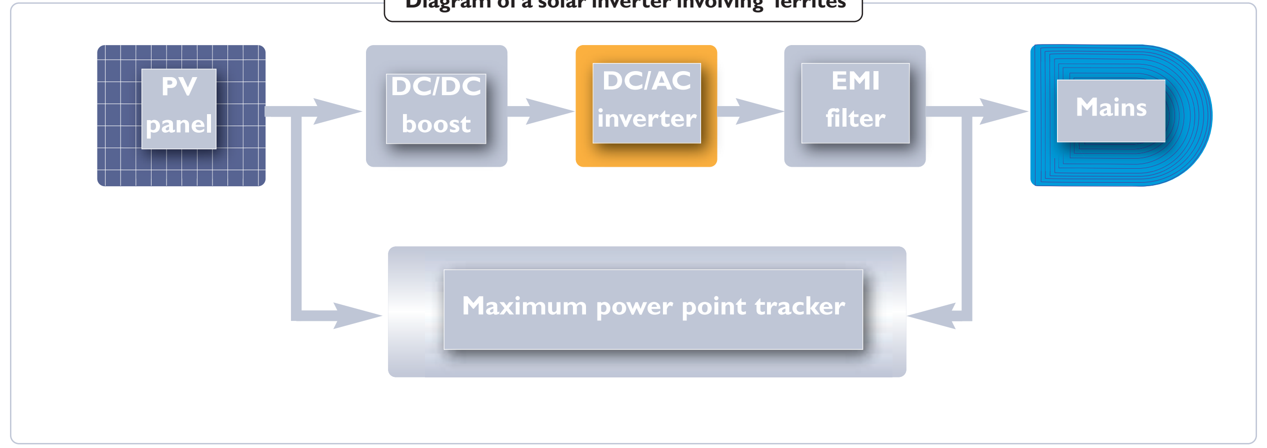
Ferroxcube ferrites in renewable energies

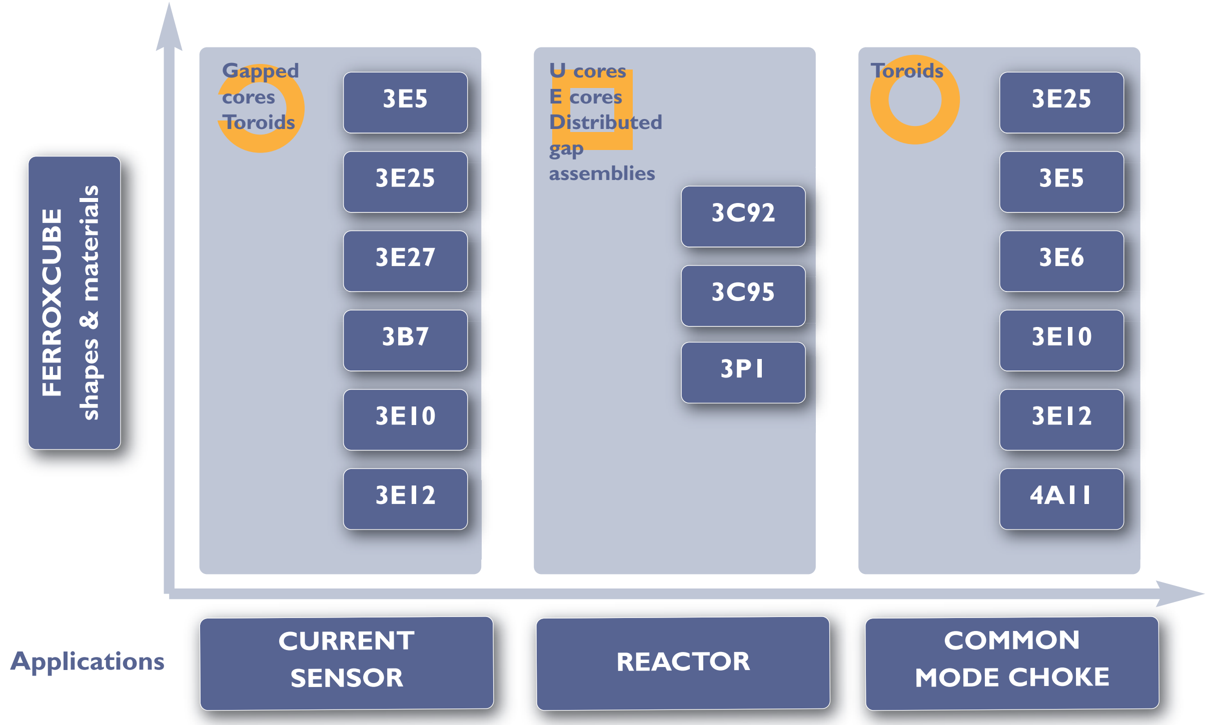
Ferroxcube ferrites have achieved great penetration in renewable energies market thanks to its leadership in materials and shapes. The constant adaptation to the latest technologies is one of our main assets. Power generation from the source to the mains, or power conversion, implies the use of different types of ferrites, especially in the case of solar inverters. Besides, we are working to offer outstanding solutions for the forthcoming development and expansion of renewable energy sources such as solar and wind power, as well as hybrid technologies.

This application note shows what type of Ferroxcube materials and shapes are suitable for each part of the inverter, and some of their features.

Diagram of a solar inverter involving ferrites


PV panel
DC/DC boost
DC/AC inverter
EMI filter
Mains
Maximum power point tracker

FERROXCUBE shapes and materials used in solar inverters


FERROXCUBE shapes & materials
Gapped cores
Toroids
3E5
3E25
3E27
3B7
3E10
3E12
U cores
E cores
Distributed gap assemblies
3C92
3C95
3P1
Toroids
3E25
3E5
3E6
3E10
3E12
4A11
Applications
CURRENT SENSOR
REACTOR
COMMON MODE CHOKE

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Internet: www.ferroxcube.com

Printed in Spain 9930 030 00011 Date of Release: March 2010

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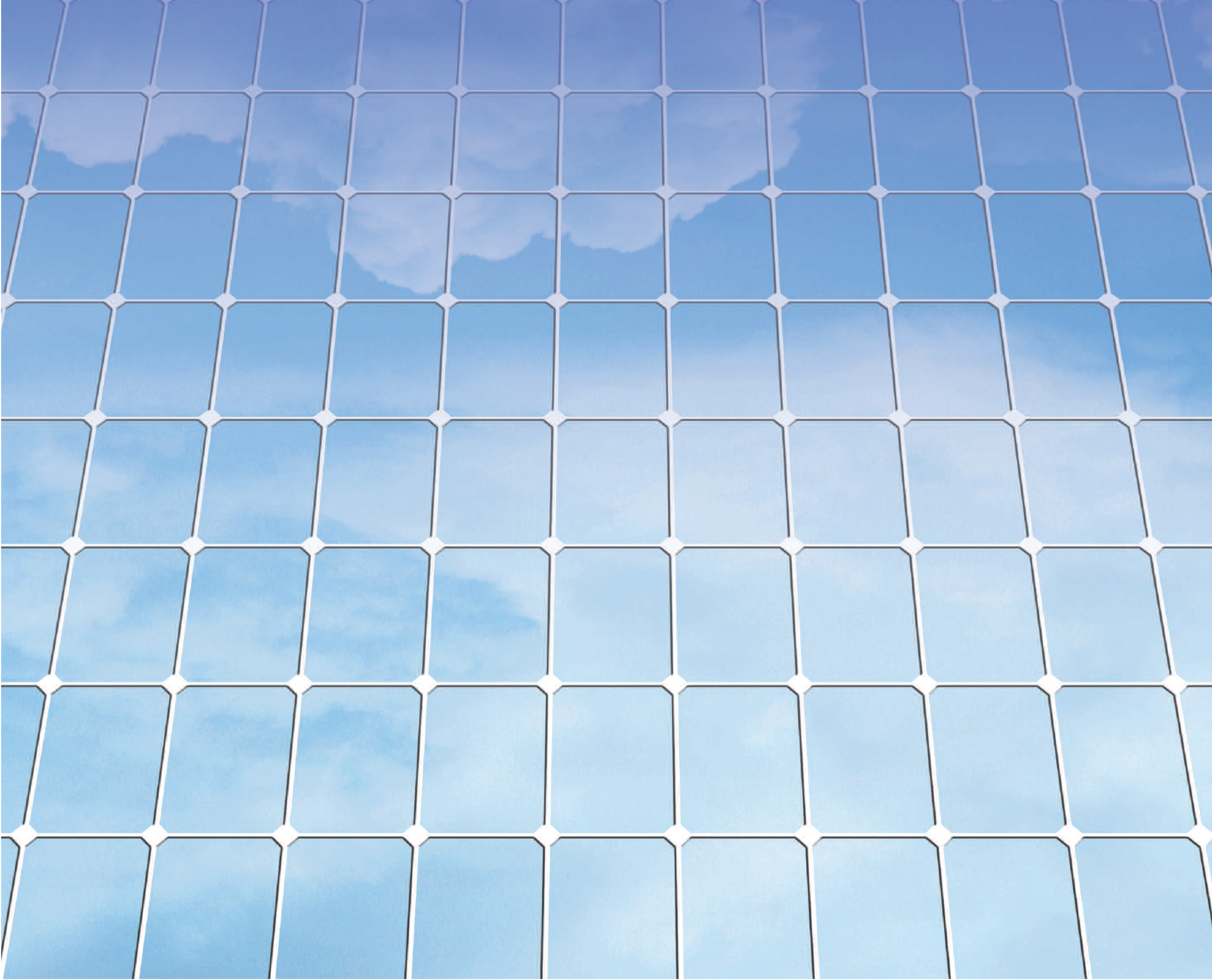
A YAGEO COMPANY

FERROXCUBE FERRITES IN RENEWABLE ENERGIES:

SOLAR INVERTERS



Energy storage inductors

The DC/DC converter supplies a continuous and stable voltage to the inverter in order to guarantee the minimum voltage level required to make the conversion possible. This implies to step up the voltage level provided by the cells. An energy storage element such as an inductor is required at this point. If galvanic isolation between the grid and the panels is needed, the DC/DC implements a transformer as a part of the boost converter.

The other inductive element of the power conversion process is the reactor, whose function is to smooth the output of the DC/AC module in order to provide the AC power signal to the grid. Inverter inductors must withstand high current and require large inductance. Consequently, the key parameter of reactors is their energy storage capability (dependent on the inductance and the current through the inductor), defined by

$W = LI^2 = B_{sat}H_{sat}V_e$ Energy

Materials

In order to optimize the energy, two types of materials are suggested:

- Ferrites: large cross section with gap, preferably distributed along the magnetic path length; in this way the Hsat is increased. 3C92 is optimal. 3C95, 3C97 are also possible.
- High saturation materials: new 3P1 material, with very high Bsat and Hsat.

The advantage of ferrites over 3P1 is that losses are significantly lower, thus the efficiency of the equipment is improved. On the other hand, 3P1 has very high Bsat, and the size of the core can be much smaller, hence cheaper and lighter. The final choice depends on the design conditions and preferences.

VARIETY OF MATERIALS

- *Low power losses at a wide range of temperature*
- *High Bsat materials*

Shapes

Optimal shape must be chosen to optimize:

- Ease of winding
- Core manufacturability
- Cooling
- Performance

Taking all these factors into account, Ferroxcube provides designers with the most suitable shape for each application, as well as support for new custom designs.

FLEXIBILITY OF SHAPES

- *Core stacking to increase Ae*
- *Different gapped shapes*
- *U cores, E cores, assembled cores, customized shapes*

Material characteristics for reactors

3C92: The perfect combination of high saturation and low losses

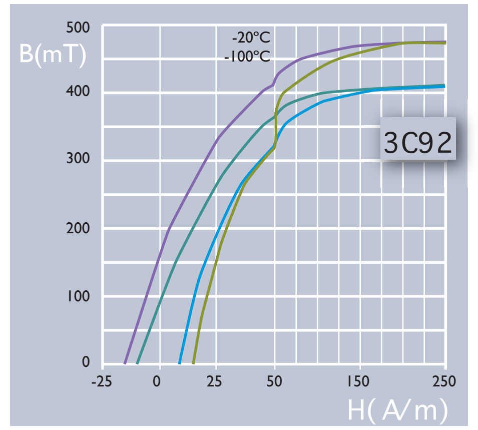


Fig. 1: Typical B-H loops

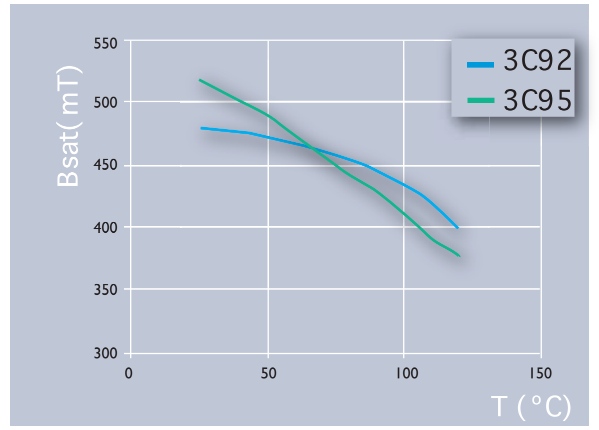


Fig. 2: T. Saturation flux density with temperature for different Ferroxcube power materials.

3C95: Stability with temperature and the lowest power losses

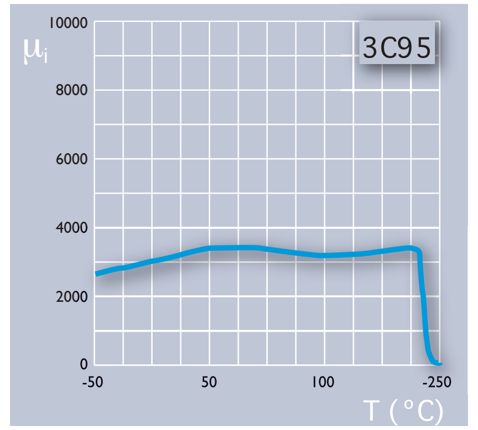


Fig. 3: Initial permeability versus temperature

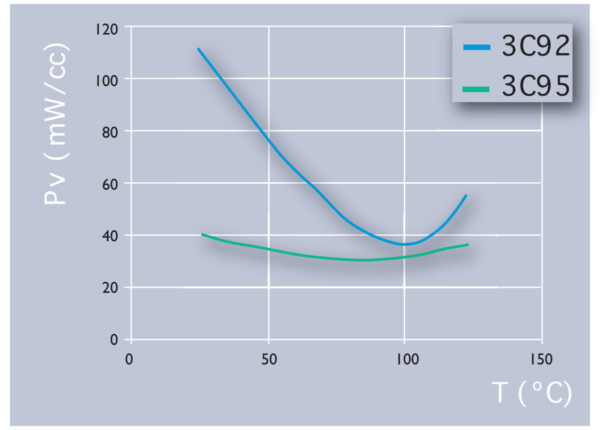


Fig. 4: Power losses with temperature, measured at 25 khz, 250mT

3P1: The lowest €/(Tesla·kg) in the market

3P1 features	
Permeability	110
Density (g/cc)	7.3
Saturation flux density (T)	1.45
€/(T kg)	5.5

Fig. 5: Main 3P1 features

Material	Amorphous	Sendust	High flux	Ferrite	3P1
€/(T kg)	9	17	44	13	5.5

Fig. 6: Comparative of €/T with other materials

Common mode chokes

The inverter requires protection against EMI noise coming from the long lines connecting the generators. At the same time it has to comply with EMC regulations, delivering a clean noise free power signal, and removing the switching harmonics.

The core shape used for this function is a big high permeability toroid. It requires high permeability because the harmonics are low frequency, in the range of 10 kHz to several hundreds. The size is big so as to allow winding with thick wire and withstand high currents. The higher the permeability and the bigger the core, the lower the number of turns in the winding, and thicker wires are possible, thus lower level of Copper losses.

Ferroxcube supplies large quantities of these cores to inverter manufacturers winding houses. Preferred materials are 3E5, 3E6, 3E25 for lower frequencies, and 4A11 for high frequency noise. New materials 3E10 and 3E12, with higher permeability and tighter tolerance are also recommended for this part of the inverter.

Typical materials for common mode choke

The following charts show impedance versus frequency for different materials. Material selection should be done based on the aforementioned application parameters.

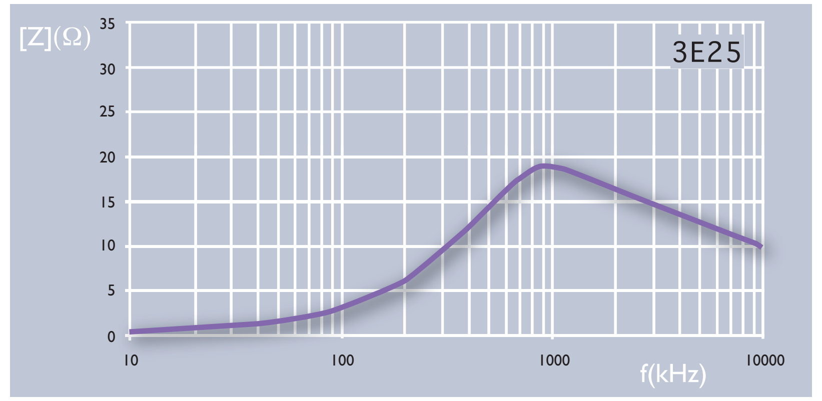


Fig. 8: Impedance as a function of frequency measured on a coated toroid of Ø36xØ23xh15mm

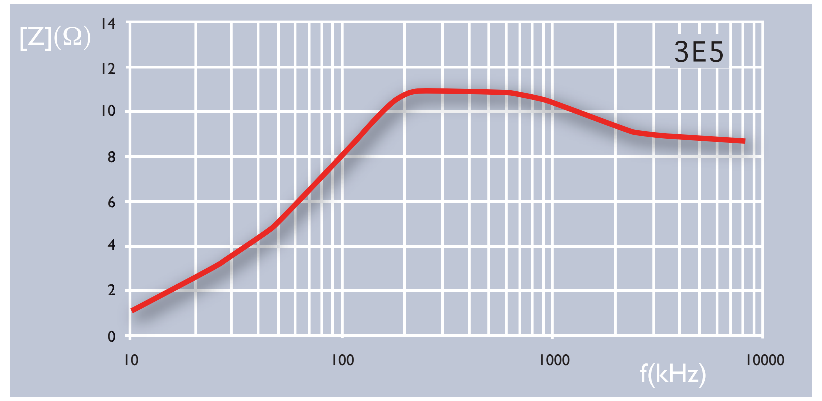


Fig. 9: Impedance as a function of frequency measured on a coated toroid of Ø36xØ23xh15mm

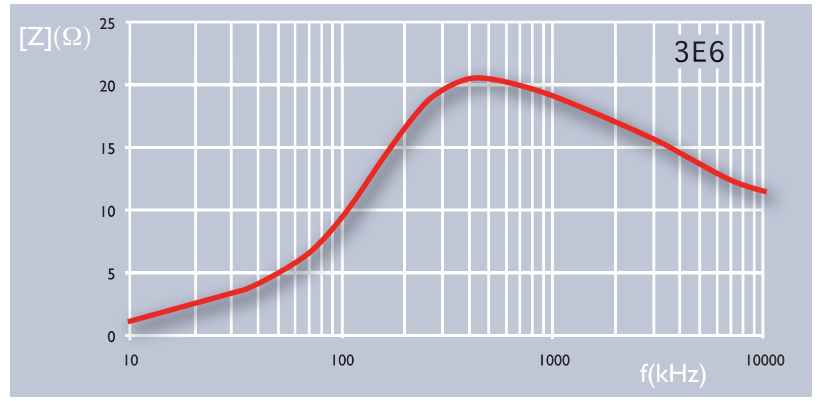


Fig. 10: Impedance as a function of frequency measured on a coated toroid of Ø36xØ23xh15mm

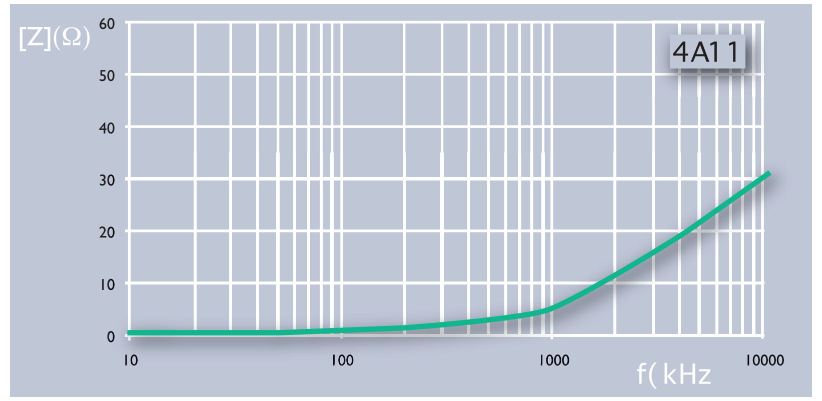


Fig. 7: Impedance as a function of frequency measured on a coated toroid of Ø36xØ23xh15mm

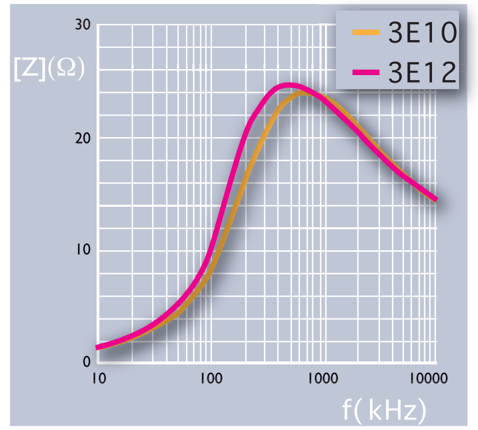


Fig. 11: Impedance as a function of frequency measured on a toroid of Ø25Ø15xh10mm