IWATSU

AC core loss measurement on high phase angle material

Power Magnetics @ High Frequency – Eliminating the Smoke and Mirrors

Technology Demonstration Session
on 3rd March, 2018

Iwatsu Electric Company Limited
Ryu Nagahama

PRODUCTS OF IWATSU ELECTRIC

PRODUCTS（Test and Measurement Business）

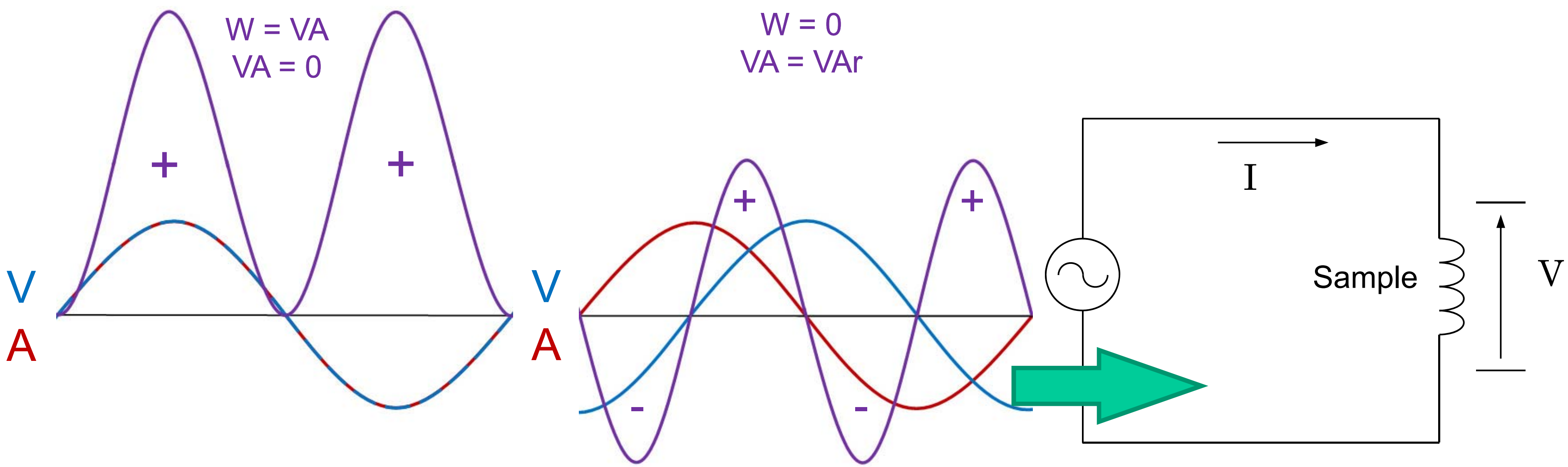
- B-H Analyzer
- Digital Oscilloscope
- Curve Tracer
- Isolation System up to 500MHz BW
- Basic Measurement (DMM, Counter, Signal Generator)
- Isolation Probe
- Current and Voltage Probe

Think Important Issue for Power Loss Measurement

- Measuring method
  - Excitation method ?
    - – Power Analyzer
    - – B-H Analyzer
    - – Digitizer
  - **Condition**
    - – Temperature ?
    - – Humidity ?

1. Power Loss Measurement by Power Analyzer

1.1 Issues in low power factor of the power measurement



Unity power factor

Zero power factor

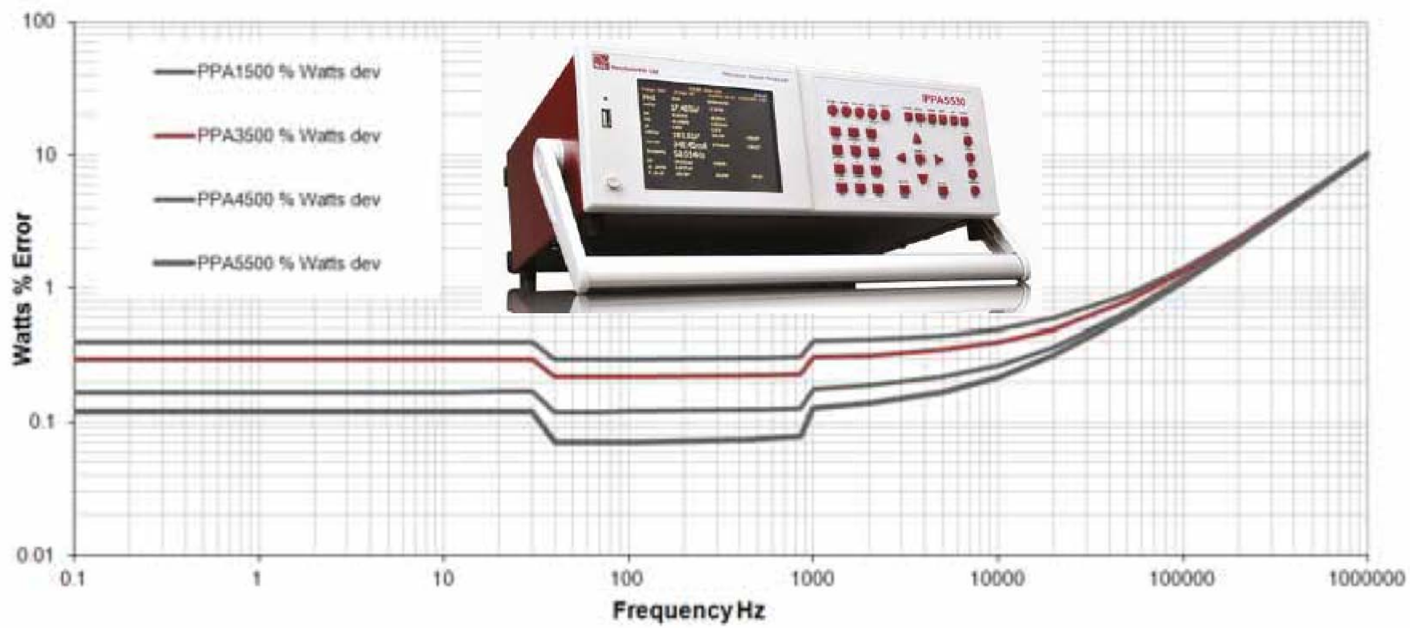
When close to the power factor = 0,

$$Pc = I_{rms} \cdot V_{rms} \cdot \cos\theta$$

Maximum of the power error at zero power factor.

Reference N4L Application

1.2 Power Analyzer Accuracy



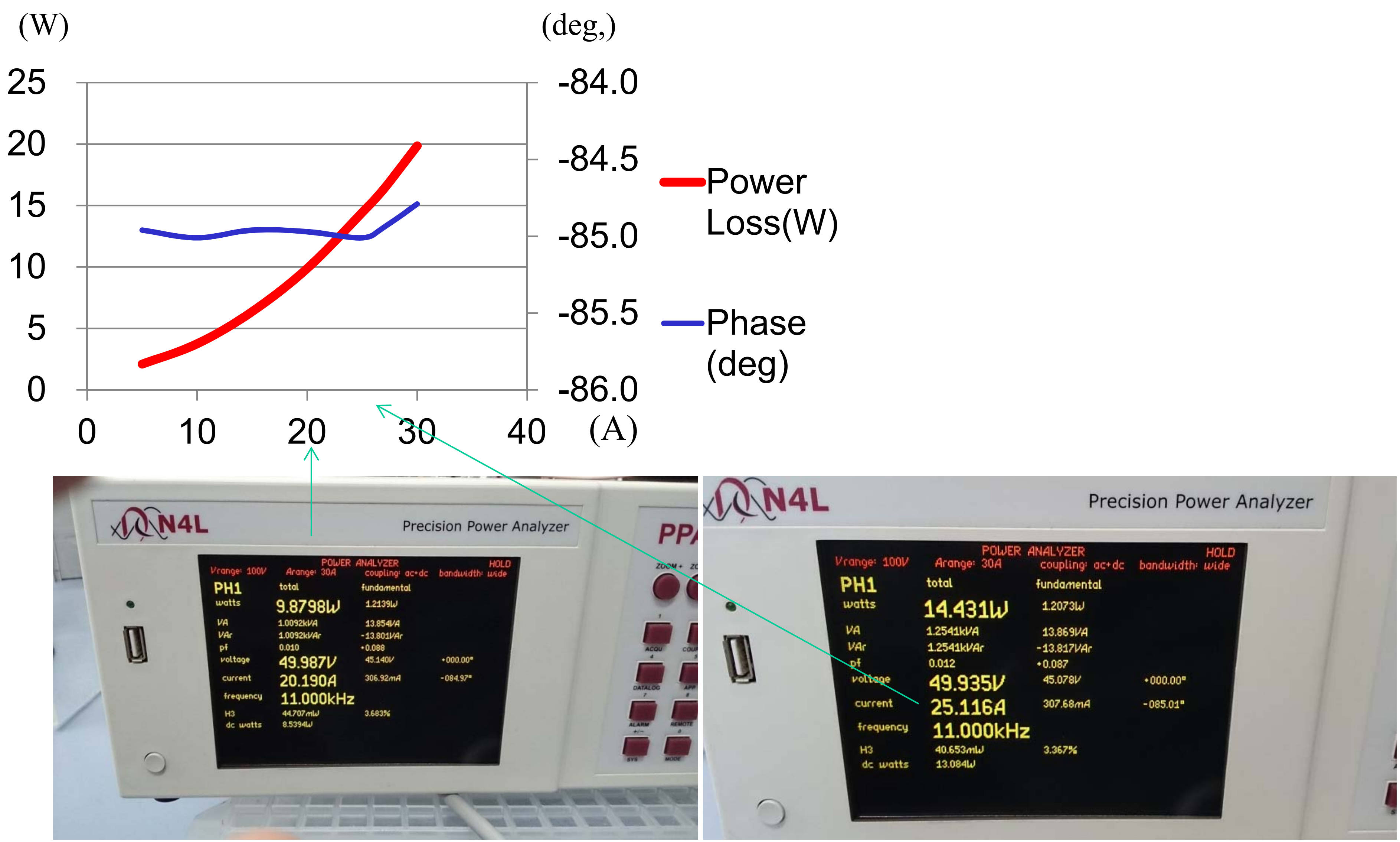
21 Nov 2011 17:35   Script file: KinetiQ PPA5500 low power factor test v2.01
Automatic Calibration Environment release ACE v2.33
NEWTONS4TH,PPA5530,00773,2.51
Fluke,6105A,176162845,2.12

Summary report

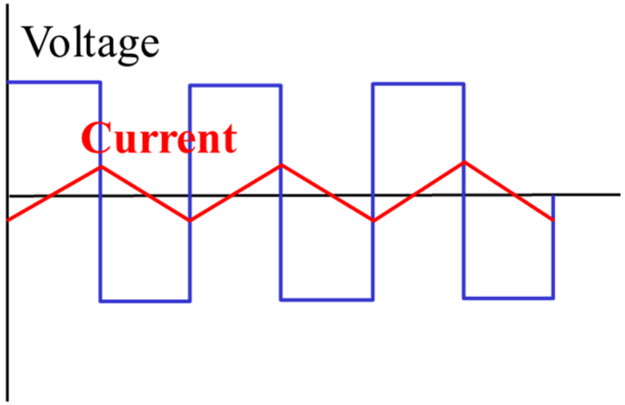
Verify power measurement at different phase angles at 220V 5A

	frequency	applied					phase 1		phase 2		phase 3		VA deviation	VA spec	W deviation	W spec
OK:	55.00 Hz	1.1000kVA	1.1000kW	0.000°	7	6	1.0998kVA	1.0998kW	1.0998kVA	1.0997kW	1.0998kVA	1.0998kW	<-0.02%>	[0.14%]	<-0.03%>	[0.14%]*
OK:	55.00 Hz	1.1000kVA	1.0958kW	5.000°	7	6	1.0998kVA	1.0956kW	1.0998kVA	1.0956kW	1.0998kVA	1.0956kW	<-0.02%>	[0.14%]	<-0.02%>	[0.14%]*
OK:	55.00 Hz	1.1000kVA	1.0833kW	10.00°	7	6	1.0998kVA	1.0831kW	1.0998kVA	1.0831kW	1.0998kVA	1.0831kW	<-0.02%>	[0.14%]	<-0.02%>	[0.14%]*
OK:	55.00 Hz	1.1000kVA	1.0625kW	15.00°	7	6	1.0998kVA	1.0623kW	1.0998kVA	1.0623kW	1.0998kVA	1.0623kW	<-0.02%>	[0.14%]	<-0.02%>	[0.15%]*
OK:	55.00 Hz	1.1000kVA	1.0337kW	20.00°	7	6	1.0999kVA	1.0335kW	1.0998kVA	1.0335kW	1.0998kVA	1.0335kW	<-0.02%>	[0.14%]	<-0.02%>	[0.15%]*
OK:	55.00 Hz	1.1000kVA	996.94 W	25.00°	7	6	1.0998kVA	996.78 W	1.0998kVA	996.75 W	1.0998kVA	996.77 W	<-0.02%>	[0.14%]	<-0.02%>	[0.15%]*
OK:	55.00 Hz	1.1000kVA	952.63 W	30.00°	7	6	1.0998kVA	952.48 W	1.0998kVA	952.45 W	1.0998kVA	952.47 W	<-0.02%>	[0.14%]	<-0.02%>	[0.16%]*
OK:	55.00 Hz	1.1000kVA	901.07 W	35.00°	7	6	1.0998kVA	900.93 W	1.0998kVA	900.91 W	1.0998kVA	900.93 W	<-0.02%>	[0.14%]	<-0.02%>	[0.17%]*
OK:	55.00 Hz	1.1000kVA	842.65 W	40.00°	7	6	1.0998kVA	842.53 W	1.0998kVA	842.51 W	1.0999kVA	842.52 W	<-0.02%>	[0.14%]	<-0.02%>	[0.18%]*
OK:	55.00 Hz	1.1000kVA	777.82 W	45.00°	7	6	1.0998kVA	777.70 W	1.0998kVA	777.69 W	1.0999kVA	777.70 W	<-0.02%>	[0.14%]	<-0.02%>	[0.19%]*
OK:	55.00 Hz	1.1000kVA	707.07 W	50.00°	7	6	1.0998kVA	706.97 W	1.0998kVA	706.96 W	1.0999kVA	706.96 W	<-0.02%>	[0.14%]	<-0.02%>	[0.20%]*
OK:	55.00 Hz	1.1000kVA	630.93 W	55.00°	7	6	1.0999kVA	630.85 W	1.0998kVA	630.84 W	1.0999kVA	630.84 W	<-0.01%>	[0.14%]	<-0.01%>	[0.23%]*
OK:	55.00 Hz	1.1000kVA	550.00 W	60.00°	7	6	1.0999kVA	549.93 W	1.0998kVA	549.93 W	1.0999kVA	549.93 W	<-0.01%>	[0.14%]	<-0.01%>	[0.25%]*
OK:	55.00 Hz	1.1000kVA	464.88 W	65.00°	7	6	1.0999kVA	464.81 W	1.0998kVA	464.82 W	1.0999kVA	464.82 W	<-0.01%>	[0.14%]	<-0.02%>	[0.30%]*
OK:	55.00 Hz	1.1000kVA	376.22 W	70.00°	7	6	1.0999kVA	376.17 W	1.0999kVA	376.18 W	1.0999kVA	376.17 W	<-0.01%>	[0.14%]	<-0.01%>	[0.36%]*
OK:	55.00 Hz	1.1000kVA	284.70 W	75.00°	7	6	1.0999kVA	284.66 W	1.0999kVA	284.67 W	1.0999kVA	284.67 W	<-0.01%>	[0.14%]	<-0.01%>	[0.46%]*
OK:	55.00 Hz	1.1000kVA	191.01 W	80.00°	7	6	1.0999kVA	190.99 W	1.0999kVA	191.00 W	1.0999kVA	190.99 W	<-0.01%>	[0.14%]	<-0.01%>	[0.68%]*
OK:	55.00 Hz	1.1000kVA	95.871 W	85.00°	7	6	1.0999kVA	95.848 W	1.0999kVA	95.867 W	1.0999kVA	95.855 W	<-0.01%>	[0.14%]	<-0.02%>	[1.32%]*

1.3 Reactor loss Measurement



1.4 Power Analyzer Accuracy for Reactor loss error



- Sin wave accuracy on the Volage
  - 0.01% Rdg+0.038% Rng+(0.004%×kHz Rdg)+5mV
- Sin wave accuracy on the Current
  - 0.01% Rdg+0.038% Rng+(0.004%×kHz Rdg)+ 300μA

- Sin wave accuracy on the Power
  - 10mHz-2MHz [0.03%+0.03%/pf+(0.005%×kHz)/pf] Rdg+0.03%VA Rng
  - 40-850Hz [0.03%+0.03%/pf+(0.005%×kHz)/pf] Rdg+0.03%VA Rng

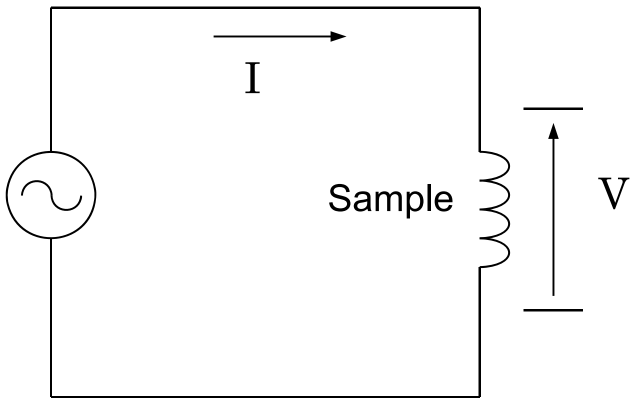
- *Fourier series expansion for square*
  - $f(x) = \frac{4}{\pi}\{sin(x) + \frac{1}{3}sin(3x) + \frac{1}{5}sin(5x) + \frac{1}{7}sin(7x) + \cdots\}$
- *Fourier series expansion for triangle*
  - $f(x) = \frac{8}{\pi}\{sin(x) + \frac{1}{9}sin(3x) + \frac{1}{25}sin(5x) + \frac{1}{49}sin(7x) + \cdots\}$

The deskew can not be highly accurate measurement.
In this case, it can be measured by high accuracy measurement.

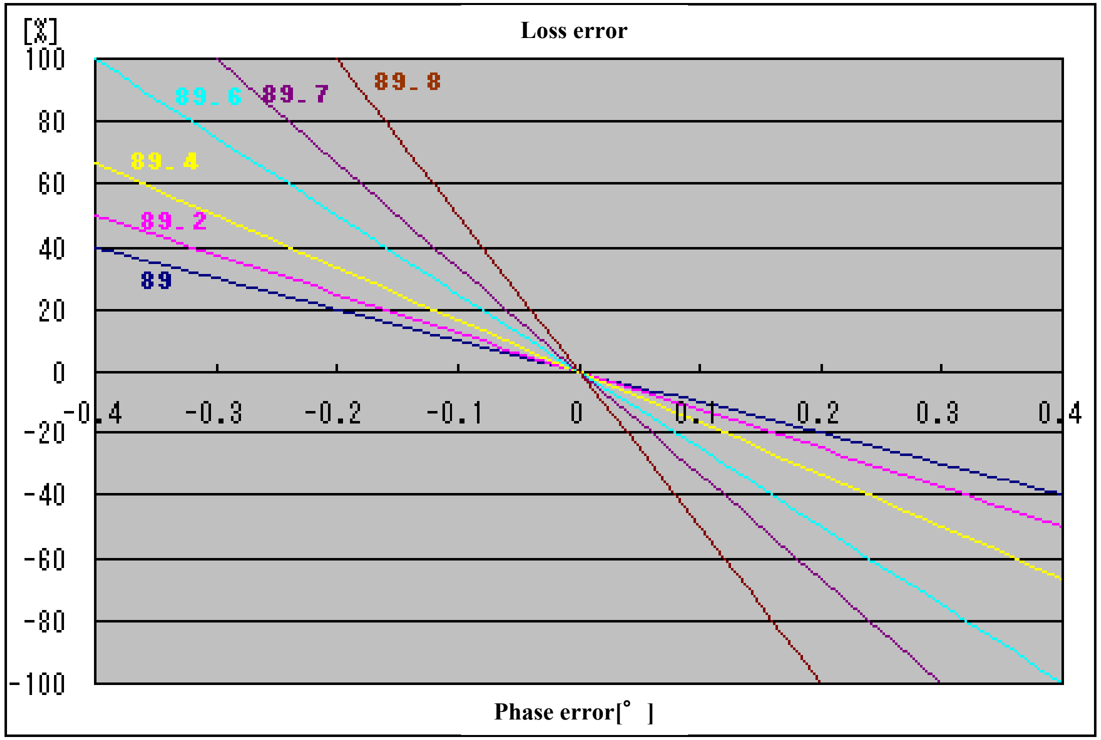
1.5 It is difficult to measure “Zero”.
～A problem in evaluating loss of low loss materials～

Core loss Pc when Current *I and Voltage V are single sine waves;*

$$Pc = I_{rms} \cdot V_{rms} \cdot \cos\theta$$



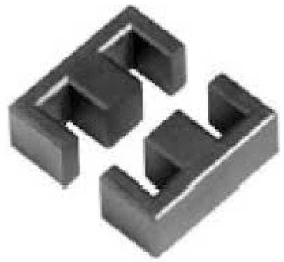
Relation between Phase error and loss measurement value error



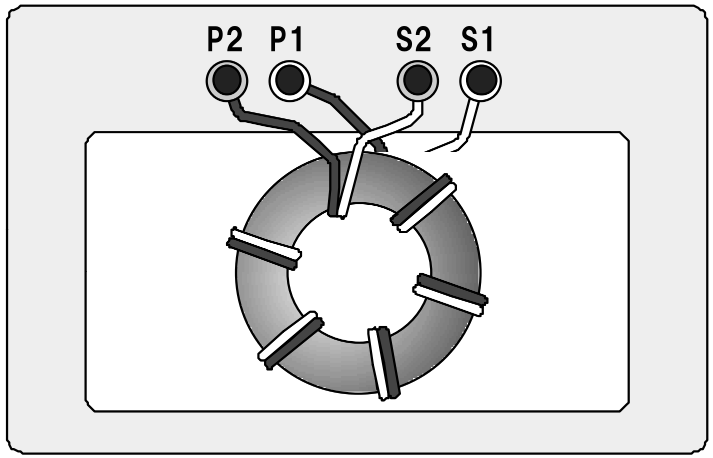
2. Power Loss Measurement by B-H Analyzer

2.1 The principles of High-precision Core loss Measurement

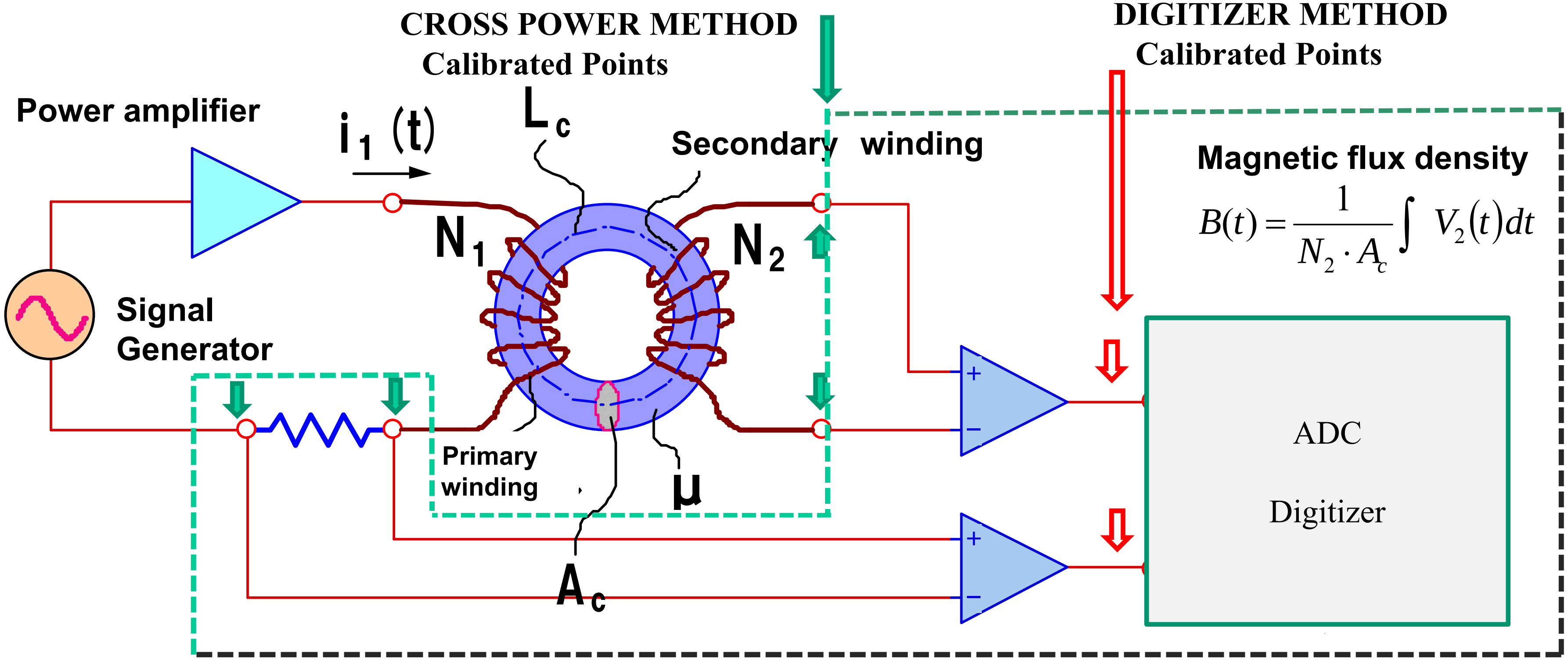
- Standard : IEC 62044-3
- Japanese Industrial Standards(JIS)



SY-8218/19 adopts CROSS-POWER method that the Standards above employ.



2.2 What is the measurement principle of AC magnetic property?



Magnetic flux density

$$B(t) = \frac{1}{N_2 \cdot A_c} \int V_2(t)dt$$

Core loss per volume

$$P_{cv} = \frac{1}{A_c L_c} \frac{N_1}{N_2} \cdot f \cdot \int_0^T i_1(t) \cdot V_2(t) dt$$

$$= f \cdot \int_C H(t) \cdot \frac{dB(t)}{dt} dt$$

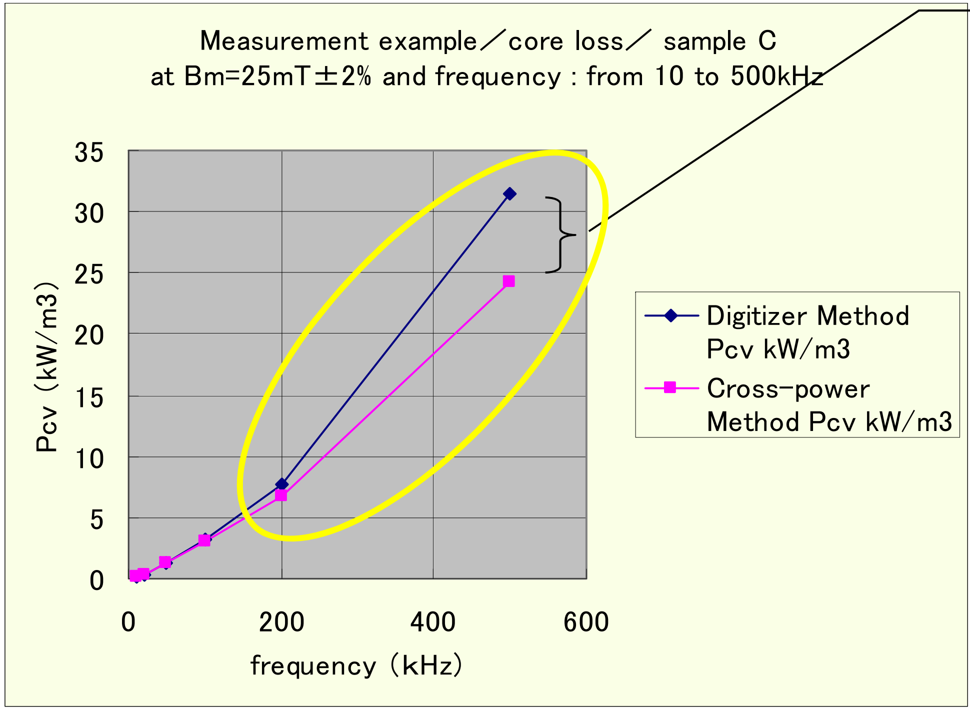
Magnetic field strength

$$H(t) = \frac{N_1 \cdot i_1(t)}{L_c} = \frac{N_1 \cdot V_s(t)}{L_c \cdot R_s}$$

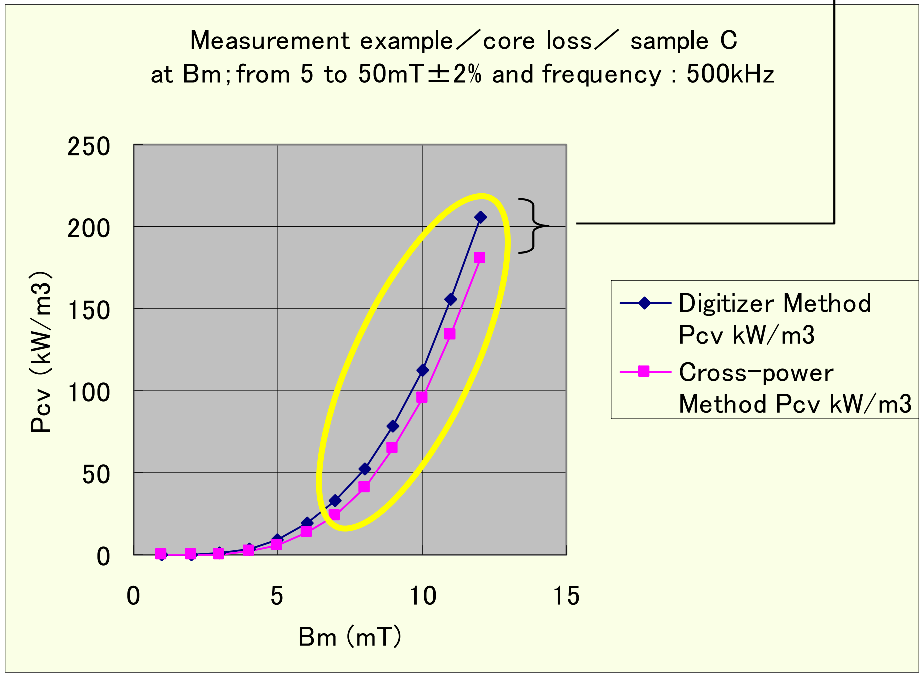
Lc; Effective length of magnetic path

Ac; Effective cross-section area

2.3 Comparison of Core loss measurement by presence or absence of phase correction



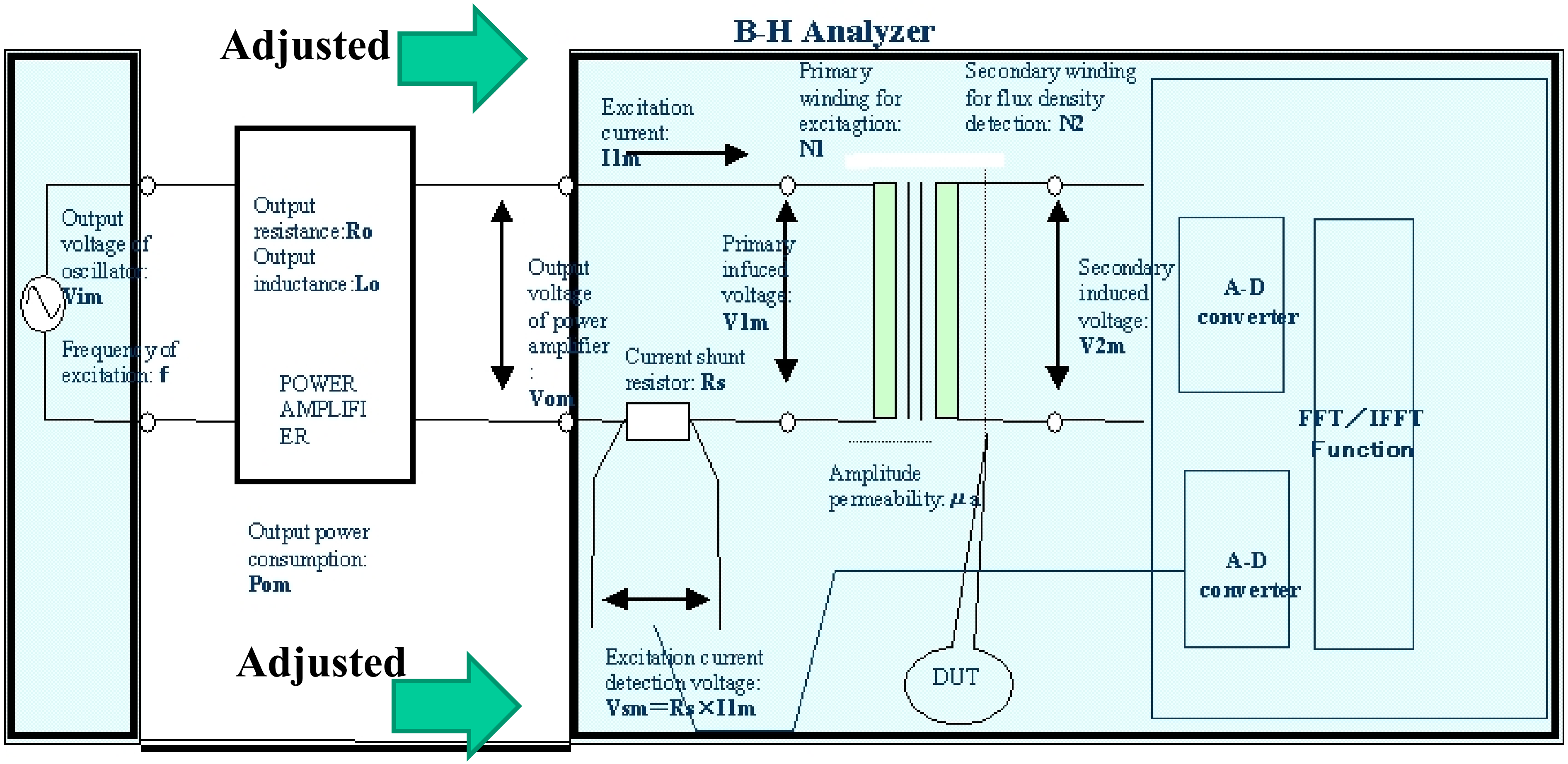
There are 20% error in Power Core loss between Digitizer and Cross-Power method when the frequency is around 500kHz.This is because the frequency property between current detection resistor and each detection circuit is not compensated at the frequency axis under the Digitizer method.



CROSS-POWER method realizes the high-precision measurement.
CROSS-POWER method is adopted in IEC 62044-3.

Data by Metropolitan University

2.4 What is CROSS-POWER method？



2.5 Comparison between Digitizer method and CROSS-POWER method

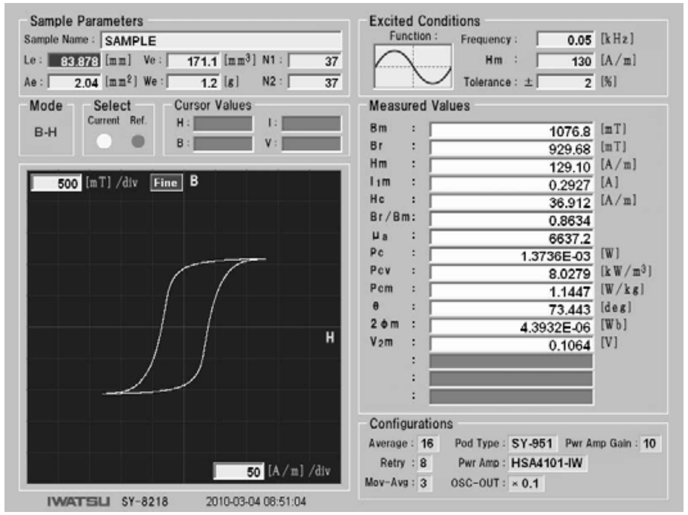
1. Both Digitizer and CROSS-POWER methods capture excitation current waveforms and inductive voltage waveforms through time sampling as the time axis waveforms （sampling data).
   However, these two methods are distinguished
   by the way of dealing with the time axis waveforms.

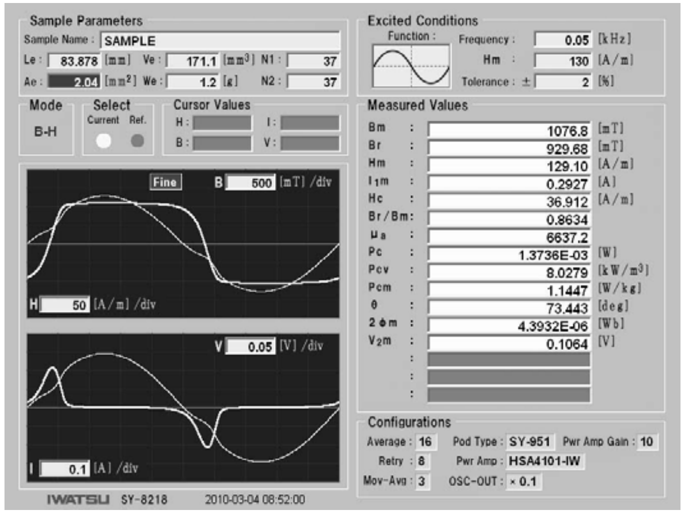
2. Digitizer method executes the time integration calculation directly as the time axis waveforms.

3. CROSS-POWER method, on the other idea
   (1) converts the time axis waveforms into the frequency spectrum
   and executes integral calculation with no phase difference
   and compensates the amplitude and the phase error of current detection sensor.
   (2) executes the compensation of the amplitude and the phase property
   of the detection circuit on the frequency axis.
   (3) captures the time axis waveforms with little error by returning the frequency
   spectrum having the error compensation to the time axis waveforms.

2.6 B-H / Core loss measurement

- B-H Analysis





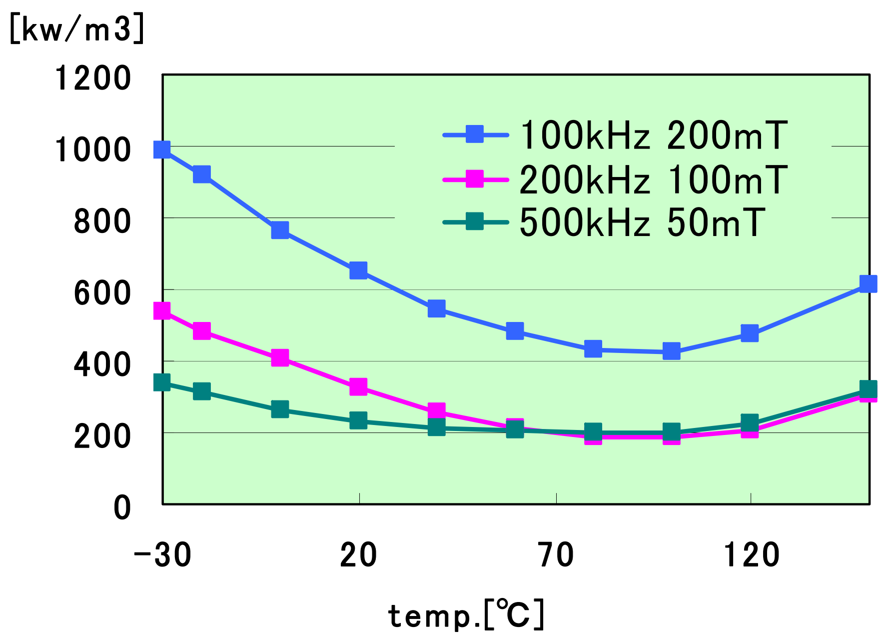
Core Loss Feature

- Excitation condition

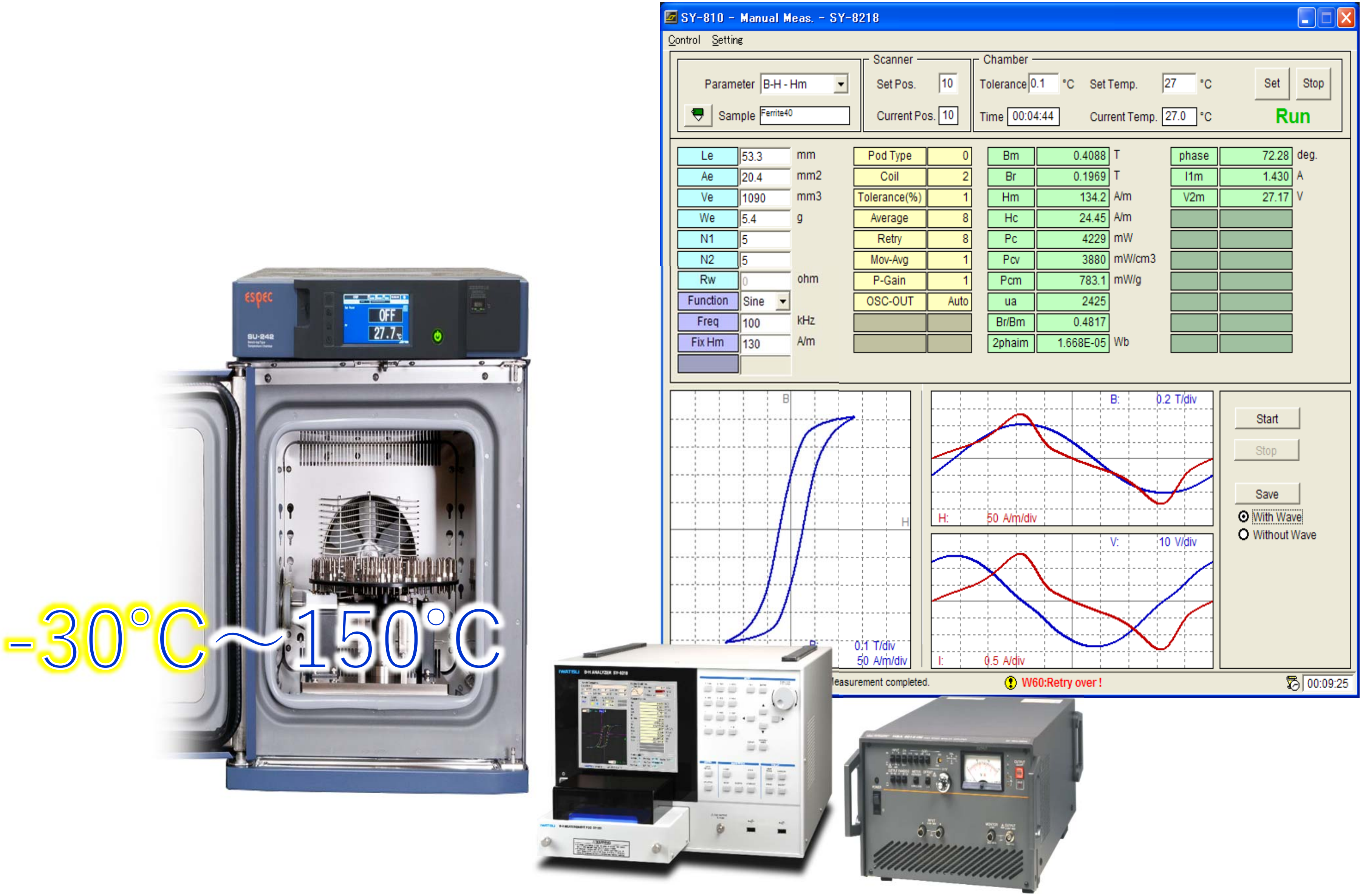
  Change in Temperature

- Evaluation under a condition equal to an actual use condition

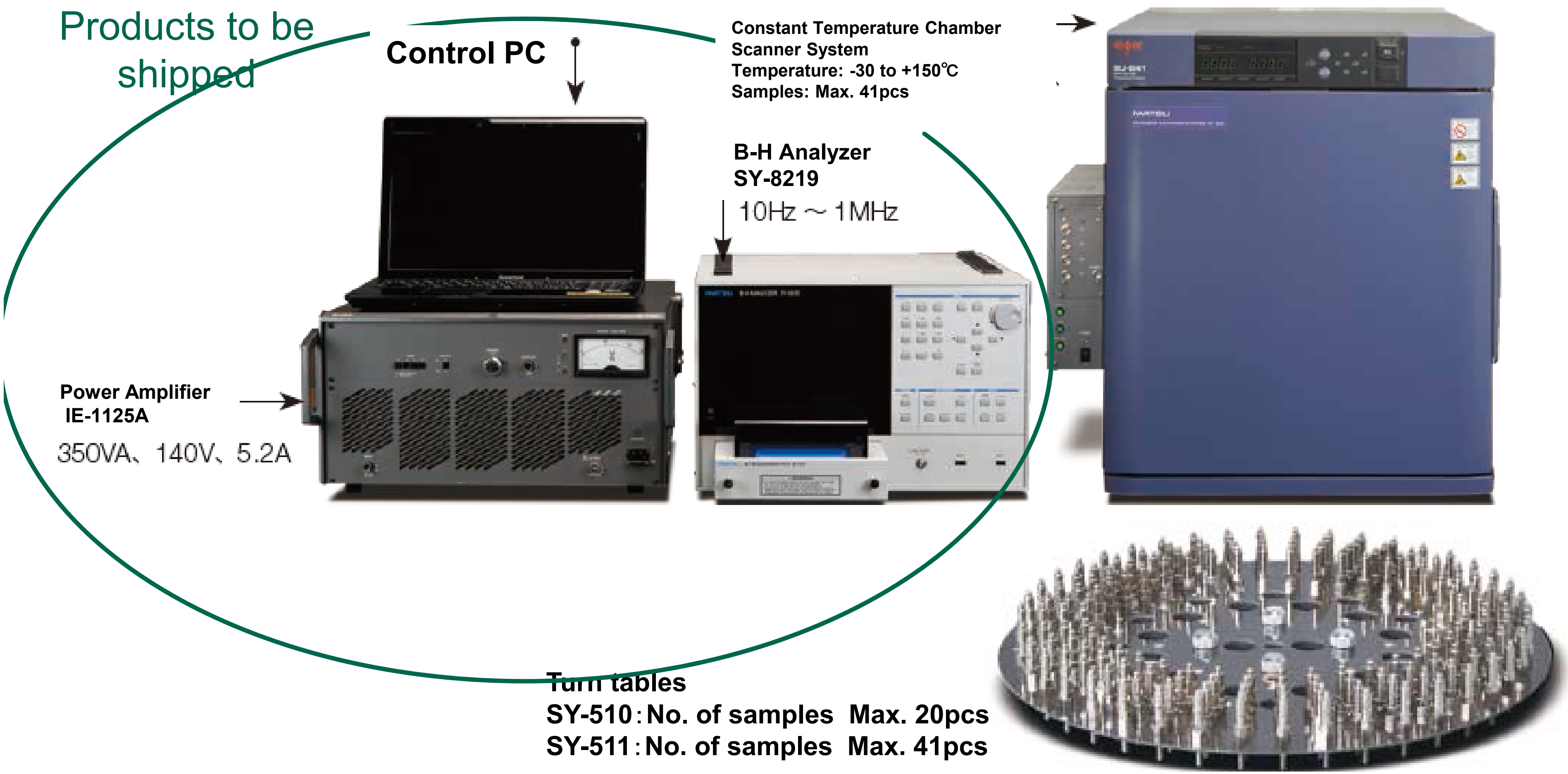
PC40 20T Pcv [Sample]



2.7　B-H / Core loss measurement



2.8 Constant Temperature Chamber Scanner System



2.9 Is the target Magnetic field (Current) or Flux density (Voltage) ?

1. Hm designated method:
   Designate Hm (Max.Magnetic field)

2. Bm designated method:
   Designate Bm (Max.flux density)

3. Current designated method:
   Designate Excitation current

4. Voltage designated method:
   Designate Inductive voltage

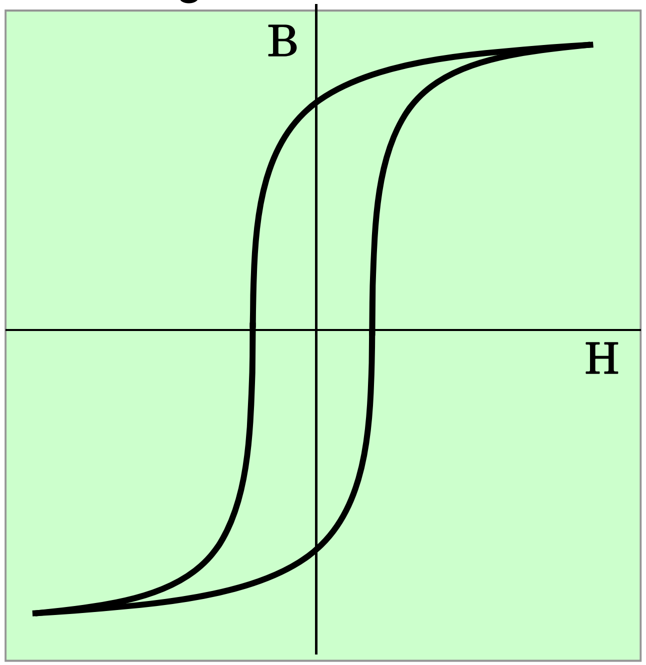
2.10 Hm method

a. Keep measurement frequency constant and excite the sample slowly.

b. Capture the excitation current waveform and the inductive voltage waveform and calculate magnetic field waveform by the excitation current waveform.

c. Adjust the output voltage of power amplifier manually or automatically so that the maximum value is within the tolerance level of the targeted magnet field.

d. After the adjustment,
calculate the saturation magnetic flux density Bs, etc. with B-H curve calculated from magnetic field waveform and magnetic flux density.



e. This method is suitable for the measurement of saturation property such as saturation magnetic flux density, residual magnetic flux and coercive force.

2.11 Bm method

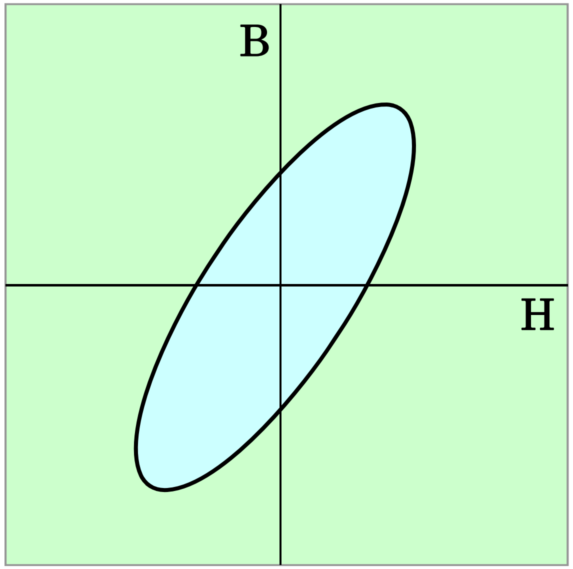
a. Keep measurement frequency constant and excite the sample slowly.

b. Capture the excitation current waveform and the inductive voltage waveform, and calculate magnetic field waveform by time integration of inductive voltage waveform.

c. Adjust the output voltage of power amplifier manually or automatically so that the maximum value is within the targeted magnet flux density Bm.

d After the adjustment, calculate time integration of multiplication of excitation current waveform by inductive voltage waveform, and then calculate core loss.

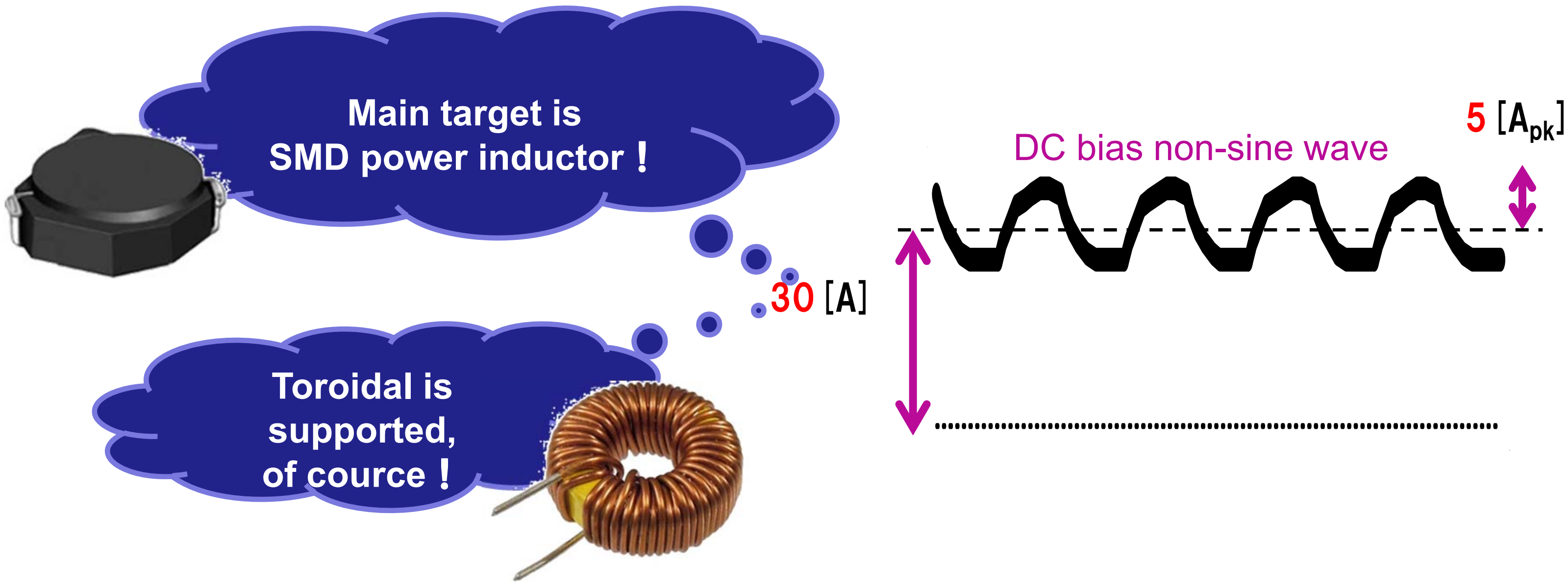
e. Calculate the phase angle by the ratio between Core loss and Appearance power, and the permeability at Max. magnetic field Hm via Max. magnetic field and Max. flux density, ie. the amplitude ratio of permeability respectively.



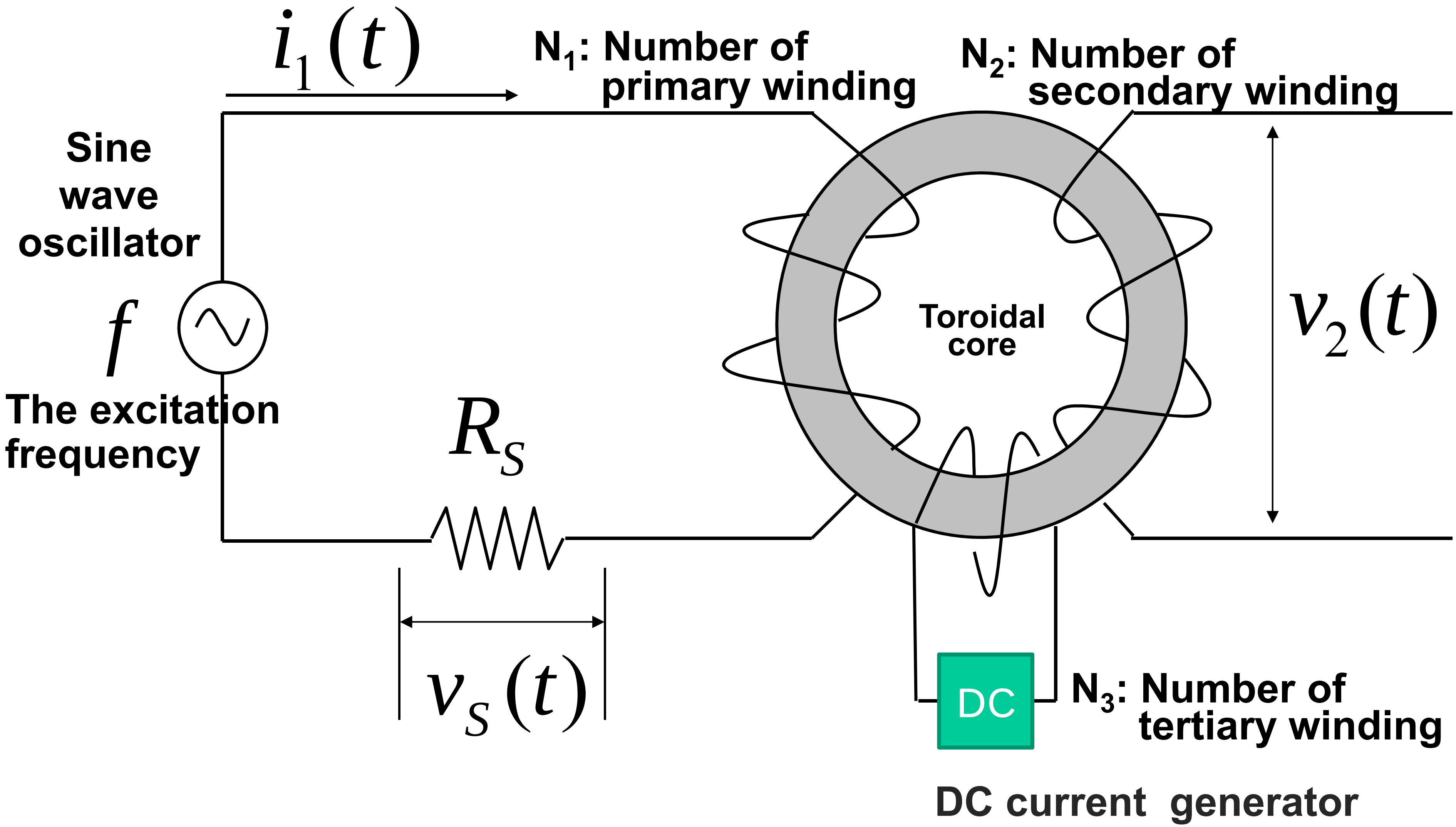
f. This method is suitable for the measurement of property for the large amplitude such as core loss, amplitude ratio of permeability, phase angle, etc.

2.12　Outline of DC bias tester

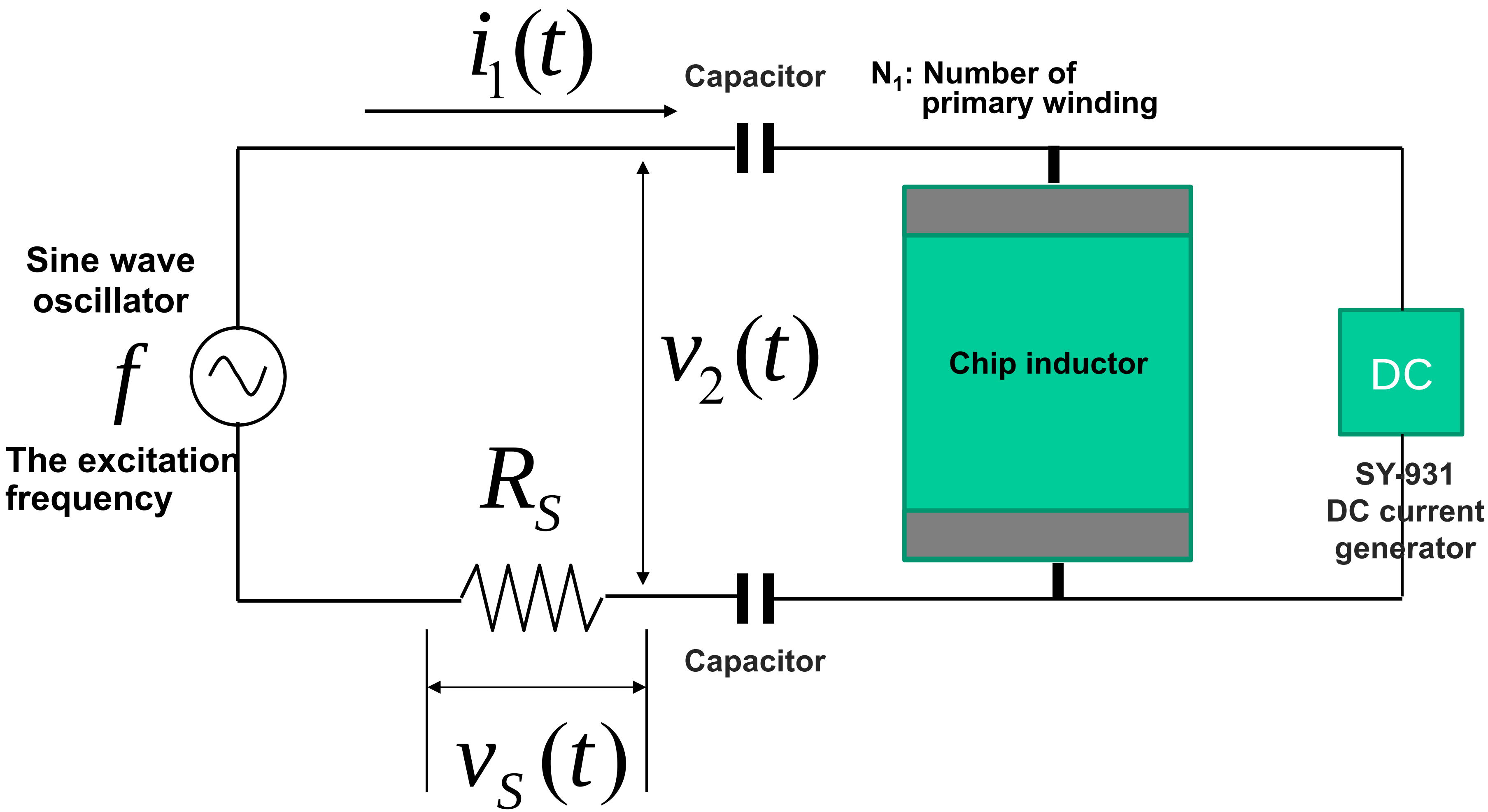
- **Fully-automatic control** is available with SY-8219 and future B-H series.
- Continuously-variable current value is available.
- DC bias non-sine wave (chopper excitation) is also available.
- DC bias current of Max.30[A] is supported.
- Ripple current of Max.5[A] is supported.
- Measurement frequency：Max.3MHz（sine wave）
- Measurement frequency：Max.1MHz（Chopper excitation）



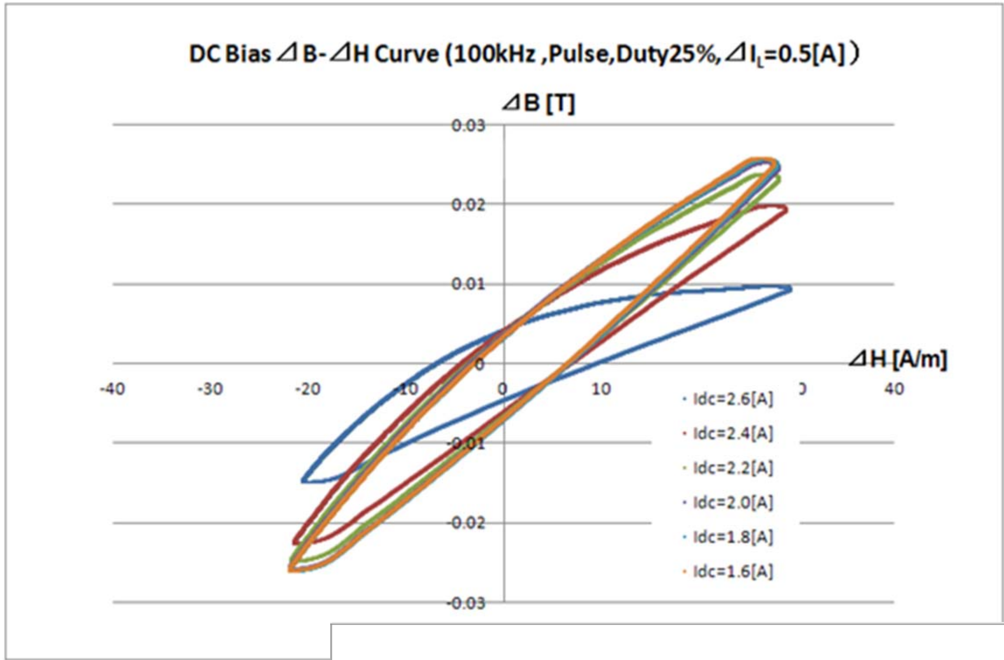
2.13 Measurement method when DC bias is overlapped with toroidal core

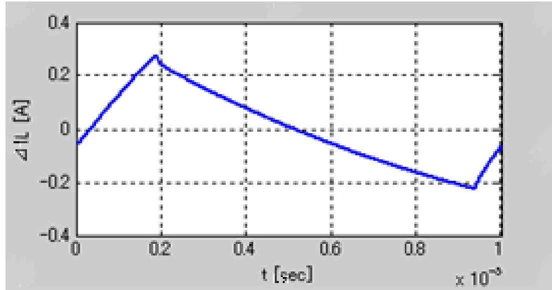


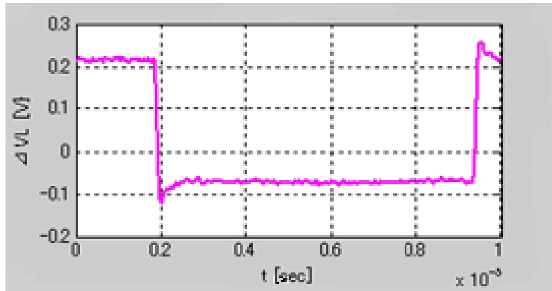
2.14 Measurement method when DC bias is overlapped with a chip inductor

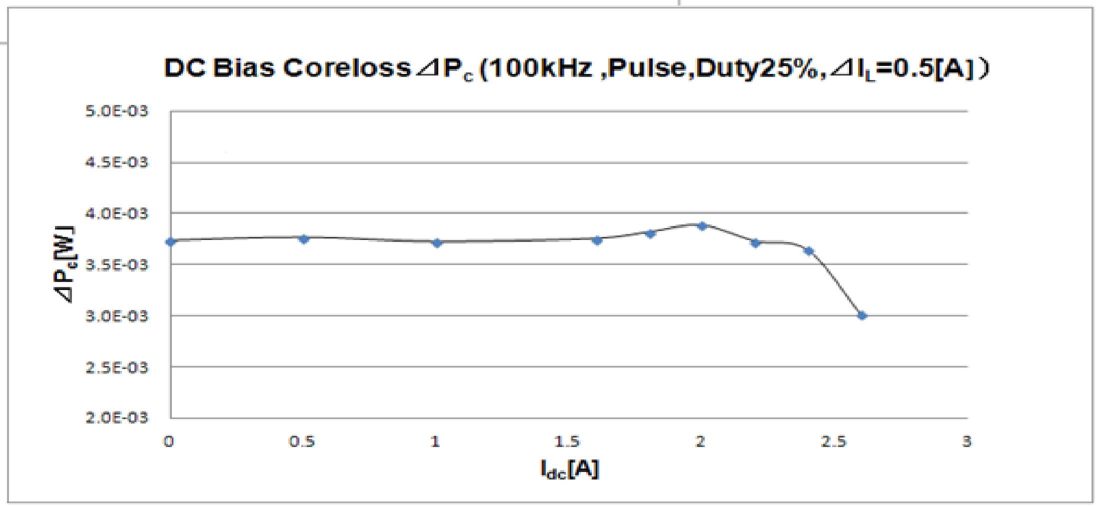


2.15 An measurement example of DC bias tester on chip inductor measurement（Pulse excitation）









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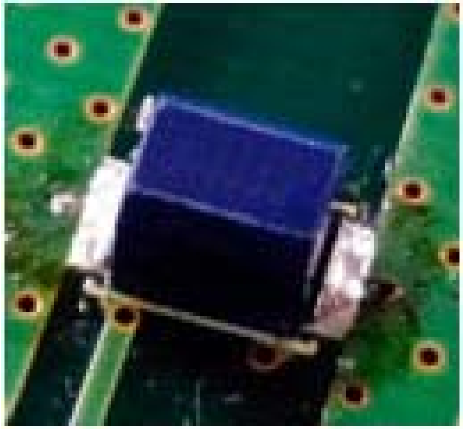
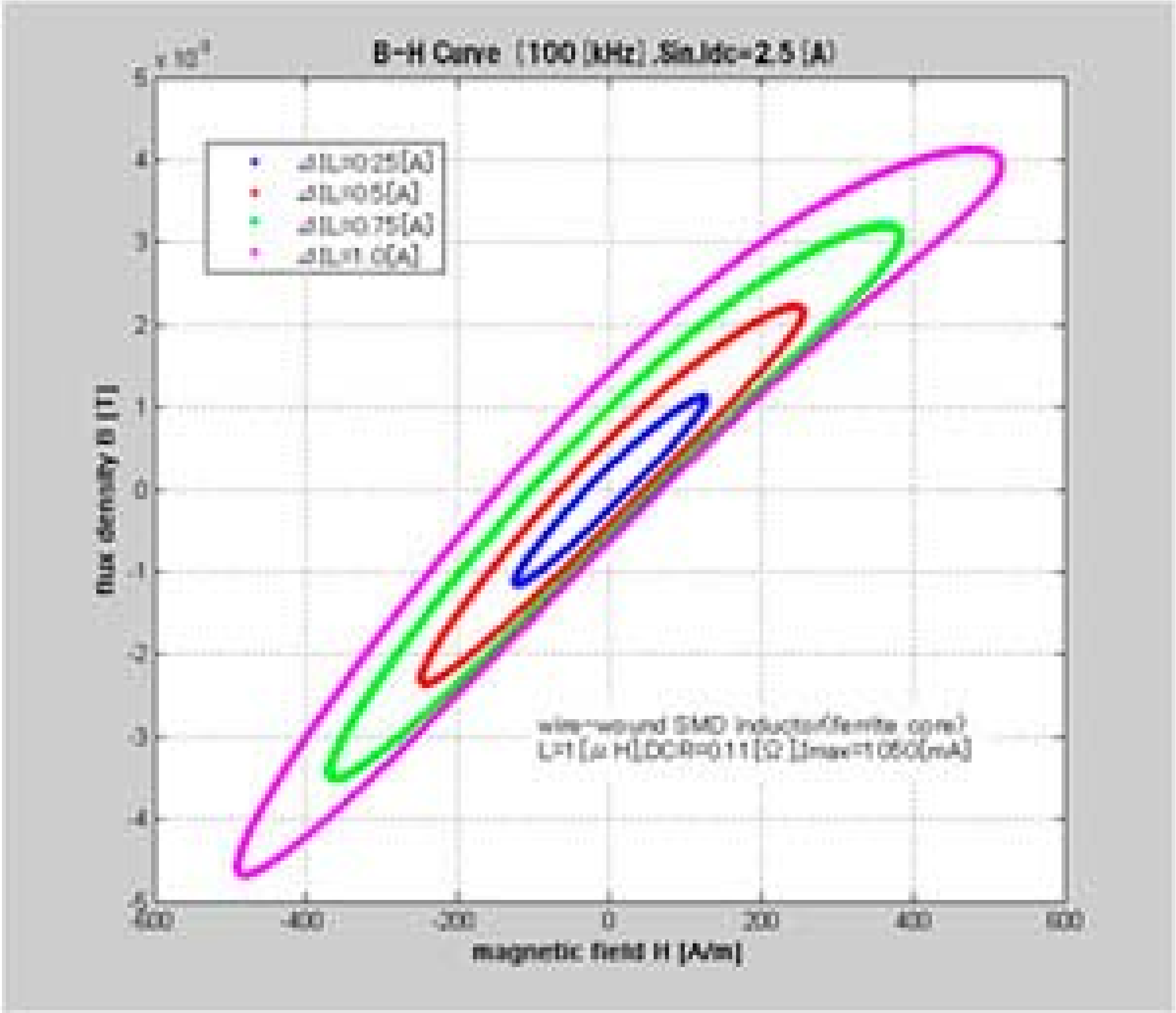
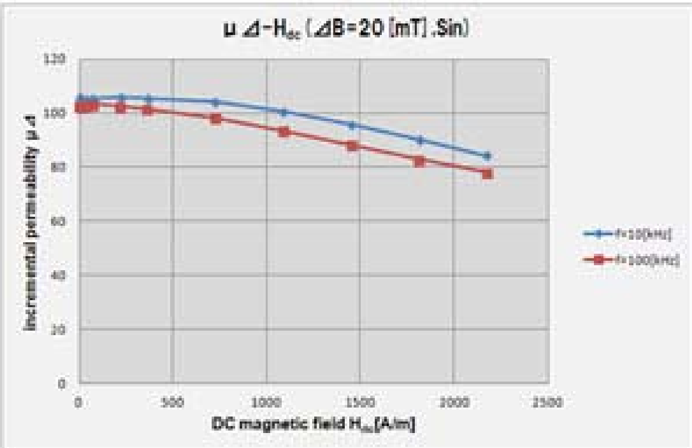
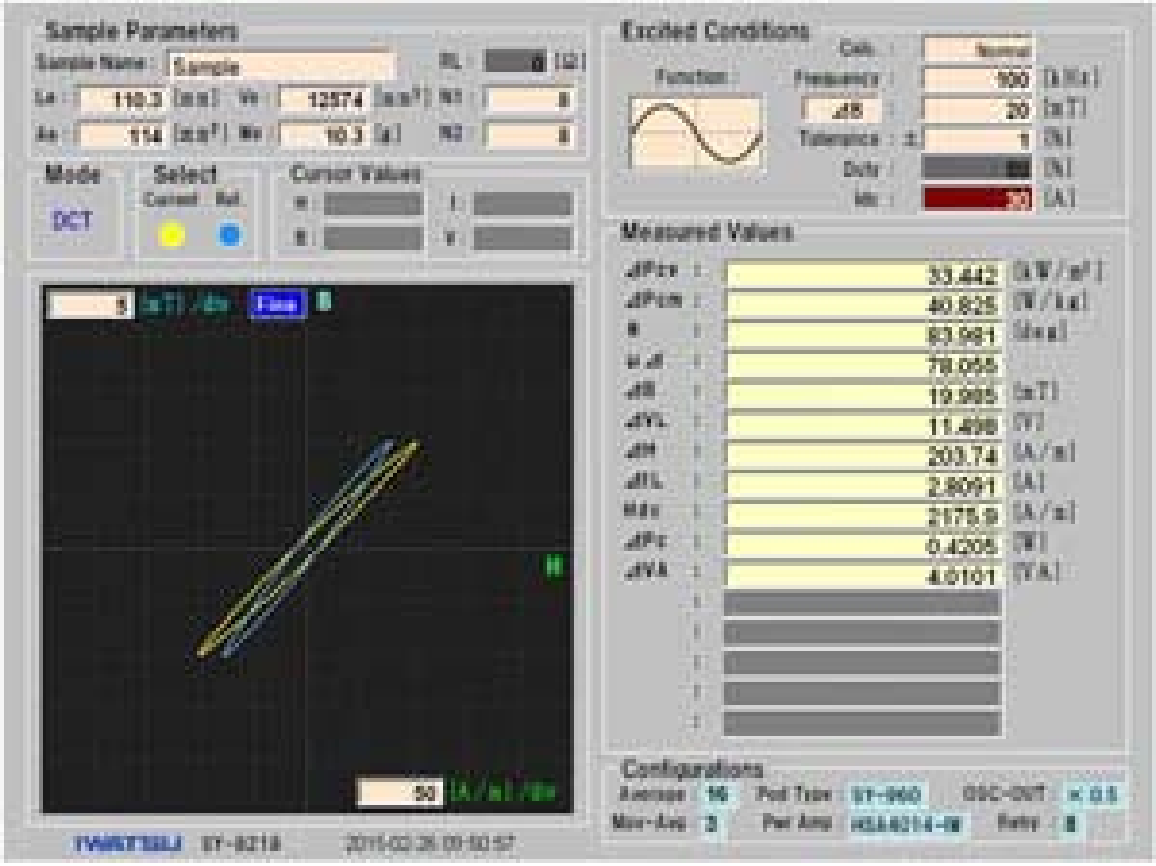
2.16 Chip Inductor





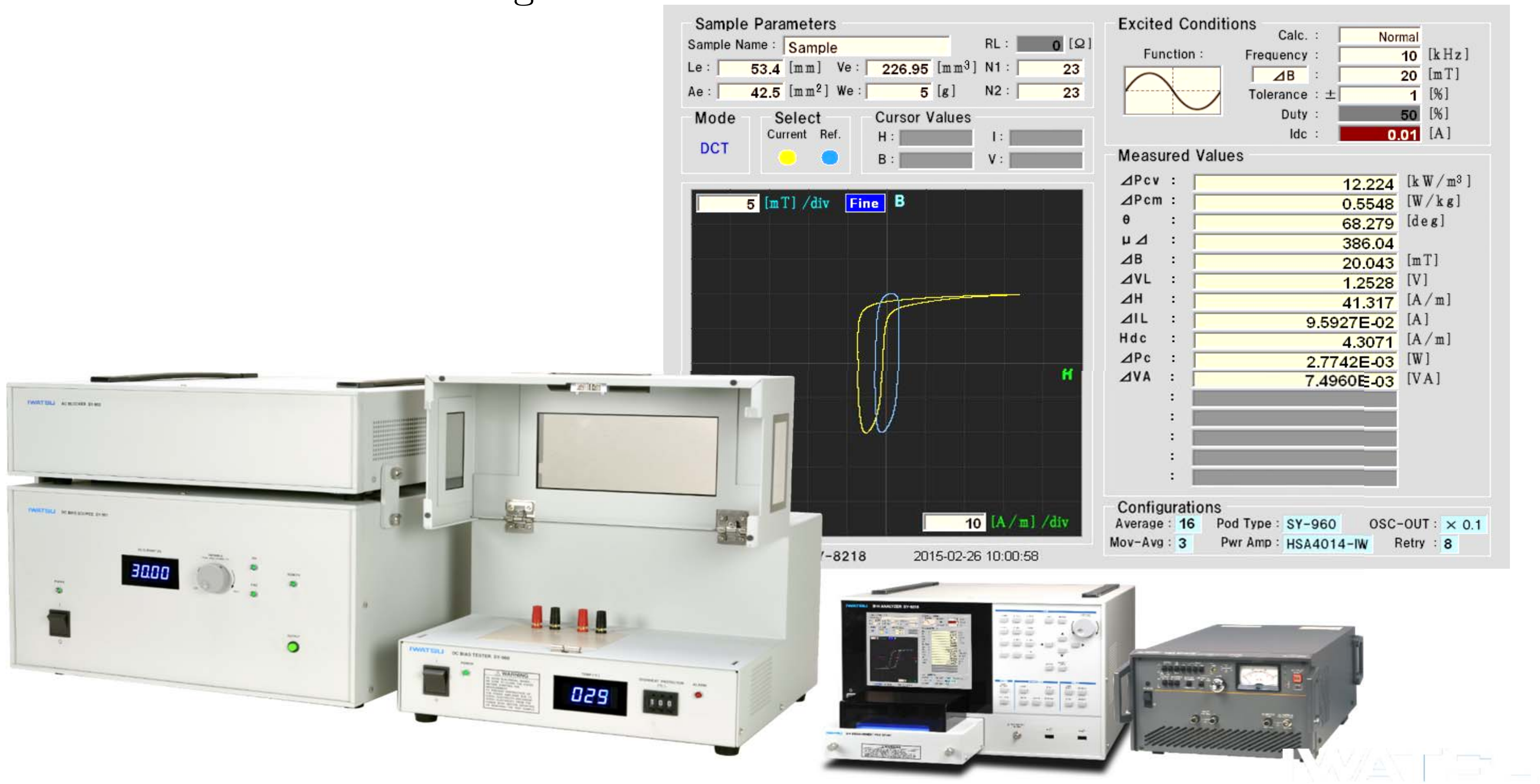
2.17 Toroidal Core Inductor

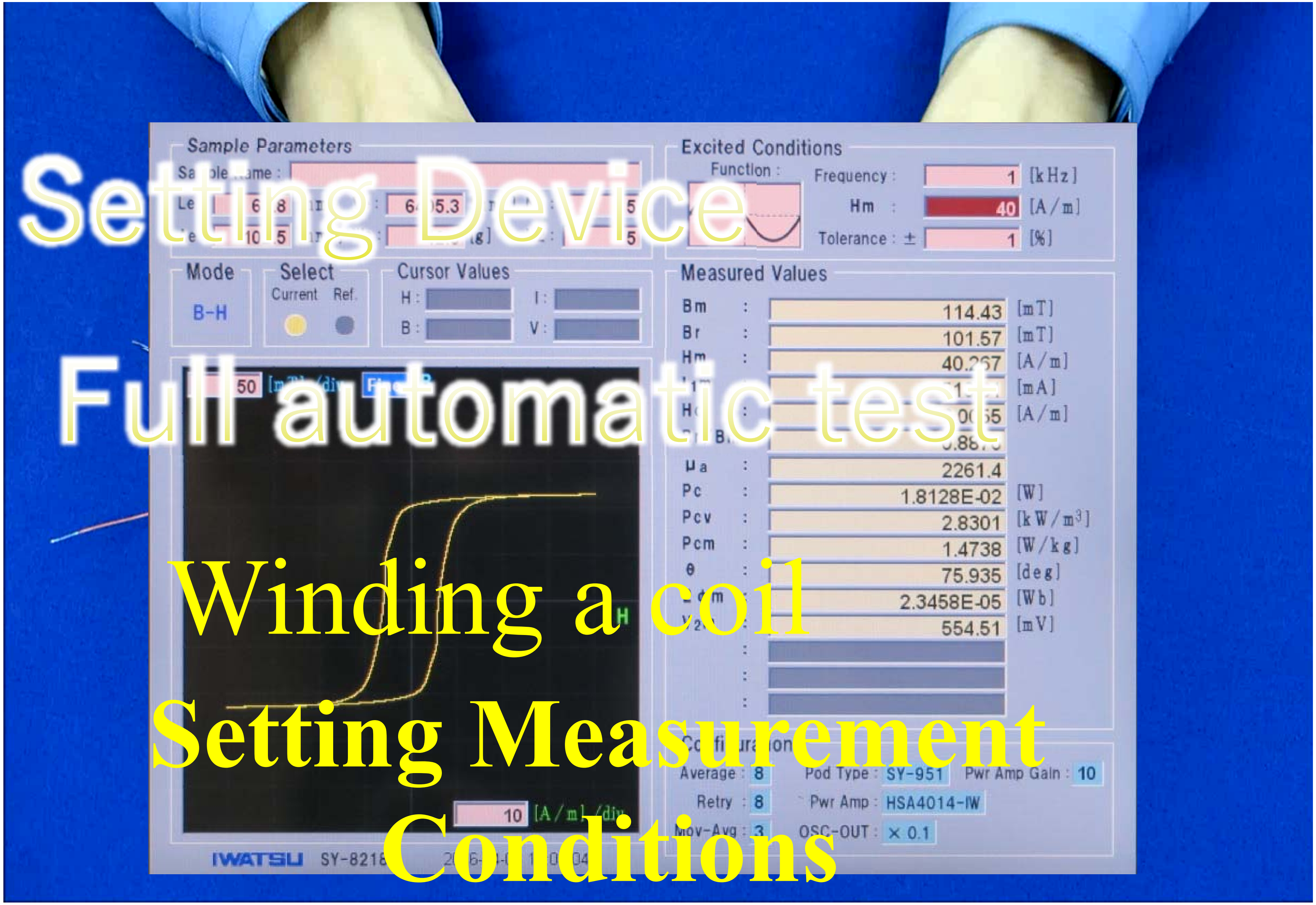




2.18 DC-Bias Sysytem

Pulse & Sinusoidal with DC biasing




Setting Device
Full automatic test
Winding a coil
Setting Measurement Conditions
Sample Parameters
Excited Conditions
Function :
Frequency :
1 [kHz]
Hm :
40 [A/m]
Tolerance : ±
1 [%]
Mode
B-H
Select
Current
Ref.
Cursor Values
Measured Values
Bm : 114.43 [mT]
Br : 101.57 [mT]
μa : 2261.4
Pc : 1.8128E-02 [W]
Pcv : 2.8301 [kW/m3]
Pcm : 1.4738 [W/kg]
θ : 75.935 [deg]
2.3458E-05 [Wb]
554.51 [mV]
Average : 8
Retry : 8
Pod Type : SY-951
Pwr Amp Gain : 10
Pwr Amp : HSA4014-IW
OSC-OUT : × 0.1
10 [A/m]/div
IWATSU

Future Events and Contact us

- Contact Us

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