

How to Choose the Right Inductor for DC-DC Buck Applications

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DC-DC converters of different varieties are widely used in markets such as telecommunications, automotive, medical (portable), and industrial. The 'buck' DC-DC converter is employed to step voltages down without isolation and utilizes an inductor as an energy storage element. This article will explain how to choose the right Inductor for DC-DC Buck applications to get optimum performance.

A simplified buck converter schematic can be observed in Figure 1. The output voltage of this converter is always lower than the input voltage.

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When S1 is open, the energy stored in the inductor sustains the current through the load through D1 with C1 also discharging into the load. S1 switches at high frequency and the duty cycle of switching defines the output voltage.

When S1 is closed, the DC input voltage is applied to the output filter inductor L1 and current flows through the inductor into the output capacitor C1 and to the load.

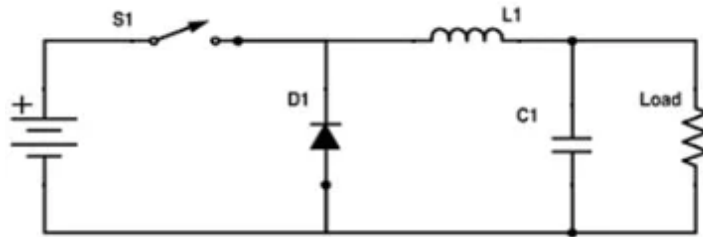


Figure 1. Simplified buck schematic

When selecting an inductor for a buck converter the following parameters need to be defined:

- Maximum input voltage = $V_{in \max}$
- Minimum input voltage = $V_{in \min}$
- Maximum output current = $I_{out \max}$
- Operating frequency = f
- Output voltage = V_{out}
- Minimum output current = $I_{out \min}$

So, for example, with $f = 500 \text{ kHz}$, $V_o = 5 \text{ volts}$, $I_{out \max} = 4 \text{ amps}$, $I_{out \min} = 0.5 \text{ amps}$, $V_{in \max} = 13.5 \text{ volts}$ (car battery) and $V_{in \min} = 8.5 \text{ volts}$.

You can select what the inductor ripple current is – it sets output ripple voltage across the ESR of C1.

For this example, the inductor current stays continuous at the minimum specified load. So, the minimum of the ripple current just touches zero at minimum load, as seen in Figure 2. This makes control loop compensation a lot simpler. The inductor current stays continuous at any load, even with high ripple current, if D1 is a synchronous rectifier MOSFET. Though high ripple current does generate higher core losses.

Calculations

Since the operating frequency is 500 kHz,

$$\text{Total period} = T = \frac{1}{f} = \frac{1}{500000} = 2 \mu\text{sec}$$

Find the minimum duty ratio, D_{\min}

$$D_{\min} = \frac{V_{\text{out}}}{V_{\text{in max}}} = \frac{5 \text{ V}}{13.5 \text{ V}} = 0.37$$

Find the required inductance value, L

$$L = \frac{(V_{\text{out}} + V_{\text{diode drop}})(1 - D_{\min})T}{2 \times I_{\text{out min}}} = \text{henry}$$

$$L = \frac{(5+1)(1-0.37)(2 \times 10^{-6})}{2 \times 0.5} = 7.56 \mu\text{H}$$

Find the delta current (ripple current), ΔI

$$\Delta I = \frac{T V_{\text{in max}} D_{\min} (1 - D_{\min})}{L} = \text{amps}$$

$$\Delta I = \frac{(2 \times 10^{-6})(13.5)(0.37)(1-0.37)}{7.56 \times 10^{-6}} = 0.833 \text{ amp}$$

Find the peak current, I_{pk}

$$I_{\text{pk}} = I_{\text{out max}} + \left(\frac{\Delta I}{2} \right) = \text{amps}$$

$$I_{\text{pk}} = 4 + \left(\frac{0.883}{2} \right) = 4.42 \text{ amps}$$

Find the RMS current, I_{rms}

$$I_{\text{rms}} = \sqrt{I_{\text{out max}}^2 + \Delta I^2} = \text{amps}$$

$$I_{\text{rms}} = \sqrt{16 + 0.69} = 4.09 \text{ amps}$$

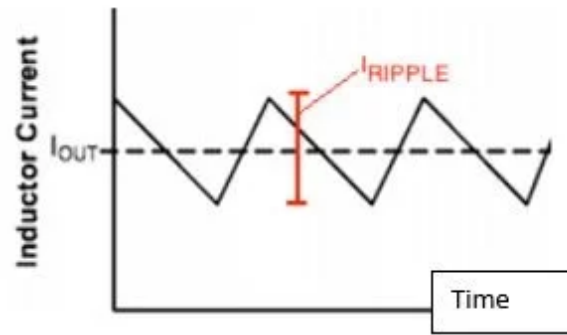


Figure 2. Typical inductor ripple current

An optimum inductor can be chosen using TT Electronics (TT) inductor datasheets. In this example, TT part number HA72L-06308R2LFTR is suggested, which is automotive grade, -55 °C to +155 °C (AEC-Q200 certified) with the electrical parameters below:


TT p/n	L @ 0 amp	DCR typical	DC R max	I rms	I dc (sat) 30% Roll off	Typical picture
HA72L-06308R2LFTR	8.2 μ H	64 m Ω	68 m Ω	4.0 amps gives about 40 °C Temp Rise	7.5 amps	

Table 1. Data sheet specification for TT part HA72L-06308R2LFTR

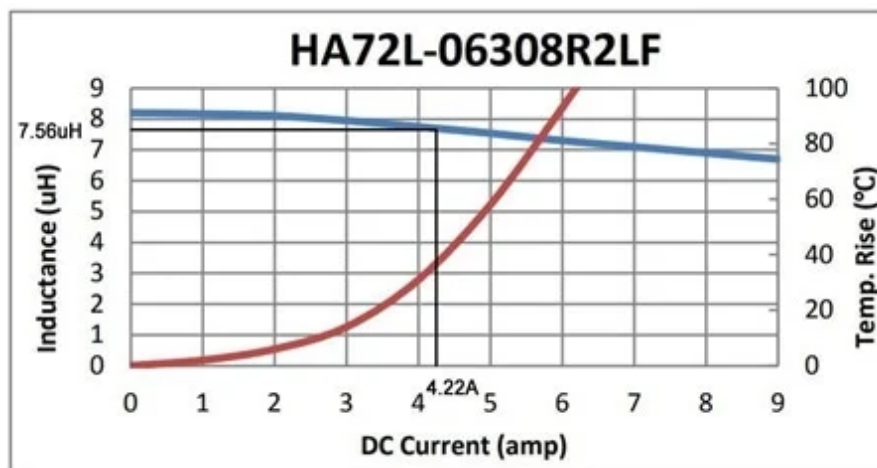


Figure 3. HA72L-06308R2LF DC bias and Temp rise

Figure 3 shows the inductance roll-off is $(1 - \frac{7.7}{8.2}) 100 = 6.1\%$ at 4.42 amps DC, which is close to the required value of 7.56 μ H with a temperature rise of less than 40 °C.

The temperature rise in the data sheet graph is for DC current. In the example, there is also AC ripple current. A more precise temperature rise calculation, including ohmic and AC loss effects in

the core and wire, is beyond the scope of this article but would be dependent on the below parameters:

1. Skin depth at the operating frequency
2. Surface area of the inductor
3. Wire resistance at the operating temperature
4. AC flux density, B_{AC} , calculated from peak current, inductance, core cross sectional area and number of turns

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