Measuring technique to characterize magnetic components & cores

JC Sun

Munich, 2017-12-5

WBG conference

Bs&T Frankfurt am Main
Hannah Arendt Str. 36
60438 Frankfurt am Main

Outline

- Introduction
- Nonlinearity
  magnetization curve and hysterese loop
- Characterize inductive components
- Characterize cores according to standards
- Conclusion

JC and his...

- physicist & engineer
- make and design ferrite 3Cx and 3Fx

FERROXCUBE
A YAGEO COMPANY

- sales amorphous metals 2605/2714/2705

Metglas®

- marketing nanocrystalline 500F components

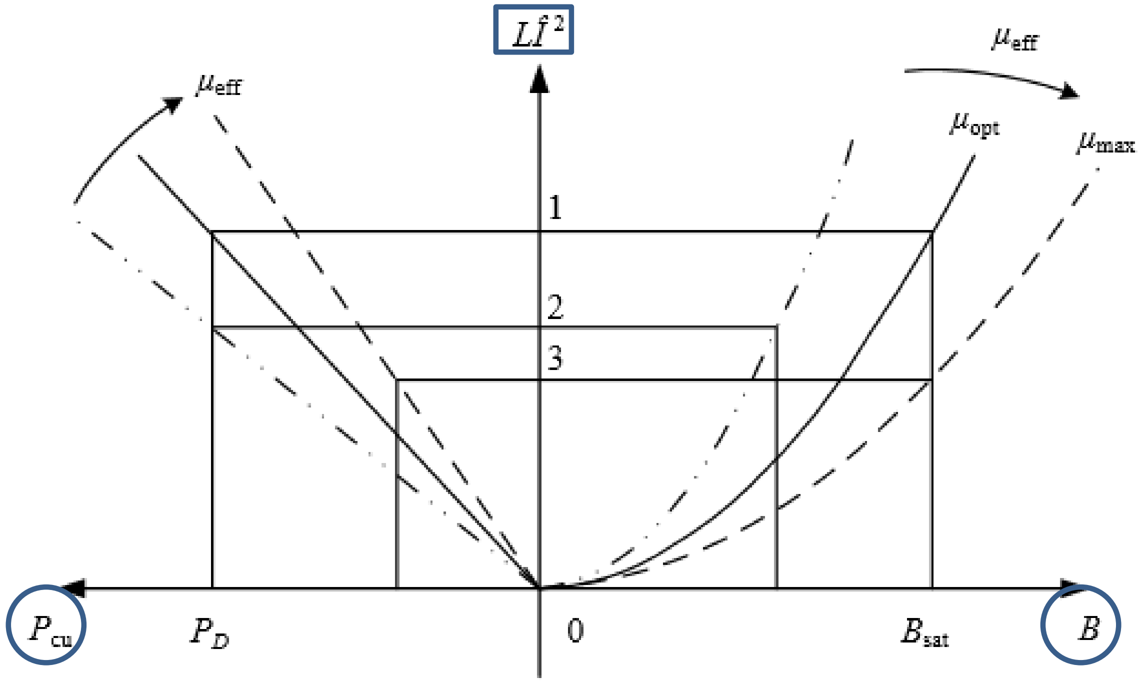
VAC
VACUUMSCHMELZE

- Bs & T Frankfurt am Main GmbH

Bs&T Analyzer

Design of inductor - to find optimum μ_{eff}

$$\tfrac{1}{2} L \hat{I}^2 = \tfrac{1}{2} \frac{A_c l_c}{\mu_{eff} \mu_0} B^2_{max} \qquad \tfrac{1}{2} L \hat{I}^2 = \tfrac{1}{2} \frac{\mu_{eff} \mu_0 A_c N A_w}{\rho_w \, \mathrm{MLT} \, K_i^2 l_c} P_{cu}$$



Stored energy as a function of flux density and dissipation

Bs&T

What is µ and μ_{eff} ?

- Amplitude permeability μ_a
- Incremental permeability μ_Δ
  - Reversible permeability μ_{rev}
- **Effective permeability μ_e**

- Initial permeability μ_i
  - Ferrite: @ B< 0,25 mT, f< 25 kHz IEC62044 TC51 WG1
  - Alloy: $\mu_{\_index}$ mA/cm IEC60404 TC68 WG2

Bs & T Analyzer

cores

components

Sinusoidal Magnetization AC

Pulse Magnetization AC

high excitation	low excitation	fast transit of magnetic state
IEC 62044-3	*IEC 62044-2*	dB/dt

loss, μ_a driven by B mode

B_{peak}, loop driven by H mode

DC superposition

BsT-Pro

loss map (f, B, T, H_{DC}) μ_{rev}

major, and biased minor loop

BsT-Pulse

differential and amplitude L

energetic L, power loss

Core Material is Nonlinear and shows Saturation

Nonlinear effects are mathematically difficult to describe and often not intuitive

Flux linkage

„secant“ inductance:

$$L_s(i) = \frac{N \cdot \Phi}{i} = \frac{\Psi}{i}$$

„differential“ inductance :

$$L_d(i) = \frac{\mathrm{d}(N \cdot \Phi)}{\mathrm{d}i} = \boxed{\frac{\mathrm{d}\Psi}{\mathrm{d}i}}$$

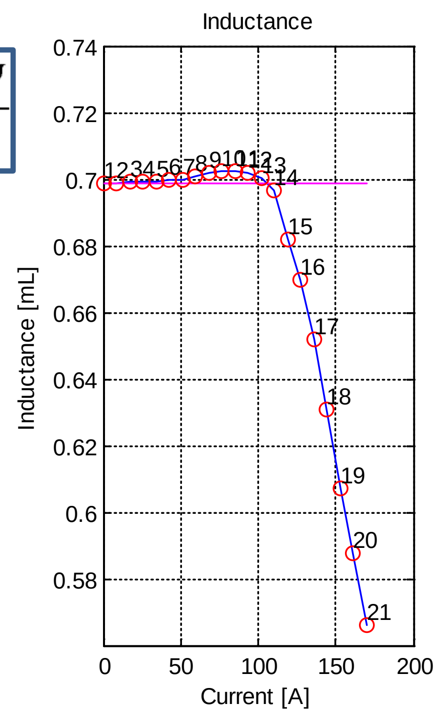
$$v(t) = L_d(i) \cdot \frac{\mathrm{d}i}{\mathrm{d}t} = \boxed{\frac{\mathrm{d}\Psi}{\mathrm{d}i}} \cdot \frac{\mathrm{d}i}{\mathrm{d}t} = \frac{\mathrm{d}\Psi}{\mathrm{d}t} =$$

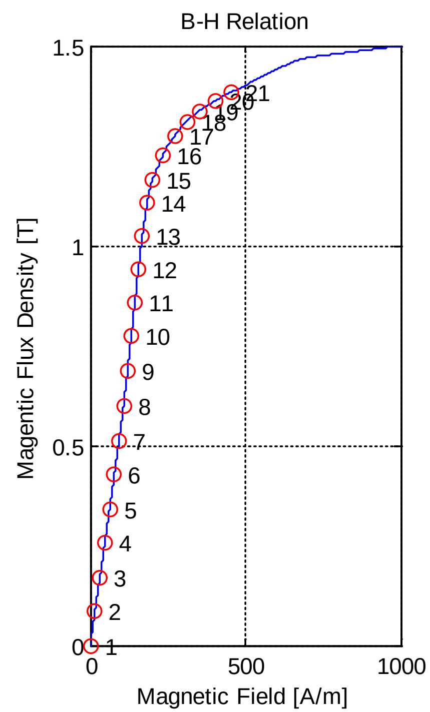
$$\frac{\mathrm{d}\left[i \cdot L_s(i)\right]}{\mathrm{d}t} = L_s(i) \cdot \frac{\mathrm{d}i}{\mathrm{d}t} + i \cdot \frac{\mathrm{d}L_s(i)}{\mathrm{d}t}$$

$$\rightarrow L_s(i) = \frac{1}{i} \int_0^i L_s(i')\, di'$$

Energetic inductance:

$$L_e(i) = \frac{2}{i^2} \int_0^i i \cdot L_s(i')\, di'$$





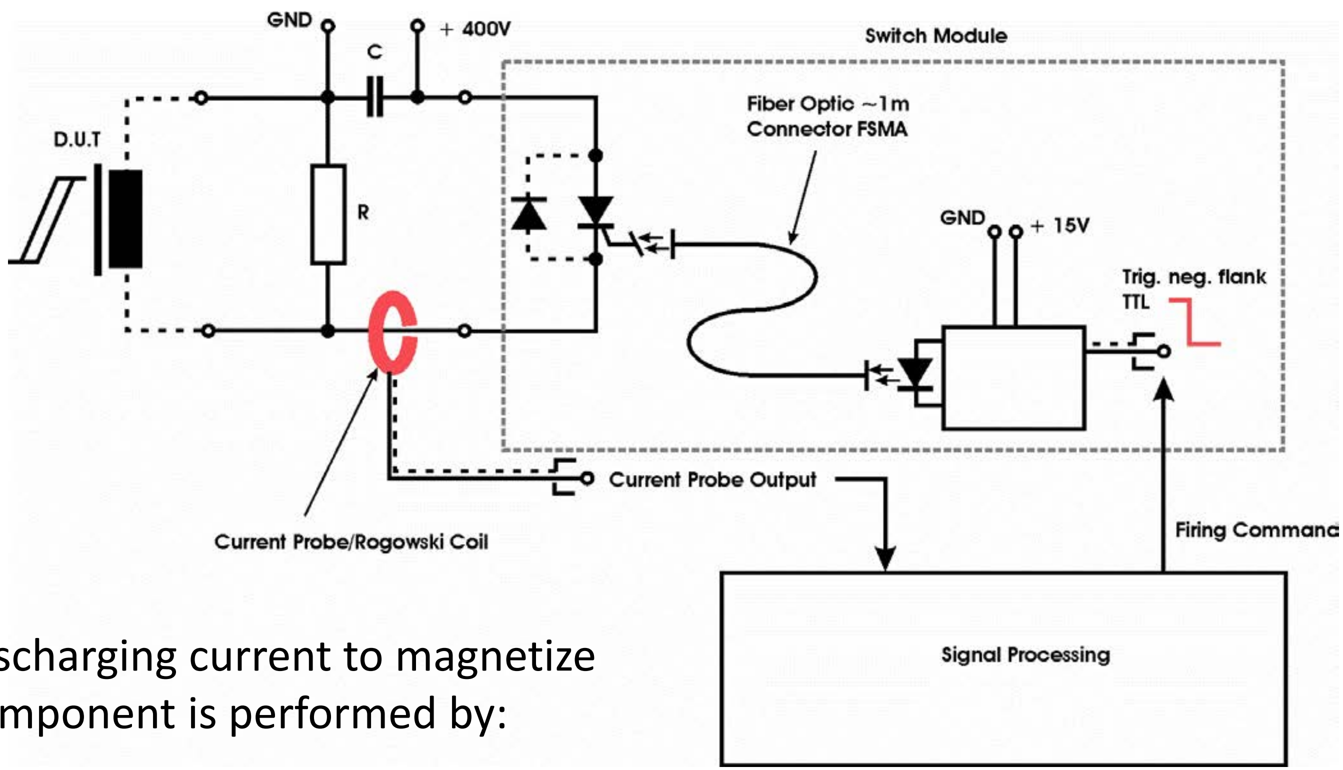
Discrepancy – Problem

- Usually, Inductance of choke is specified with no load
- Often, Inductance of choke is in use under load

- Manufacturer provides material characteristics i.e. permeability under low excitation; and indicates only **TYPICAL** value under load, mostly with *fitting* parameters
- Choke maker needs to commit with **LIMIT** value to his design

measurement is indispensable, and requires good judgment and this is only possible if the underlying scientifice issues are understood

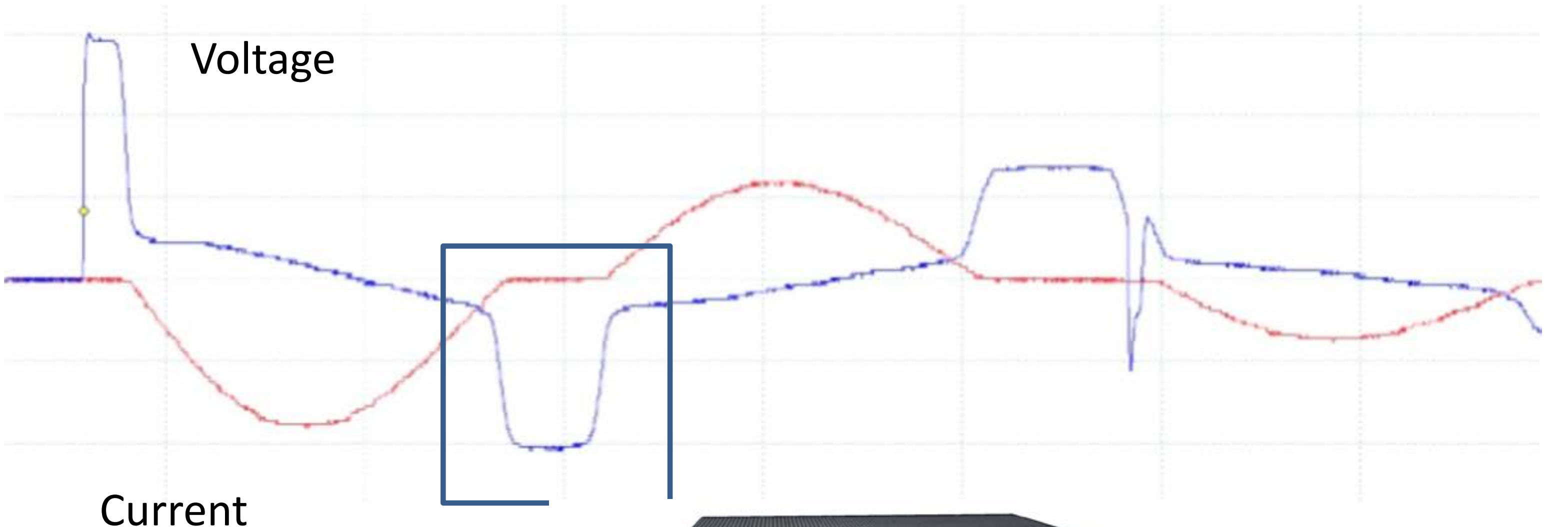
Circuit to characterize components



Discharging current to magnetize component is performed by:

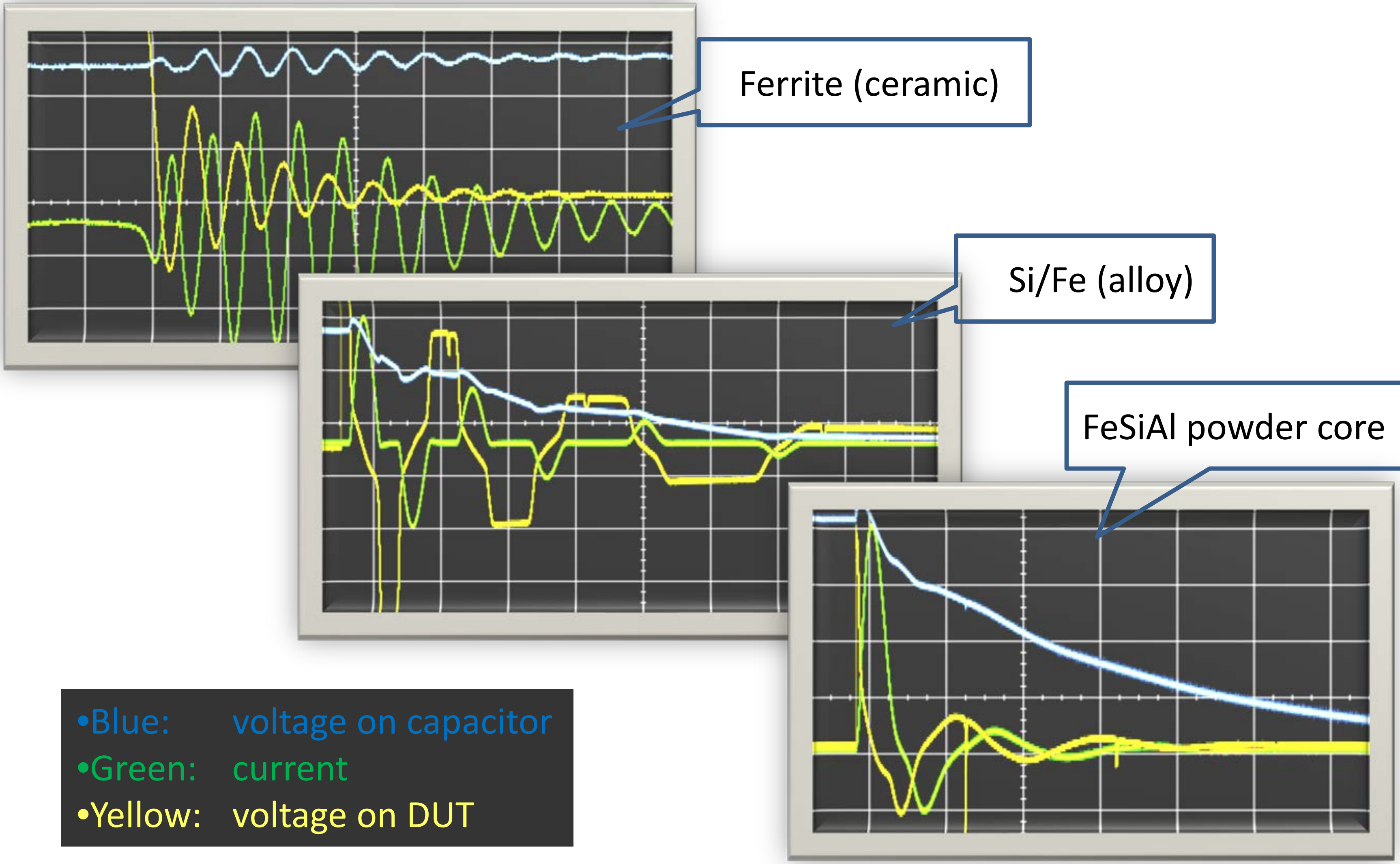
•Thyristor (BsT-pulse)

Typical cycle of measurement



New !

Examples of different materials



Solution with di/dt tester

- Incremental Permeability can be quantified as Amplitude, or Reversible Permeability by definition
- Incremental Permeability can be measured by pulse with large magnetization current amplitude in time range of µs ~ ms, without potential temperature increased caused by heat dissipation
- With calculation by input of magnetic effective geometric parameter, the demagnetization curve can be provided, not only typical but also limit value can be specified for material vendor, winding house and and component user

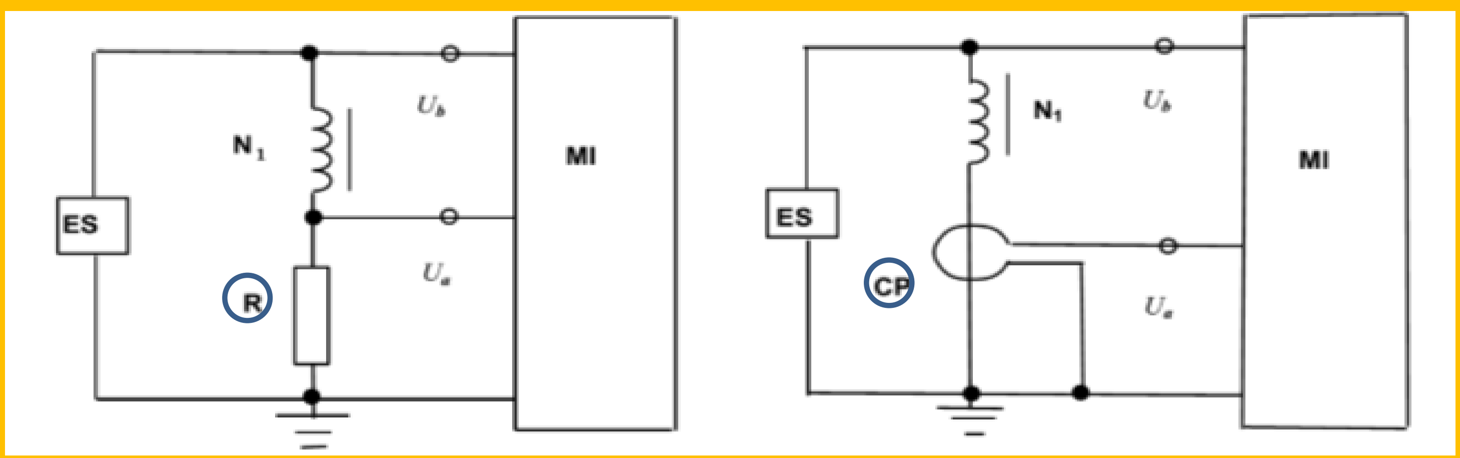
Output choke design

Core loss measurement acc. IEC 62044-3

Power loss

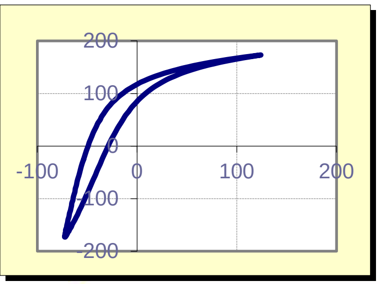
Table 1 – Some multiplying methods and related domains of excitation waveforms, acquisition, processing

Measuring method	Domain of useable excitation waveform	Domain of acquisition	Domain of processing	Subclause of annex C
V-A-W meter	Sinusoidal	Time	Time	C.1.1
Impedance analyser	Sinusoidal	Not applicable	Not applicable	C.1.2
Digitizing	Arbitrary	Time	Time	C.1.3
Vector spectrum	Arbitrary	Frequency	Frequency	C.1.4
Cross-power	Arbitrary	Time	Frequency	C.1.5

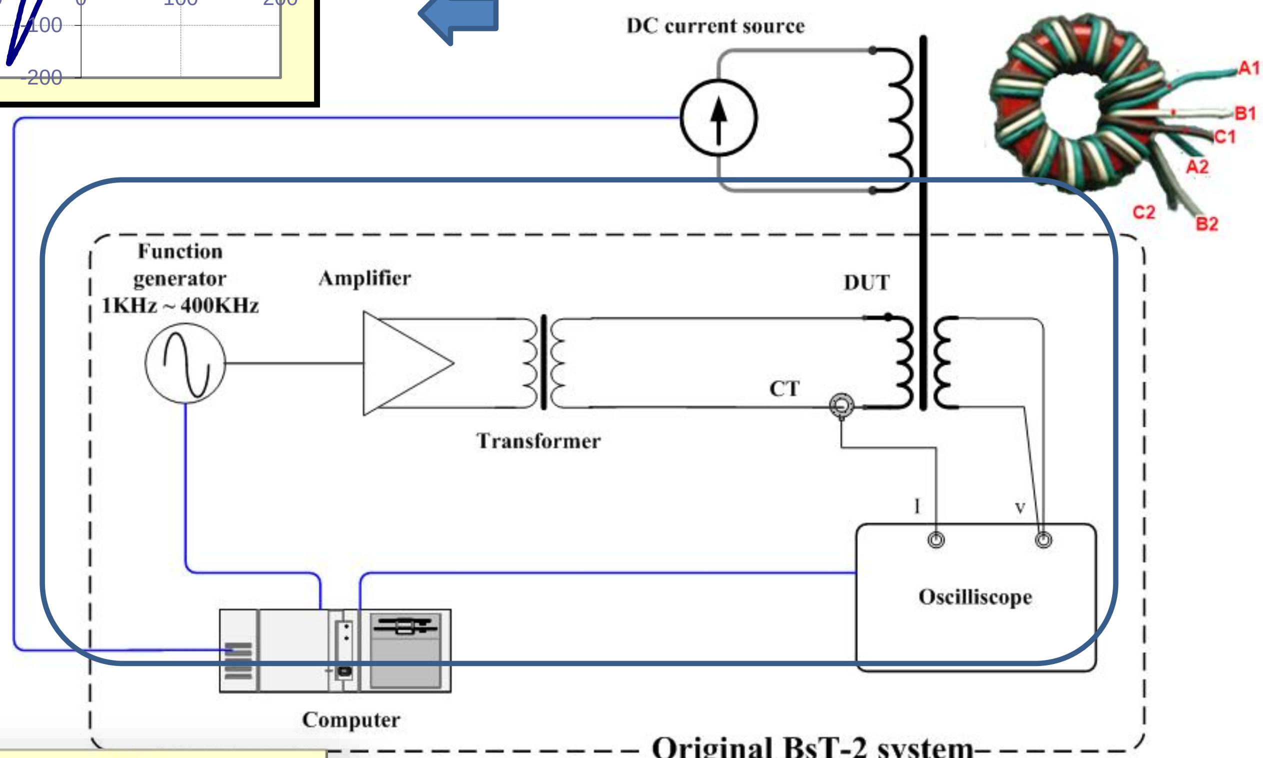


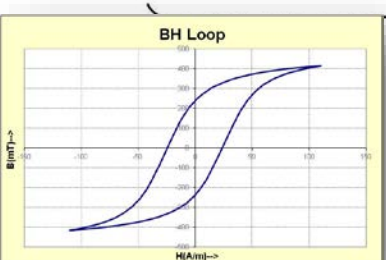
Part of IEC62044-3

Configuration BsT-Pro



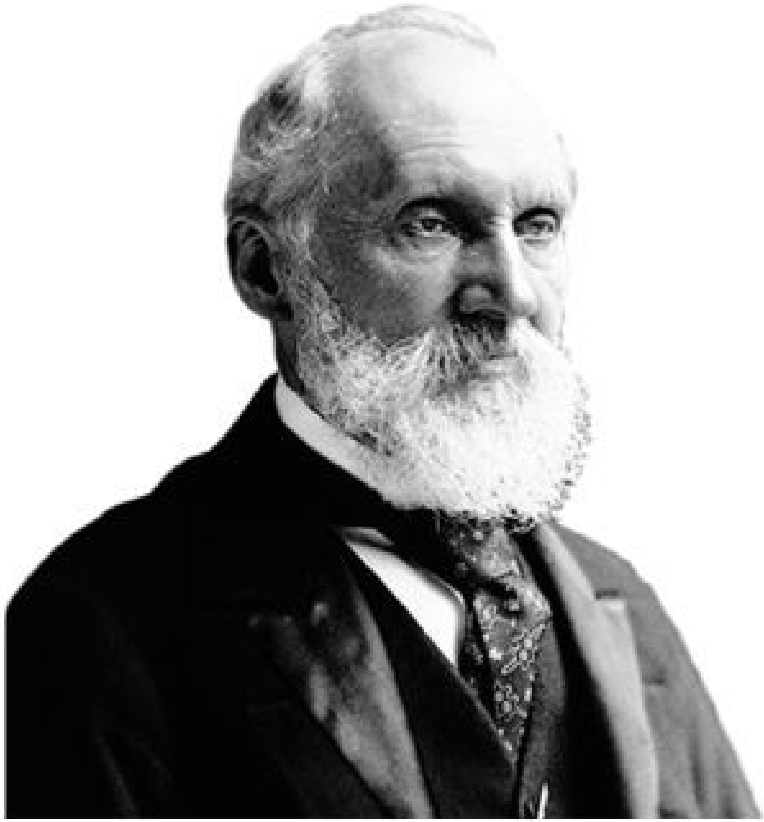
BsT-pro 3 windings scheme





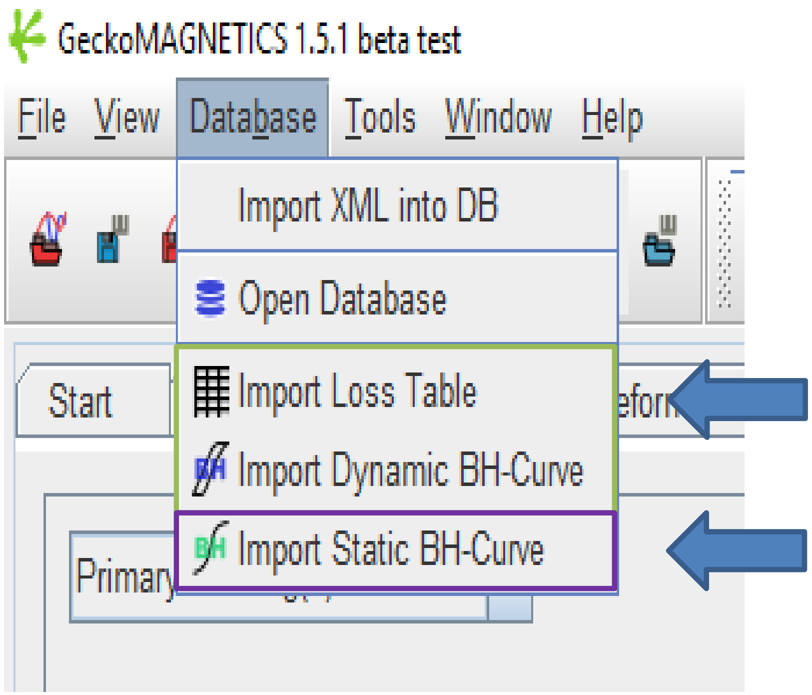
Conclusion

- BsT-Pulse based on thyristor technology (kA within ms) is the impulse device to charachterize the magnetic component; provides essential information to specify the limit inductance value under load
- BsT-Pro extend AC core conform IEC62044/3 with biased DC
- Output (measured data) can be read directly into material library for design and model of inductive component with tools like GeckoMagnetics (annex @ booth)
- Measurements means knowledge, are the prerequisite for any conceivable development in the production and trading of goods, incl. inductive component and core



To measure
is to know.
If you can not
measure it,
you can not
improve it.
- Lord Kelvin

Annex measuring data for simulation



import_loss_table.mp4

BsT-Pro 2016

BsT-Pulse 2017

Video import loss map as an example ***FeSiAl*** powder material:
Step 1: rename particular material
Step 2: mark frequency, flux density, and bias, and import