

NON-STANDARD MEASUREMENT AND EVALUATION OF HYSTERESIS LOOP OF FERROELECTRICS

PROF. RNDR ING. MILOSLAV KOSEK, CSC.¹

ING. JAN VODOLAN²

Abstract: A digital apparatus for automated hysteresis loop measurement controlled by a PC was designed, realized and verified. The only analogous instrument is a high voltage amplifier. Digital approach has many advantages, especially full automation, high flexibility due to the computer control, reduction of noise and line interference, exact data processing, data saving etc. The only disadvantage is a little reduction of real time processing. The resulting hysteresis loop can be presented by three different means: in time, frequency and field domain. The frequency spectrum, as a result of the discrete Fourier transform, is used for filtering, elimination of DC component, effective loop approximation etc. In the field domain the spectrum components can be displayed as Lissajouse figures and the dissipation power of individual harmonics can be found. Complete data processing gives a lot of information for the explanation of physical processes, design of ferroelectrics devices, etc.

Keywords: hysteresis loop, ferroelectrics, automated measurement, data processing, data presentation, Lissajouse figures.

1 Introduction

Measurement of hysteresis loop of ferroelectrics is a standard well-known procedure. In a typical arrangement, the apparatus consists of analogous commercial instruments. This approach has several disadvantages: complicated and expensive instruments, difficult hand control, noise and line interference effects, no possibility of data saving, etc. The use of this method requires a high operator skill and experience. Also the difficult protection of the operator and instruments against the used high voltage must be made. The important advantage, however, is the full real time operation.

¹Technical University of Liberec, Hálkova 6, 46117 Liberec 1, e-mail: miloslav.kosek@vslib.cz

²Technical University of Liberec, Hálkova 6, 46117 Liberec 1, e-mail: jan.vodolan@vslib.cz

On the other hand, the proposed and verified digital method allows a fully automated measurement and exhibits high flexibility. It removes the disadvantages of the analogous apparatus and has new important features, for instance, new possibilities of measured data processing and presentation. This approach is well suited for research or industry, where a lot of measurements is necessary and the results should be saved and processed by a uniform and simple way. It is also an important part of a universal system of complete piezoelectric measurement [1].

2 Apparatus and Data Processing

The digital method, shown in Fig. 1, requires only one external instrument – a high voltage amplifier. All other instruments and components are either replaced by a standard, cheap and universal A/D card in the control PC, or are inserted into a user-manufactured board. The PC generates the input harmonic signal for the high voltage amplifier numerically. The D/A output of the universal card is the input of the high voltage amplifier. Its output voltage feeds the specimen. Since a relatively low specimen current must be measured, the resistance converters are controlled by TTL logic to get an optimum input voltage with respect to the input range of A/D transducer and improve the voltage to noise ratio. The buffer amplifier is used to protect the computer, if the specimen breakdown appears. Resulting signal is converted to a digital one by the A/D channel of the card. Then the program numerically integrates this signal.

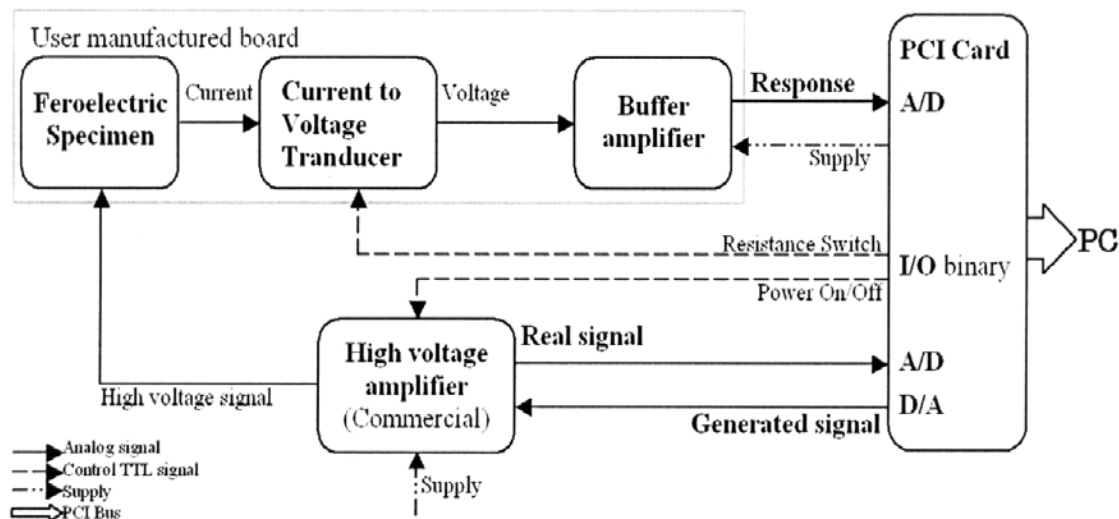


Fig. 1. Digital apparatus

The PC plays at least three roles: controls the apparatus, processes the data and displays them in a scientific form. A menu system performs the apparatus control. Only a few numerical input parameters (limit values and step

of frequency and amplitude) are necessary and the complete material measurement is possible. Furthermore, the program searches optimum conditions for measurement. The individual set-up of all parameters is also possible. The measured data are saved for later processing and investigation

Basic data processing operation is the Discrete Fourier Transform (DFT). The signal spectrum is used for offset error correction due to the DC component, if several periods (loops) are measured, for data filtration to reduce noise and power net interference and for the loop approximation by a suitable choice of the most important harmonics. The condition of the best filtration of the net frequency is to use such a loop frequency that the loop harmonics are not multiples of power net frequency harmonics. Then inverse DFT (IDFT) is used to transform the improved spectrum into time domain.

The data visualization can be made in three areas:

1. In time domain as a function of time
2. In frequency domain as amplitude and phase spectrum
3. In field domain as the dependence of electric flux density D on the electric field strength E

Although the same information is in each of areas of visualization, different information is enhanced in individual domains. As a new feature is the decomposition to harmonics is made not only in time domain but also in the field domain as Lissajouse figures. The visualisation part of program also checks, if the condition of harmonic exciting electric field strength is valid with satisfactory accuracy.

3 Results

We focus only to the presentation of typical results in this section. The presentation of measured data in all three domains is in Fig. 2.

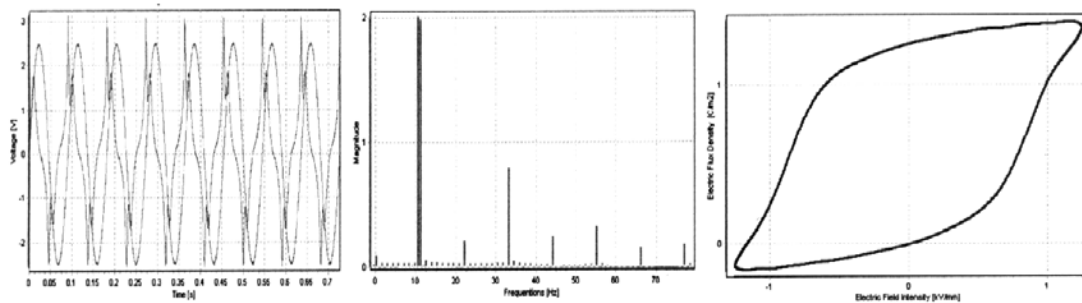


Fig. 2. Hysteresis loop presentation an all three domains, from left to right time, frequency and amplitude domain

The decomposition of hysteresis loop in amplitude domain into Lissajouse figures is in Fig. 3. Only three of them are in Fig. 3a, while in Fig. 3b calculation of dissipated/accumulated power for the third harmonics is shown.

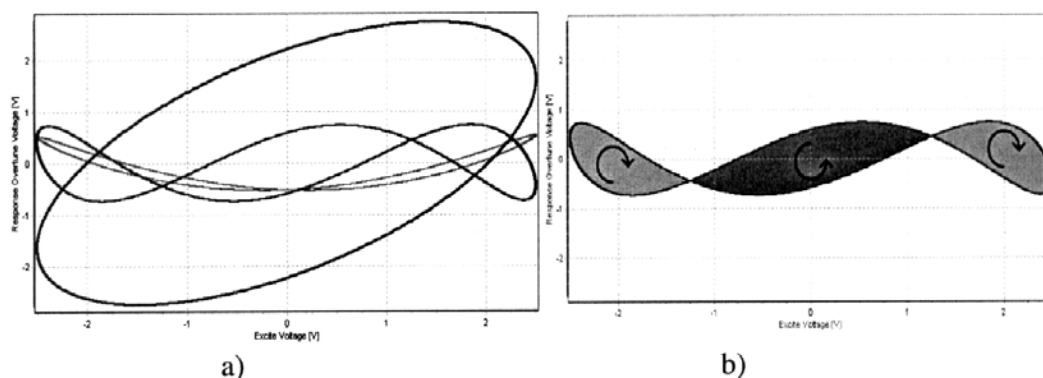


Fig. 3 Decomposition of hysteresis in amplitude domain, a) Lissajouse figures, b) Dissipated/accumulated power

4 Conclusions

The system allows fully automated not only hysteresis loop measurement in a wide range of frequencies and excitations but also processing and visualization of measured data. All the operations are menu controlled [2] and the user has many degrees of freedom how to arrange and control the measurement and report the results.

As for results presentation, to our knowledge we have used also a rare method of Lissajouse figures. One of main advantages of this approach is that the energy consideration for different harmonics can be visualised. From the physical point of view, it may be possible to judge to different type of loss for different harmonics.

Very important feature of this method is the fact that number of measured periods (loops) is unlimited. It can be used to improve the data, for example, by defining an average loop, to estimate material errors, to check the reproducibility, etc. A lot of other regimes exist, for instance, the measurement of a small loop in the presence of bias.

Acknowledgement

This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic – project MSM 242200002.

References

- [1] Košek, M.: A Simple Apparatus for Complex Measurement of Piezoelectric and Ferroelectric Materials, *Ann. Chim. Sci. Mat.* 2001, Vol. 26, pp. 63 – 66.
- [2] Vodolan, J.: Automated Measurement and Interpretation Hysteresis Loop of Ferroelectric, Diploma work, Technical University of Liberec, Faculty of Mechatronics, May 2003