

The Right Storage Inductor Calculation for DC/DC Converters



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Agenda



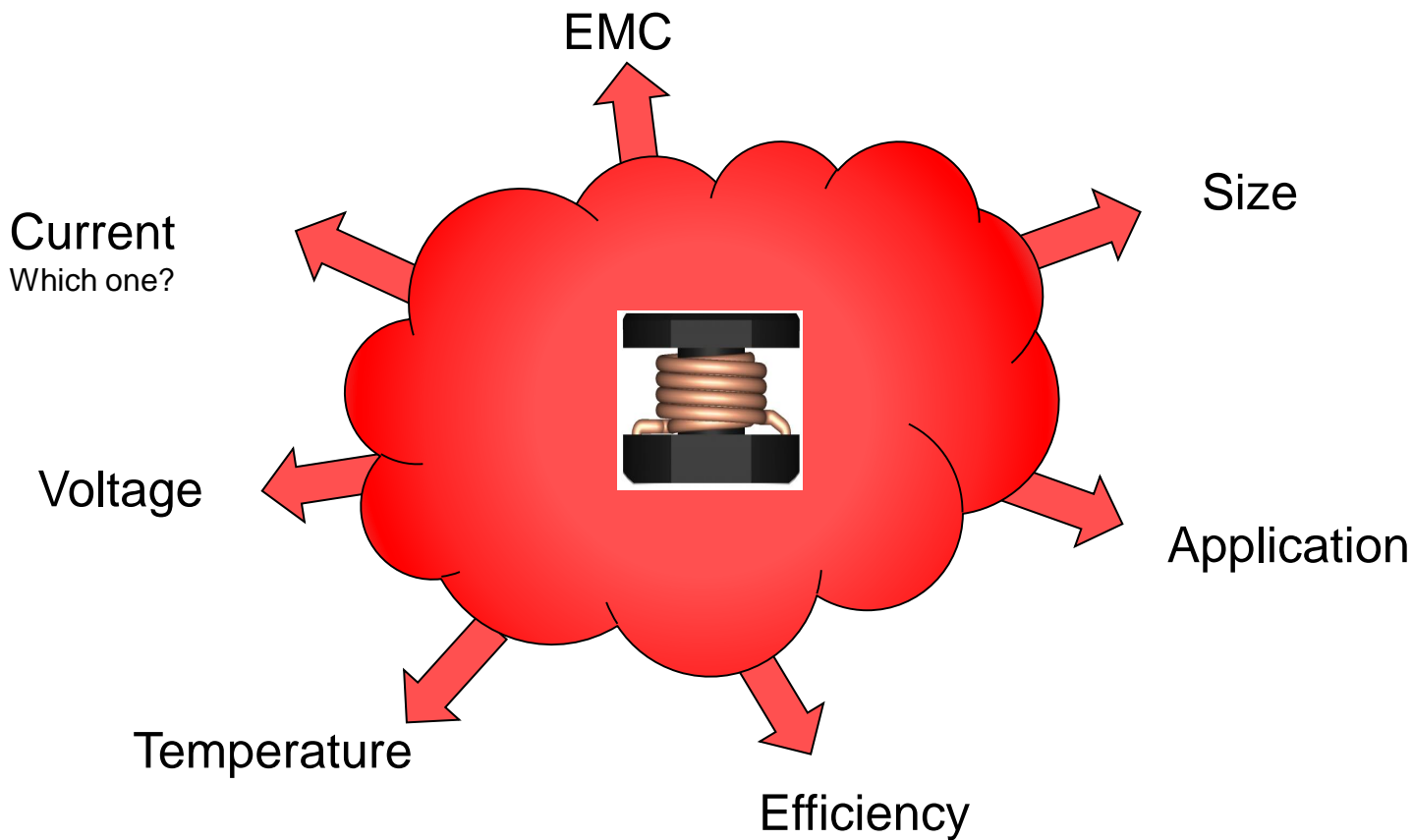
- **How to choose a power Inductor ?**
- **Electromagnetism**
 - Permeability
 - Effect of air gap
- **SMPS Topologies**
 - Buck
 - Boost
 - Sepic
- **Inductance Parameter & selection**
- **Inductor Losses**
 - Copper losses
 - Core losses
- **Inductor design**
- **Tools**
 - REDEXPERT
- **EMC recommendations**
- **General information**



HOW TO CHOOSE A POWER INDUCTOR



HOW TO CHOOSE A POWER INDUCTOR





ELECTROMAGNETISM AND PHYSIC

MAXWELL'S EQUATIONS

- Integral forms

$$\oint \vec{E} d\vec{A} = \frac{Q}{\epsilon_0}$$

Gauss' law for electrostatics

$$\oint \vec{B} d\vec{A} = 0$$

Gauss' law for magnetism

$$\oint \vec{E} d\vec{l} = -\frac{\partial \Phi_B}{\partial t}$$

Faraday's law of induction

$$\oint \vec{B} d\vec{l} = \mu_0 I + \mu_0 \epsilon_0 \frac{\partial \Phi_E}{\partial t}$$

Ampere's law

- Differential forms

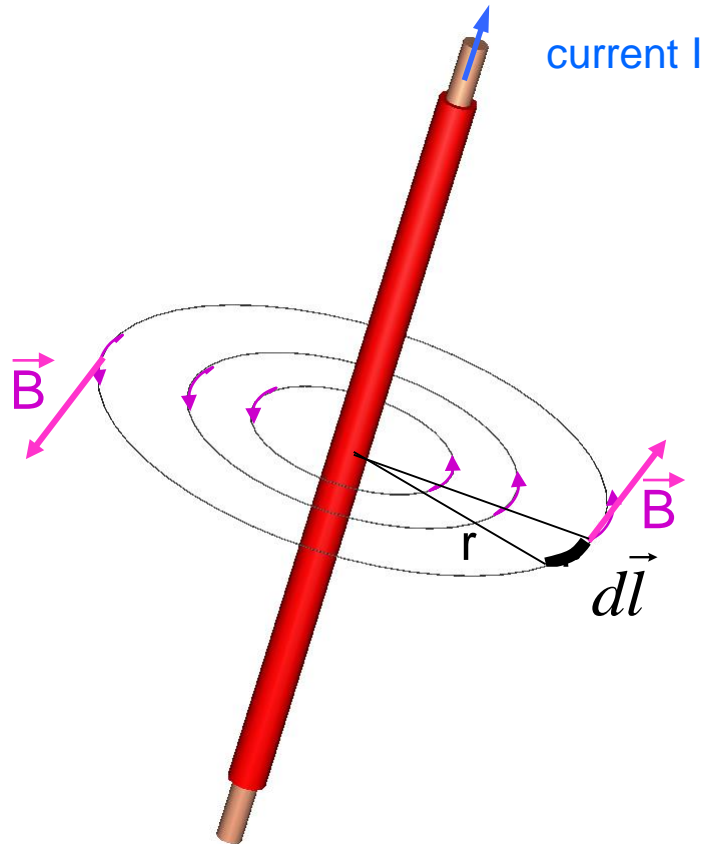
$$\nabla \cdot \vec{E} = \frac{\rho}{\epsilon_0}$$

$$\nabla \cdot \vec{B} = 0$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \times \vec{B} = \mu_0 \vec{J} + \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}$$

ELECTROMAGNETISM : Magnetic flux density



$$\oint \vec{B} \cdot d\vec{l} = \mu_0 I$$

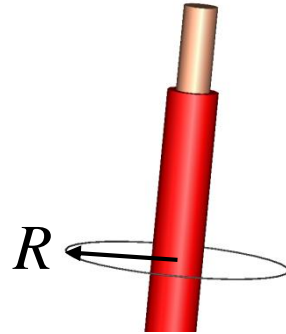
$$B \int d\vec{l} = \mu_0 I$$

$$B 2\pi r = \mu_0 I$$

$$B = \frac{\mu_0 I}{2 \cdot \pi \cdot r}$$

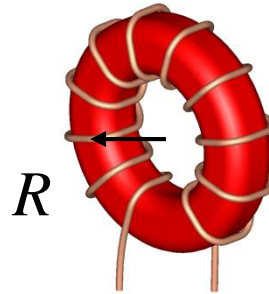
ELECTROMAGNETISM : Magnetic Field

Straight wire



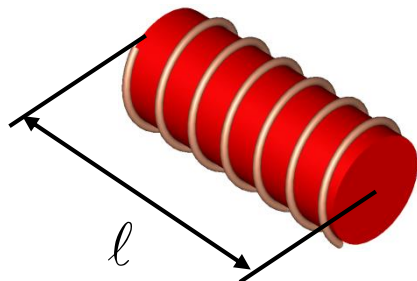
$$H = \frac{I}{2 \cdot \pi \cdot R}$$

Toroidal



$$H = \frac{N \cdot I}{2 \cdot \pi \cdot R}$$

solenoid



$$H = \frac{N \cdot I}{l}$$

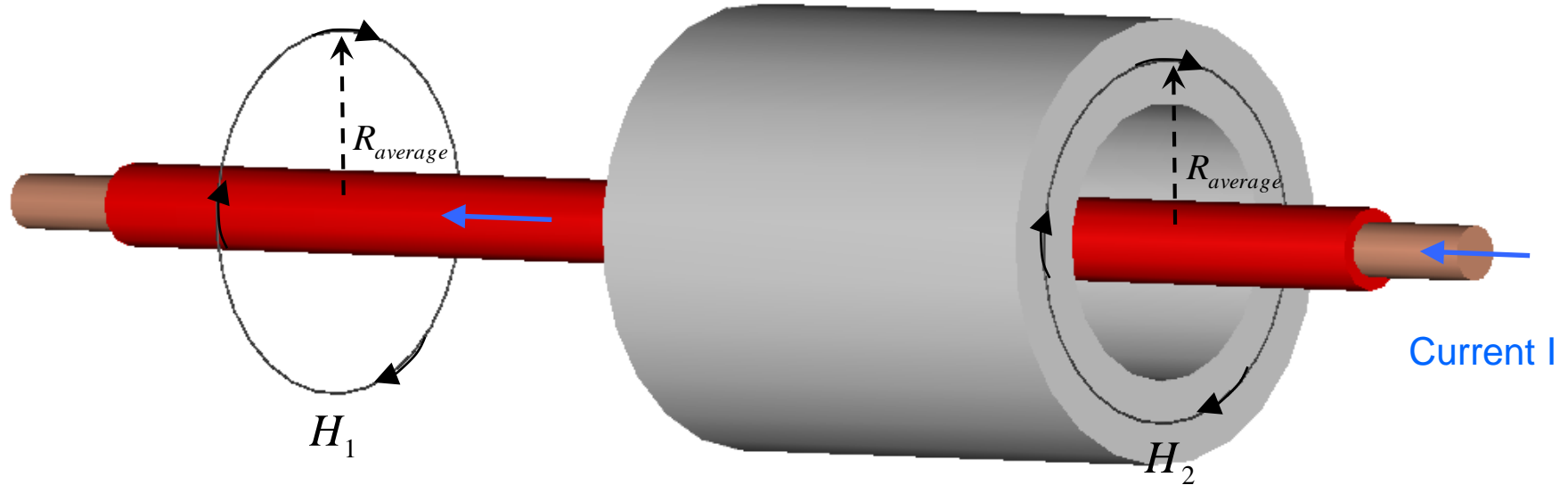
The magnetic field strength is dependent on:

- geometries
- number of turns
- current

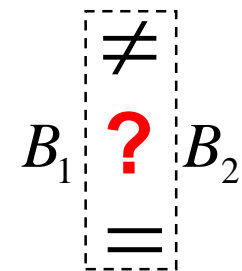
but

NOT ON MATERIAL

ELECTROMAGNETISM : Magnetic Field



$$H_1 = H_2 = H = \frac{I}{2 \cdot \pi \cdot R_{average}}$$

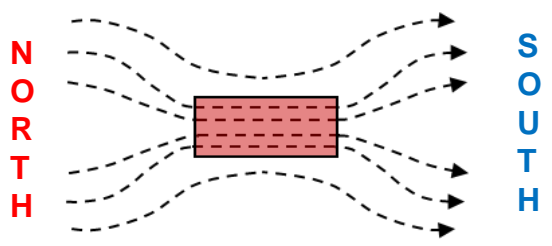




ELECTROMAGNETISM : Permeability

$$\vec{B} = \mu_0 \vec{H} + \mu_0 \vec{J}$$

In material



$\vec{J} = \chi \vec{H}$: a defined vector quantity

$$\vec{B} = \mu_0 (1 + \chi) \vec{H}$$

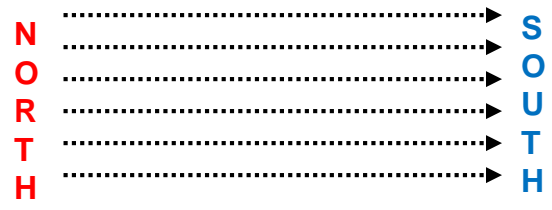
$$\vec{B} = \mu_0 * \mu_r * \vec{H}$$

$$\vec{B} = \mu * \vec{H}$$

μ_r = Relative Permeability
 μ = Absolute relativity

$\mu_0 = 4. \pi. 10^{-7}$
= vacuum permeability

Free space

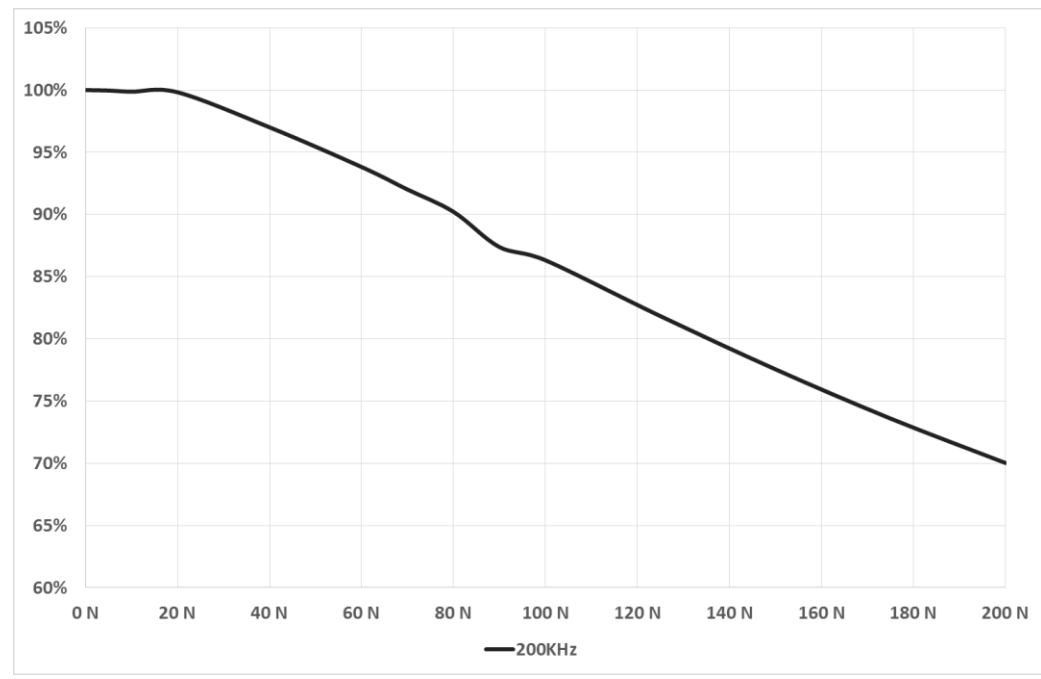
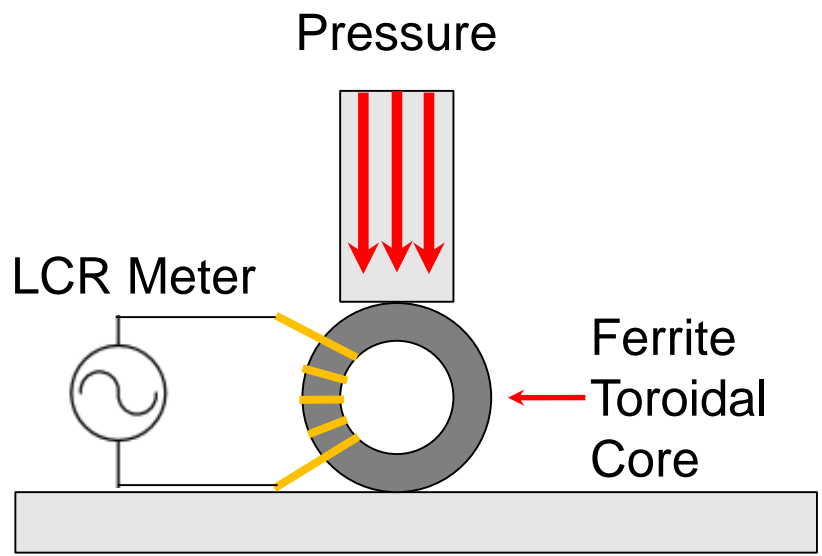


$$\mu_r \text{ of air} = 1$$

$$\vec{B} = \mu_0 * \vec{H}$$



ELECTROMAGNETISM : Permeability



The relative permeability is sensitive to pressure.

ELECTROMAGNETISM : Permeability Vs Material

Material used

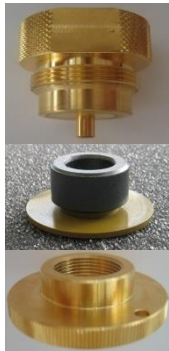
$$\mu_r = \frac{1}{\mu_0} \cdot \frac{\Delta B}{\Delta H}$$



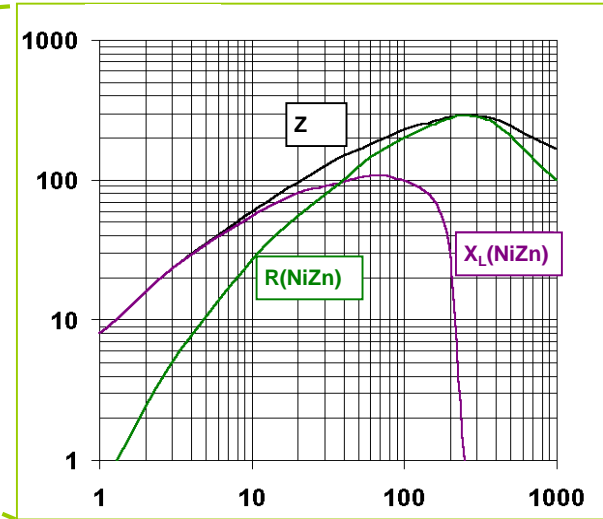
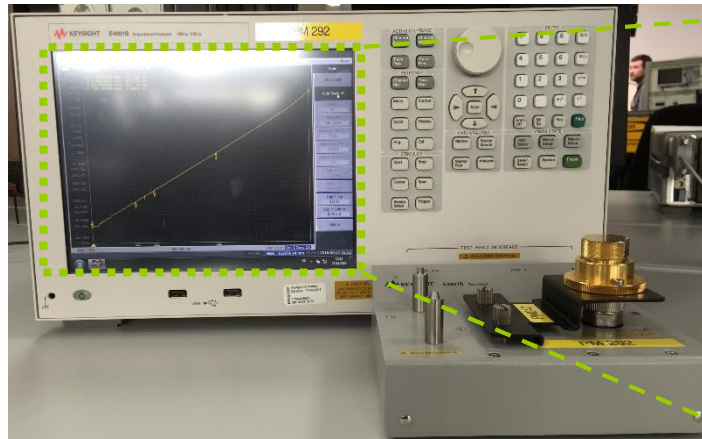
Typical Permeability:

- Iron Powder = 50 ~ 150
- Nickel Zinc (NiZn) = 40 ~ 1500
- Manganese Zinc (MnZn) = 300 ~ 20000

Permeability - Impedance



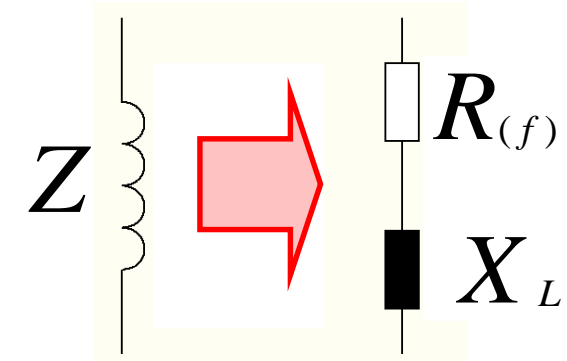
=1 turn



Core material-Parameter

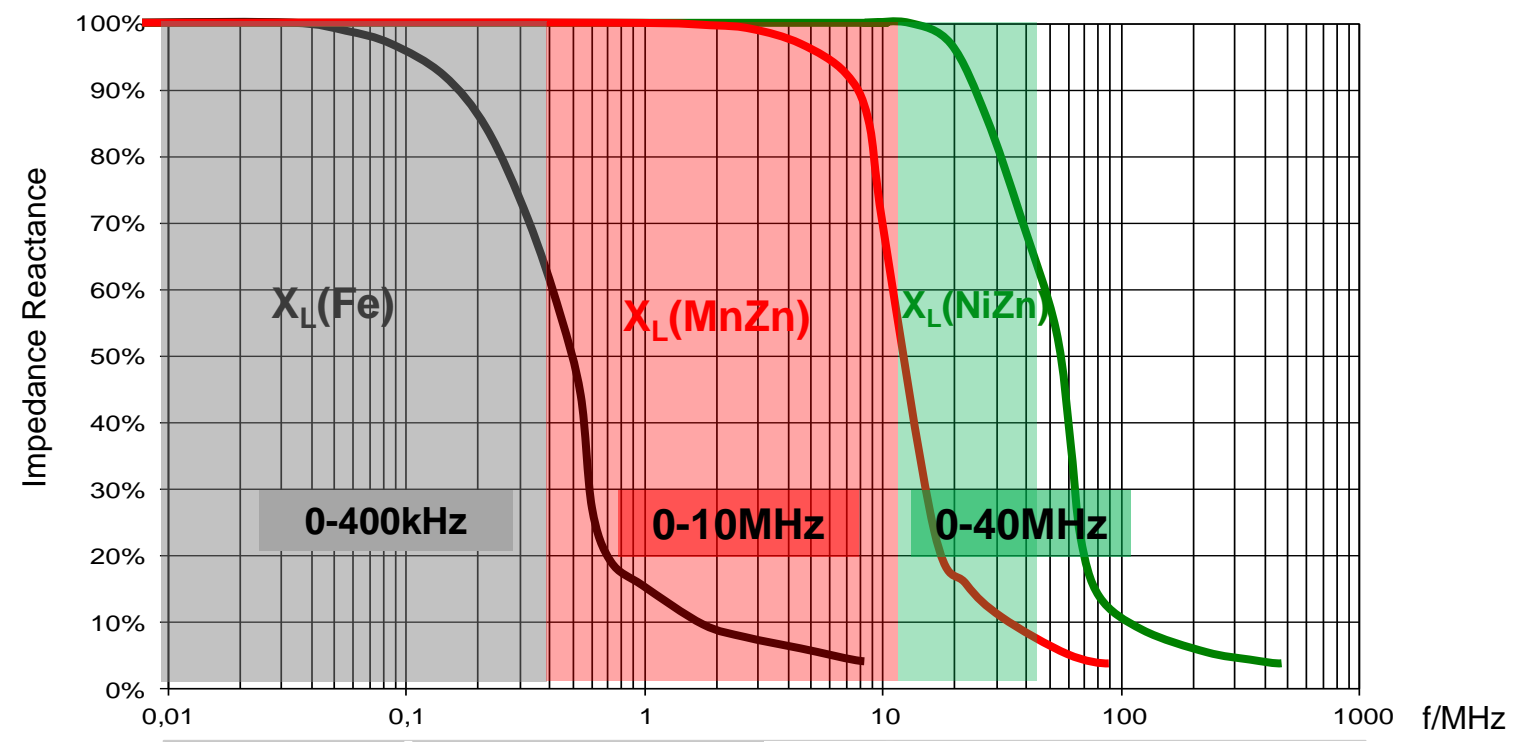
Replacement circuit

$$Z = \sqrt{R_{(f)}^2 + X_L^2}$$

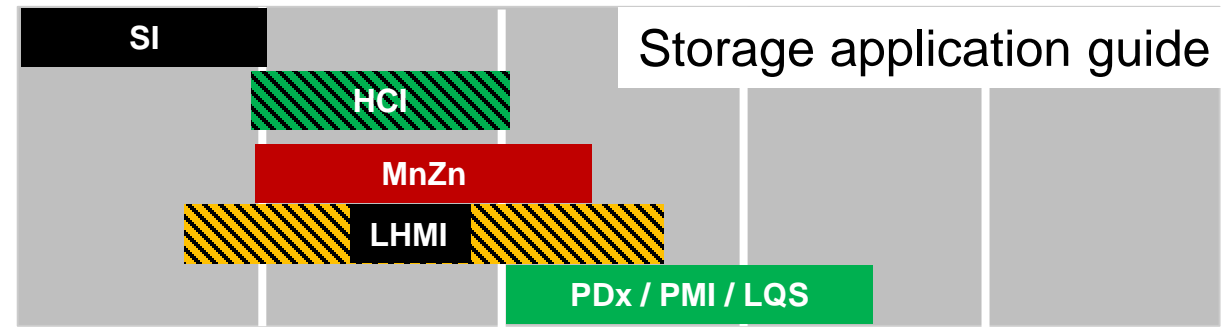




ELECTROMAGNETISM : Permeability Vs Frequency

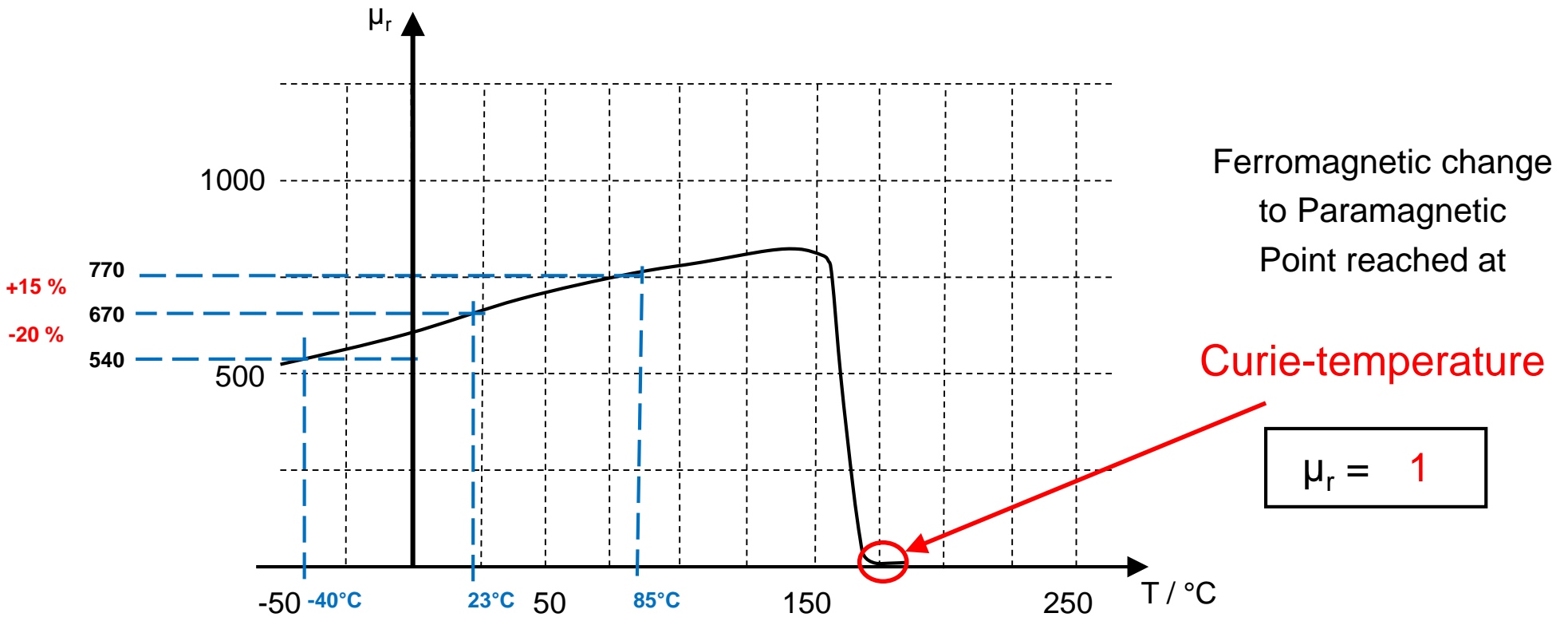


-  Metal Alloy/
NiZn/MnZN
-  Hyperflux
-  NiZn / MnZn
-  MnZn
-  WE-PERM
-  Metal Alloy
-  Superflux
-  NiZn
-  Fe





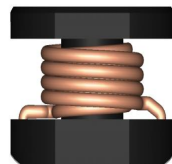
ELECTROMAGNETISM : Permeability Vs Temperature





ELECTROMAGNETISM : Impact of the Air Gap

$$L = \frac{(\mu_0 * \mu_r * A_{eff} * N^2)}{l_{eff} + l_{gap} * \mu_r}$$



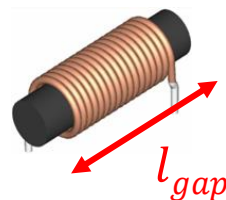
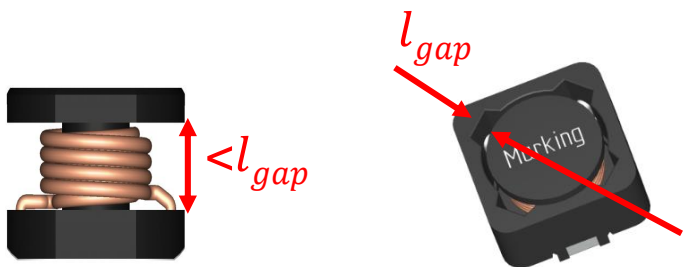
- μ_r = relative permeability
- N = No. of turns
- A_{eff} = effective magnetic area
- l_{eff} = effective magnetic length in the core
- l_{gap} = effective magnetic length in air
- R = Reluctance

- Decrease inductance value
- Inductance is less dependent on core permeability

$$L = \frac{N^2}{R_{core} + R_{gap}}$$

$$R_{core} = \frac{l_{eff}}{\mu_0 * \mu_r * A_{eff}}$$

$$R_{gap} = \frac{l_{gap}}{\mu_0 * A_{eff}}$$



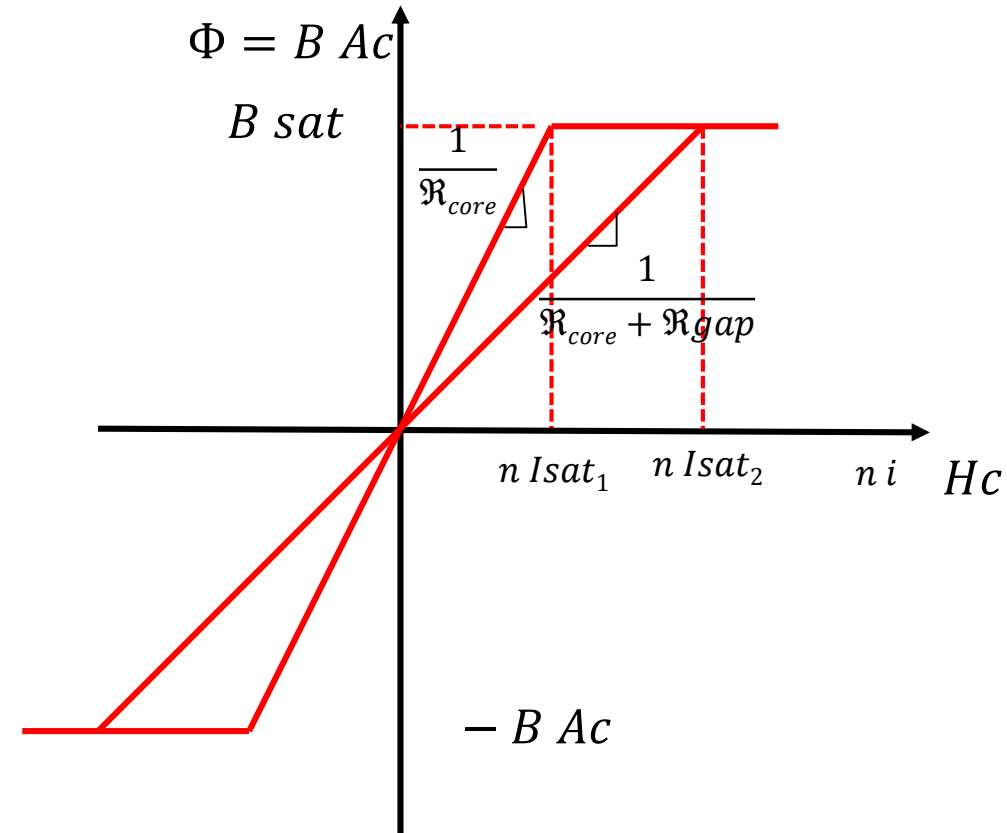
Distributed air Gap

ELECTROMAGNETISM : Impact of the Air Gap

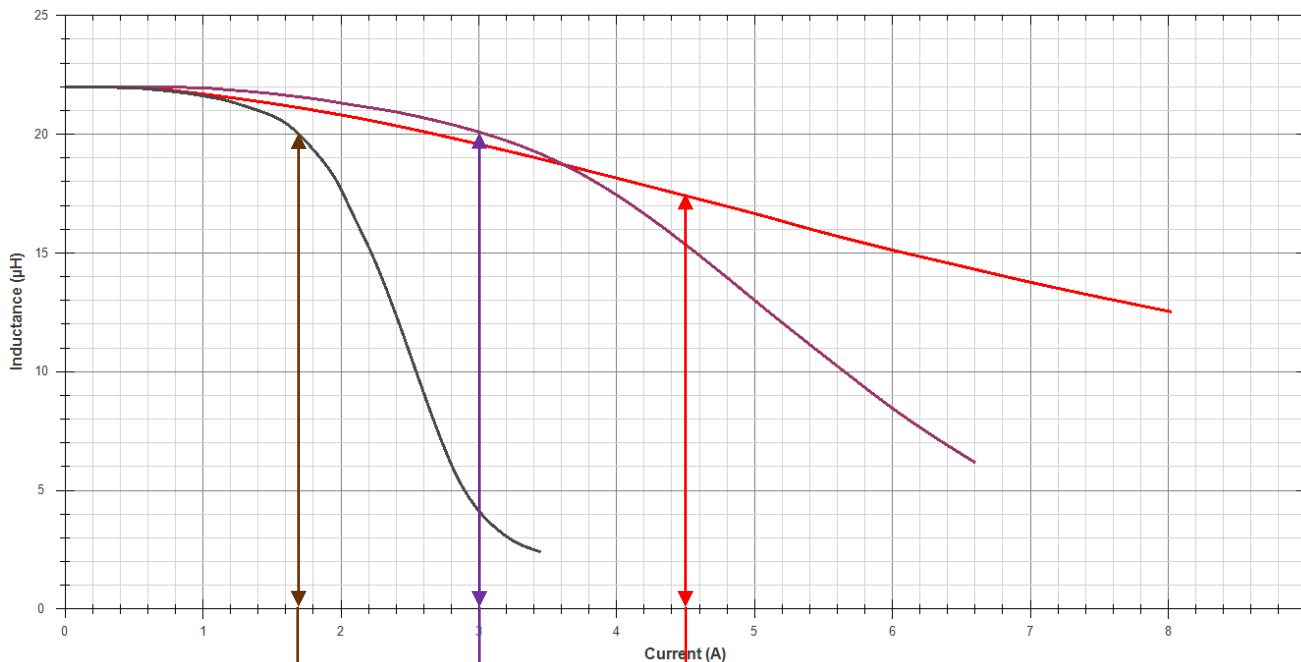
- Effect of air gap
- Increase saturation current

$$\Phi_{sat} = B_{sat} A_c$$

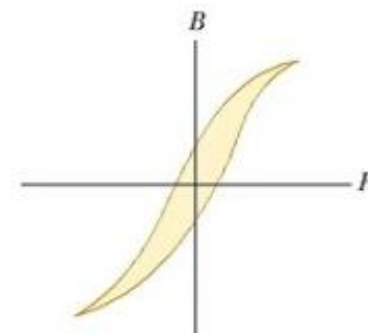
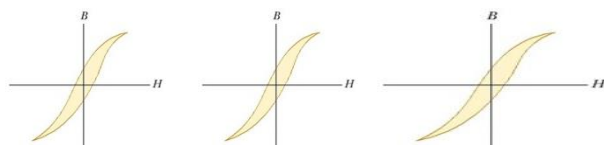
$$I_{sat} = \frac{B_{sat} A_c}{n} * (R_{core} + R_{gap})$$



ELECTROMAGNETISM : Impact of the Air Gap



- Same inductance value.
- 1.7A shielded
- 3.0A unshielded
- 4.5A distributed air gap



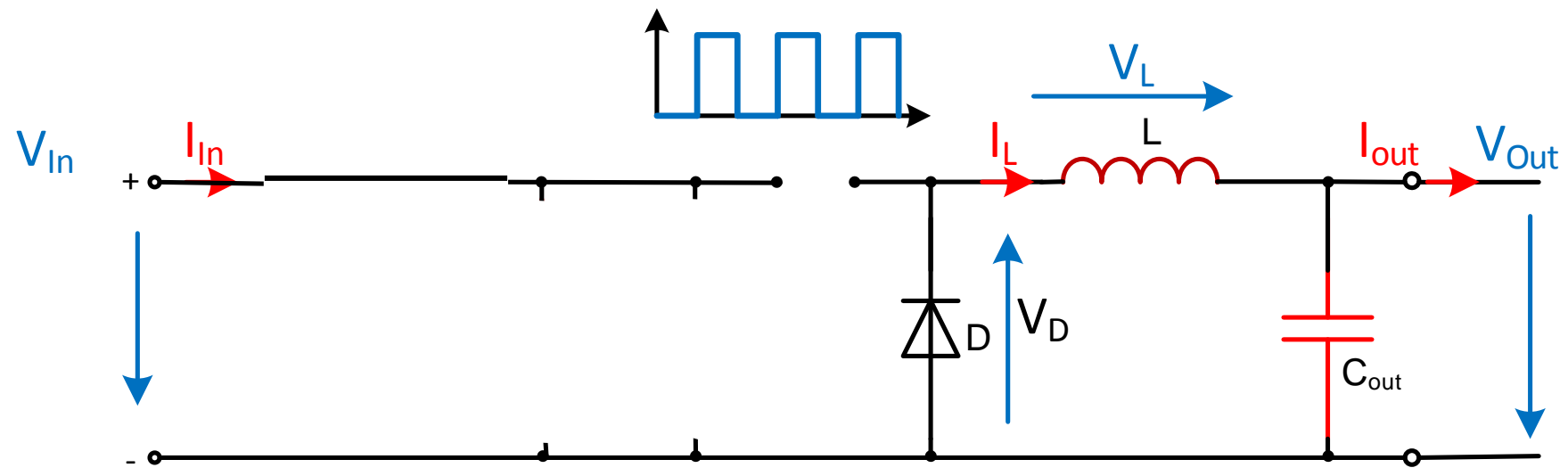
- Typical hysteresis loop of hard ferromagnetic iron powder material.

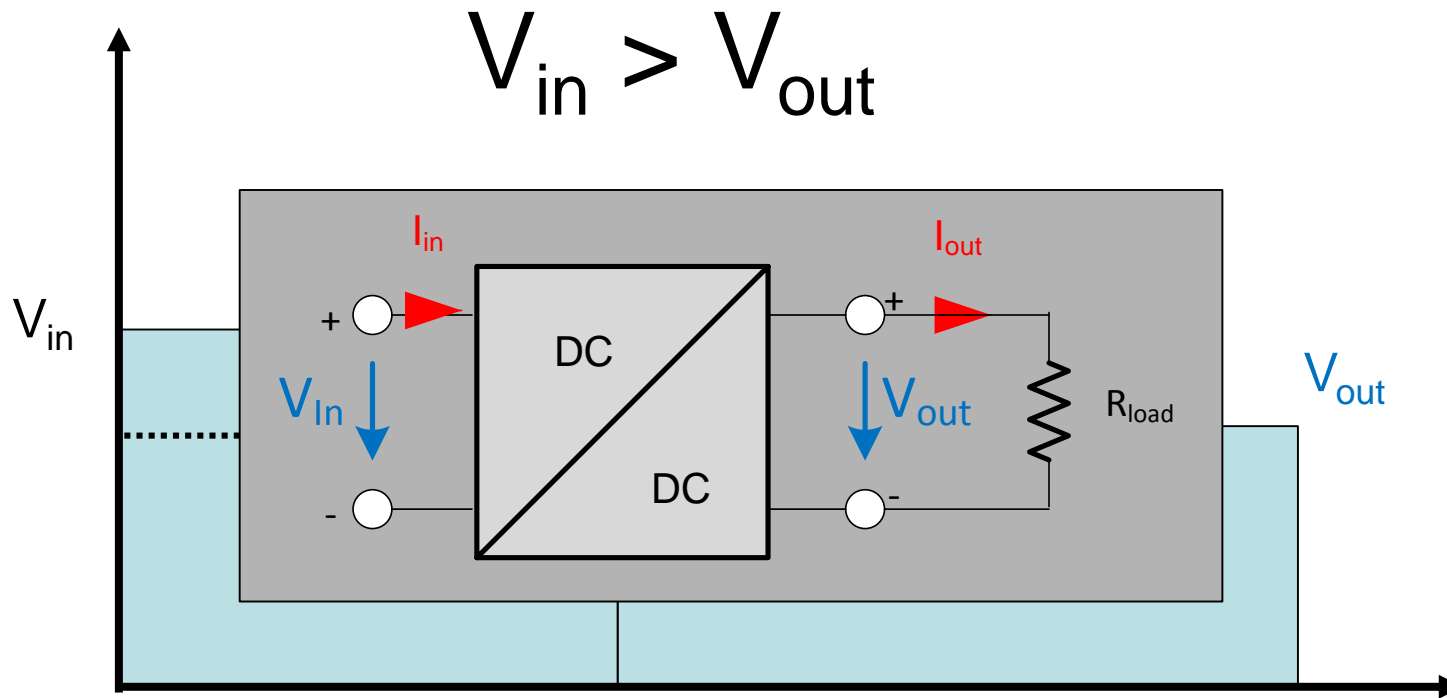


SMPS TOPOLOGIES



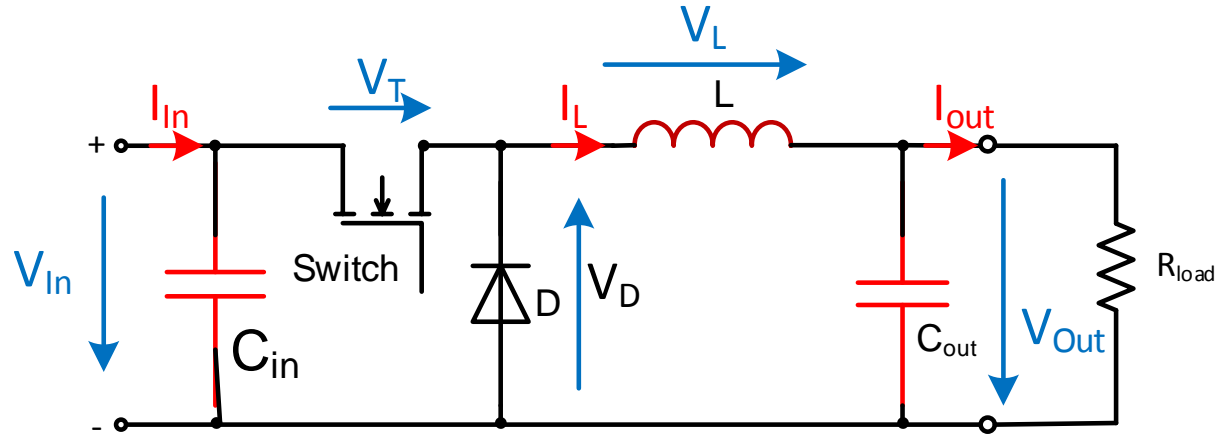
SMPS : Concept (Buck)



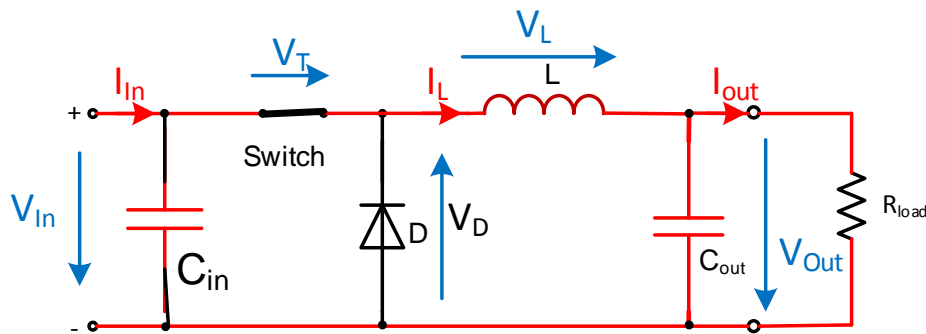


BUCK

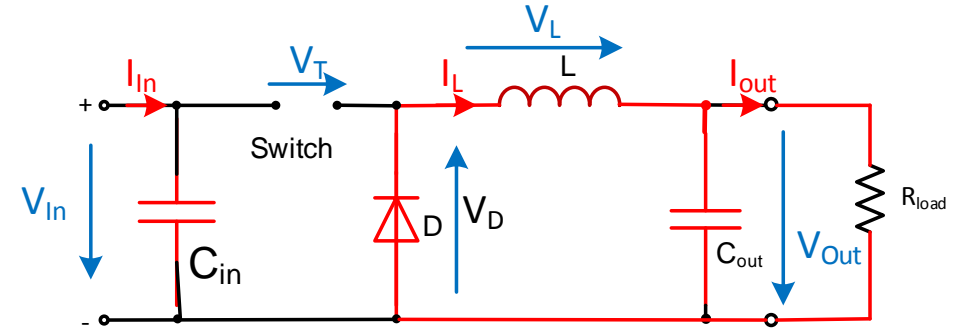
BUCK CONVERTER : Topology



Switch Closed



Switch Open



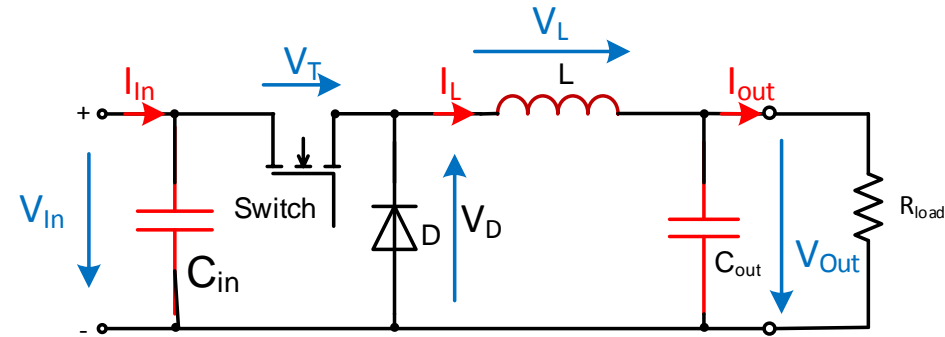


BUCK CONVERTER : Inductor calculation

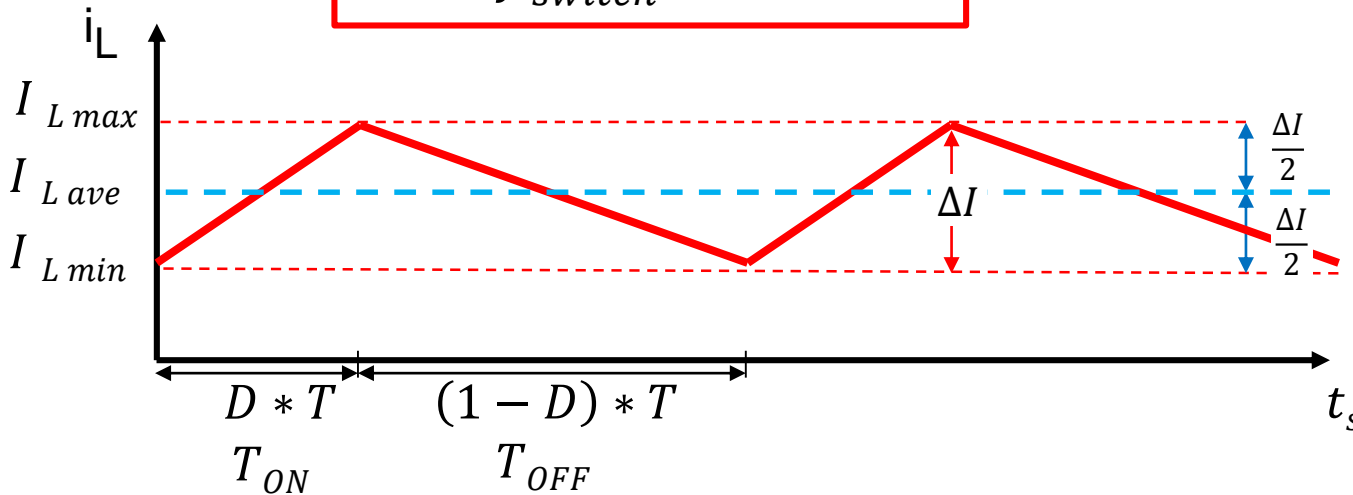
@ DT $V_L = L \frac{di_L}{dt}$

$L * (I_{Lmax} - I_{Lmin}) = (V_{in} - V_{out}) * DT$

$(I_{Lmax} - I_{Lmin}) = \Delta I = r * I_{out}$



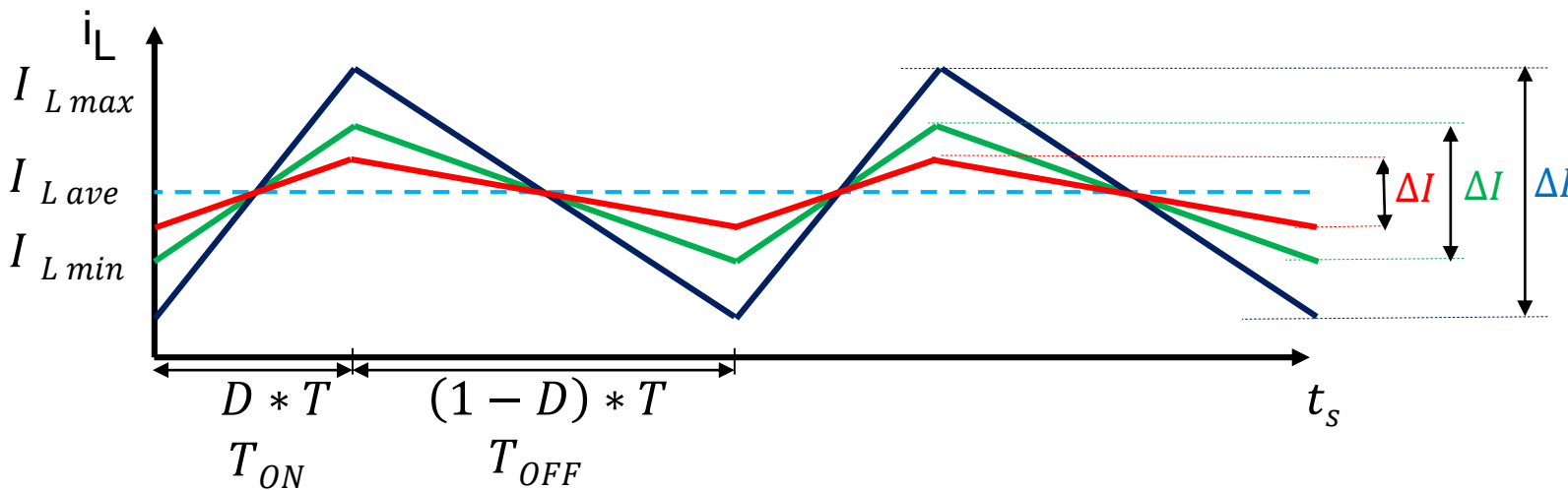
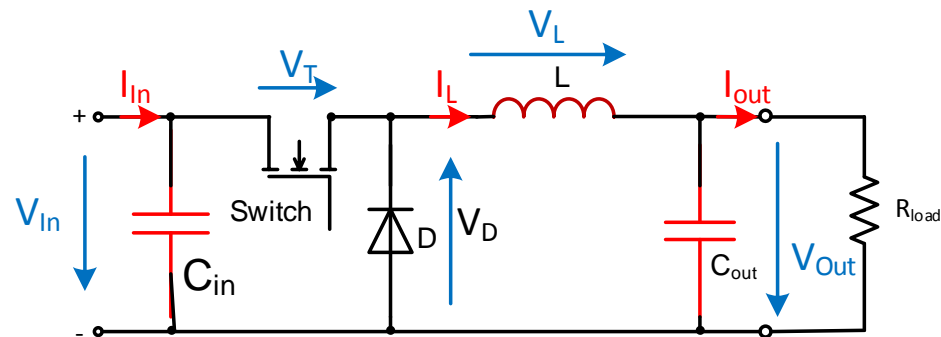
$$L = \frac{(V_{in} - V_{out}) * D}{f_{switch} * r * I_{out}}$$



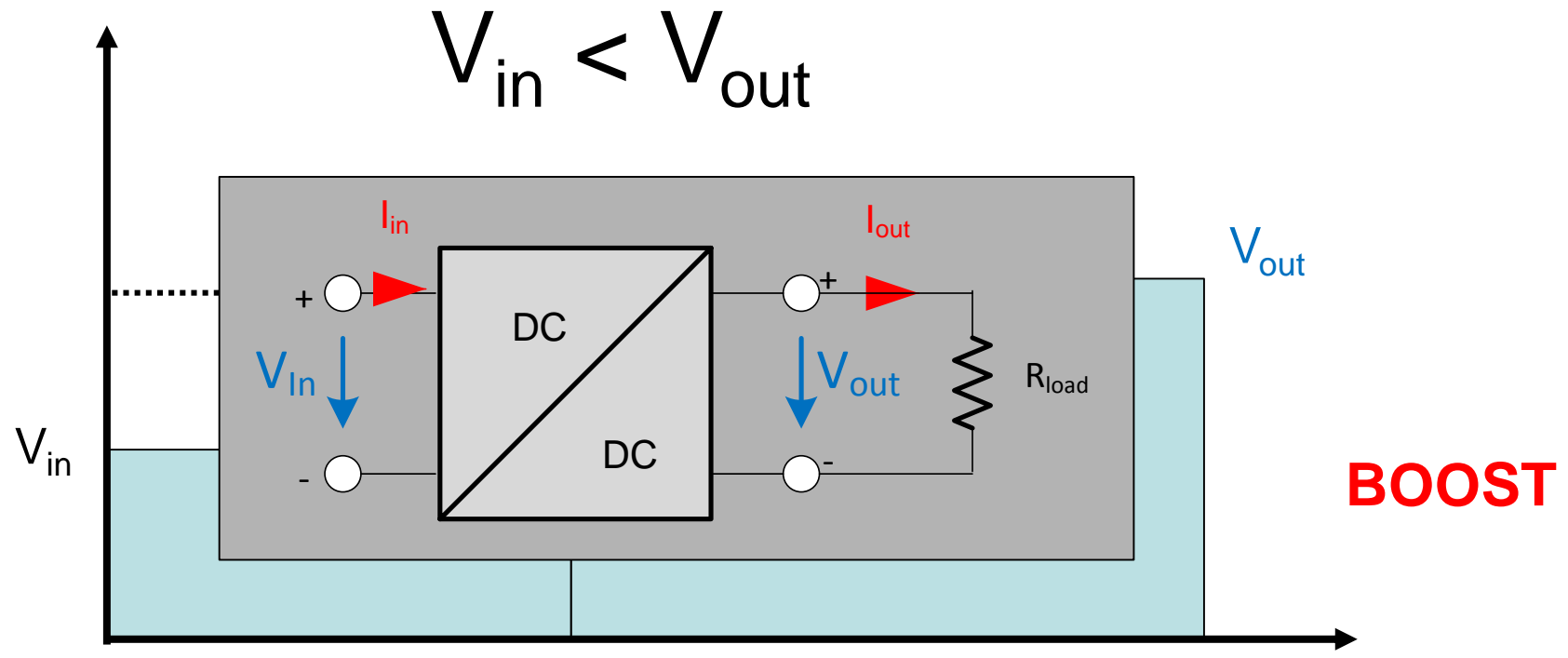


BUCK CONVERTER : Inductor calculation

$$L = \frac{(V_{in} - V_{out}) * D}{f_{switch} * r * I_{out}}$$

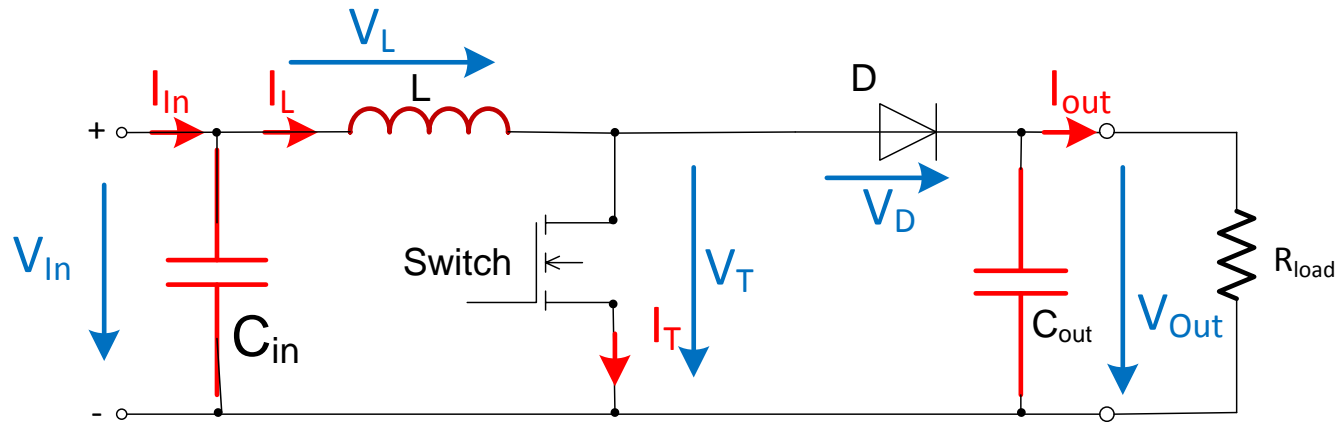


$L \uparrow \Rightarrow r \downarrow$
 $L \downarrow \Rightarrow r \uparrow$

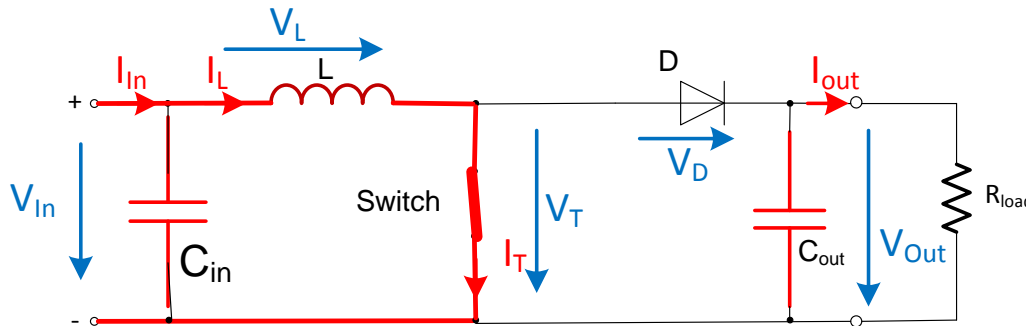




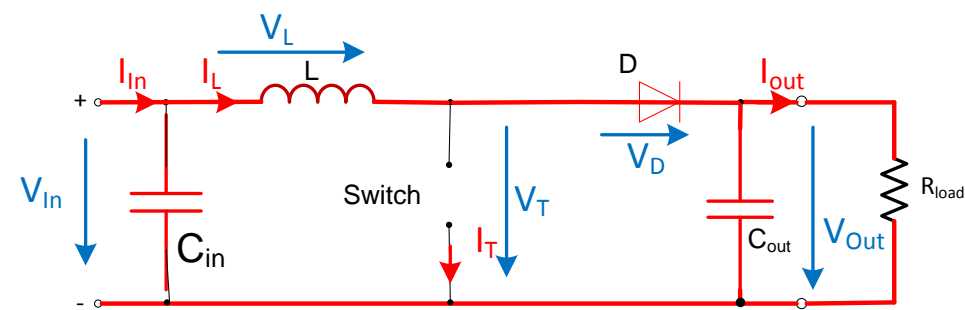
BOOST CONVERTER : Topology



Switch Closed

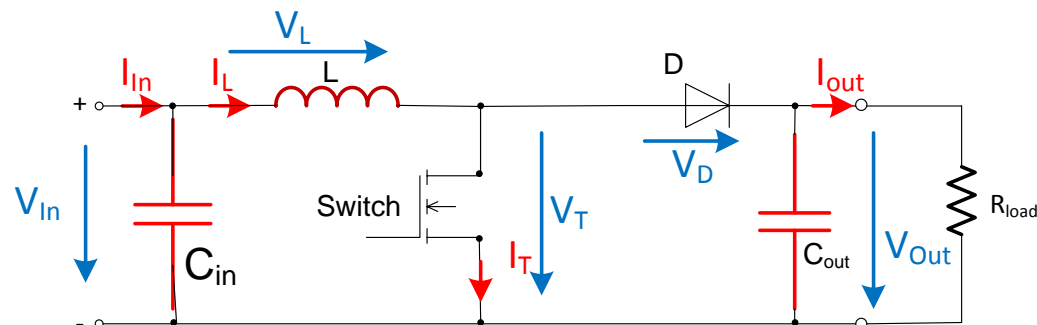


Switch Open

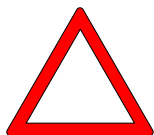


BOOST CONVERTER : Inductor calculation

$$L = \frac{V_{in} * D}{f_{switch} * r * I_L}$$



$$I_{in} \approx I_L \approx \frac{V_{out} * I_{out}}{V_{in}}$$



$$I_L > I_{out}$$

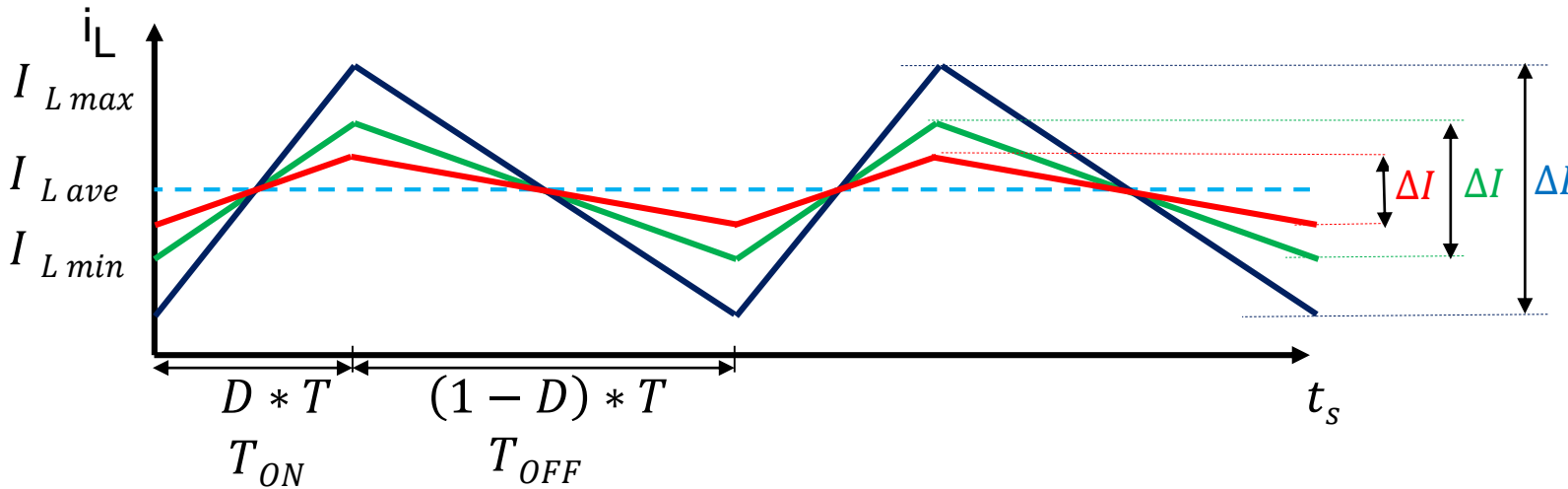
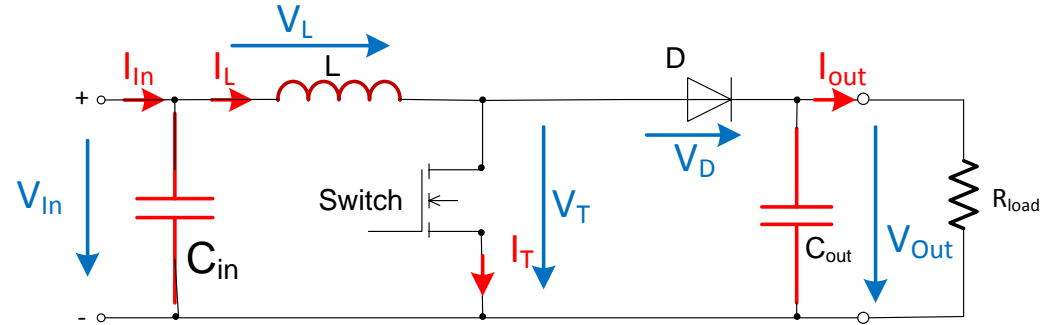
$$L = \frac{V_{in}^2 * D}{f_{switch} * r * V_{out} * I_{out}}$$

$$L = \frac{V_{out} * D * (1 - D)^2}{f_{switch} * r * I_{out}}$$



BOOST CONVERTER : Inductor calculation

$$L = \frac{V_{out} * D * (1 - D)^2}{f_{switch} * r * I_{out}}$$



$L \uparrow \Rightarrow r \downarrow$
 $L \downarrow \Rightarrow r \uparrow$

BUCK and BOOST CONVERTER : Summary

BUCK

$$D = \frac{V_{out}}{V_{in}}$$

BOOST

$$D = 1 - \frac{V_{in}}{V_{out}}$$

I_{out} ... operating current

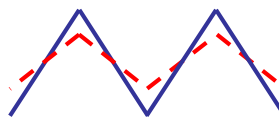
V_{out} ... output voltage

V_{in} ... input voltage

f_{switch} ... switching frequency of IC

$r \approx 0,2 \text{ to } 0,4$

$$L = \frac{(V_{in} - V_{out}) * D}{f_{switch} * r * I_{out}}$$



$$L = \frac{V_{out} * (1 - D)^2 D}{f_{switch} * r * I_{out}}$$

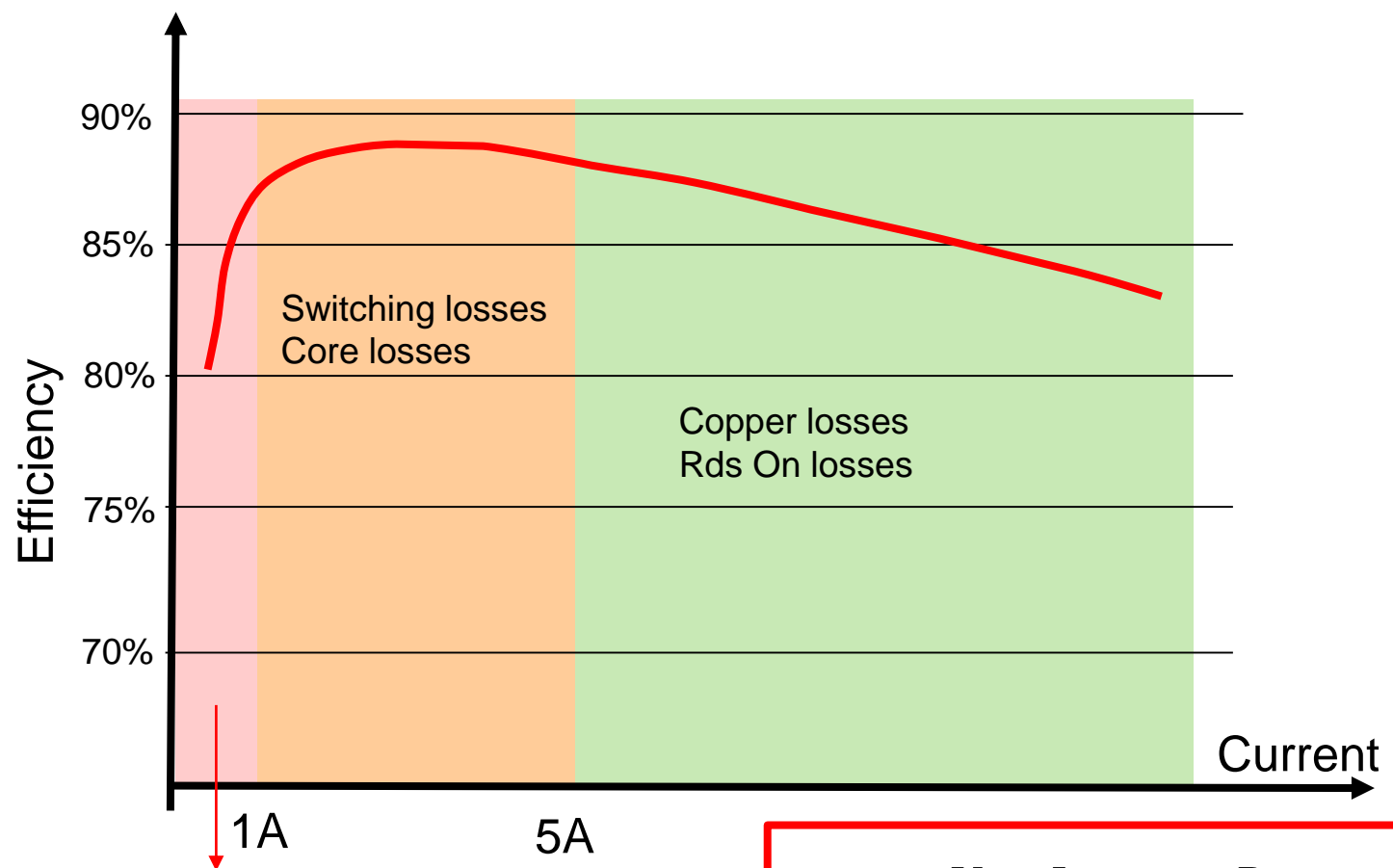
Rated current

$$I_{L_{RMS}} \approx I_{out_application}$$

$$I_{L_{RMS}} = \frac{V_{out}}{V_{in}} * I_{out_application}$$



SMPS : Efficiency



Constant losses

$$\eta[\%] = \frac{V_{out} \cdot I_{out}}{V_{in} \cdot I_{in}} = \frac{P_{out}}{P_{out} + P_{heat}} \cdot 100$$



INDUCTOR PARAMETER & SELECTION

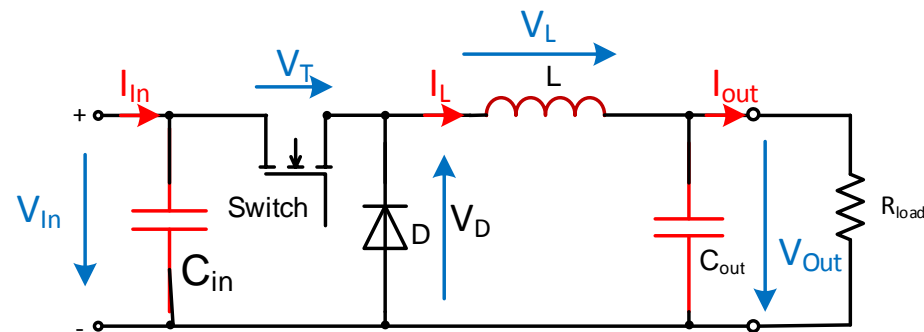
INDUCTOR SELECTION : Inductance value Buck

$$D = \frac{V_{out}}{V_{in}}$$

$$D = 0,208$$

$$D_3 = \frac{V_{out} + V_d}{V_{in} - V_{sw} + V_d}$$

$$D_3 = 0,22$$



$$L = \frac{(V_{in} - V_{out}) * D}{f_{switch} * r * I_{out}}$$

$$r = 20\%$$

$$I_{peak} = 2,2A$$

$$L = 18,5\mu H - 19,4\mu H$$

$$I_{peak} = I_{out} + \frac{\Delta I}{2}$$

$$I_{nom} = I_{out}$$

$$r = 40\%$$

$$I_{peak} = 2,4A$$

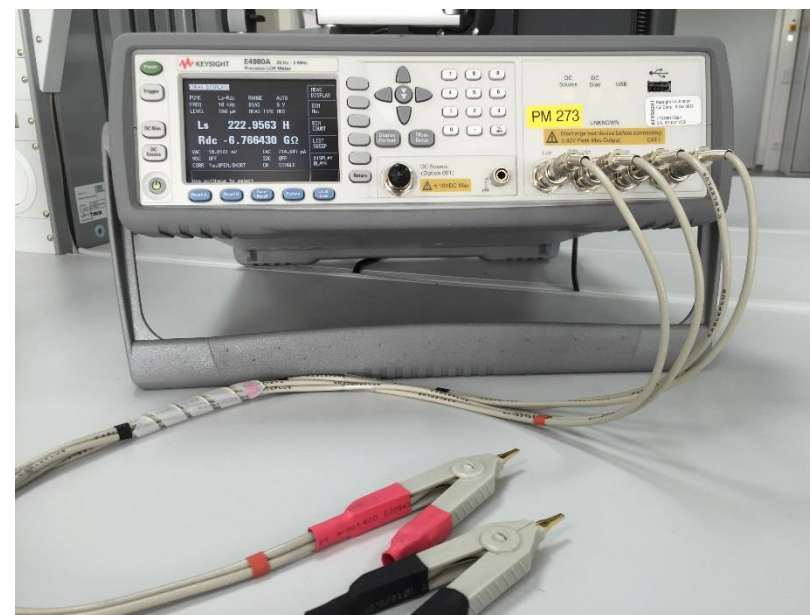
$$L = 9,3\mu H - 9,7\mu H$$

- $V_{in} = 24V$
- $V_{out} = 5V$
- $I_{out} = 2A$
- $F_{sw} = 535 kHz$
- $V_{sw} = 0,3V$
- $V_D = 0,3V$

Standard value : 8,2 μ H; 10 μ H, 12 μ H, 15 μ H, 18 μ H, 22 μ H

INDUCTOR SELECTION : Inductance value

- Inductance is measured with LCR meter
With a specific set up

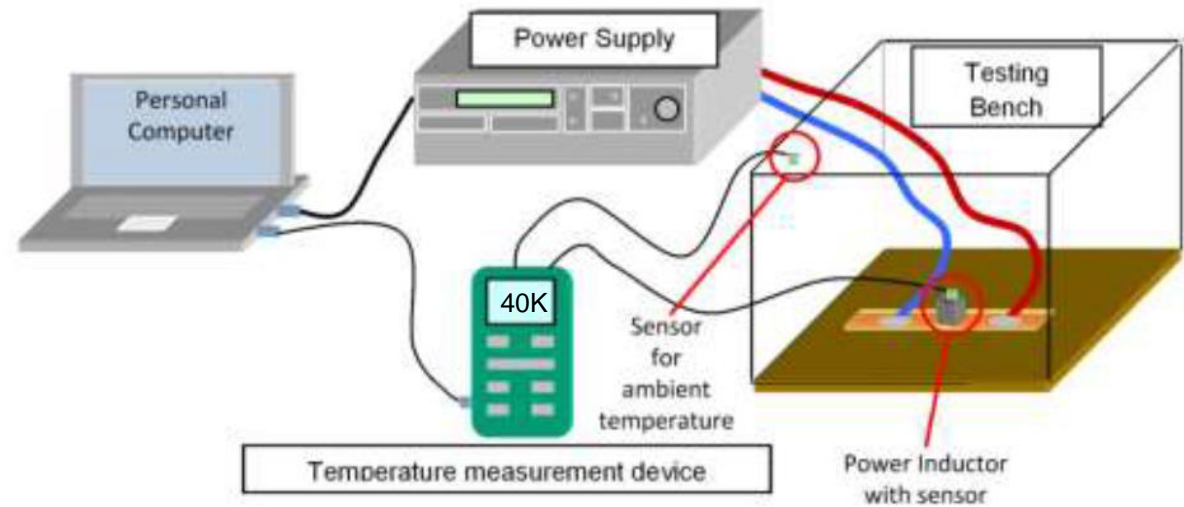


Electrical Properties:

| Properties | Test conditions | | Value | Unit | Tol. |
|-------------------------|---------------------------|------------------|-------|------|------|
| Inductance | 1 kHz/ 250 mV | L | 10 | μH | ±20% |
| Rated current | $\Delta T = 40 \text{ K}$ | I_R | 7.1 | A | max. |
| Saturation current | $ \Delta L/L < 10\%$ | I_{sat} | 10.5 | A | typ. |
| DC Resistance | @ 20°C | R_{DC} | 0.013 | Ω | typ. |
| DC Resistance | @ 20°C | R_{DC} | 0.021 | Ω | max. |
| Self resonant frequency | | f_{res} | 21 | MHz | typ. |

INDUCTOR SELECTION : Rated Current

Rated Current : I_R



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INDUCTOR SELECTION : Rated Current

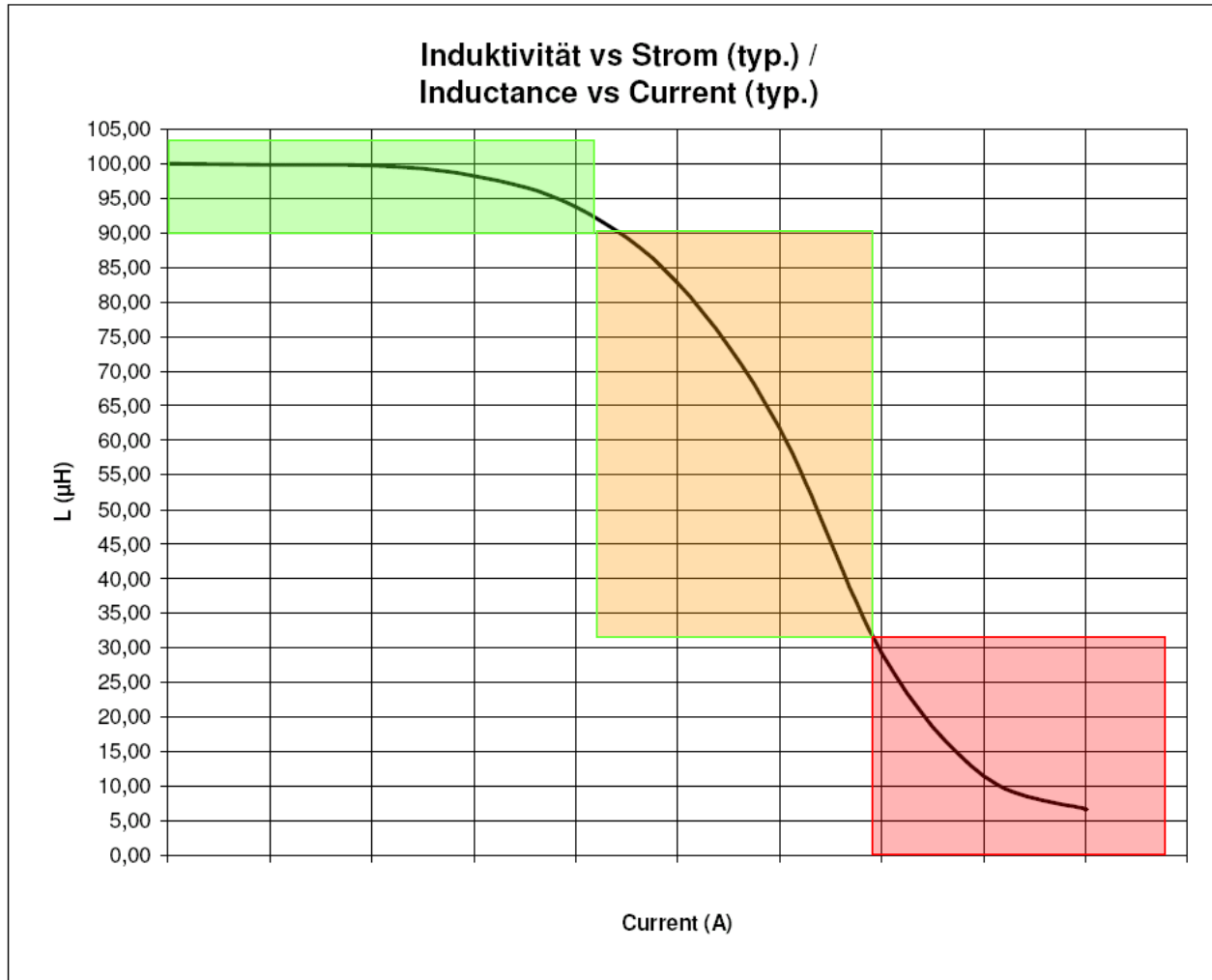
Impact of the setup

Rated current is link to the R_{DC} of the Inductor

| Contacting The Inductor | | $\Delta T @ 9 A$ |
|--|--|------------------|
| <ul style="list-style-type: none"> - WE-LHMI 7030 - 74437346220 - inductor on wires - huge clamps | | 30,9 K |
| <ul style="list-style-type: none"> - WE-LHMI 7030 - 74437346220 - inductor on wires - small clamps | | 35,8 K |
| <ul style="list-style-type: none"> - WE-LHMI 7030 - 74437346220 - inductor on PCB - recommended pad design | | 40,0 K |



INDUCTOR SELECTION : L vs Current



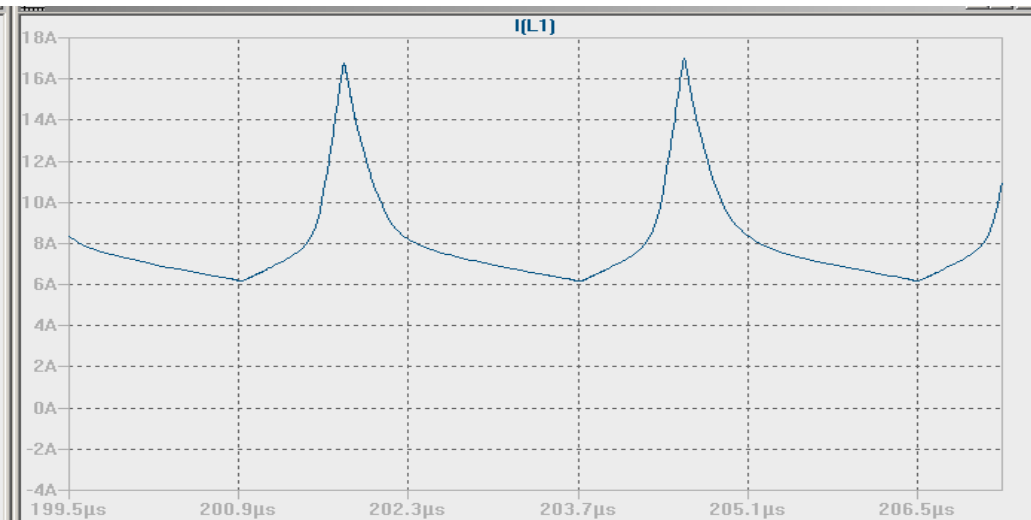
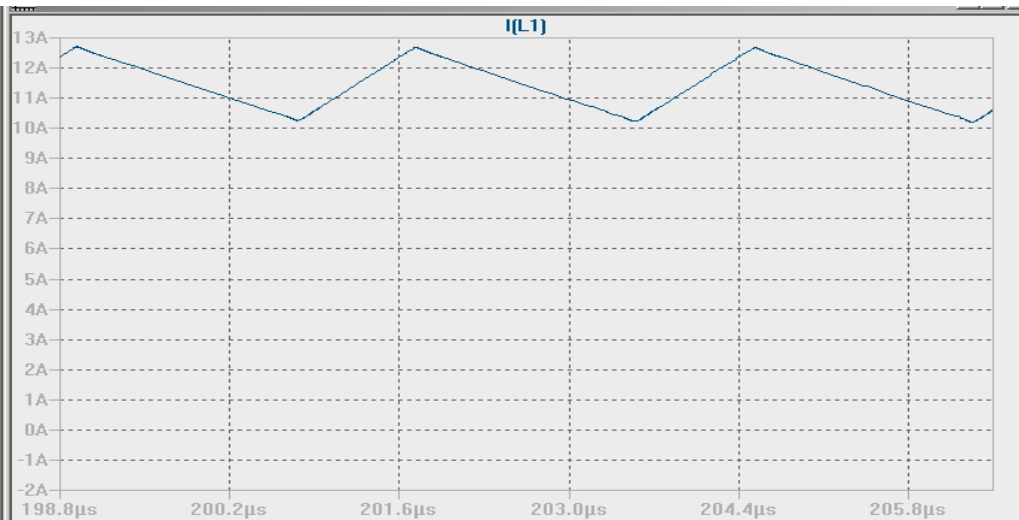
safe operation area

critical operating area

total saturation area

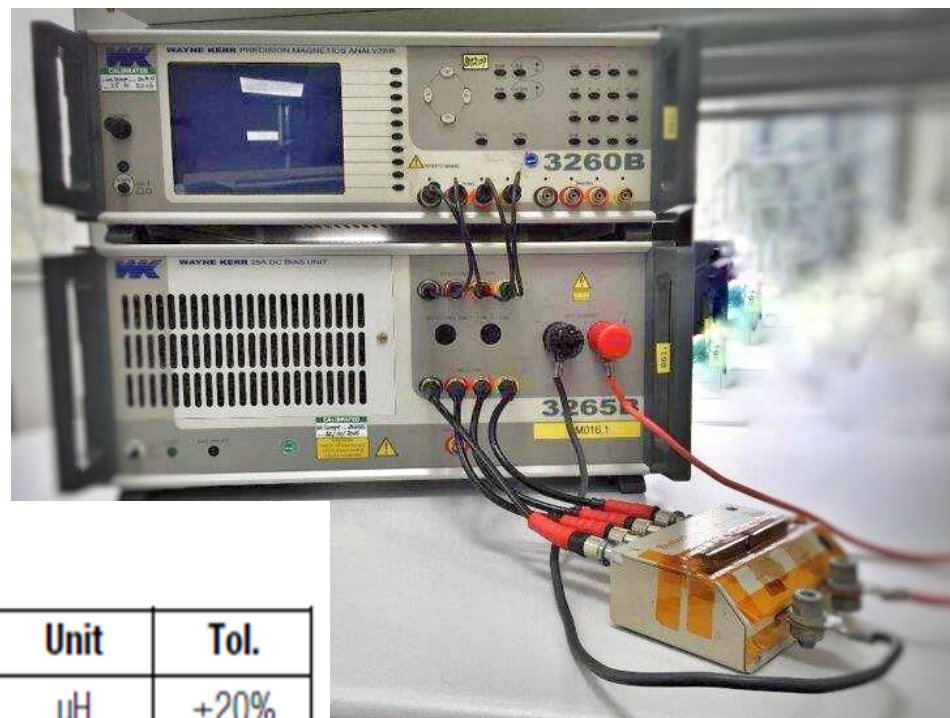


INDUCTOR SELECTION : Saturation effect



INDUCTOR SELECTION : Saturation Current

- The current that causes an inductance drop compared to its initial inductance value. In most cases for our inductors a drop of 10% is specified.

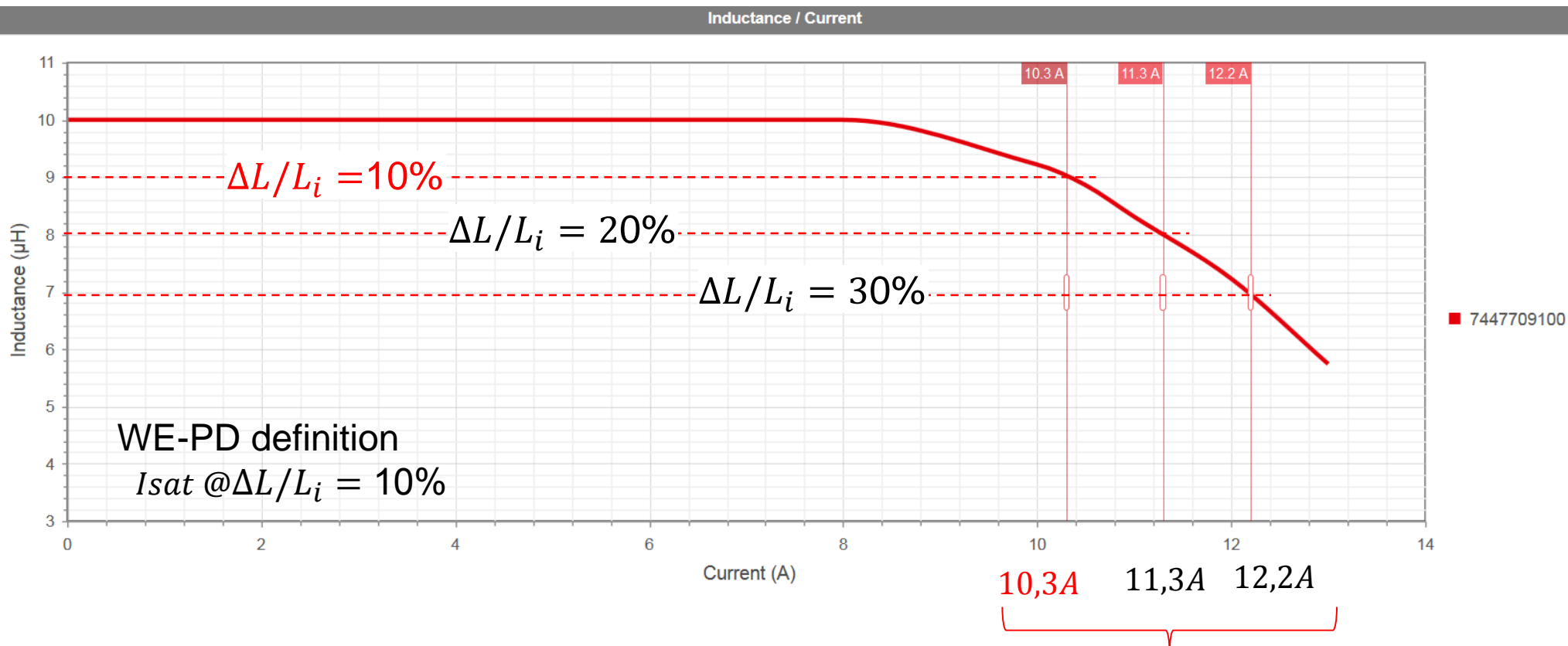


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| DC Resistance | @ 20°C | R_{DC} | 0.021 | Ω | max. |
| Self resonant frequency | | f_{res} | 21 | MHz | typ. |



INDUCTOR SELECTION : Saturation Current

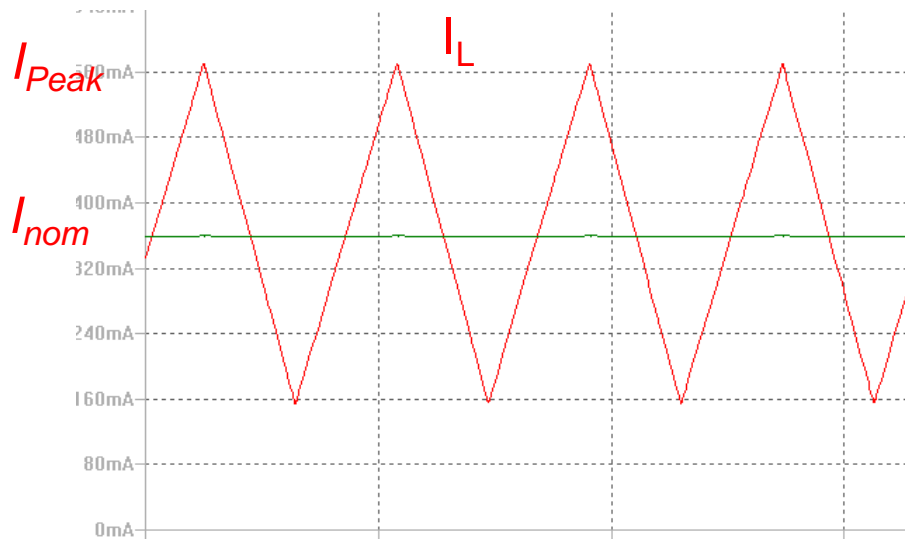


WE-PD definition
Isat @ $\Delta L/L_i = 10\%$

Isat = Depend on the definition



INDUCTOR SELECTION : Current



Buck

$$I_{L_{RMS}} \approx I_{out\ application}$$

Boost

$$I_{L_{RMS}} = \frac{V_{out}}{V_{in}} * I_{out\ application}$$

Electrical Properties:

| Properties | Test conditions | |
|-------------------------|--------------------------|-----------|
| Inductance | 1 kHz/ 250 mV | L |
| Rated current | $\Delta T = 40\text{ K}$ | I_R |
| Saturation current | $ \Delta L/L < 10\%$ | I_{sat} |
| DC Resistance | @ 20°C | R_{DC} |
| DC Resistance | @ 20°C | R_{DC} |
| Self resonant frequency | | f_{res} |

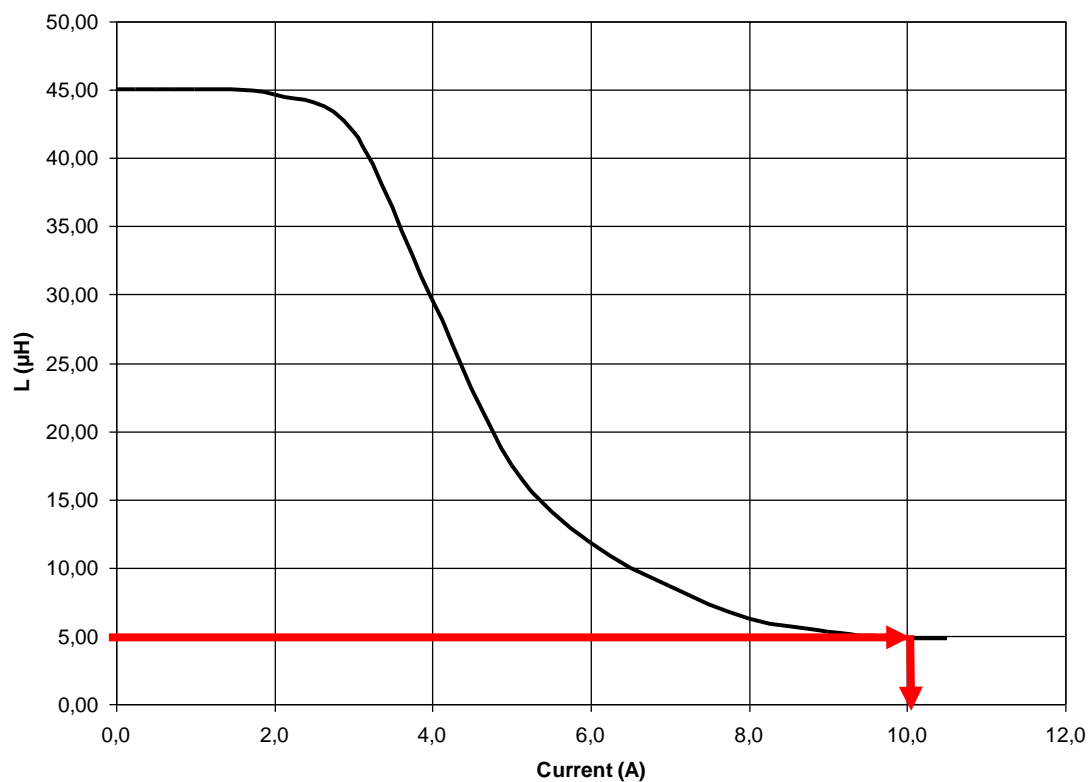
$$I_R \text{ Inductor} > I_{nom}$$

$$I_{sat} \text{ Inductor} > I_{peak}$$

INDUCTOR SELECTION : Volt μ seconds

Et (in $V\mu$ sec) for the Inductor can be estimate with the formula :

$$V\mu \text{ sec}(Inductor) = L_{\text{REST}} \cdot I_{\text{Max}}$$

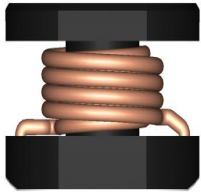


$$V\mu \text{ sec}(L) = 5\mu H * 10A$$

$$V\mu \text{ sec}(L) = 50 V\mu \text{ sec}$$

I_{max} is defined when we reach a flat zone
 L_{REST} , residual inductance value for I_{max}

INDUCTOR SELECTION : Volt μ seconds



$$V_{\mu\text{sec}}(L) = L_{\text{REST}} \cdot I_{\text{Max}}$$

$$V_{\mu\text{sec}}(L) = k * L_{\text{REST}} \cdot I_{\text{Max}}$$

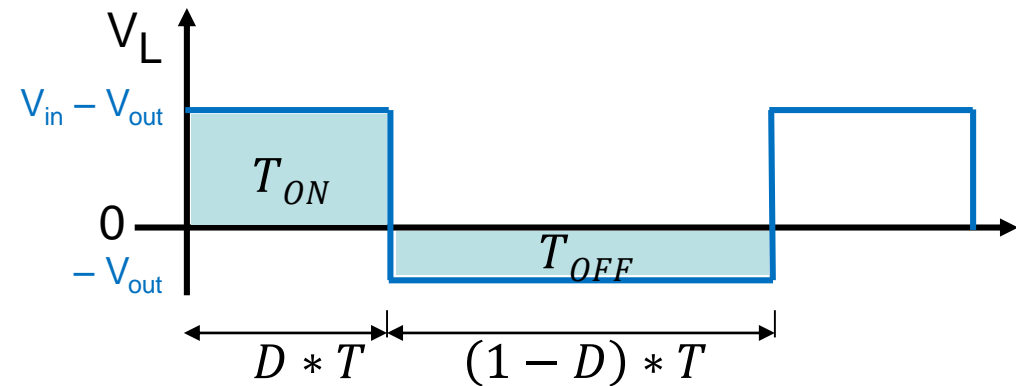
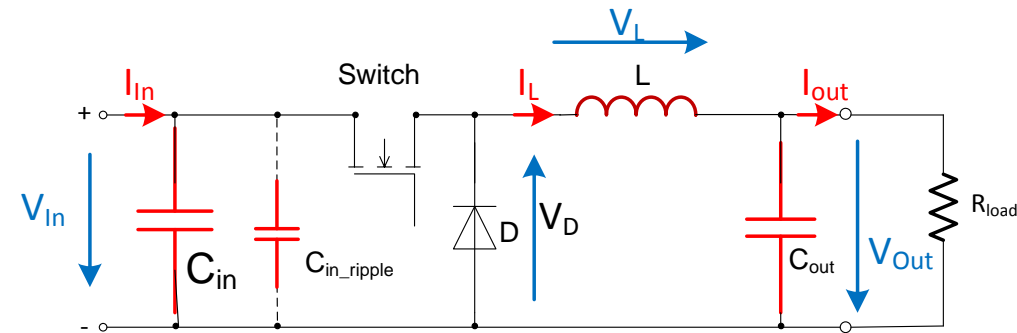
K : Security factor

$$K = 1$$

for iron powder, Superflux based inductors

$$K = 0,7$$

for ferrite based inductors



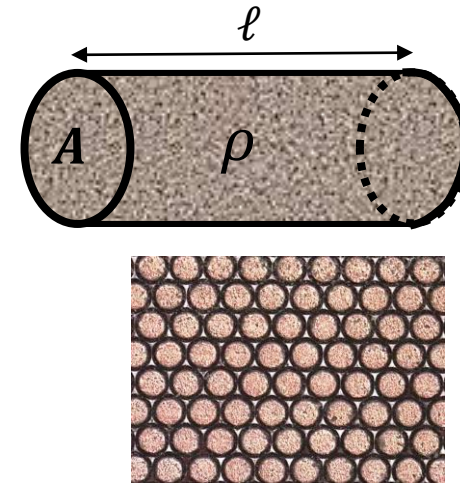
$$V_{\mu\text{sec}}(\text{application}) = V_L * T_{\text{ON}}$$

$$V_{\mu\text{sec}}(\text{Inductor}) > V_{\mu\text{sec}}(\text{application})$$

INDUCTOR SELECTION : DC Resistance

- RDC or DCR
- Depends on the following parameters
 - Wire material
 - Wire length
 - Wire cross section

$$R_{DC} = \rho * \frac{l}{A}$$



Electrical Properties:

| Properties | Test conditions | | Value | Unit | Tol. |
|-------------------------|-----------------|------------------|-------|------|------|
| Inductance | 1 kHz/ 250 mV | L | 10 | μH | ±20% |
| Rated current | ΔT = 40 K | I _R | 7.1 | A | max. |
| Saturation current | ΔL/LI < 10% | I _{sat} | 10.5 | A | typ. |
| DC Resistance | @ 20°C | R _{DC} | 0.013 | Ω | typ. |
| DC Resistance | @ 20°C | R _{DC} | 0.021 | Ω | max. |
| Self resonant frequency | | f _{res} | 21 | MHz | typ. |

INDUCTOR SELECTION : Self Resonant Frequency

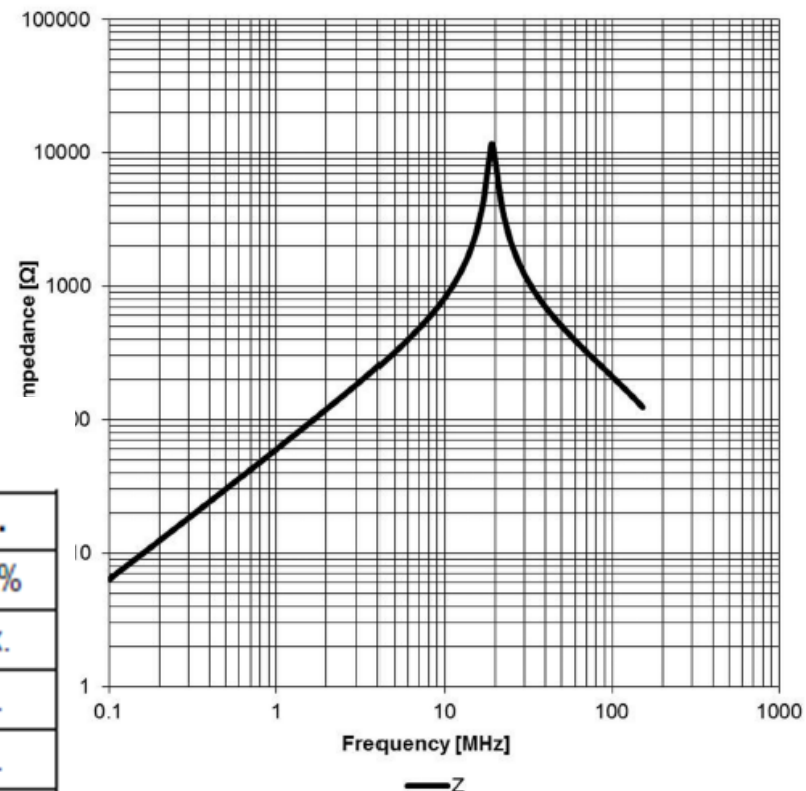
Self Resonant Frequency : SRF

SRF \gg *Switching frequency*

Electrical Properties:

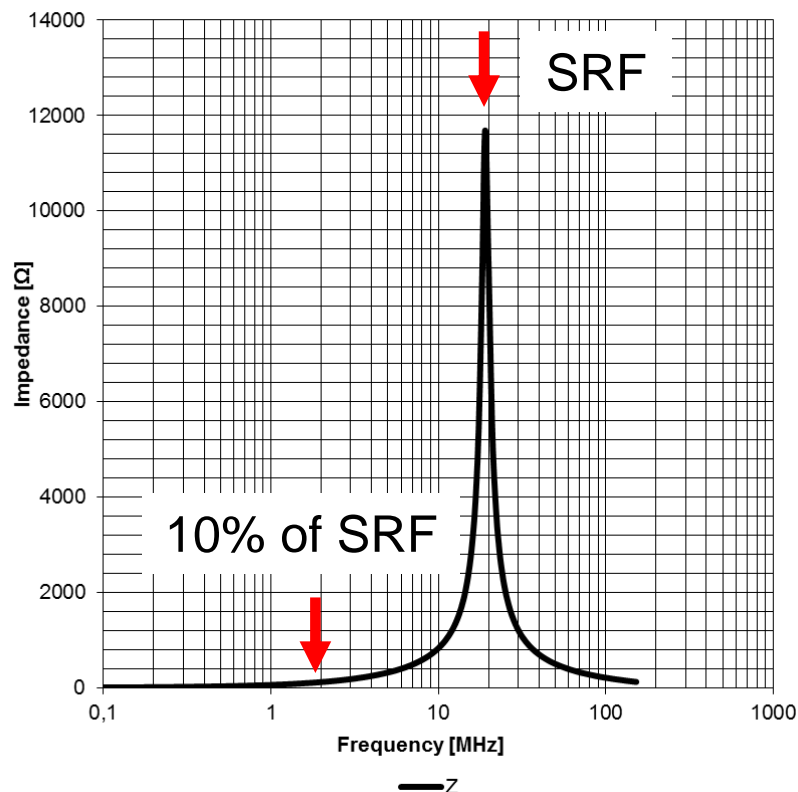
| Properties | Test conditions | | Value | Unit | Tol. |
|-------------------------|-----------------------|-----------|-------|----------|------------|
| Inductance | 1 kHz/ 250 mV | L | 10 | μ H | $\pm 20\%$ |
| Rated current | $\Delta T = 40$ K | I_R | 7.1 | A | max. |
| Saturation current | $ \Delta L/L < 10\%$ | I_{sat} | 10.5 | A | typ. |
| DC Resistance | @ 20°C | R_{DC} | 0.013 | Ω | typ. |
| DC Resistance | @ 20°C | R_{DC} | 0.021 | Ω | max. |
| Self resonant frequency | | f_{res} | 21 | MHz | typ. |

F2 Typical Impedance Characteristics:

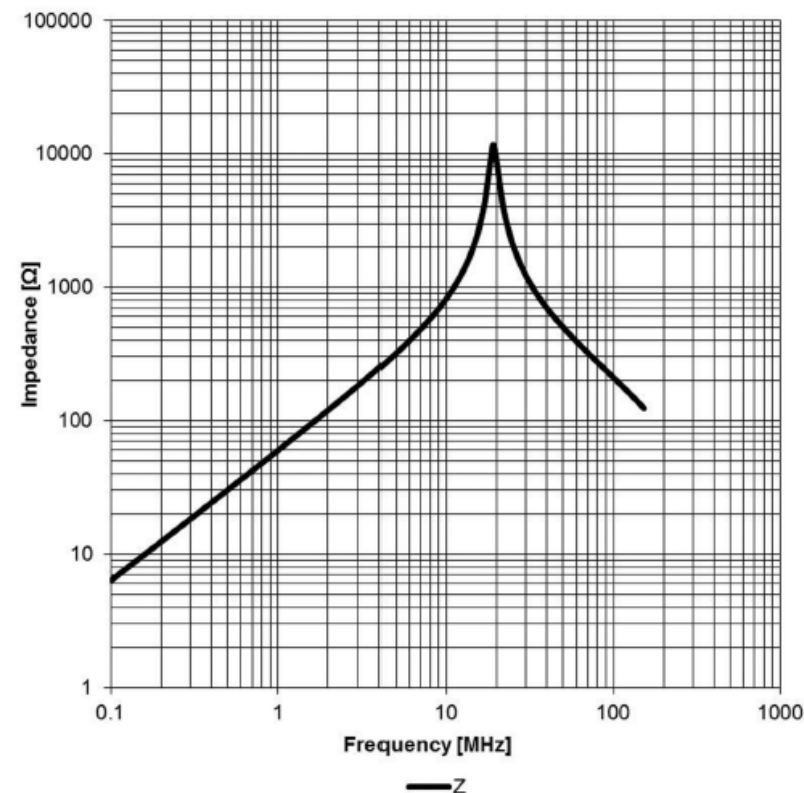


INDUCTOR SELECTION : Self Resonant Frequency

Linear Impedance Scale

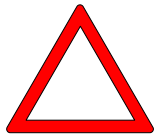


Logarithmic Impedance Scale



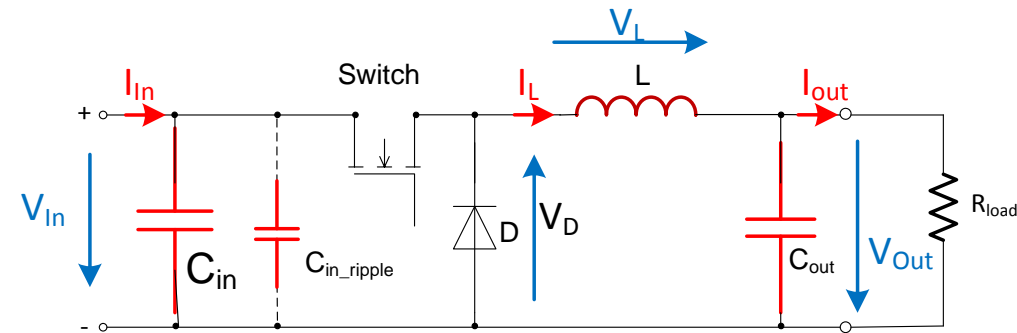
Use switching frequency for DC/DC converter up to 10% of SRF.
If it can't be avoided, check losses

INDUCTOR SELECTION : High voltage version



$V_L \text{ max} = 80 V_{pk} \text{ max}$
for standard version

Cannot be used for OFF line buck
Risk of short circuit



$$V_L = 300V$$



400 V_{pk} max for HV version

- Better insulated wire
- Winding testing process
- According WE-STD 1516
- WE is only manufacturer with statement for Voltage

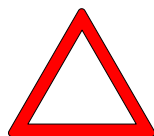
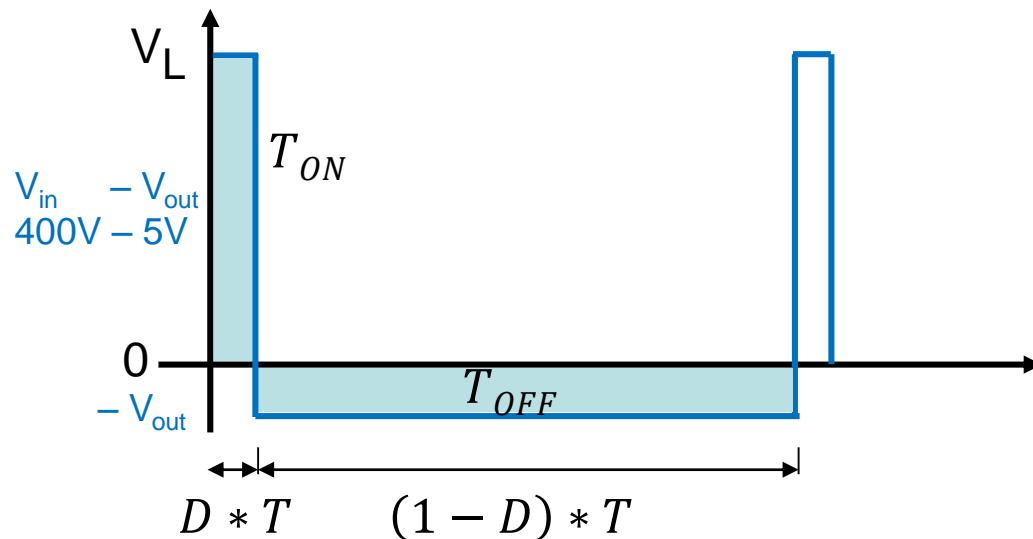




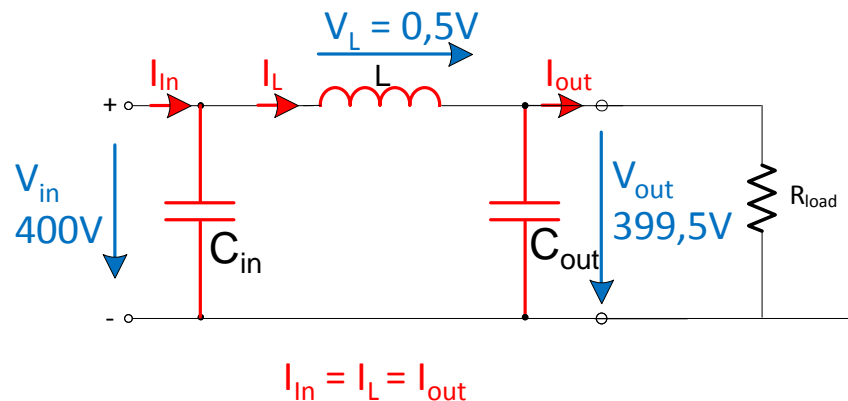
INDUCTOR SELECTION : High voltage version



- HV is needed when 300V to 400V drops over the inductor



- HV is not needed in a input filter inductor
- 300V to 400V will drop over the capacitor, not the inductor
- Standard inductor can be chosen



INDUCTOR SELECTION : Derating current

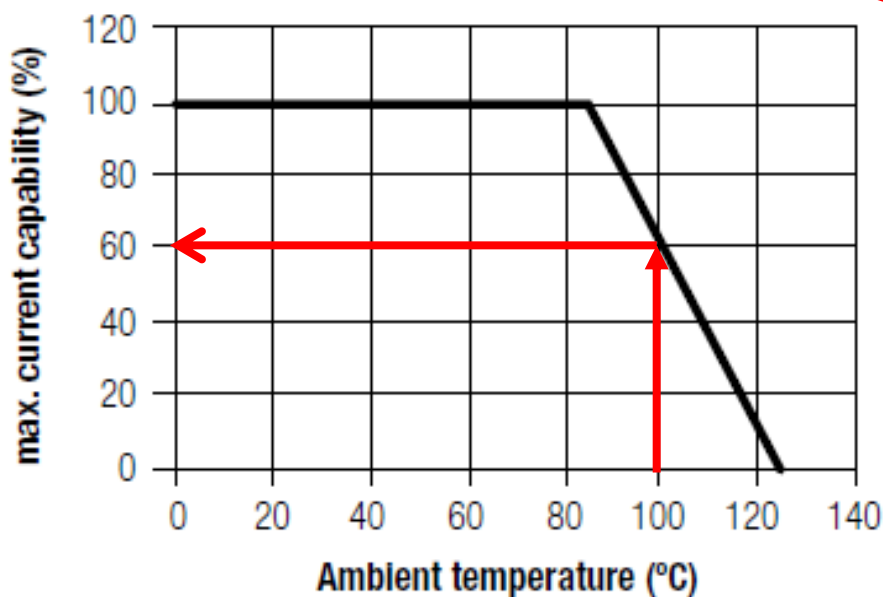
- Ambient temperature : -40°C to 85°C referring to I_R
- Operating temperature : -40°C to 125°C

Only DC losses !

$$R_{DC} I^2$$

Ambient temperature
+
Self heating (Inductor)

Operating Temperature

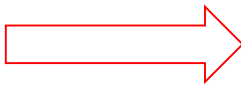


→ If ambient temperature is higher than 85°C the self heating inductor must be reduced

INDUCTOR SELECTION : Self Heating

Ambient temperature
+
Self heating (Inductor)

Operating Temperature



$$P_{total} = P_{AC} + P_{DC}$$

Reduce the losses of the inductor help to

- Optimize the efficiency
- Reduce effort for cooling system



INDUCTOR LOSSES

Inductor Losses

$$P_{total} = P_{core} + P_{copper}$$

AC Core losses

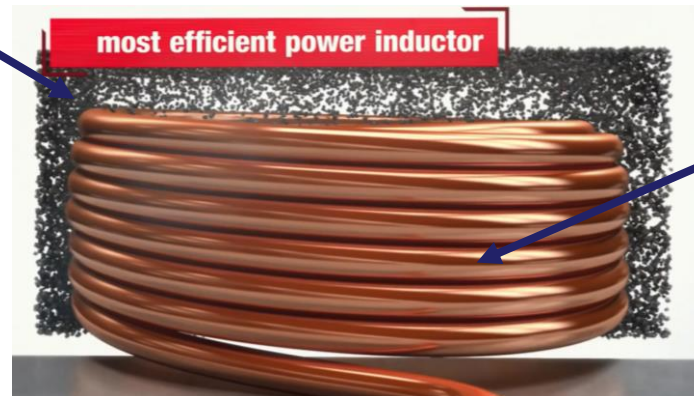
Hysteresis losses
Eddy current losses

DC losses – depending on DCR

AC-losses – dep. on winding structure

→ Skin-Effect

→ Proximity-Effect



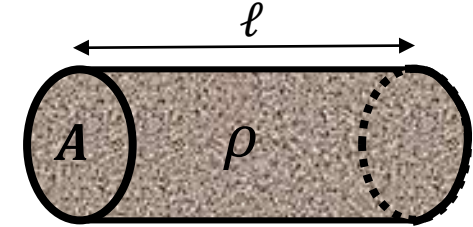


INDUCTOR LOSSES : Copper DC losses



$$P_{cu} = R_{DC} * I_{RMS}^2$$

$$R_{DC} = \rho * \frac{l}{A}$$

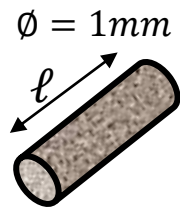


$$\rho = 1,78 * 10^{-2} \frac{\Omega \cdot mm^2}{m}$$

- ρ : Resistivity of copper
- l : Length of wire
- A : Cross Sectional area

$$R_{DC} \downarrow \Rightarrow P_{cu} \downarrow$$

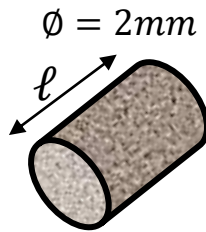
Optimization



$l=1m$

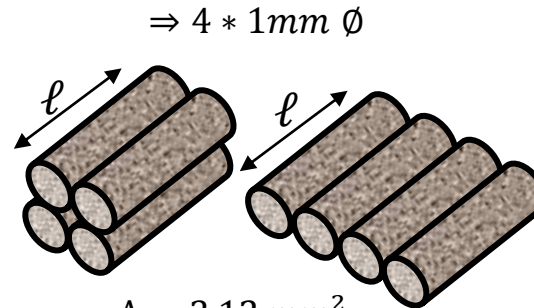
$$A = 0,78 \text{ mm}^2$$

$$R_{DC} = 23m\Omega$$



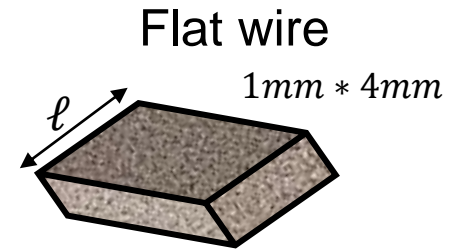
$$A = 3,714 \text{ mm}^2$$

$$R_{DC} = 5,7m\Omega$$



$$A = 3,12 \text{ mm}^2$$

$$R_{DC} = 5,75m\Omega$$

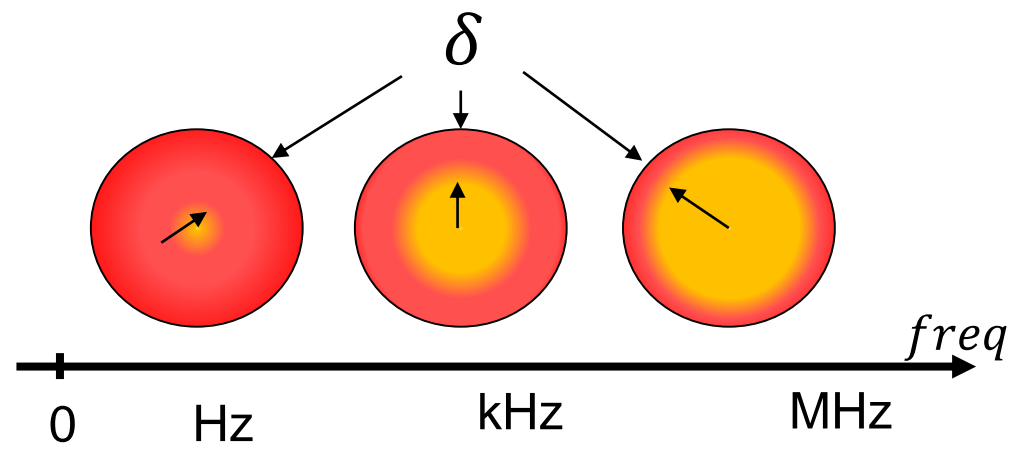


$$A = 4 \text{ mm}^2$$

$$R_{DC} = 4,48m\Omega$$

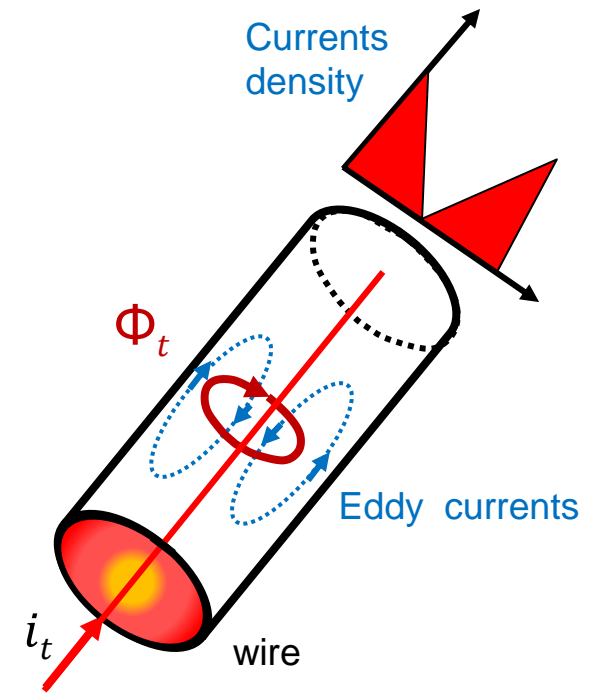


INDUCTOR LOSSES : Copper AC losses, Skin effect



$$\delta = \sqrt{\frac{2 * \rho}{\omega * \mu}} \text{ mm}$$

$$\delta = \frac{76}{\sqrt{f}} \text{ mm @ } 100^{\circ}\text{C}$$



δ = skin depth
 ρ = resistivity
 ω = angular frequency $2\pi f$
 μ = permeability

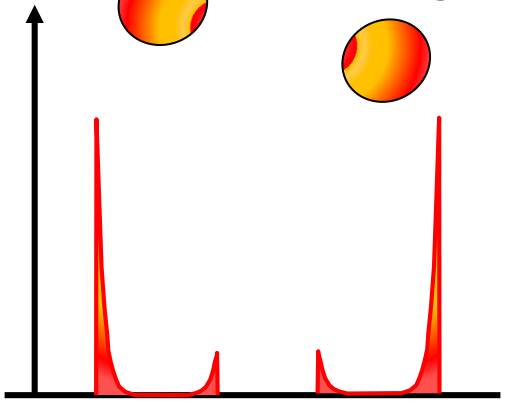
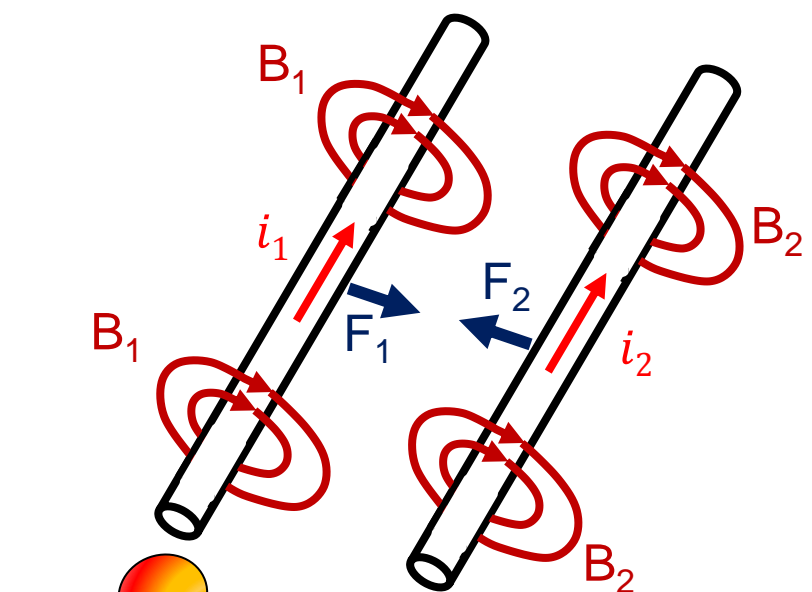
For Copper

| | | |
|------------|--------|-----------|
| δ @ | 50Hz | = 9.38 mm |
| δ @ | 10kHz | = 0.66 mm |
| δ @ | 100kHz | = 0.22 mm |

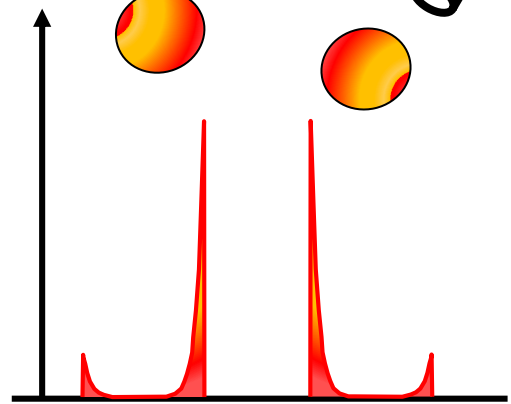
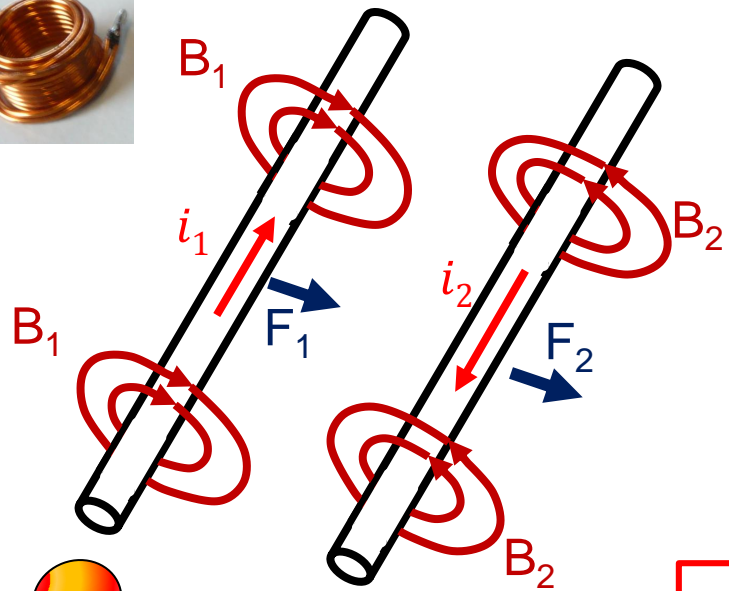
$f \uparrow \Rightarrow R_{AC} \uparrow$



INDUCTOR LOSSES : Copper AC losses, Proximity effect



Current in same direction



Current in opposite direction

$$f \uparrow \Rightarrow R_{DC} \uparrow$$

Like the skin effect, the distribution of current inside the wire is reduced



INDUCTOR LOSSES : Copper AC losses, Proximity effect

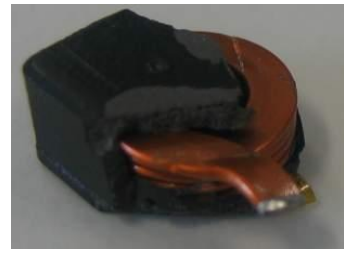
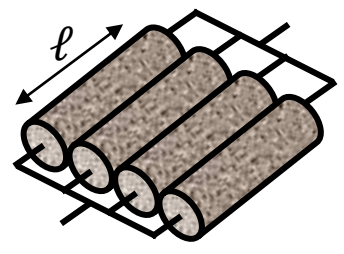


How to reduce Copper AC losses



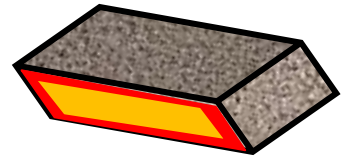
- Multi wire

$$R_{ac\ Total} \sim \frac{n}{R_{ac}}$$



- Flat wire

1mm * 4mm



$$A = 4\text{ mm}^2$$

Circumference = 10mm

∅ = 1,128mm



$$A = 4\text{ mm}^2$$

Circumference = 7,09mm

>

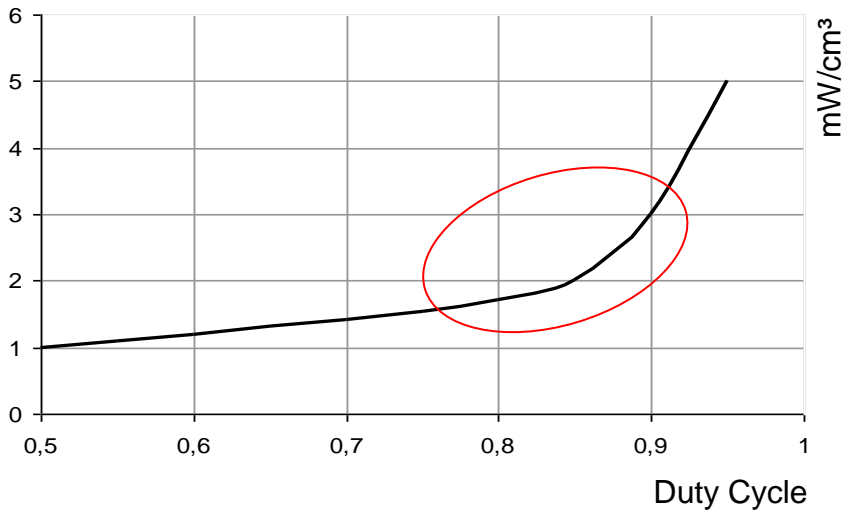
$$R_{ac\ Flat\ wire} < R_{ac\ Round\ wire}$$

INDUCTOR LOSSES : Core losses

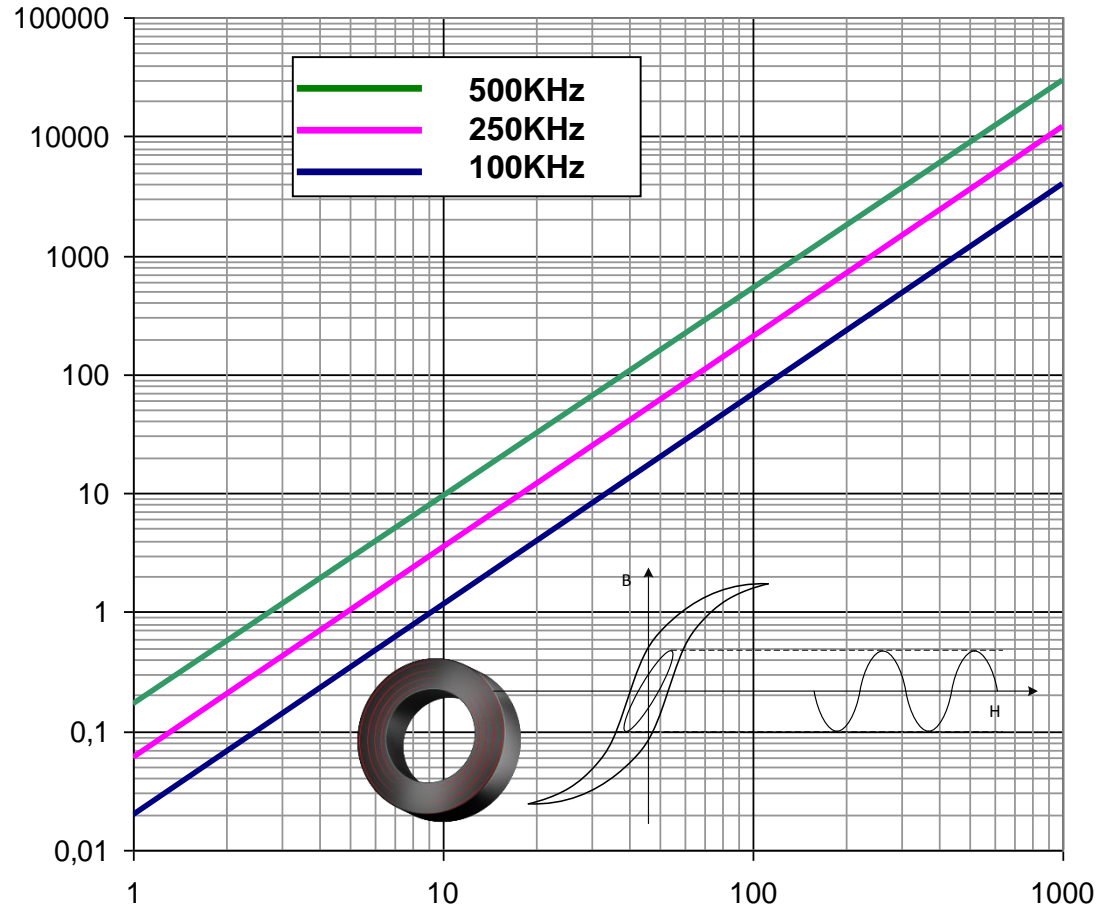
- Steinmetz formula

$$P_{core} = K \cdot f^a \cdot B^b$$

Error factor



B(peak) in mT



INDUCTOR LOSSES : Core losses

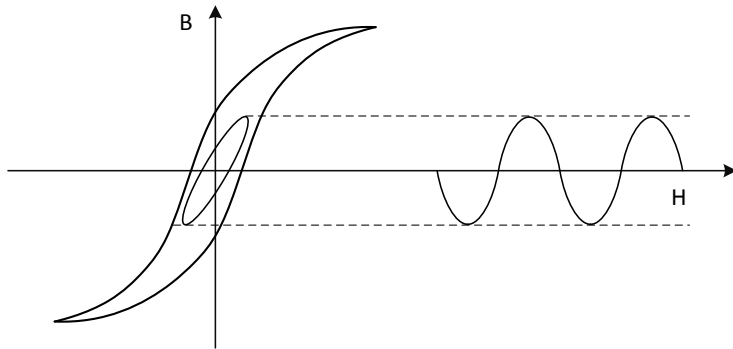
Steinmetz Models

$$P_V = K \cdot f^\alpha \cdot \Delta B^\beta$$

$$P_V = K \cdot f^{\alpha-1} \cdot \Delta B^\beta \times f^r$$

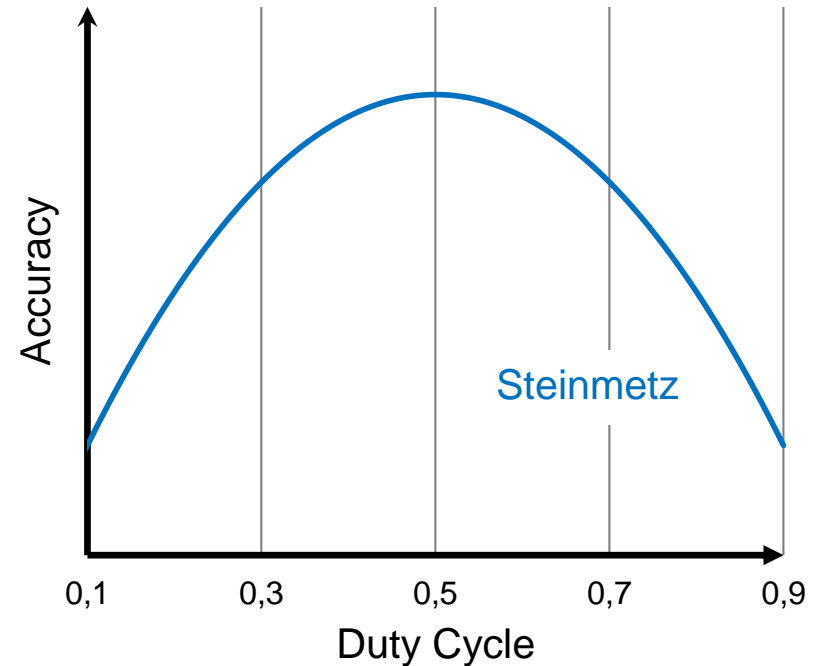
$$P_V = K \cdot f_{eq}^\alpha \cdot \Delta B^\beta$$

➔ core loss only



➔ major loop approach
only sine wave

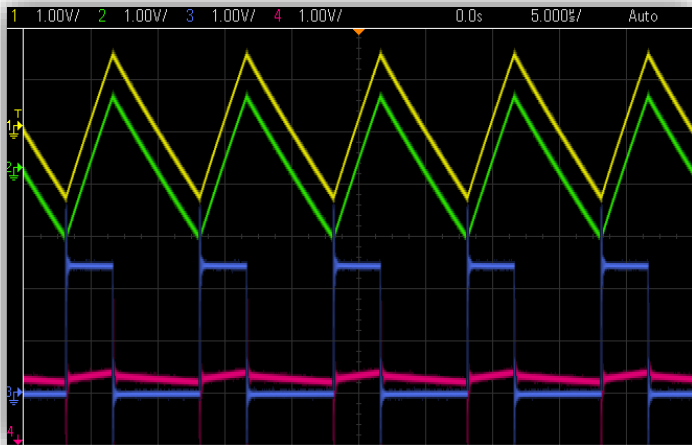
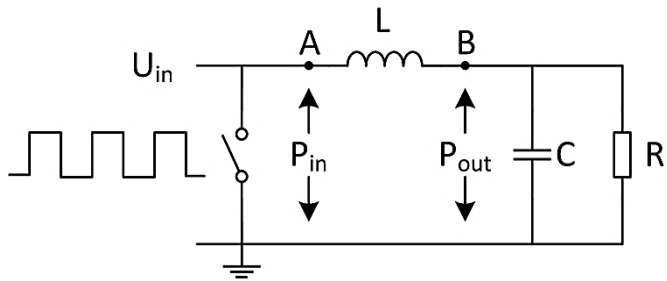
Steinmetz Models



acceptable accuracy at 50%,
even worse for other DC

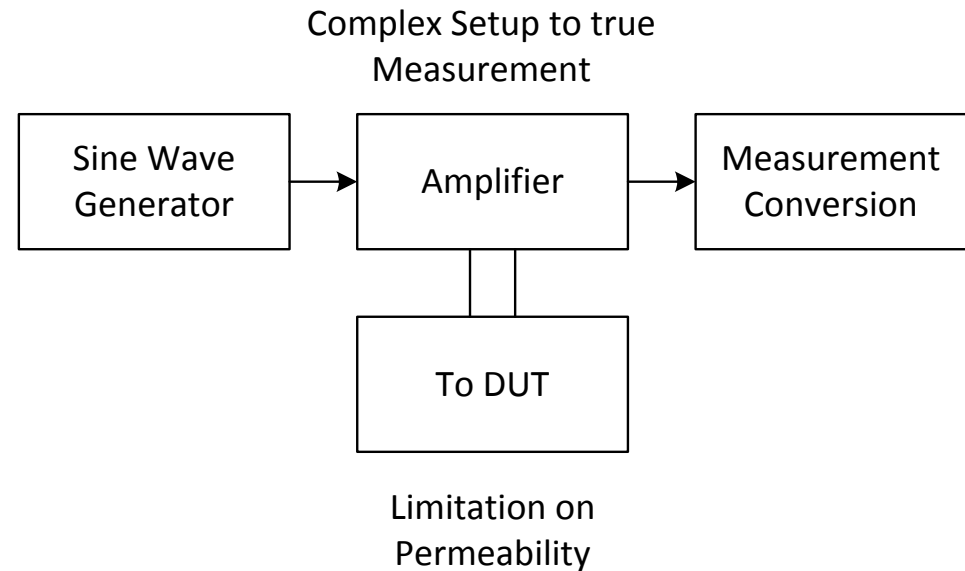
INDUCTOR LOSSES : Core losses **REDEXPERT**

Würth AC Loss Model



simple Class-D amplifier

Steinmetz Models



complex setup to measure

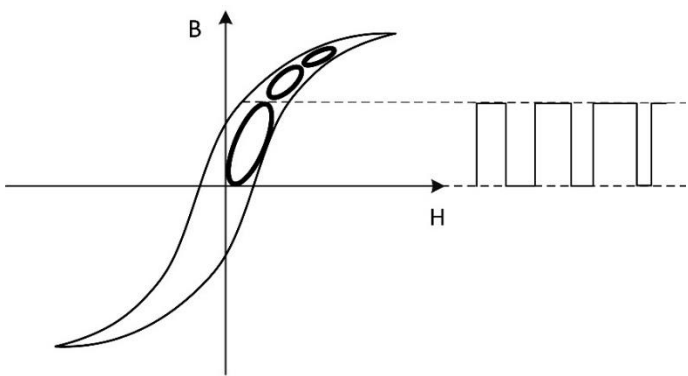


INDUCTOR LOSSES : Core losses **REDEXPERT**

Würth AC Loss Model

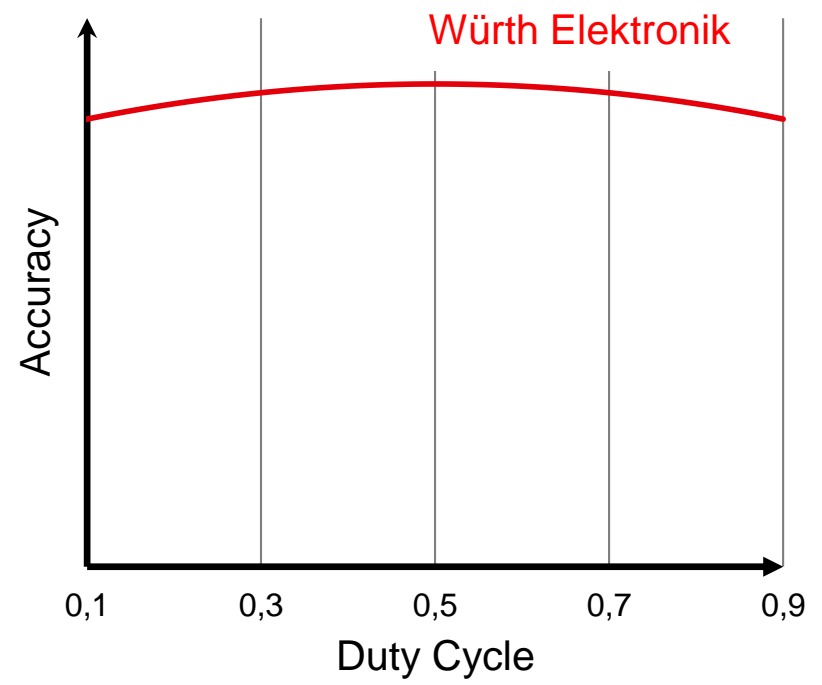
$$P_{AC} = f (\Delta I, \text{freq}, DC, k1, k2)$$

➔ core loss & AC wire loss



➔ point of operation approach
triangular current form

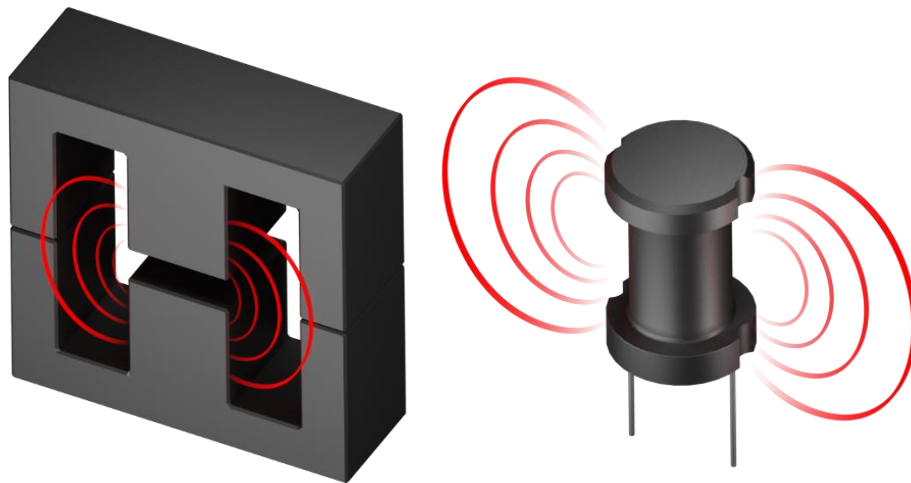
Würth AC Loss Model



highest accuracy
over wide DC range

INDUCTOR LOSSES : Core losses **REDEXPERT**

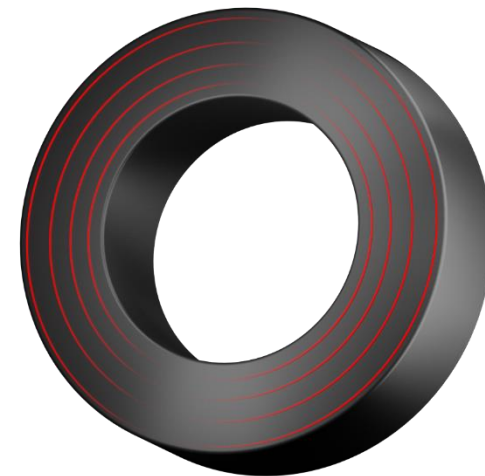
Würth AC Loss Model



consideration of:

- real core shapes
- losses due to air gap (fringing effects)
- winding structure

Steinmetz Models



consideration of:

- ring cores only

INDUCTOR LOSSES : AC losses Vs Core losses



Buck Converter

Reapply

PARAMETERS EDIT

Input: 12.0 V, 12.0-12.0 V
Output: 5.00 V, 300 mA
Switch: 2 MHz
Inductor: 50 %
Diode: 0.30 V, Single

DETAILS

I_{rms} I_{max} L_{opt}
 ≥ 300 mA ≥ 375 mA 10.0 μ H

WE-MAPI - 74438324082

t_{on} DC ΔL I_{peak}
 215 ns 0.43 184 mA 392 mA

AC Losses: 20.0 mW
DC Losses: 56.7 mW
Total Losses: 76.7 mW
Warming: 10.2 K

Démarrer

Filters: Type = Single 0.300 A $\leq I_a \leq 2.00$ A $I_{rms} \geq 510$ mA 7.00 μ H $\leq L \leq 13.0$ μ H Height Max ≤ 2.0 mm Series = WE-LQS, WE-MAPI, WE-TPC

| Order Code | Series | Size | Spec | Type | L | L @ 0.40 A | Roc... | I_r | K @ 0.40 A | I_{sat} | AC Losses | DC Losses | Total Losses | Wa... | Len... | V |
|-------------|---------|------|------|--------|--------------|--------------|----------------|---------|------------|-----------|-----------|-----------|--------------|--------|--------|---|
| 74404024100 | WE-LQS | 2512 | | Single | 10.0 μ H | 9.39 μ H | 435 m Ω | 0.470 A | 27.3 K | 850 mA | 80.6 mW | 39.2 mW | 120 mW | 48.1 K | 2.5 mm | |
| 74438323100 | WE-MAPI | 2510 | | Single | 10.0 μ H | 9.70 μ H | 733 m Ω | 0.600 A | 18.3 K | 1.35 A | 18.0 mW | 66.0 mW | 84.0 mW | 15.5 K | 2.5 mm | |
| 74438323082 | WE-MAPI | 2510 | | Single | 8.20 μ H | 7.98 μ H | 646 m Ω | 0.700 A | 14.6 K | 1.45 A | 21.9 mW | 58.1 mW | 80.0 mW | 12.8 K | 2.5 mm | |
| 74438324100 | WE-MAPI | 2512 | | Single | 10.0 μ H | 9.78 μ H | 680 m Ω | 0.700 A | 11.6 K | 1.40 A | 16.4 mW | 61.2 mW | 77.6 mW | 12.0 K | 2.5 mm | |
| 744031100 | WE-TPC | 3816 | | Single | 10.0 μ H | 9.53 μ H | 185 m Ω | 0.740 A | | 560 mA | 46.1 mW | 16.6 mW | 62.7 mW | 20.2 K | 3.8 mm | |
| 74438324082 | WE-MAPI | 2512 | | Single | 8.20 μ H | 8.04 μ H | 630 m Ω | 0.800 A | 10.6 K | 1.50 A | 20.0 mW | 56.7 mW | 76.7 mW | 10.2 K | 2.5 mm | |

74404024100 WE-LQS - Single 10.0 μ H - 435 m Ω 0.470 A - 850 mA

74438323100 WE-MAPI - Single 10.0 μ H - 733 m Ω 0.600 A - 1.35 A

74438324100 WE-MAPI - Single 10.0 μ H - 680 m Ω 0.700 A - 1.40 A

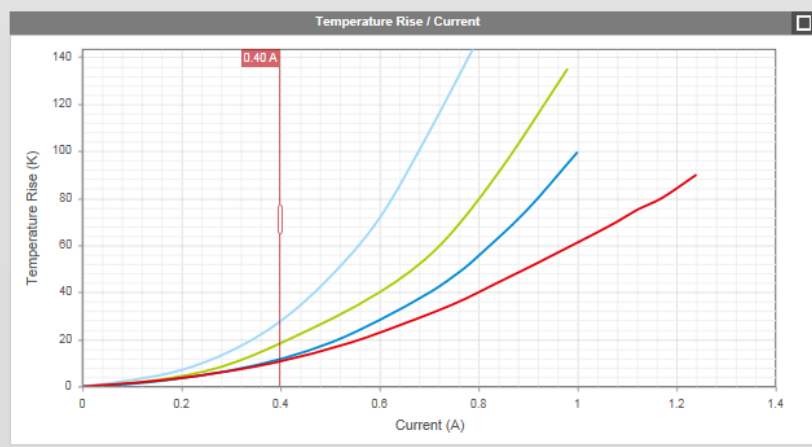
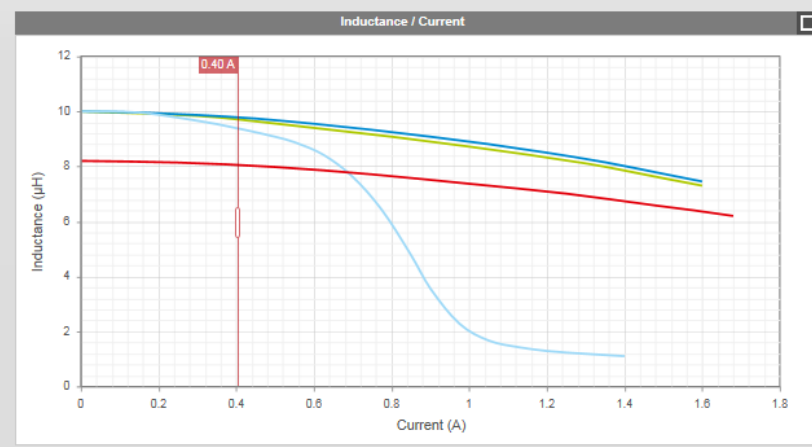
74438324082 WE-MAPI - Single 8.20 μ H - 630 m Ω 0.800 A - 1.50 A

Drop Order Codes in this bar to add

Drop out buttons to delete them

Free Samples

Tidy Up





INDUCTOR LOSSES : AC losses Vs Core losses

Filters: Type = Single $I_R \geq 300 \text{ mA}$ $I_{sat} \geq 380 \text{ mA}$ $10.0 \mu\text{H} \leq L \leq 18.0 \mu\text{H}$ Series = WE-MAPI, WE-LQS, WE-PD 66 items

| Order Code | Series | Size | Spec | Type | L | $R_{DC,typ}$ | I_R | I_{sat} | P_{AC} | P_{DC} | P_{TOT} | ΔT | Length |
|-------------|---------|------|------|--------|--------------------|-----------------|--------|-----------|----------|----------|-----------|------------|--------|
| 74438324100 | WE-MAPI | 2512 | PDF | Single | 10.0 μH | 680 m Ω | 700 mA | 1.40 A | 16.4 mW | 61.2 mW | 77.6 mW | 12.0 K | |
| 74438335100 | WE-MAPI | 3015 | PDF | Single | 10.0 μH | 446 m Ω | 850 mA | 2.00 A | 9.48 mW | 40.1 mW | 49.6 mW | 8.53 K | |
| 74438335150 | WE-MAPI | 3015 | PDF | Single | 15.0 μH | 720 m Ω | 650 mA | 1.71 A | 6.32 mW | 64.8 mW | 71.1 mW | 12.0 K | |
| 74438336100 | WE-MAPI | 3020 | PDF | Single | 10.0 μH | 280 m Ω | 1.20 A | 2.35 A | 8.13 mW | 25.2 mW | 33.3 mW | 5.10 K | |
| 74438357100 | WE-MAPI | 4030 | PDF | Single | 10.0 μH | 101 m Ω | 2.70 A | 4.60 A | 6.63 mW | 9.07 mW | 15.7 mW | 1.67 K | |
| 74477810 | WE-PD | 7332 | PDF | Single | 10.0 μH | 68.0 m Ω | 1.83 A | 2.20 A | 20.6 mW | 6.12 mW | 26.7 mW | 6.81 K | |
| 744778112 | WE-PD | 7332 | PDF | Single | 12.0 μH | 76.0 m Ω | 1.73 A | 2.15 A | 17.2 mW | 6.84 mW | 24.0 mW | 6.24 K | |

74438335100 WE-MAPI · 3015 10.0 μH · 446 m Ω

74438336100 WE-MAPI · 3020 10.0 μH · 280 m Ω

74477810 WE-PD · 7332 10.0 μH · 68.0 m Ω



Free Samples More...

- $V_{in} = 12V$
- $V_{out} = 5V$
- $I_{out} = 300mA$
- $V_D = 0,3V$
- $F_{sw} = 2 \text{ MHz}$
- $r = 50\%$

AC losses can be > DC Losses

AC losses < DC Losses

www.we-online.de/REDEXPERT

Select the best inductor for the application

Estimate the total losses

Estimate the self heating

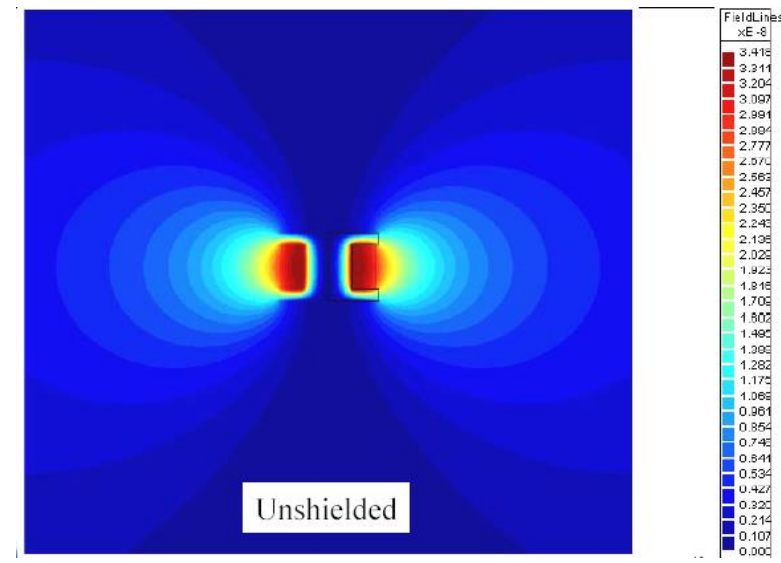
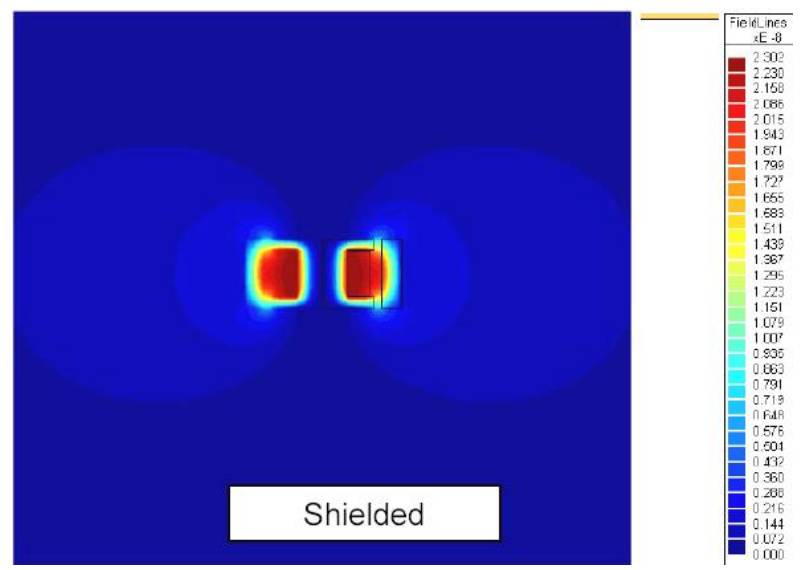
World's Most Accurate AC Loss Model





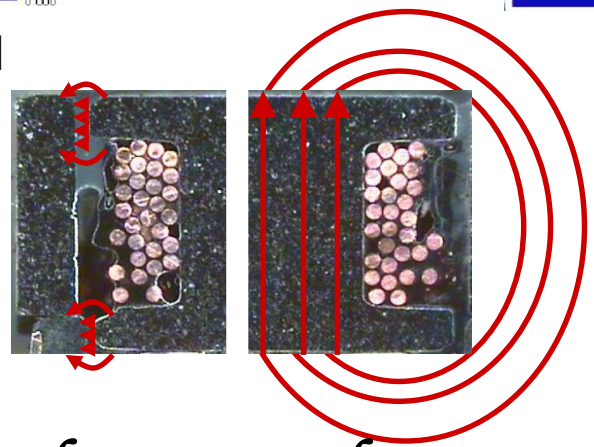
EMC_ INPUT FILTER

EMC : shielded VS. unshielded



shielded

unshielded

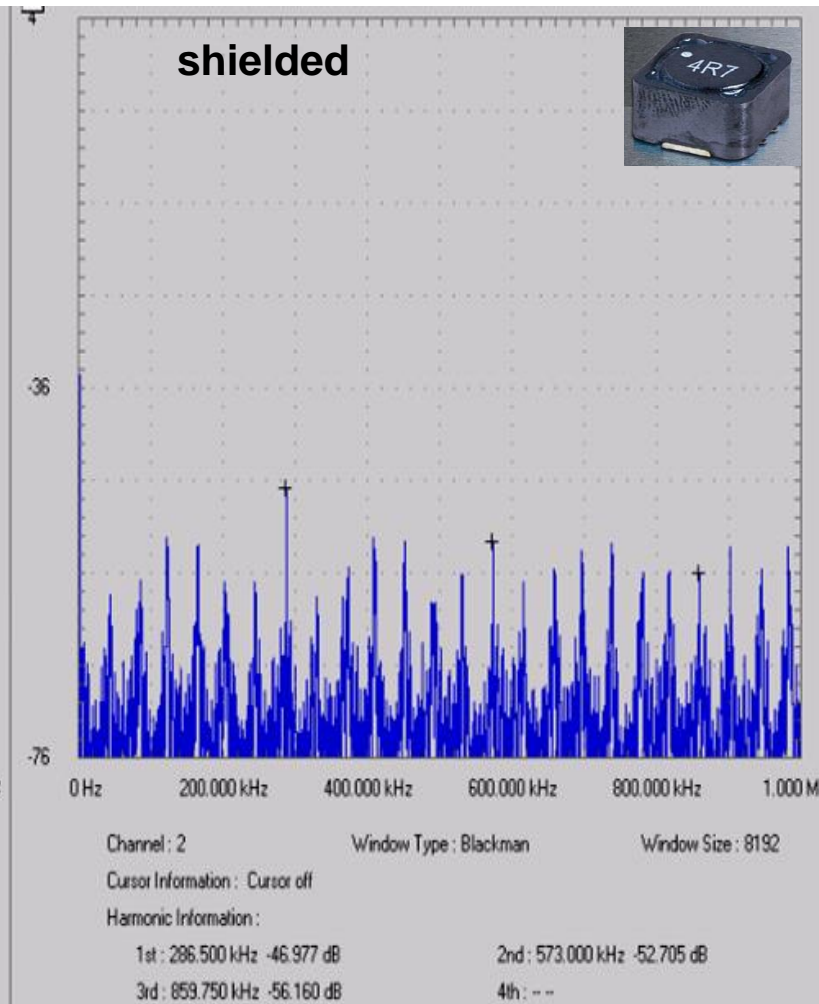
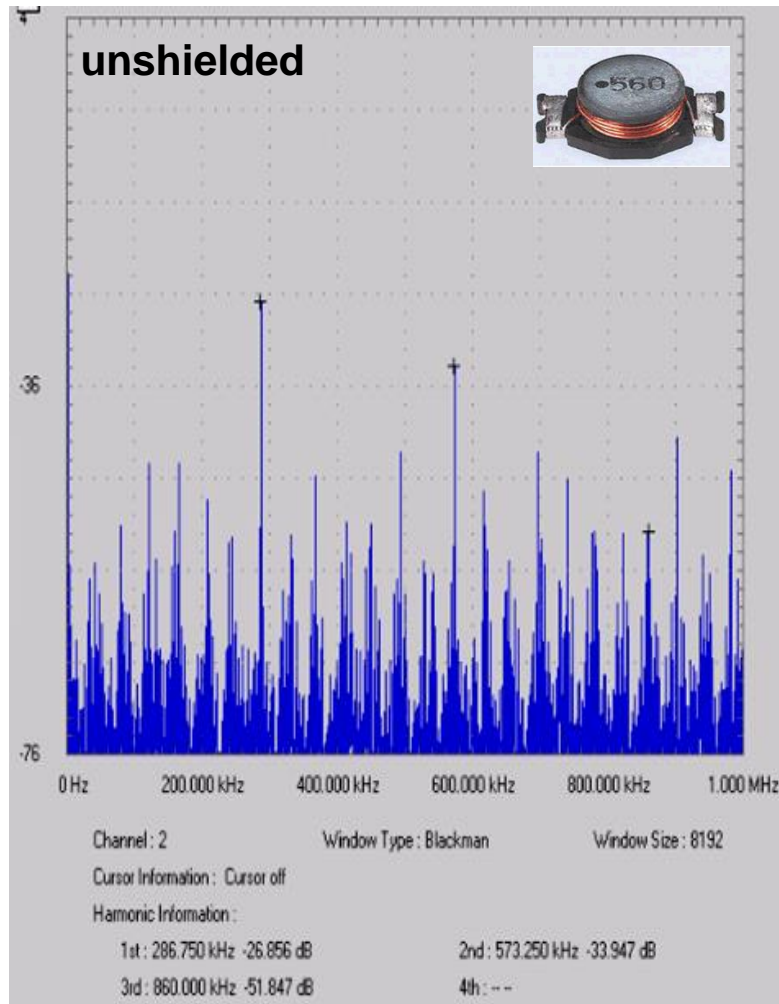


smaller L_{eff}

bigger L_{eff}

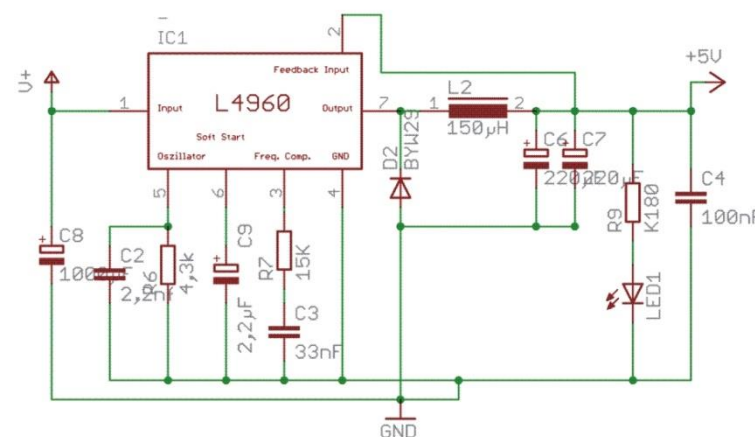
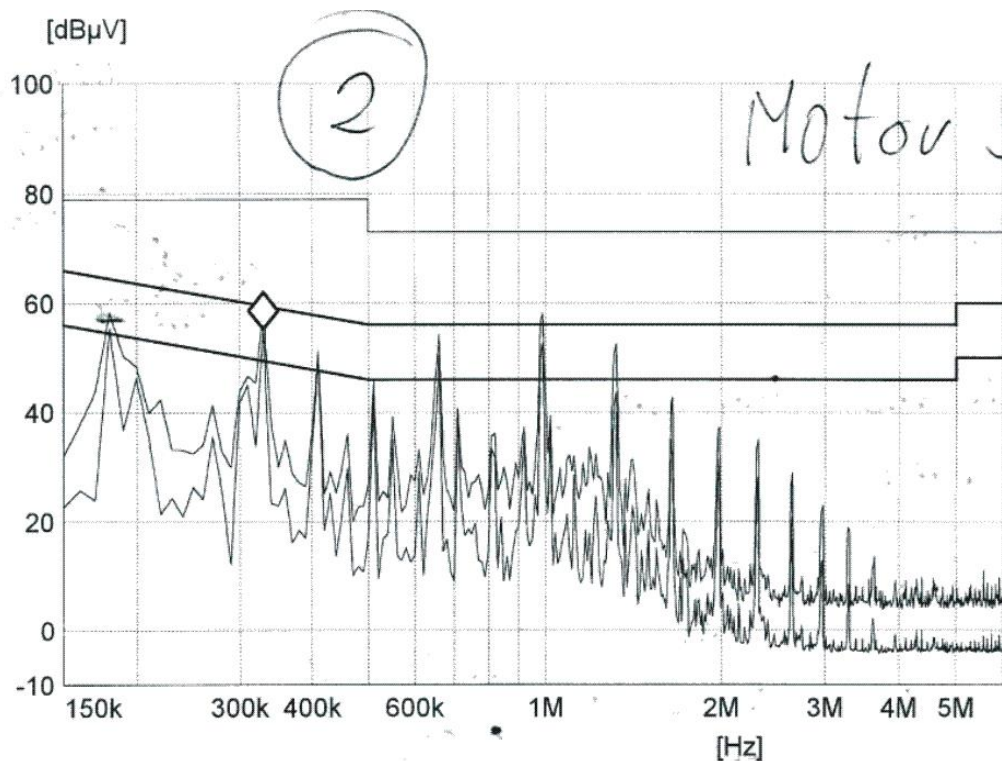


EMC : shielded VS. unshielded



Magnetic Fields – Conducted Emission Measurement

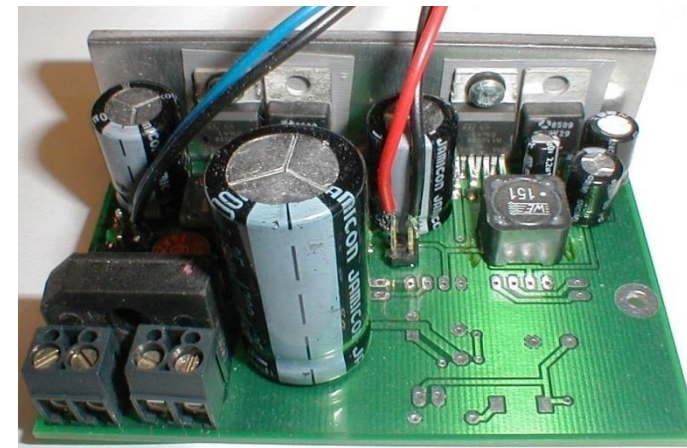
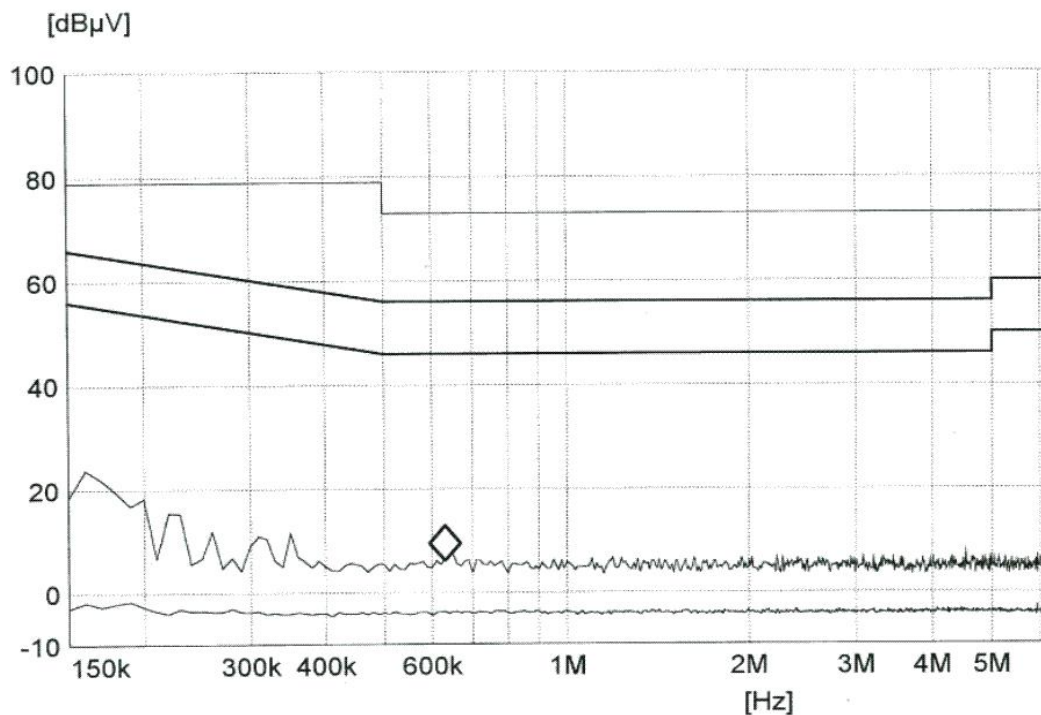
Power supply V 1.0



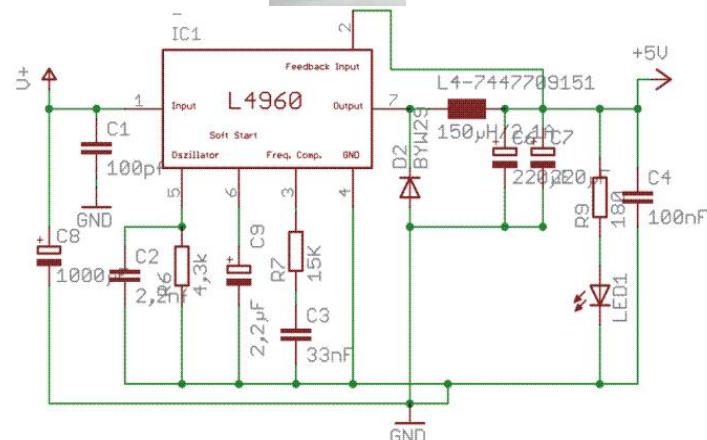
Buck Converter ST L4960/2.5A/fs 85-115KHz

Magnetic Fields – Conducted Emission Measurement

Power supply V 1.1

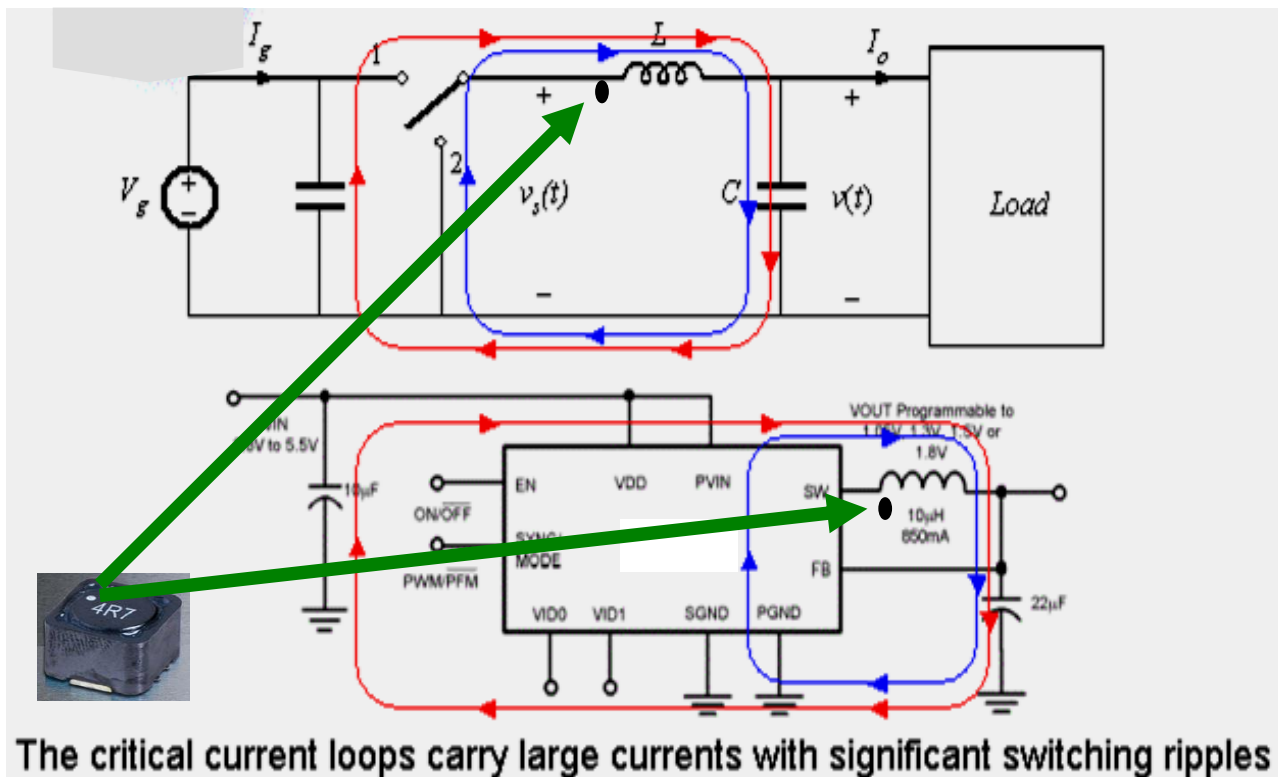


PCB

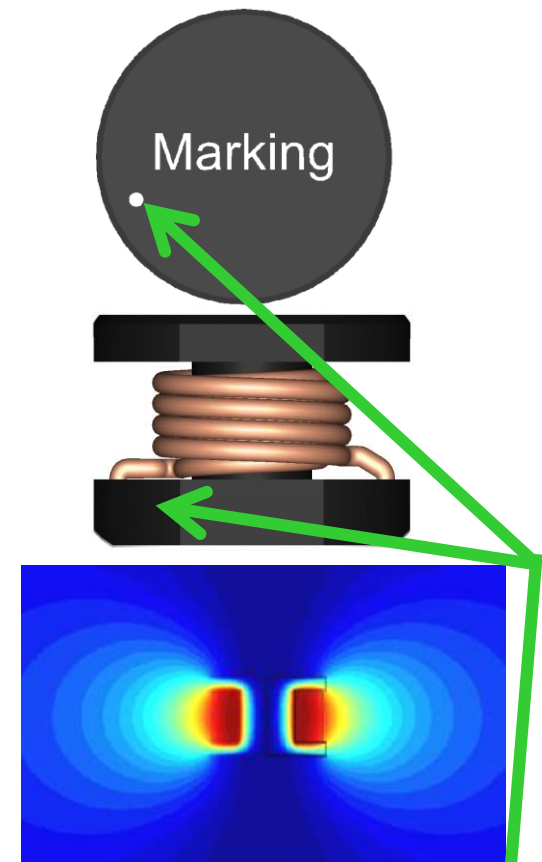


Schematic

Layout recommendation



Inductors are two poles only
 → but start of winding is important
 → use effect of self shielding of the winding



connection switch node
 "EMI hot side"



GENERAL INFORMATION

Trilogy of Magnetics



- 1. LTspice Book
 - How to use and build spice models
- 2. Trilogy of Magnetics
 - Design Guide for EMI Filter Design, SMPS & RF Circuits
- 3. Trilogy of Connectors
 - Basic Principles and Connector Design Explanations
- 4. ABC of Power Modules
 - Functionality, Structure and Handling of a Power Module
- 5. ABC of Capacitors
 - Basic principles, characteristics and capacitor types

If you still have questions?

Just call us: we try to help you

Don't give up !!!





Technical support needed?

Ask our design engineer Lorandt Fölkel



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we-online.com/youtube

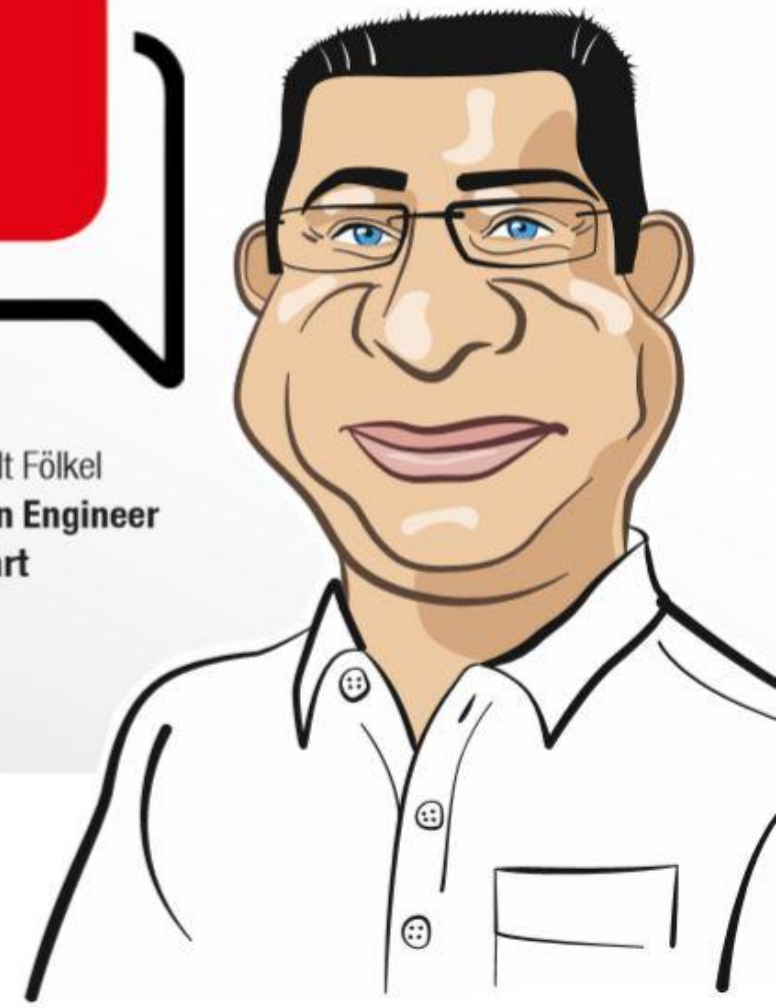


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