Approach to 2-dimensional High Frequency Magnetic Characteristic Measurement with High Speed & Accuracy “Vector (2D) Hysteresis Analyzer System”

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Abstract:

Two-dimensional magnetism characteristic measurement is equipped measuring alternating current magnetization characteristic of magnetic material (electromagnetic steel plates, Permalloy) with vector. The vector measurement equipment can measure magnetic characteristic of magnetic material from overall into more details compared with traditional scalar magnetic measurement. We aim at providing solutions for new technique of optimum design such as transformer or electric motor with this equipment.

Previously, the scalar finite-element magnetic field analysis method has been used for magnetic field analysis of materials used for transformers or electric motors. Recently, an ecological requirements of these devices being designed with the materials which shows strong magnetic anisotropy such as hi-oriented silicon steel reveals the differences between scalar analytically measured results and actually operated results. In such situation, the vector finite-element magnetic field analysis method has been paid attention.

Herewith, we introduce the V-H(Vector-Hysteresis) analyzer which purposed faster and easier measurement of a grained directional steel sheet at various magnetic excitation conditions with vector magnetic characteristics. Measured data would be applied to the E&S Vector two-dimensional measuring method and modeling. This report describes the V-H analyzer and it’s measurement examples.

Keywords:
Two-dimensional magnetism characteristic, Vector finite-element magnetic field analysis, E&S Vector two-dimensional measuring method and modeling

Fig.1 V-H Analyzer IE-1131

Fig.2 Excitation Jig IE-955

1. Preface

This equipment has been purposed for research and development of two-dimensional magnetism characteristic of magnetic materials. The conditions such as an excitation frequency, a magnetic flux density and a variable angle are set for two-dimensional magnetism characteristic measurements.

Excitation JIG: model IE-955 gives alternating magnetic field or rotating magnetic field to a device under test(DUT).The Yoke excitation frequency is varied from 10Hz to 1kHz. The magnetic flux density is varied from 0.1 T to 1.5 T.

An exciting magnetic field intensity is calculated by induced voltage signal detected with X axis and Y axis detection coils.

Magnetic flux density is calculated by an induced voltage signal detected with X axis and Y axis detection coils which wound at the center of a DUT.

An H-vector is calculated by an X-axial and a Y-axial intensity of magnetic fields. A B-vector is calculated by an X-axial and a Y-axial magnetic flux densities. Two-dimensional various magnetism characteristics are calculated by an H-vector and a B-vector.

All results are showed with graphical display and also numeric values. Measured data are stored in built-in MO(Magnetic-optical storage device). These data may be applied to magnetic field analysis simulating software.

2. Features

(1) Dimension of equipment became small

It was designed with simple framing of an ALL-IN-ONE structure.

(2) Low noise

An ALL-IN-ONE structure has improved a signal to noise ratio.

(3) High-speed

Data acquisition rate was speeded up more than 10 times by using internal high-speed data bus, instead of data transfer with GP-IB interface bus during a control time shortened too.

Convergence algorithm estimating magnetic flux sine wave excitation minimized calculation time.

(4) High accuracy

High accuracy was given by development of higher resolution digitizer.

3. Configuration and Principle of operation

3.1 Configuration

This chapter describes a system configuration and circuit structure of V-H analyzer mainframe.

3.1.1 system configuration

This equipment consists with the following equipment. The Fig.3 shows system configuration

(1) V-H analyzer IE –1131 ...1 set
(2) Excitation Power Amplifier for X axis ...1 set
(3) Excitation Power Amplifier for Y axis ...1 set
(4) Vector Excitation JIG IE-955 ...1 set

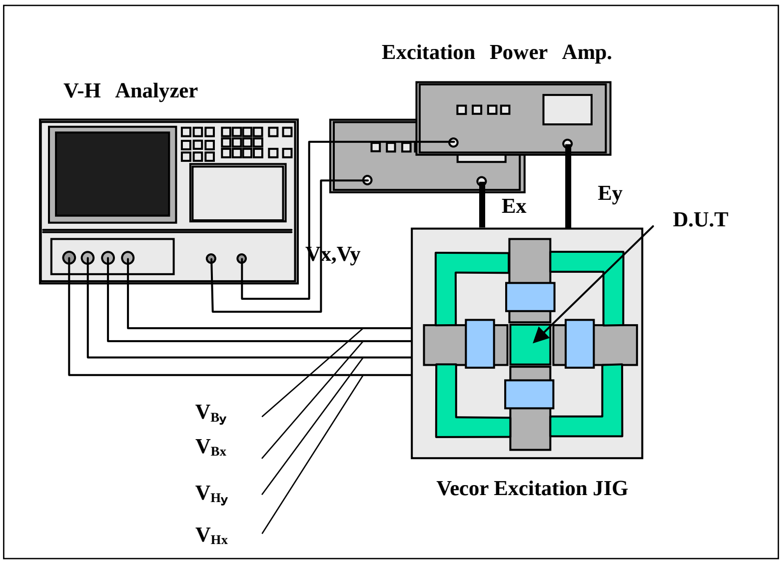


Fig.3 System Diagram

3.1.2 Circuit structure of a V-H analyzer

The Fig.4 shows a circuit diagrams. The circuit structure of a V-H analyzer consists with the following blocks.

(1) Digitizer block

Each voltage detected with X axis magnetic field detection coil, Y axis magnetic field detection coil, X axis magnetic flux density detection coil and Y axis magnetic flux density detection coil is amplified to be suitable for preamplifier block.

Each voltage waveform is sampled with Analog - Digital Converter by 512 sample / period.

Each sampled signal waveform is taken in as digital data into a signal Memory.

A. Pre-Amplifier block

An automatic range function is possessed.

The maximum sensitivity is at ± 5mV.

B. Analog – Digital(A/D) Converter

A 14bits-resolution A/D converter is hired.

Sampling rate is at 102.4kSPS.

C. Signal Memory

Memory size is 512*16*64 bits / ch.

Maximum 64 times averaging is done in signal acquisition

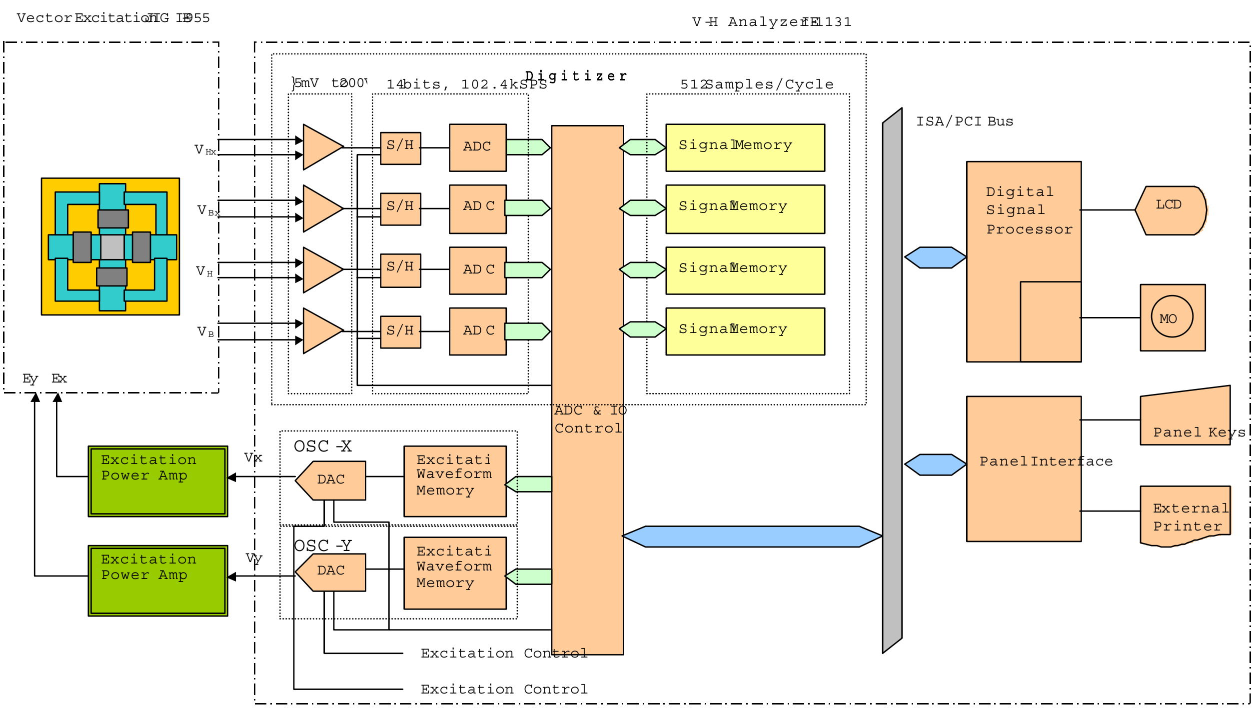


Fig.4 Block Diagram

(2) Excitation Signal Generator

Excitation signal generator consists of X,Y axis(2ch).

An X axis part outputs excitation signals of X axis orientation.

An Y axis part outputs excitation signals of Y axis orientation.

Excitation signal generator outputs an arbitrary waveform written in at excitation waveform storage means during estimated magnetic flux sine wave waveform.

A varied angle is controlled by waveform phase difference of an X axis part and a Y axis part.

A. Excitation Waveform Memory

Excitation signal waveform is stored in 512*16bits / ch memory.

B. Digital - Analog Converter

Stored excitation signal waveform data is converted into analog signal and outputted.

(3) ADC & IO Control block

The Digital Signal Processor (DSP) controls digitizer block and excitation Signal Generator block.

(4) Internal High Speed Bus

ISA and PCI buses are hired for high speed data acquisition.

(5) Digital Signal Processor block

DSP block controls digitizer block and excitation signal generator as shown in Fig.12.

DSP block controls the Error Correction of obtained each voltage waveform at frequency domain as shown in Fig.10.

Magnetic field and magnetic flux density are calculated by each voltage waveform as shown in Fig.11.

DSP block controls generated excitation signal waveform also shown in Fig.11.

DSP block controls LCD display and data stored into MO.

(6) Panel Interface block

Panel Interface block interfaces signal between operated key and DSP.

(7) Peripheral Device block

A. Display part

Color LCD at VGA system

A Graphical User Interface (GUI) function is offered

B. MO part

Measurement data is stored into MO disk.

Approx. 100MB / sample capacity is needed .

C. Panel Key part

D. External Printer

4. Operation

Each measurement function is selected at a starting menu.

Measurement function includes Alternating Flux Measurement and Rotational Magnetic Flux Measurement.

Main functions and measurements are shown with the following flow charts.

Select of function:	Fig.5 System Flow Chart-1
Measurement setup:	Fig.6 System Flow Chart-2
Measurement by an Alternating Flux condition:	Fig.7 System Flow Chart-3
Measurement by a Rotational Magnetic Flux condition:	Fig.8 System Flow Chart-4

A main flow is as follows.

In each measurement screen, a measurement condition is set and measurement is started.

IE -1131 drives power amplifier by frequency and a magnetic flux level set at measurement condition menu.

Excitation signal output from power amplifier is inputted into excitation yokes of measurement JIG IE-955.

When excitation yokes excite DUT, voltage waveforms of magnetic field are detected with X detection coil and Y detection coil built-in JIG IE-955.

Voltage waveforms of magnetic flux density are detected with X detection coil and Y detection coil wound on DUT.

Each detected voltage waveform is input into V-H analyzer IE -1131, and IE -1131 calculates both input signals and magnetic characteristic parameters.

Parameters and data are displayed on screen and stored into built-in MO.

Fig.5 System Flow Chart-1

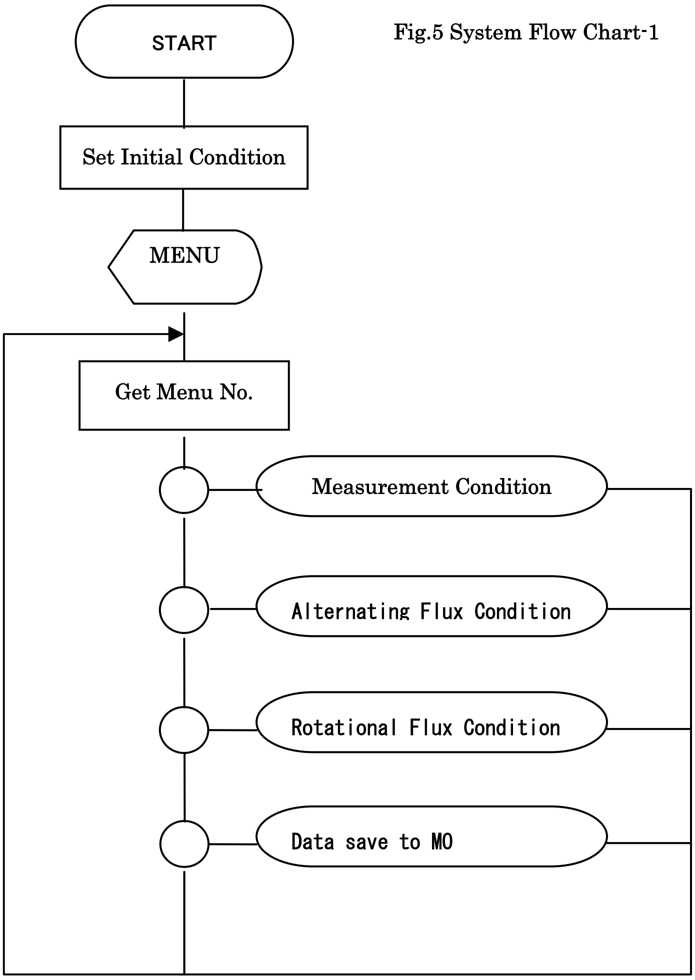
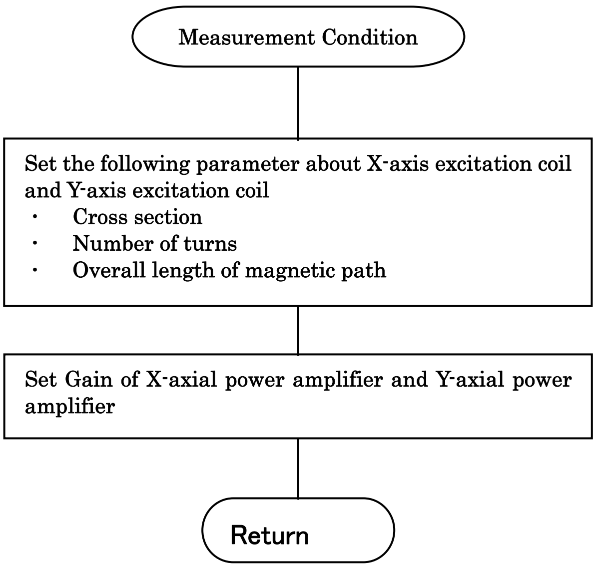


Fig.6 System Flow Chart-2



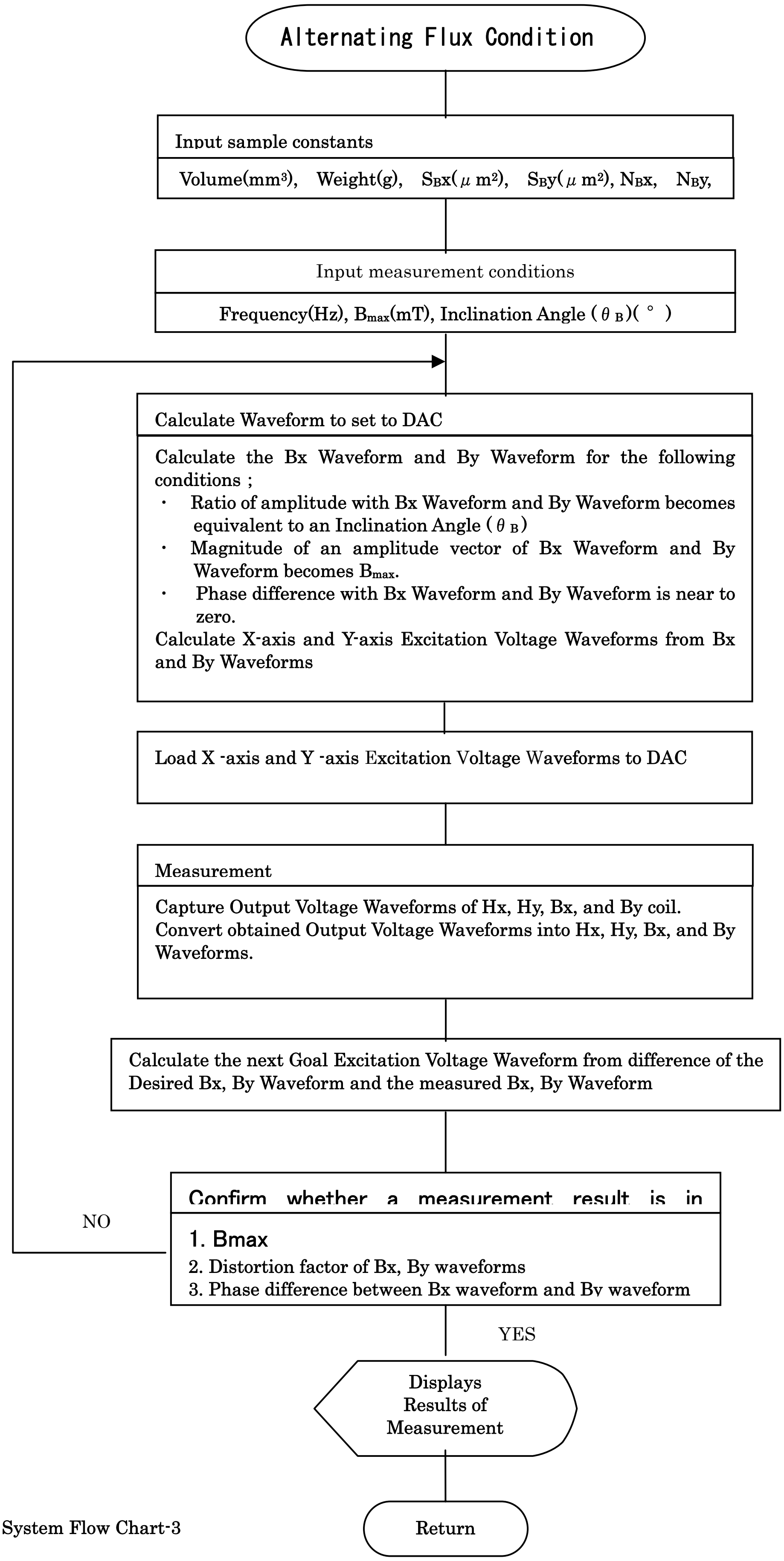


Fig.7 System Flow Chart-3

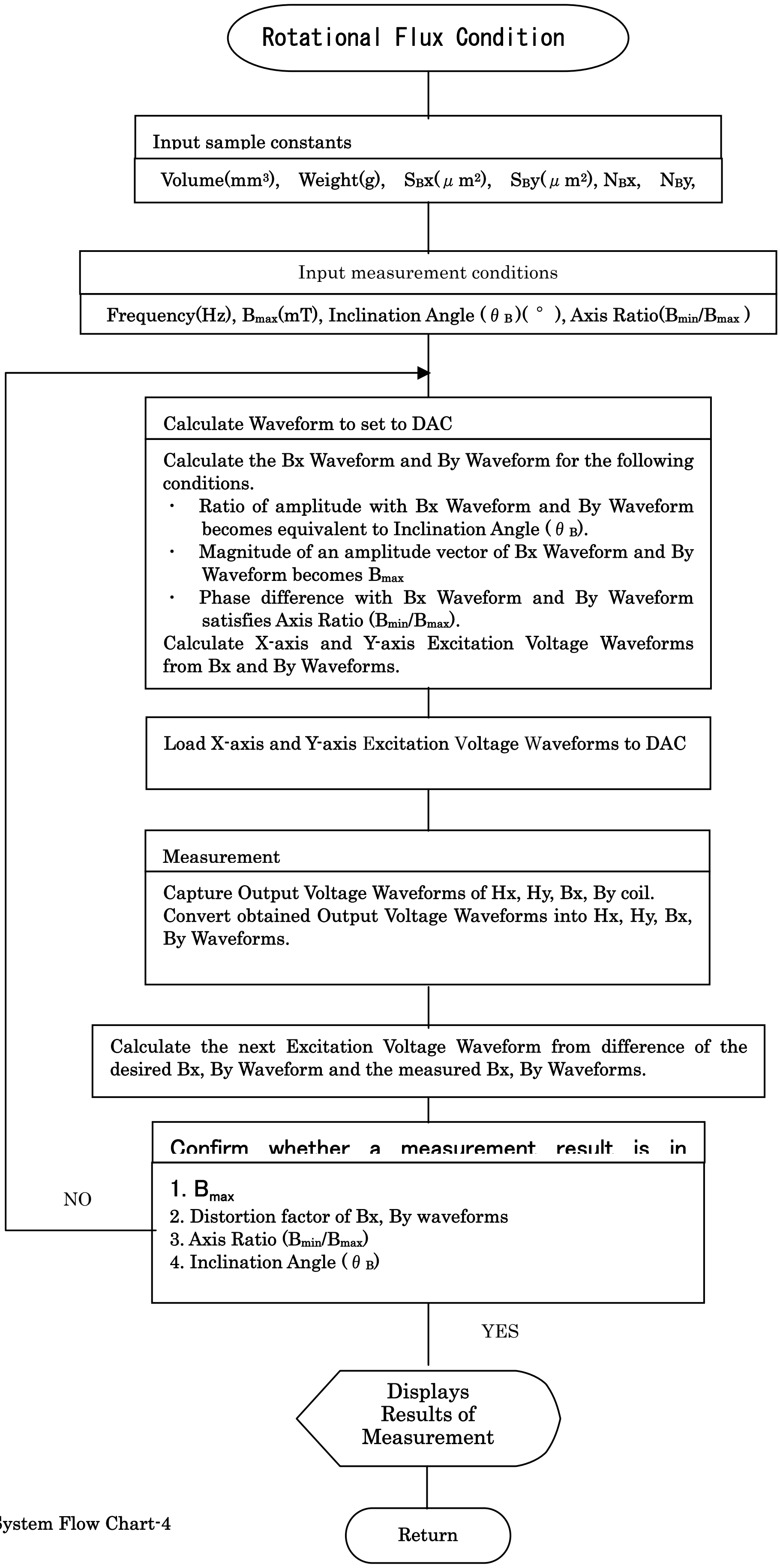


Fig.8 System Flow Chart-4

5. An Important Point of Development

We particularly paid attention to that we realize highly precise measurement. It is written in Fig.9 Get High Accuracy.

(1) Error caused by a difference of transmitting characteristic of input circuit is compensated (see Fig.10 Correct Characteristics of Input Circuit). Input circuit consists of preamplifier, sample hold circuit and A/D converter. In addition, error by phase difference between each ranges of each channel is also compensated.

(2) The excitation waveform which estimated magnetic flux density waveform seems to become sine wave and generations of excitation waveform are calculated in high-speed (see Fig.11 Generate and Control The Excitation Waveform).

(3) This equipment controls excitation waveform amplitude while maximum magnetic flux density being within tolerance of set condition. Each phase consists of an pre excitation process, constant excitation process and post magnetization process (see Fig.12 Control Amplitude of Excitation Waveform).

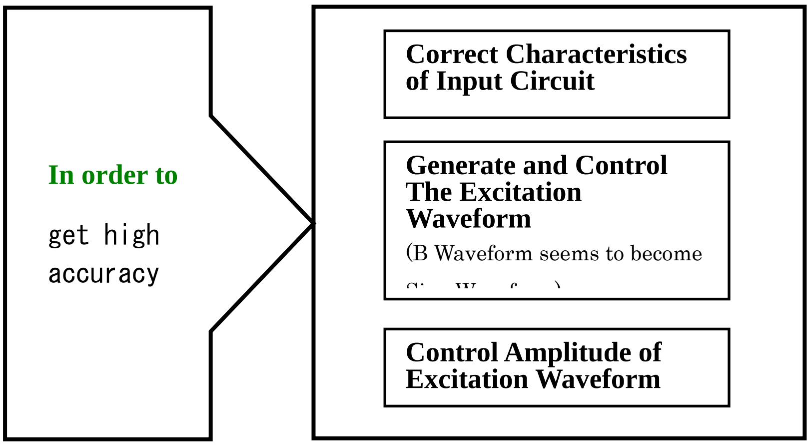


Fig.9 Get High Accuracy

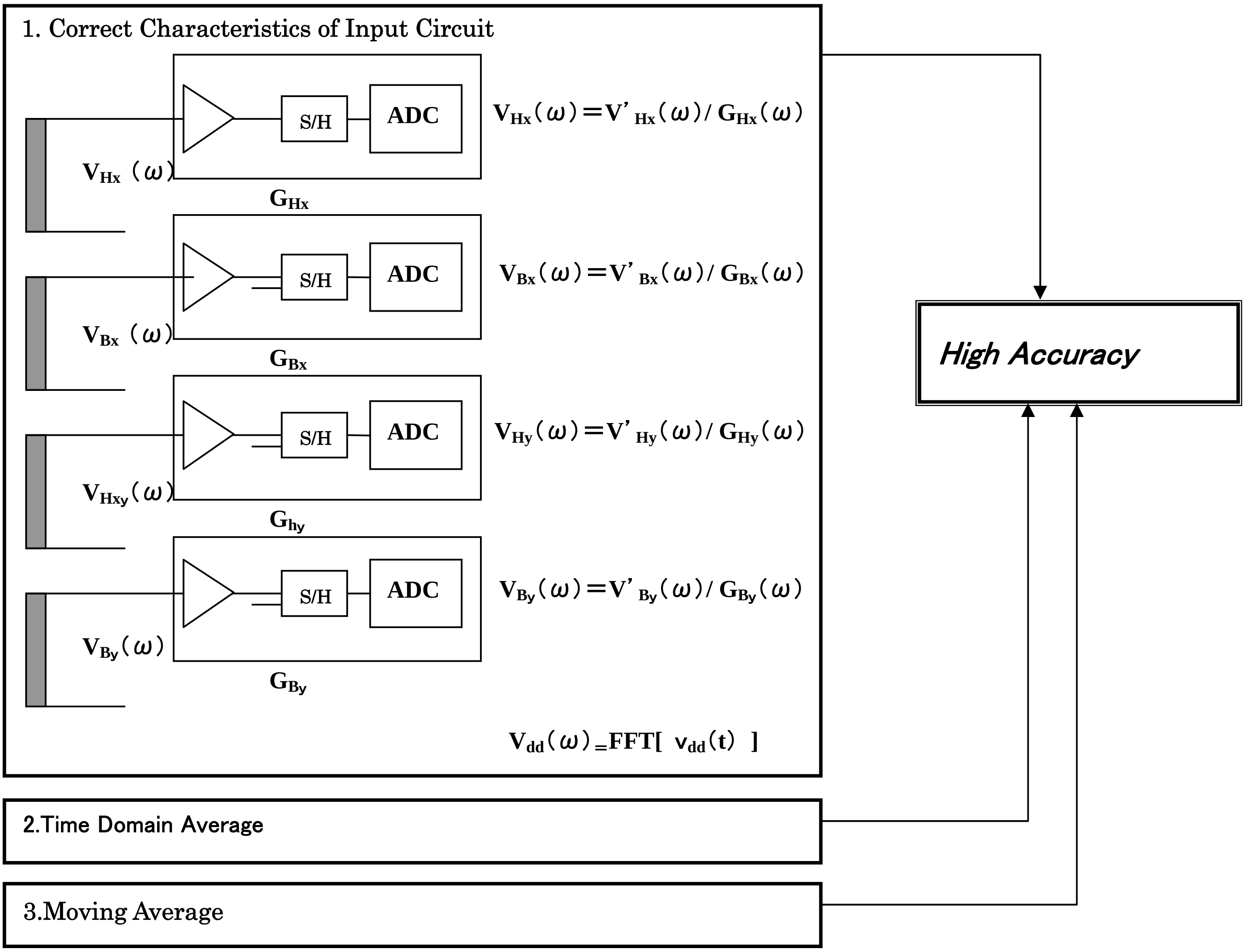


Fig.10 Correct Characteristics of Input Circuit

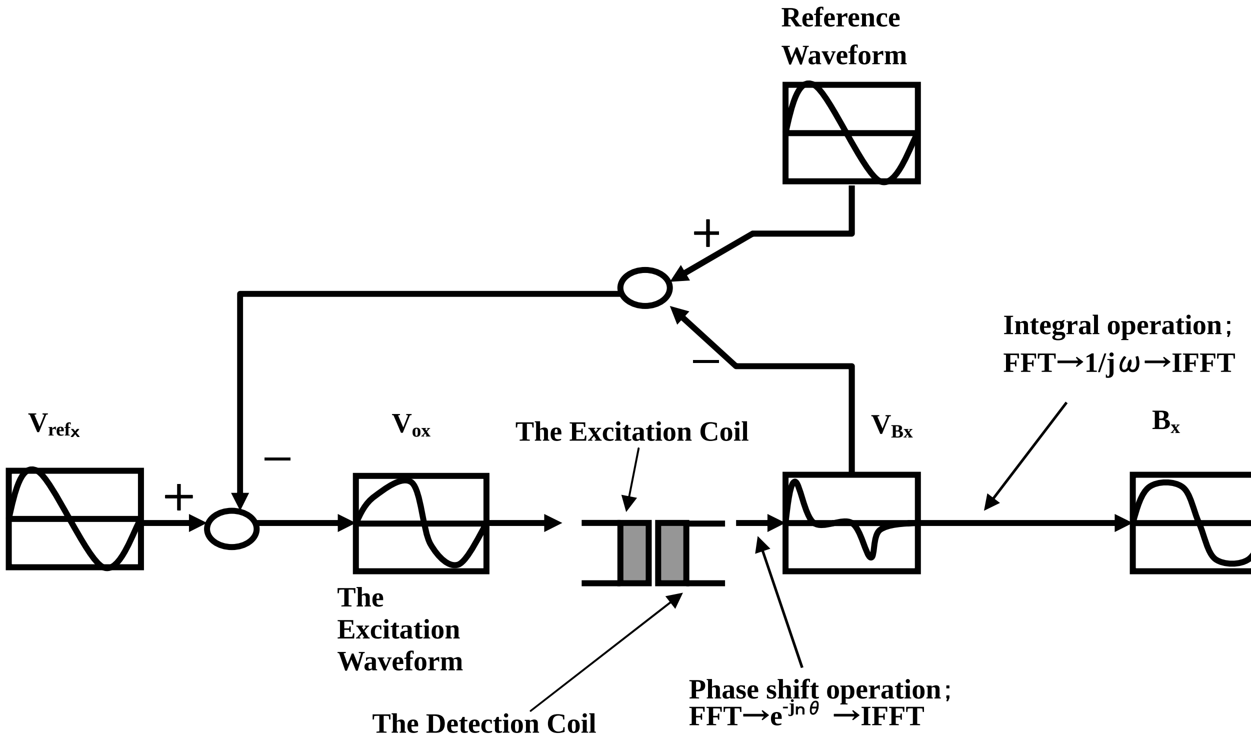


Fig.11 Generate and Control Excitation Waveform

(B Waveform Seems to Become Sine Waveform)

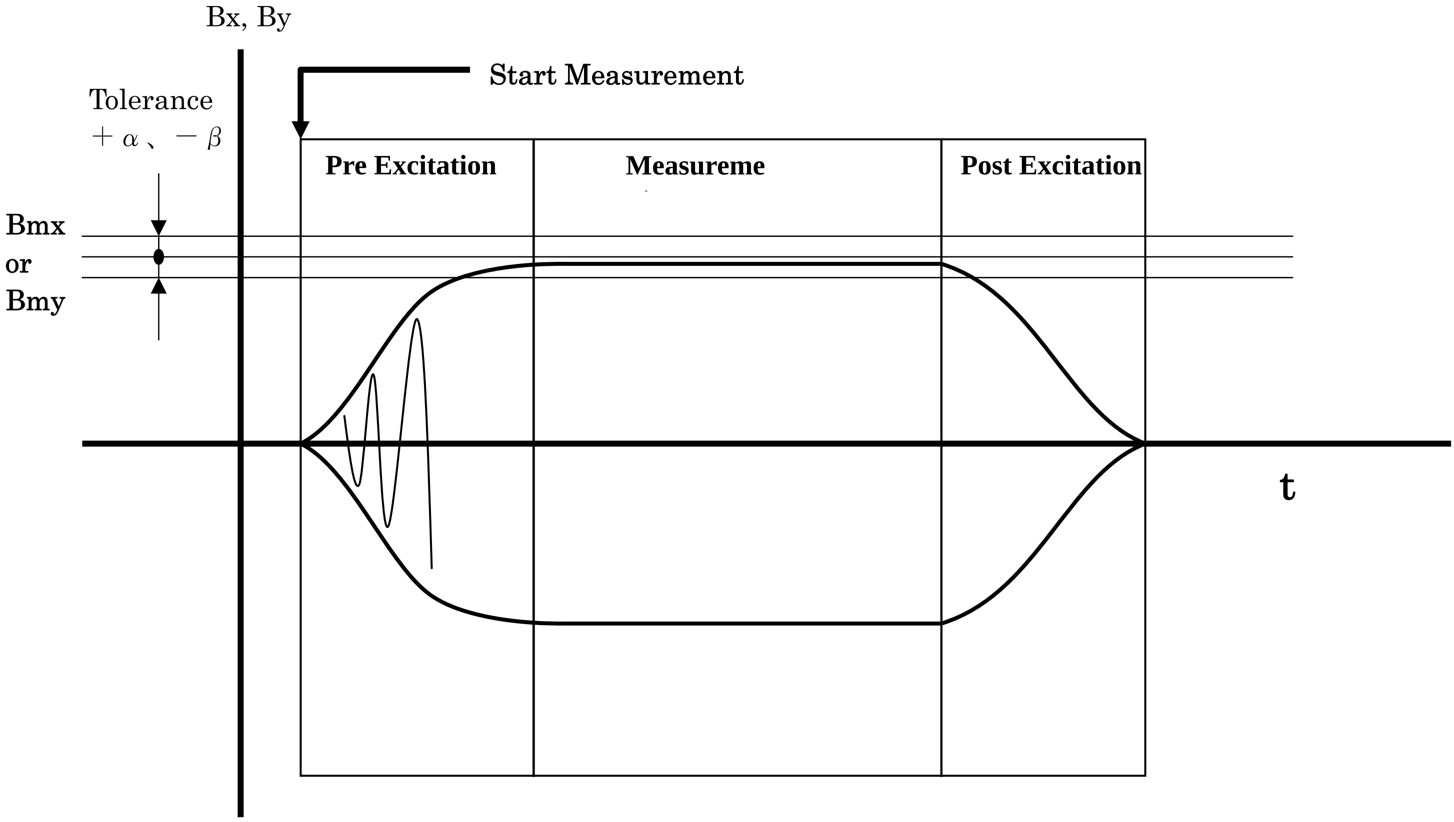


Fig.12 Control Amplitude of Excitation Waveform

6. Display examples of measurement result

6.1 MENU screen and Measurement conditioning screen

Various facility of this equipment is selected with MENU screen. This equipment has three facility of Alternating Flux Condition measurement function, Rotational Flux Condition measurement function and measurement condition set shown in Fig.13

Basic condition is set with Measurement condition entry screen as Fig.14.

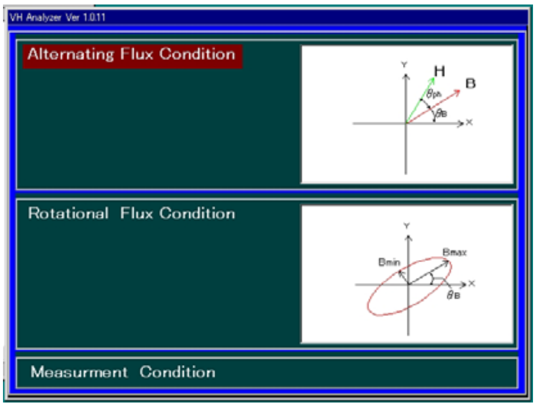


Fig.13 Menu panel

Fig.14 Measurement condition entry screen

6.2 An example of measurement result by Alternating Flux Condition

Fig. 15 to Fig. 21 are examples measured with the following measurement condition.

A. measurement transmission mode = Alternate Flux Condition

B. magnetic flux density =1.0 T

C. frequency =50Hz

D. angle of inclination =0 ° to 90 ° (STEP=15 °)

Fig.15 Alternate Flux Condition (1.0T, 00° ,50Hz)

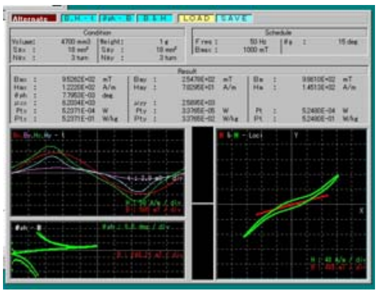


Fig.16 Alternate Flux Condition (1.0T, 15° ,50Hz)

Fig.17 Alternate Flux Condition (1.0T, 30° ,50Hz)

Fig.18 Alternate Flux Condition (1.0T, 45° ,50Hz)

Fig.19 Alternate Flux Condition (1.0T, 60° ,50Hz)

Fig.20 Alternate Flux Condition (1.0T, 75° ,50Hz)

Fig.21 Alternate Flux Condition (1.0T, 90° ,50Hz)

6.3 An example of measurement result by Rotational Flux Condition

Fig. 22 to Fig. 27 are examples measured with the following measurement condition.

A. measurement transmission mode = Rotational Flux Condition
B. magnetic flux density =0.9 T
C. frequency =50Hz
D. angle of inclination =15 ° to 90 ° (STEP=15 °)
E. Axial ratio=0.8

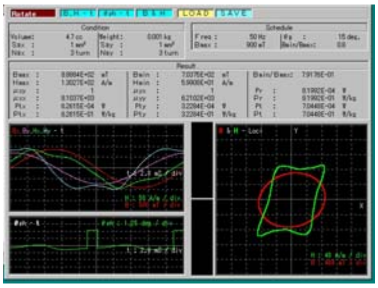


Fig.22 Rotational Flux Condition
(0.9T,15° ,50Hz)

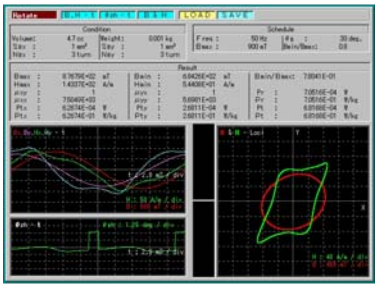


Fig.23 Rotational Flux Condition
(0.9T,30° ,50Hz, 0.8)

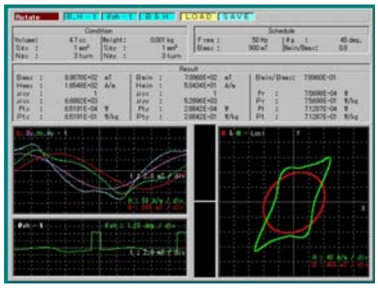


Fig.24 Rotational Flux Condition
(0.9T,45° ,50Hz, 0.8)

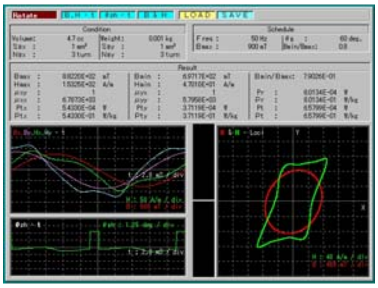


Fig.25 Rotational Flux Condition
(0.9T,60° ,50Hz, 0.8)

Fig.26 Rotational Flux Condition
(0.9T,75° ,50Hz, 0.8)

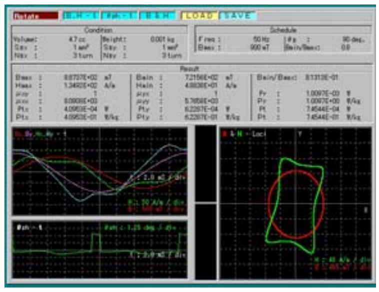


Fig.27 Rotational Flux Condition
(0.9T,90° ,50Hz, 0.8)

7． Specifications and Functions

Major functions and specifications of VH analyzer are shown as follows:

7.1 V-H analyzer system

■ **Measurement method**	E&S vector two-dimensional characteristic measurements method with X-Y detecting coils(H-coil method)
■ Excitation current detection sensitivity:	+/-5mA to +/-5A
■ Induced Voltage detection sensitivity:	+/-5mV to +/-200V
■ H-coil B-coil amplitude accuracy:	+/-2% (nominal)
■ Phase measurement accuracy:	+/-0.2deg. (nominal)
■ X, Y excitation signal output:	OSC-x, OSC-y
■ Data output:	CSV file format

7.2 External Amplifier

■ X, Y axis:	1CH/each
■ Frequency Band width:	DC to 1kHz*
■ Output Voltage:	+/-150V max.
■ Output Current:	+/-5A max.
■ Output Power:	350VA max.

7.3 Excitation current detection section (IE-1131+IE-955)

■ System of measurement:	X-Y detection coil method
■ Measurement frequency:	DC to 1KHz
■ Excitement:	1.5T max.
■ Cohesive force detecting:	H-coil with thin shape
■ Inducing voltage detection:	Detecting winding wires at 90deg.

7.4 Measurement parameters

■ Measurement items:	(see at measurement menu)
■ Frequency bandwidth	10Hz to 1kHz
■ Measurement Flux Density:	0.5T to 1.5T
■ Short axes and Long axes ratio setting:	0.4, 0.5, 0.6, 0.8, 1.0
■ Phase angle set range:	0 to 180deg (5-deg/step)
■ Excitation signal error	4% max
■ Measurement time	3min. or less(Nominal value, at 50Hz, angle/measurement time)

8. Discussions

・Improvement of calculation speed to control estimation of magnetic flux density waveform in sine waveform

Refer to a B-H curve and estimate excitation waveform to be a sine waveform

An application of FUSSY theory

・Improvement of excitation jig

Produce detection coils on silicon LSI process in order to improve an accuracy of H-coil and to get high sensitivity

・Development of jig for various dimensions of DUT

・The deployment of simultaneous measurement facility of magnetostriction

・Two-dimensions magnetism characteristic measurement in random location by detection probe method

9. References

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