Start Time: November 30, 2023 | 5:00 PM CET | 8:00 AM PST | 11:00 AM EST

Choosing the Right Inductor for Your DC/DC Converter

Monolithic Power Systems

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Speaker

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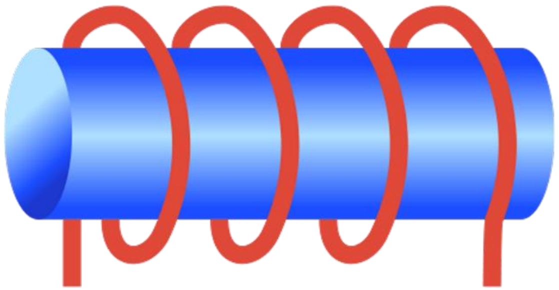
Agenda

1. Magnetics Basics
2. DC/DC Converter
3. Buck Converter Topology
4. Inductance, Ripple Current, Efficiency
5. Saturation Current
6. Rated Current
7. Efficiency Comparison
8. Q&A

What Is an Inductor?



What is the main task of the inductor?

Inductors oppose changes
in current from a circuit

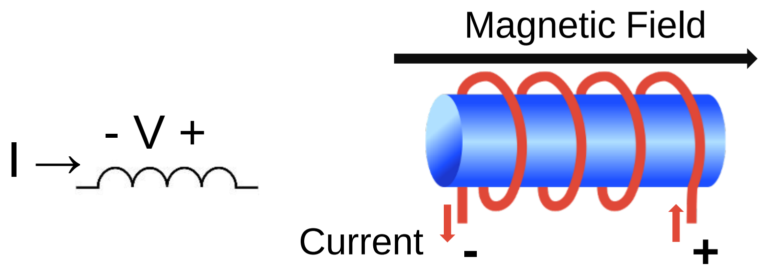
$$V = L \times \frac{di}{dt}$$

Inductors always have a voltage across them if
there is change of current

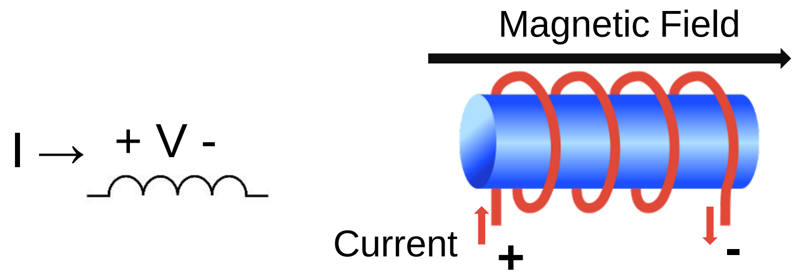
I = constant V = 0

Wire is wound in a coil shape with or without a core.

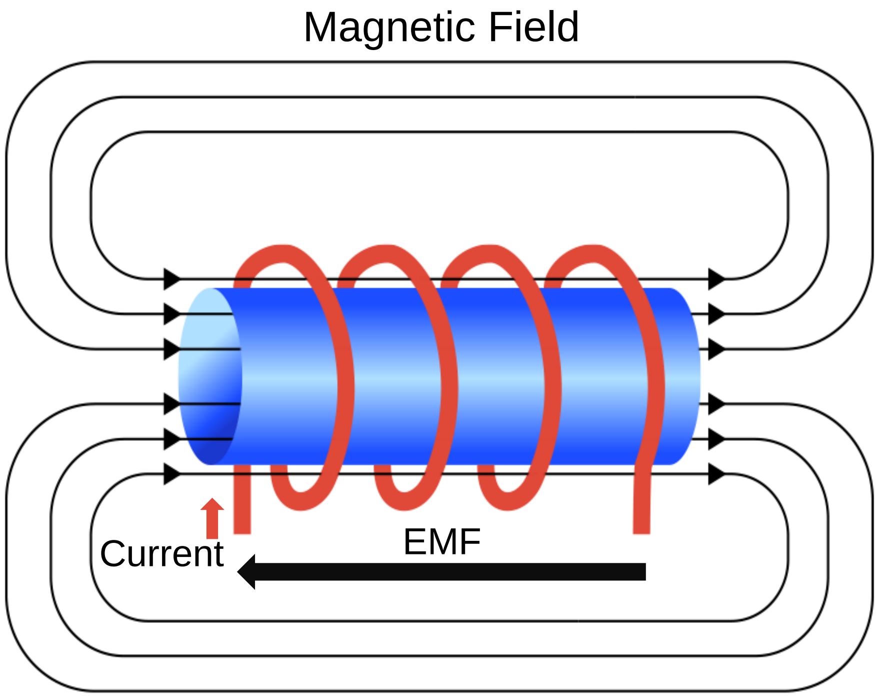
- If current is increasing, inductors try to keep the current from increasing.



- If the current is decreasing, inductors try to keep the current from decreasing.



What Is an Inductor?



- Inductors can store induced electric energy as magnetic energy.
- With the change of current in time, the induced magnetic energy changes, causing electromotive force.

$$e = -\frac{d\varphi}{dt} = -L\frac{di}{dt}$$

e = Electromotive force (EMF)

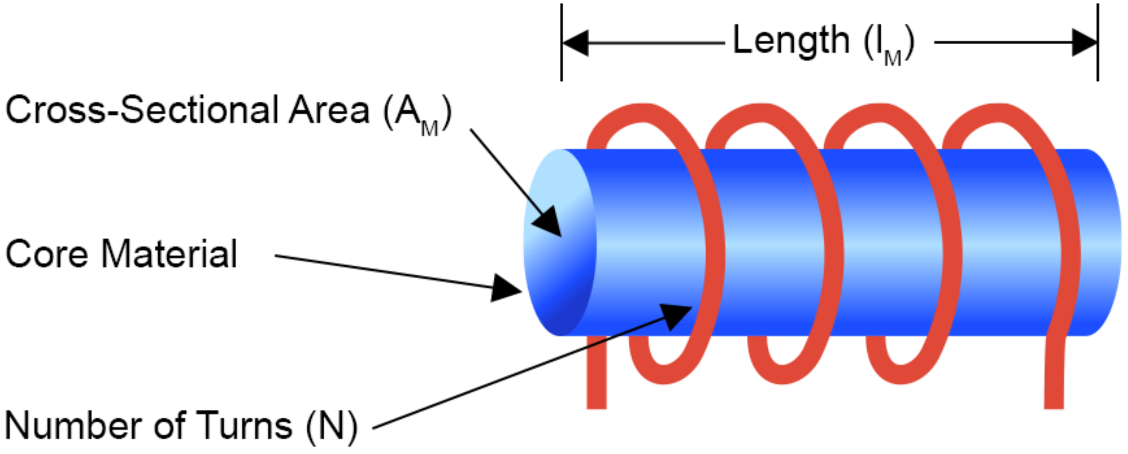
$\frac{d\varphi}{dt}$ = Change of magnetic flux over the change in time

$\frac{di}{dt}$ = Change of current over the change in time

L = Inductance, measured in Henries (H)

Inductance

$$L = \frac{\mu_o \times \mu_r \times A}{l} \times N^2$$

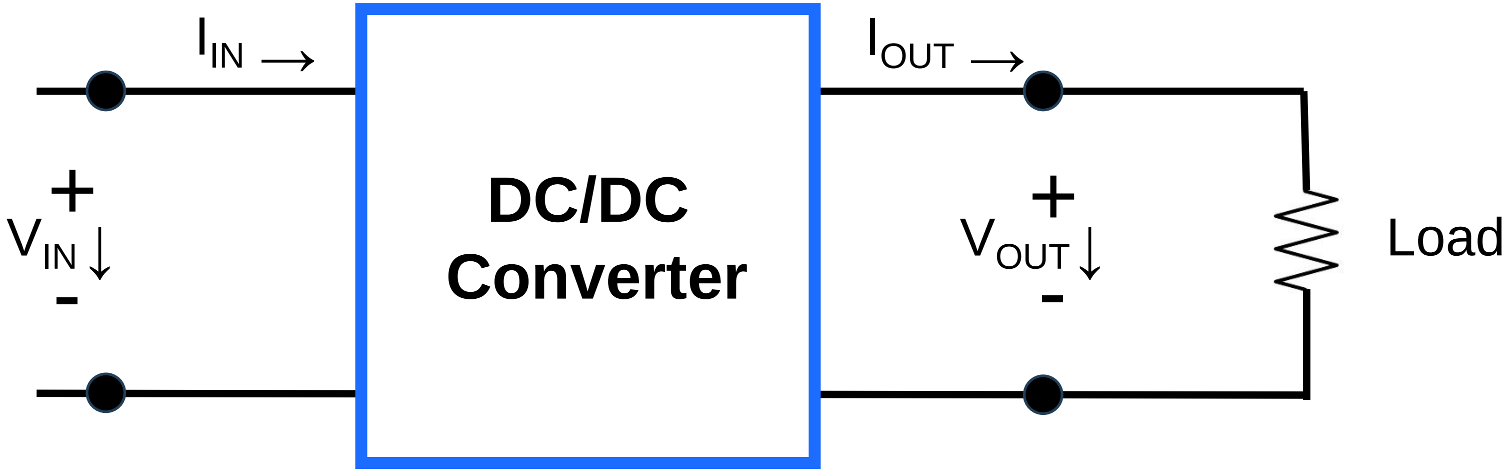


- L = Inductance (in H)
- μ_o = Constant of Nature ($4\pi \times 10^{-7}$)
- μ_r = Relative Permeability
- A_M = Area of the Coil
- l_M = Length of the Coil
- N = Number of Turns

$$L = \frac{\mu_o \times \mu_r \times A}{l} \times N^2 \rightarrow L = A_L \times N^2$$

Parameters Related to Core Material

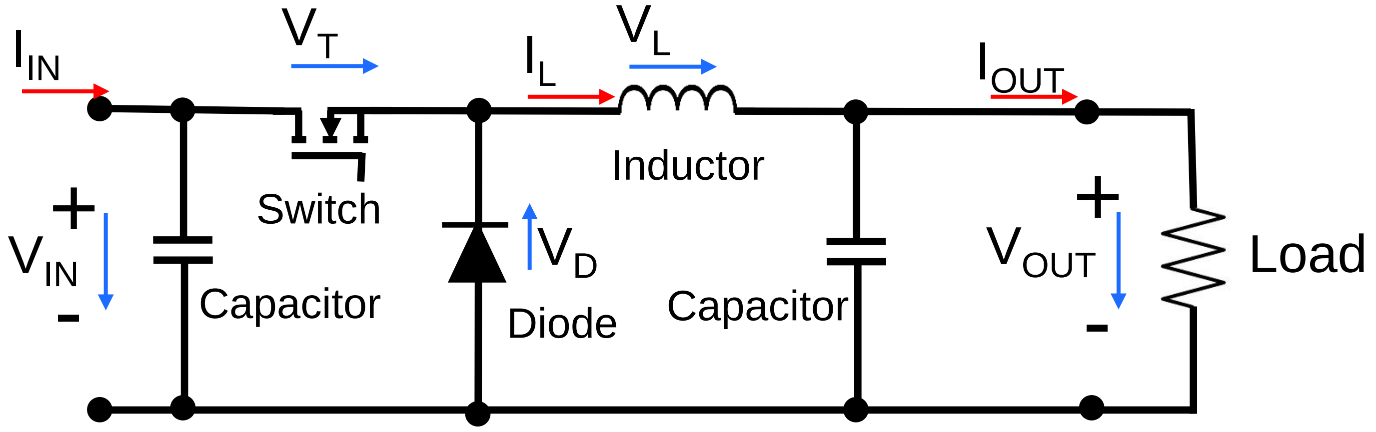
DC/DC Converter



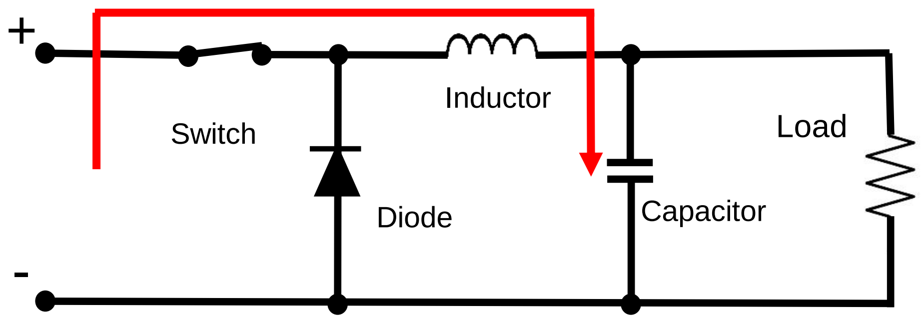
- **Buck Converter:**
  - **V_{IN} > V_{OUT}**
  - **I_{IN} < I_{OUT}**

- **Boost Converter:**
  - **V_{IN} < V_{OUT}**
  - **I_{IN} > I_{OUT}**

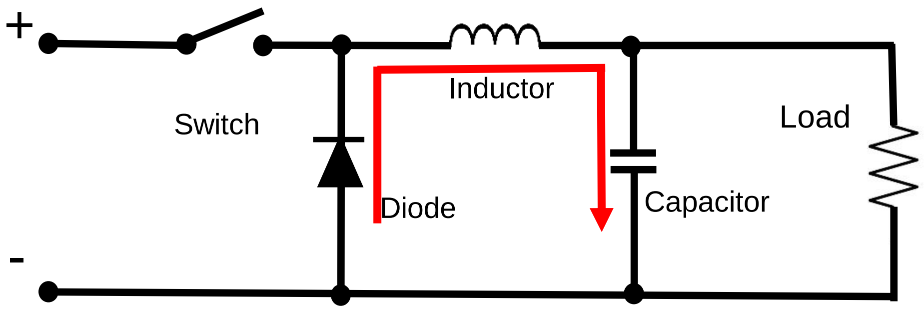
DC/DC Buck Converter



Switch On



Switch Off



DC/DC Buck Converter – Current Definitions

- I_{OUT} Output current
  The average inductor current

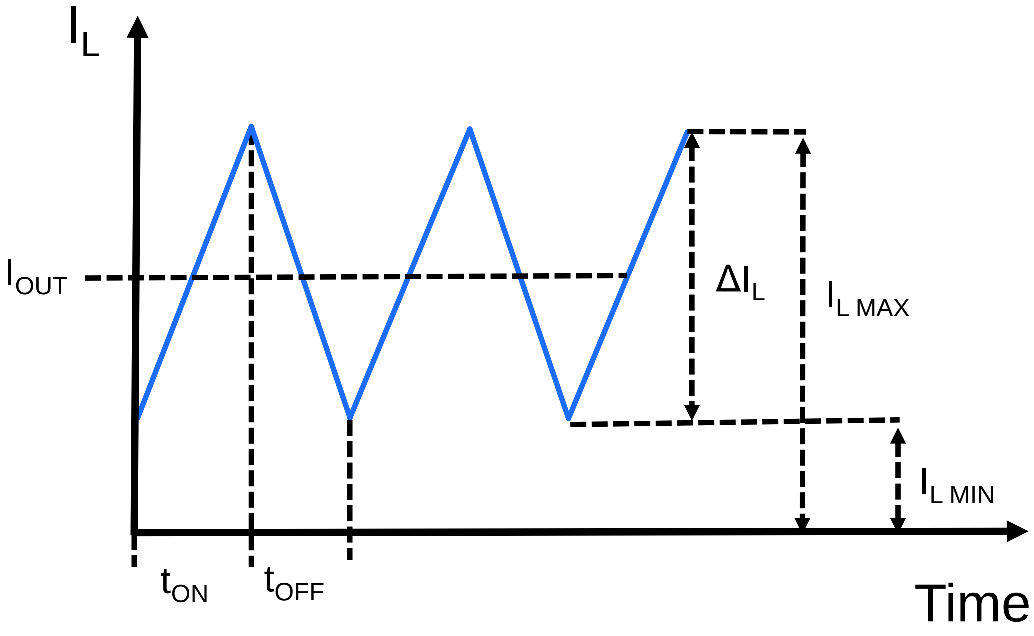
$$I_{OUT} = I_{AVG} = I_L = I_{DC} \approx I_{L\ RMS}$$

- $I_{L\ MAX}$ Maximum current of the inductor
  The required saturation current

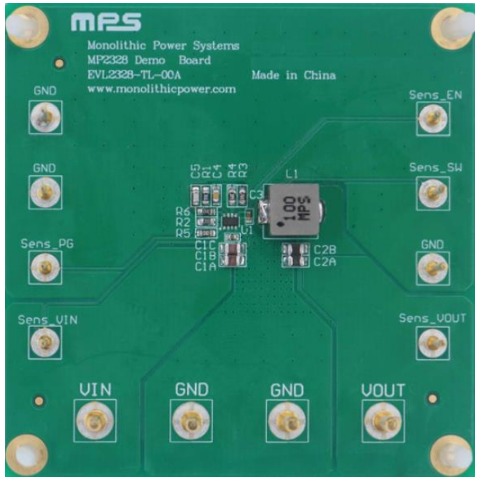
$$I_{L\ MAX} = I_{L\ PEAK} = ISAT = I_{OUT} + \frac{r \times I_{OUT}}{2}$$

- ΔI_L Inductor ripple current
  Current ripple ratio ~ 20% to 40%

$$\Delta IL = r \times I_{OUT}$$



DC/DC Buck Converter – Inductance



EVL2328-TL-00A: Synchronous Buck Converter Evaluation Board

Converter Parameters:

- Input voltage (V_{IN}) = 24V
- Output voltage (V_{OUT}) = 5V
- Output current (I_{OUT}) = 2A
- Switching frequency (f_{SW}) = 430kHz
- Ripple current factor (r) = 40%

$$DC = \frac{V_{OUT}}{V_{IN}} = \frac{t_{ON}}{T} = 0.208$$

$$L = \frac{V_{IN} - V_{OUT}}{f_{sw} \text{ x } \Delta I_L \text{ x } I_{OUT}} \text{ x DC} = \mathbf{11.5\mu H}$$

$$I_{OUT} = \mathbf{2\ A}$$

$$I_{L\,MAX} = I_{OUT} + \frac{\Delta I_L}{2} = \mathbf{2.4\ A}$$

Standard Inductance Value:
8.2µH / 10µH / 12µH / 15µH

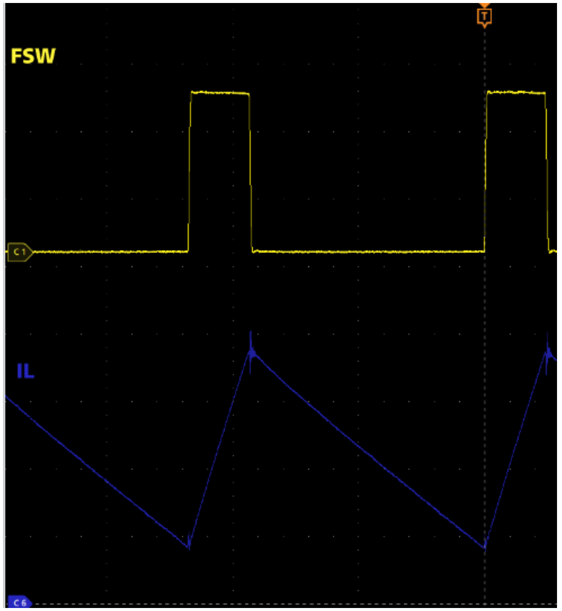
- Test different inductor values
- Inductance tolerances

DC/DC Buck Converter – Ripple Current

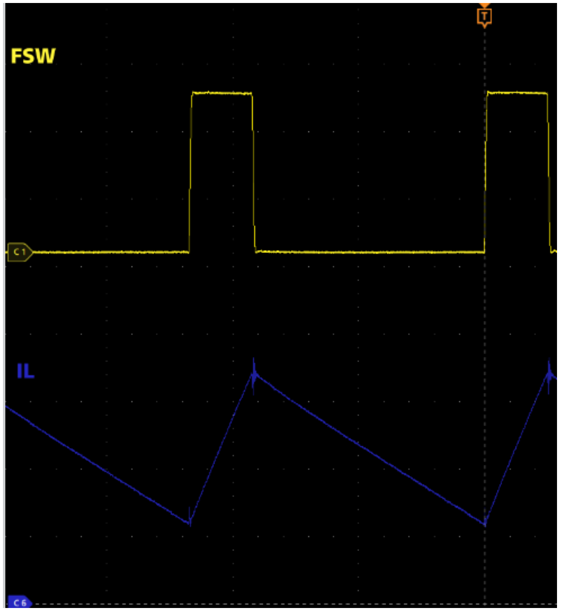
EVL2328-TL-00A: Synchronous Buck Converter Evaluation Board

Input voltage (V_{IN}) = 24V
Output voltage (V_{OUT}) = 5V
Output current (I_{OUT}) = 2A
Switching frequency (f_{SW}) = 430kHz

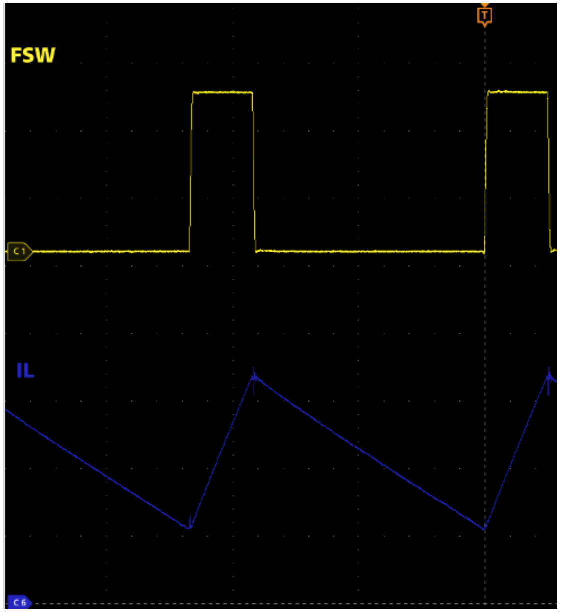
Higher Inductance = Smaller Ripple Current
Lower Inductance = Higher Ripple Current



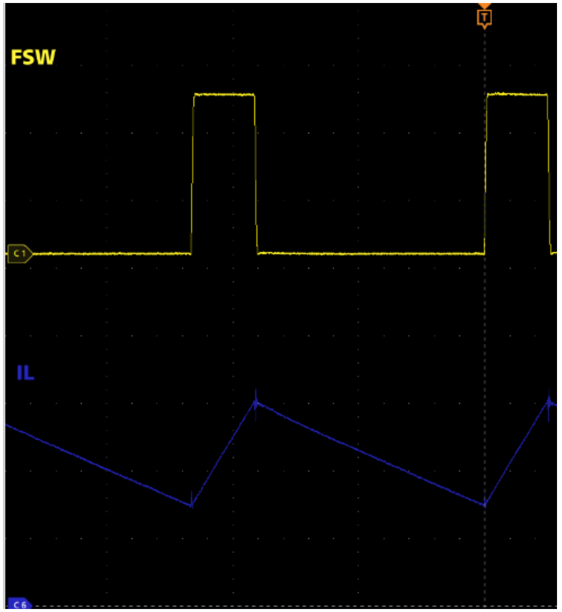
6.8µH
Peak-to-Peak = 1.62A



8.2µH
Peak-to-Peak = 1.26A



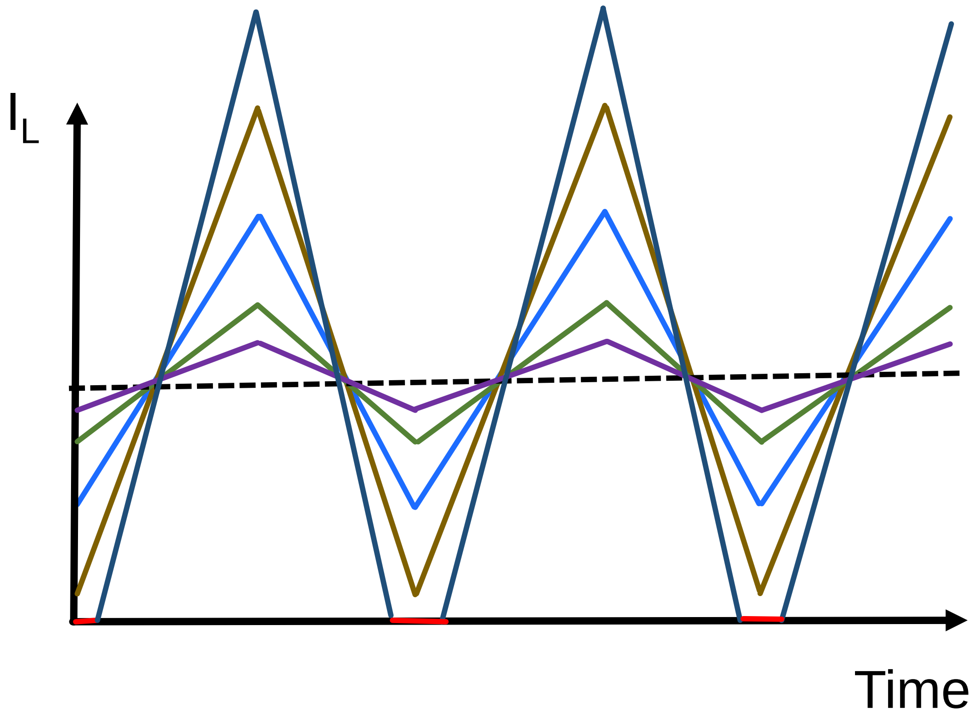
10µH
Peak-to-Peak = 1.18A



15µH
Peak-to-Peak = 0.89A

DC/DC Buck Converter – Ripple Current

A higher ripple current increases AC losses.



Lower Inductance

Higher Ripple Current (ΔI_L)

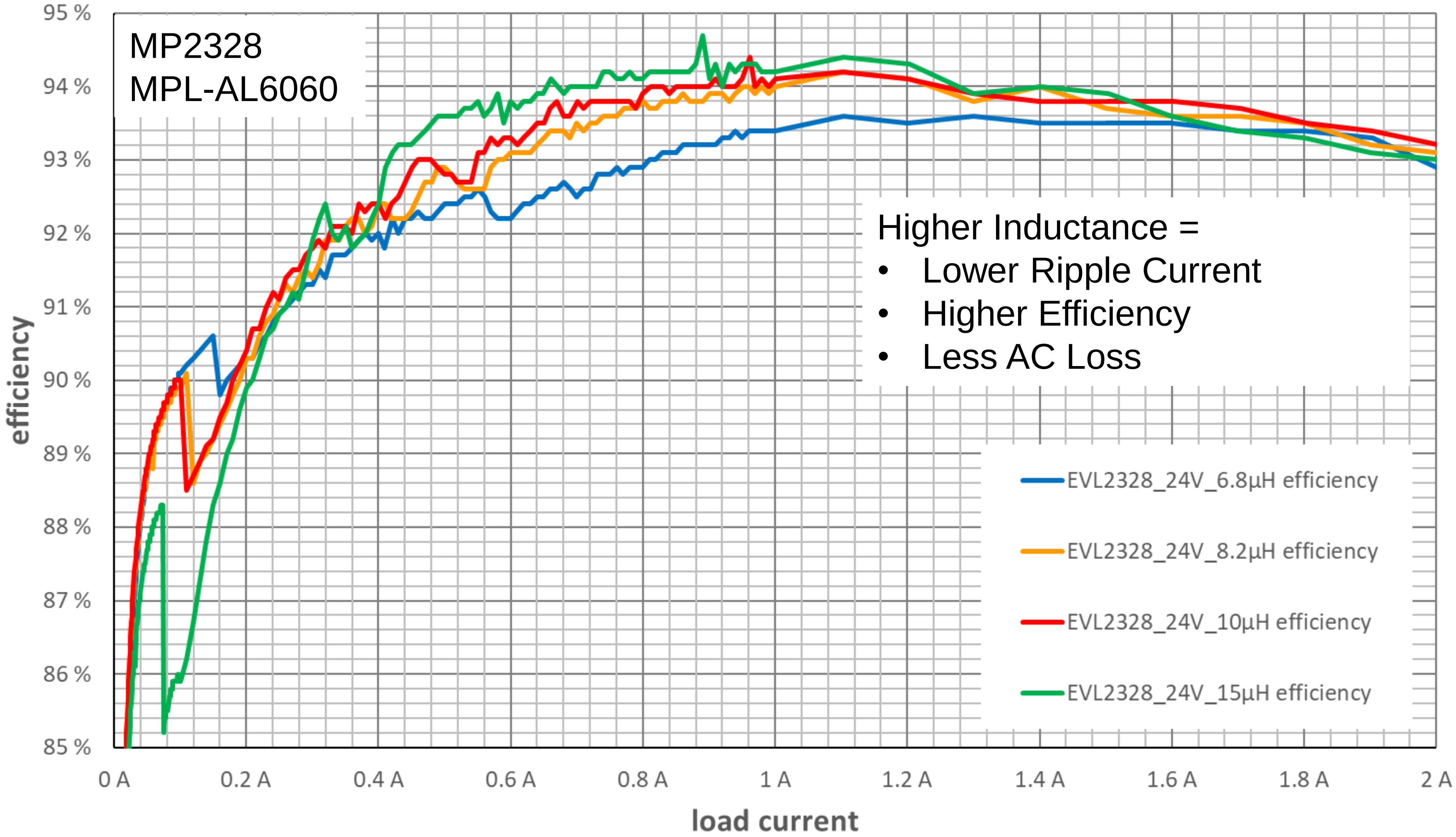
Lower Resistance (R_{DC})

Higher Inductance

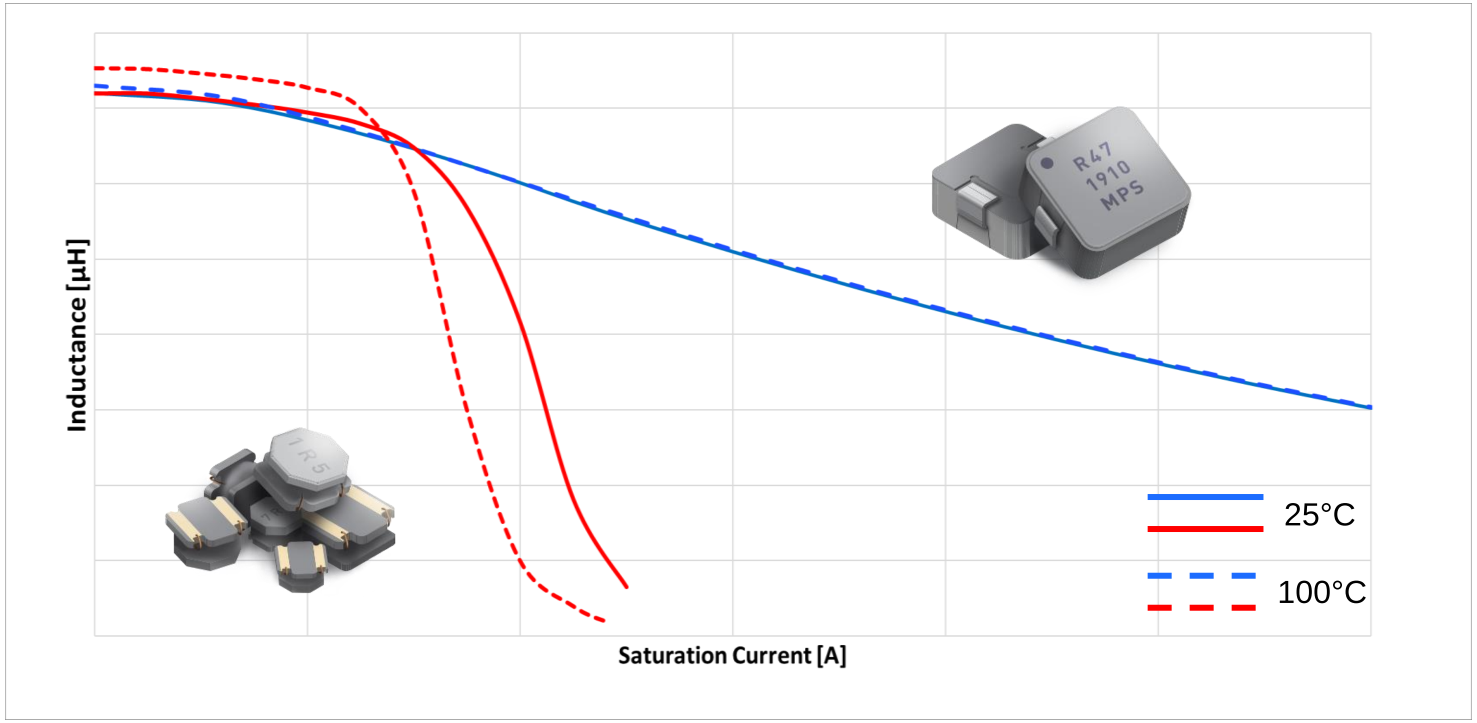
Smaller Ripple Current (ΔI_L)

Higher Resistance (R_{DC})

DC/DC Buck Converter – Efficiency

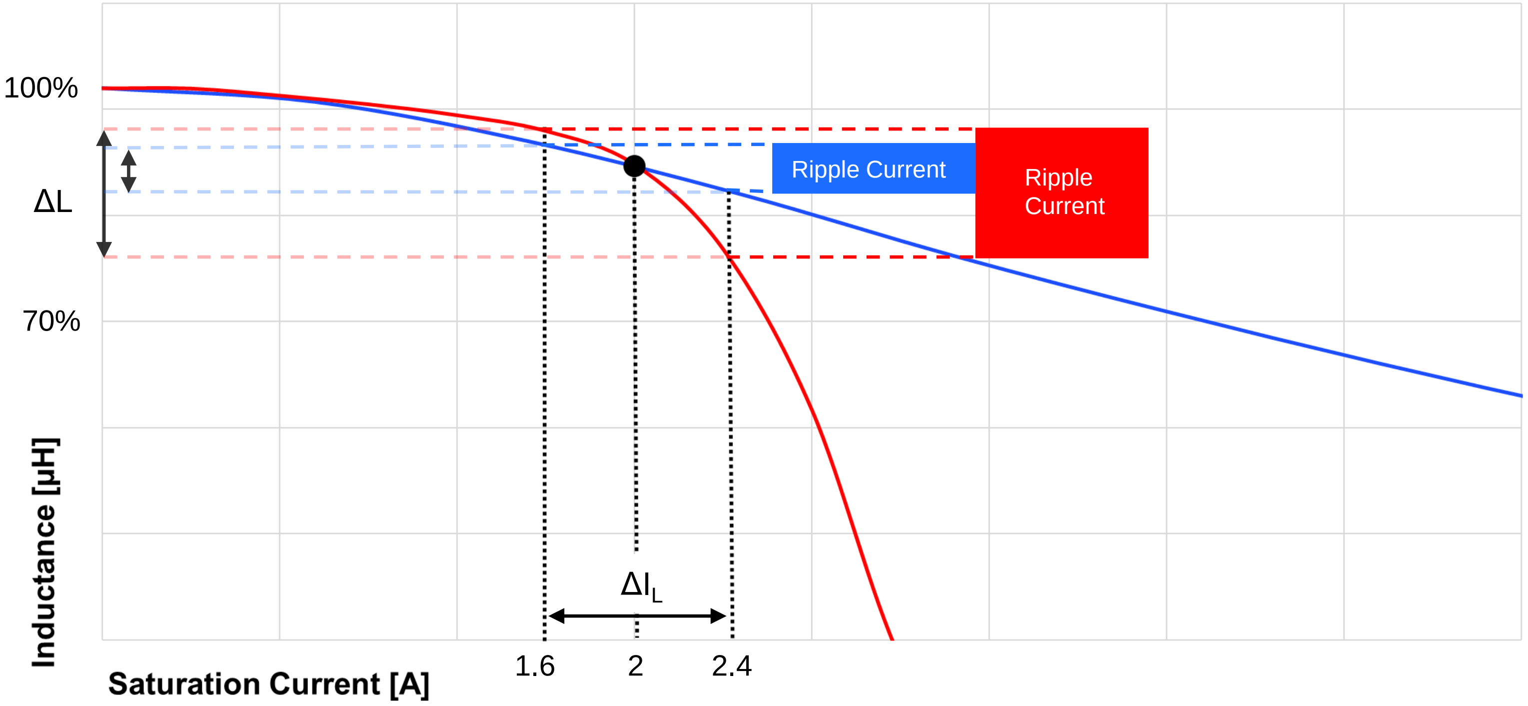


Saturation Current



Type / Characteristics
Ferrite Drum Core Inductors • High Permeability • Hard Saturation • Temperature-Dependent
Molded Inductors • Low Permeability • Soft Saturation • Stable Across Temperatures

Saturation Current

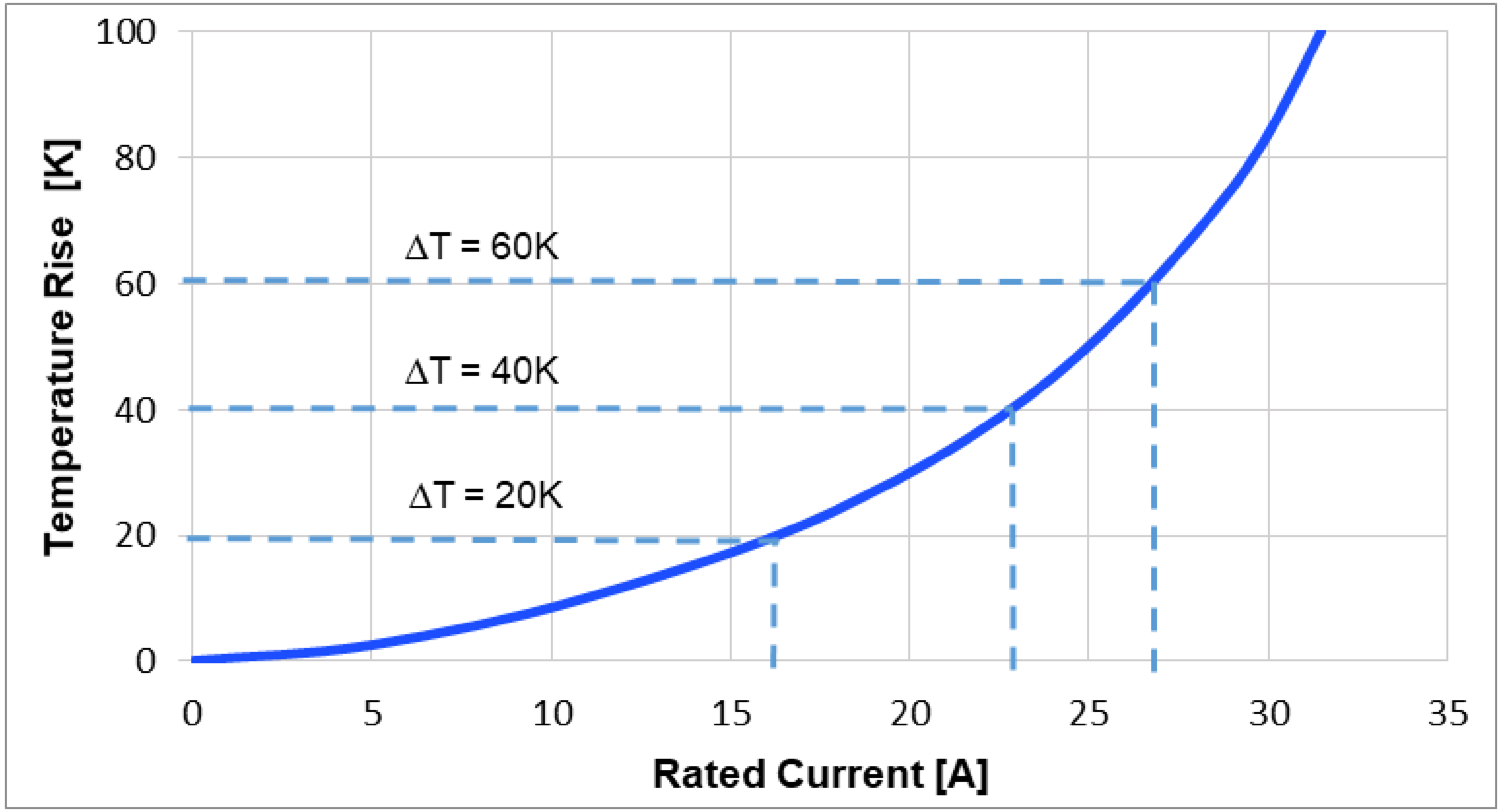


$I_{OUT} = \mathbf{2\ A}$

$I_{L\ MAX} = I_{OUT} + \frac{\Delta I_L}{2} = \mathbf{2.4\ A}$

- Safe range of use.
- Inductance value changes.
- Molded-type inductors provide flexibility and wider operating ranges.
- Ferrite drum core inductors are stable until the drop-knee point; beyond this point, functionality is reduced.

Rated Current



Do not exceed the maximum operating temperature.

Self-heating of the component caused by the wire's DC resistance (R_{DC}).

The temperature rise is not standard, and it varies between manufacturers.

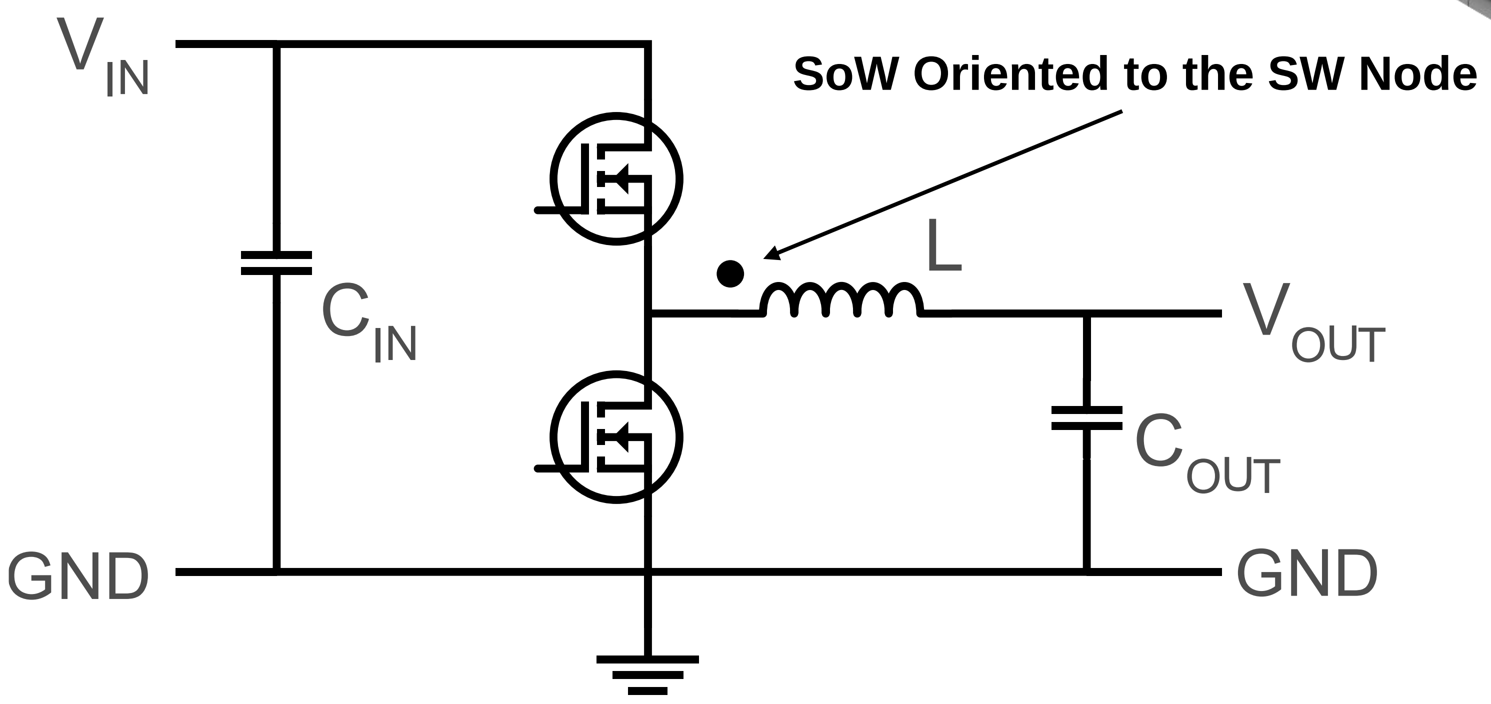
Consider the maximum operating temperature conditions and the ambient temperature.

$$T_{OPERATING} = T_{AMBIENT} + \Delta T_{SELF\text{-}HEATING}$$

$T_{OPERATING}$	$T_{AMBIENT}$	$\Delta T_{SELF\text{-}HEATING}$
125°C 155°C Other?	?	?

Start of Winding

The converter switch node is close to the start of winding side



- Avoids audible noise from harmonics.
- Reduces emissions caused by the inductor.

Inductor Selection Considerations

Inductor

- Calculate the required inductance (L)
- Calculate the maximum current flowing in the inductor
  - I_{OUT}
  - I_{LMAX}
- Select an inductor close to the calculated inductance, and ensure that the current can be at least as large as the maximum calculated current
- Application‘s frequency
- EMI
- Start of winding

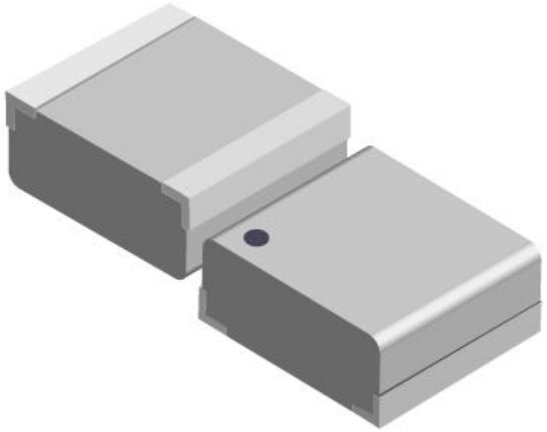
Currents

- Saturation current
  - Soft or hard saturation
  - Peak current
  - Maximum ripple current
  - Lower inductance = higher ripple current
  - Higher inductance = lower ripple current
- Rated current
  - Application‘s ambient temperature
  - Operating temperature limits
  - Low R_{DC} for less DC losses (higher I_{DC})

MPL-AT Series

MPL-AT (Tiny Molded Inductors)

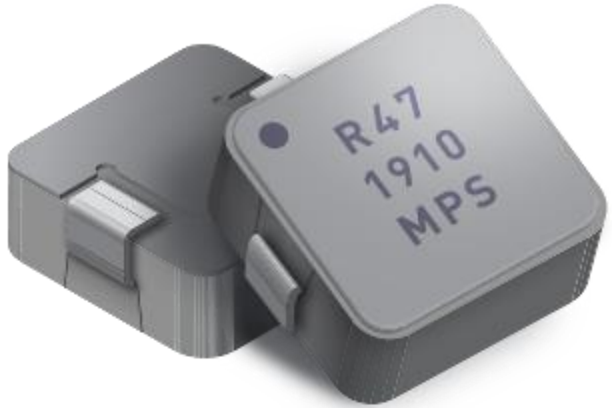
- Start of Winding Indication
- Low-Profile Inductors
- Low DCR
- High Saturation Current
- Soft Saturation
- Stable Across Temperatures
- Max Operating Temperature: 125 ° C
- Sizes: 2010 / 2512



MPL-AY Series

MPL-AY (Molded Inductors)

- Start of Winding Indication
- Low DCR
- High Saturation Current
- Soft Saturation
- Stable Across Temperatures
- Max Operating Temperature: 125°C/155°C
- Sizes: 3020 / 4020 / 1050 / 1265



MPL-AL Series

MPL-AL (Low-Resistance Molded Inductors)

- Start of Winding Indication
- Flat Wire Construction
- Lowest DCR
- High Performance
- High Saturation Current
- Soft Saturation
- Stable Across Temperatures
- Max Operating Temperature: 155°C
- Sizes: 4020 / 5030 / 5050 / 6050 / 6060

Flat Wire, Low DCR, High Efficiency

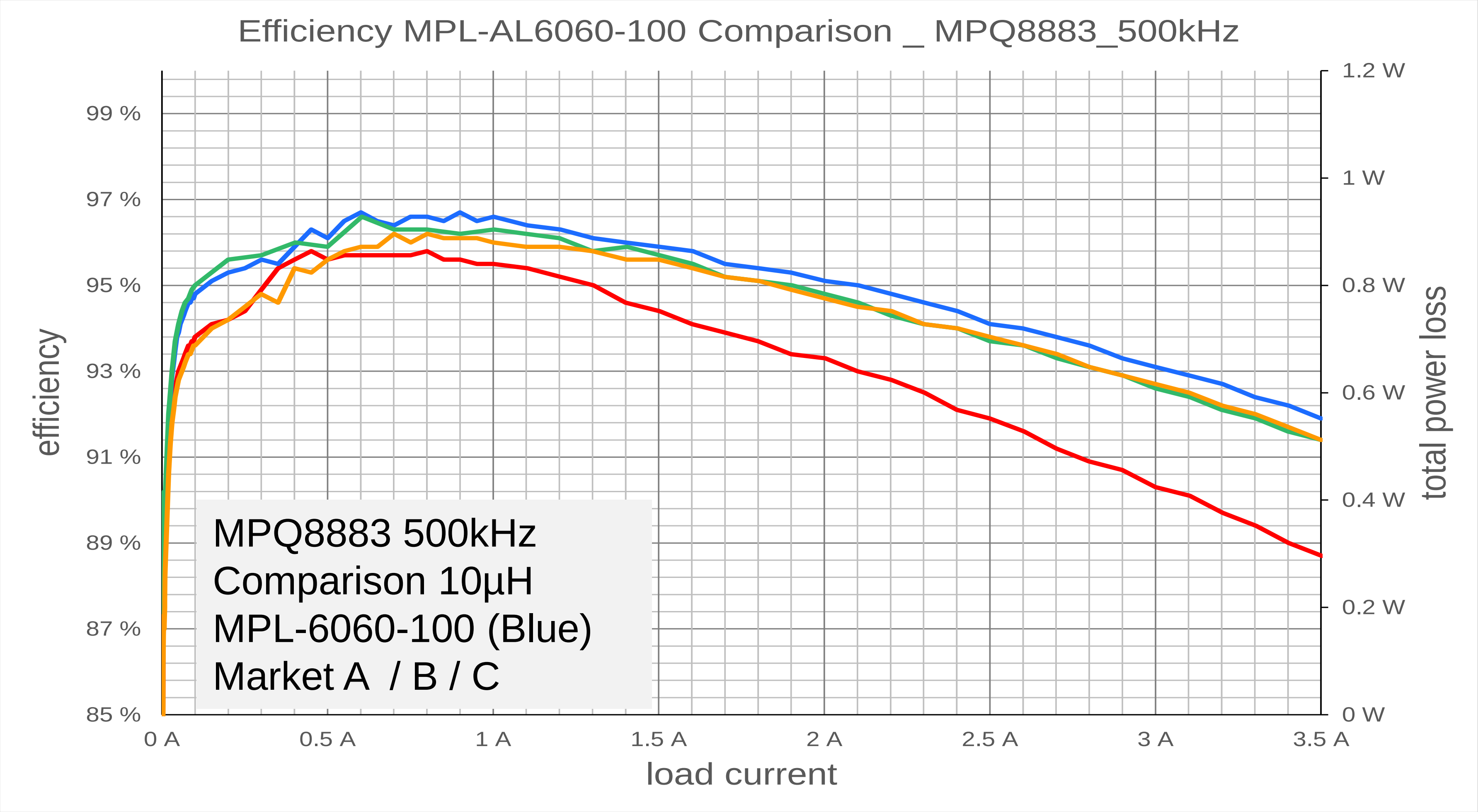
MPL-SE Series

MPL-SE (Semi-Shielded Inductors)

- External Epoxy Resin for Better Magnetic Characteristics
- Magnetically Shielded
- Low DCR
- High Current
- Max Operating Temperature: 125°C
- Sizes: 2512 / 4030 / 5040 / 6040

MPS Inductors - Efficiency

Part Number	L	R_{DC}	I_{DC}	I_{SAT}
MPL-AL6060-100	10µH	24mΩ	6.9A	6.6A



A / B / C	MPS

Q&A

Contact

PowerMagnetics@monolithicpower.com

Power Inductors Page and Inductor Selector Tool

https://www.monolithicpower.com/en/products/inductor.html

MPS Flyer – Power Inductors Brochure

https://www.monolithicpower.com/en/support/product-literature.html

Last Webinar "Understanding Power Inductor Parameters"

Webinar On-Demand Understanding Power Inductor Parameters