

# Magnetic Hysteresis Measurement Using Virtual Instrumentation

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**Abstract** – In this paper the approach of improving a laboratory experiment of magnetic hysteresis measurement is presented. In order to achieve targets, the modern tools of software design and coding such as unified modeling language and graphical programming are implemented. The concepts of virtual instrumentation are applied to create laboratory workbench.

**Keywords** – Virtual Instrumentation, LabVIEW, Magnetic Hysteresis, UML.

## I. INTRODUCTION

One of the base magnetic features of ferromagnetic materials is its hysteresis loop. To identify the hysteresis parameters, it is necessary to measure these characteristics as great accuracy as possible. In magnetic materials, the relationship between  $H$  and  $B$  is usually nonlinear and is expressed graphically by the  $BH$  curve of the material. For a cyclic, input current waveform, a typical  $BH$  curve of a magnetic material can be observed.

Many laboratories still use old swept sine measurement systems consisting of separate standalone hardware linked together by set of cables. In a traditional hardware-based test system (see Figure 1) [1], a sine generator performs a continuous sweep through the amplitude range of interest. The investigated ferromagnetic material has toroidal shape because of the demagnetizing field. The examined material contains two coils. The  $BH$  curve can easily be obtained if the magnetic circuit is operated on alternating current. In the circuit,  $H$  is proportional to this current flowing in the winding, and  $B$  is proportional to the integral of the voltage ( $v$ ) across the winding.

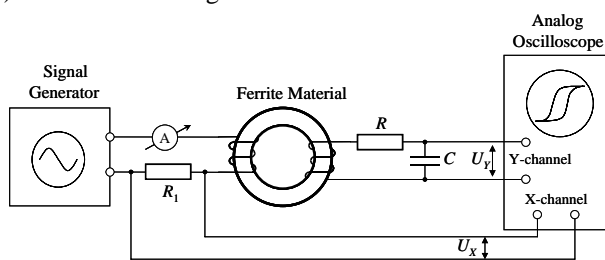


Figure 1 Traditional hysteresis measuring setup

The first coil is the excitation coil, which controlled by the signal generator. The second coil is used for measuring the

effect of excitation; in this case the induced voltage of coil is measured. The amplitude of excitation current can be measured as a voltage of the  $R_1$  resistance. The value of resistance  $R_1$  is prescribed and constant independently the temperature and voltage. This resistor is kept small in comparison with the inductive reactance of the wound sample. Flux density of the cores is determined by integrating the secondary voltage using the  $RC$  circuit. The excitation ( $U_x$ ) and induced ( $U_y$ ) voltages on the measuring coil can be observed by two-channel oscilloscope. The curves depicted in oscilloscope's tube are in scale to  $BH$  curve according to the following equations [1, 5]:

$$U_x(t) = R_1 \frac{l}{N_1} H(t), \quad (1)$$

$$U_y(t) = \frac{1}{RC} \int_0^t v(t) dt = \frac{N_2 S}{RC} B(t), \quad (2)$$

where  $N_1$  is the number of turns of the excitation coil,  $l$  - effective length of the magnetic core,  $N_2$  - the number of turns of the second coil and  $S$  - the cross-sectional area of the magnetic core.

As disadvantages of this traditional measurement systems for education and research applications can be noted:

- Low resolution;
- Unattractive visualization;
- A lot of fatiguing mathematical calculations necessity;
- The experiment's equipment complexity distract attention of the students from essence of the magnetic quantity;
- Impossibility to compare the magnetic hysteresis loops of different materials in the same time.

## II. THE BENEFITS OF VIRTUAL INSTRUMENTATION

Recent developments and applications, specifically the computer-based applications, have shown that many pure lecture-based engineering courses and conventional experiments (which are heavily dependant upon specialized instruments) can be updated and integrated with custom-written virtual instrumentation (VI), and can be delivered by computers [4]. In addition to this, the courses and experiments can be delivered remotely without having multiple copies of the experimental setups. Additional scientific visualizations and advanced analysis can also be added in the form of virtual instruments with minimal cost, which is limited or not possible in the conventional laboratory practice. Moreover, the virtual instrumentation approach is open to further improvements and developments, which may increase the student participation and enthusiasm while providing ideal delivery environment.

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However, due to the diverse nature of the lectures and the laboratory courses in every institution, custom-built software and hardware development is required most of the time. In addition, due to the fast developments in technology, the choice of the software and hardware should be considered carefully along with the cost.

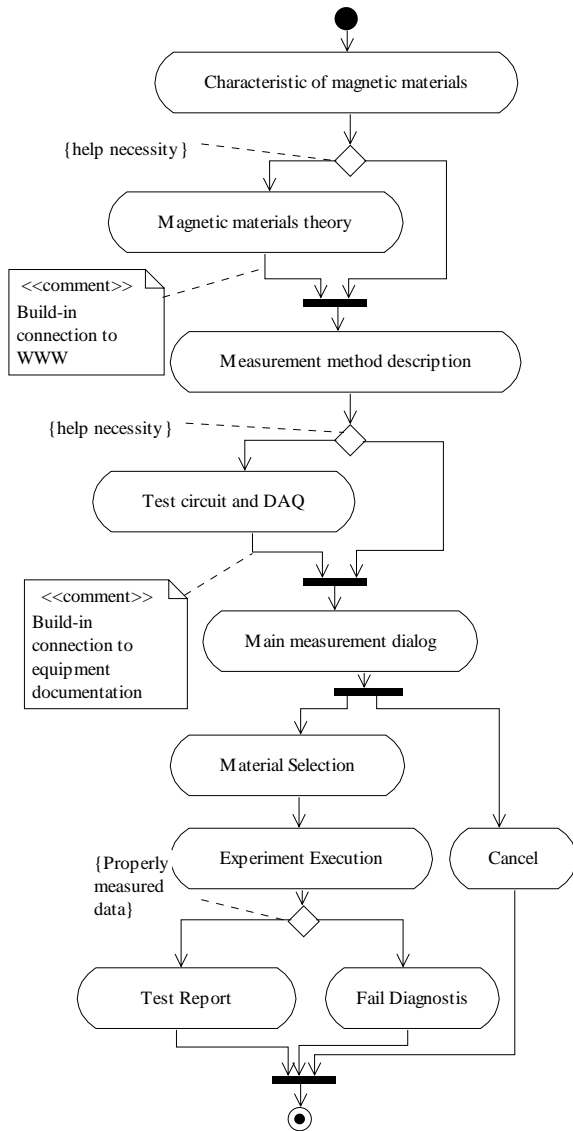


Fig. 2 The activity diagram for hysteresis experiment modeling

A number of interactive computer-delivered simulation, control, and scientific visualization software solutions are available in the market. It is found that the number of criteria may be contemplated for selecting application software to build virtual instrumentation used in engineering education. Because of its overall versatility as an engineering tool, the software package LabVIEW is chosen to create virtual workbench for magnetic hysteresis measurement. It is a graphical programming language that allows engineers and scientists to develop their own virtual instrument, which is flexible, modular and economical [3]. Furthermore, the software meets most of the software selection criteria, and it

not only does the data manipulation, analysis, and control, but also has some multimedia authoring capabilities with the help of the add-on tools. The LabVIEW software allows for the creating of application-specific templates (sub-virtual instruments) to reduce the production time for the identical subjects. Many useful functions can be incorporated with the LabVIEW programs to perform very useful tasks in a laboratory virtual instrumentation system design.

A virtual test system is proposed that operates on the same principles as a traditional measurement system consisting of a sine generator, and two-channel oscilloscope. The main difference is that all these functions are implemented in multifunctional data acquisition system (DAQ), power voltage to current converter and software ADE as LabVIEW. This virtual system uses a similar but improved approach, for magnetic hysteresis measuring. By the way the automated magnetic hysteresis measurement is controlled by a personal computer. For the measurement experiment the NI 6024 multifunctional DAQ is used. The data acquisition and the generation of excitation current can be performed simultaneously.

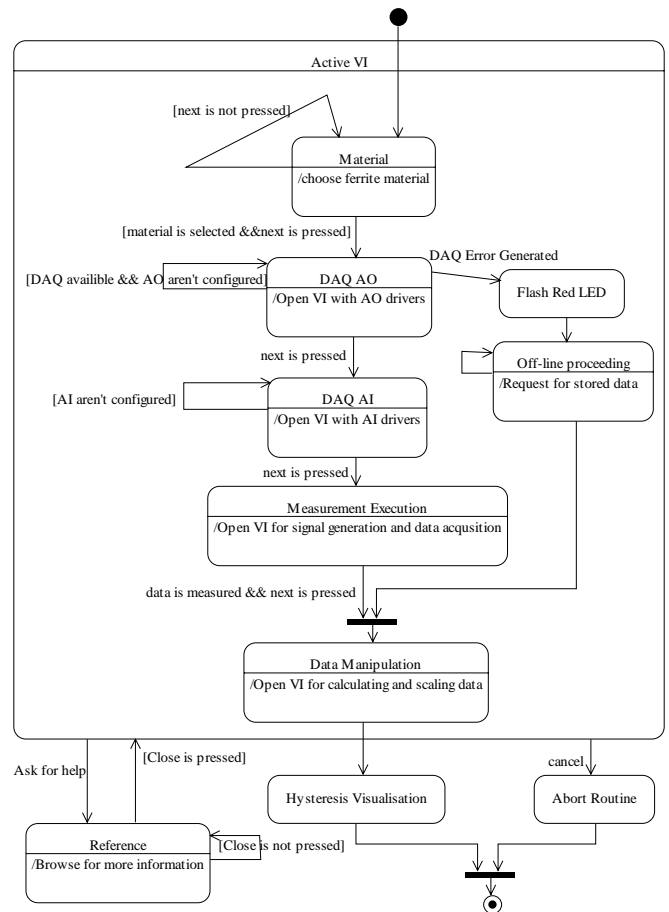


Fig. 3 The state diagram modelling execution of measurement experiment

The VI Generate\_Sine.vi generates a sinewave analog output waveform on the DAQ board specified. It is the simplest form of continuous waveform generation. A sine wave is computed using the trigger functions in a “for loop”.

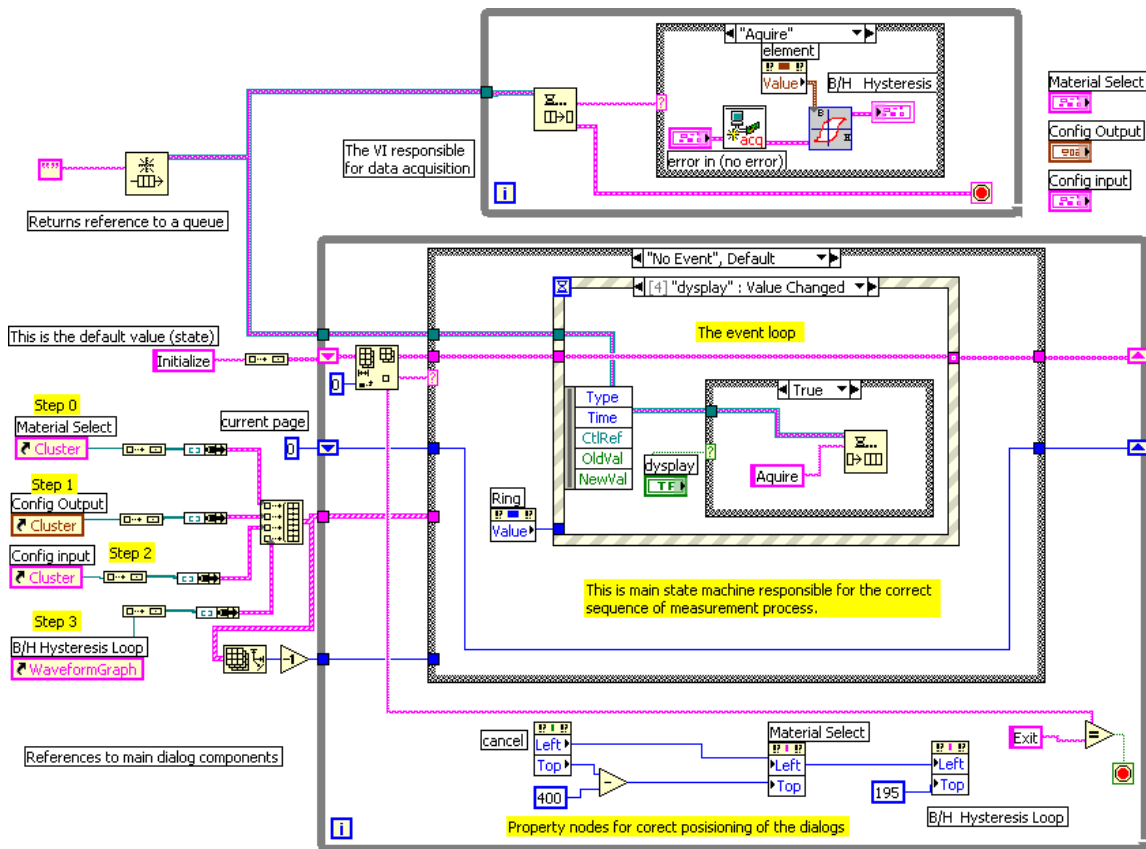


Fig. 4 LabVIEW block diagram for execution of measurement **experiment**

The analog output channel and buffer is initialized, the waveform written to the waveform buffer and continuous waveform generation is initiated at the specified update rate.

The Acquire\_Data.vi VI retrieves the specified amount of data from two analog input channels. The VI is a timed acquisition, meaning that a hardware clock is used to control the acquisition rate for fast and accurate timing. It is also a buffered acquisition. Data are stored in an intermediate memory buffer after they are acquired from the DAQ board. Once the data have been acquired, LabVIEW retrieves the data from that buffer and displays it.

### III. DESIGNING THE EXPERIMENT SEQUENCE

Modeling is a proven and well-accepted engineering technique. Engineers study models to assess the impact of environmental forces and anticipate the behavior of actual structures. The Unified Modeling Language (UML) is a modeling language for specifying, visualizing, constructing and documenting the artifacts of a system-intensive process.

The UML [3] has become the standard for documentation and high-level design of modern software. As an example of this approach the application layer of the magnetic hysteresis measurement system based on concept of virtual instrumentation is presented. UML defines nine types of diagrams. The most appropriate to hysteresis measurement experiment modeling are activity and state diagrams.

Activity diagrams illustrate the dynamic nature of a system by modeling the flow of control from activity to activity. An activity represents an operation on some subVI in the system

that results in a change in the state of the system. Activity diagrams are used to model workflow and internal operation. The dynamic behavior of the virtual workbench modeled by activity diagram is shown in fig. 2.

Statechart diagrams describe the dynamic behavior of a system in response to external stimuli. Statechart diagrams are especially useful in modeling reactive objects whose states are triggered by specific events. The state diagram that is used to model execution of measurement experiment is shown in fig. 3.

### IV. LABVIEW CODING

Recently widely treated in realm of software engineering is the term “pattern”. Design patterns represent techniques that have proved themselves useful time and time again. They typically have evolved through the efforts of many developers and have been fine-tuned for simplicity, maintainability and readability. Furthermore, as a pattern gains acceptance, it becomes easier to recognize. This recognition alone helps other developers to read and make changes to the code.

The state machine pattern is one of the most widely recognized and highly useful design patterns for LabVIEW. This pattern neatly implements any algorithm explicitly described by a state diagram. A state machine usually illustrates a moderately complex decision making algorithm, such as a diagnostic routine or a process monitor.

The standard LabVIEW state machine consists of a large “while loop”, a shift register to remember the current state, and a case structure that holds separate code to run for each state.

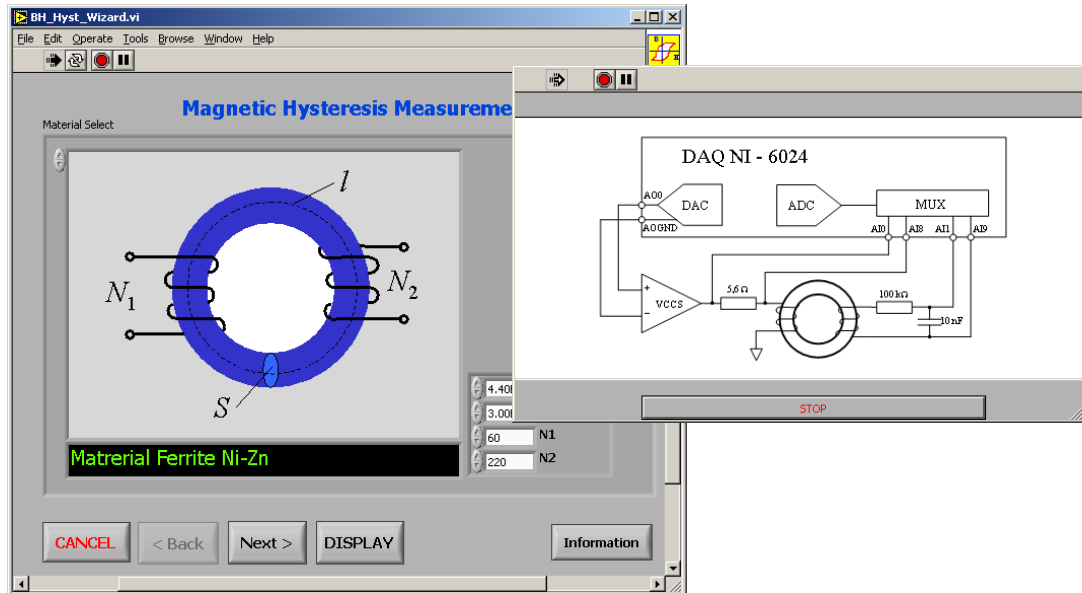


Fig. 5 Front panel for selection of ferrite material

The state machine that is created following the UML consideration (fig.3) is shown in fig.4. This programming code is responsible to ensure the correct sequence of measurement process.

Another design pattern, so called “event loop”, is applied in software code and can be seen also in fig.4. As the state machine it is suggested by UML modeling also. The event loop is a powerful and efficient method for handling user interaction with a LabVIEW program. Because the event loop wakes up precisely when an event happens and sleeps in between, it is not needed to read control values over and over again in order to detect when a user presses a button. This will allow using the processor much less without risking loss of interactivity.

Of course, to complete the full LabVIEW program many other build-in functions and subVI are used, which are less or more described in appropriate documentation [4].

## V. REALIZATION OF VIRTUAL LABORATORY WORKBENCH

In order to illustrate some of benefits offered by virtual instrumentation in this topic the user interface (front panels) is appended. This user interface corresponds of state diagram shown in fig.3 and program code (block diagram) of fig. 4.

The first step of magnetic hysteresis measurement – selection of ferrite is shown in the fig. 5. In the right of figure is shown the opportunity to investigate the experiment’s details without leave the working environment. As can be seen the great representational possibility of LabVIEW focus attention of the user in the base objective of experiment.

In the next figure 6, the successful completion of the measurement procedures are shown. The user can to turn of profit the build-in markers for desired magnetic parameter extraction.

## VI. CONCLUSION

The design and development a set of virtual instruments measuring magnetic hysteresis is presented. The modern software technologies namely the unified modeling language and graphical programming are implemented in order to complete laboratory workbench. The exposed material can be

useful for test and design engineers that going to involve the virtual measurement technologies into their practice. The applications of introduced modeling approach and software code cover – design of behavioral models for relatively large virtual instruments; using design patterns; magnetic materials characterization and measuring; engineering education; etc. It is relevant to remark that LabVIEW and UML have provided the educator with excellent opportunities to deliver curricula: in the hardware laboratory, to provide student self study resources, or for research purposes.

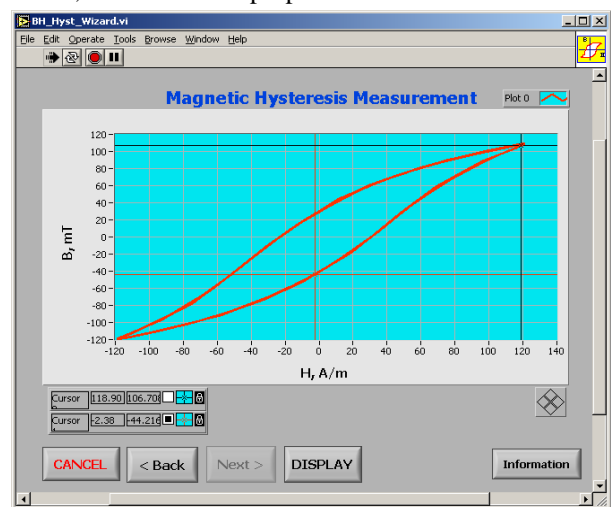


Figure 6 Measured hysteresis

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