THE FUTURE OF POWER INDUCTORS: MINIMAL LOSSES AND COMPACT DESIGNS

Theo Ritzmann – Technical Lead PM Passive Power

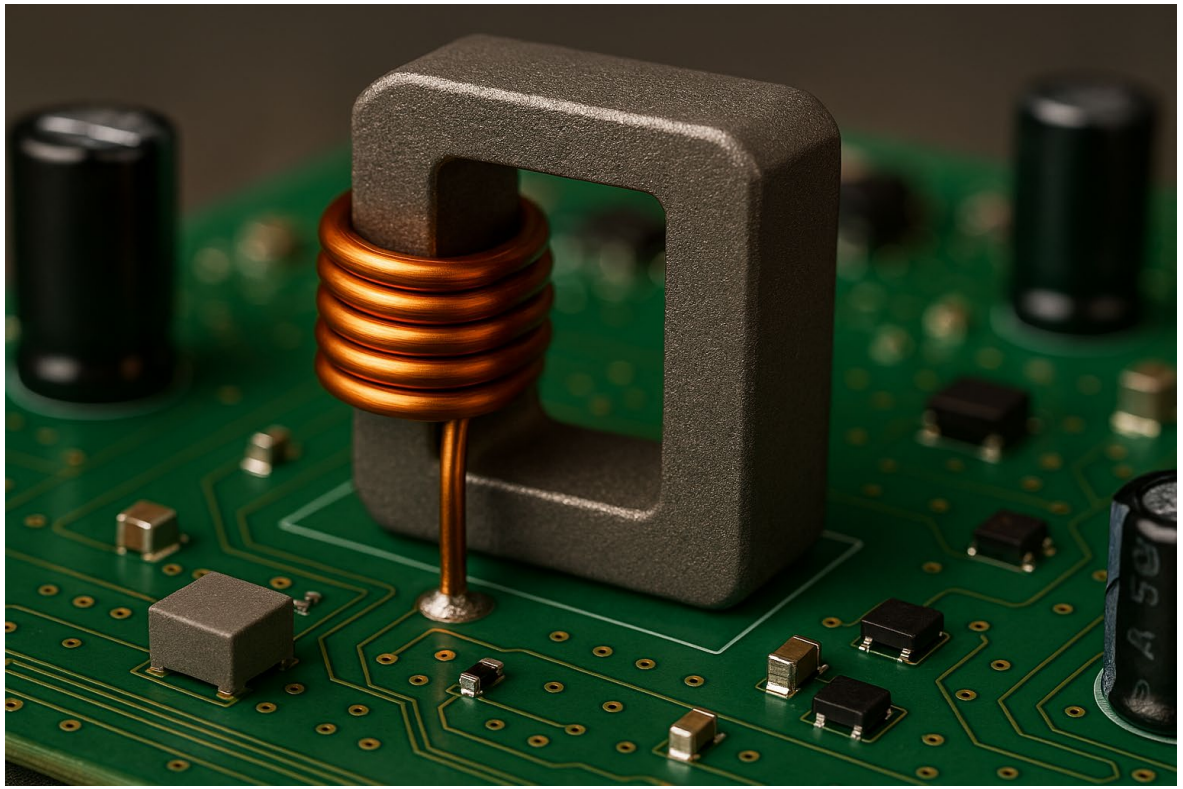
WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

AGENDA

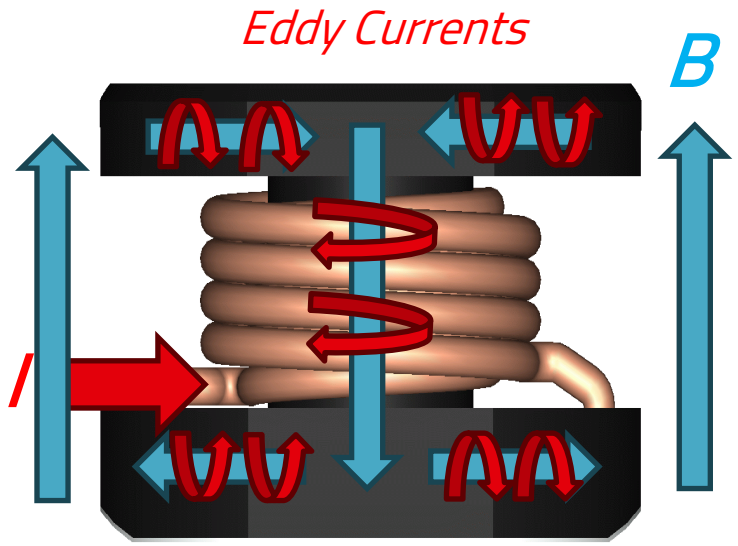
- Early 20th century
  - Inductors based on massive iron cores
- 1970s / 1980s
  - Inductors based on ferrites
- 1990s / 2000s
  - Inductors based on iron/alloy powders
- Present / Future Trends
  - Inductors based on …

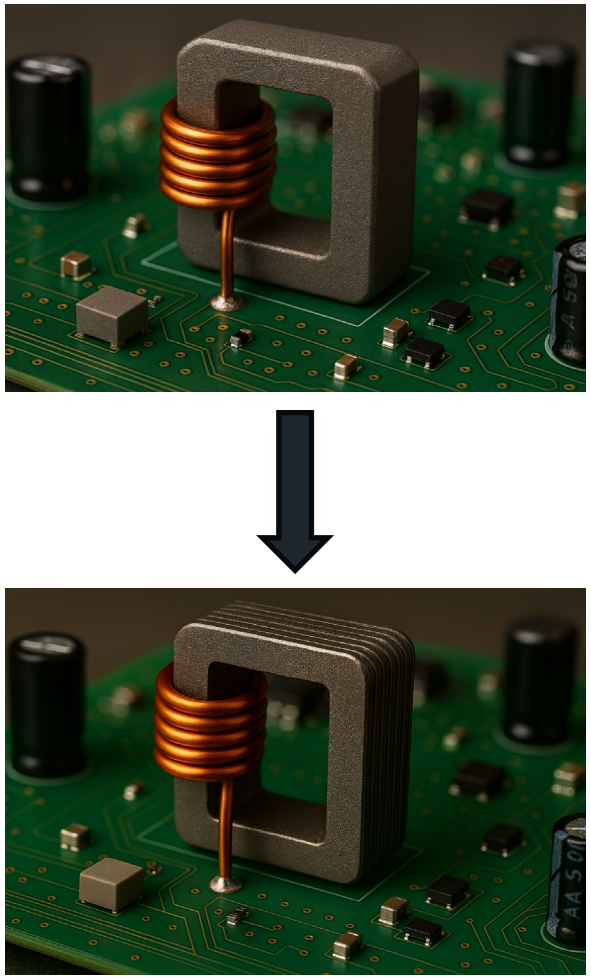
EARLY 20TH CENTURY

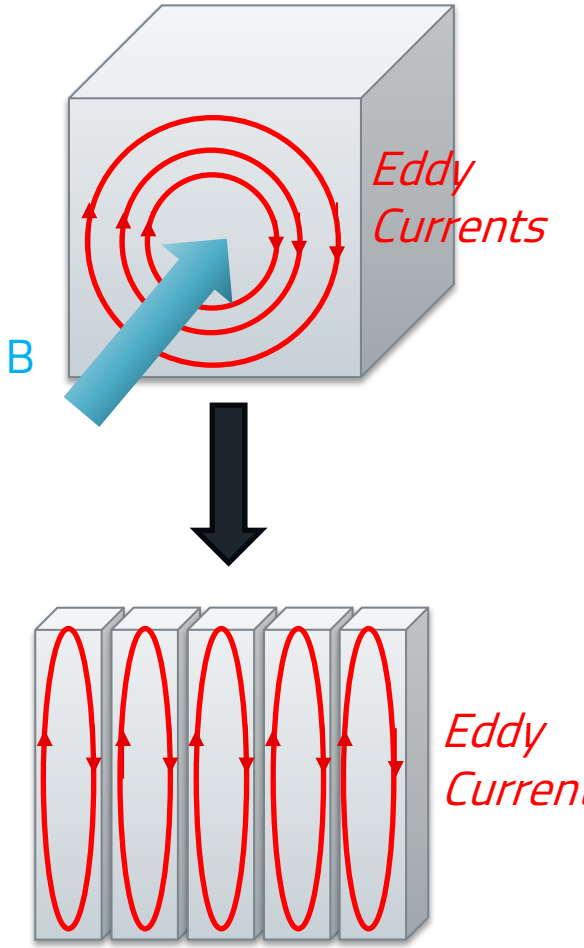
- Applications in the low frequency range up to single digit kHz
- Inductors based on massive iron cores
- Advantages of these cores
  - High permeability and saturation flux density
- Disadvantages of these cores
  - Electrically conductive



EDDY CURRENTS AND PREVENTION

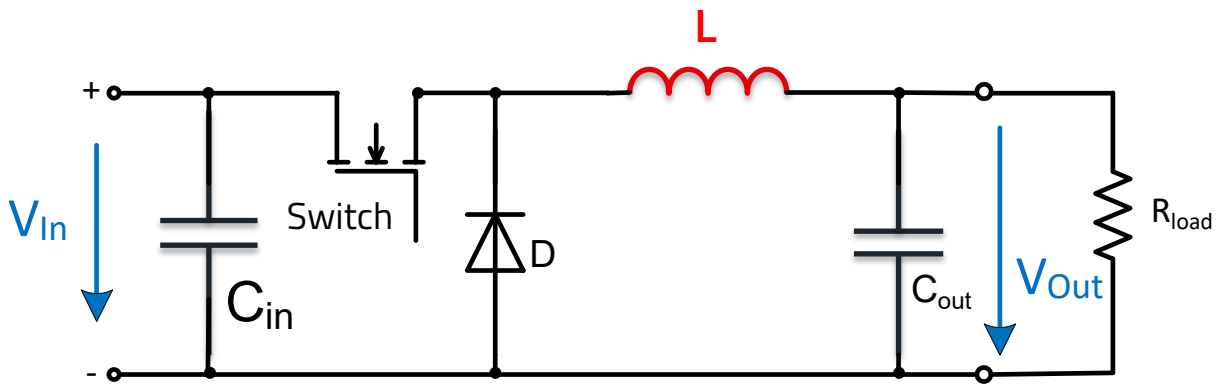






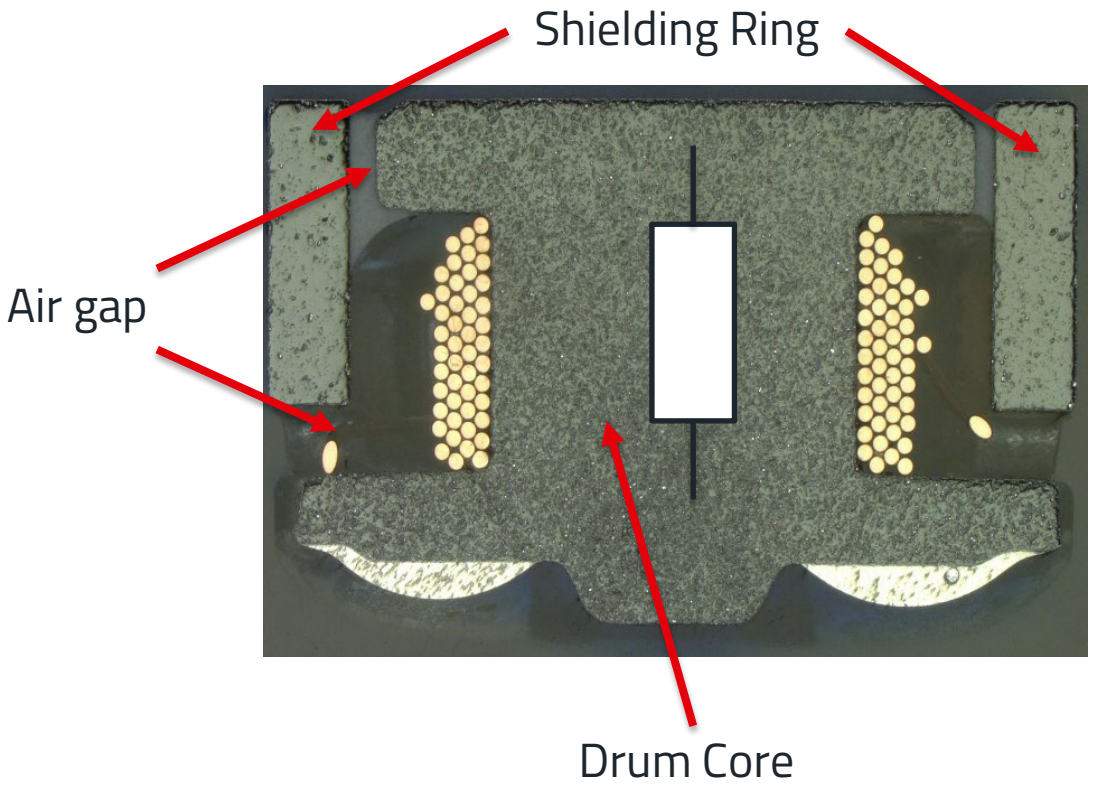
1970S / 1980S

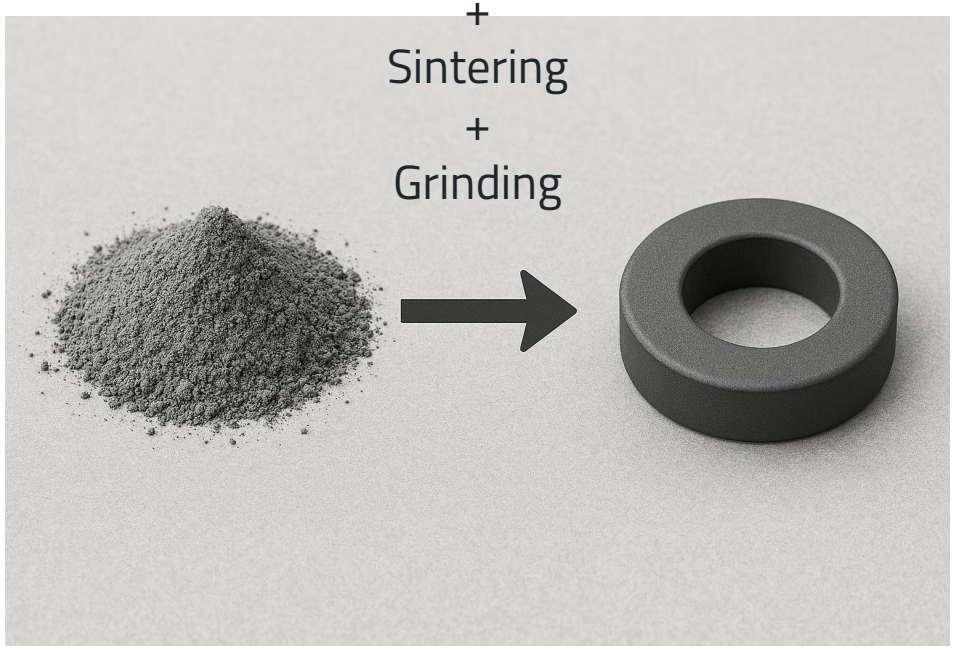
- Switch mode power supplies based on semiconductor technology
- frequency range from double digit to triple digit kHz
- Need for lower AC losses
- Ferrite power inductors
- Also popular material for EMC inductors



FERRITE BASED POWER INDUCTORS

Material & Design

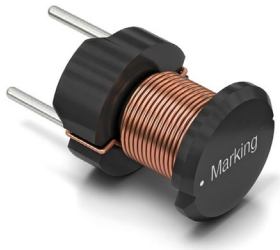




FERRITE BASED POWER INDUCTORS

Products

WE-TI

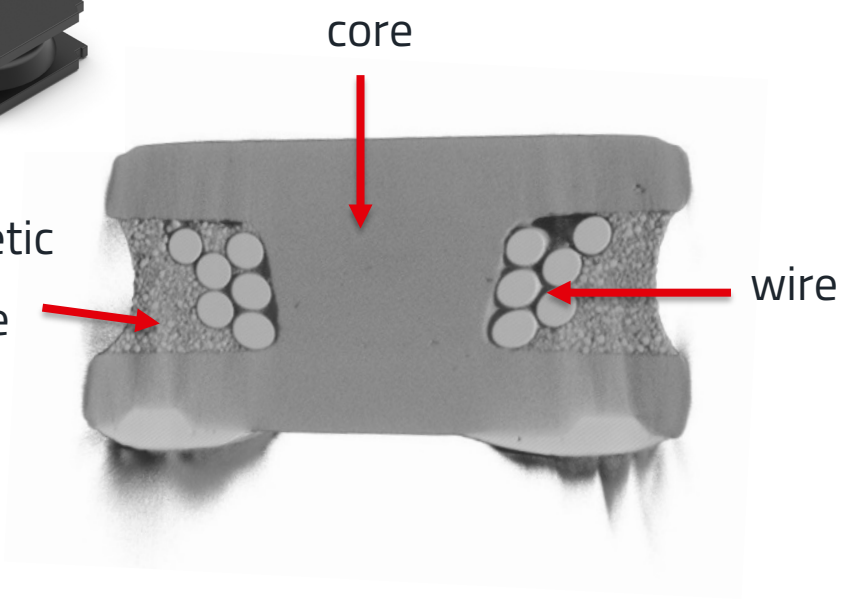


WE-PD2

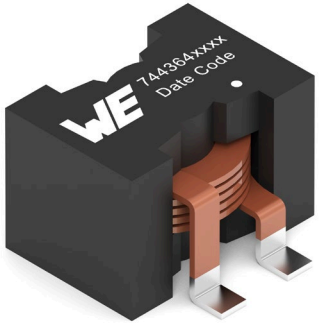
WE-TPC

WE-PD

WE-LQS



WE-HCF

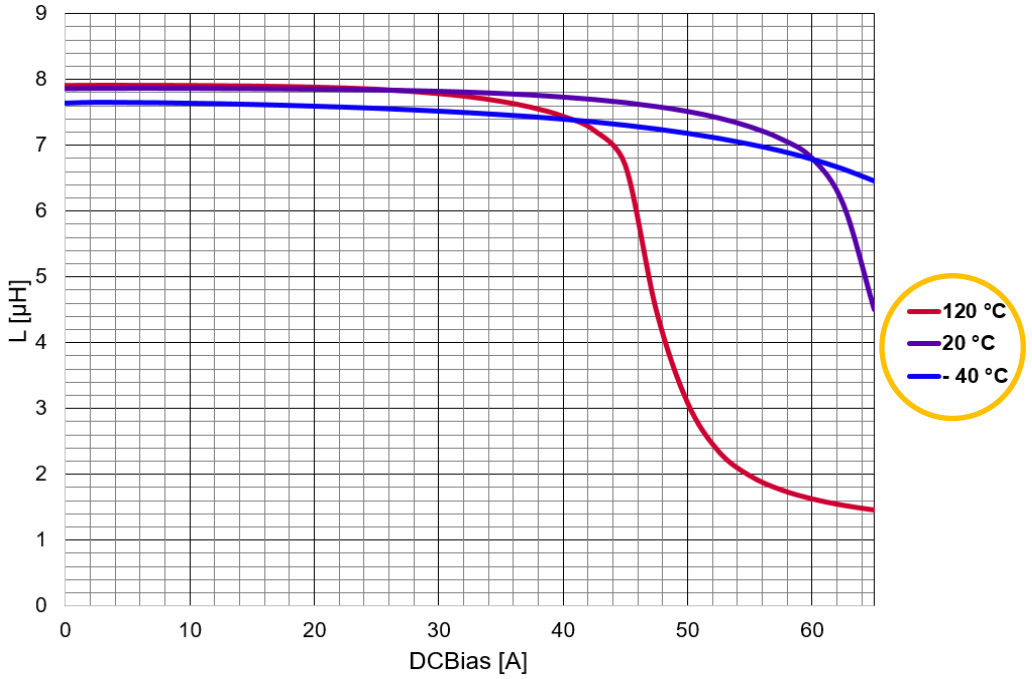


WE-HCFT

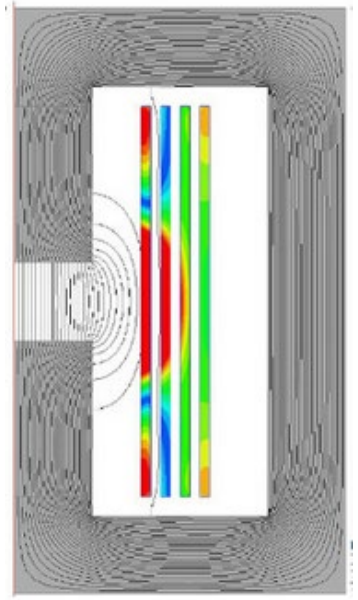
FERRITE BASED POWER INDUCTORS

Disadvantages

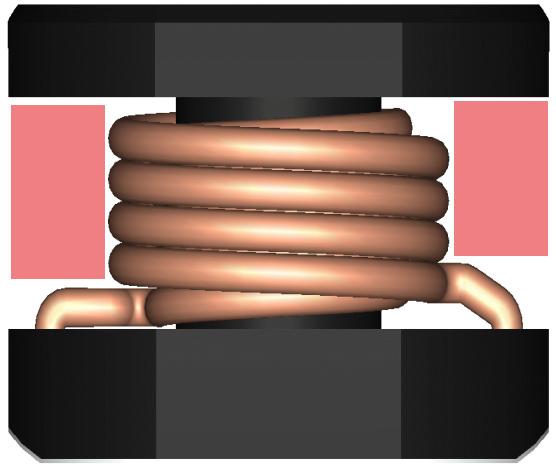
Temperature dependancy



Leakage

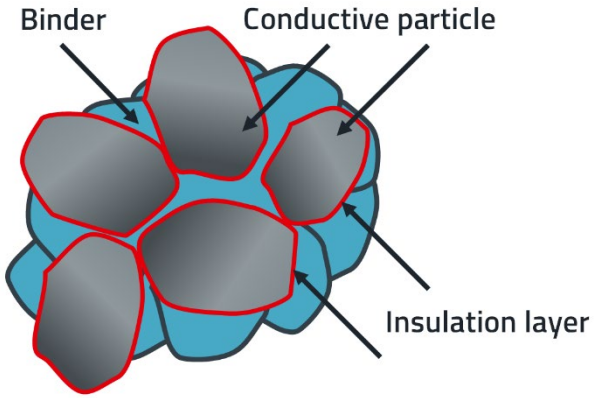


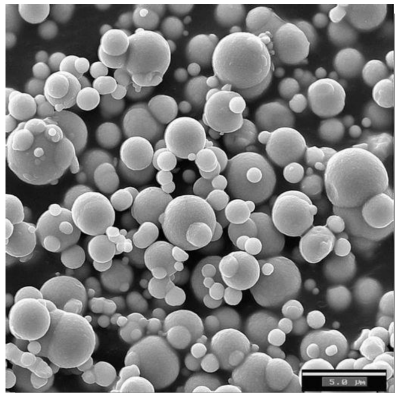
Space utilisation



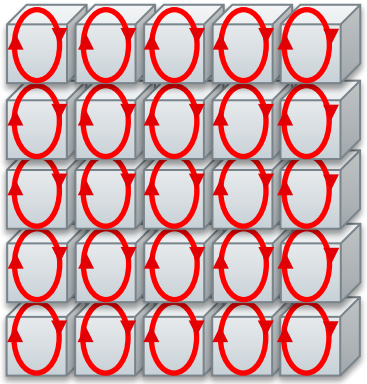
1990S / 2000S

- Frequency range from triple digit kHz up to lower MHz
- Need for more efficient low inductance value products
- Use of iron again, but in powder form
- Same material advantages like massive iron cores, but less eddy currents





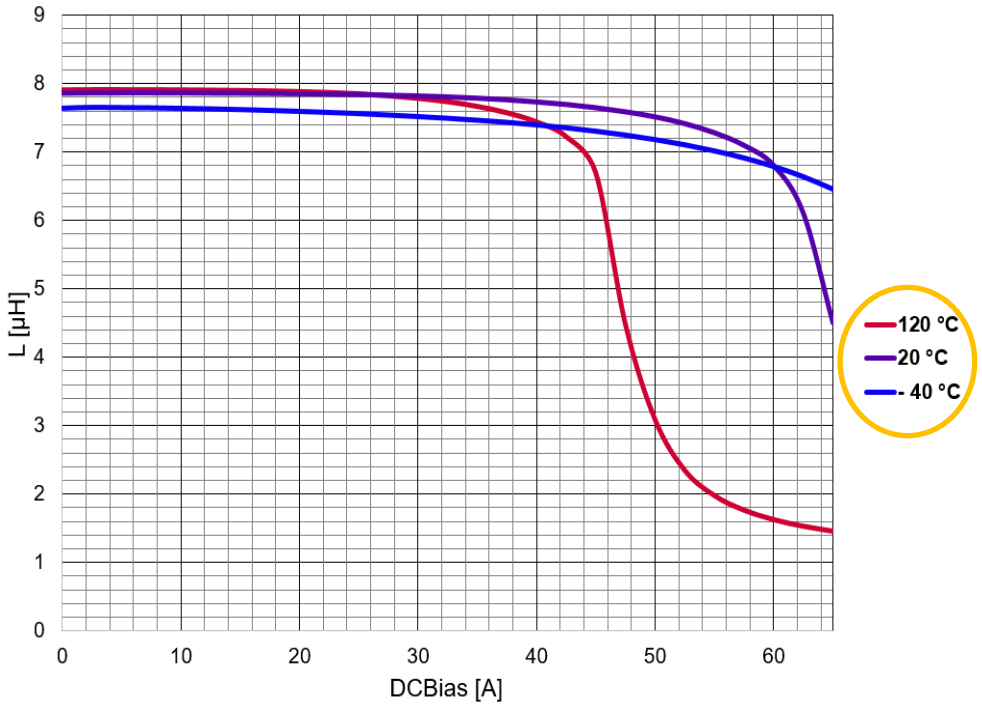
Iron Powder Particles
- BASF Website



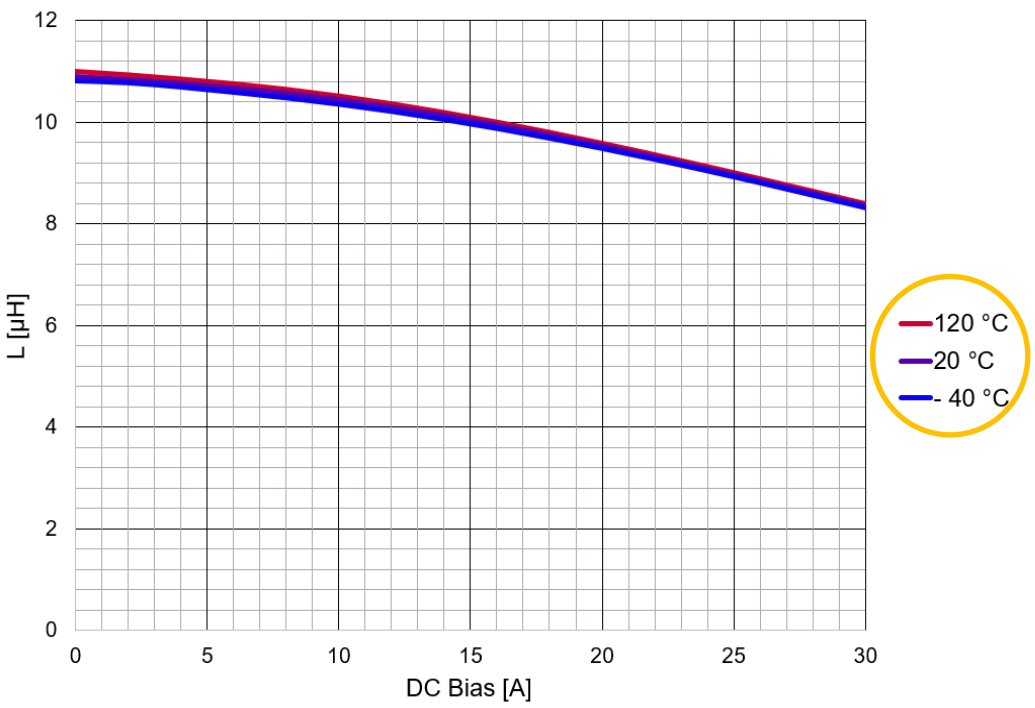
Eddy Currents

SATURATION BEHAVIOR

Ferrite



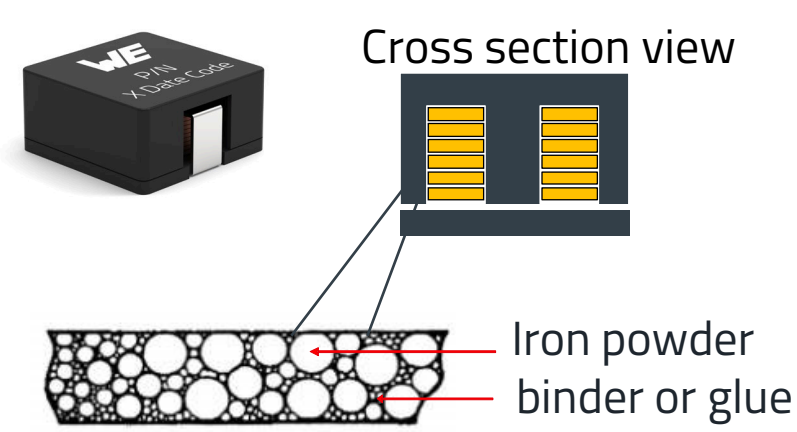
Iron powder



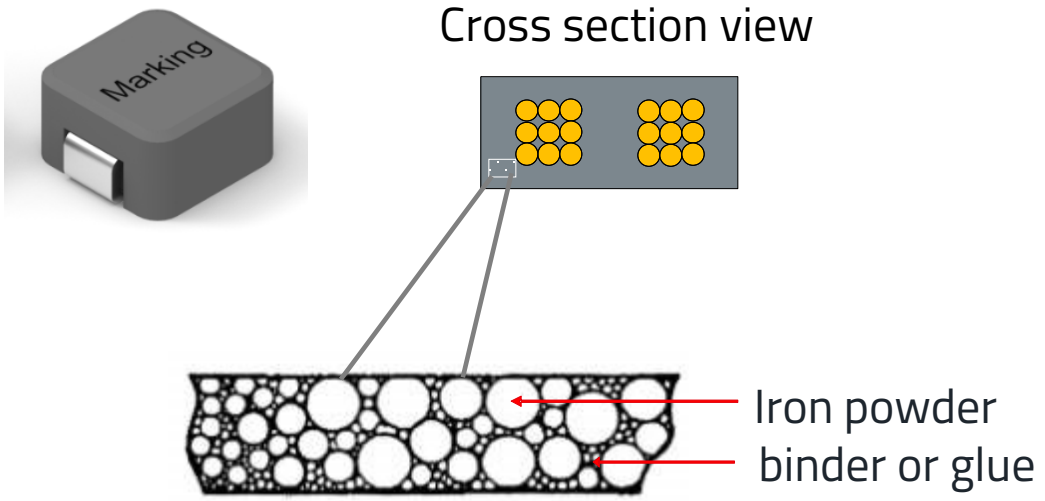
POWDER BASED POWER INDUCTORS

Designs

Assembly products
WE-HCI



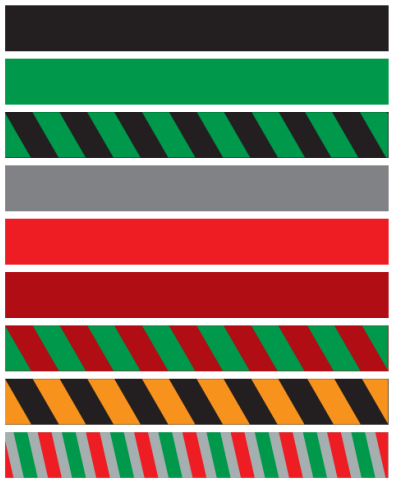
Molding products
WE-LHMI



POWDER BASED POWER INDUCTORS

Materials

- Further requirements on efficiency, current capability and reliability
- Alloys of Iron with Si, Cr, Ni or Al are popular in the market
- Enhanced powder structures known as amorphous or nanocrystalline



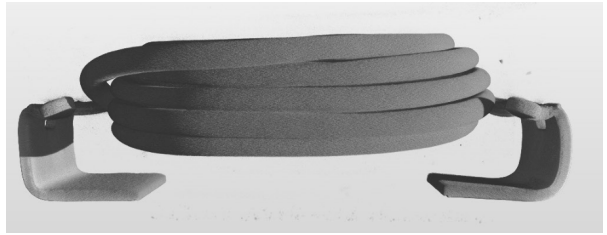
Iron Powder (Fe)
Nickel-Zinc (NiZn)
Superflux
Metal Alloy
WE-PERM®
Manganese-Zinc (MnZn)
Nickel-Zinc / Manganese-Zinc (NiZn / MnZn)
Hyperflux®
Nickel-Zinc / Manganese-Zinc / Metal Alloy (NiZn / MnZn / Metal Alloy)

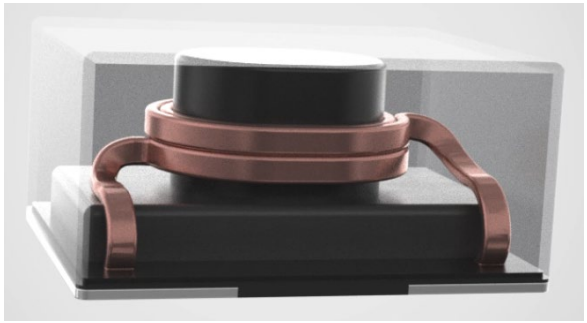
® Registered European Trademark

POWDER BASED POWER INDUCTORS

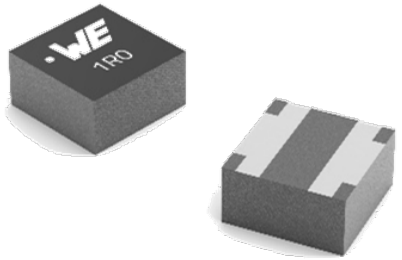
Further optimizations

- Leadframeless designs for better space utilisation
  - E.g. WE-XHMI, WE-PMCI or WE-MAPI
- Mixture of assembly and molding
  - E.g. WE-PMFI
- Production process adjustments for performance improvement
  - E.g. Molding under temperature



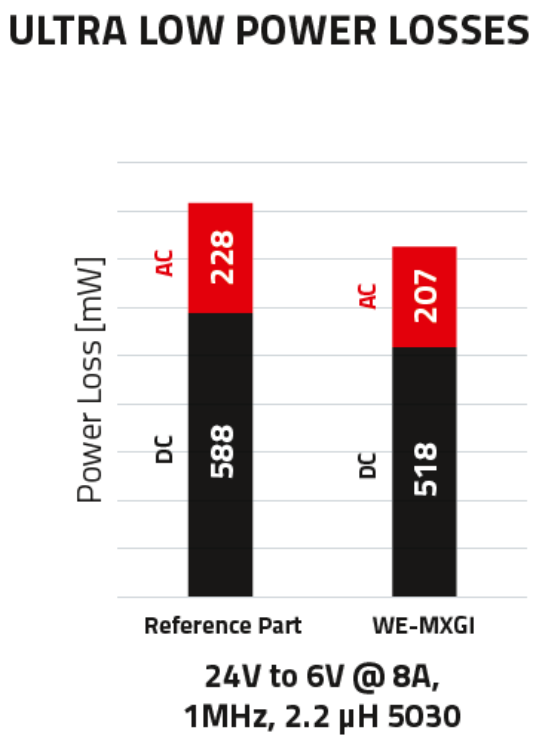


WE-MXGI



- Innovative and high performing product, combining all the mentioned trends in material, design and production technology

- Nanocrystalline core material
- Leadframeless design
- Extremely high power density
- Ultra low RDC values and AC losses
- Optimized for high switching frequencies beyond 1 MHz



FUTURE TRENDS

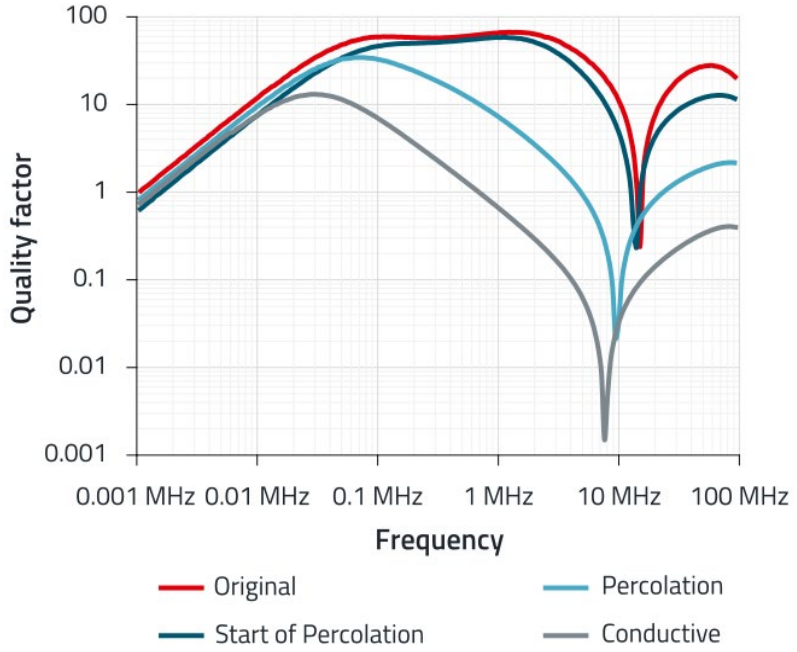
Limitations with current technologies are…

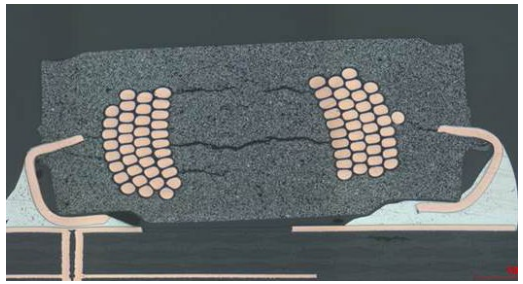
1. Rough operating conditions
   Percolation phenomenon caused by binding and insulation materials

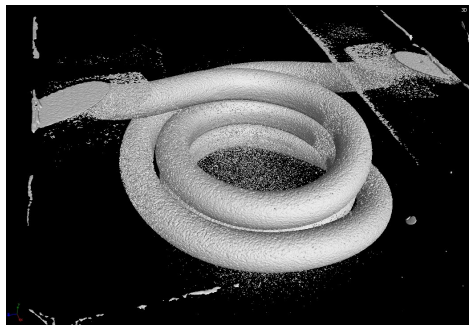
2. Reliability
   Internal damage or cracks caused by molding process pressure

3. Lower inductance values
   Bad power density caused by poor space utilisation

4. Miniaturisation
   Very small structures can’t be molded







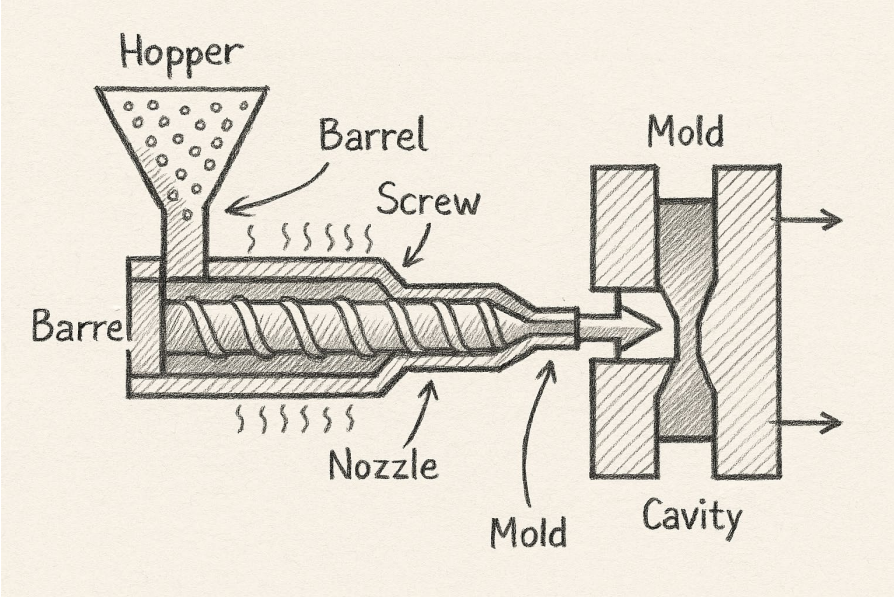
PLASTIC BASED POWER INDUCTORS

- To avoid percolation the binding and insulation materials need to change
- Can be adressed by switching to inorganic binding and insulation materials
- Using plastics instead of binders, is an approach here
- Additionally this gives the potential of recycling

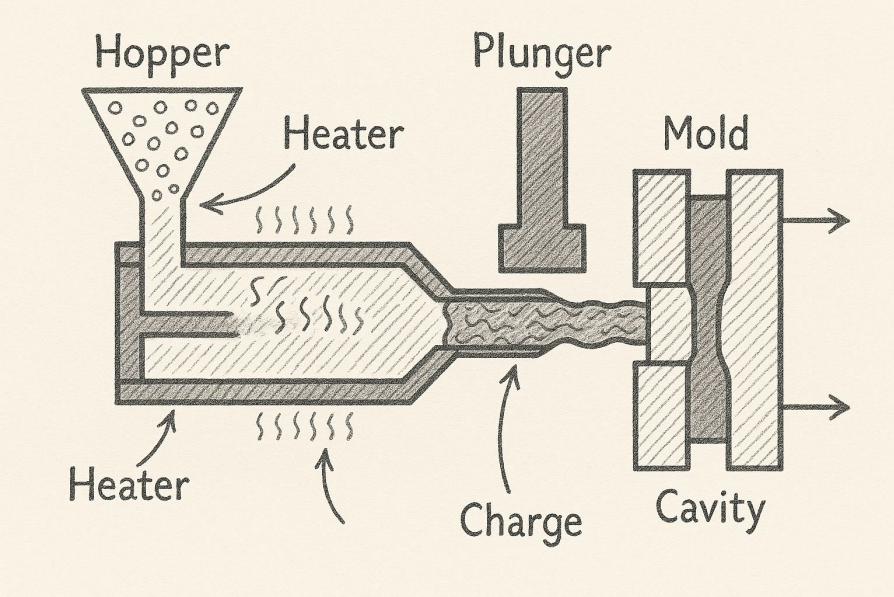
PLASTIC BASED POWER INDUCTORS

Production Process

Injection Molding



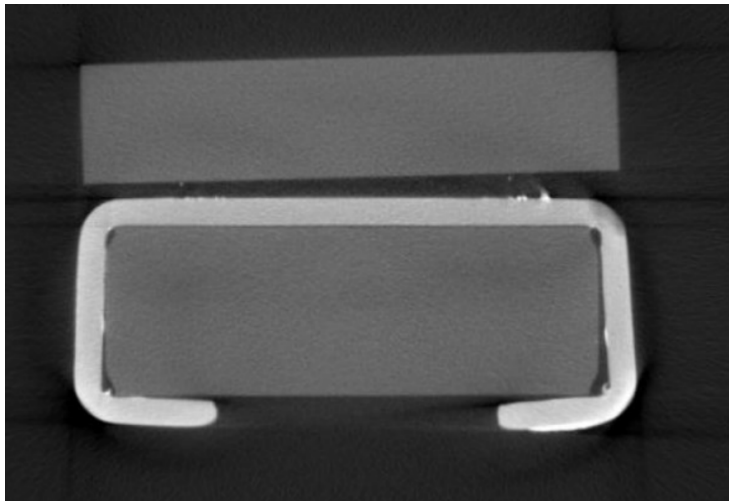
Transfer Molding

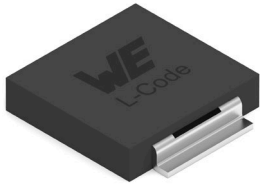


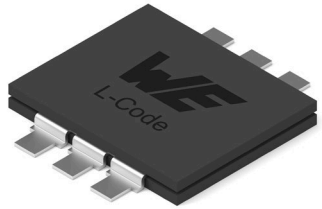
CLIP BASED POWER INDUCTORS

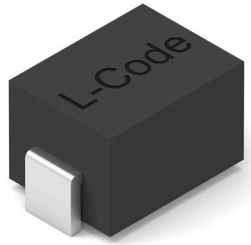
Design

- Low inductance values with clip designs
- Existing products like WE-HCM are based on ferrite
- Highly customized to customer needs
- Transition to powder based solutions





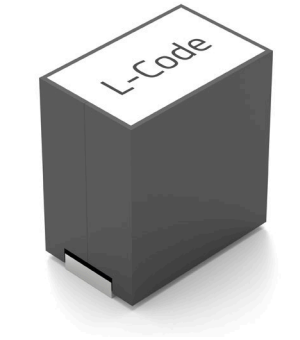


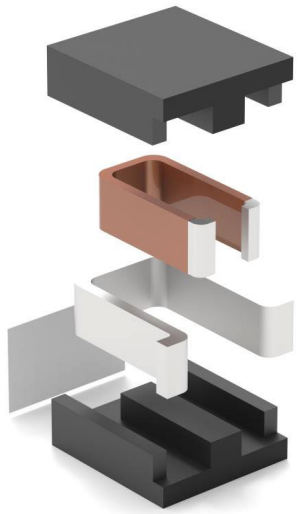


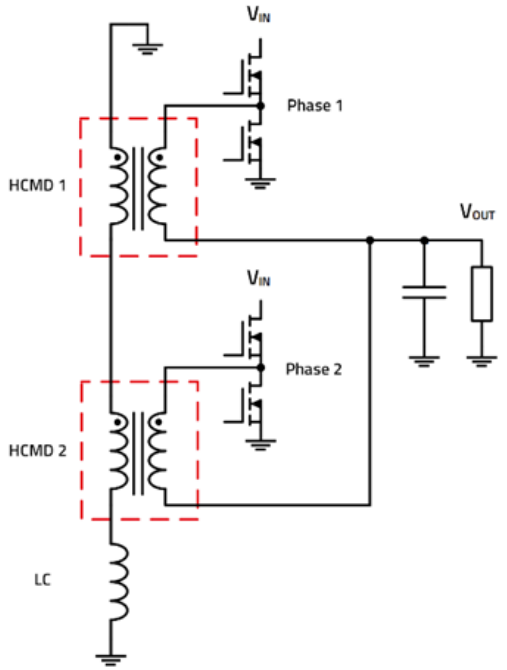
CLIP BASED POWER INDUCTORS

Applications

- Main applications are multiphase topologies
- Dual coil designs for TLVR topology
- Trends like vertical power delivery or heat transfer
- Become more and more attractive for high switching frequency applications



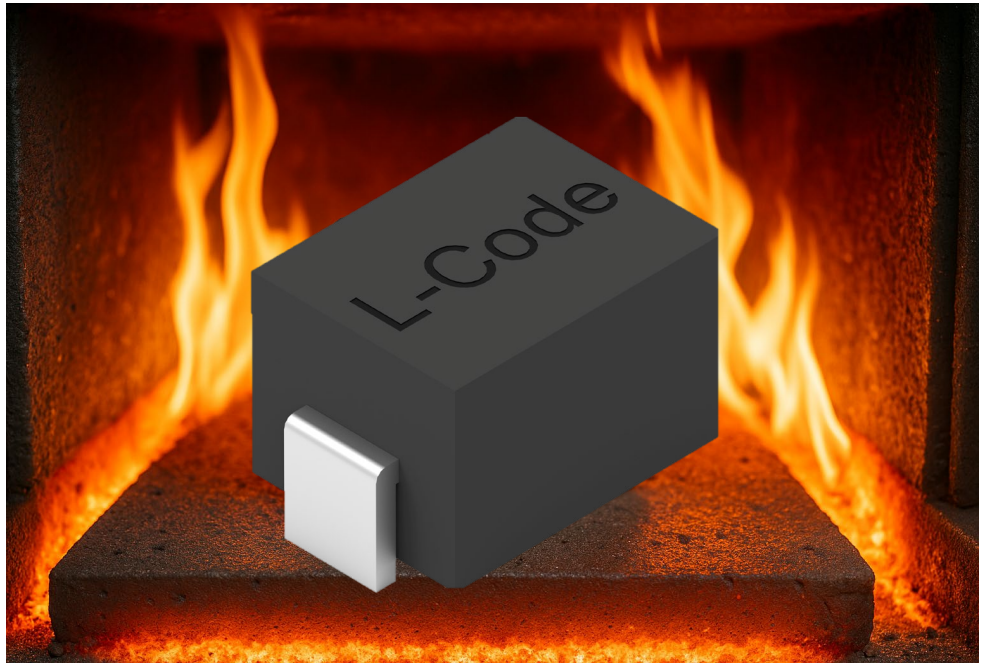




CLIP BASED POWER INDUCTORS

Co-sintering

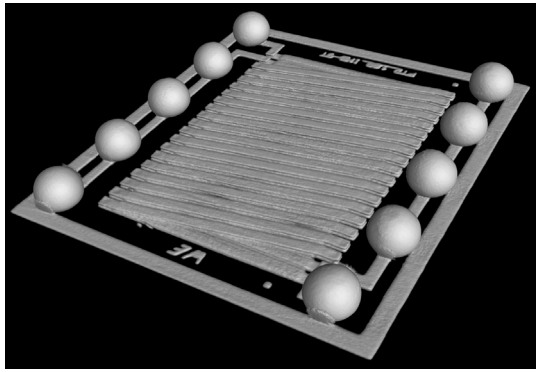
- Powder based solutions
- Classical assembly or molding
- Co-sintering is combining the benefits of assembly materials with the production process of molding
- Exlusively applicable for clip inductors

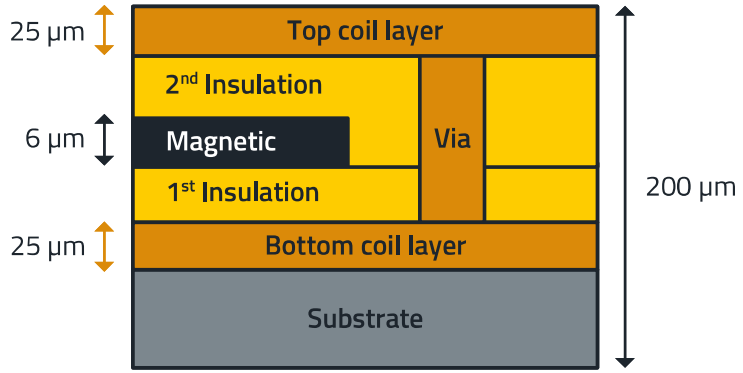


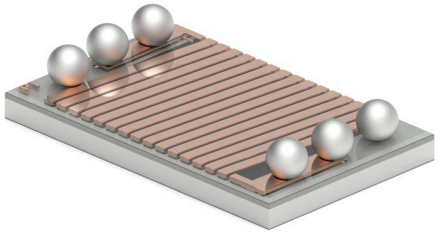
SILICON BASED POWER INDUCTORS

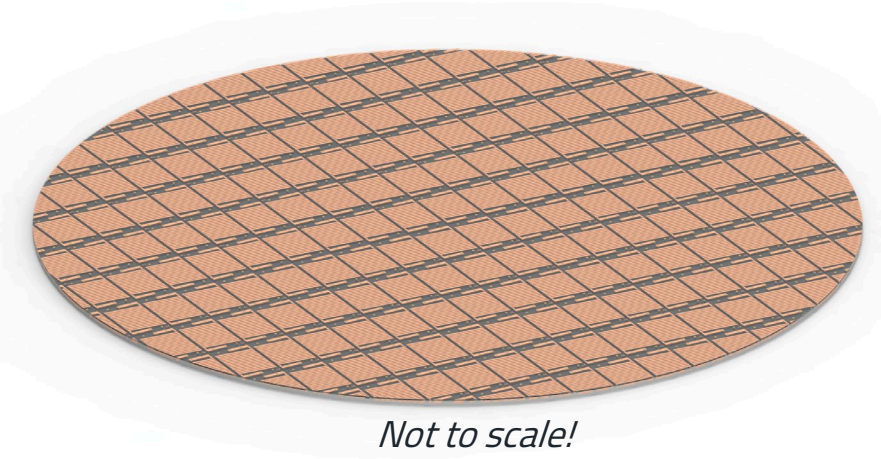
Design

- For miniaturisation and embedding there is a new technology
- Inductors based on silicon
- Multilayer Construction
- Produced on wafer level like semiconductors







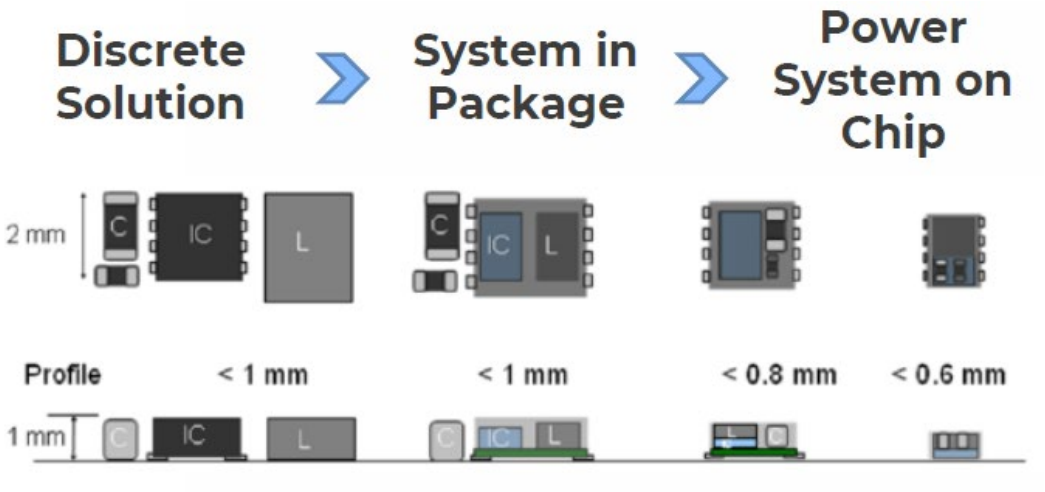


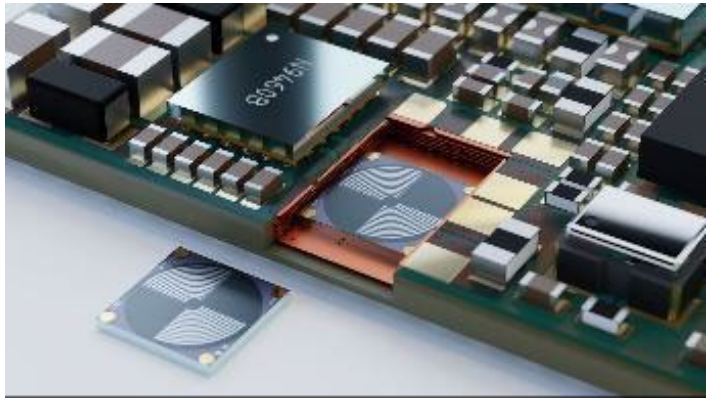
Not to scale!

SILICON BASED POWER INDUCTORS

Processing

- Different solutions to meet customer processability requirements
- With ball drop for PCB soldering and package in package integration
- Bare die with copper pads for wire bonding or embedding
- Chiplet integration

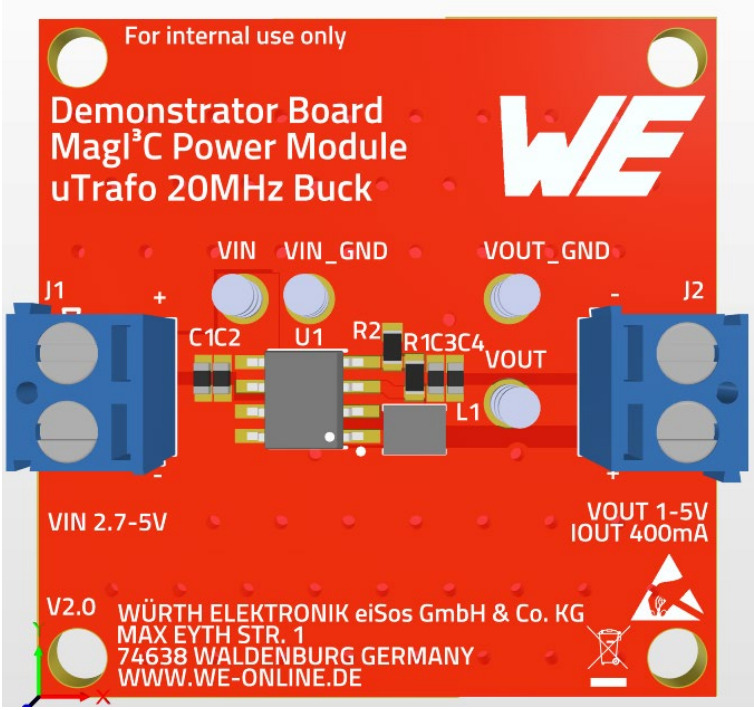




Source: Open Visions, OV Tech GmbH

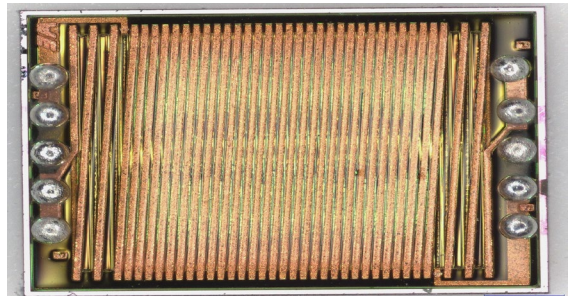
SILICON BASED POWER INDUCTORS

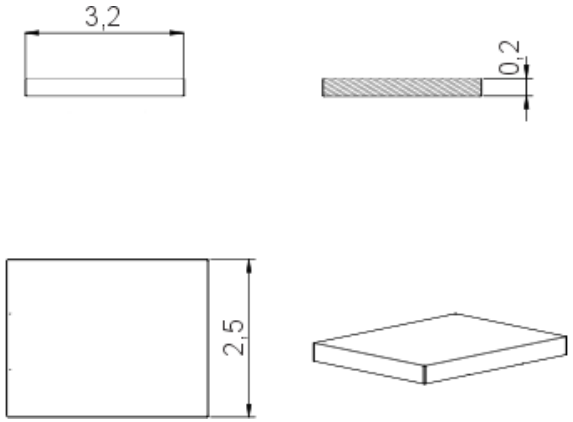
Applications



Converter specifications:

- VIN 2.7V – 5V
- VOUT 1V – 5V
- IOUT up to 400mA
- fsw 20MHz



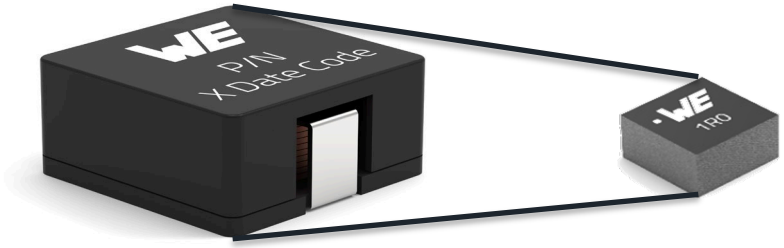


Microtransformer:

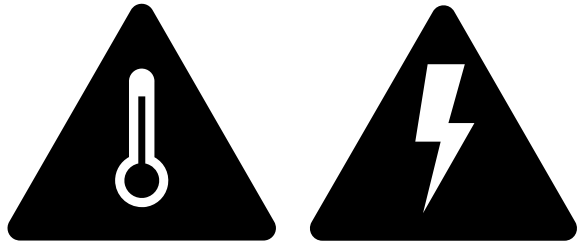
- Size 1210
- L = 360nH
- RDC = 1.65Ω
- Isat = 450mA

OUTLOOK

Miniaturisation



Harsh environment



High Power

THANK YOU