantly more complex. For this reason, the capacitor configuration used to obtain specifications in the converter’s datasheet is employed: there is a 10 μF tantalum capacitor and a 1 μF ceramic capacitor at the output.

# Section 6: Calculations

The trim resistor value is most easily calculated using Equation 1:

To fit within the allowable output voltage range of 4.9 V to 5.1 V, the resistor can take on a range of values:

For the input capacitor, the duty cycle must first be calculated:

Therefore, using the minimum input capacitor value equation,

As previously stated, this document will be updated at a future date with the output capacitor value.

# Section 7: Results/Conclusions

The calculated value of the trim resistor used to control the output voltage should be ~268 Ω, but any value between 262 Ω and 268 Ω will still provide a typical output voltage between 4.9 V and 5.1 V.

The calculated value of the input ceramic capacitor should be greater than or equal to 36.4μF, since increasing this value as necessary for parts selection makes sense as higher capacitances continue to improve noise rejection.

The selected output capacitors are a 10 μF tantalum capacitor and a 1 μF ceramic capacitor at the output, per the datasheet’s “Output Specifications” table.

(Although calculations are not required for it, this seems an appropriate place to report selecting a pull-up resistor value of 10kΩ for the enable pin of the DC-DC converter. Pull-up resistors are typically large values to mitigate odd behaviours, and 10kΩ is a common value.)