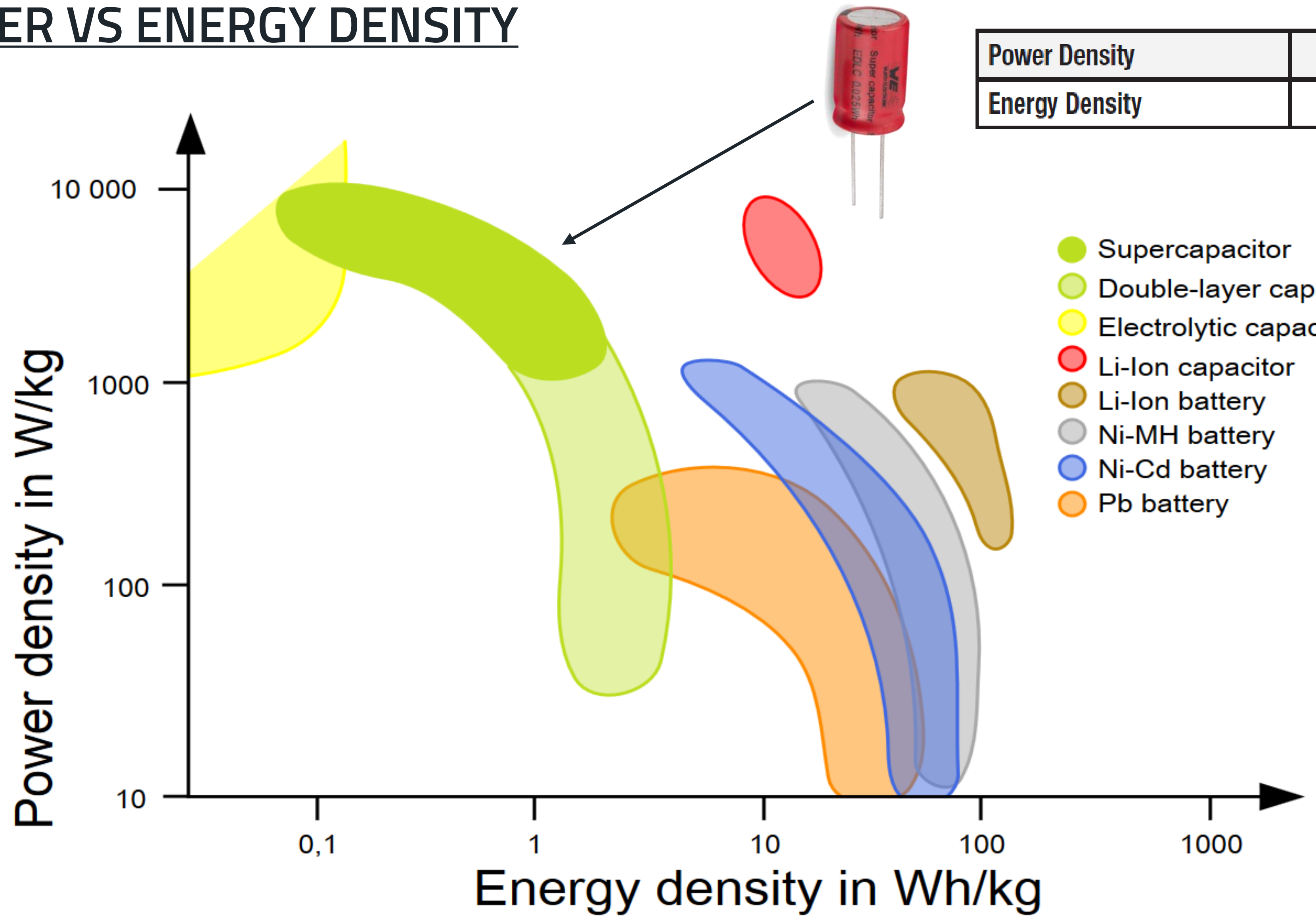
CHOIX DE COMPOSANTS POUR L'OPTIMISATION D'UNE ALIMENTATION FOCUS DANS LE MÉDICAL

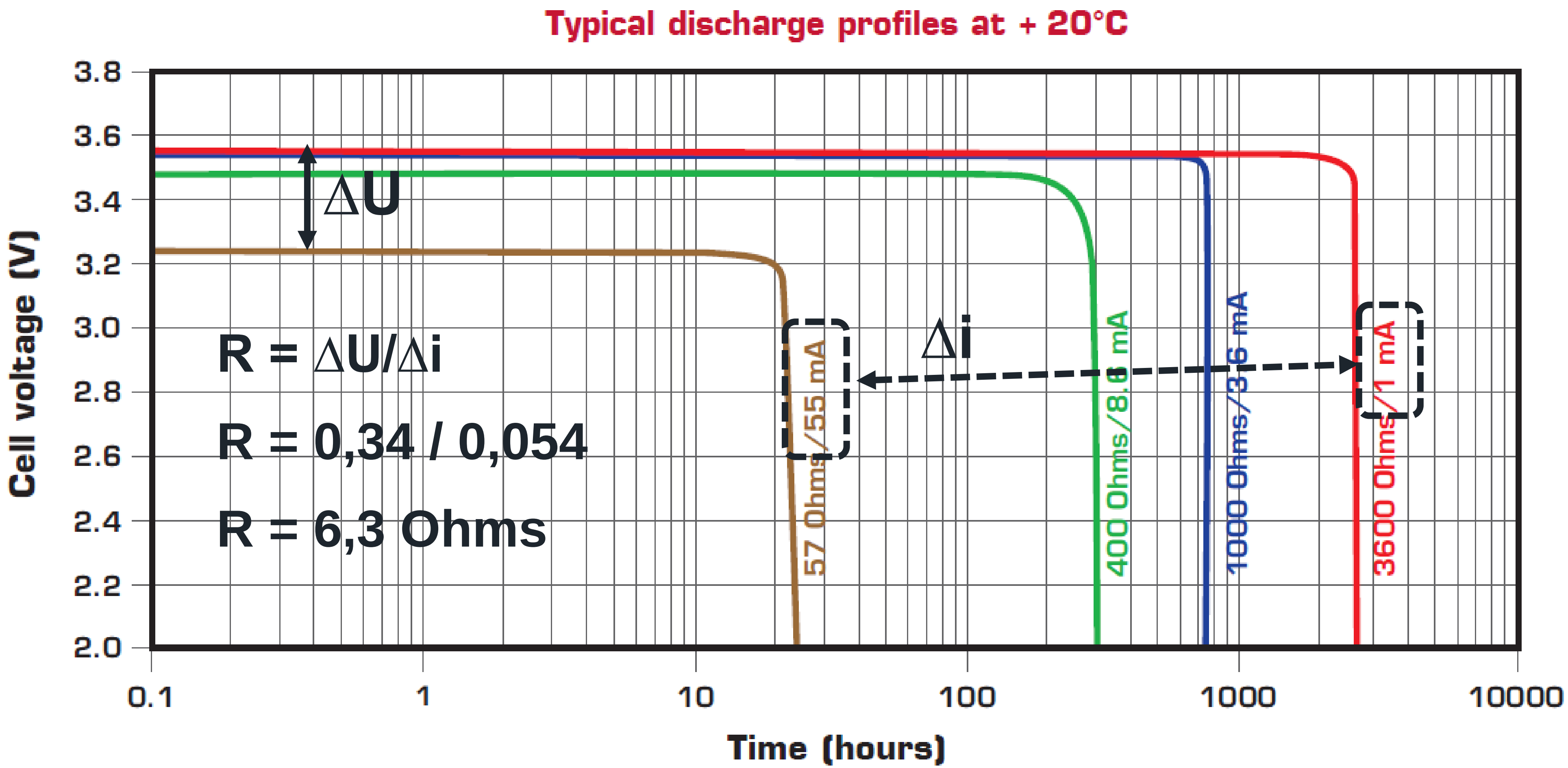
Paul Le Nézet - FAE

POWER VS ENERGY DENSITY

Power Density	P	8.13	kW/ kg
Energy Density	E	4.5	Wh/ kg



INTERNAL RESISTANCE



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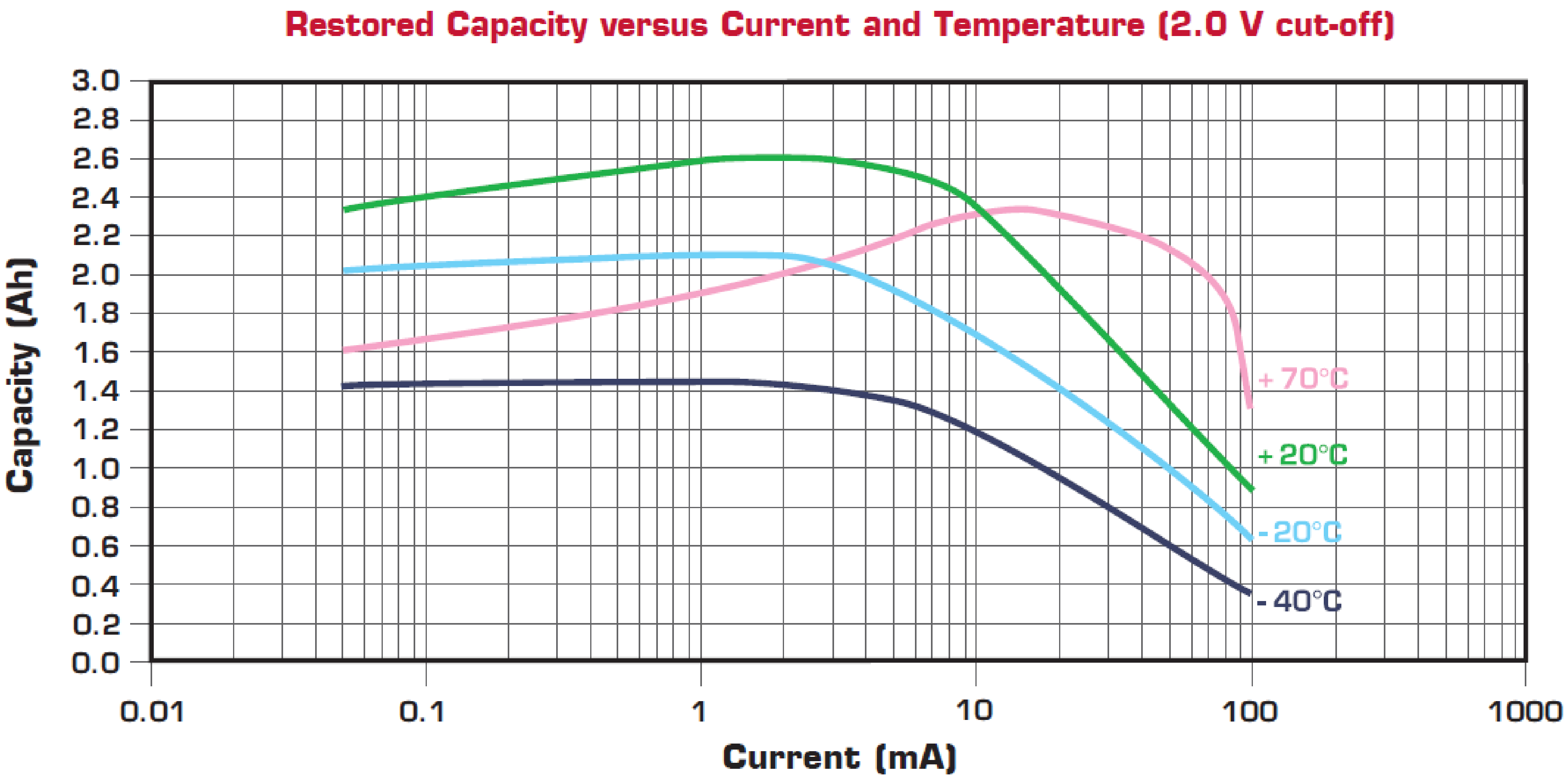
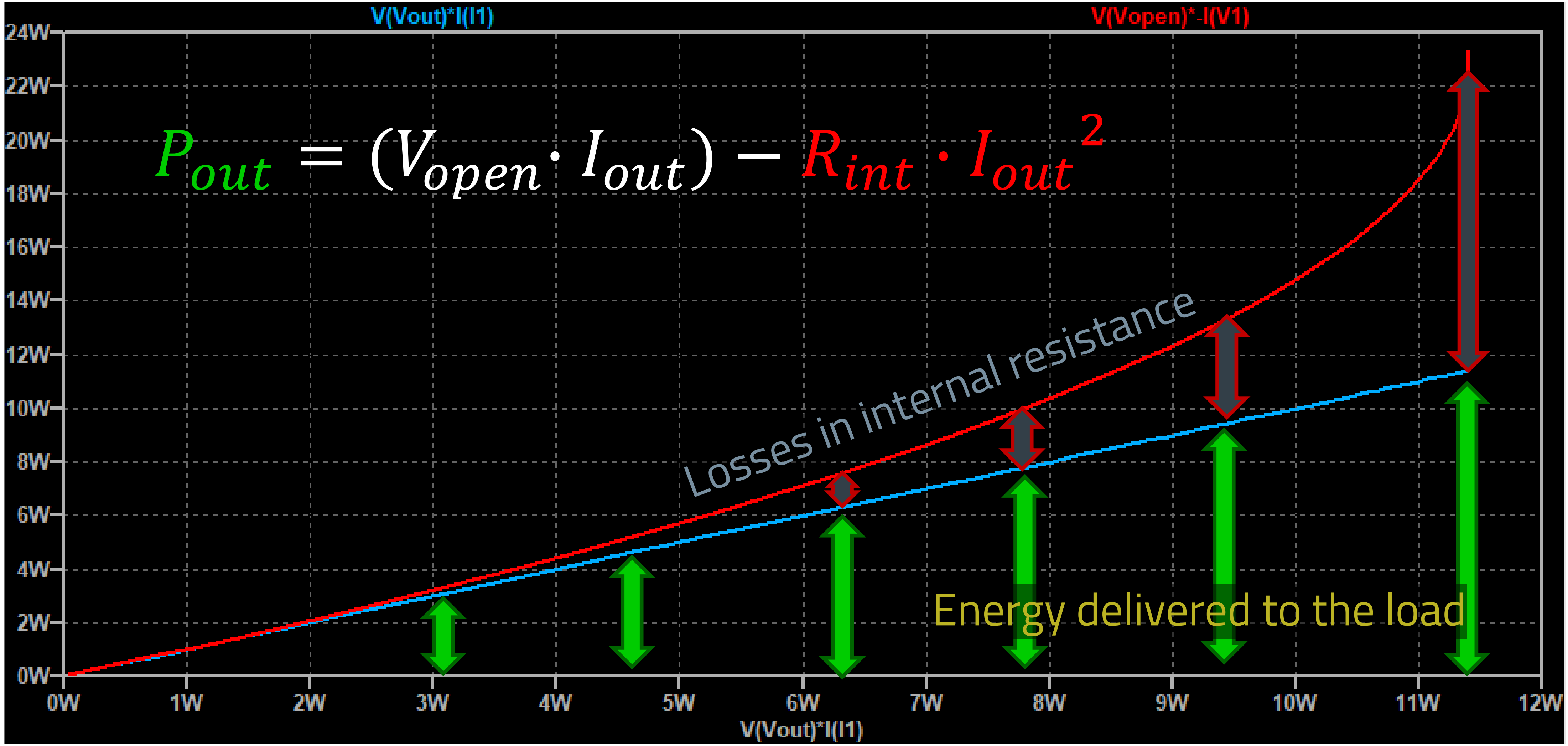
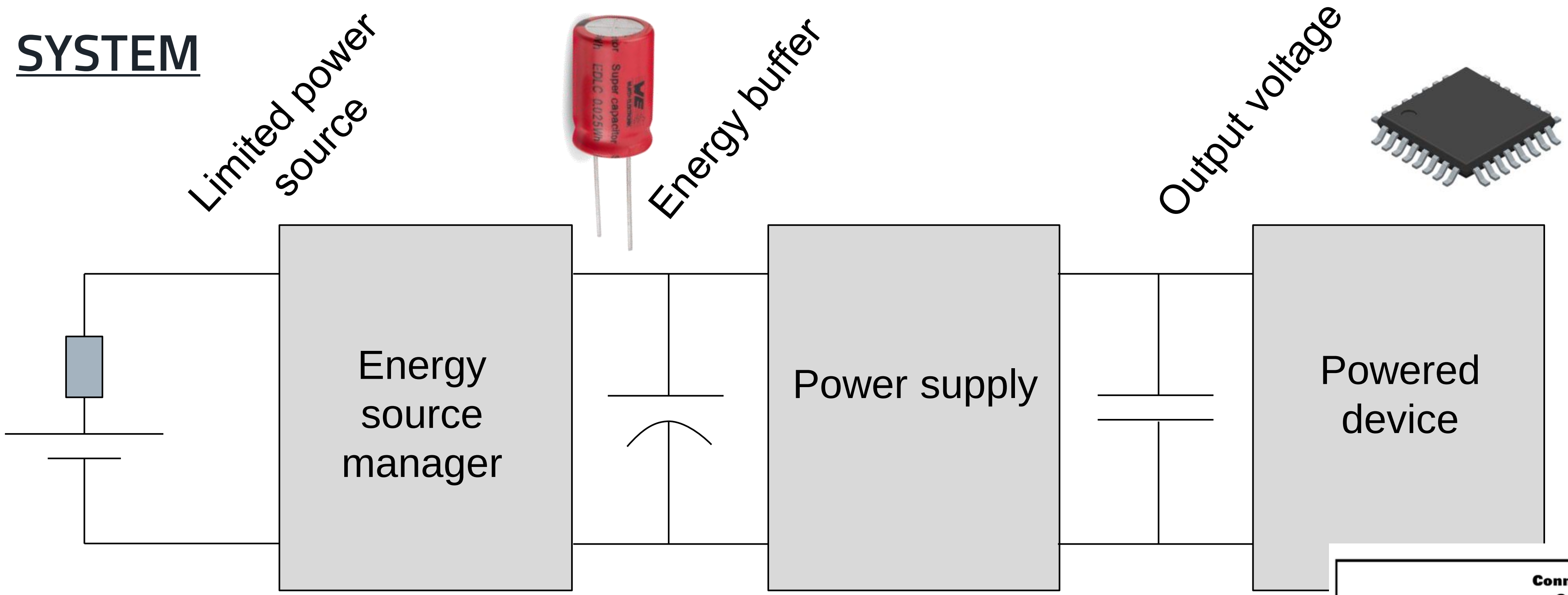


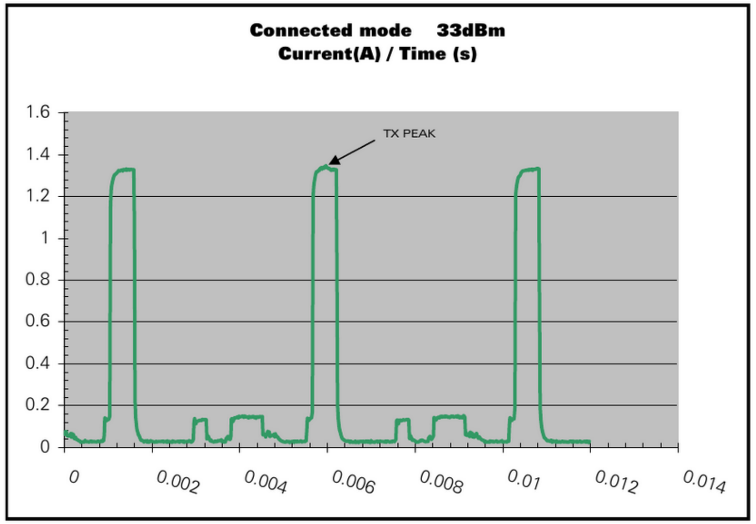
INTERNAL RESISTANCE & POWER



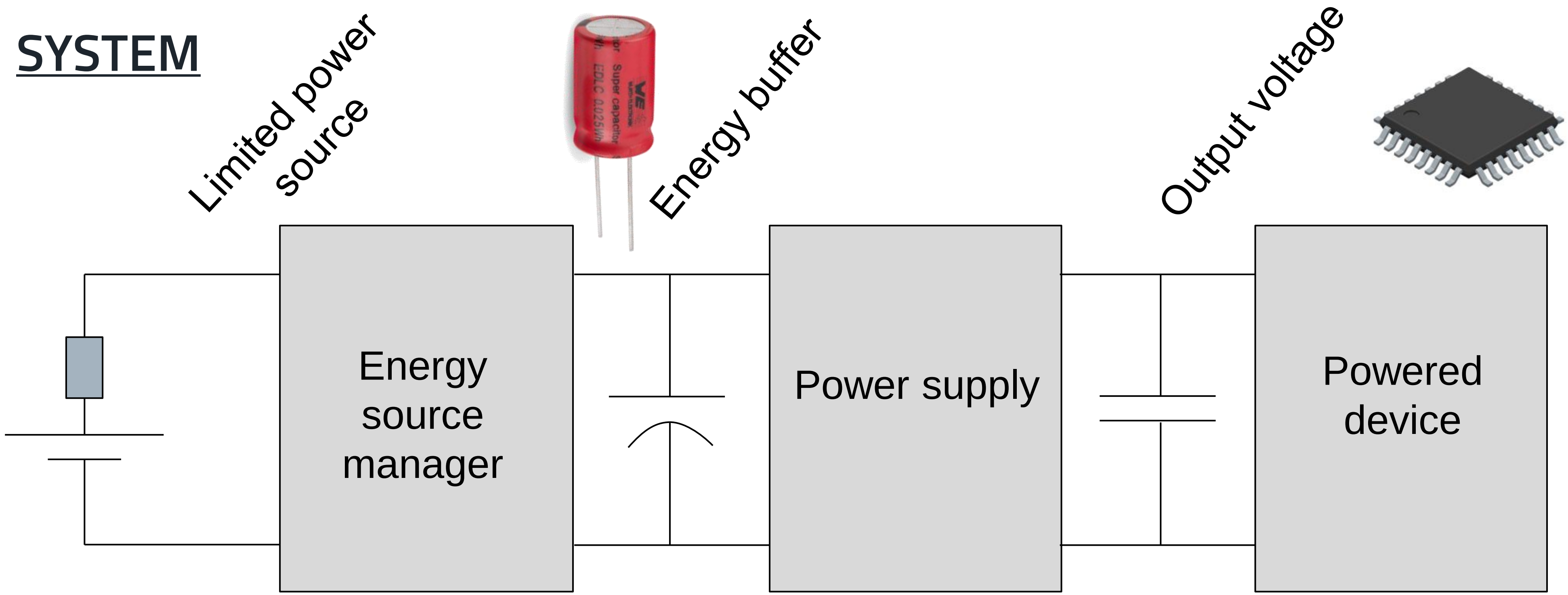
SYSTEM



Target :
- Deliver more power to the powered device
- Use batteries were they are efficient
- Increasing battery autonomy



SYSTEM

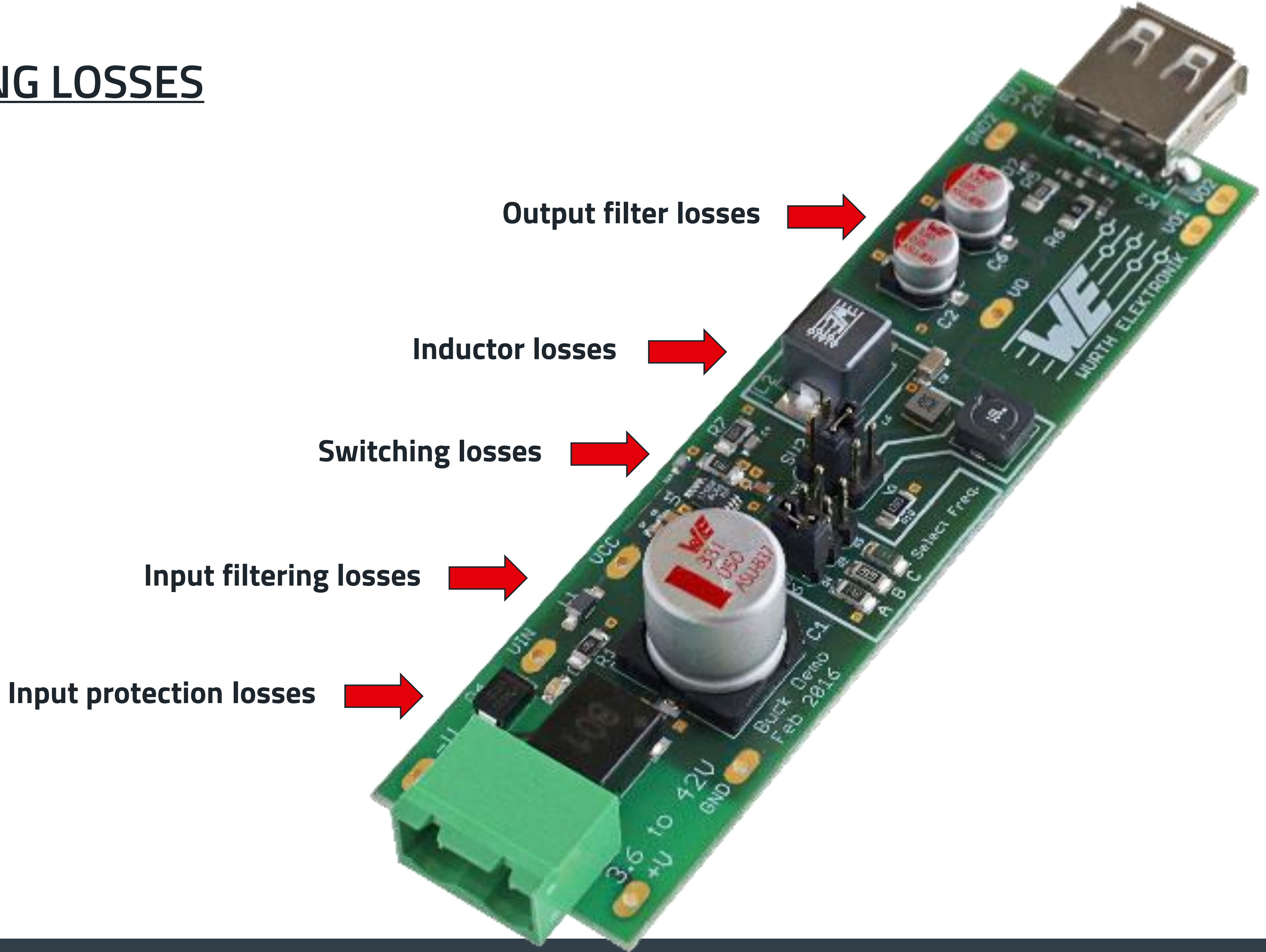


Target :

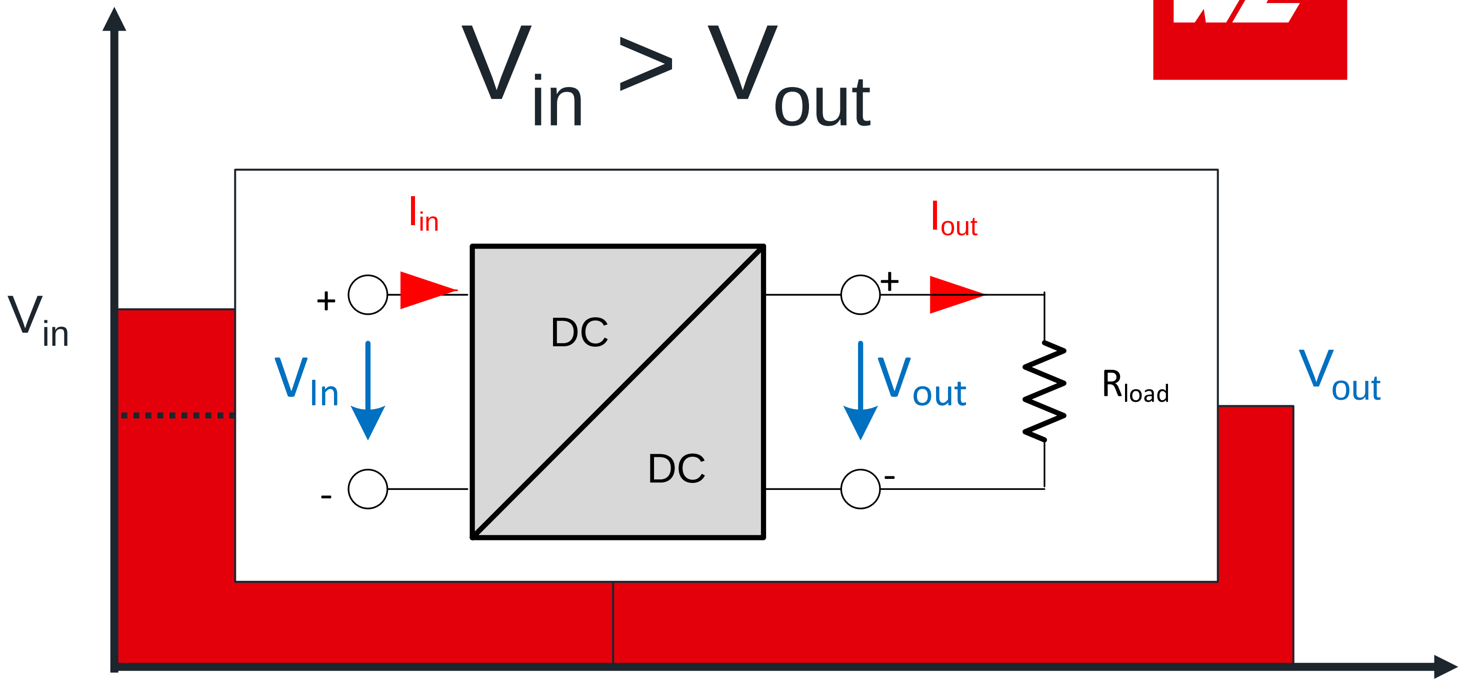
- Deliver more power to the powered device
- Use batteries were they are efficient
- Increasing battery autonomy

Reducing the losses at every stage

REDUCING LOSSES

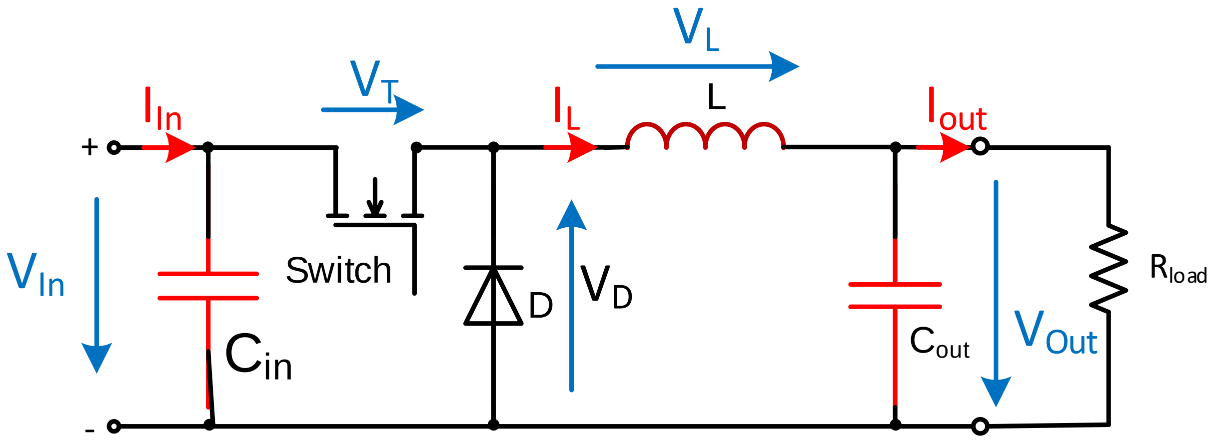


SMPS TOPOLOGIES : BUCK

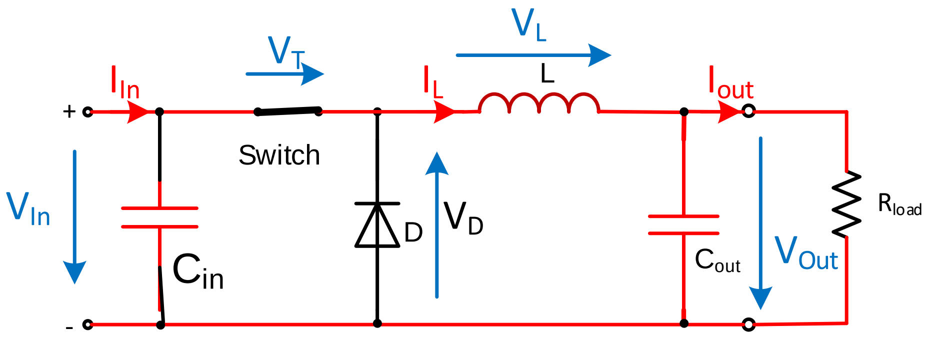


BUCK CONVERTER :

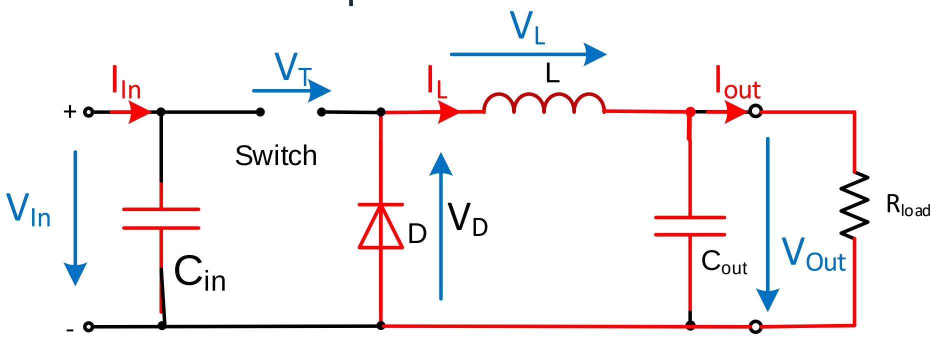
Topology



Switch Closed



Switch Open

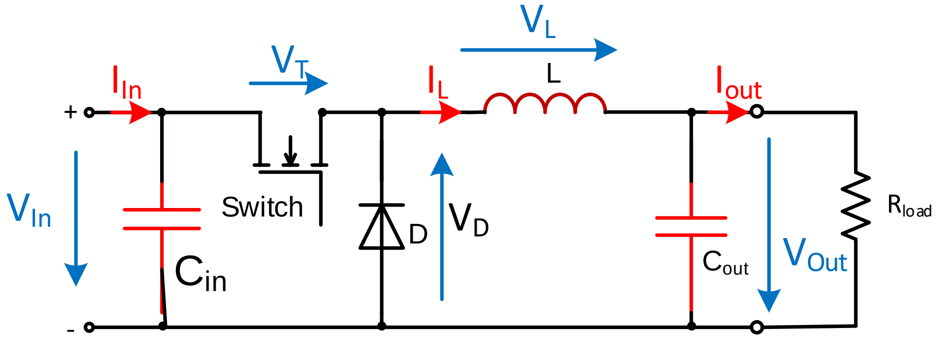


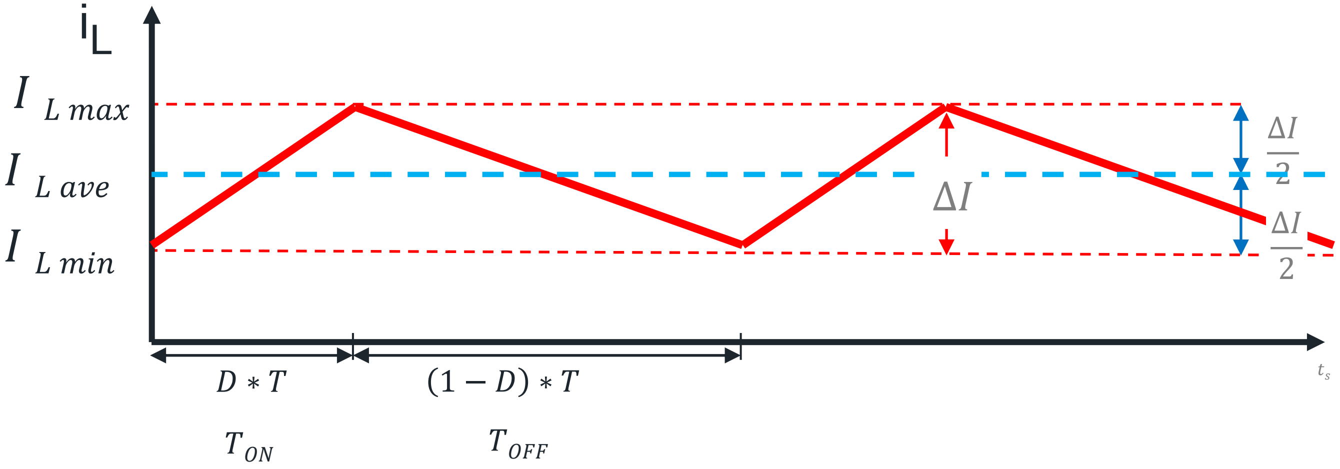
BUCK CONVERTER : RIPPLE CURRENT

Ripple current : $$r = \frac{\Delta IL}{I_L}$$

Switching Frequency :

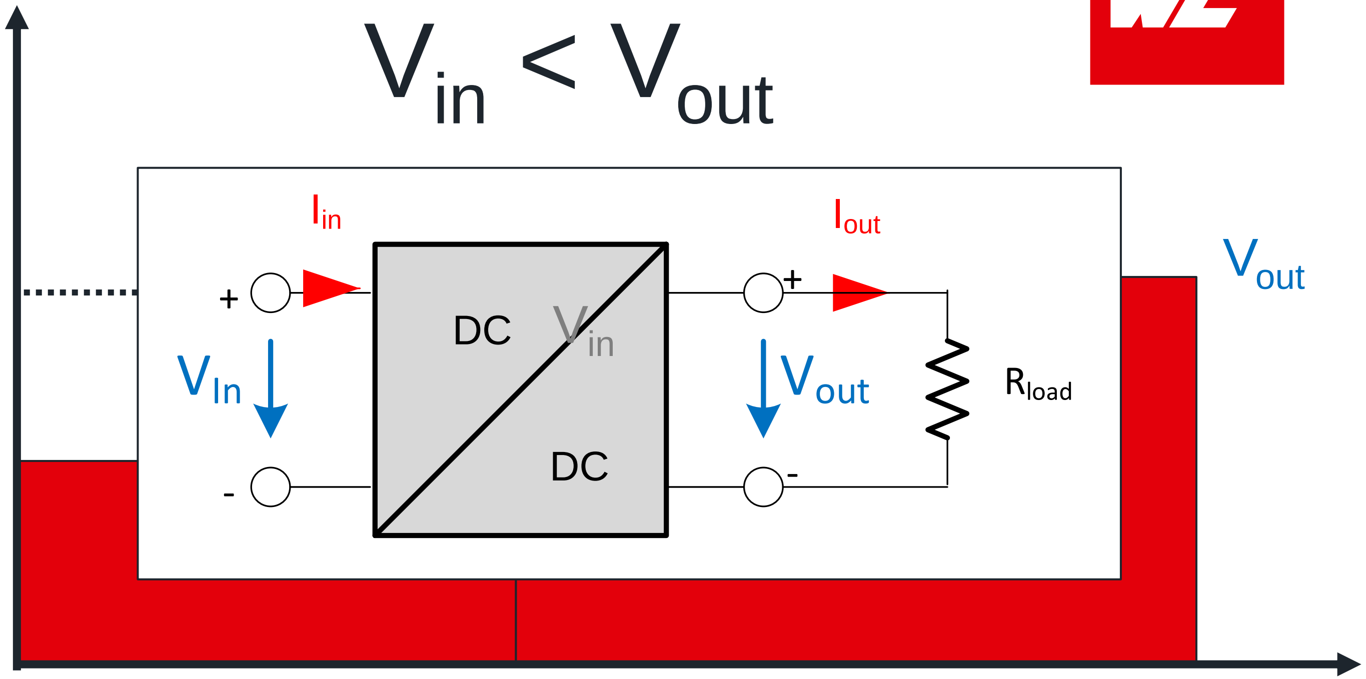
$$F_{switch} = \frac{1}{T} = \frac{1}{T_{ON} + T_{OFF}}$$





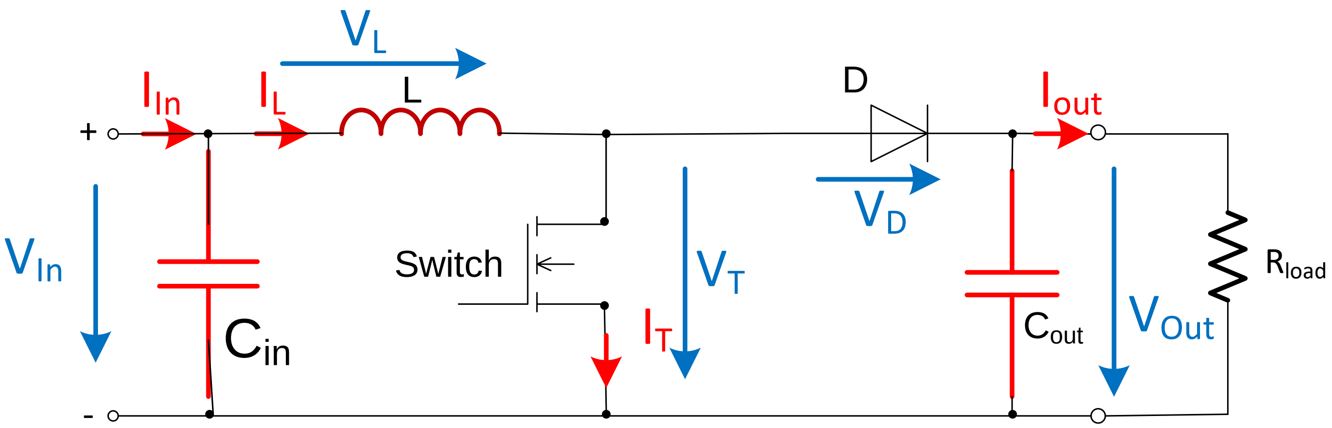
$$\Delta IL = ILmax - I_{Lmin}$$

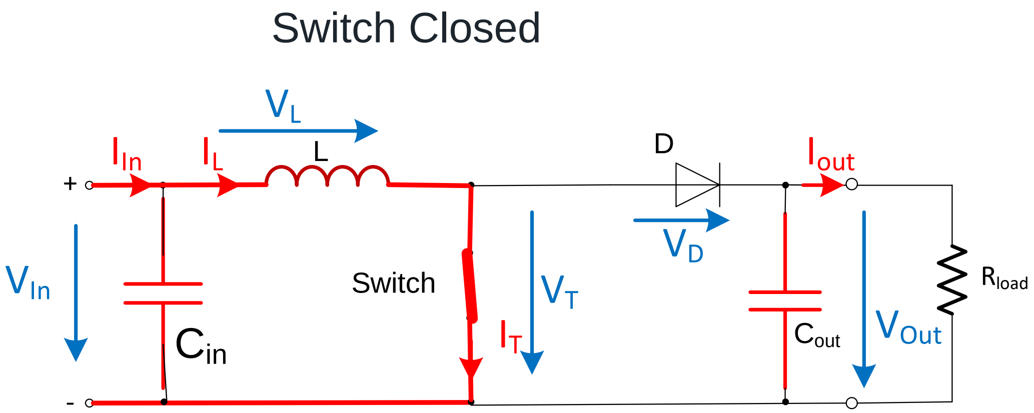
SMPS TOPOLOGIES : BOOST

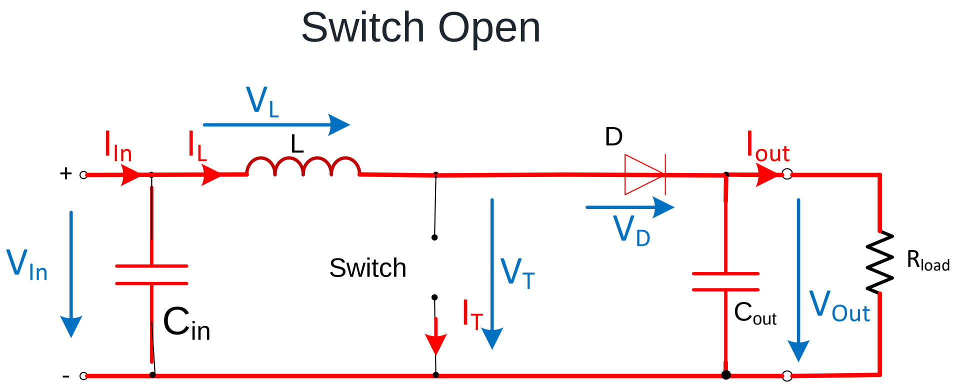


BOOST CONVERTER :

Topology



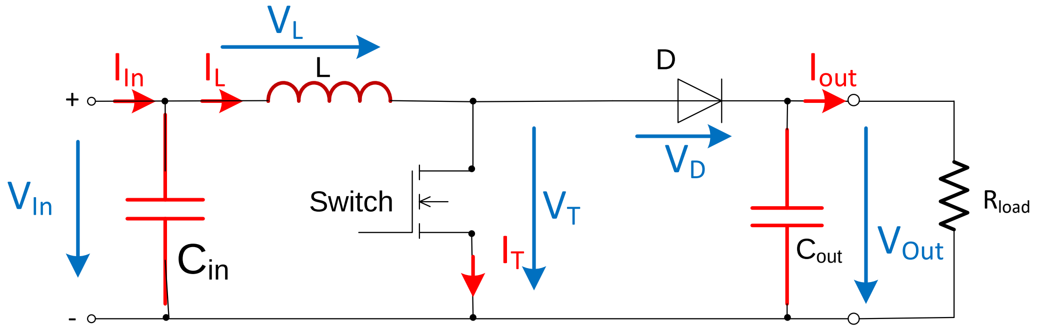




BOOST CONVERTER : RIPPLE CURRENT

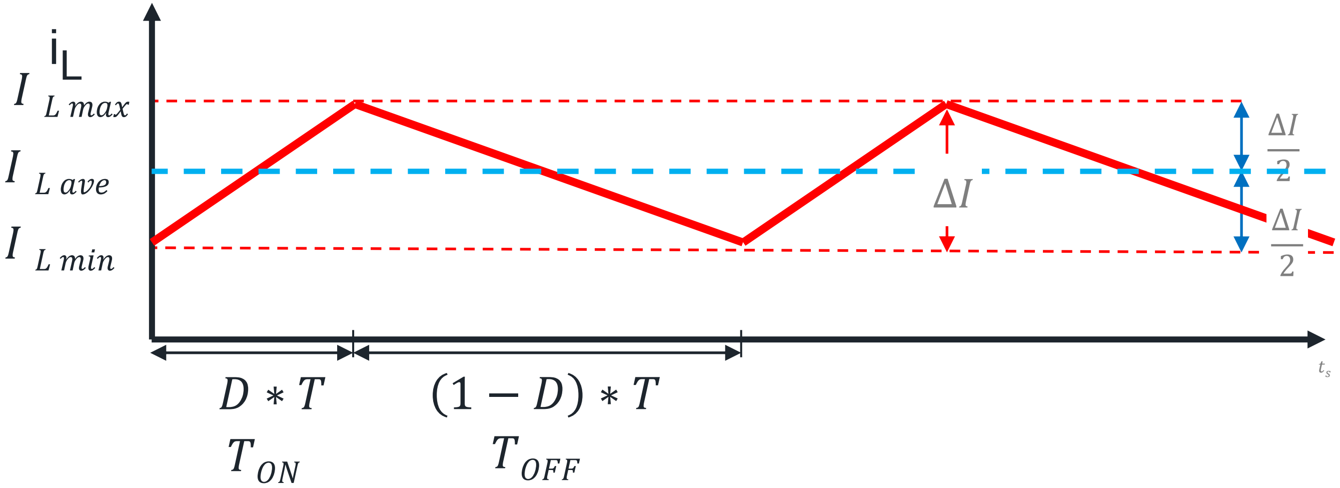
Ripple current :

$$r = \frac{\Delta IL}{I_L}$$



Switching Frequency :

$$F_{switch} = \frac{1}{T} = \frac{1}{T_{ON} + TOFF}$$



$$\Delta IL = ILmax - I_{Lmin}$$

BUCK AND BOOST CONVERTER : SUMMARY

BUCK

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

BOOST

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

I_{out} … operating current

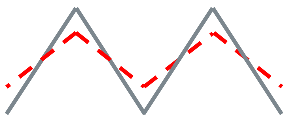
V_{out} … output voltage

V_{in} … input voltage

f_{switch} … switching frequency of IC

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

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



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

Inductor rms current

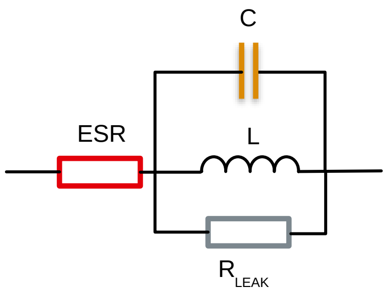
$$I_{L_{RMS}} \approx I_{out\_application}$$

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

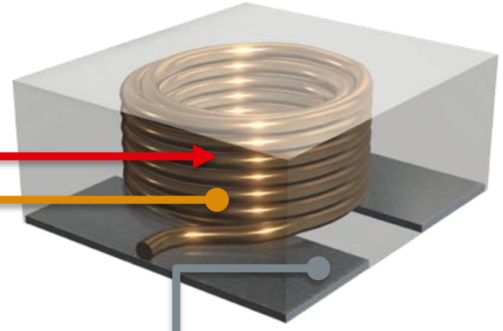
HOW TO CHOOSE A POWER INDUCTOR

POWER INDUCTORS

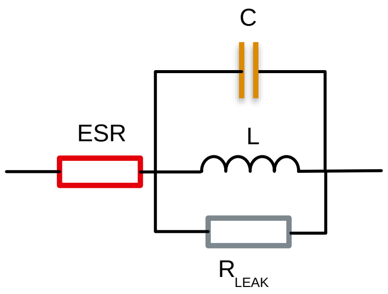
Theory : Inductor and losses sources

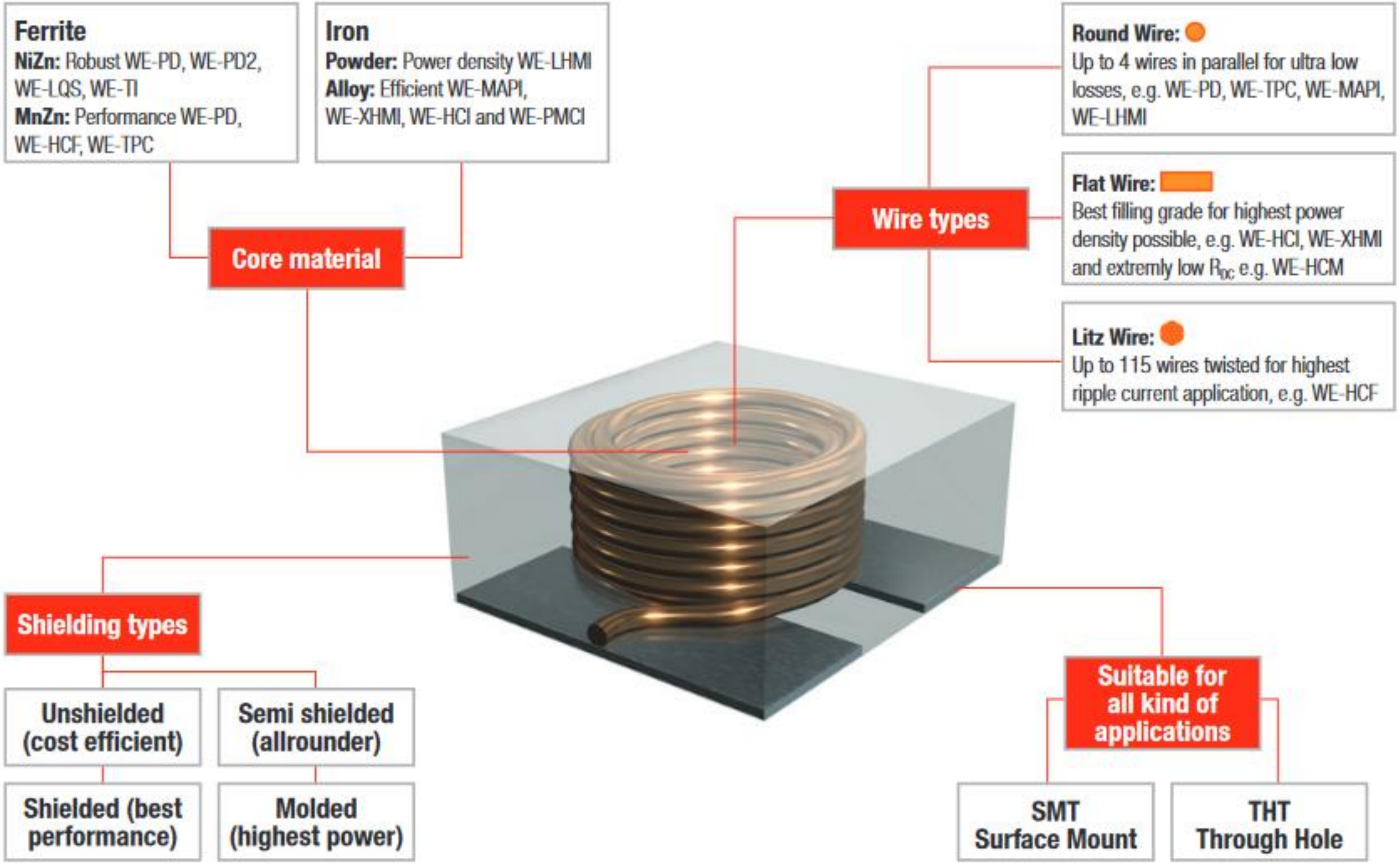


- DC Losses:
  - copper losses with average DC current through the component
    - estimation of DC loss is straight forward: $P_{dc} = R_{dc} \cdot I_{RMS}^2$
- AC Losses:
  - winding losses due to skin effect, proximity effect, etc.
  - core losses : eddy current & hysteresis loss in the core due to magnetization
    - Related to (f, β)
- Total Losses:
  - $P_{tot} = P_{dc} + P_{ac}$



POWER INDUCTORS





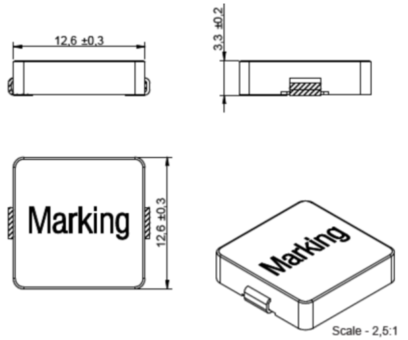
RATED CURRENTS

POWER INDUCTORS

Rated Current:

- Rated curent definition :

LHMI – 74437377010

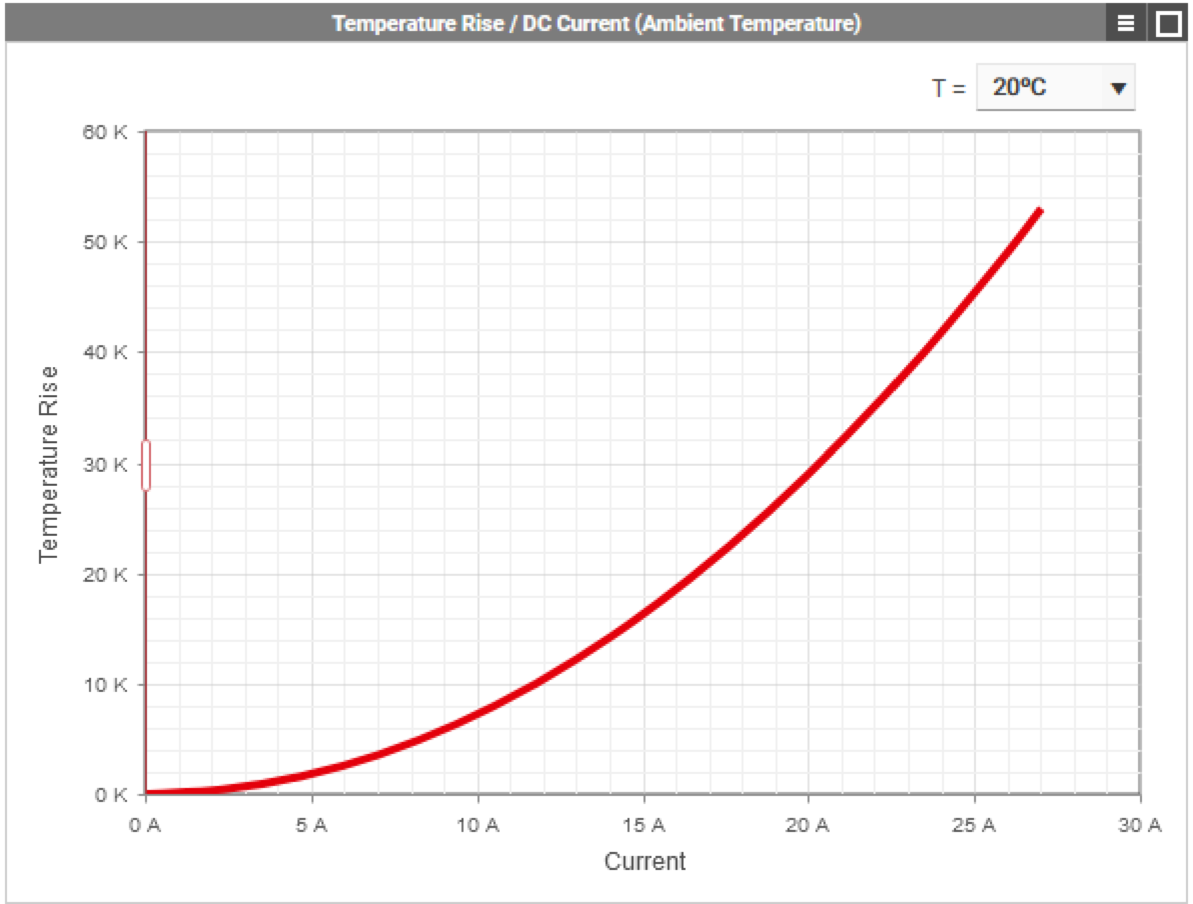


Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	100 kHz/ 10 mA	1	µH	±20%
Rated Current	$I_{R,40K}$	ΔT = 40 K	15	A	max.
Saturation Current @ 10%	$I_{SAT,10\%}$	|ΔL/L| < 10 %	15.4	A	typ.
Saturation Current @ 30%	$I_{SAT,30\%}$	|ΔL/L| < 30 %	38	A	typ.
DC Resistance	R_{DC}	@ 20 °C	2.7	mΩ	typ.
DC Resistance	R_{DC}	@ 20 °C	3.5	mΩ	max.
Self Resonant Frequency	f_{res}		41	MHz	typ.

[1] refer to IEC 62024-2-2020

Application Note MIL-PRF-27F - Temperature Rise for Inductors



POWER INDUCTORS

Rated current I_R vs performance rated current I_{RP}: Practise

- Setup (minimal and Class C are hand made prototypes)
  - 600009 Board (Filter demo base)
  - 600011 Plug x2 One modified for minimal footprint
  - IEC62024-2:2020 Class C Board
- Temperature measurements with 3,0A & 3,75A:

Item	ΔT° rise @ IDC 3,0A	ΔT° rise @ I Perf 3,75A
Standard (minimal)	+67°K	**+116°K**
Enhanced (60011)	+35°K	+55°K
Class C	+26°K	**+42°K**

Temp rise above max as expected for Iperf on minimal

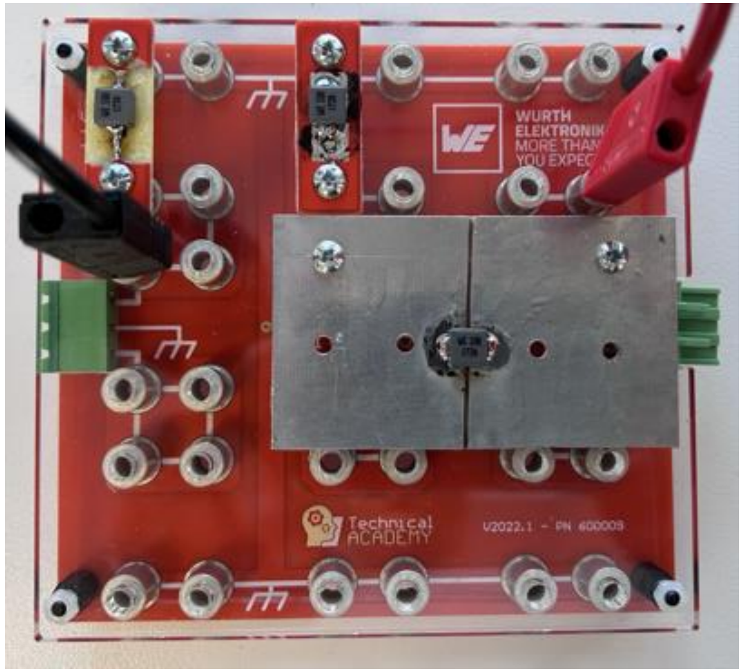
Temp rise near +40°C for IEC62024 Class C proto PCB

WE-LHMI# 74437346100

Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	100 kHz/ 10 mA	10	µH	±20%
Rated Current	$I_{R,40K}$	ΔT = 40 K	3	A	max.
Performance Rated Current [1)]	$I_{RP,40K}$	ΔT = 40 K	3.75	A	max.
Saturation Current @ 10%	$I_{SAT,10\%}$	|ΔL/L| < 10 %	5	A	typ.
Saturation Current @ 30%	$I_{SAT,30\%}$	|ΔL/L| < 30 %	9.8	A	typ.
DC Resistance	R_{DC}	@ 20 °C	75	mΩ	typ.
DC Resistance	R_{DC}	@ 20 °C	85	mΩ	max.
Self Resonant Frequency	f_{res}		15	MHz	typ.

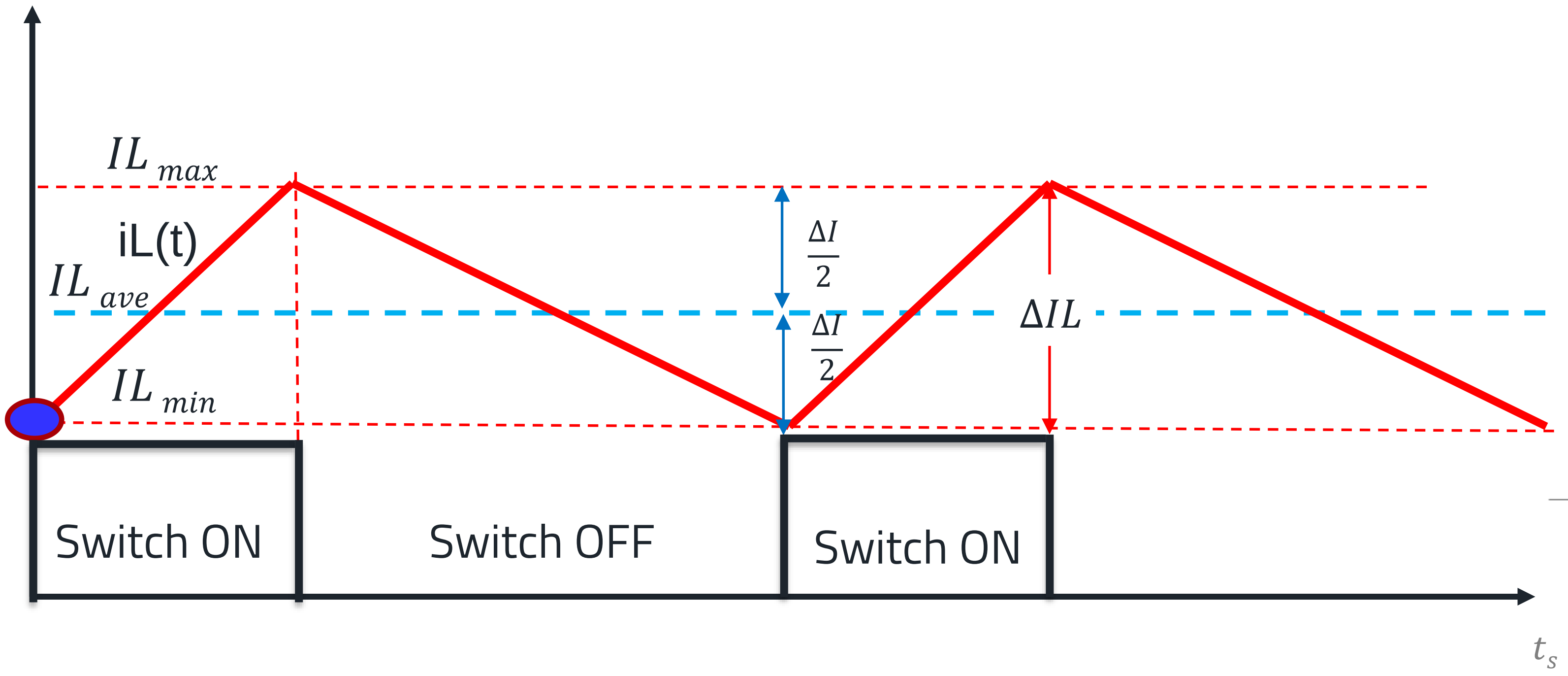
[1)] refer to IEC 62024-2-2020

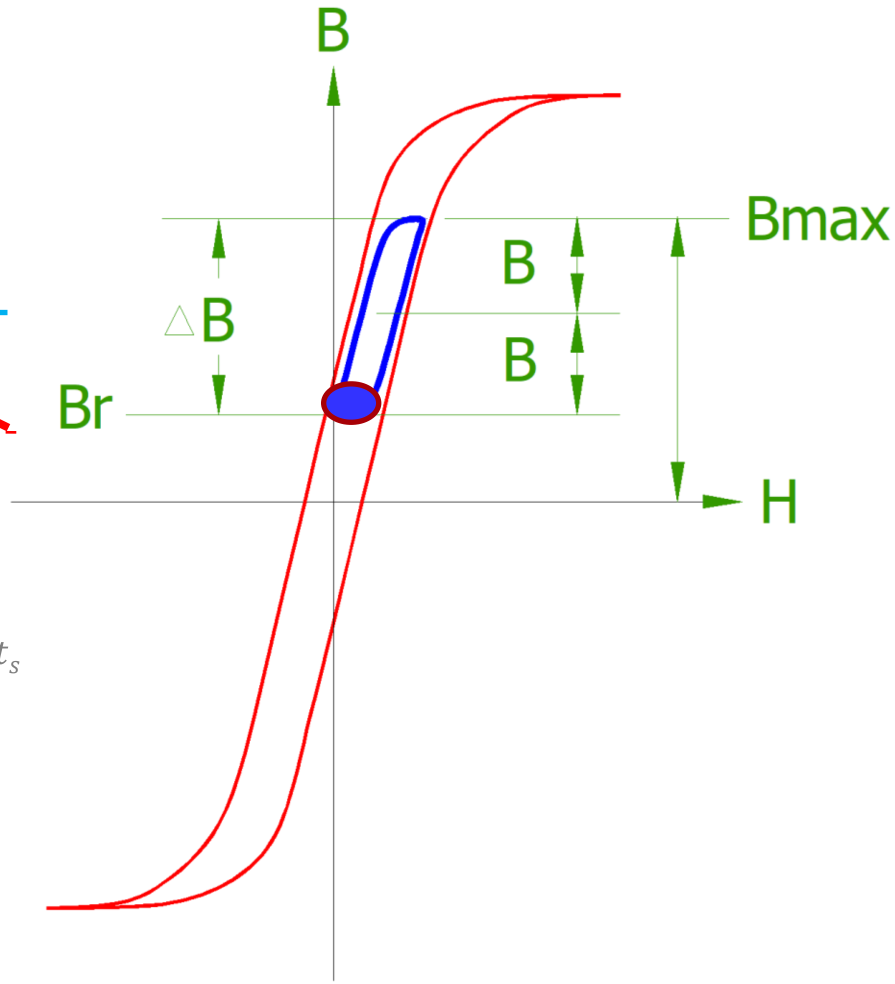


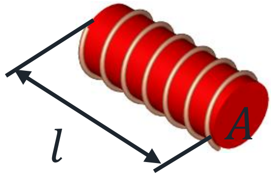
SATURATION EFFECT

POWER INDUCTORS

Cycle explanation : linear behavior (Buck in Steady State)



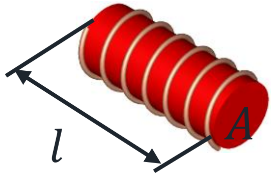


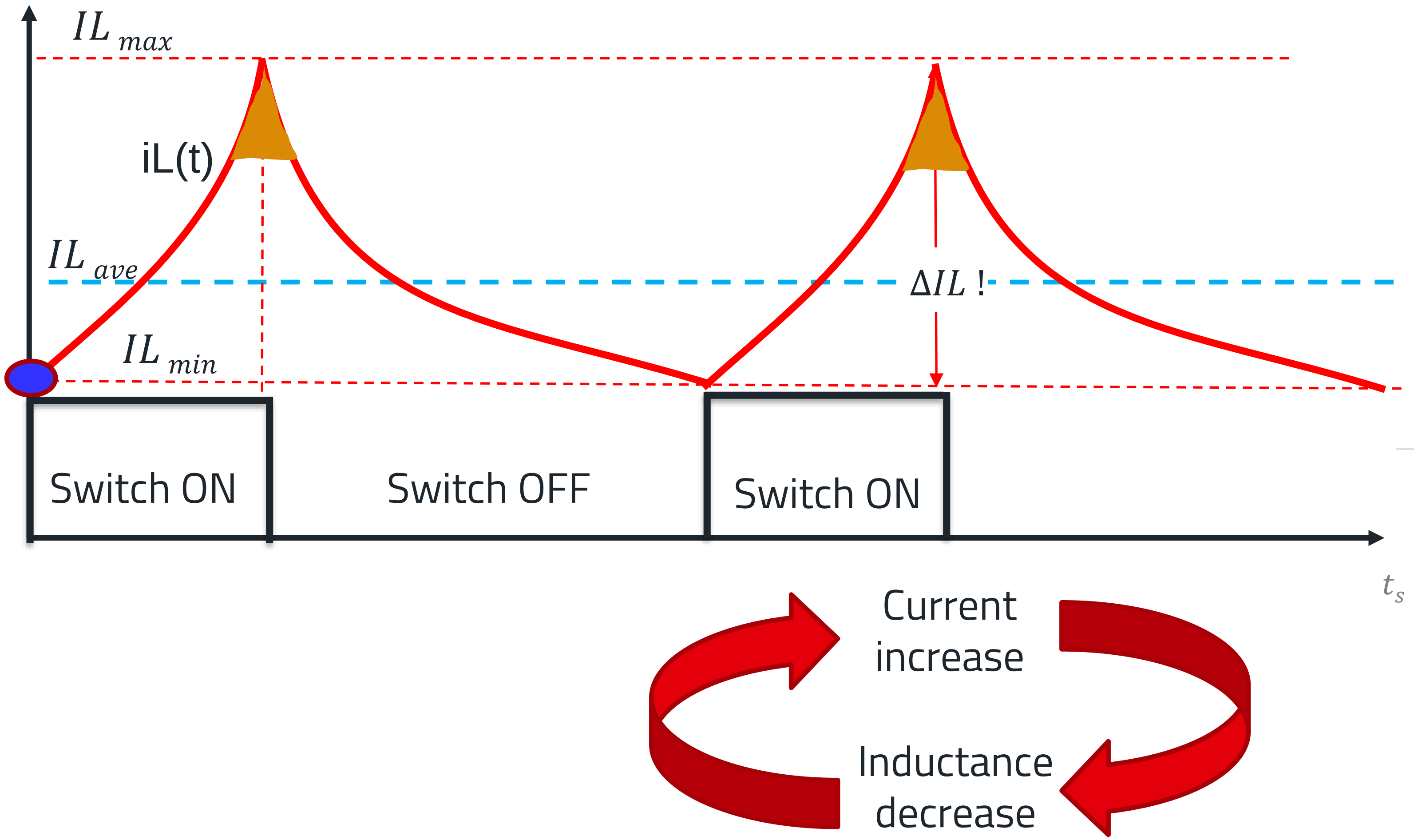


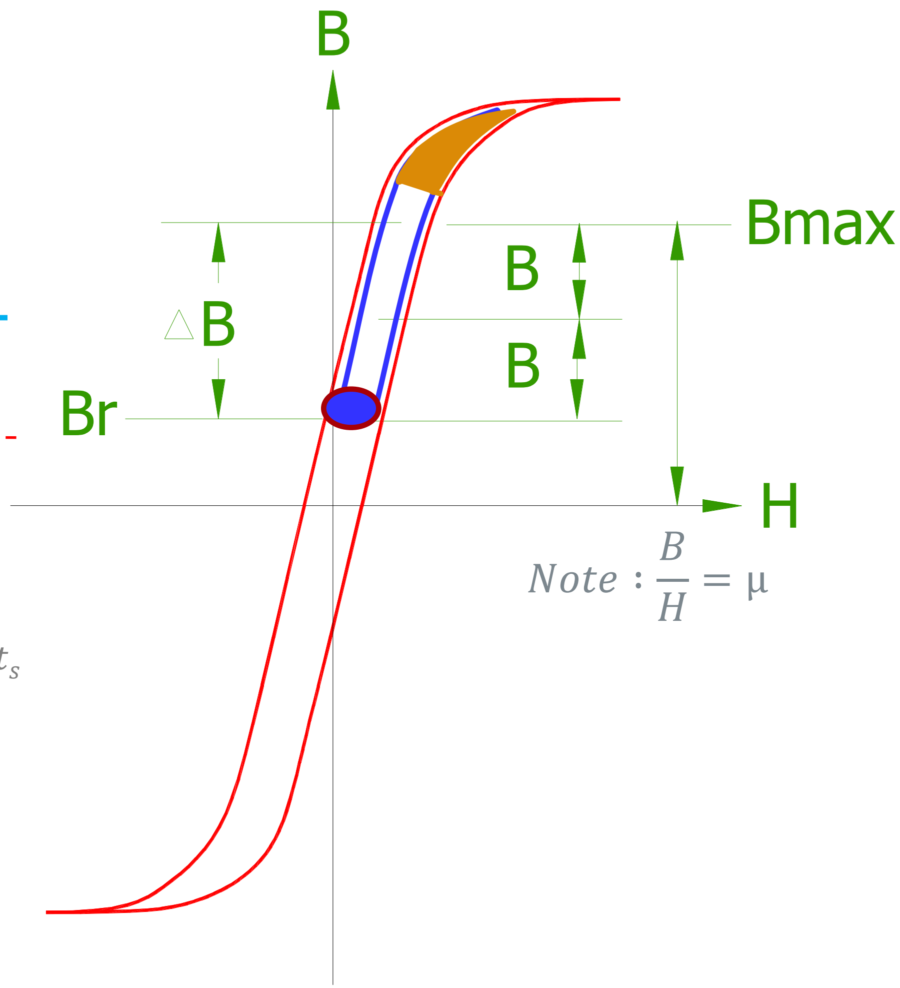
POWER INDUCTORS

Cycle explanation : saturation behaviour

$$L = \frac{\mu_0 \cdot \mu_r \cdot A \cdot N^2}{l}$$







POWER INDUCTORS

Rated Current: Who says the truth?

- Rated curent definition :

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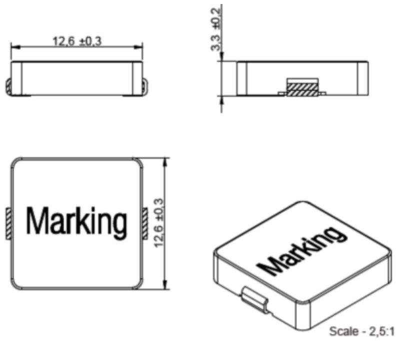

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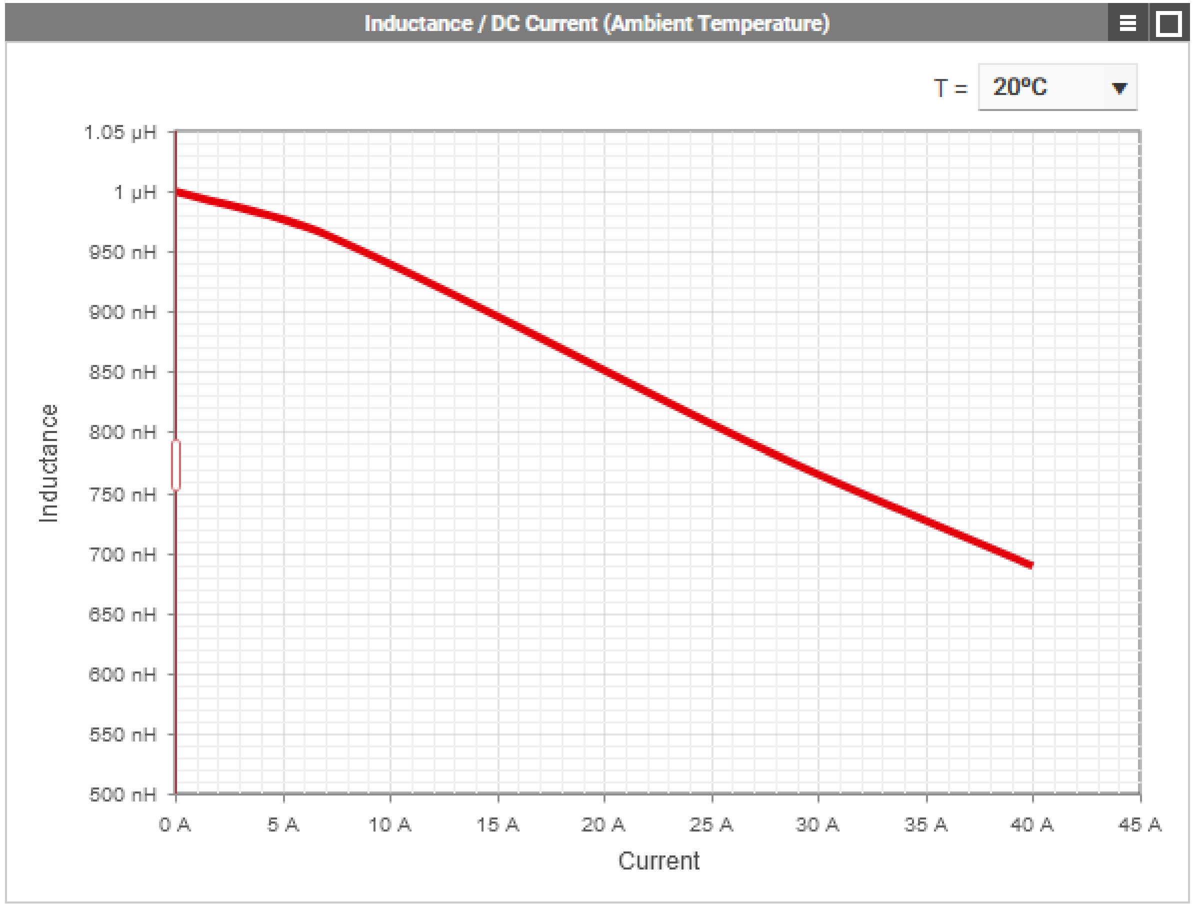
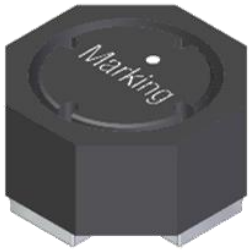
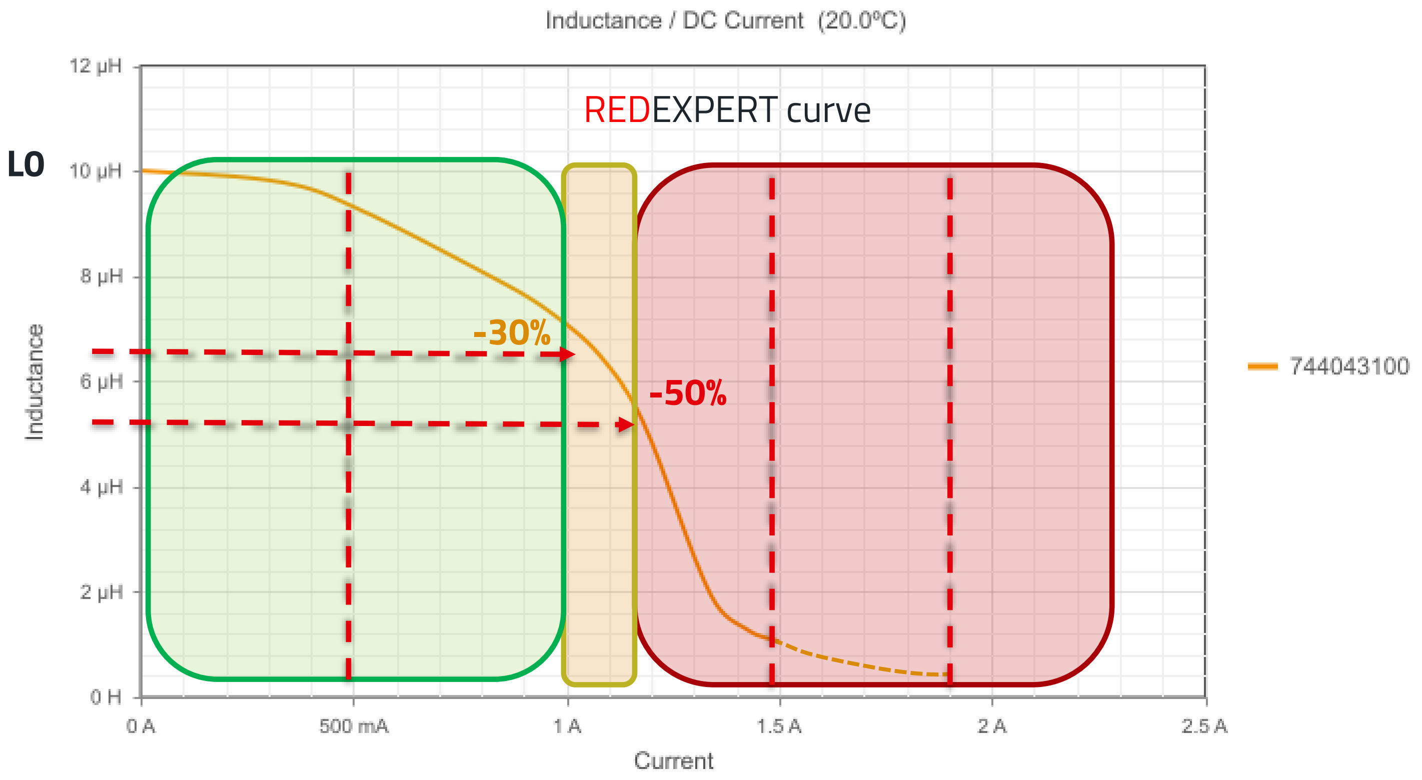
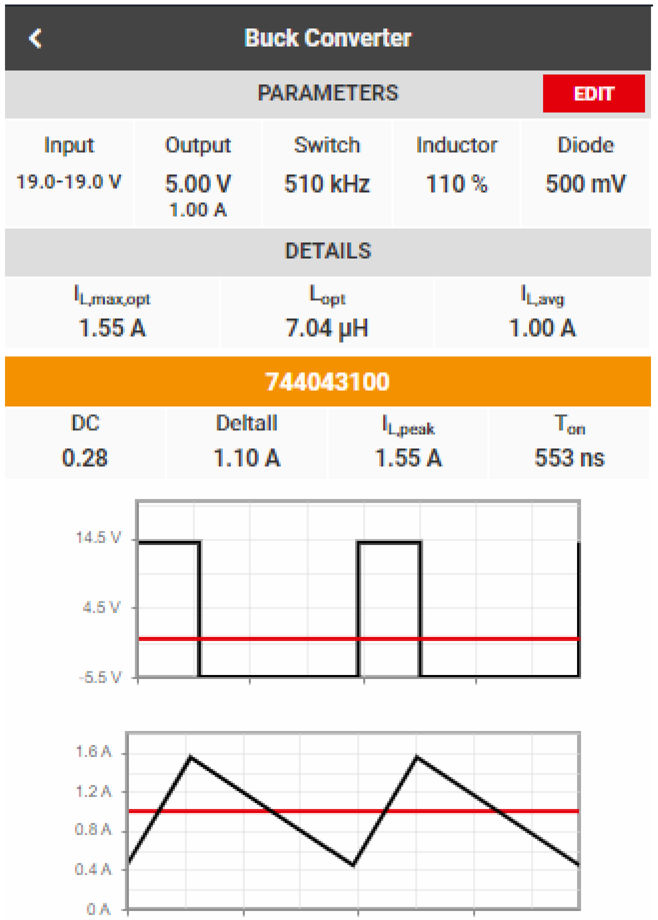


POWER INDUCTORS

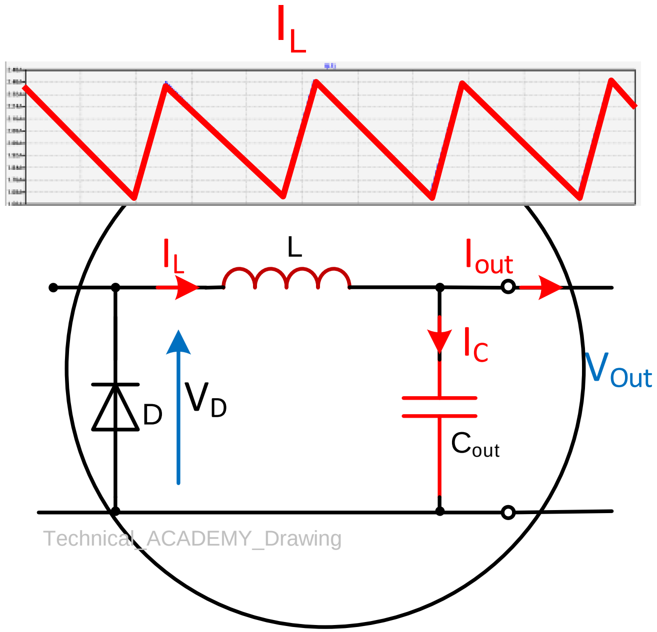
REDEXPERT WE-TPC# 744043100 $I_{sat} = 1{,}0A$

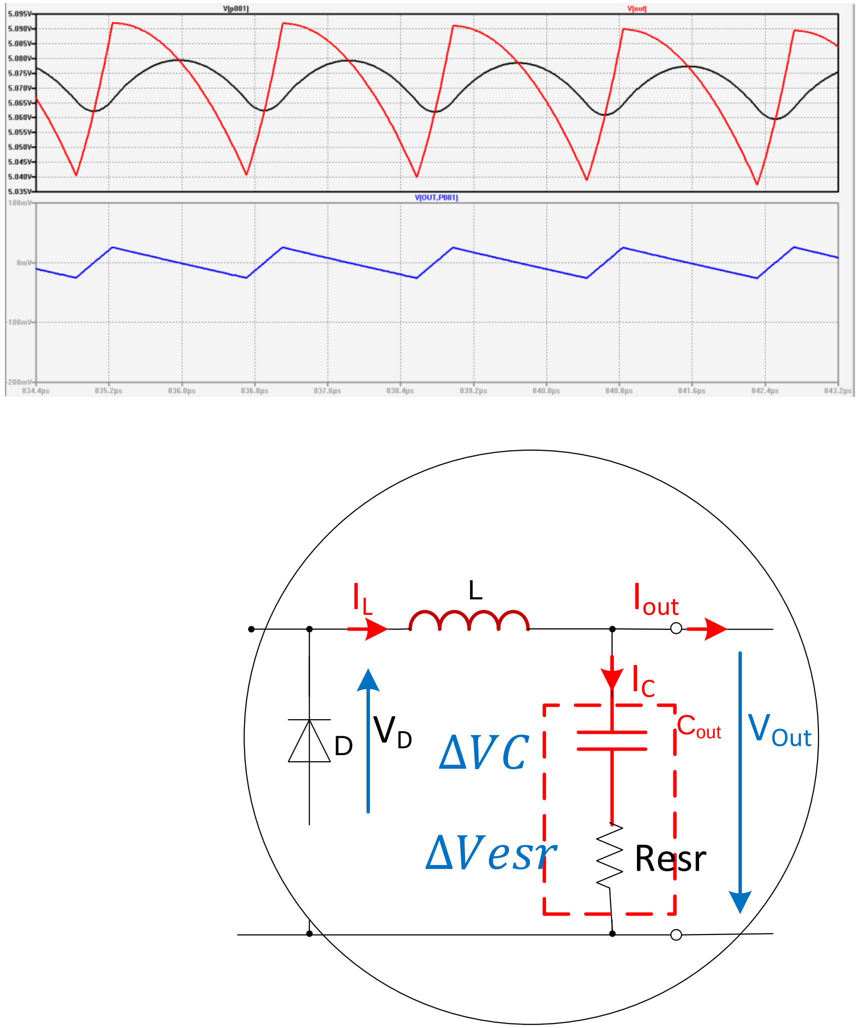






OUTPUT STAGE



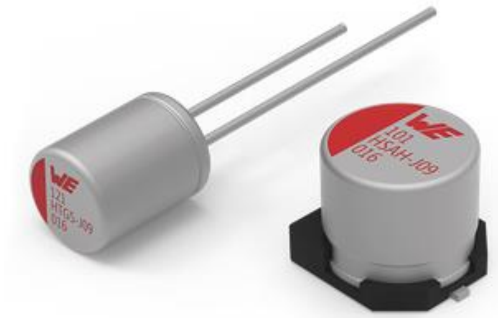


COMPARISON OF ALUMINUM CAPACITORS

Aluminum Electrolytic Capacitors

- Stable capacitance values at high temperature
- High voltage ratings
- Low leakage current

Aluminum Hybrid Polymer Capacitors

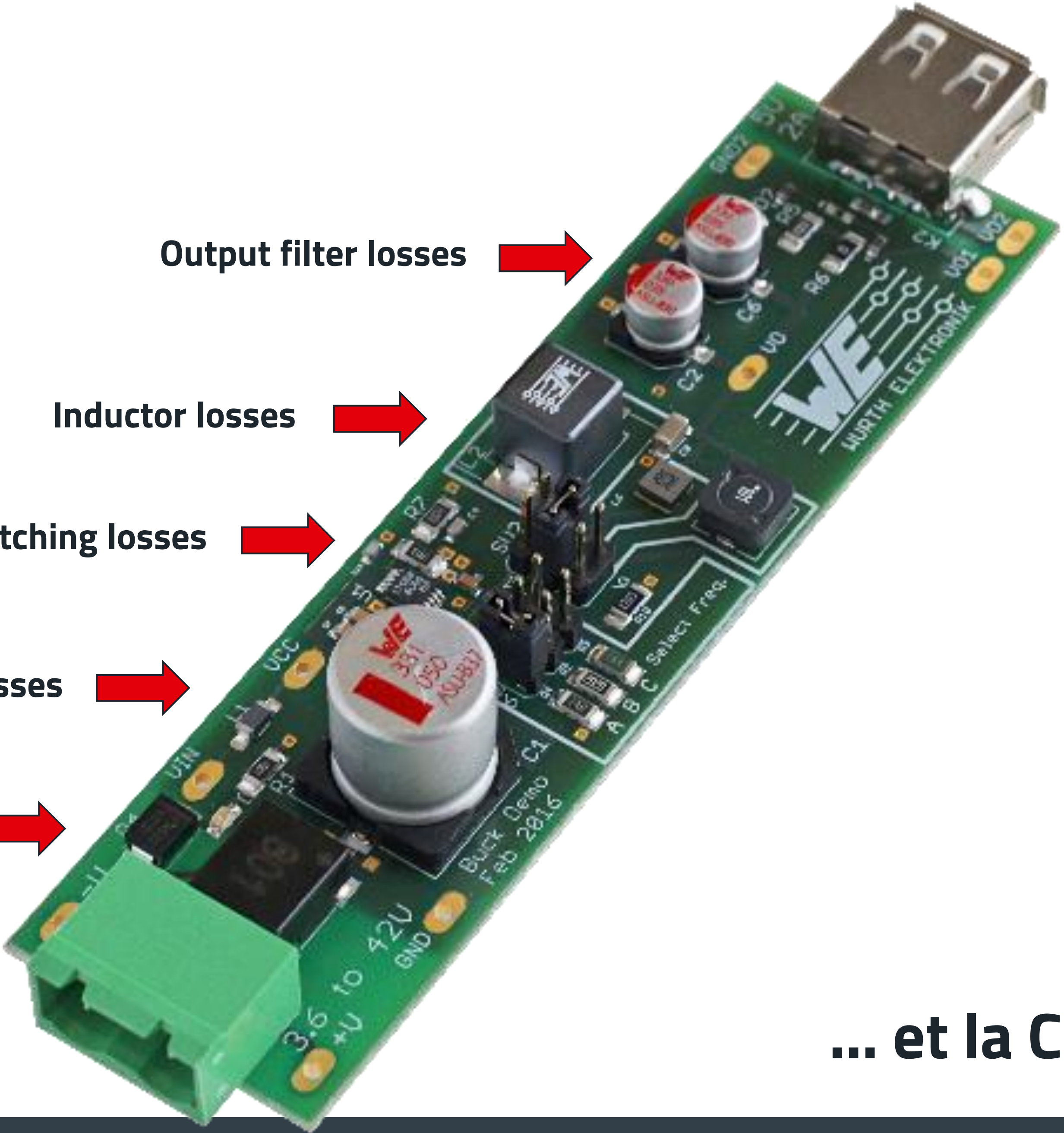


- Low ESR
- High ripple current characteristics
- High stability over the temperature range
- Low leakage current
- High lifetime performance

Aluminum Polymer Capacitors

- Low ESR
- High ripple current characteristics
- High lifetime performance

REDUCING LOSSES



Output filter losses

Inductor losses

Switching losses

Input filtering losses

Input protection losses

... et la CEM ???