

Hexapod DC-DC Buck Converter Calculations

Primary IC: LT3741EFE#PBF

Data Sheet: <https://www.analog.com/media/en/technical-documentation/data-sheets/37411fg.pdf>

$$V_O := 15 \text{ V} \quad V_{IN} := 22 \text{ V} \quad (\text{Vin varies between 17V and 25V})$$

Frequency

$$R_T := 82.5 \text{ k}\Omega \quad \therefore \quad f_S := 500 \cdot \text{kHz} \quad \text{Table 4 of Data Sheet}$$

Current Limit

$$R_S := 5 \cdot 10^{-3} \cdot \Omega \quad \therefore \quad I_{Omax} := 10 \text{ A} \quad \text{From Figure 2 of Data Sheet}$$

$$P_{Rs} := I_{Omax}^2 \cdot R_S = 0.5 \text{ W}$$

$$V_{CTRL1} := 2 \text{ V} \quad \therefore \quad I_O := \frac{V_{CTRL1}}{30 \cdot R_S} = 13.333 \text{ A} \quad \text{Io is regulated output current}$$

Output current regulation

Maximum Current is drawn and voltage drops (no overcurrent shutdown)

$$V_{CTRL1} := 2 \text{ V} \quad V_{CTRL2} := 2 \text{ V}$$

$$I_{output_max} := \frac{I_{Omax} \cdot V_{CTRL2}}{V_{CTRL1}} = 10 \text{ A}$$

Inductor

$$L := \left(\frac{V_{IN} \cdot V_O - V_O^2}{0.3 \cdot f_S \cdot I_{Omax} \cdot V_{IN}} \right) = 3.182 \text{ }\mu\text{H} \quad \text{15% ripple at maximum regulated current}$$

$$L_{actual} := 4.7 \cdot \mu\text{H}$$

$$I_{sat} := I_{Omax} \cdot 1.2 = 12 \text{ A} \quad \text{20% higher than maximum current}$$

Boot Capacitor

Should be between 50nF and 220nF. $C_{Boot} := 100 \text{ nF}$

Feedback

$$R_1 := 5.6 \text{ k}\Omega \quad R_{POTmax} := 64 \text{ k}\Omega \quad \text{Using a 100k Potentiometer}$$

$$V_{OUTmax} := 1.21 \cdot V \cdot \left(1 + \frac{R_{POTmax}}{R_1} \right) = 15.039 \text{ V}$$

Mosfets

$$I_{MAX} := I_{Omax} + \left(\frac{V_{IN} \cdot V_O - V_O^2}{2 \cdot f_S \cdot L_{actual} \cdot V_{IN}} \right) = 11.015 \text{ A}$$

$$R_{PD} := 1.3 \text{ } \Omega \quad R_{PU} := 2.3 \text{ } \Omega \quad \rho_T := 1.3 \quad @70^\circ\text{C Ambient operating temperature}$$

MOSFET LOW SIDE: <https://www.infineon.com/dgdl/irf7413zpdf.pdf?fileId=5546d462533600a4015355fab6901bc2>

$$Q_{GD_L} := 3 \cdot \text{nC} \quad Q_{GS_L} := 3 \cdot \text{nC} \quad Q_{GL} := 14 \cdot \text{nC}$$

$$R_{DS_ON_L} := 10 \cdot 10^{-3} \cdot \Omega \quad R_{G_L} := 3 \text{ } \Omega \quad \text{Arbitrary gate resistance}$$

$$P_{LOSS_L} := \left(\frac{V_O}{V_{IN}} \cdot I_O^2 \cdot R_{DS_ON_L} \cdot \rho_T \right) + \left(\left(\frac{V_{IN} \cdot I_O}{5 \cdot V} \right) \cdot ((Q_{GD_L} + Q_{GS_L}) \cdot f_S) \cdot (2 \cdot R_{G_L} + R_{PU} + R_{PD}) \right) = 3.265 \text{ W}$$

MOSFET HIGH SIDE: <https://assets.nexperia.com/documents/data-sheet/BUK9Y21-40E.pdf>

$$Q_{GD_H} := 2.7 \cdot \text{nC} \quad Q_{GS_H} := 1.2 \cdot \text{nC} \quad Q_{GH} := 7 \cdot \text{nC}$$

$$R_{DS_ON_H} := 21 \cdot 10^{-3} \cdot \Omega \quad \rho_T := 1.3 \quad @70^\circ\text{C Ambient operating temperature}$$

$$R_{G_H} := 4 \text{ } \Omega \quad \text{Arbitrary gate resistance}$$

$$P_{LOSS_H} := \left(\frac{V_O}{V_{IN}} \cdot I_O^2 \cdot R_{DS_ON_H} \cdot \rho_T \right) + \left(\left(\frac{V_{IN} \cdot I_O}{5 \cdot V} \right) \cdot ((Q_{GD_H} + Q_{GS_H}) \cdot f_S) \cdot (2 \cdot R_{G_H} + R_{PU} + R_{PD}) \right) = 4.636 \text{ W}$$

$$P_{LOSS_LDO} := (V_{IN} - 5 \text{ V}) \cdot (Q_{GH} + Q_{GL}) \cdot f_S = 0.179 \text{ W}$$

Input Capacitor

4 uF/A of output current "The input CAP should have a ripple current rating equal to half of the maximum output current."

$$\therefore C_{IN} := 47 \text{ } \mu\text{F}$$

\therefore Ripple should be > 5A

<https://www.mantech.co.za/ProductInfo.aspx?Item=14M2932> Not sure this meets the ripple rating requirements

Additionally add 1uF grounded ceramic cap close to Vin pin

Output Capacitor

min 20 uF/A of output current

$$\therefore C_{OUT} := 20 \cdot \frac{\mu\text{F}}{\text{A}} \cdot I_{Omax} = 200 \text{ } \mu\text{F}$$

should have as low as possible ESR & **surge rated to maximum output current**, use capacitors in parallel to achieve lower ESR

<https://za.rs-online.com/web/p/aluminium-capacitors/8392338/>

$$C_{CAP} := 100 \cdot \mu\text{F}$$

$$ESR := 25 \cdot 10^{-3} \cdot \Omega$$

$$\therefore C_{OUT} := 4 \cdot C_{CAP} = 400 \text{ } \mu\text{F}$$

$$ESR_{Total} := \frac{ESR}{4} = 0.006 \text{ } \Omega$$

VCC_INT Capacitor Selection

"For driving MOSFETs with gate charges larger than 10nC, use 0.5uF/nC of total gate charge"

$$Q_{Total} := Q_{GH} + Q_{GL} = 21 \text{ nC}$$

"It is recommended ESR be lower than 50mOhm to reduce noise within LT3741"

$$C_{VCC_INT} := 0.5 \cdot \frac{\mu F}{nC} \cdot Q_{Total} = 10.5 \mu F$$

<https://www.mantech.co.za/ProductInfo.aspx?Item=14M2932>

$$\therefore C_{VCC_INT} := C_{IN} = 47 \mu F$$

VCC_INT Shottkey Diode Selection

<https://www.mantech.co.za/ProductInfo.aspx?Item=35M1016>

Low Voltage input shutdown

"common mode range is from 0V to 2V below Vin supply rail."

$$V_{HYST} := 0.5 \text{ V} \quad V_{UVLO} := 15 \cdot V$$

$$R_2 := \frac{V_{HYST}}{5.5 \cdot \mu A} = 90.909 \text{ k}\Omega \quad \therefore R_2 = 91 \cdot k\Omega$$

$$R_3 := \frac{1.55 \cdot V \cdot R_2}{V_{UVLO} - 1.55 \cdot V} = 10.477 \text{ k}\Omega \quad \therefore R_3 = 10.5 \cdot k\Omega$$

Average Current Mode Control Compensation

$$R_C := \frac{f_S \cdot L_{actual} \cdot 1000 \text{ V}}{V_O \cdot R_S} \cdot \Omega = 31.333 \text{ k}\Omega \quad \therefore R_C = 31.6 \cdot k\Omega$$

$$C_C := \frac{0.002}{f_S} \cdot \frac{F}{s} = 4 \text{ nF} \quad \therefore C_C = 4.7 \cdot nF$$