



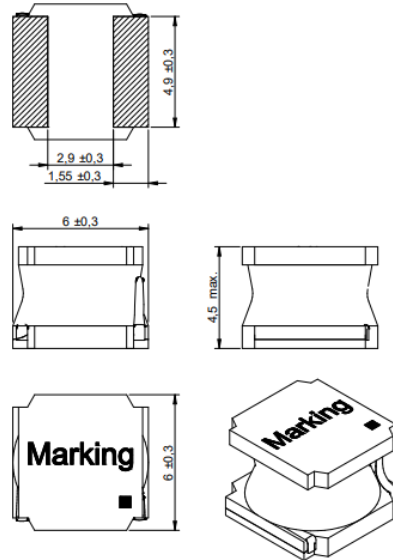
# COMPONENT HEATING OF POWER INDUCTORS IN SWITCHING REGULATORS USING IEC 62024

Alexander Lang Tech Lead Power Magnetics

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

# HEATING SHOWN IN THE DATASHEET

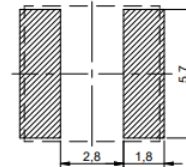
## Dimensions: [mm]



## 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	$I_{RMS}$ $\Delta T = 40 \text{ K}$	5.9	A	max.
Saturation Current	$I_{SAT}$ $\Delta L/L < 30 \%$	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 J5709B]
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



ORDERED ChrB	REVISION 002.003	DATE (YYYY-MM-DD) 2022-05-24	GENERAL TOLERANCE DIN ISO 2768-1m	INDUCTOR REVISED	
DESCRIPTION <b>WE-LQS SMT Semi-Shielded Power Inductor</b>				ORDER CODE <b>74404064010</b>	
REVISION 00405	REVISION e505	DATE Valid	INDUCTOR 1/R0		

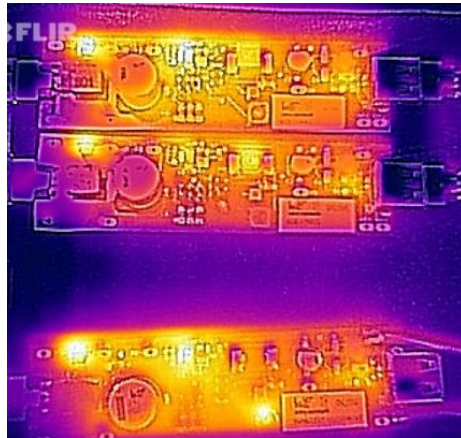
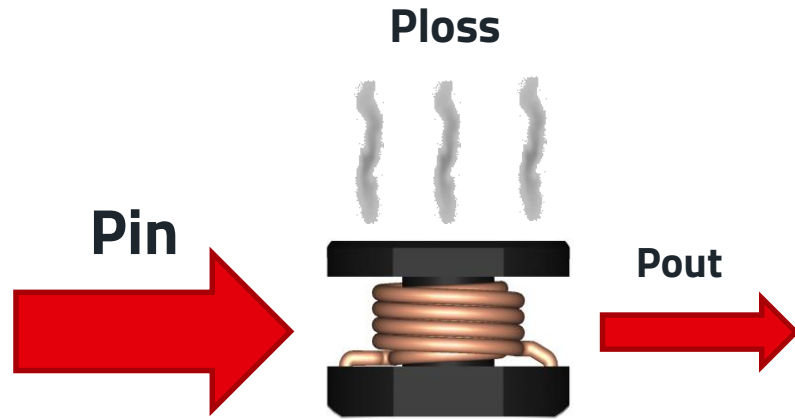
This electronic component has been designed and developed for usage in general electronic equipment only. This product is not authorized for use in equipment where a higher safety standard and reliability standard is especially required or where a failure of the product is reasonably expected to cause severe personal injury or death, unless the parties have executed an agreement specifically governing such use. Moreover WURTH ELEKTRONIK GmbH & Co KG products are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc. WURTH ELEKTRONIK GmbH & Co KG must be informed about the intent of such usage before the design-in stage. In addition, sufficient reliability evaluation checks for safety must be performed on every electronic component which is used in electrical circuits that require high safety and reliability functions or performance.

## HEATING SHOWN IN THE DATASHEET

### Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	100 kHz/ 1 V	1	$\mu\text{H}$	$\pm 30\%$
Rated Current	$I_R$	$\Delta T = 40 \text{ K}$	5.9	A	max.
Saturation Current	$I_{\text{SAT}}$	$  \Delta L / L   < 30 \%$	11.5	A	typ.
DC Resistance	$R_{\text{DC}}$	@ 20 °C	11	m $\Omega$	$\pm 30\%$
Self Resonant Frequency	$f_{\text{res}}$		159	MHz	typ.
Operating Voltage	V	DC	120	V	max.

# WHY DOES THE COMPONENT HEAT UP



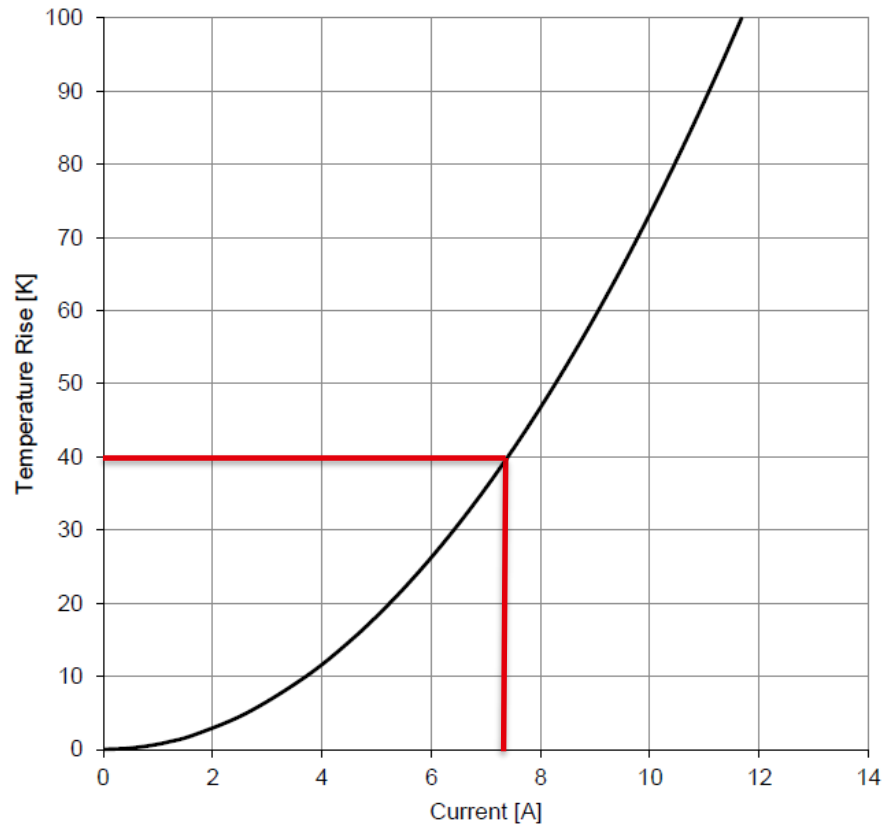
$$P_{loss} = P_{DC} + P_{AC}$$



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

# WHAT IS RATED CURRENT

Typical Temperature Rise vs. Current Characteristics:



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

**$I_R = 7,3 \text{ A} \mid \text{test condition } \Delta T = 40\text{K}$**

# MARKET SITUATION OF RATED CURRENT DEFINITION

**I<sub>rms</sub> (A)<sup>6</sup>**  
20°C rise    40°C rise

**I<sub>temp</sub> (A)typ.**  
**(ΔT=40deg.C)**

<b>Rated Current</b>	I <sub>R</sub>	ΔT = 50 K	32	A	max.
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- (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

I<sub>rms</sub> is the DC current which cause the surface temperature of the part increase less than 45°C.

<b>Rated Current (max)</b>	1.4 A (ΔL=30%, ΔT=25°C), 1.8 A (ΔL=30%, ΔT=40°C)
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DC current (A) that will cause an approximate ΔT of 40 °C

Temperature Rise .....40 °C at rated I<sub>rms</sub><sup>1</sup>

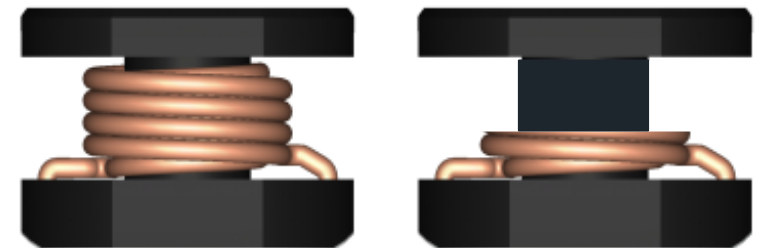
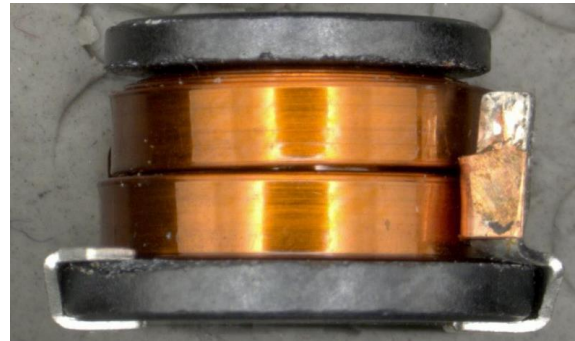
Rated Current

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.

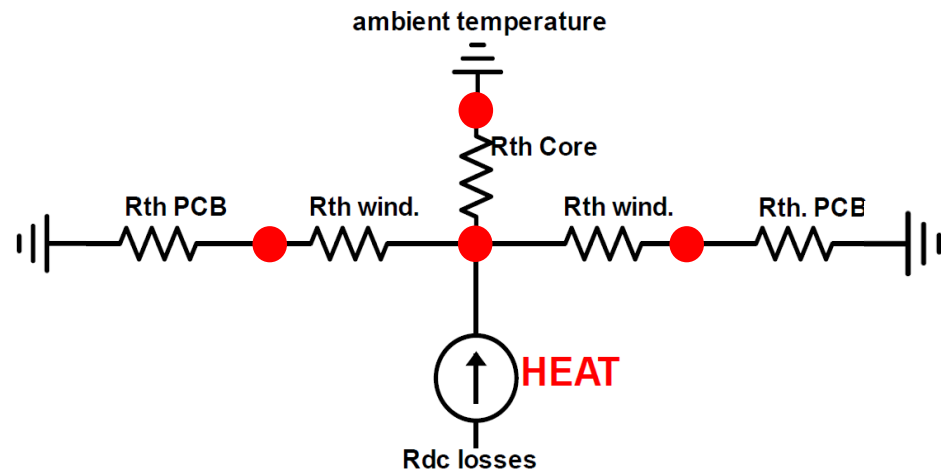
## HOW TO INCREASE THE RATED CURRENT

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

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

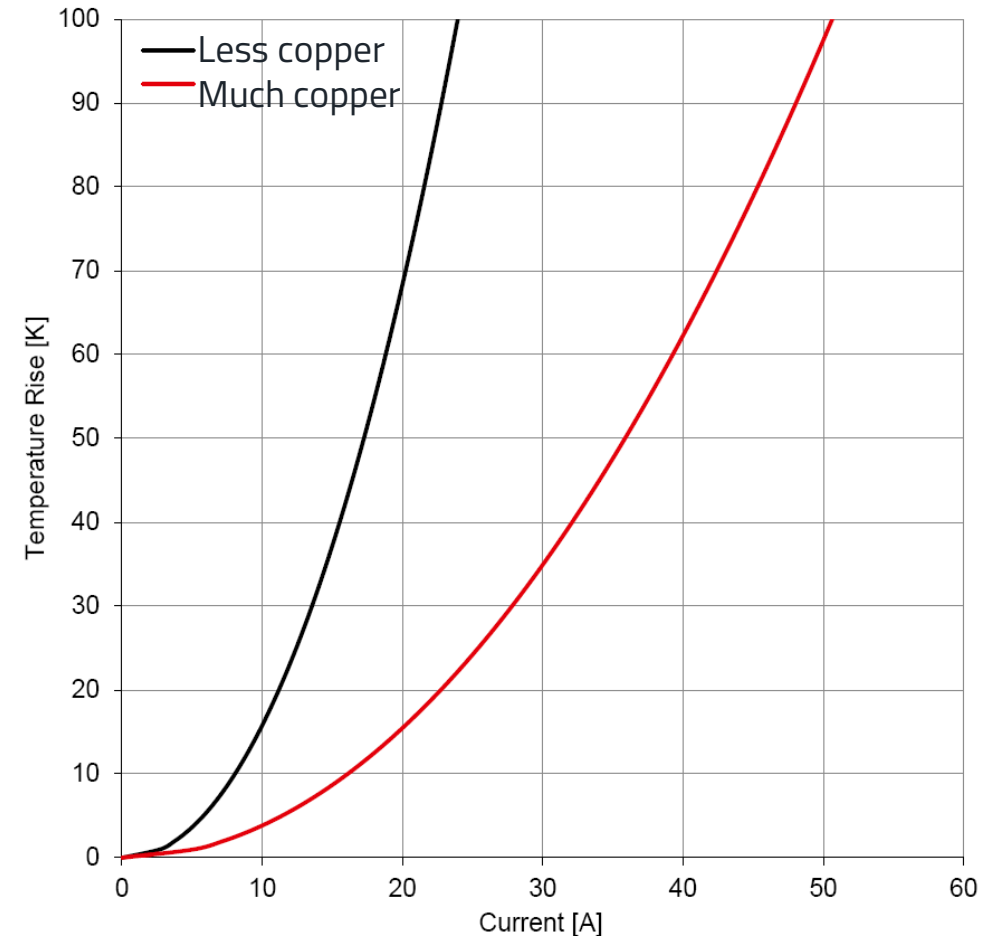
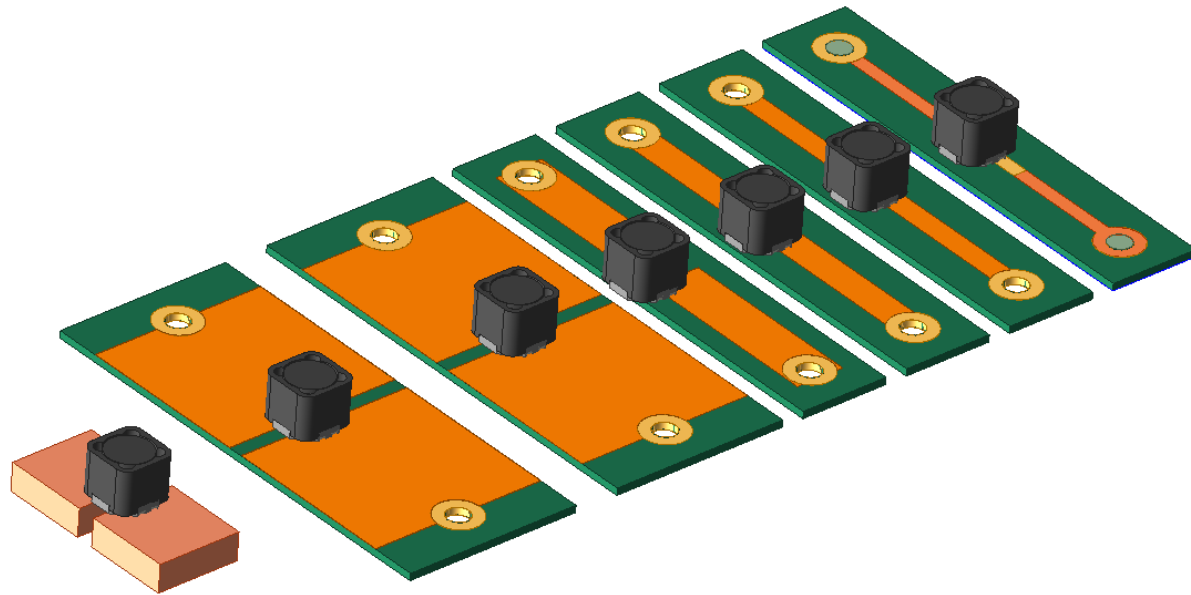


# OTHER OPTIONS NEXT TO THE RDC





# 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  $\Delta T=40^{\circ}\text{C}$  ( $T_a=25^{\circ}\text{C}$ ) Board conditions: FR4, Copper=70 $\mu\text{m}$ , 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  $I_{\text{temp,typ}}$

Current that will cause a  $\Delta 40^{\circ}\text{K}$  self-heating at room temperature

## Irms Testing

Irms testing was performed on 0.75 inch wide  $\times$  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.

<sup>1</sup>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

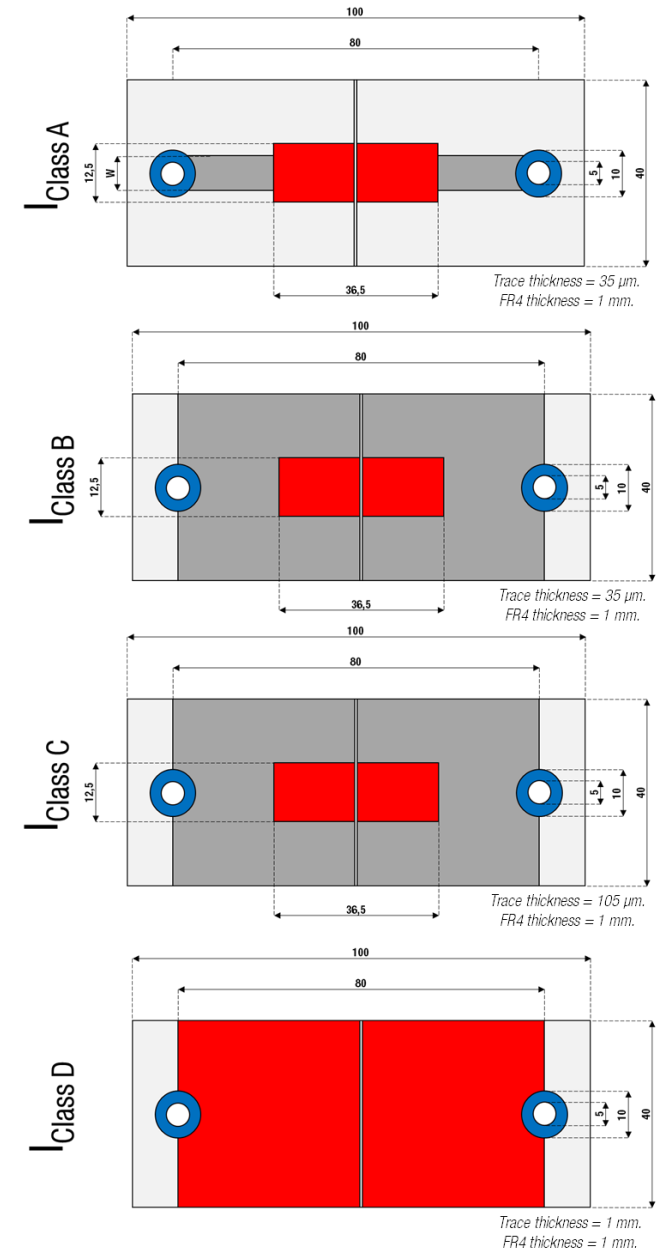
- Test setup with insufficient description
  - Many influences which can corrupt the final result
- Specified value is difficult to put in relation to the real application
  - Is a first indicator, but hard to assume if it useful for end application
  - Choosing the best component out of many is difficult because the numbers aren't comparable
- How to improve?

# IEC 62024-2:2020

## Classification Performance Rated Current

Tabelle 2 – Leiterbahnbreite und -dicke

Bemessungsstromklasse	Leiterbahnbreite $W$ mm	Leiterbahndicke $t$ $\mu\text{m}$	Beispielanwendung
$I_{\text{Klasse A}}$	$(1,0 \text{ bis } 22,0) \pm (0,2 \text{ bis } 0,5)$	$35 \pm 10$	Verbraucheranwendung (Anwendungen mit einseitigen Leiterplatten)
$I_{\text{Klasse B}}$	$40 \pm 0,2$	$35 \pm 10$	Verbraucheranwendung (Anwendungen mit doppelseitigen Leiterplatten)
$I_{\text{Klasse C}}$	$40 \pm 0,2$	$105 \pm 10$	Verbraucheranwendung (Anwendungen mit mehrlagigen Leiterplatten)
$I_{\text{Klasse D}}$	$40 \pm 0,2$	$1\ 000 \pm 50$	Anwendungen von Automobil- oder Energieversorgungsunternehmen
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	$\mu\text{H}$	$\pm 30\%$
Rated Current	$I_{R,40K}$	$\Delta T = 40 \text{ K}$	13.5	A	max.
Performance Rated Current <sup>1)</sup>	$I_{RP,40K}$	$\Delta T = 40 \text{ K}$	16.2	A	max.
Saturation Current @ 10%	$I_{SAT,10\%}$	$ \Delta L/L  < 10 \%$	21	A	typ.
Saturation Current @ 30%	$I_{SAT,30\%}$	$ \Delta L/L  < 30 \%$	27	A	typ.
DC Resistance	$R_{DC}$	@ 20 °C	4.6	m $\Omega$	typ.
DC Resistance	$R_{DC}$	@ 20 °C	7	m $\Omega$	max.
Self Resonant Frequency	$f_{res}$		45	MHz	typ.
Operating Voltage	V	DC	120	V	max.

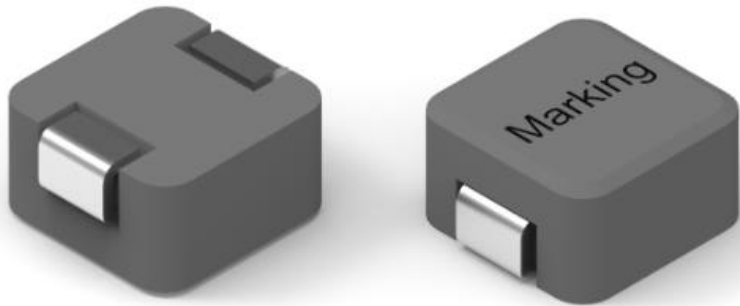
<sup>1)</sup> refer to IEC 62024-2-2020

Test conditions of Performance Rated Current: refer to IEC 62024-2-2020, Class B PCB Copper Width: 40 mm; PCB Copper Thickness: 35  $\mu\text{m}$ )

# EXAMPLE CLASS C

74437377010

- WE-LHMI



## Electrical Properties:

Properties		Test conditions	Value	Unit	Tol.
Inductance	L	100 kHz/ 10 mA	1	$\mu$ H	$\pm 20\%$
Rated Current	$I_{R,40K}$	$\Delta T = 40$ K	15	A	max.
Performance Rated Current <sup>1)</sup>	$I_{RP,40K}$	$\Delta T = 40$ 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	m $\Omega$	typ.
DC Resistance	$R_{DC}$	@ 20 °C	3.5	m $\Omega$	max.
Self Resonant Frequency	$f_{res}$		41	MHz	typ.

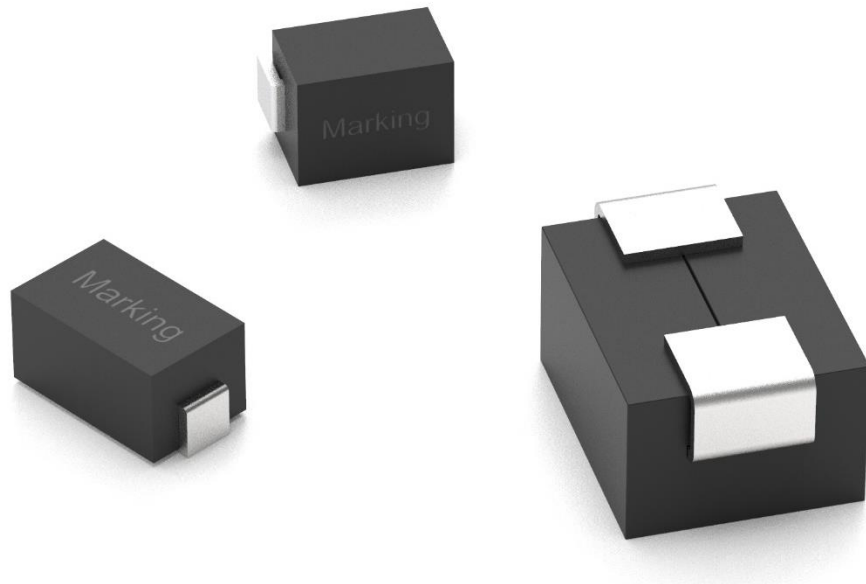
<sup>1)</sup> refer to IEC 62024-2-2020

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

# 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 <sup>1)</sup>	$I_{RP,40K}$	$\Delta T = 40 K$	63.9	A	max.
Saturation Current @ 10%	$I_{SAT,10\%}$	$ \Delta L/L  < 10 \%$	44.5	A	typ.
Saturation Current @ 30%	$I_{SAT,30\%}$	$ \Delta L/L  < 30 \%$	51.5	A	typ.
DC Resistance	$R_{DC}$	@ 20 °C	0.325	mΩ	±7%
Self Resonant Frequency	$f_{res}$		110	MHz	typ.

<sup>1)</sup> refer to IEC 62024-2-2020

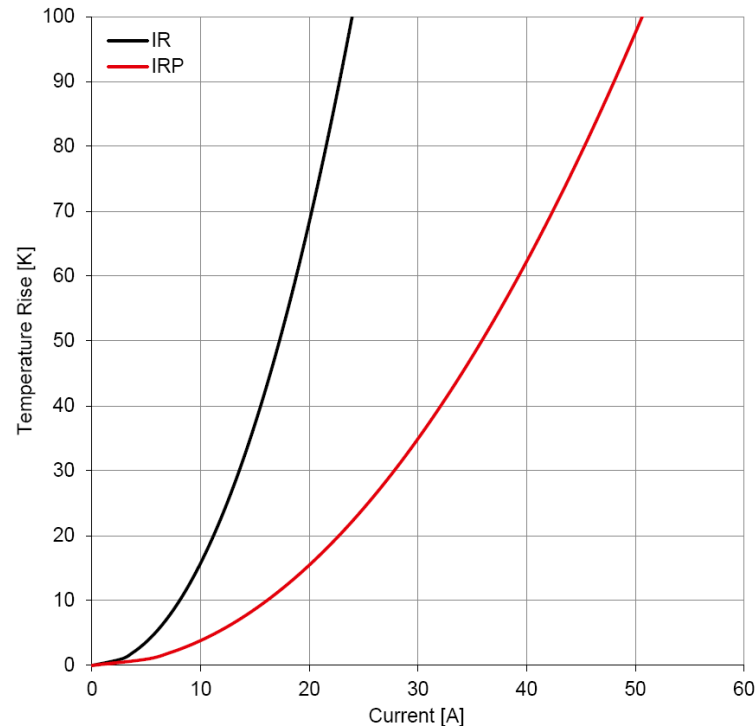
Test conditions of Performance Rated Current: refer to IEC 62024-2 Class D (PCB Copper Width: 40 mm; PCB Copper Thickness: 1000 μm)



# 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	$I_R$	$\Delta T = 40$ K	16	A	max.
Performance Rated Current <sup>1)</sup>	$I_{RP,40K}$	$\Delta T = 40$ K	32.05	A	max.
Saturation Current @ 10%	$I_{SAT,10\%}$	$ \Delta L/L  < 10\%$	15.65	A	typ.
Saturation Current @ 30%	$I_{SAT,30\%}$	$ \Delta L/L  < 30\%$	32.1	A	typ.
DC Resistance	$R_{DC}$	@ 20 °C	2.2	mΩ	±10%
Self Resonant Frequency	$f_{res}$		28	MHz	typ.

<sup>1)</sup> 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

The screenshot displays the REDEXPERT Power Inductors software interface. On the left, a sidebar titled 'Rated Current Calculator' is highlighted with a red box. It features a 3D model of an inductor on a PCB, a 'Temperature' section with input fields for 'Ambient Temperature' (20 °C) and 'Component Temperature' (50 °C), and a 'CALCULATE RATED CURRENT' button. Below this are input fields for 'Length (L)' (8 mm), 'Width (W)' (2 mm), and 'Copper Thickness (t)' (35 μm), with a 'CALCULATE CURRENT' button.

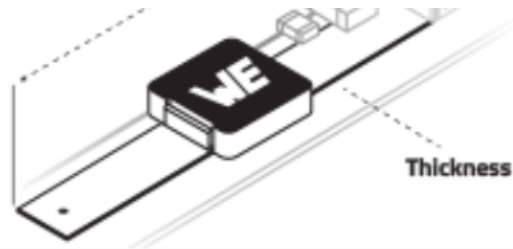
The main area shows a table of inductor specifications. The table has columns for Order Code, Series, Size, Turns, Type, L<sub>DC</sub>, R<sub>DC</sub>, I<sub>DC</sub>, I<sub>CR</sub>, I<sub>CR</sub>, L<sub>AC</sub>, L<sub>AC</sub>, W, H<sub>max</sub>, T<sub>max</sub>, Shielded, AEC-Q, and Automotive. The first row is highlighted in red.

Order Code	Series	Size	Turns	Type	L <sub>DC</sub>	R <sub>DC</sub>	I <sub>DC</sub>	I <sub>CR</sub>	I <sub>CR</sub>	L <sub>AC</sub>	L <sub>AC</sub>	W	H <sub>max</sub>	T <sub>max</sub>	Shielded	AEC-Q	Automotive
34430213047	WE-MAP1	1610	Single	470 nH	77.0 mΩ	2.50 A	1.81 A	3.60 A	200 MHz	1.60 mm	1.60 mm	1.00 mm	125 °C	Shielded	X	X	M
34430213056	WE-MAP1	1610	Single	560 nH	90.0 mΩ	2.70 A	1.96 A	3.20 A	150 MHz	1.60 mm	1.60 mm	1.00 mm	125 °C	Shielded	X	X	M
34430213068	WE-MAP1	1610	Single	680 nH	101 mΩ	2.55 A	1.56 A	4.80 A	120 MHz	1.60 mm	1.60 mm	1.00 mm	125 °C	Shielded	X	X	M
34430213080	WE-MAP1	1610	Single	820 nH	115 mΩ	2.35 A	1.81 A	4.60 A	110 MHz	1.60 mm	1.60 mm	1.00 mm	125 °C	Shielded	X	X	M
34430213090	WE-MAP1	1610	Single	1.00 μH	127 mΩ	2.20 A	1.57 A	4.25 A	111 MHz	1.60 mm	1.60 mm	1.00 mm	125 °C	Shielded	X	X	M
34430213092	WE-MAP1	1610	Single	1.20 μH	140 mΩ	2.10 A	1.30 A	4.10 A	109 MHz	1.60 mm	1.60 mm	1.00 mm	125 °C	Shielded	X	X	M
34430213095	WE-MAP1	1610	Single	1.50 μH	189 mΩ	1.80 A	1.10 A	3.45 A	90.0 MHz	1.60 mm	1.60 mm	1.00 mm	125 °C	Shielded	X	X	M
34430213022	WE-MAP1	1610	Single	2.20 μH	357 mΩ	1.25 A	800 mA	2.25 A	70.0 MHz	1.60 mm	1.60 mm	1.00 mm	125 °C	Shielded	X	X	M

At the bottom, three graphs are displayed: 'Inductance / DC Current (Ambient Temperature)' showing inductance decreasing from ~500 nH to ~250 nH as current increases from 0.4 A to 7.0 A; 'Temperature Rise / DC Current' showing temperature rise increasing from 0 °C to ~100 °C as current increases from 0.4 A to 7.0 A; and 'Impedance / Frequency' showing impedance increasing from ~100 mΩ at 10 kHz to ~1.0 Ω at 100 MHz.

# REDEXPERT

Simulation Tool for specific PCB Design



Temperature

Ambient Temperature

Component Temperature

CALCULATE RATED CURRENT

Length (L)

Width (W)

Copper Thickness (H)

**CALCULATE CURRENT**

## 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** Power Inductors

Filters: Type = Single, Single HV |  $5.50 \mu\text{H} \leq L @ 2.00 \text{ A} \leq 10.2 \mu\text{H}$  |  $I_{\text{sat}} \geq 2.40 \text{ A}$  |  $I_r \geq 2.01 \text{ A}$  |  $V_p \geq 12.0 \text{ V}$  |  $\Delta T_{\text{TOT}} \leq 80.0 \text{ K}$

Order Code	Series	Size	Automotive	Spec	Type	$L_0$	$L @ 2.00 \text{ A}$	$R_{\text{DC,TP}}$	$\Delta L_L$	$I_r$	$I_{\text{sat}}$	$f_{\text{res}}$	$P_{\text{AC,L}}$	$P_{\text{DC,L}}$	$P_{\text{TOT,L}}$	$\Delta T_{\text{TOT}}$	L	W
74438336068	WE-MAPI	3020	x	20	Single	6.80 $\mu\text{H}$	6.03 $\mu\text{H}$	168 m $\Omega$		2.15 A	3.65 A	22.0 MHz					3.00 mm	3.4
74438357068	WE-MAPI	4030	x	20	Single	6.80 $\mu\text{H}$	6.49 $\mu\text{H}$	69.4 m $\Omega$		3.75 A	7.20 A	19.5 MHz					4.10 mm	4.1
74438357082	WE-MAPI	4030	x	20	Single	8.20 $\mu\text{H}$	7.79 $\mu\text{H}$	81.0 m $\Omega$		3.45 A	6.80 A	17.0 MHz					4.10 mm	4.1
74438357100	WE-MAPI	4030	x	20	Single	10.0 $\mu\text{H}$	9.43 $\mu\text{H}$	101 m $\Omega$		3.05 A	5.95 A	15.0 MHz					4.10 mm	4.1
74438367082	WE-MAPI	5030	x	20	Single	8.20 $\mu\text{H}$	7.82 $\mu\text{H}$	50.0 m $\Omega$		4.85 A	6.60 A	13.0 MHz					5.40 mm	5.4
7440650068	WE-TPC	1028	x	20	Single	6.80 $\mu\text{H}$	6.57 $\mu\text{H}$	25.0 m $\Omega$		4.20 A	3.60 A	30.0 MHz					10.0 mm	10
7440650082	WE-TPC	1028	x	20	Single	8.20 $\mu\text{H}$	7.67 $\mu\text{H}$	28.5 m $\Omega$		3.80 A	2.80 A	28.0 MHz					10.0 mm	10
744065100	WE-TPC	1028	x	20	Single	10.0 $\mu\text{H}$	9.29 $\mu\text{H}$	40.0 m $\Omega$		3.00 A	2.50 A	25.0 MHz					10.0 mm	10
7440660062	WE-TPC	1038	x	20	Single	6.20 $\mu\text{H}$	6.09 $\mu\text{H}$	20.0 m $\Omega$		5.00 A	4.50 A	25.0 MHz					10.0 mm	10
744066100	WE-TPC	1038	x	20	Single	10.0 $\mu\text{H}$	9.70 $\mu\text{H}$	27.0 m $\Omega$		3.90 A	4.00 A	20.0 MHz					10.0 mm	10

Click and type or drop an Order Code here

Show Panel: L vs. I(T) | K vs. I(T)

**Buck Converter**

PARAMETERS

Topology  
 Sync  
 Non Sync

Input  
 $V_{\text{min}}$  10 V |  $V_{\text{max}}$  12 V

Output  
 $V_{\text{out}}$  5 V |  $I_{\text{out}}$  2 A

Switch  
 $f_{\text{sw}}$  500 kHz

Inductor  
 $\Delta L_L$  40% | Show Suitable

Diode  
 $V_f$  0.7 V

UPDATE | DETAILS

**Inductance / DC Current (Ambient Temperature)**

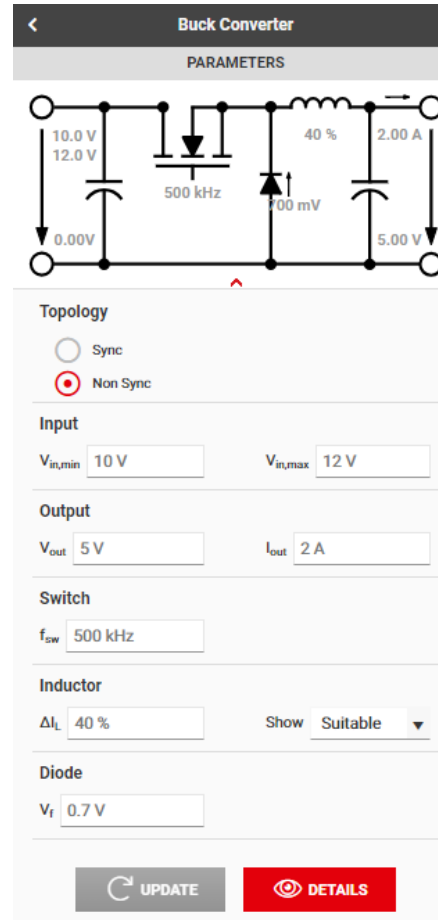
T = 20°C

**Temperature Rise / DC Current (Ambient Temperature)**

T = 20°C

# REDEXPERT

## Simulation of AC Losses



## CONCLUSION DEFINITION OF PERFORMANCE 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!