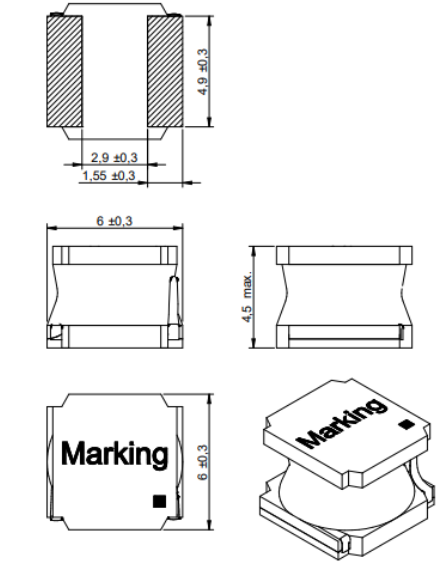
COMPONENT HEATING OF POWER INDUCTORS IN SWITCHING REGULATORS USING IEC 62024

Alexander Lang Tech Lead Power Magnetics

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

HEATING SHOWN IN THE DATASHEET

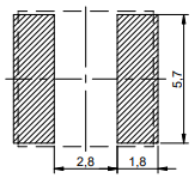
Dimensions: [mm]



Product Marking:

Start of Winding	•
Marking	1R0 (Inductance Code)

Recommended Land Pattern: [mm]



Schematic:

Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	100 kHz/ 1 V	1	µH	±30%
Rated Current	I_R	ΔT = 40 K	5.9	A	max.
Saturation Current	I_{SAT}	|ΔL/L| < 30 %	11.5	A	typ.
DC Resistance	R_{DC}	@ 20 °C	11	mΩ	±30%
Self Resonant Frequency	f_{res}		159	MHz	typ.
Operating Voltage	V	DC	120	V	max.

Certification:

RoHS Approval	Compliant [2011/65/EU&2015/863]
REACh Approval	Conform or declared [(EC)1907/2006]
Halogen Free	Conform [JEDEC JS709B]
Halogen Free	Conform [IEC 61249-2-21]
Component Qualification	AEC-Q200 Grade 1

General Information:

Ambient Temperature (referring to I_R)	-40 up to +85 °C
Operating Temperature	-40 up to +125 °C
Storage Conditions (in original packaging)	< 40 °C ; < 75 % RH
Moisture Sensitivity Level (MSL)	1

Test conditions of Electrical Properties: +20 °C, 33 % RH if not specified differently

RoHS COMPLIANT | REACh COMPLIANT | HALOGEN FREE | AEC Q200 125 °C GRADE 1

CHECKED	REVISION	DATE (YYYY-MM-DD)	GENERAL TOLERANCE	PROJECTION METHOD
ChriB	002.003	2022-05-24	DIN ISO 2768-1m	

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

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EMC & Inductive Solutions
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74638 Waldenburg
Germany
Tel. +49 (0) 79 42 945 - 0
www.we-online.com
eiSos@we-online.com

DESCRIPTION: **WE-LQS SMT Semi-Shielded Power Inductor**

ORDER CODE: **74404064010**

SIZE/TYPE	BUSINESS UNIT	STATUS	PAGE
6045	eiSos	Valid	1/6

HEATING SHOWN IN THE DATASHEET

Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	100 kHz/ 1 V	1	µH	±30%
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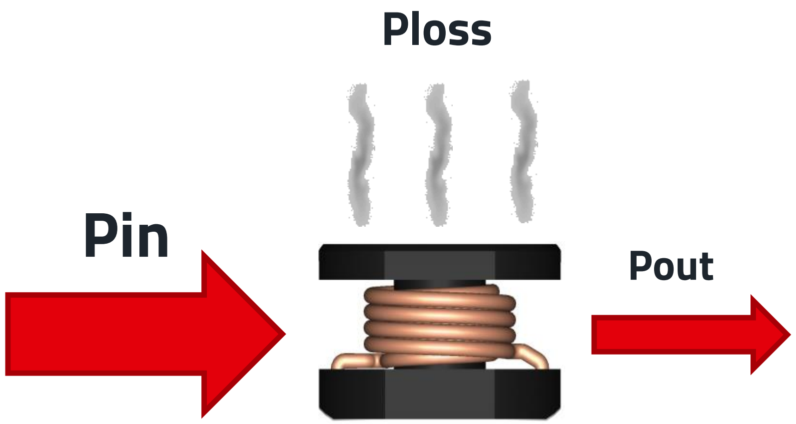
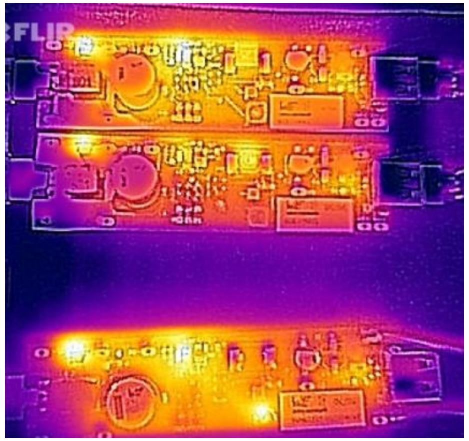
Saturation Current	I_{SAT}	$\lvert\Delta L/L\rvert < 30$ %	11.5	A	typ.
DC Resistance	R_{DC}	@ 20 °C	11	mΩ	±30%
Self Resonant Frequency	f_{res}		159	MHz	typ.
Operating Voltage	V	DC	120	V	max.

WHY DOES THE COMPONENT HEAT UP





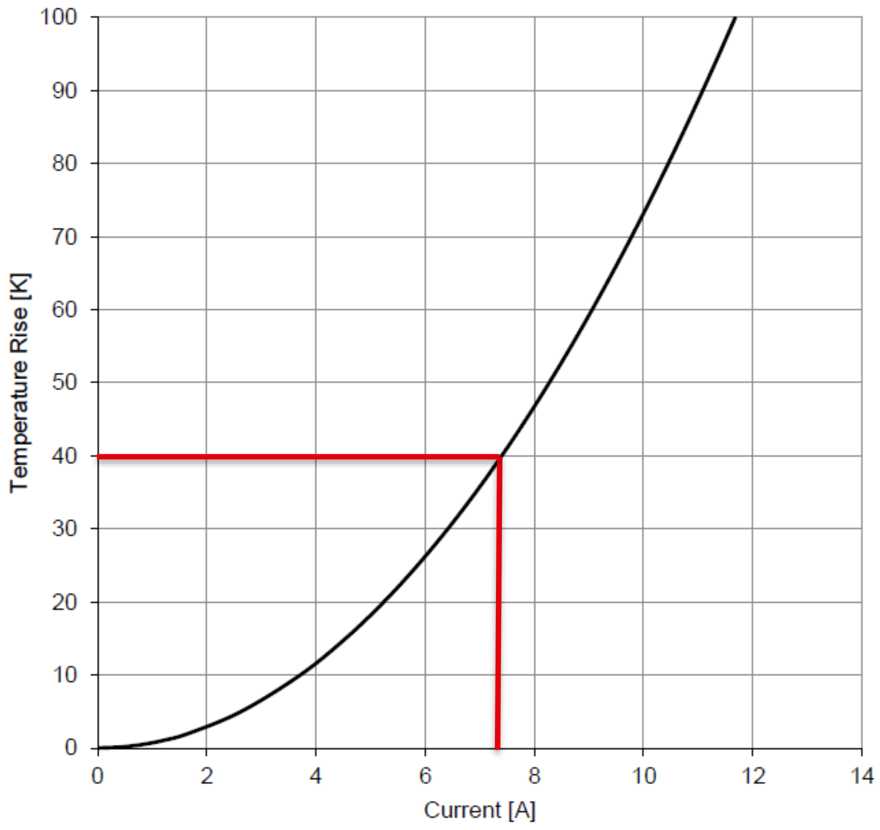
$$P_{loss} = P_{DC} + \cancel{P_{AC}}$$

$$\downarrow$$

$$P_{loss} = I_{DC}^2 * R_{DC}$$

WHAT IS RATED CURRENT

Typical Temperature Rise vs. Current Characteristics:



$$P_{loss} = I_{DC}^2 * R_{DC}$$

I_R = 7,3 A | test condition ΔT = 40K

MARKET SITUATION OF RATED CURRENT DEFINITION

Irms (A)[6]	
20°C rise	40°C rise

Itemp (A)typ.
(ΔT=40deg.C)

Rated Current	I_R	ΔT = 50 K	32	A	max.

(3) DC current (A) that will cause an approximate ΔT of 40 °C after one hour
(4) DC current (A) that will cause an approximate ΔT of 100 °C after one hour

Irms is the DC current which cause the surface temperature of the part increase less than 45°C.

Rated Current (max)	1.4 A (⊿L=30%, ⊿T=25℃), 1.8 A (⊿L=30%, ⊿T=40℃)

DC current (A) that will cause an approximate ΔT of 40 °C

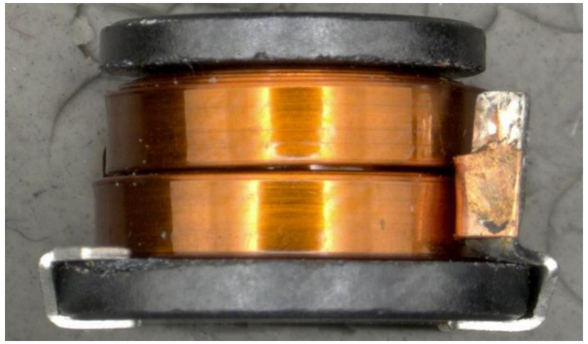
Temperature Rise .....40 °C at rated I_{rms}[1]
Rated Current

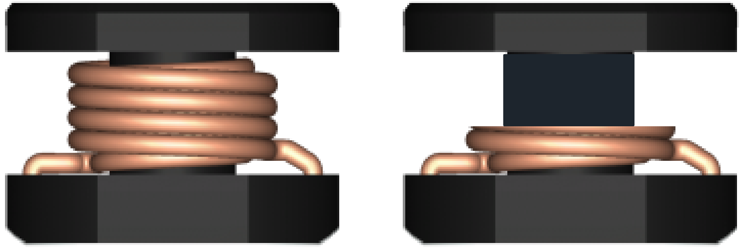
Rated Current : Value defined when DC current flows and Rated Current (Based on Inductance change) or when DC current flows and Rated Current (Based on Temperature rise) whichever is smaller.

HOW TO INCREASE THE RATED CURRENT

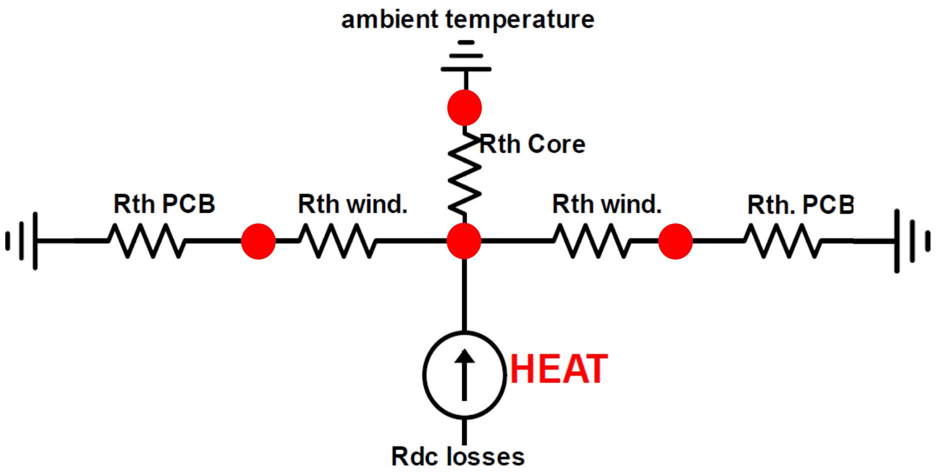
$$P_{loss} = I_{DC}^2 * R_{DC}$$

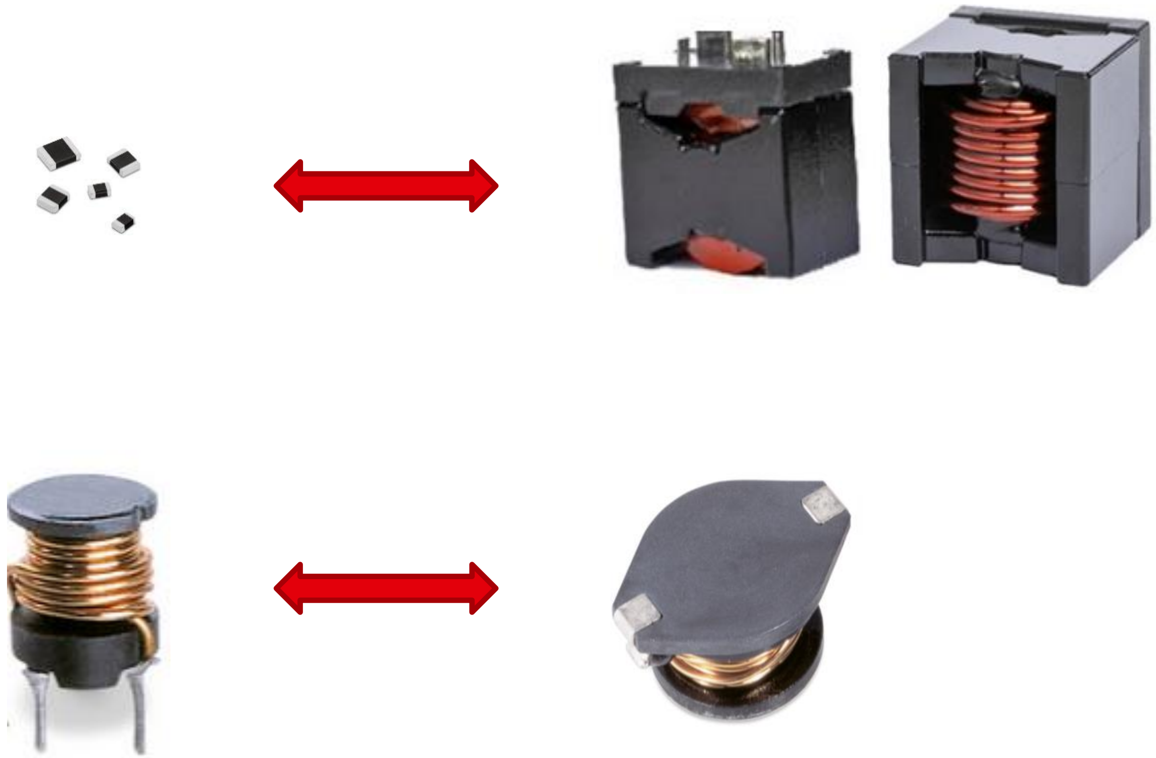
$$R = \rho * \frac{l}{A}$$



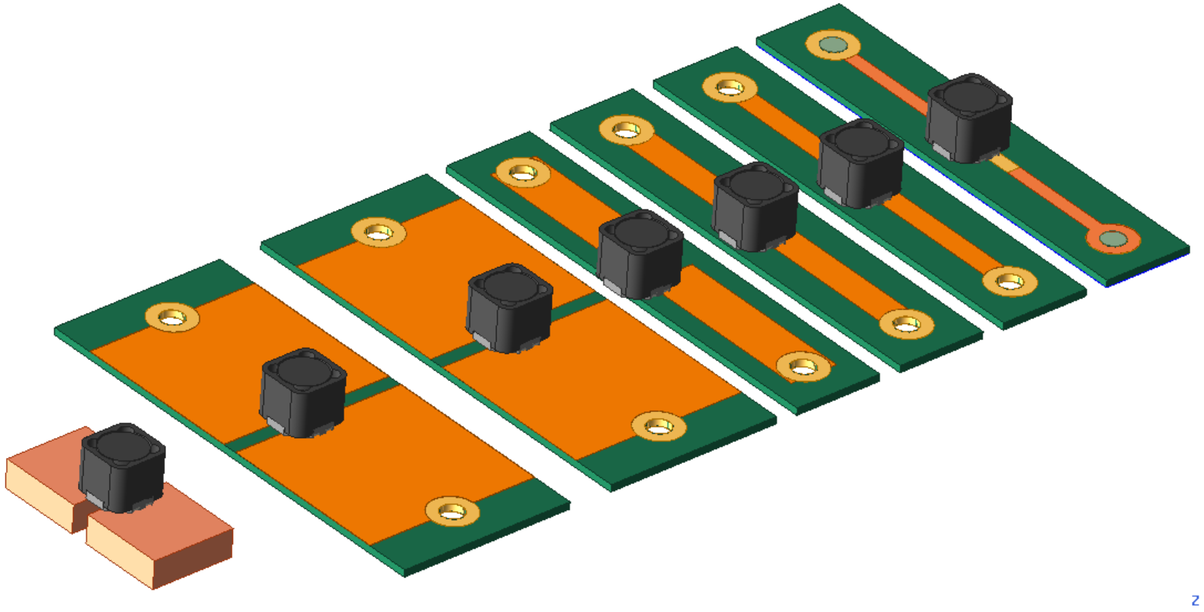


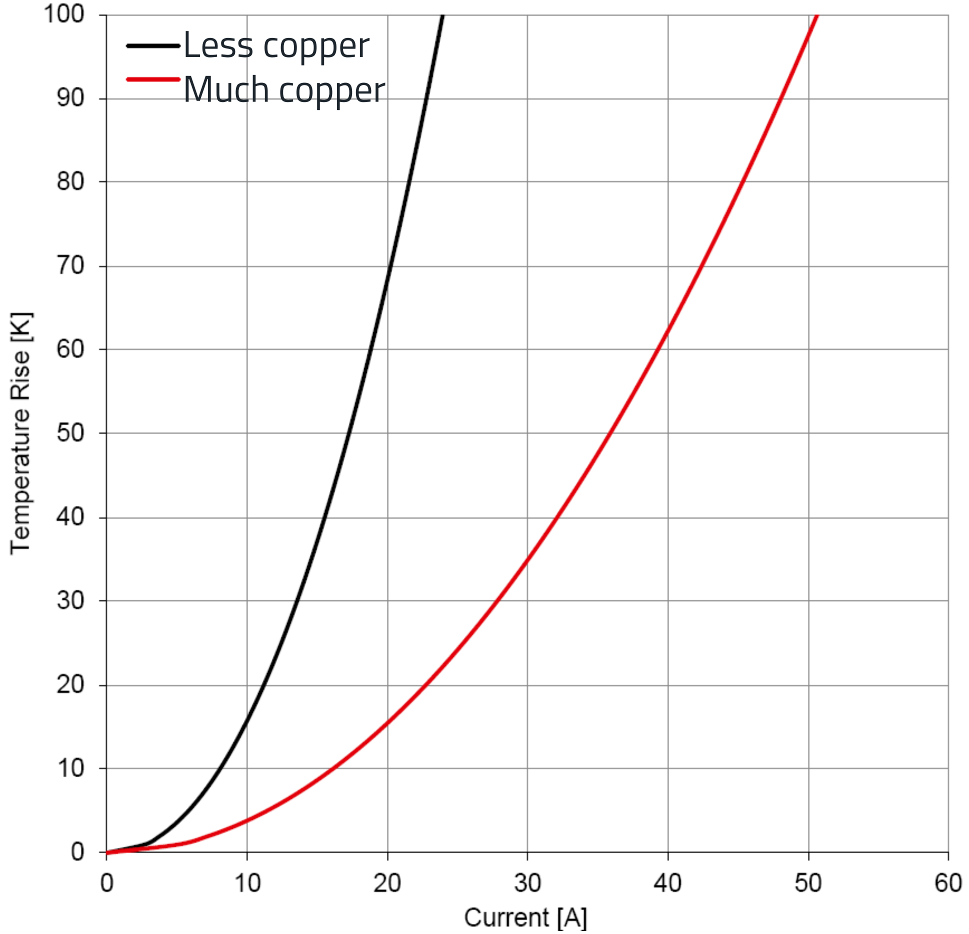
OTHER OPTIONS NEXT TO THE RDC





IMPACT OF THE PCB ON THE HEATING





RATED CURRENT DEFINITION AND SPECIFICATION

※3 Temperature rise current: The actual value of DC current when temperature of coil rise is △T=40℃(Ta=25℃) Board conditions: FR4, Copper=70μm,four-layer PWB, t=1.6mm.

The part temperature (ambient + temp. rise) should not exceed 155 °C under worst case operating conditions. Circuit design, component placement, PWB trace size and thickness, airflow and other cooling provisions all affect the part temperature. Part temperature should be verified in the end application

Rated current $I_{temp,typ}$	Current that will cause a Δ40°K self-heating at room temperature

Irms Testing

Irms testing was performed on 0.75 inch wide × 0.25 inch thick copper traces in still air.

Temperature rise is highly dependent on many factors including pcb land pattern, trace size, and proximity to other components. Therefore temperature rise should be verified in application conditions.

[1]Circuit design, component, PCB trace size and thickness, airflow and other cooling provisions all affect the part temperature. Part temperature should be verified in the end application.

WEAK POINTS OF CURRENT SPECIFICATION

- Test setup with insufficient description
  - Many influences which can corrupt the final result
- Specified value is difficult to put in relation to the real application
  - Is a first indicator, but hard to assume if it useful for end application
  - Choosing the best component out of many is difficult because the numbers aren‘t comparable

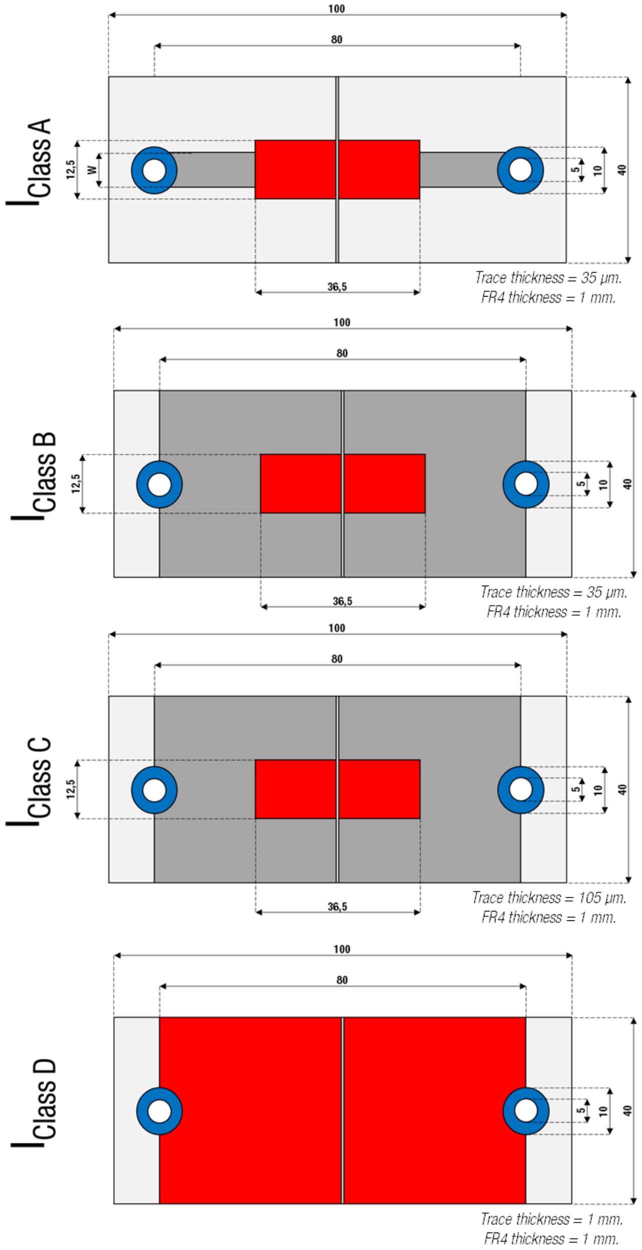
- How to improve?

IEC 62024-2:2020

Classification Performance Rated Current

Tabelle 2 – Leiterbahnbreite und -dicke

Bemessungs-stromklasse	Leiter-bahnbreite W mm	Leiter-bahndicke t µm	Beispielanwendung
$I_{\text{Klasse A}}$	(1,0 bis 22,0) ± (0,2 bis 0,5)	35 ± 10	Verbraucheranwendung (Anwendungen mit einseitigen Leiterplatten)
$I_{\text{Klasse B}}$	40 ± 0,2	35 ± 10	Verbraucheranwendung (Anwendungen mit doppelseitigen Leiterplatten)
$I_{\text{Klasse C}}$	40 ± 0,2	105 ± 10	Verbraucheranwendung (Anwendungen mit mehrlagigen Leiterplatten)
$I_{\text{Klasse D}}$	40 ± 0,2	1 000 ± 50	Anwendungen von Automobil- oder Energie-versorgungsunternehmen
ANMERKUNG 1	$I_{\text{Klasse A}}$: siehe Bild 2a).		
ANMERKUNG 2	$I_{\text{Klasse B}}$, $I_{\text{Klasse C}}$, $I_{\text{Klasse D}}$: siehe Bild 2b).		



IEC 62024-2:2020

WE Definition of Performance Rated current

- Class B: Product Series with standard requirement profile
- Class C: Product with are used in high packing density application
- Class D: Products with current capability higher then 30A

EXAMPLE CLASS B

74477001

- WE-PD

Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	100 kHz/ 250 mV	1.2	µH	±30%
Rated Current	$I_{R,40K}$	ΔT = 40 K	13.5	A	max.
Performance Rated Current [1)]	$I_{RP,40K}$	ΔT = 40 K	16.2	A	max.
Saturation Current @ 10%	$I_{SAT,\ 10\%}$	|ΔL/L| < 10 %	21	A	typ.
Saturation Current @ 30%	$I_{SAT,30\%}$	|ΔL/L| < 30 %	27	A	typ.
DC Resistance	R_{DC}	@ 20 °C	4.6	mΩ	typ.
DC Resistance	R_{DC}	@ 20 °C	7	mΩ	max.
Self Resonant Frequency	f_{res}		45	MHz	typ.
Operating Voltage	V	DC	120	V	max.

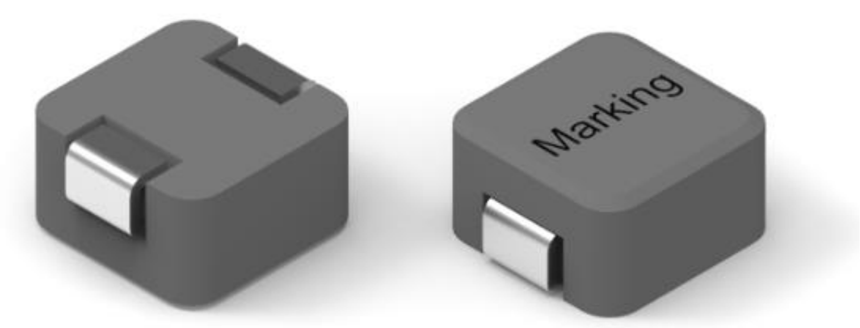
[1)] refer to IEC 62024-2-2020

Test conditions of Performance Rated Current: refer to IEC 62024-2-2020, Class B PCB Copper Width: 40 mm; PCB Copper Thickness: 35 µm)

EXAMPLE CLASS C

74437377010

- WE-LHMI



Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	100 kHz/ 10 mA	1	µH	±20%
Rated Current	$I_{R,40K}$	$\Delta T = 40$ K	15	A	max.
Performance Rated Current [1)]	$I_{RP,40K}$	$\Delta T = 40$ K	23.5	A	max.
Saturation Current @ 10%	$I_{SAT,10\%}$	$\|\Delta L/L\| < 10$ %	15.4	A	typ.
Saturation Current @ 30%	$I_{SAT,30\%}$	$\|\Delta L/L\| < 30$ %	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.

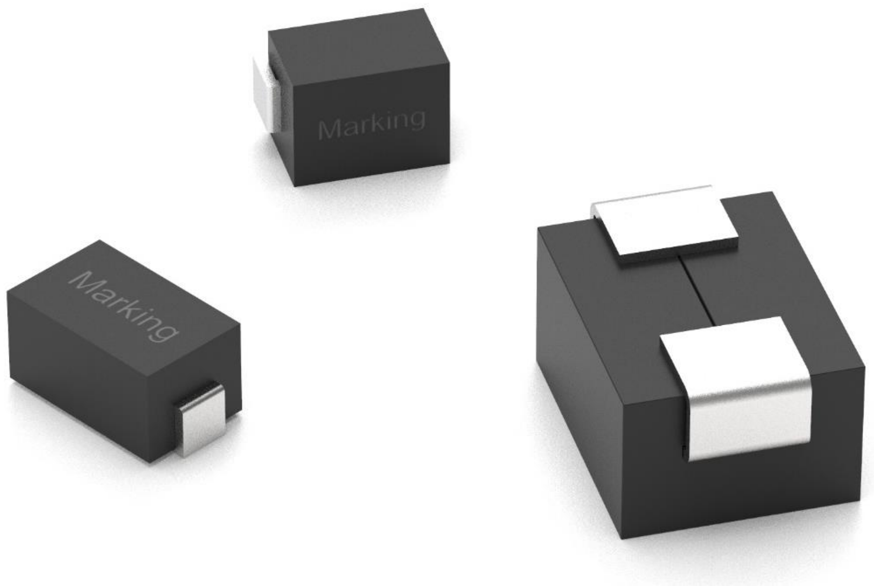
1) refer to IEC 62024-2-2020

Test conditions of Rated Current: refer to IEC 62024-2-2020, Class C (PCB Copper Width: 40 mm; PCB Copper Thickness: 105 µm)

EXAMPLE CLASS D

744303015

- WE-HCM



Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	100 kHz/ 10 mA	155	nH	±20%
Rated Inductance	L_R	100 kHz/ 10 mA/ 31.0 A	150	nH	typ.
Rated Current	$I_{R,40K}$	$\Delta T = 40$ K	31	A	max.
Performance Rated Current [1]	$I_{RP,40K}$	$\Delta T = 40$ K	63.9	A	max.
Saturation Current @ 10%	$I_{SAT,10\%}$	$\lvert\Delta L/L\rvert < 10$ %	44.5	A	typ.
Saturation Current @ 30%	$I_{SAT,30\%}$	$\lvert\Delta L/L\rvert < 30$ %	51.5	A	typ.
DC Resistance	R_{DC}	@ 20 °C	0.325	mΩ	±7%
Self Resonant Frequency	f_{res}		110	MHz	typ.

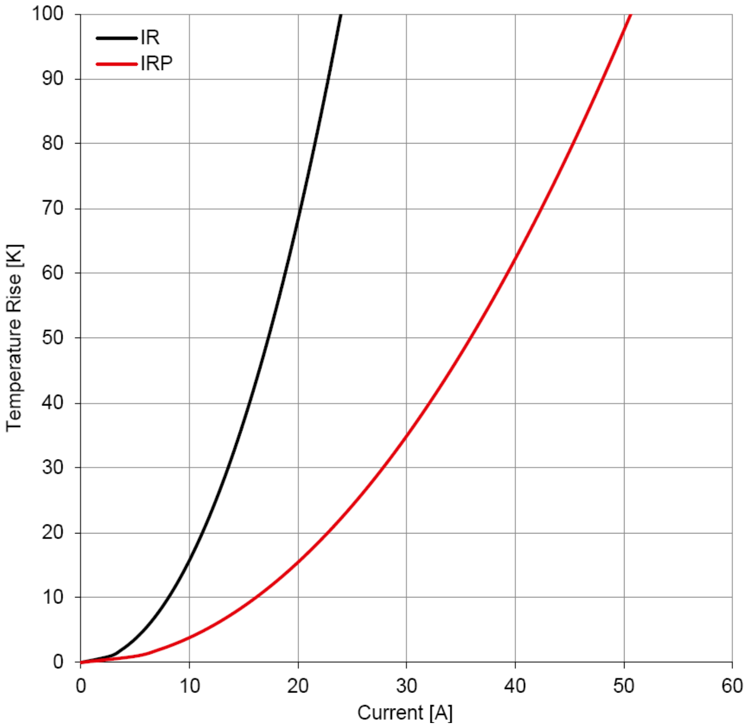
1) refer to IEC 62024-2-2020

Test conditions of Performance Rated Current: refer to IEC 62024-2 Class D (PCB Copper Width: 40 mm; PCB Copper Thickness: 1000 µm)

PERFORMANCE RATED CURRENT

- Rated Current (I_R) measured on WE legacy PCB boards
- Performance Rated Current (I_{RP}) measured on Class B, Class C or Class D PCBs

Further information can be found in application note ANP096



Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	100 kHz/ 10 mA	2.2	µH	±20%
Rated Current	I_R	ΔT = 40 K	16	A	max.
Performance Rated Current [1]	$I_{RP,40K}$	ΔT = 40 K	32.05	A	max.
Saturation Current @ 10%	$I_{SAT,10\%}$	$\lvert\Delta L/L\rvert < 10\,\%$	15.68	A	typ.
Saturation Current @ 30%	$I_{SAT,30\%}$	$\lvert\Delta L/L\rvert < 30\,\%$	32.1	A	typ.
DC Resistance	R_{DC}	@ 20 °C	2.2	mΩ	±10%
Self Resonant Frequency	f_{res}		28	MHz	typ.

[1] refer to IEC 62024-2-2020

Certification:

RoHS Approval	Compliant [2011/65/EU&2015/863]
REACh Approval	Conform or declared [(EC)1907/2006]
Halogen Free	Conform [JEDEC JS709B]
Halogen Free	Conform [IEC 61249-2-21]
Component Qualification	AEC-Q200 Grade 1

General Information:

Ambient Temperature (referring to I_R)	-40 up to +85 °C
Operating Temperature	-40 up to +125 °C
Storage Conditions (in original packaging)	< 40 °C ; < 75 % RH
Moisture Sensitivity Level (MSL)	1

Test conditions of Electrical Properties: +20 °C, 33 % RH if not specified differently

Test conditions of Performance Rated Current: refer to IEC 62024-2, Class D (PCB Copper Width: 40 mm; PCB Copper Thickness: 1000 µm)

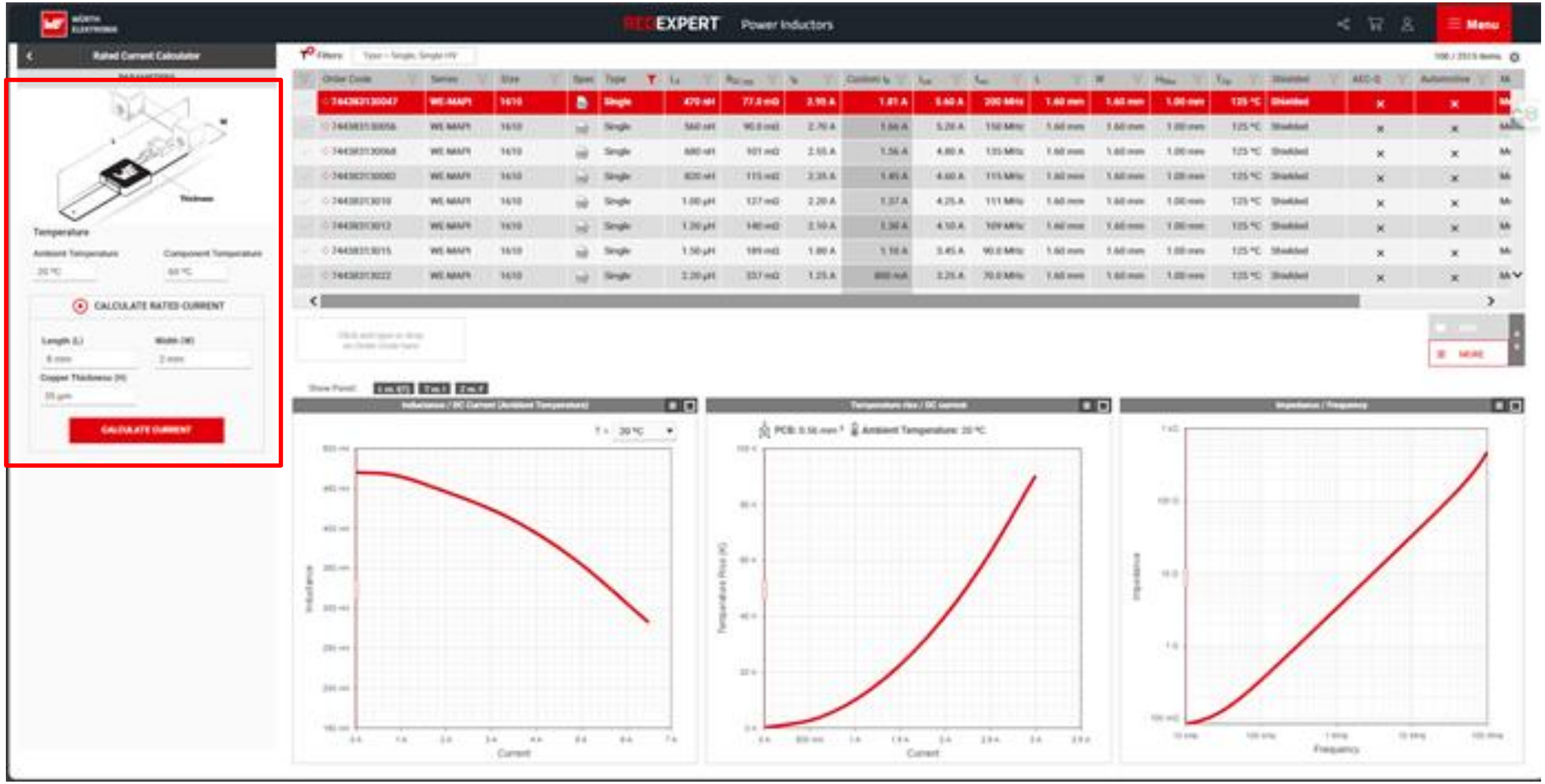
Temperature rise is highly dependent on many factors including PCB land pattern, trace size, and proximity to other components. Therefore, temperature rise should be verified in application conditions.

CONCLUSION IEC STANDARD

- By using the IEC 62024-2:2020 we perform the measurement with highest possible transparency.
- Series can be compared on a defined level
- Better appraisal for end application by knowing the used PCB layout
- High trust for the value in the datasheet

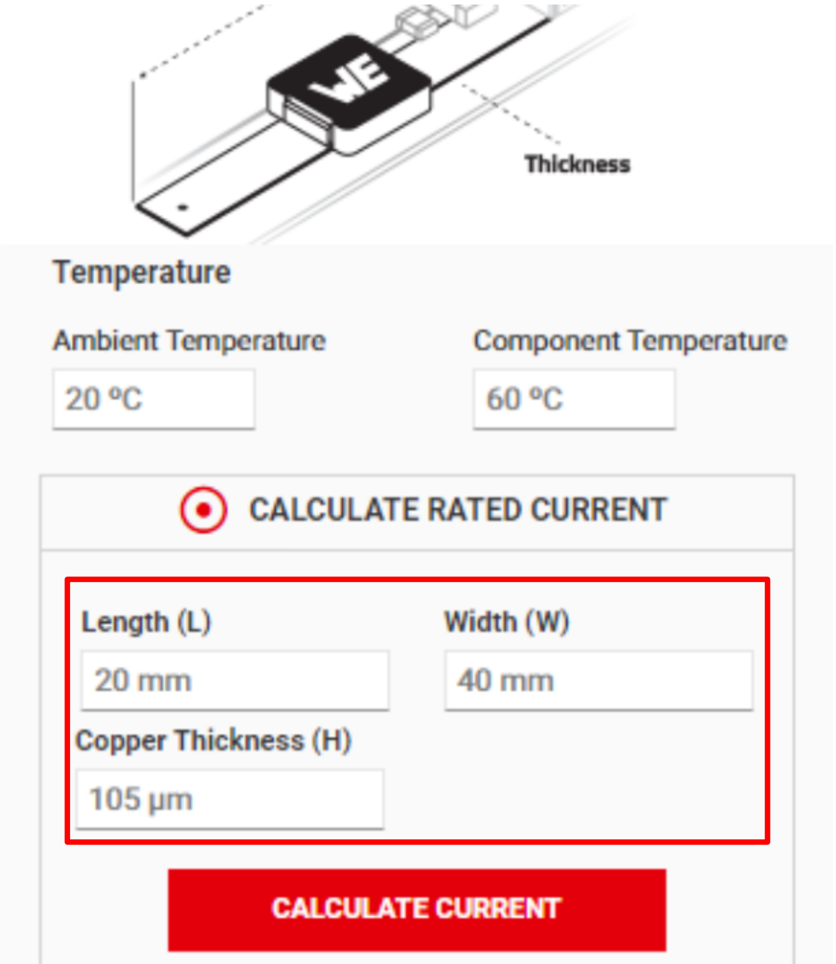
REDEXPERT

Simulation Tool for specific PCB Design



REDEXPERT

Simulation Tool for specific PCB Design



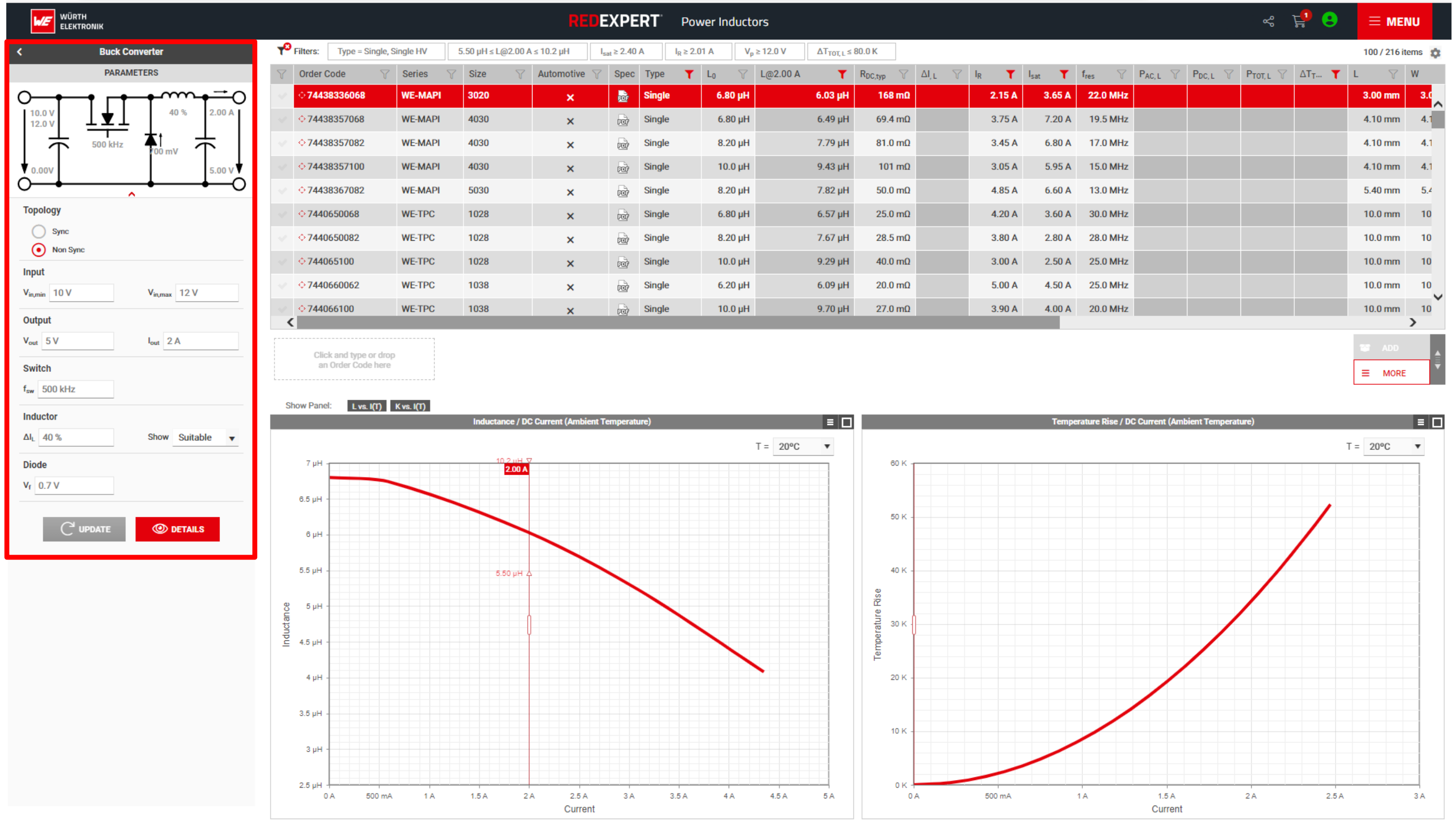
REDEXPERT

What else is missing?

- Power Inductors are mainly used in DC DC Converter.
- In a DC DC Converter the inductor needs to handle 2 currents.
  - DC losses
  - AC losses
- To have most usable result we suggest to use Redexpert which is calculation the total losses of the application

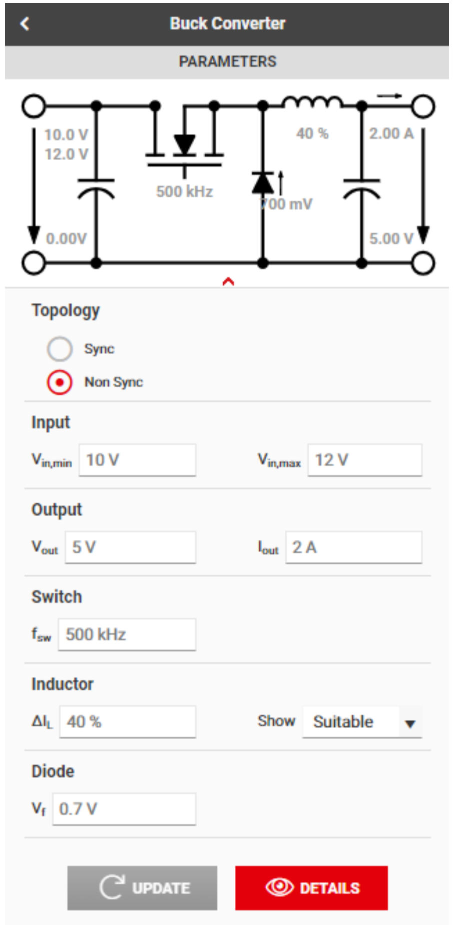
REDEXPERT

Simulation of AC Losses



REDEXPERT

Simulation of AC Losses



CONCLUSION DEFINITION OF PERFROMANCE RATED CURRENT

- By using IEC Standard we have a method where values can be compared very easily
- By offering new PCB Layout tool we can offer custom specific DC heating simulation tool

- By offering Redexpert DC DC loss, we can offer a tool where AC loss can be calculated very convenient

- Self heating can be specified and simulated in all kind of complexity.
  - From comparing datasheet values up to expected self heating in end application

THANK YOU!