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Ferrites for sensor applicatons – design and properties

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Topics

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- Common exploited properties of Ferrites
- Forming fields
- Shaping ferrites
- Contacting coils
- Permeability µ changes with

frequency	temperature
air gap	excitation level
DC bias/magnetic fields	mechanical forces

- What do you need?
- Wireless power and data transfer
- Less common exploited properties of Ferrites

Properties and applications of Ferrites 1

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Common thought of properties of soft magnetic ferrites:

- "collecting" and shaping of magnetic fields
  => sensors, antennas, transponders

- Increasing "inertia" of electric current
  => chokes, noise suppression, filters, delay lines

- Increase magnetic coupling of conductors
  => transformers, converters, storage chokes, impedance matching

Antennas and Sensors

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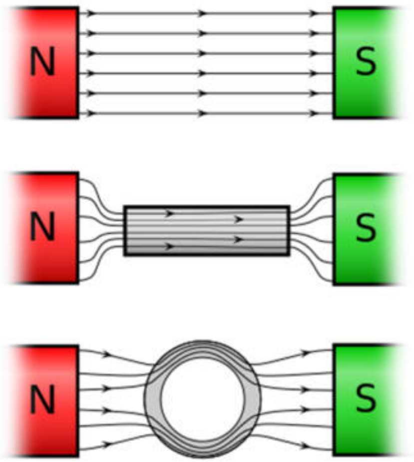
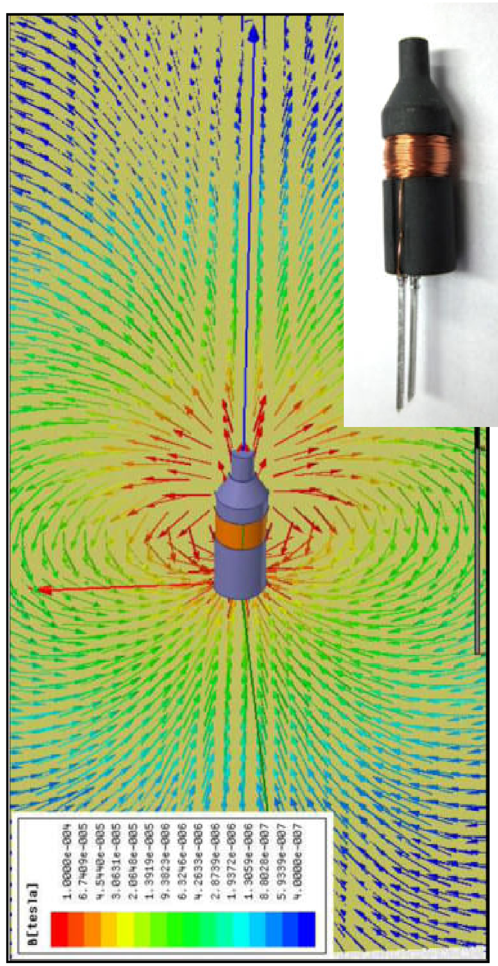
Directing and collecting magnetic fields

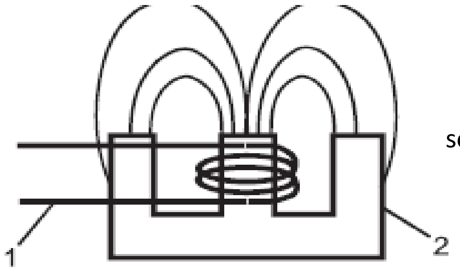


source: Wikipedia



Metal detection and recognition

Inductive proximity switch:
Directing and focussing magnetic field



source: IFM

Non destructive Material testing:

- Material sorting
- Material thickness

} e.g. Coin recognition

- Crack detection and depth determination
- Imaging of material faults

source http://eddycation.de/

Dry pressing of ferrites

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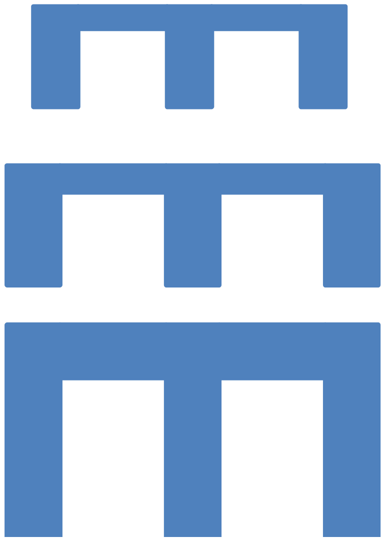
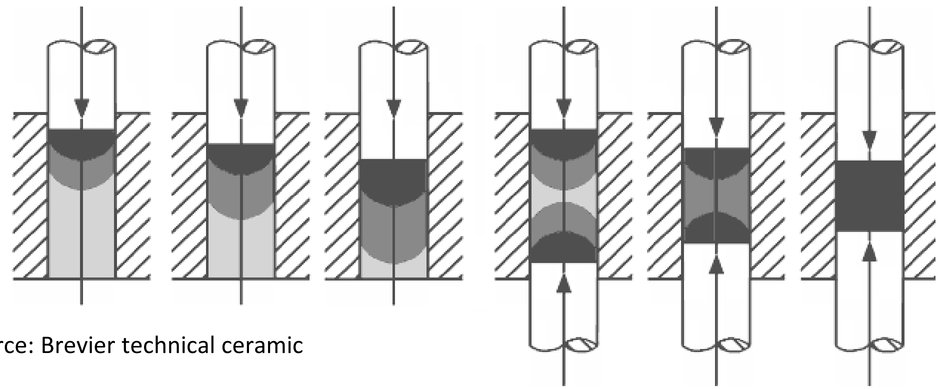


Cross-section through a sintered pot core

pressed part before sintering

powder column in the mould before pressing



uneven densification
=> strains and cracks,
particularly at the lines
where portions of
different thicknesses meet

source: Brevier technical ceramic

one-sided two-sided

uniaxial dry pressing: areas of differing densification (grey scale)

Crack formation in pressed ferrites

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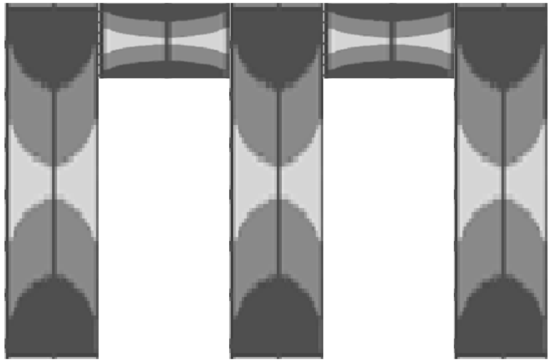
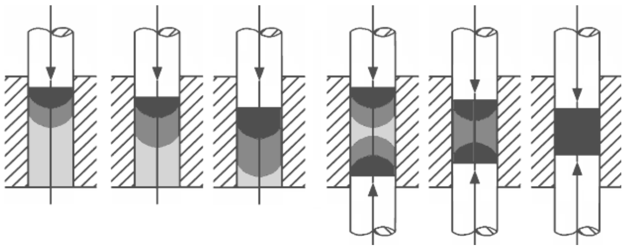


Density differences during powder pressing

=> differing densification in thinner and thicker areas of the part can cause crack formation at the intersections



one-sided two-sided
uniaxial dry pressing: areas of differing densification (grey scale)

source: Brevier technical ceramic

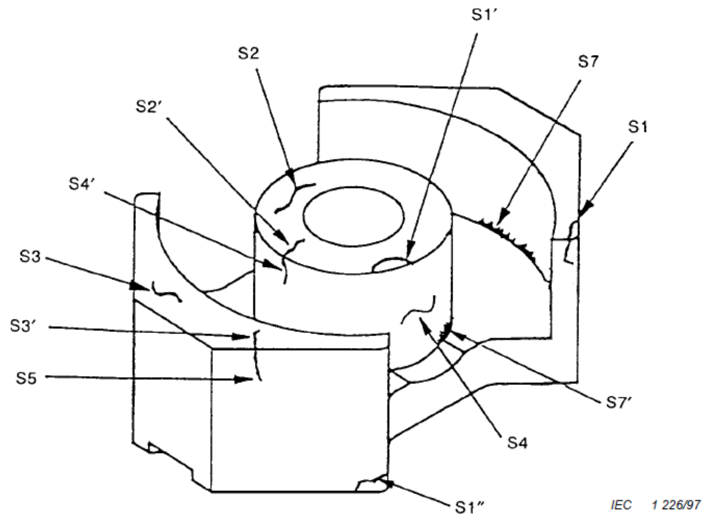


Figure 2 – Cracks location – Top view

Source:

IEC 60424-2 Ed.2: Ferrite cores - Guidelines on the limits of surface irregularities - Part 2: RM-cores

Examples for injection molded parts

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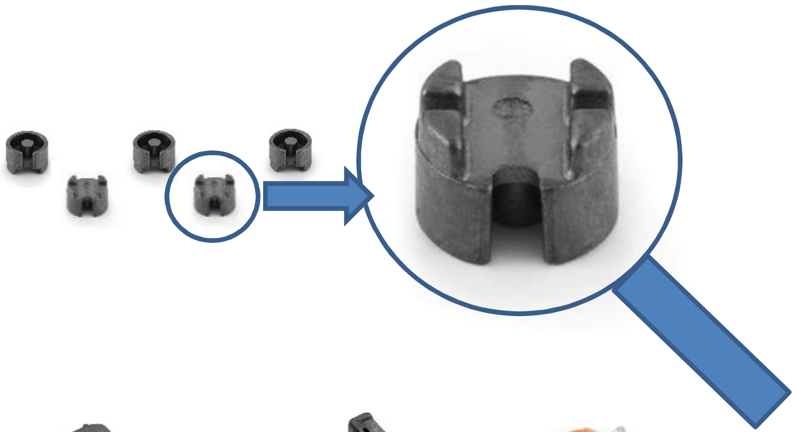

Isotropic 3D-cube antenna 9x9x9mm

- monolytic, hollow ferrite
- high Q-factor, high sensitivity
- reduction in material and weight

smallest customer specific designs

- wall thickness ≥ 0,22mm,
- volume ≥ 1mm^3
- tolerances down to +-1%

SMD transponder coils

- high Q-factor, high sensitivity
- high reliabilty in vibration und drop tests

Ferrite production at NEOSID

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• mixing oxides	main components Fe Mn Ni Zn
• pre sintering	homogenization and formation of the ferrite structure
• milling	creating a very fine powder
• compounding	mixing ferrite powder and binder
• injection moulding	1 to 28 cavities
• barrel finishing	rounding edges, removing flash
• sintering	in air or under controlled oxygen concentration
• annealing	establishing an optimum domain structure
• grinding	tight tolerance, flat surface, round, thread grinding,
	CNC milling of prototypes
• coating	e.g. parylene, self-locking screw cores, metallization
• Inspection	electrical, geometrical

Contacting Technologies

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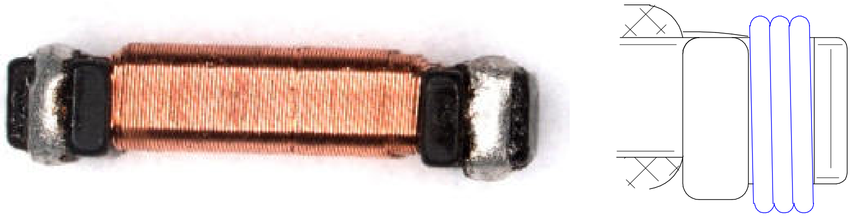
Wire wound terminal



Metal pin terminal

Metallized core terminal

Common competitors Metallisations

- **Dipping**

  Dipping in silverpaste, burning in and plating

  => low quality factor caused by eddy currents in end faces

  => Nickel-Zink-Ferrite only

- **single layer PVD**

  selective deposition of e.g. silver

  => poor adhesion

  => dissolves during soldering, does not withstand thermo-compression

Metallisation from NEOSID

3-layer PVD

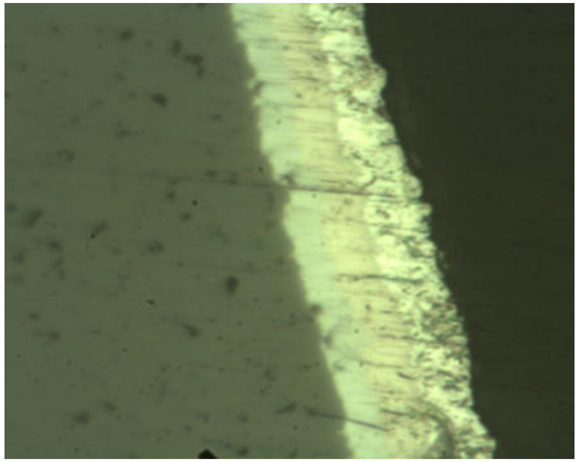
selective deposition of 3 layers where whished for, no burning in

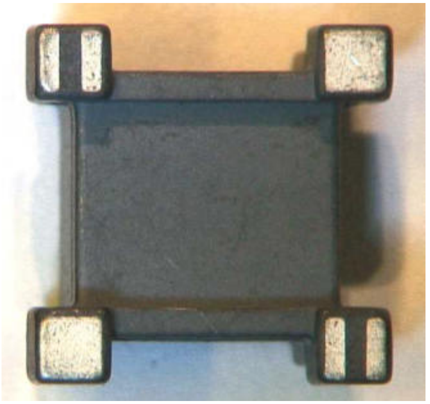
=> reduction of eddy currents

=> works on Manganese- and Nickel-Zink-Ferrite

=> good adhesion

=> withstands soldering and thermo-compression





automated 100 % optical inspection

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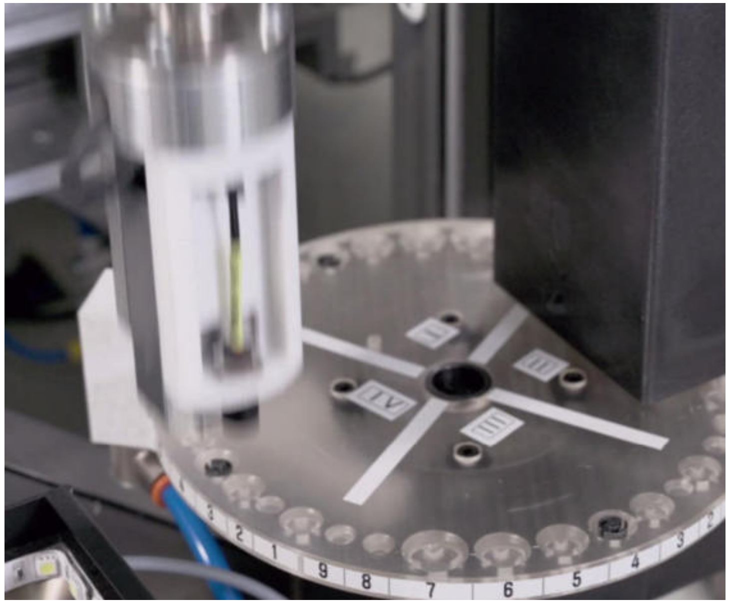

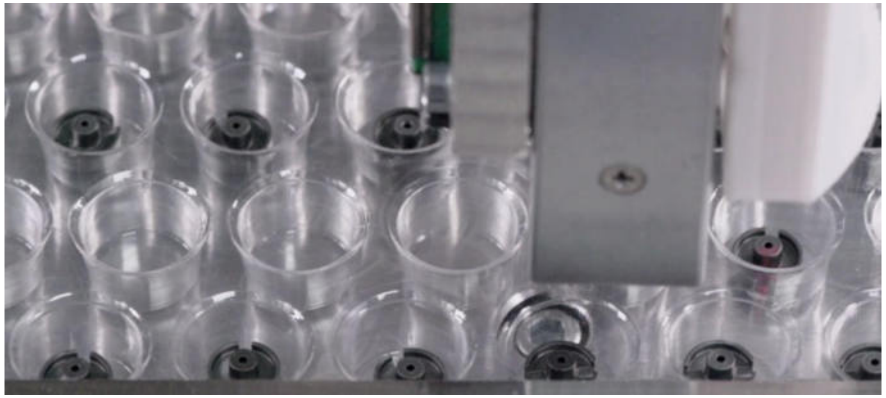

Soft magnetic Ferrites

NiZn-Ferrites

- µi from 10 to 2.000
- high Q between 0 and 100 MHz
- large electrical resistance
- higher Tc
- sintering in air

MnZn-Ferrites

- µi from 700 to 20.000
- high Q between 0 and 1 MHz
- small electrical resistance
- lower Tc
- sintering under controlled atmosphere only

Influence of Frequency

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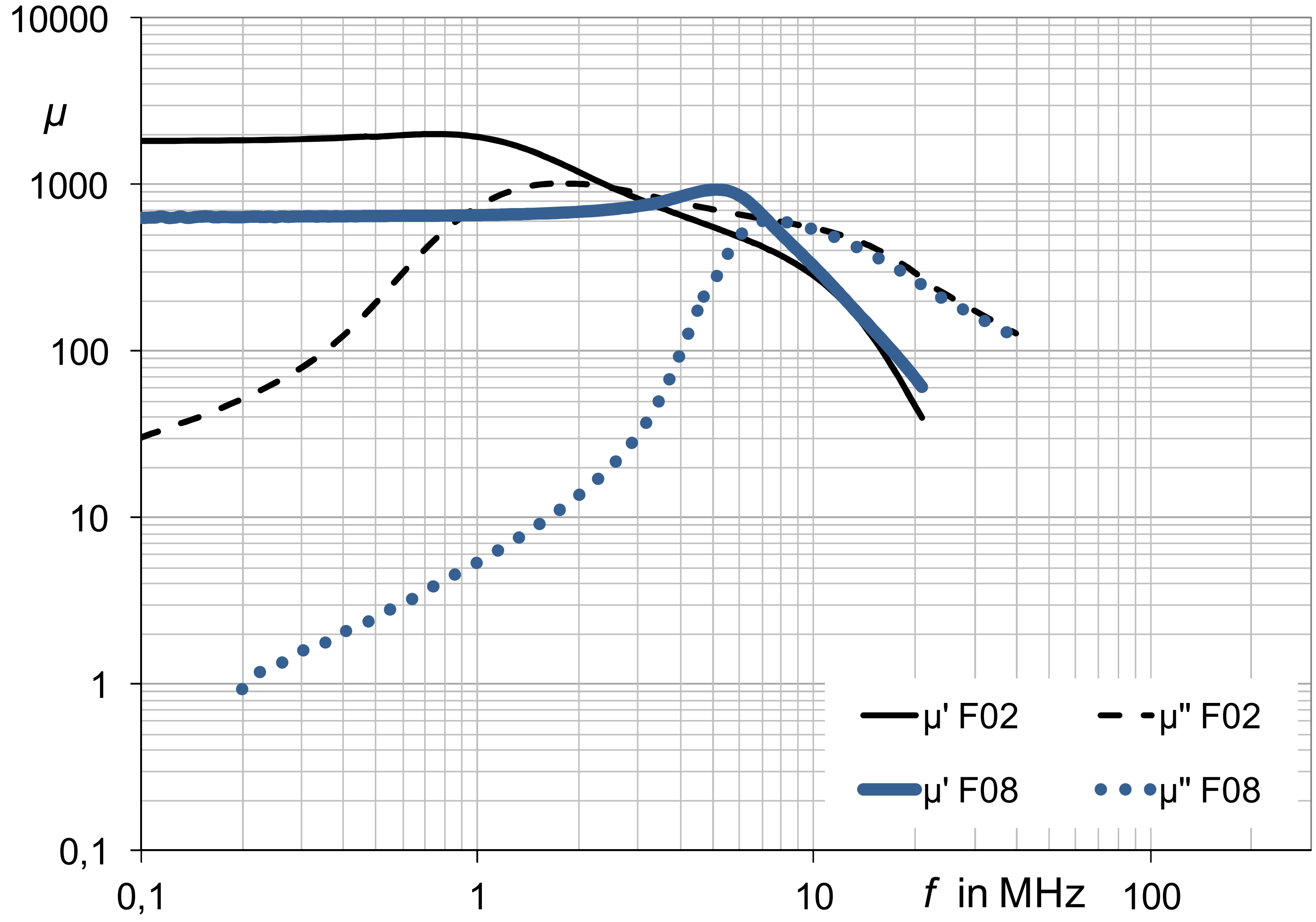

μ‘ = permeability
μ“ = losses

Q = μ‘/μ“

For lower losses (higher Q) at higher frequencies chose lower μ material

Influence of Temperature

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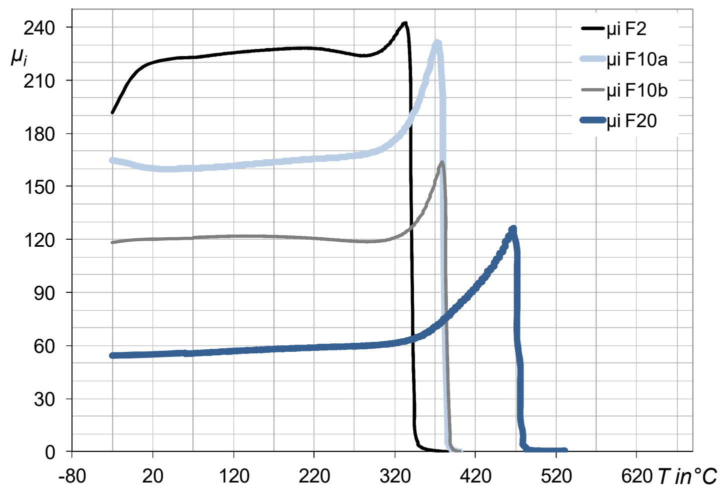
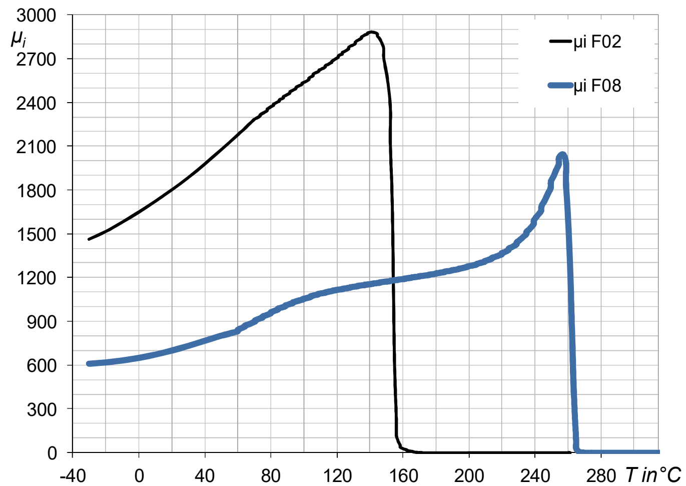
Medium and small µi
- Very small temperature drift



High µ
- Almost linear temperature drift (can be compensated)



Very high µ materials

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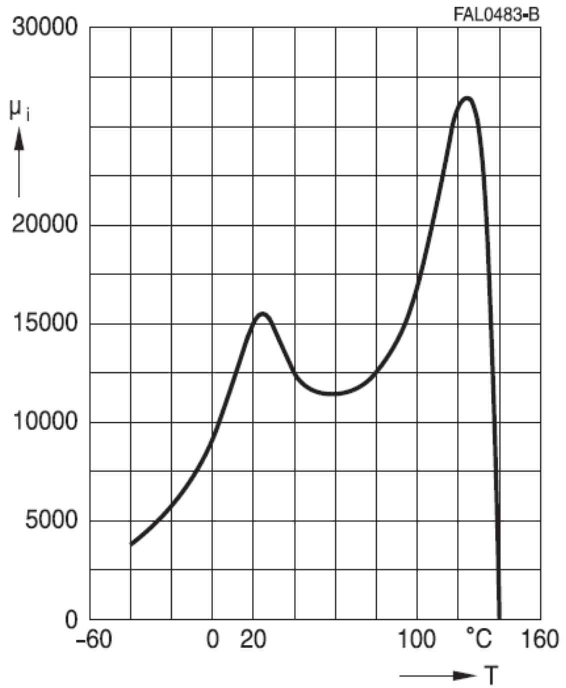
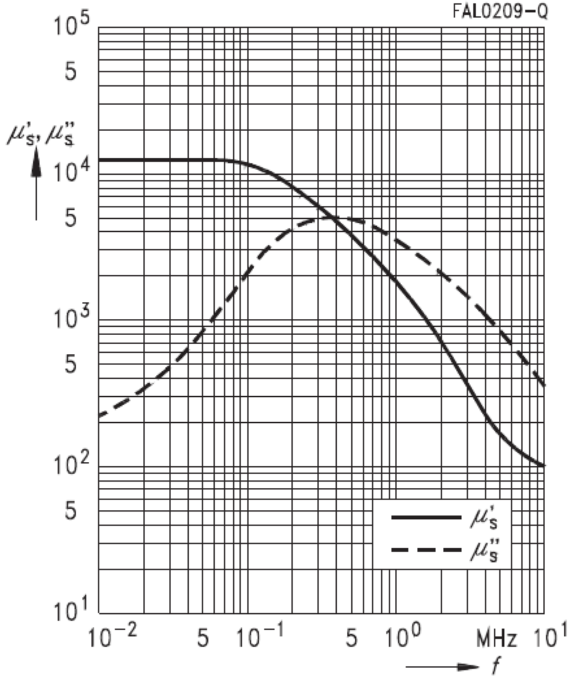
Initial permeability μ_i
versus temperature
(measured on R9.5 toroids, $\hat{B} \leq 0.25$ mT)



Complex permeability
versus frequency
(measured on R9.5 toroids, $\hat{B} \leq 0.25$ mT)



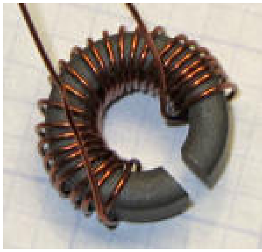
Sources: TDK-Catalogue

Very unstable µ
=> troublesome compensation

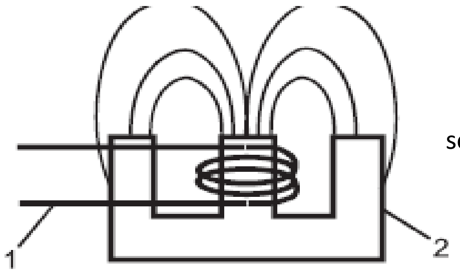
Only for very low
frequency applications

Influence of air gap

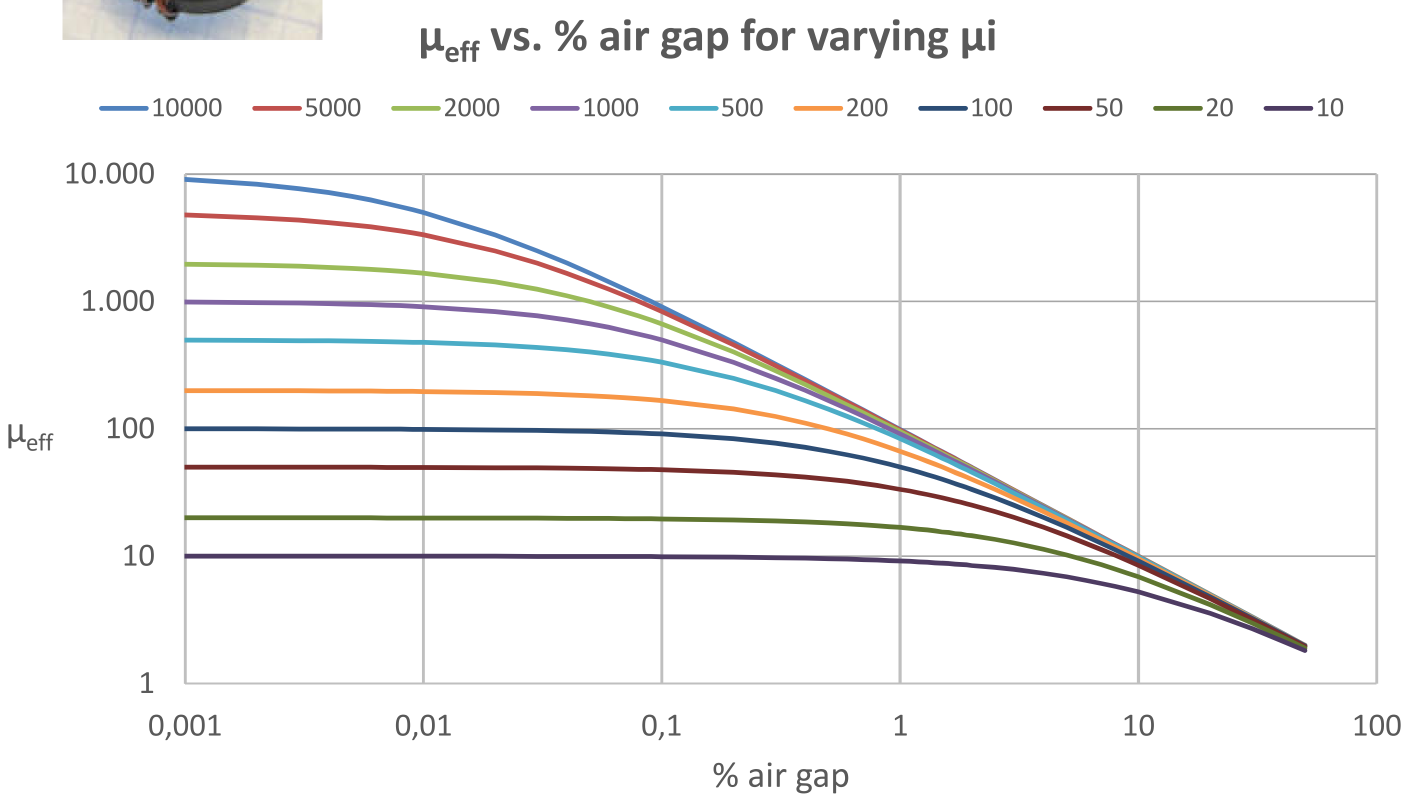
Air gap: Fraction of magnetic path not running in ferrite material



Sensing Coils are mainly open magnetic circuits with a large air gaps (≈ 50% for a pot core).

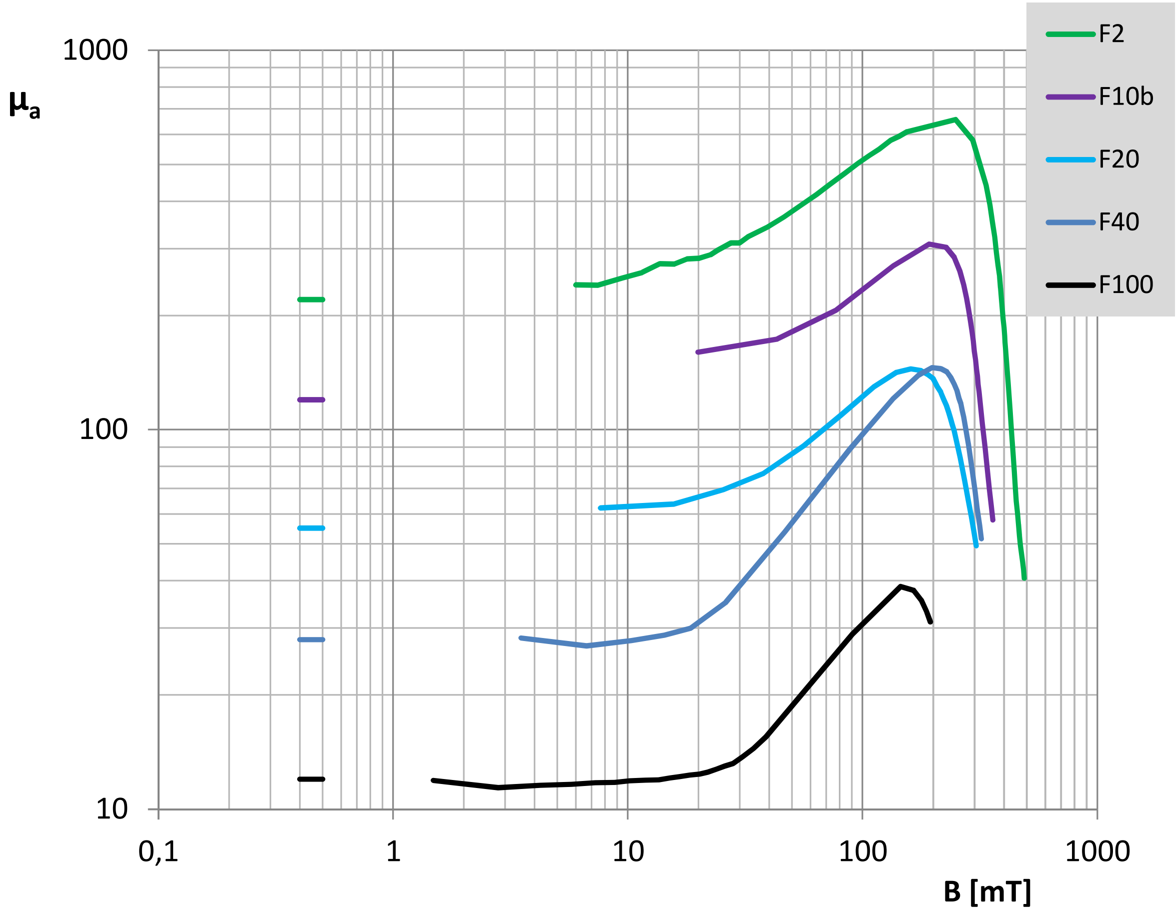


source: IFM



The larger the air gap,
the less difference in μ_{eff} remains between high and medium μ materials.

Influence of excitation level



Initial permeability μ_i is
  µ measured at low excitation levels (B < 0,5 mT)

µa changes at high excitation levels

With open magnetic circuits

$\mu_{eff} \ll \mu_a$

B = µeff*µo*H is rather small and sensors usually work in stable µ regime

Influence of DC-Bias and external Fields

Permeability decreases with application of

- DC-bias
- external magnetic fields

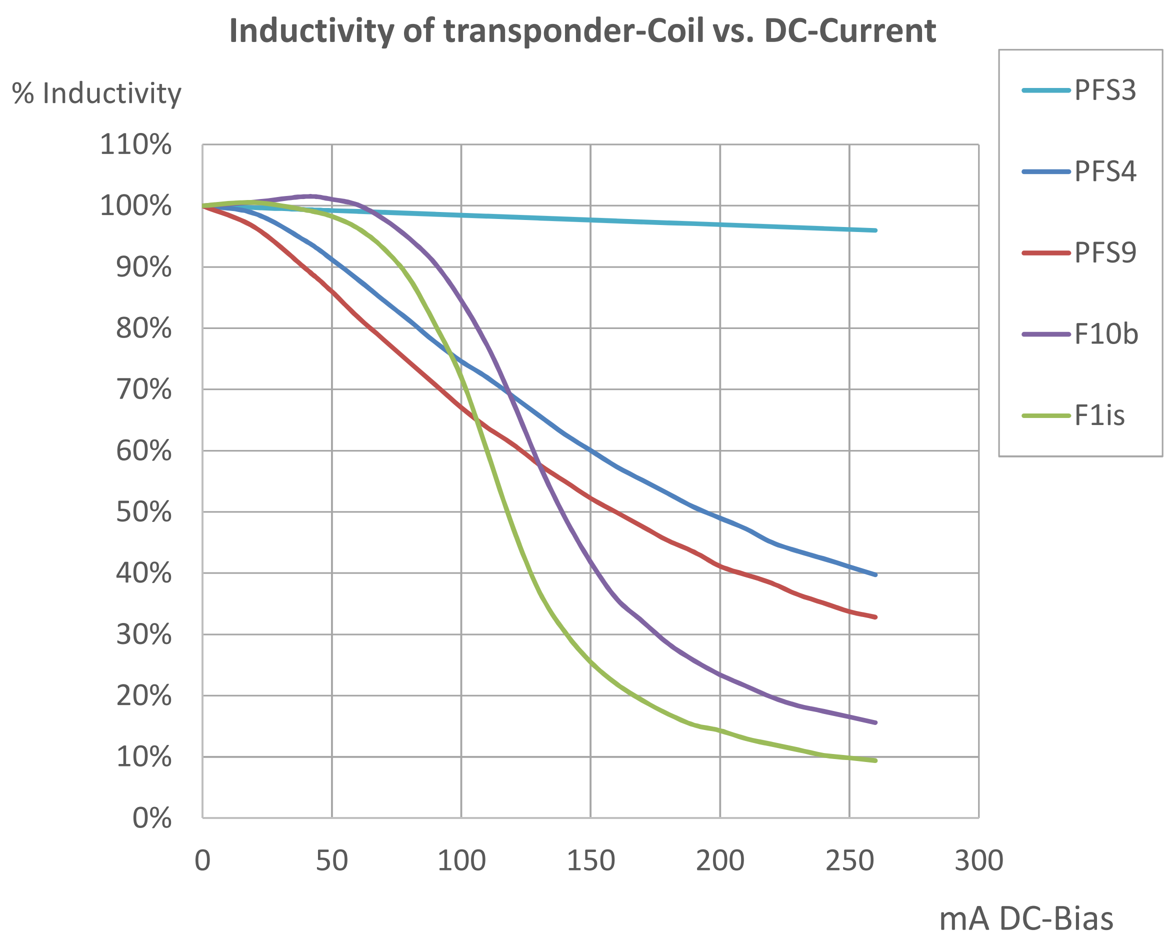
ferrites stay stable up to a certain level and than drop quite fast

Higher µ ferrites suffer earlier

Composites PFS4 and PFS9 drop earlier but slower

Composite Material PFS3 is extremely stable

up to > 1000 mT



Impact of strong magnetic fields and excessive mechanical force

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3 ferrite material classes

NiZn-ferrites F2a to F100b
- Some impact, extremely slow recovery
- complete recovery can be reached only through thermal annealing
- a-Types (like F2a) are less sensitive

MnZn-ferrites F02 and F08
- impact, but fast recovery

NiZn-ferrites F1ib, F1is, F5is and Composite Materials
- hardly any impact

Composite materials

- Hardly any impact
- distributed air gap => lower permeability
- Saturation flux density > 1000 mT for PFS3
- Tighter mechanical tolerances
- Easy to machine

What do you need ?

High Q value at your frequency

- wide range of ferrite materials F02 to F100
- number in name gives maximum frequency in MHz for which high Q is still achieved (02 is 0.2 MHz)

Excelent temperature stability

- materials F2 to F100 are your choice

High temperature applications

- Materials with Curie Temperature ranging from 150 to 600 °C are available

Highest excitation levels
Large DC-Bias or strong external magnetic fields

- PFS3 will do your job

Temporary Magnetic or mechanical stress

- F1ib does not remember the torture

Smallest sizes, Customized shapes

Complicated geometries, Design for automation

- Ceramic Injection Moulding of ferrites turns your vision into products

Contacting Pads, Shielding

Thermal compression of wire ends

- Selective metallization of ferrites serves your needs

Medical applications

- Parylene coating gives you coverage

You do not like cables and plugs

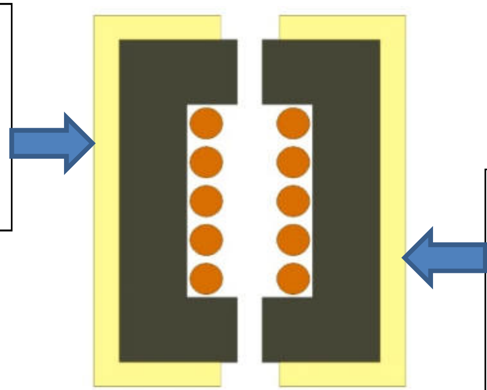
- Wireless data and power transfer gets rid of cables

Wireless power and data transfer

Rotating scanner system

Primary module

- Ferrite core
- (Coil former)
- Coil



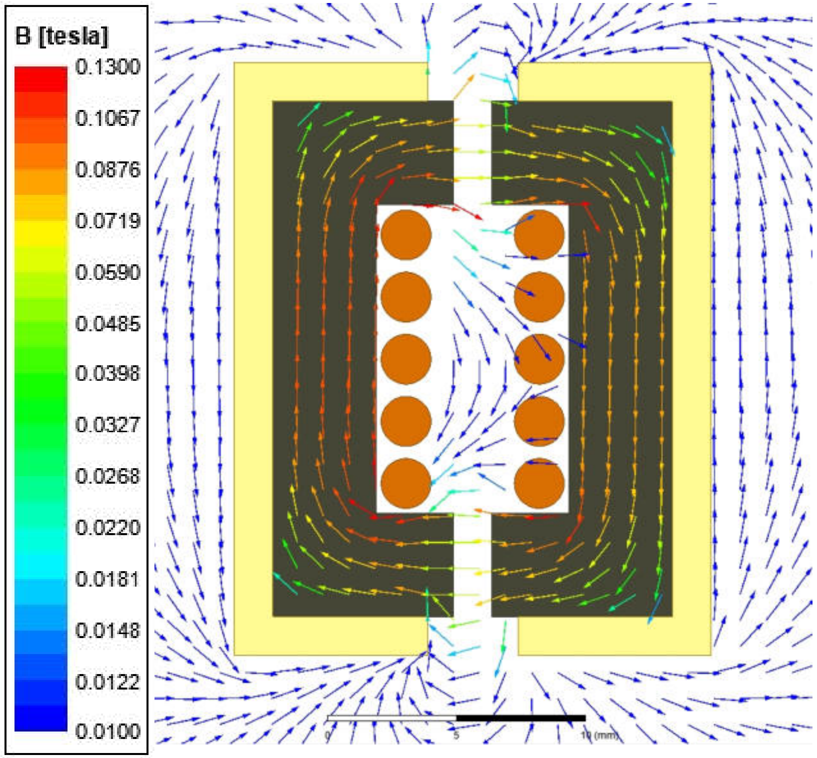
Secondary module

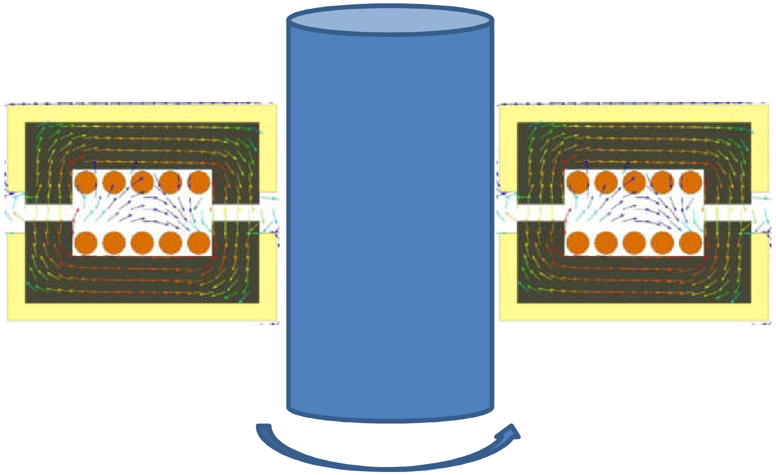
- Ferrite core
- (Coil former)
- Coil

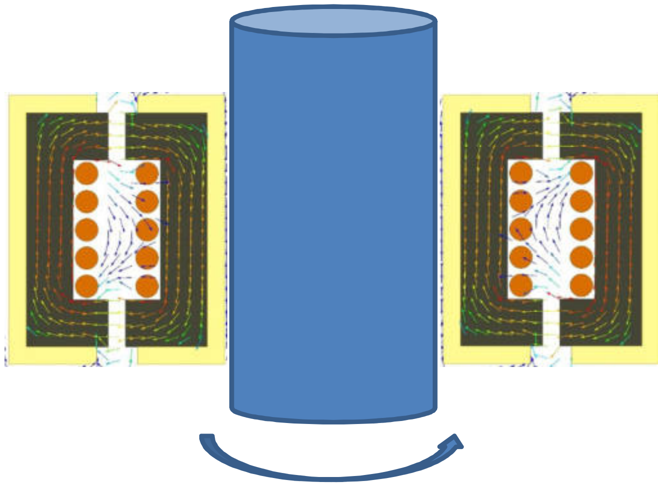
Energy transfer from primary to secondary side.

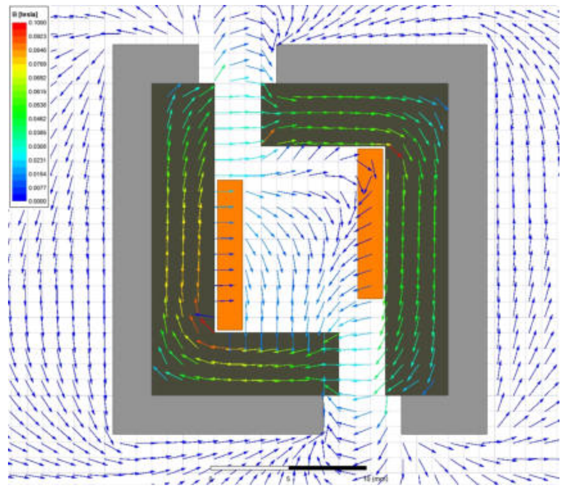
Bi-directional data transfer

Wireless power and data transfer









Properties and applications of Ferrites 2

Less common thought of properties of soft magnetic ferrites:

- Magnetostriction
  => Ultrasonic actuators and sensors, “invisible speakers”
- Lossy interaction with fields from MHz to some GHz
  => Inductive Heating, selective microwave heating
- Colour and magnetics
  => Copier powder
- DC-Magnetization
  => Switchable mechanical forces