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An automated loop tracer for the study of the growth of ferroelectric hysteresis

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An automated ferroelectric hysteresis loop tracer, developed using an INTEL 8085 microprocessor is described. This setup can be used to study the growth of a hysteresis curve at any desired temperature instantaneously after the application of a field. Since the setup allows the storage of data for each cycle of the applied field, this can be used to study the response of ferroelectric domains in an applied alternating field with time on unpoled or poled samples. The setup is interfaced with a personal computer to obtain directly the values of loop parameters.

I. INTRODUCTION

A Sawyer–Tower circuit, based on charging a known capacitor with the charge developed across the sample,[1–5] or its modified version,[6,7] which compensates for both the finite conductivity and capacitance of the sample is conventionally used for measuring hysteresis properties of ferroelectric materials. In these methods, the loop is displayed on a CRO screen and the data are not stored or plotted and hence cannot be retrieved subsequently. Glacer *et al.*[8] have overcome this difficulty by introducing a circuit which compensates for both the conductivity and capacitance of the sample and plotting the loop on a $X-Y$ plotter. Digital technology has also been employed to study the change of loop parameters as a function of time and field.[9,10]

In this paper, the development of an automated loop tracer constructed using an INTEL 8085 microprocessor is described. In the conventional hysteresis loop measurement using a cathode ray oscilloscope (CRO), one would miss the information on the influences of mobile space charges, domains and aging, the degradation of ferroelectric properties, on the growth of the hysteresis curve after the application of the field.[10] The advantage of this setup is that the measurement can be done instantaneously after the application of an electric field at any given temperature, which can be programmed, for any number of cycles of the applied field with required delay between each measurement and the data can be stored.

The provision for interfacing with a personal computer (PC) enhances the advantages of this setup to store a lot of data and can be used to calculate the values of remanent polarization, coercive field, and hysteresis loss directly.

The paper, in the following sections, explains the construction of the hysteresis loop tracer, flowchart, system overview, and the advantages of the setup, using the data

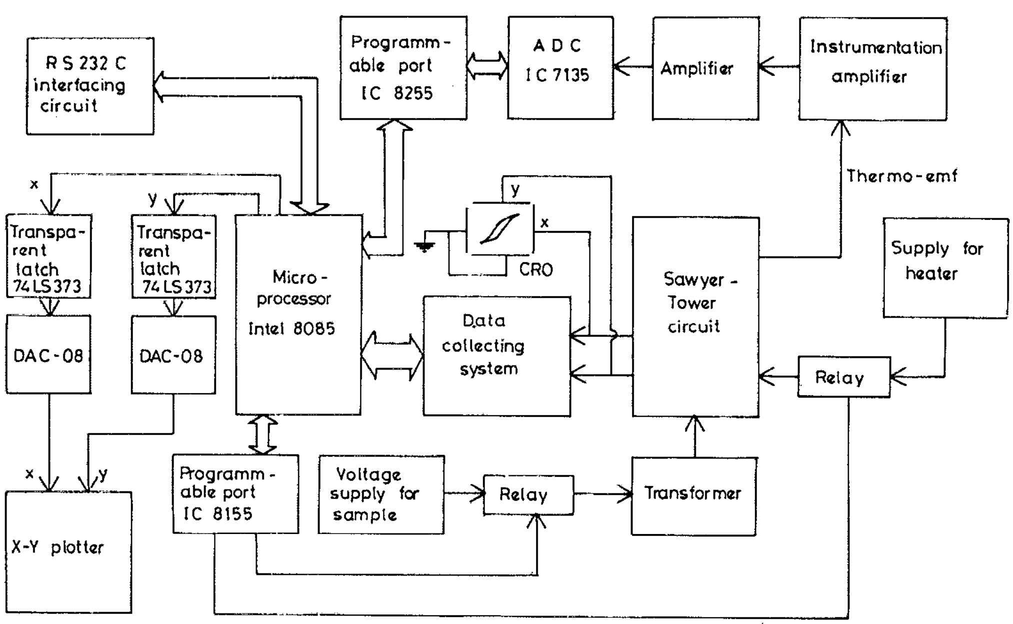

FIG. 1. Block diagram of the automated hysteresis loop tracer.

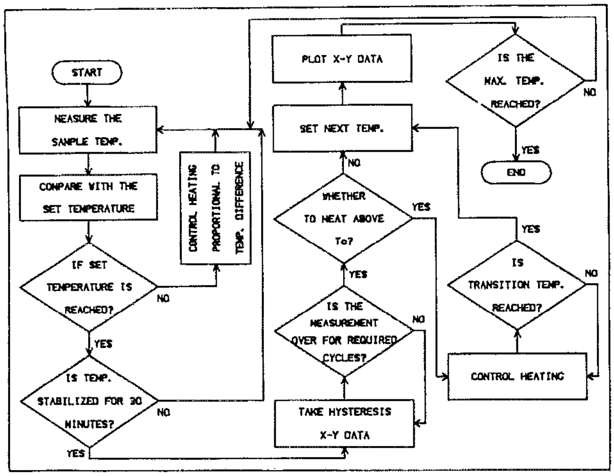

FIG. 2. Flowchart of the overall functioning of the measurement setup.

obtained from the measurements on ceramic barium titanate, respectively.

II. SYSTEM OVERVIEW

The block diagram of the setup is given in Fig. 1. The setup starts functioning by measuring the temperature of the sample and controlling the heating to reach the required set temperature. After stabilizing the temperature for the required time, the processor triggers a relay connected to the voltage source for applying the field across the sample.

X and Y outputs of a prototype Sawyer–Tower circuit are the X and Y inputs to an oscilloscope as well as to an analog to digital converter (ADC) through buffer circuits and a processor controlled analog switch (Quad Analog switch MCI4066). Knowing the number of data points collected per each cycle for a given frequency, the microprocessor is programmed to collect the digitized X and Y data for each cycle with the specified delay between the cycles. The processor stores the X and Y data in separate memory locations of a 2K-RAM (6264, static RAM). Then the processor switches off the field applied across the sample and switches on the heater so as to reach the next programmed temperature and at this temperature the data is collected again. Since the sample is already subjected to a field required for saturation the virginity of the sample would have been lost. Accordingly, there is a provision for selecting the sequences for heating the sample. Either the sample is heated above the transition temperature, to depolarize and release the internal stresses developed by the applied field during the measurement, and cooled to the next required temperature or the sample is directly heated to the next required temperature. The detailed functioning of the setup is shown in the flowchart given in Fig. 2.

After the measurement, the data is sent through two digital to analog convertors (DAC) to a $X-Y$ plotter (Digital Electronics Ltd., model 2000). The parameters are then calculated from the curve. Otherwise, if a PC is attached, the data is transferred to the PC through RS-232C for calculating the parameters automatically.

III. COLLECTION OF THE DATA USING A SINGLE ADC AND THE CALCULATION OF LOOP PARAMETERS

The detailed block diagram of the ADC circuit and the interface with the processor are given in Fig. 3. Both the X and Y inputs are converted to digital data by using a single ADC constructed using a successive approximation register (National Semiconductor MM74C905). The DAC (DAC 08), connected to the output of the successive approximation register is functioning in unipolar mode. The bipolar data from the Sawyer–Tower circuit are added with a known sufficient DC bias to shift the negative voltage to positive. During computation of the loop parameters the added bias voltage is suitably corrected for.

The ADC circuit functions as follows: The ADC is connected to the processor in I/O mode. The assembly level language program (for 8085) for collecting the data through the ADC starts by initializing a programmable timer (IC 8253) for a required delay between successive data. Minimum delay must be at least equal to the conversion time of the ADC. After the required delay, the timer sends a signal which is connected to the ADC through 74LS123, which is a dual retriggerable one-shot device with clear and comple-

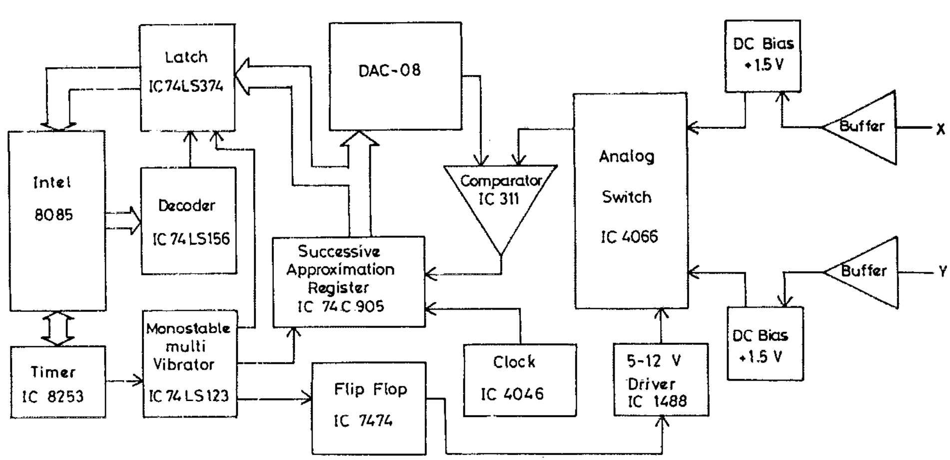

FIG. 3. Block diagram of the ADC used for collecting the hysteresis loop data.

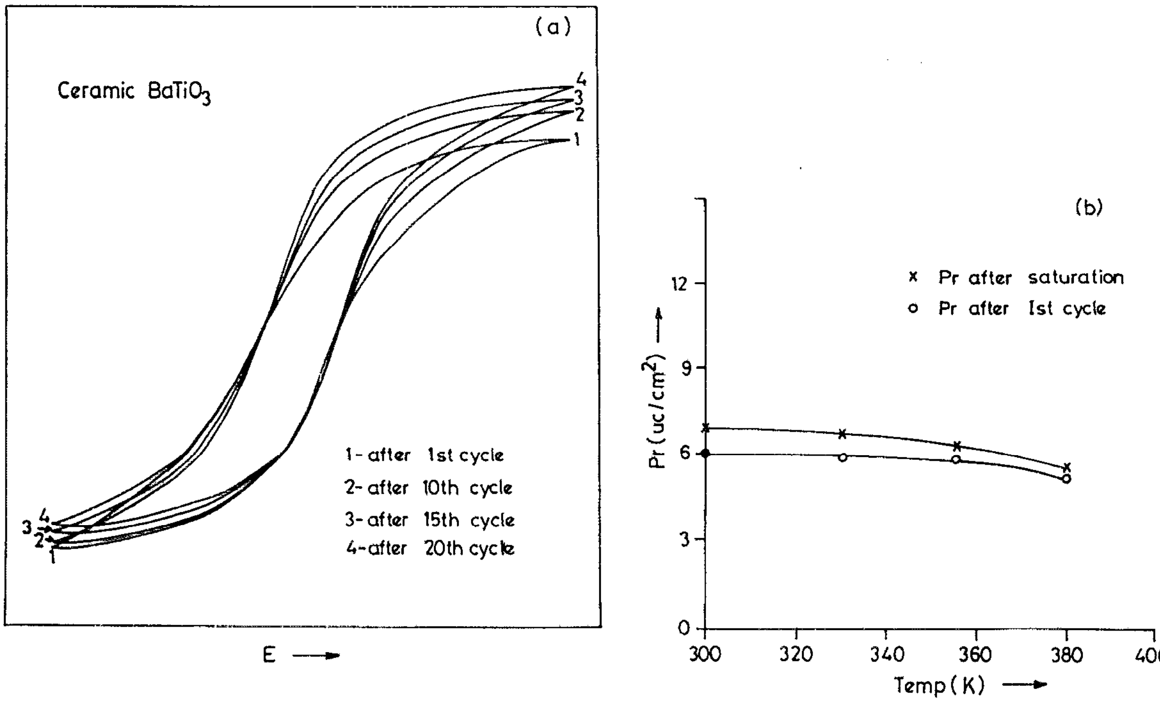

FIG. 4. (a) Variation of hysteresis loop with number of applied field cycles. (b) Variation of remanent polarization with temperature for the different number of cycles of applied field.

mentary outputs. Before enabling the interrupt from the timer, the processor initializes memory locations for collecting data, selects the channel X through the analog switch, and waits for the interrupt signal. As the processor gets interrupted after the conversion of the signal by ADC, it reads the input from the channel X and closes the channel, selects the channel Y, and repeats the same procedure. This continues for the required number of cycles with the required delay between successive readings.

The software developed in GWBASIC transfers the data from the microprocessor to the PC. After collecting the data, it tabulates the X and Y values simultaneously and plots it on a cathode-ray tube (CRT) screen. To analyze the data, the program converts the data to corresponding voltages as per the calibration. Then using the thickness and area of the sample and the capacitance, the X-axis voltage values are converted to the corresponding field values and the Y-axis voltage values to the corresponding values of polarization.

The computer then plots the X and Y axes corresponding to the DC bias voltages and finds the four intercepts (two on X axis and two on Y axis). These points correspond to the coercive field and remanent polarization, respectively. The area of the graph is also calculated by the program and is displayed.

IV. TYPICAL EXPERIMENTAL RESULTS

Initially, the value of the saturating field for the ceramic $BaTiO_3$ sample is determined by observing the hysteresis loop. The sample is then annealed at 200 °C for 24 h. It is then kept in the setup and the measurement is carried out at room temperature by collecting the data immediately after applying the field required for saturation for four cycles with specified delay (see Fig. 4). It is then heated above the transition temperature (125 °C) and cooled to the next set temperature and the measurement is repeated. The measurement is continued until the set temperature is reached, 150 °C.

The loops observed from measurements at 60 °C is shown in Fig. 4(a). The temperature dependence of the remanent polarization of the sample measured immediately after the application of the field and after stabilizing the loop are shown in Fig. 4(b). It is clear from the data shown in Fig. 4 that the growth of the hysteresis loop does not take place instantaneously on the application of the field. The temperature dependence of the rate of growth of hysteresis is also evident from the data given in Fig. 4(b).

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