METCOM
KEMET POWER INDUCTORS

Electronic Components
KEMET
CHARGED®

Application Note for DC-DC Regulators

INTRODUCTION

The basic inductance versus voltage relationship is the starting point for any switching regulator:

$$V_L = L\frac{di}{dt}$$

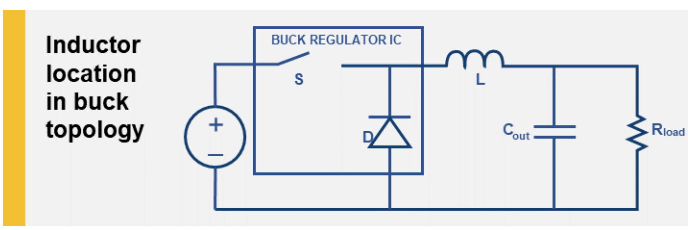
$$E = \frac{1}{2}L \times I^2 \quad \text{(Peak Core Energy in Joules)}$$

Where:

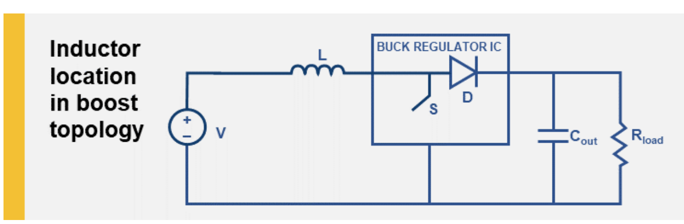
- *L* : Inductance in Henrys
- *I* : Peak current in Amps
- V_L : Voltage across the inductor
- *di* : Ripple current (changes in current)
- *dt* : Duration the voltage is applied
- *E* : Energy in Joules

Next, the application voltage needs to be defined:

If $V_{in} > V_{out}$ use a buck converter.



If $V_{in} < V_{out}$ use a boost converter.



The amount of inductance needed is determined by:

- Output voltage
- Input voltage (max)
- Switching frequency (IC and EMI)
- Maximum ripple current

The output current (I_{out}) of the regulator should be less than the maximum rated current of the inductor.

The inductor current and peak current of the design is based on the following relationships:

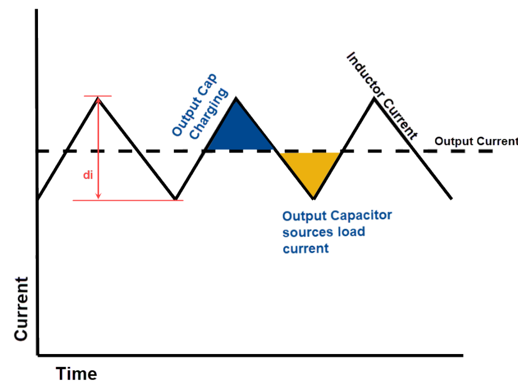


Figure 1 – Inductor Current

The ratio between the inductor current (AC component) and the output current (DC component) is the Ripple Current Ratio (r_{cr}).

SWITCHING FREQUENCY

The typical switching frequency for these regulators is between 30 kHz and 1 Mhz. The most common switching frequencies range from 300 – 500 kHz, and as switching frequency increases, the inductor size is reduced.

The current from a switching regulator has AC components that will flow through the output capacitor. The output capacitor ESR defines the ripple voltage generated by the AC component of the current.

INDUCTANCE SIZE

As the needed inductance is reduced, the amount of generated ripple current is also reduced. A smaller ripple current means smaller ripple voltage, allowing higher ESR capacitors for a given voltage output.

The r_{cr} is commonly used in a range of 0.25 to 0.4. Selecting a low r_{cr} means the inductance will be higher, while a lower RMS current is demanded by the output capacitor. r_{cr} selection also drives the actual physical size of the inductors.

BUCK CONVERTER INDUCTOR SELECTION

The driving equation to estimate the inductor is:

$$L = \frac{(V_{in} - V_{out}) \times (V_{out} + V_D)}{(V_{in} + V_D) \times r_{cr} \times I_{out} \times freq.} \times 10^6 \ (\mu H)$$

V_D Diode Voltage losses (~0.5 V for Schottky).

V_{in} is the <u>maximum</u> voltage expected.

For this example, assume the following requirements:

Input Voltage:	12 V – 36 V	Output Voltage:	5 V
Ripple Voltage:	40 mV p-p	Output Current:	1 A
Ripple Current:	300 mA	Current Frequency:	350 kHz

$$di = \frac{Ripple\ Voltage}{ESR\ Capacitor} = \frac{40mV}{120m\Omega} = 0.33A$$

$$r_{cr} = \frac{di}{I_{out}} = \frac{0.33A}{1A} = 0.33 \quad (\textit{within 0.25 to 0.4})$$

Note: Selecting r_{cr} influences where the discontinuous mode will be triggered.

$$L = \frac{(36V - 5V) \times (5V + 0.5)}{(36V + 0.5) \times 0.33 \times 1A \times 350kHz} \times 10^6 \ (\mu H)$$

$$L = 40.44 \ \mu H$$

Located inside METCOM's data sheet is part number **MPX1D0840L470**, which is 47 µH.

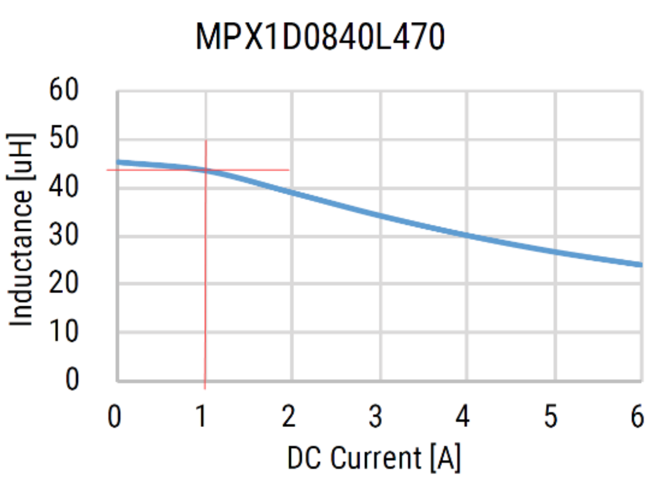


Figure 2 – Buck Inductor Rating

The next step after this is to pick your input capacitor and output capacitor to meet the requirements. Note the assumed 120 mΩ ESR.

BOOST CONVERTER INDUCTOR SELECTION

The driving equation to estimate the inductor is:

$$L = \frac{V_{in}^2 \times (V_{out} + V_D - V_{in})}{(V_{out} + V_D)^2 \times r_{cr} \times I_{out} \times 2 \times freq.} \times 10^6 \ (\mu H)$$

V_D Diode Voltage losses (~0.5 V for Schottky).

V_{in} is the <u>minimum</u> voltage expected.

For this example, assume the following requirements:

Input Voltage:	3.3 V	Output Voltage:	5 V
Ripple Voltage:	30 mV p-p	Output Current:	0.5 A
Ripple Current:	150 mA	Current Frequency:	150 kHz

$$di = \frac{Ripple\ Voltage}{ESR\ Capacitor} = \frac{20mV}{100m\Omega} = 0.2A$$

$$r_{cr} = \frac{di}{I_{out}} = \frac{0.2A}{0.5A} = 0.4 \quad (\textit{within 0.25 to 0.4})$$

Note: Selecting r_{cr} influences where the discontinuous mode will be triggered.

$$L = \frac{3.3V^2 \times (5V + 0.5 - 3.3V)}{(5V + 0.5)^2 \times 0.4 \times 0.5A \times 2 \times 150kHz} \times 10^6 (\mu H)$$

$$L = 13.2 \ \mu H$$

Located inside METCOM's data sheet is part number **MPX1D0530L150**, which is 15 µH.

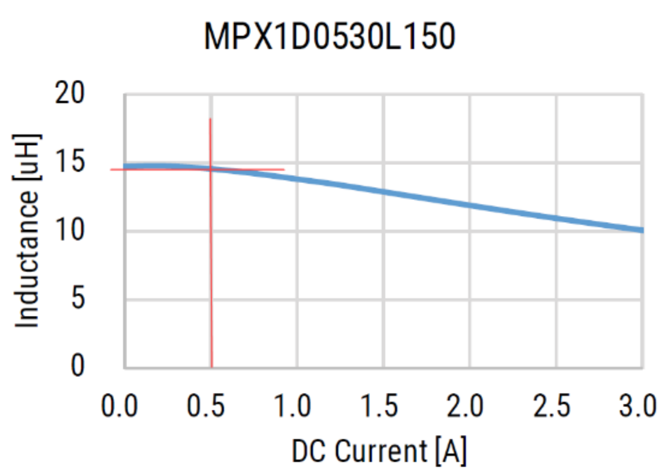


Figure 3 – Buck Inductor Rating

The next step after this is to pick your input capacitor and output capacitor to meet the requirements. Note the assumed 100 mΩ ESR.

The following graph is useful in identifying the case size available to meet design requirements.

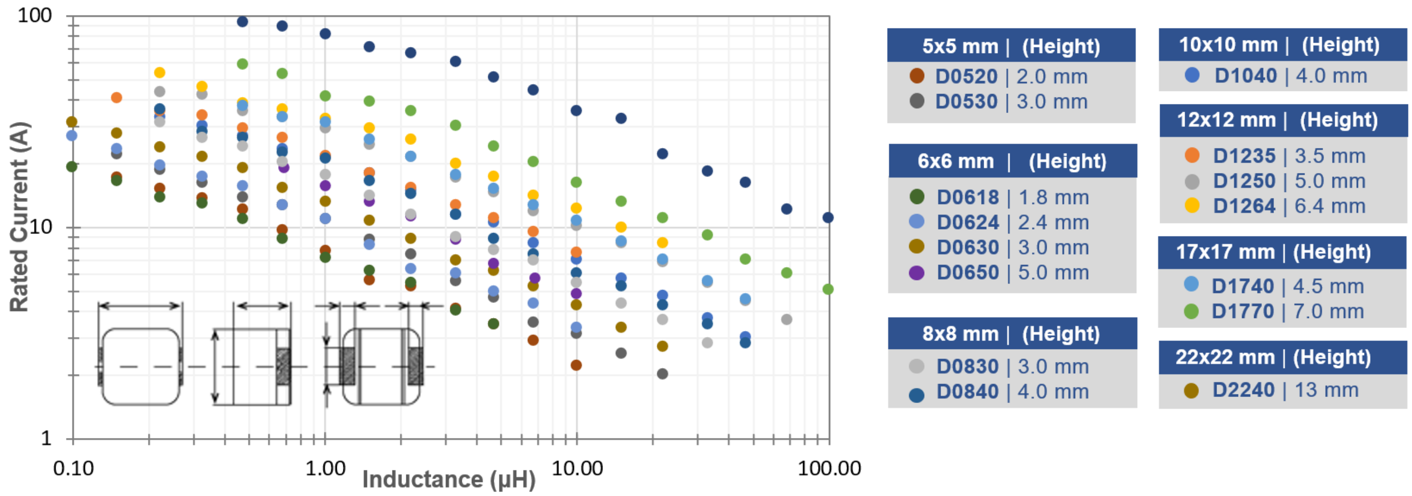


Figure 4 – Case Size Selection Guide

Using the boost convertor inductor example, the requirement is to have a 15 µH inductor at 0.5A. Based on Figure 4, at the 15 µH mark, there are four case sizes available. The selection for the case size would be based on physical design constraints as well as cooling needs. There are different case sizes available from 5x5 mm to 8x8 mm and at different heights depending on the required saturation current.

METCOM MPX series of power inductors provides the designer with the flexibility to use different case sizes based on requirements, while maintaining the key parameters needed, such as stable inductance and current capabilities. KEMET continues to add more part numbers to expand the range of available options, visit www.kemet.com/metcom for more information.

DISCLAIMER

All product specifications, statements, information and data (collectively, the “Information”) in this datasheet are subject to change. The customer is responsible for checking and verifying the extent to which the Information contained in this publication is applicable to an order at the time the order is placed. All Information given herein is believed to be accurate and reliable, but it is presented without guarantee, warranty, or responsibility of any kind, expressed or implied.

Statements of suitability for certain applications are based on KEMET Electronics Corporation’s (“KEMET”) knowledge of typical operating conditions for such applications, but are not intended to constitute – and KEMET specifically disclaims – any warranty concerning suitability for a specific customer application or use. The Information is intended for use only by customers who have the requisite experience and capability to determine the correct products for their application. Any technical advice inferred from this Information or otherwise provided by KEMET with reference to the use of KEMET’s products is given gratis, and KEMET assumes no obligation or liability for the advice given or results obtained.

Although KEMET designs and manufactures its products to the most stringent quality and safety standards, given the current state of the art, isolated component failures may still occur. Accordingly, customer applications which require a high degree of reliability or safety should employ suitable designs or other safeguards (such as installation of protective circuitry or redundancies) in order to ensure that the failure of an electrical component does not result in a risk of personal injury or property damage.

Although all product–related warnings, cautions and notes must be observed, the customer should not assume that all safety measures are indicted or that other measures may not be required.

When providing KEMET products and technologies contained herein to other countries, the customer must abide by the procedures and provisions stipulated in all applicable export laws and regulations, including without limitation the US Export Administration Regulations and the Japan Foreign Exchange and Foreign Trade Act.