CHILISIN ELECTRONICS CORP.
Total Solution Provider for Power, EMI and RF.

FERROXCUBE

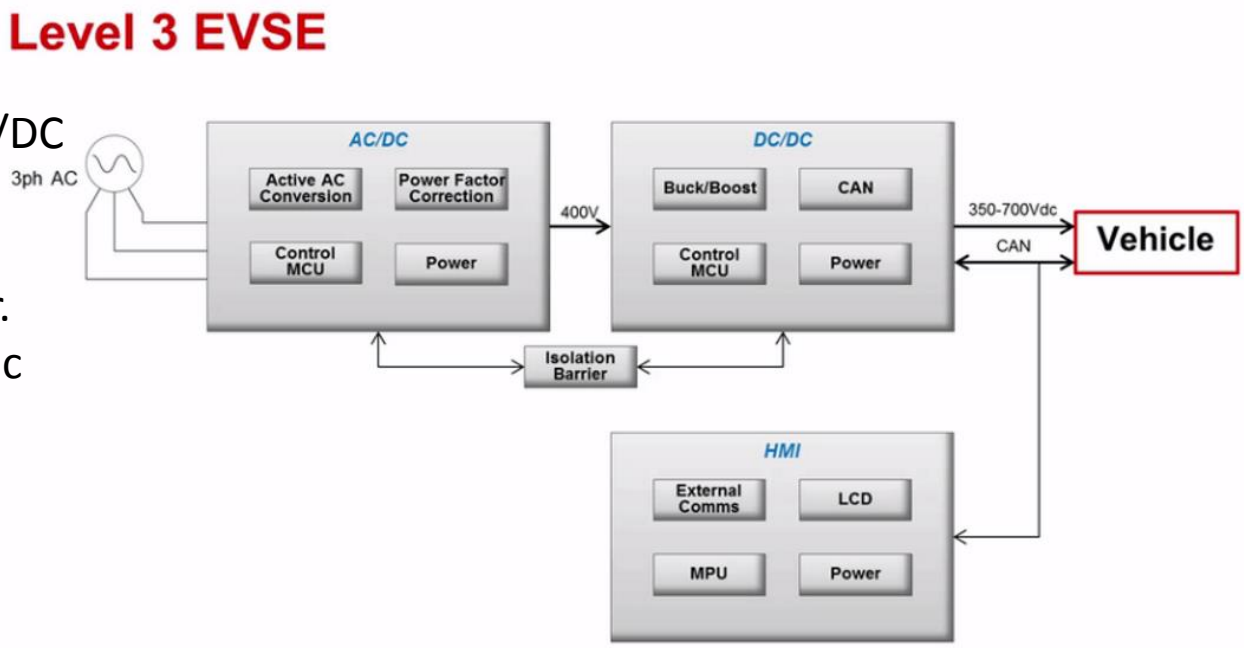
Ferrites for Stationary Chargers

June 2020

DC Stationary charger Schematic

System is split in 2 units:

- PFC: carries out the AC/DC initial conversion and ensures low EMI and maximum power factor. May implement galvanic isolation
- DC/DC: adjusts PFC voltage to the level required by each car. There is galvanic isolation

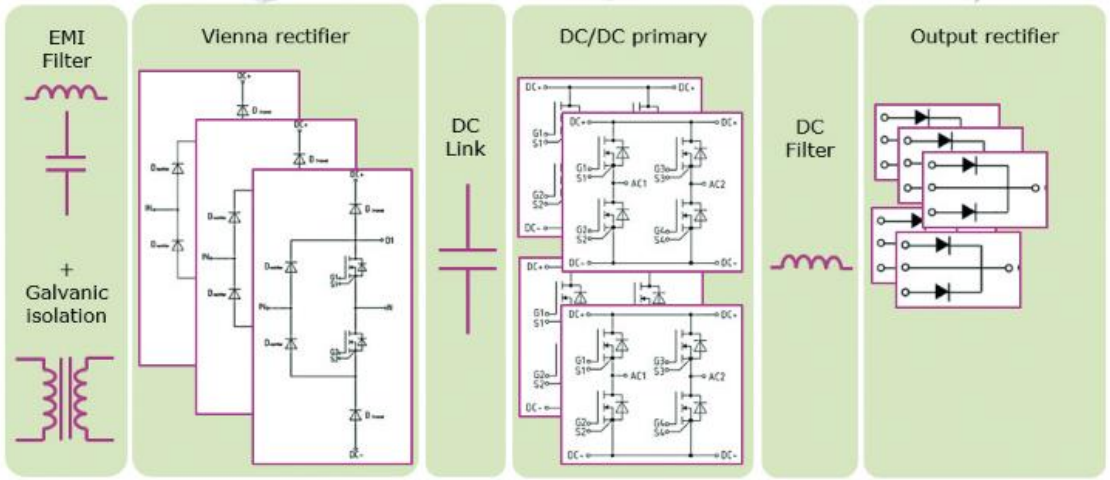


Info from Texas Instruments and Infineon

Topologies

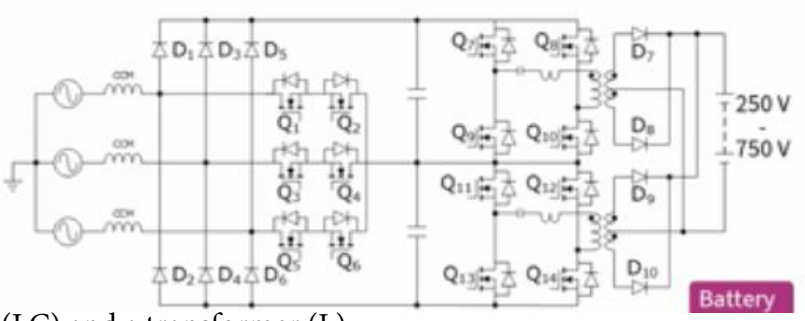
PFC operates at relatively low freq (ca. 40 kHz).
Topologies:

- Vienna rectifier: very commonly used
- Multipulse rectifier



DC/DC converter: can work up to 150-200 kHz.
Resonant topologies to allow switching at Zero Volt / Zero Amp

- LLC Resonant tank with a capacitor and a inductor (LC) and a transformer (L)
- Phase Shift Full Bridge



Ferrite/Inductive Functions

Common mode choke: big toroid ferrite cores in 3Nx or more expensive Nanocrystalline

Inductor for PFC with large gap ferrite core or Powder cores

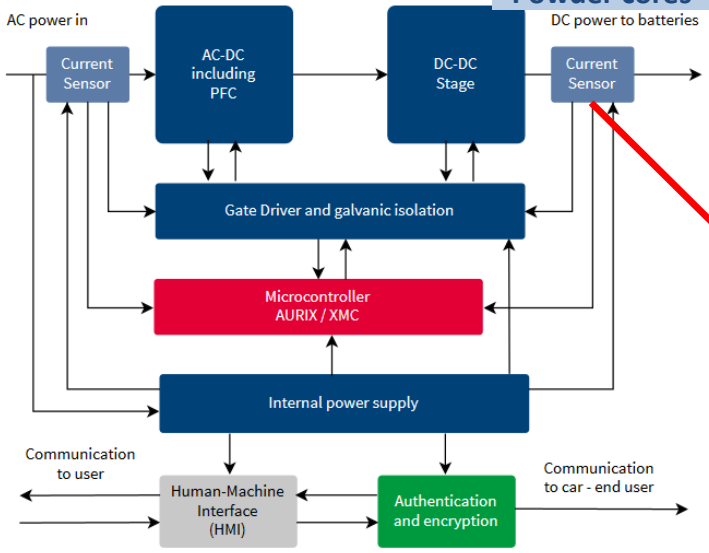
Transformer for gate driver EP7 ferrite cores

Power transformer. Large shapes E71, E100 stacked

Resonant inductor with gap / multigap ferrite cores or Powder cores

Common mode choke: big toroid ferrite cores in 3Nx or more expensive Nanocrystalline

Transformer for gate driver EP7 ferrite cores

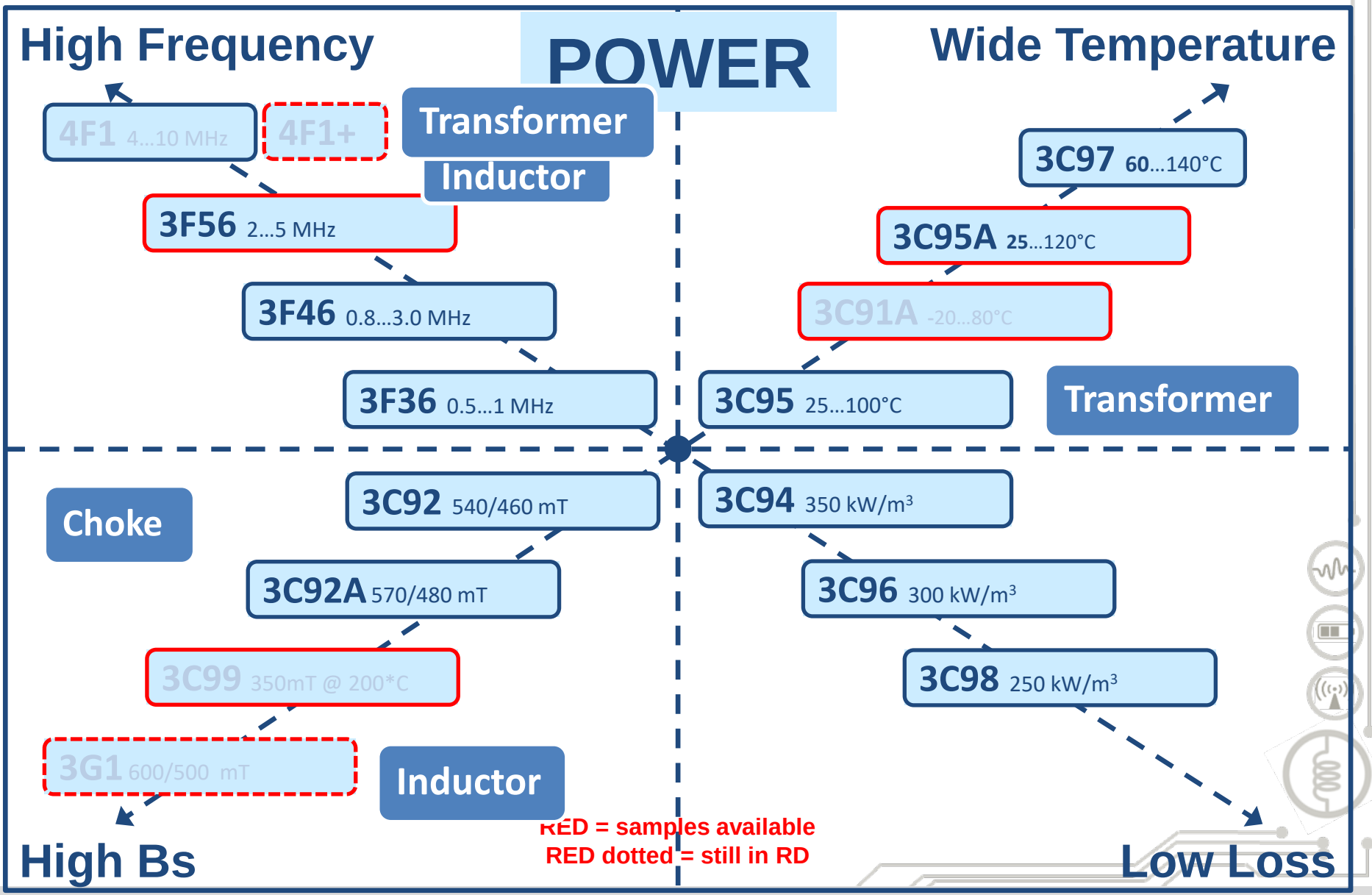


Gapped ferrite for Hall effect sensor Common: nanoC

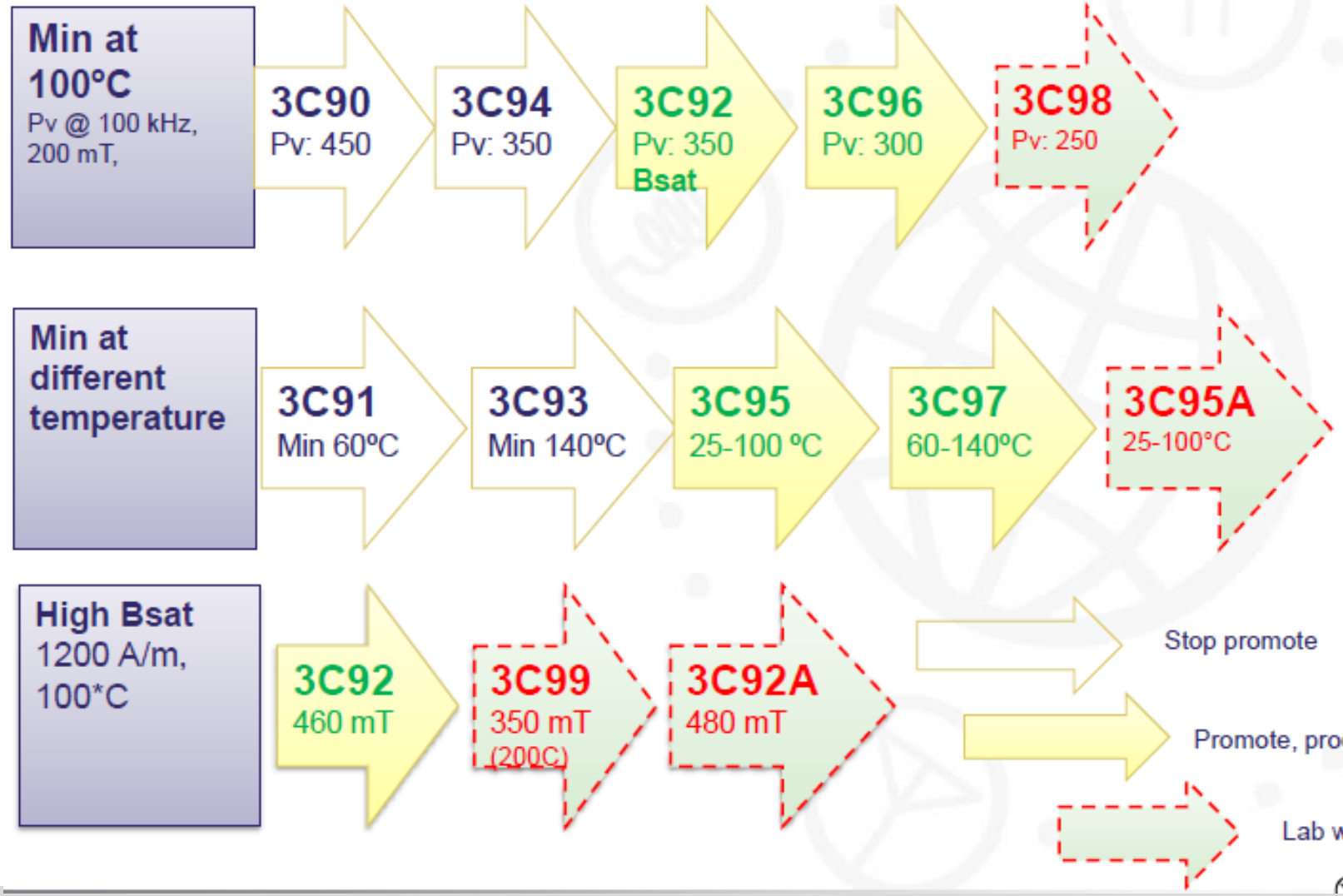
Some funtions are made with other materials (nanocrystalline, powder cores…) than ferrite, but still ferrite would be possible.

Low chance for ferrite: dark back

High chance: light background


High Frequency
POWER
Wide Temperature
4F1 4...10 MHz
4F1+
Transformer
Inductor
3F56 2...5 MHz
3F46 0.8...3.0 MHz
3F36 0.5...1 MHz
3C97 60...140°C
3C95A 25...120°C
3C91A -20...80°C
3C95 25...100°C
Transformer
Choke
3C92 540/460 mT
3C92A 570/480 mT
3C99 350mT @ 200*C
3G1 600/500 mT
Inductor
3C94 350 kW/m3
3C96 300 kW/m3
3C98 250 kW/m3
RED = samples available
RED dotted = still in RD
High Bs
Low Loss

LF (<300kHz) power materials evolution (3C9.)



3C98 – Premium material low frequency

NEW

- ✓ **3C96 – reference material for power conversion used in transformer and inductors below 400 kHz with optimal working temperature at 100˚C**
- ✓ **3C98 – new best-in-class material with lowest losses under high flux conditions**

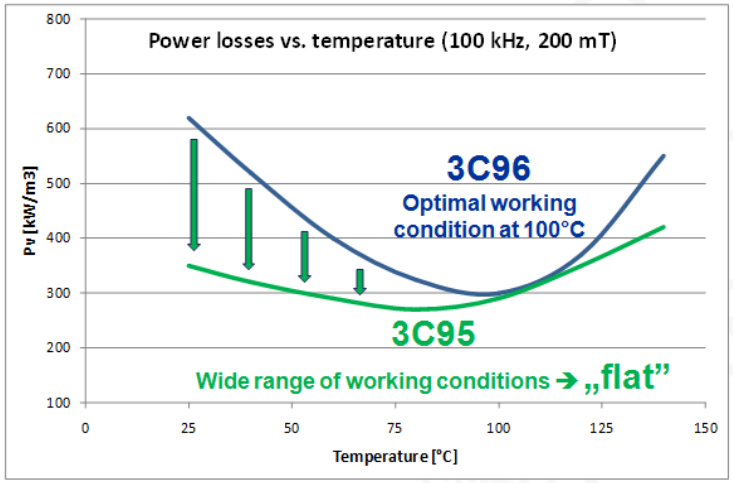
Symbol	Conditions	3C98	3C96	UNIT
μ_i	25 °C; 10 kHz; 0.25 mT	2500 ± 20%	2000 ± 20%	
μ_a	100 °C; 25 kHz; 200 mT	5500	5500	
B_{sat}	25 °C; 10 kHz; 1200 A/m 100 °C; 10 kHz; 1200 A/m	530 440	500 440	mT
P_v	100 °C; 100 kHz; 100 mT 100 °C; 100 kHz; 200 mT 100 °C; 500 kHz; 50 mT	40 250 250	40 300 250	kW/m³
T_c		>230	>240	°C
ρ	DC; 25 °C	8	5	Ωm
Density		4850	4800	kg/m³

3C95 &3C97 – Low power loss, wide temperature range

✓**3C95** – reference material for broad temperature range applications (25 – 100˚C)

✓**3C97** – premium material optimized for higher temperature range (60 - 140 ˚C)

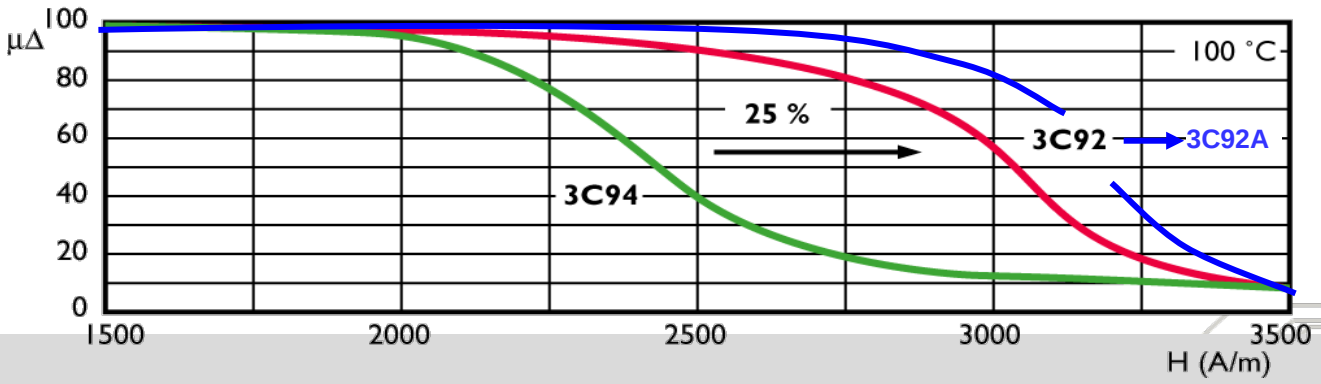
→ Automotive / Solar
→ Energy Star compliant equipment
→ Mobile/handheld devices



3C92 - high saturation low loss ferrite material

Best choice for output chokes in buck converters and inverter reactors, where the main property is High Flux density

Property	Conditions			3C92	3C94	Unit
μi	25°C	10 kHz	0.25 mT	1500 ±20%	2300 ±20%	
μa	100°C	25 kHz	200 mT	≈ 5000	≈ 5500	
Bsat	25°C	10 kHz	1.2 kA/m	**≈ 540**	≈ 470	mT
	100°C			**≈ 460**	≈ 380	
Pv	100°C	100	100	≈ 50	≈ 50	kw/m3
		100	200	≈ 350	≈ 350	
ρ	25°C	DC		≈ 5	≈ 5	Ωm
Tc				≥ 280	≥ 220	°C
Density				≈ 4800	≈ 4800	kg/m3



•Storage Energy: I^2L

$$I^2L = \frac{B^2 \times V_e}{\mu_0 \times \mu_e}$$

Increase of > 25 % for the current I gives an increase of > 50 % for for storage energy: (I2L)

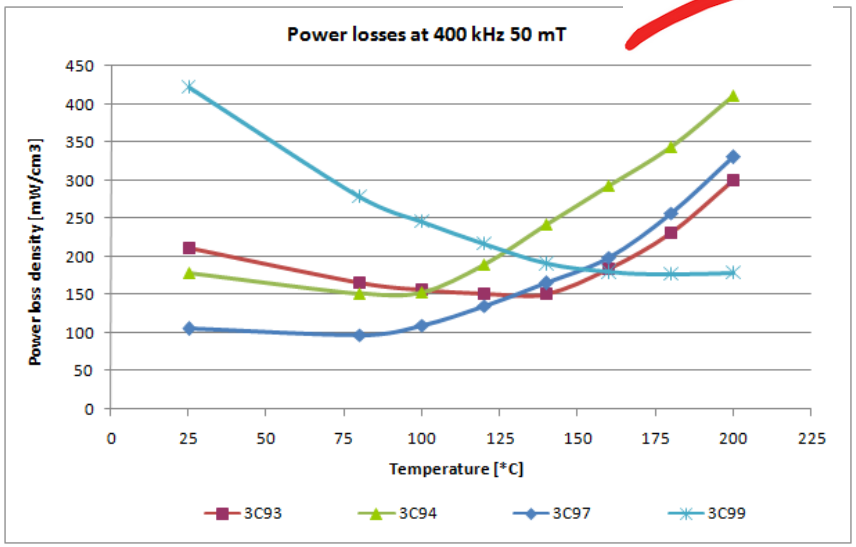
3C99 – Premium high temperature power material

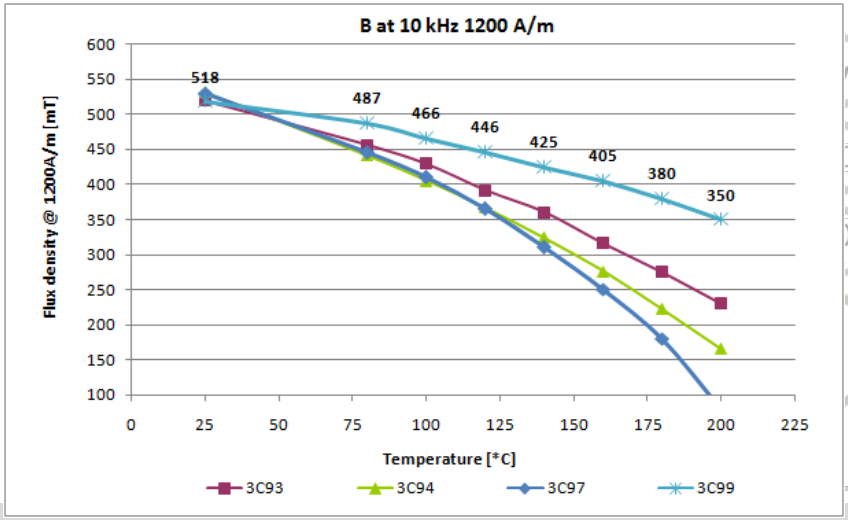
NEW

3C99 SPECIFICATION

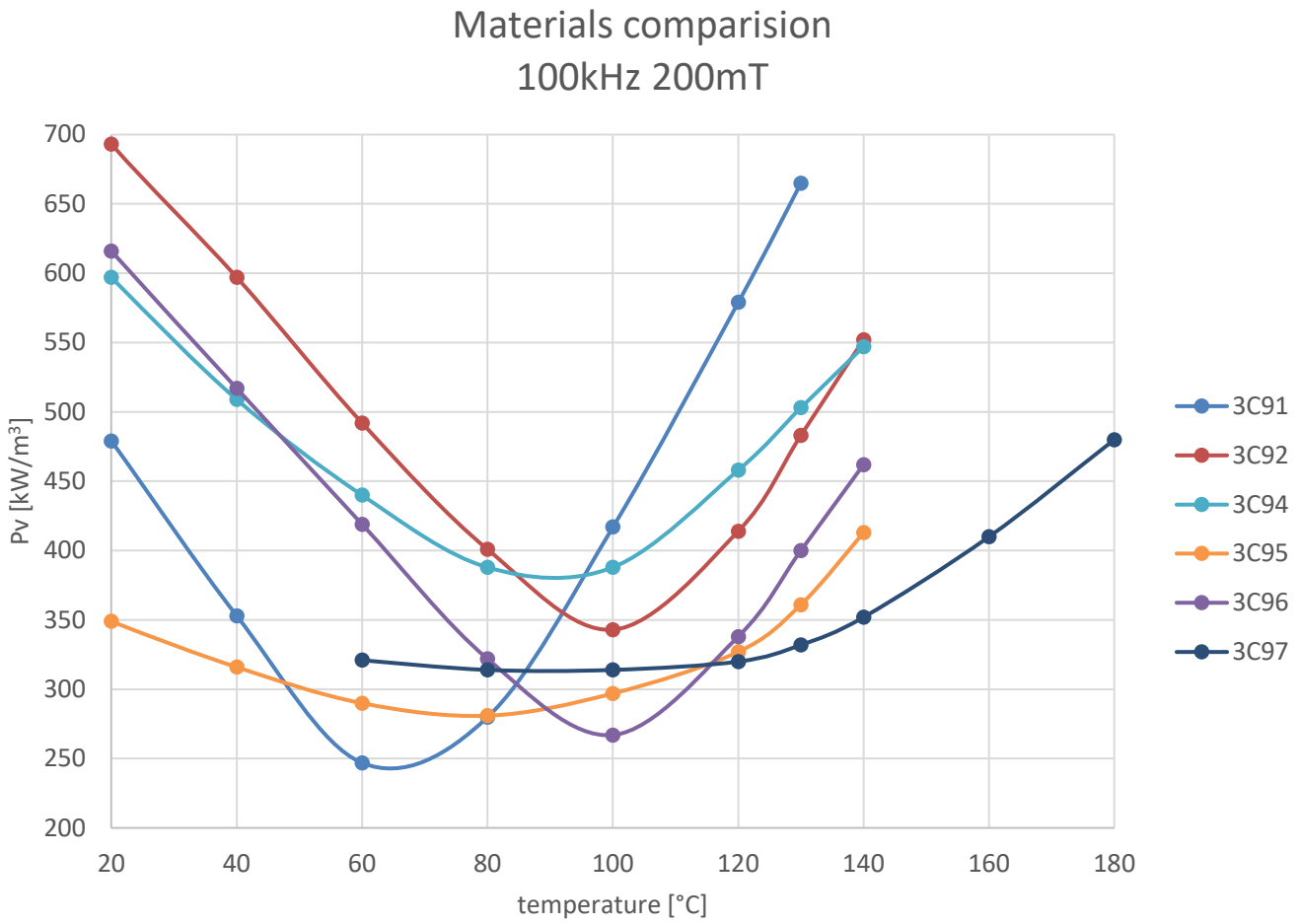
A medium frequency power material with high Curie temperature, optimized for 200°C working temperature.

SYMBOL	CONDITIONS	VALUE	UNIT
μi	25°C; 10kHz; 0.25mT	800 ± 20%	
μa	200°C; 10kHz; 200mT	≈ 4000	
B	25°C; 10kHz; 1200A/m	≈ 500	mT
	100°C; 10kHz; 1200A/m	≈ 450	
	200°C; 10kHz; 1200A/m	≈ 320	
Pv	200°C; 25kHz; 200mT	≈ 140	kW/m³
	200°C; 100kHz; 100mT	≈ 140	
	200°C; 400kHz; 50mT	≈ 220	
ρDC	25°C	≈ 6	Ωm
Tc		≥ 300	°C
density		≈ 4800	kg/m3





Power loss vs temperature 3C9.

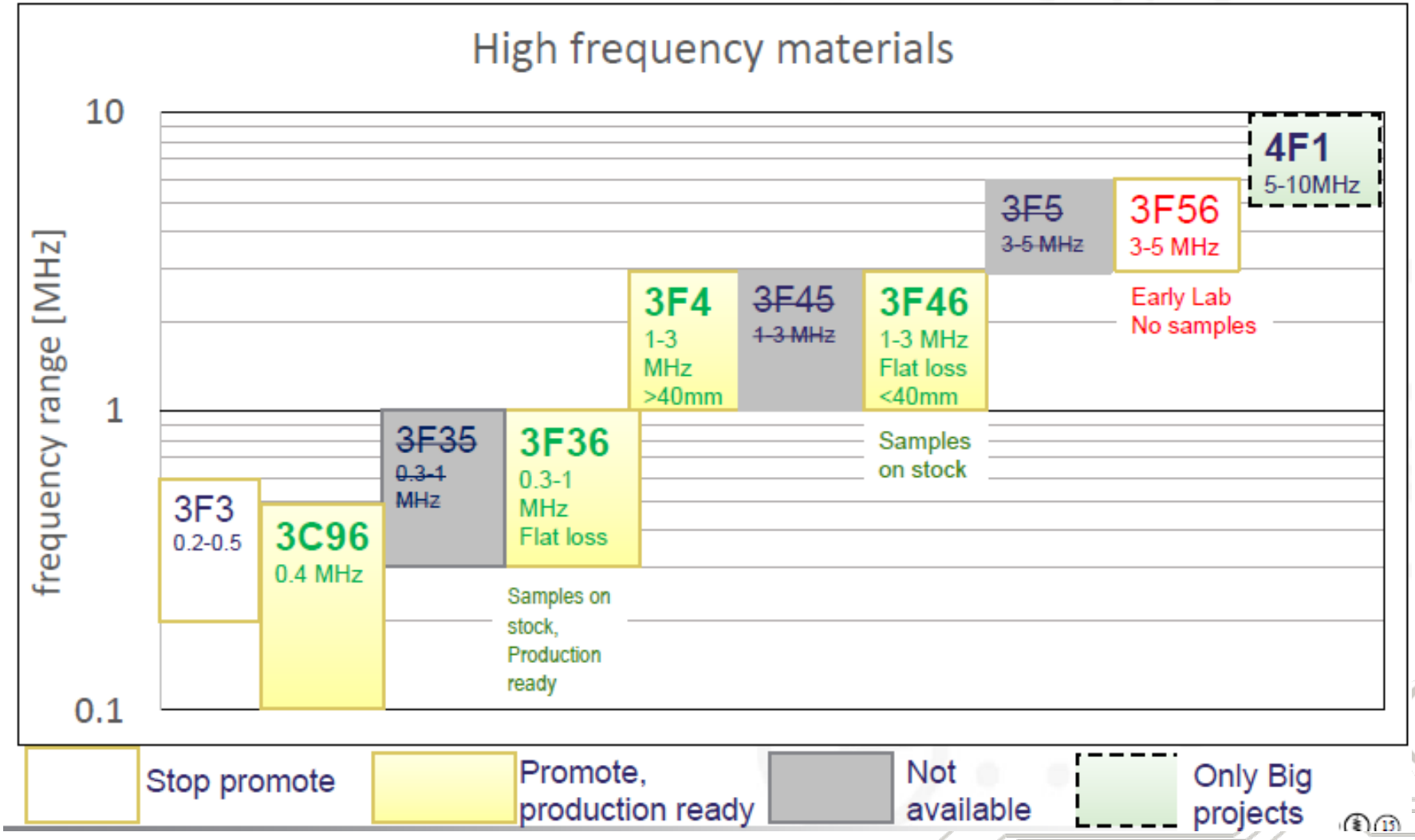


3C91, 3C92, 3C94, 3C96, Not flat losses materials
3C95 and 3C97 - Flat losses materials

3Cxx material selector

Material	Low loss 100C	Wide Temp	High Temp	Low Temp	High Bsat
3C91	√√	√√√	√	√√√	√√
3C92	√	√	√√	√	√√√
3C94	√√	√√	√	√√	√
3C95	√√	√√√	√√	√√√	√√
3C96	√√√	√	√√	√	√√√
3C97	√√√	√√√	√√√	√√	√√
3C98	√√√	√√	√√	√√	√√√
3C99			√√√		√√√

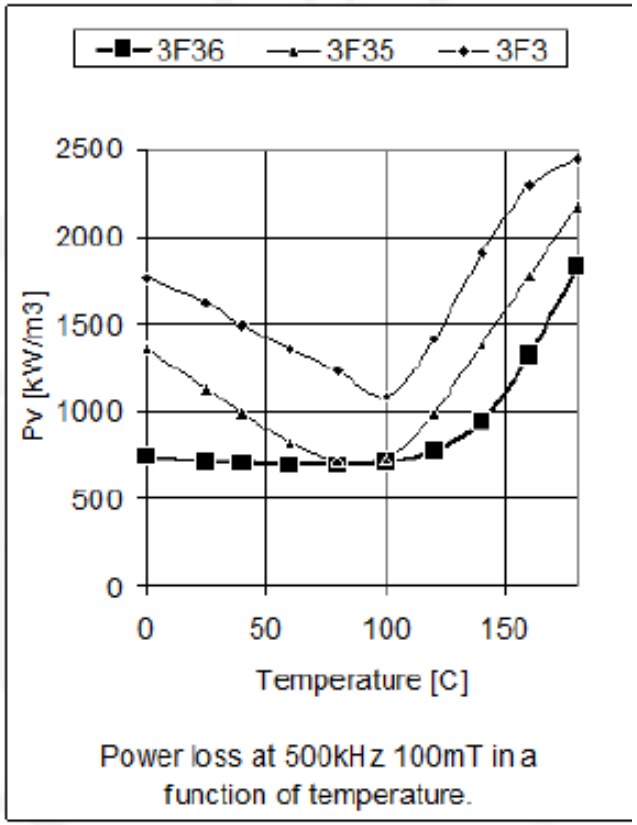
High Frequency power materials



3F36 - Flat MnZn material for power conversion

- Optimized for 300 – 1000 kHz
- Flat power loss
- Flat permeability
- High Bsat

	CONDITIONS	UNIT	3F36	3F35	3F3
μi	25ºC; 10kHz; 0.25mT		1600 ± 20%	1400 ± 20%	2000 ± 20%
μa	100ºC; 25kHz; 200mT		≈ 2400	≈ 2400	≈ 4000
B	25ºC; 10kHz; 1200A/m	mT	≈ 520	≈ 500	≈ 440
	100ºC; 10kHz; 200A/m		≈ 420	≈ 420	≈ 370
Pv	100ºC; 400kHz; 50mT	kW/m³	≈ 50	≈ 60	≈ 140
	100ºC; 500kHz; 50mT		≈ 90	≈ 90	≈ 220
	100ºC; 500kHz; 100mT		≈ 700	≈ 700	≈ 1200
ρDC	25ºC	Ωm	≈ 12	≈ 10	≈ 2
Tc		ºC	≥ 230	≥ 240	≥ 200
density		kg/m³	≈ 4750	≈ 4750	≈ 4700



Power loss at 500kHz 100mT in a function of temperature.

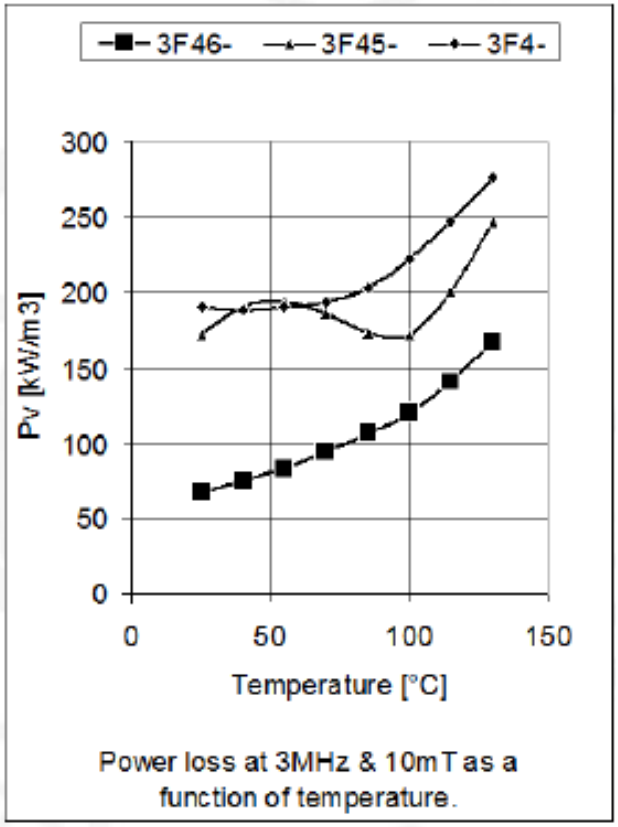
Table and chart refers to typical values for ring T25/15/10

Standard range: E13-E55, EFD, EP, EQ, ETD, P, planar E, planar ER, PQ, RM

3F46 - Flat MnZn material for power conversion

- Optimized for 1 - 3 MHz, small core size
- Outstanding power loss
- Flat μi
- High Bsat

	CONDITIONS	UNIT	3F46	3F46	3F45	3F4
MEASURED ON			T14/9/5	T25/15/10		
μi	25ºC; 10kHz; 0.25mT		750 ± 20%	750 ± 20%	900 ± 20%	900 ± 20%
μa	100ºC; 25kHz; 200mT		≈ 1500	≈ 1500	≈ 1700	≈ 1700
B	25ºC; 10kHz; 1200A/m	mT	≈ 520	≈ 520	≈ 410	≈ 410
	100ºC; 10kHz; 200A/m		≈ 430	≈ 430	≈ 370	≈ 350
Pv	100ºC; 1MHz; 50mT	kW/m³	≈ 150	≈ 300	≈ 300	≈ 600
	100ºC; 3MHz; 10mT		≈ 50	≈ 120	≈ 150	≈ 220
ρDC	25ºC	Ωm	≈ 5	≈ 5	≈ 10	≈ 10
Tc		ºC	≥ 280	≥ 280	≥ 300	≥ 220
density		kg/m³	≈ 4750	≈ 4750	≈ 4800	≈ 4700



Power loss at 3MHz & 10mT as a function of temperature.

Chart refers to typical values for ring T25/15/10

Standard range: EFD, EP, EQ, P, planar E, planar ER, PQ, RM

Summary

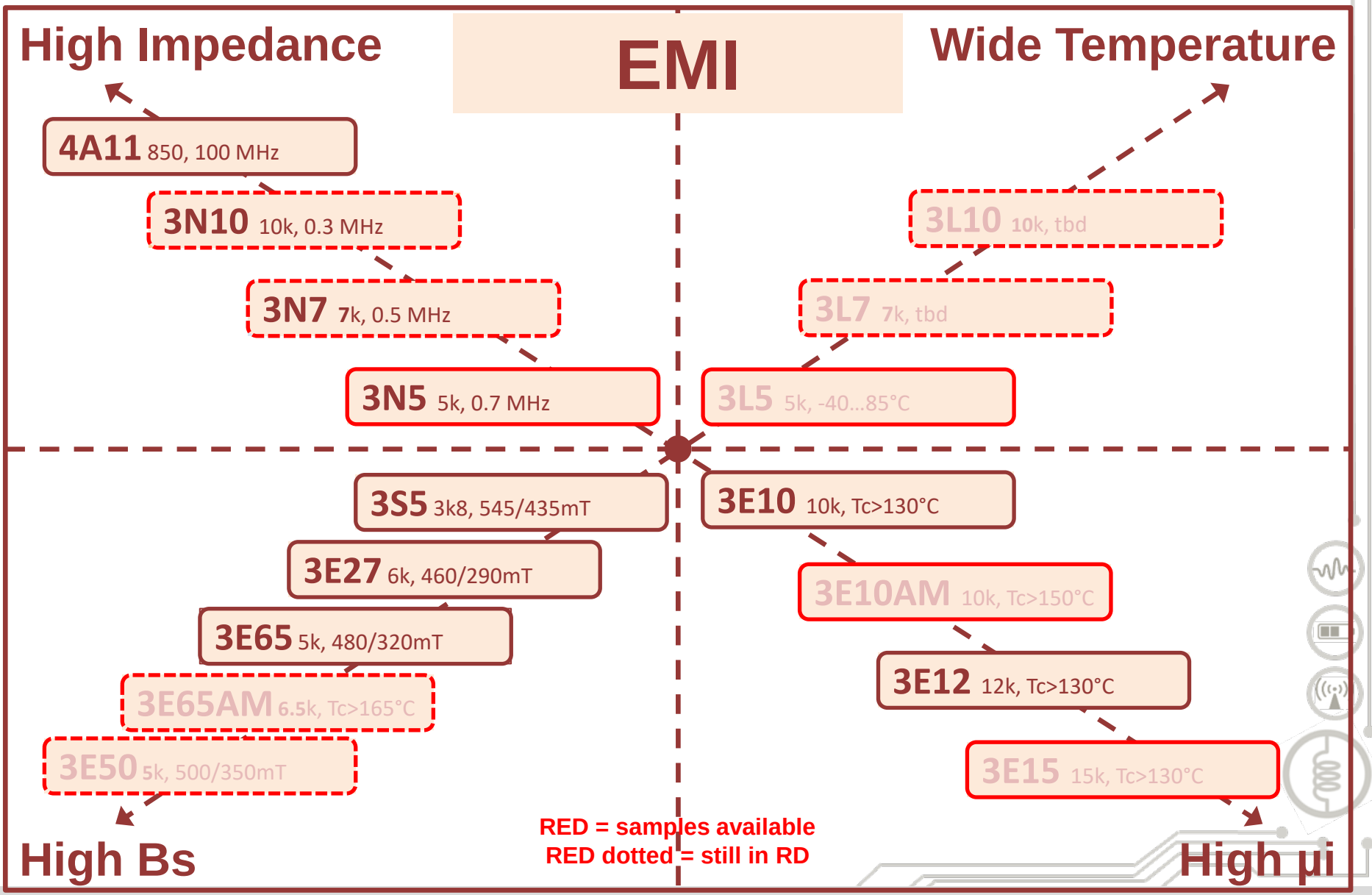
For low frequency power conversion (<300kHz)

Start Promote:

3C92, 3C95, 3C96, 3C97

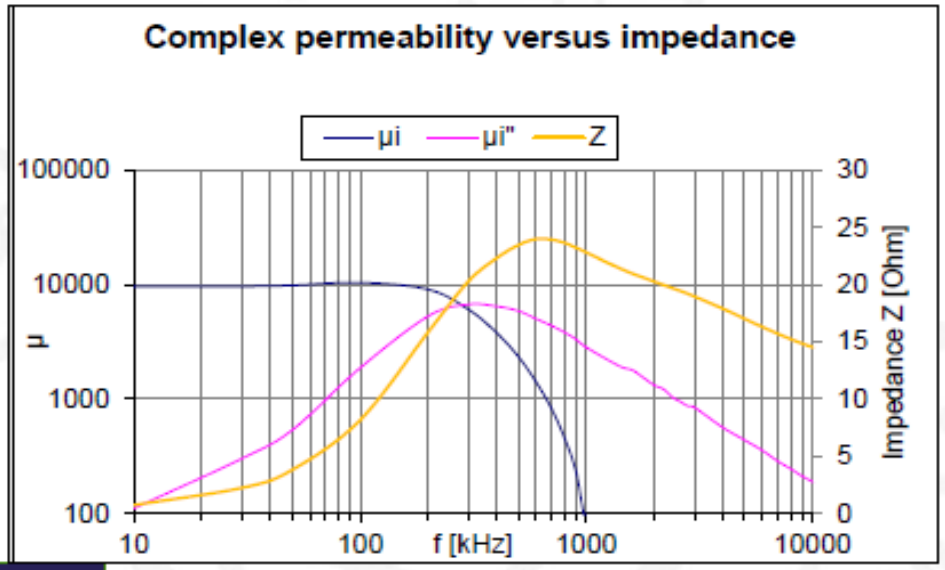
For High Frequency Power conversion (300kHz – 3MHz) **Start Promote:**

3F36, 3F4, 3F46


EMI
High Impedance
Wide Temperature
4A11 850, 100 MHz
3N10 10k, 0.3 MHz
3N7 7k, 0.5 MHz
3N5 5k, 0.7 MHz
3L10 10k, tbd
3L7 7k, tbd
3L5 5k, -40...85°C
3S5 3k8, 545/435mT
3E27 6k, 460/290mT
3E65 5k, 480/320mT
3E65AM 6.5k, Tc>165°C
3E50 5k, 500/350mT
3E10 10k, Tc>130°C
3E10AM 10k, Tc>150°C
3E12 12k, Tc>130°C
3E15 15k, Tc>130°C
High Bs
High μi
RED = samples available
RED dotted = still in RD

FXC EMI suppresion materials

- FXC EMI materials offer best in class frequency stability
- Both μ' and μ'' contribute to high impedance
- FXC offers a wide range of materials:



Material	Perm	Key feature
3E12	12k	High permeability
3E10	10k	Best balance μ-freq stability
3E27	6k	High impedance
3E65	5.2k	Automotive very high Tc
3C11	4.3k	Large cores TX63-TX140

$$|Z| = \omega \times N^2 \times \frac{Ae}{le} \times \mu_0 \times \sqrt{\mu'^2 + (\mu'' \cdot \omega)^2}$$

3E10 – Best Balance Perm-Frequency

- Optimized for 10 – 3000 kHz
- Broad frequency range
- Full range of sizes

Symbol	Conditions	Value	Unit
		3E10	
μ_i	25 °C; ≤10 kHz, 0.25 mT	10000±20%	
Bsat	25 °C; 10 kHz, 1200 A/m	≈ 460	mT
	100 °C; 10 kHz, 1200 A/m	≈ 270	
$\tan\delta/\mu_i$	25 °C; 30 kHz; 0.25 mT	≤ 5 x 10^{-6}	
	25 °C; 100 kHz; 0.25 mT	≤ 20 x 10^{-6}	
η_B	25 °C; 10 kHz; 1.5 to 3 mT	≤ 0.5 x 10^{-3}	T^{-1}
ρ	DC; 25 °C	≈ 0.5	Ωm
T_C		≥130	°C
Density		≈ 5000	kg/m^3

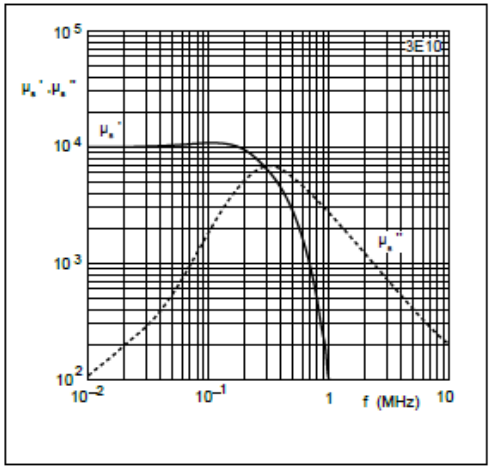


Fig. 1 Complex permeability as a function of frequency.

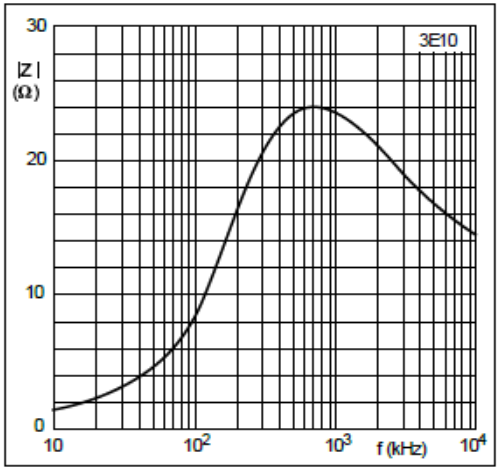


Fig. 5 Impedance as a function of frequency, measured on a toroid T25/15/10

3E65 – High temperature Common Mode EMI

NEW

- Optimized for 10kHz – 10 MHz
- Broad frequency range
- Full range of sizes
- Operating temp up to 155 °C (Curie temperature > 165°C)
- Magnetic flux density 480 mT

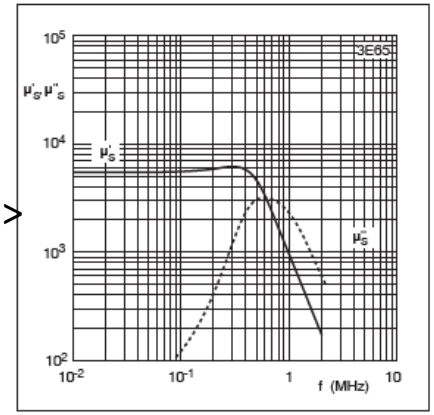


Fig. 1 Complex permeability as a function of frequency

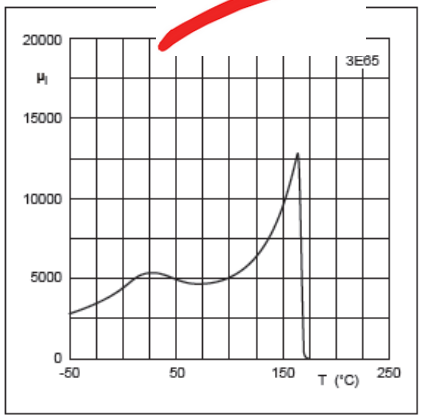
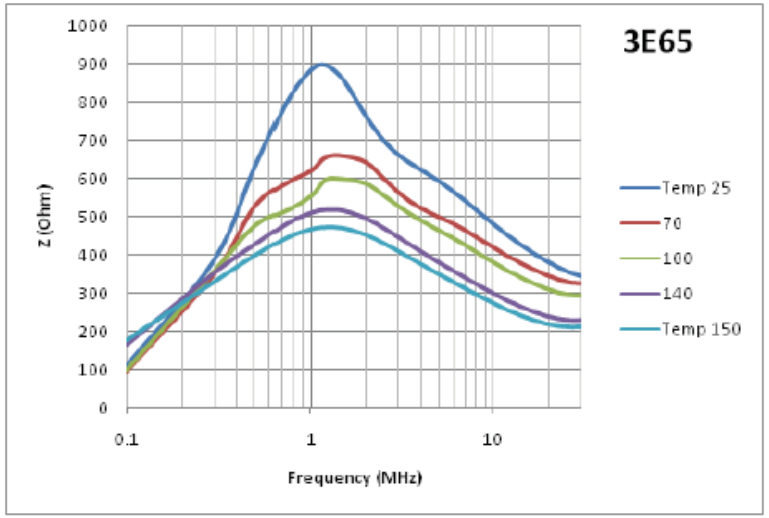


Fig. 2 Initial permeability as a function of temperature

3E65 SPECIFICATIONS

A medium permeability material with low losses and high Tc, optimized for use in wideband transformers as well as EMI-suppression filters.

SYMBOL	CONDITIONS	VALUE	UNIT
μ_i	25 °C; ≤10 kHz; 0.25 mT	5200 ± 20%	
B	25 °C; 10 kHz; 1200 A/m	≈ 480	mT
	100 °C; 10 kHz; 1200 A/m	≈ 320	
$\tan\delta/\mu_i$	25 °C; 100 kHz; 0.25 mT	≤ 10×10^{-6}	
$\tan\delta/\mu_i$	25 °C; 200 kHz; 0.25 mT	≤ 25×10^{-6}	
ρ	DC; 25 °C	≈ 0.5	Ωm
T_C		≥ 165	°C
density		≈ 4900	kg/m³



Summary

For low freqency EMC **Start Promote:**

3E10, 3E12, 3E27, 3E65, 3C11

For high freqeuncy EMC **Promote:**

4A11 (4S2), 3S4

Total Solution Provider for Power, EMI and RF

Thank you!