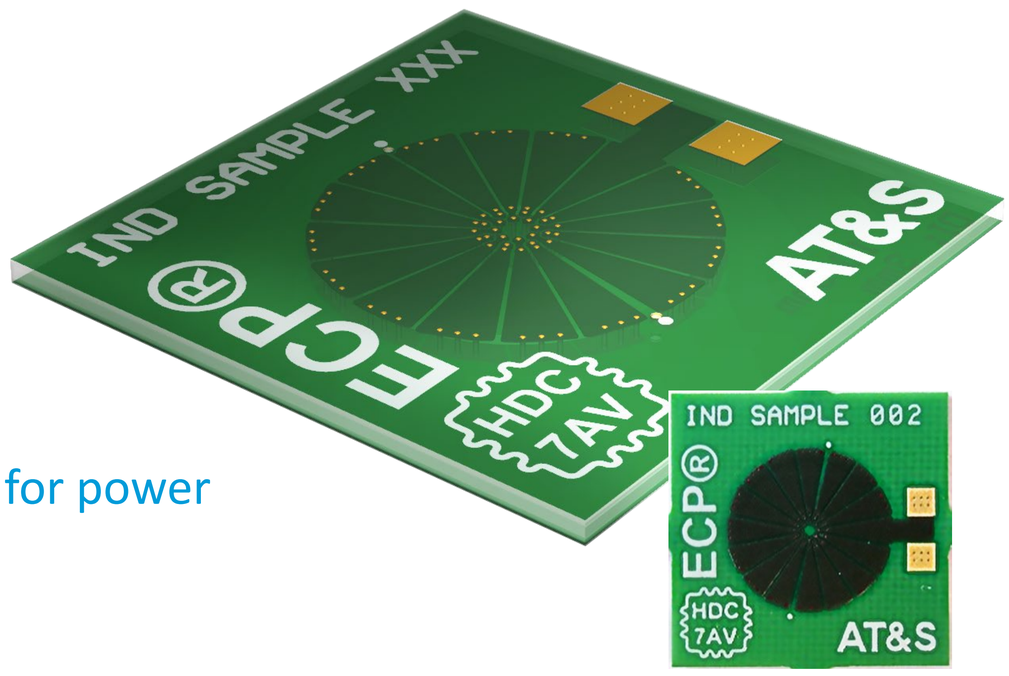
Calculation, Simulation and Production of PCB-integrated Inductors with Focus on Fringing Effect

Gerald Weis, Ivan Salkovic



INTRODUCTION AND AIM

Demonstrators of ultra-thin PCB based inductors for power applications compared in terms of:

- Fringing effect
- Thermal performance
- Electrical characteristics

01 THEORETICAL

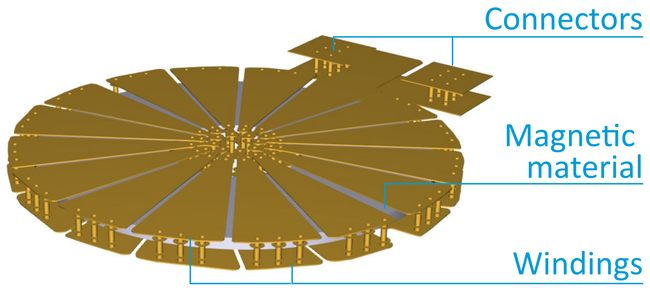
Fringing effect based on modified McLyman formula to get a stable L vs. I characteristics while reducing EMI.

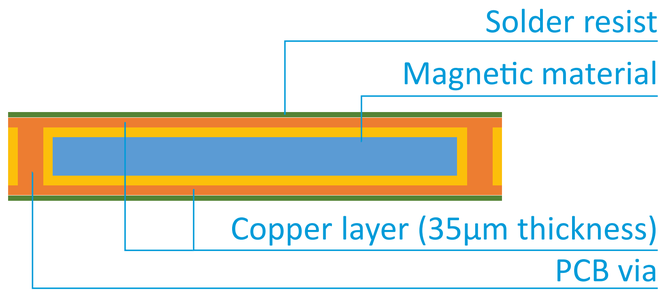
$$F = 1 + \frac{l_g}{N_g\sqrt{A_e}} ln\left(\frac{2W}{l_g}\right)$$

$$L = \frac{N^2}{R_{Fe} + R_g} = \frac{N^2}{\frac{l_e - l_g}{\mu_0 \times \mu_R \times A_e} + \frac{l_g}{\mu_0 \times F \times A_e}}$$

02 CONSTRUCTION

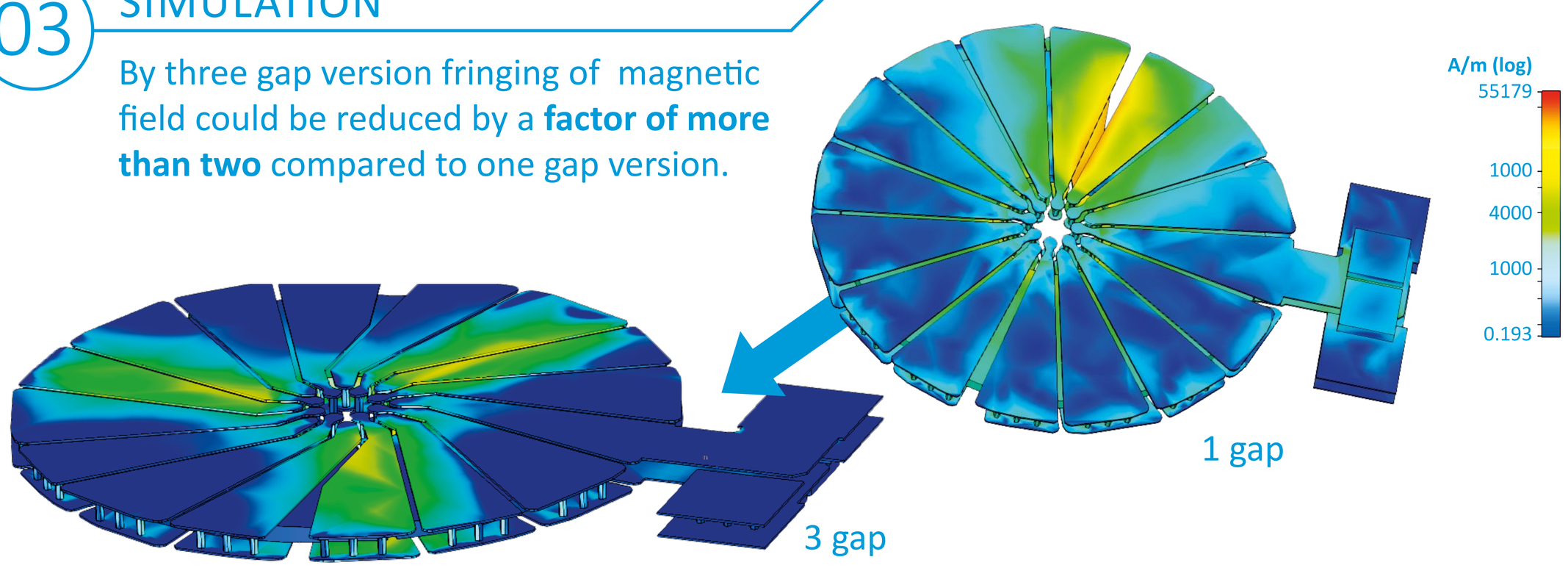
- Planar concept based on PCB technology
- PCB-laminated magnetic sheet
- High flexibility in core shape design
- Height of magnetic material: 300 µm





03 SIMULATION

By three gap version fringing of magnetic field could be reduced by a **factor of more than two** compared to one gap version.



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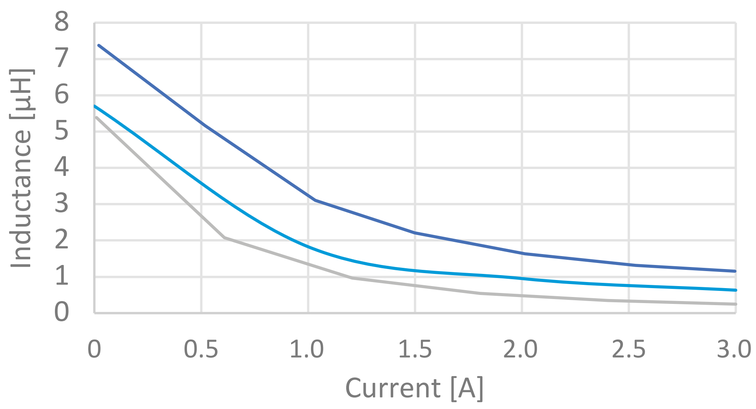
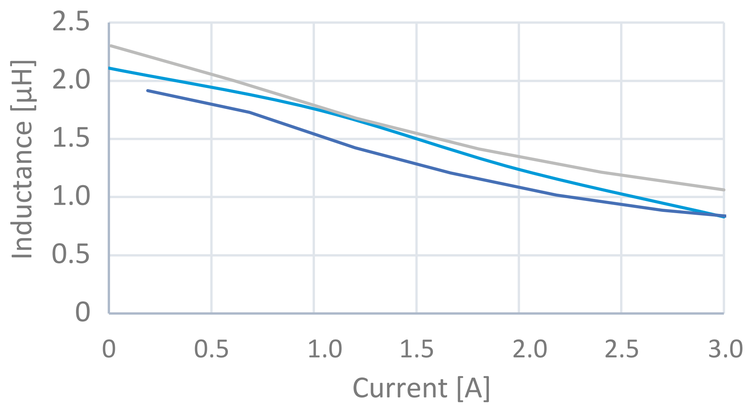
04 RESULTS

Measured
Simulated
Calculated

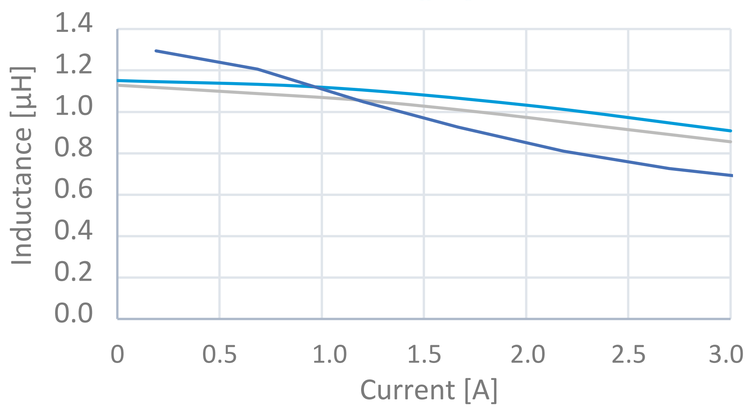
Without air gap



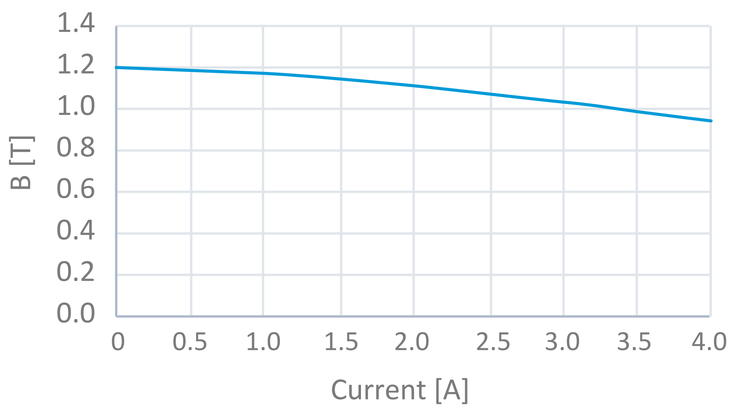
With one air gap



With three air gaps



Standard SMT *(2)*



05 PROPERTIES

	Symbol	Without air gap	With one air gap	With three air gaps	Standard SMT *(2)*
Inductance	L (@ 1 MHz)	5.7 µH	2.2 µH	1.15 µH	1.2 µH
Saturation current	I_{SAT} *(1)*	300 mA	1.5 A	3.6 A	3.8 A
Rated current (DC)	I_R (@ ΔT = 40 K)		2.0 A		1.9 A
DC Resistance	R_{DC} (@ 0.1 A)		79 mΩ		82 mΩ
Self-resonance frequency	f_{res}	30 MHz	40 MHz	80 MHz	75 MHz
Package size	DI/DO		3/10.5 mm		2.5 x 2 mm
Air gap length	l_g	-	500 µm	3 x 170 µm	-
Total thickness	h		500 µm		1 mm

(1) Inductance drops 30% at I_{SAT} *(2) Würth Electronics (74438323012)*

CONCLUSION

- PCB-based production offers customizable solutions
- FEM simulation is needed to predict inductor properties
- Thinner solution in comparison to standard components
- Decreased proximity effects
- PCB-based inductors help to minimize power electronic systems
- Technology can be used for inductors and transformers