This thesis is devoted for characterizing transducer ferroelectric material in context of application point of view. The properties of ferroelectric material which make them important for transducer application is first time measured on computer. Dielectric measurement though studied extensively but again each class of material from ferroelectric data analysis done through acquisition card. Ferroelectric films are being introduced as technological important transducers in this thesis measurement on capacitance on controlled bias voltage, various physical conditions such as stress and temperature. This thesis is devoted for characterizing transducer ferroelectric material in context of application point of view. The properties of ferroelectric material which make them important for transducer application is first time measured on computer. Dielectric measurement though studied extensively but again each class of material from ferroelectric data analysis done through acquisition card. Ferroelectric films are being introduced as technological important transducers in this thesis measurement on capacitance on controlled bias voltage, various physical conditions such as stress and temperature. The main theme of this thesis is supplementing the study of thin film, pellets ceramics and crystal forms for physical characterization under following headings.

1. Measurement circuit designing which is compatible with add-on-card.
2. Study of ferroelectric - semiconductor device for memory application on computer.
3. Hysteresis analysis on elevated temperature on computer.

Mostly samples are fabricated in laboratory by various suitable methods like vacuum evaporation; melt casting and solution casting spinning disc technique as detailed in various chapters.

In the present investigation a special credit goes to the author for development of various circuits for measuring purposes. Instrument development
for characterizing ferroelectrics properties by commercially available integrated circuits and digital devices, first time used for ferroelectrics material research.

First Chapter deals with concept of ferroelectricity, their classification which characterized material for transducer application since these studies were related to transducer application detail review of material and analysis of mechanism involved for transducer properties has been discussed here. In the chapter I Introduction, the applied aspects of Ferro-electricity and its basic inherent properties useful for transducer application in crystals, thin films, ceramics form are presented. Particularly properties and applications, which are relevant to the objective of the present study, are largely reviewed. The key point to develop circuit designing is discussed for understanding the behavior of ferroelectrics.

A brief review of up-to-date work related to the present study on ferroelectrics application point of view has been incorporated in this chapter. The unique properties of thin film their synthesis methods and device applications have also mentioned in short. At the end of the chapter, the objective of the present study has been elaborated.

The material chosen for these studies are:

a. Ferroelectric Material
   (i) PZT (Lead Zirconate titanates)
   (ii) PLZT (Lead Lanthanum Zirconate titanates)
   (iii) TGS (Triglycine sulphate)
   (iv) TGSe (Triglycine Selenate)
   (v) TGS doped with L-alanine
   (vi) TGS doped with Phosphoric acid

b. Polymer PVF₂ (Poly Vinlydene fluoride)
CHAPTER II

This chapter deals with experimental techniques involved in preparation of ferroelectric and ferroelectric related material crystal growth, thin films, pellets preparation under stress. Ferroelectric ceramics are traditionally made from powders formulated from individual oxides by chemical co precipitation techniques. The details of processing method selection of constituents the parameter to be controlled presented in deep further more the different sample holder and temperature, pressure cells also discussed. The working principle of some important instrument existing in laboratory for comparing studies concisely described. In this chapter deals with the preparation experimental techniques adapted for preparations, measurements of Aluminum thin film electrode. Procedure for observing the poly crystalline structure of the ferroelectrics films and their birefringence for estimating the lamellar crystalline size and physical faults through the crossed polarizing microscope also mentioned usual method adapted for measurement of thickness of film, poling have been briefly discussed. Temperature cell was used for sample can be kept at -5°C to room temperature. More than room temperature variations are obtained within sample holder arrangement. Low pressure chamber also developed and discussed here. PZT and PLZT solid state sol-gel reaction process and spin disc employed for obtaining film. TGS and TGSE are water soluble solution casting spin disc technique was employed.

Next part of this section contains measurement like thickness, physical faults using polarizing microscope. The different techniques used for surface morphological studies of transducer material are also described in this chapter such as x-ray diffractrogram, infrared spectroscopic and electron microscope studies.

Electrodes were prepared by vacuum evaporation for Films ferroelectric capacitor sandwiched by solution casting technique and spin disc method. Pellets were prepared by solid state reaction route.

In this laboratory preparation and growth of single crystal as well as thin films of ferroelectric material are made by ex-research worker. It is also a part
of studies. Detailed measurement of dielectric properties as dielectric constant $\varepsilon$, loss ($\tan \delta$) and A.C and D.C conductivity over a wide range of frequency and temperature with existing instruments described here.

The present work is the continuation of such studies more particularly the study under stress and on different temperature. Hysteresis analysis is done on computer aided system. Extensions of this work instruments exist in Laboratory were interfaced by computer via add-on-card. Necessary hardware circuits have been developed by author. Results have been taken on data acquisition (computerized) system and verified.

CHAPTER III

A data acquisition system (DAS) performs the complete function of converting the raw output form one or more transducer into equivalent digital signals usable for further processing control or display applications. PCL 812 card (Dynalog India Ltd.) with PC is used to interface various circuit developed by author. Computer software has been developed to generate signal and analysis.

During the work an attempt has been made to develop a PC based automatic analyzer to perform the task like capacitance measurement with effect of pressure and temperature. Temperature and pressure parameters also measured via acquisition card on computer.

Chapter briefly described the various components of the work starting from the concept of circuit, automatic parameter measurement, hardware involved and software complete flowchart. The detailed descriptions of block diagrams of hardware as well as actual circuits of individual blocks are represented.

PCL 812 card is an enhanced multifunction Analog/ Digital input/output card with five different functions available on a single programmable card like ADC, DAC, timer and counter. In this application data is to be collected
through software commands. Utility software containing high level commands in C-Language routines by which transducer output measurement is possible waveform recording and signal analysis done on computer.

In this chapter a general introduction of data acquisition system review and parameter affective it, are presented together. The heart of data acquisition is PCL812 card. This is first time circuit interfaced for measurement of temperature of ferroelectrics capacitor and pressure through computer. The variation of capacitance on different bias voltage is also done on computer. The detail of circuit made their block diagram and various components briefly described one-by-one. The software developments for study is also presented via flow-chart. The detail software used is presented at appendix at the end of thesis.

The material used for C-V characterization, C-T and C-P plots are PZT, PLZT, PVF₂, TGS and TGSe in thin film and pellet forms. For the preparation of uniform homogenous poly crystalline films of these materials, the spinning disc technique has been used. Commercially available Pellets of PZT and PLZT and PVF₂ films are also used for some of the studies.

The vibrational spectral studies and XRD studies were performed at various laboratories to support the transducer activity-taking place by physical changes on crystal morphology.

Complete hardware of computer based interfacing circuits described in this chapter. First circuit was capacitance and voltage characterization interfacing measurement and control circuits. The main constituents' building blocks of circuits are Wien Bridge circuits using IC 741, Driver circuit again utilized by IC 741 and pair transistors BC 187 and BC 188. Frequency to voltage converter block comprises of IC 9400. The whole circuit is connected to PCL 812 card. The working principles and utilization process for measurement also described briefly. Control of voltage is implemented by making programmable power supply. Again detail has been presented.
Second circuit a simple arrangement based on PCL 812 card for temperature recording and monitoring has been designed fabricated and tested for ferroelectrics transducer. Here thermo-couple is mounted on sample attached with differential amplifier by IC 741. Semiconductor temperature sensor AD 590 is utilized to maintain electronically cold junction for accurate measurement offset and gain controlled circuit also employed. Total unit then interfaced to channel No 12 on PCL 812 card.

The output of chromel-alumel thermocouple is attached to amplification unit before fed to ADC card for temperature measurement. Instrumentation amplifier made up of three Op-Amps (IC 741). The first two op-amps provide high input impedance because the signal goes directly into non inverting inputs of the op-amp and op-amp third represents the usual differential amplifier. The signal source of the instrumentation amplifier is the output of the transducer. For transducer characterization change of capacitance as well as dielectric constant depends on change in temperature. A software programme for the PC has written for recording and monitoring temperature.

Next part of study based on pressure chamber interfaced with pressure measurement circuit. Pressure sensor is attached with charge amplifier. This can have signal in milli-volt and varying. This signal is rectified and amplified by circuit consists of LM108 and IC 741 before fed to ADC channel No 13 of PCL 812 card.

Further the result part ·tabulated various parameters taken into consideration of final measurement of various samples. Existing calibration techniques error checks the circuit performance; efficiency and resolution are also calculated. C-V measurement circuit characterizes the ferroelectrics semiconductor device. PZT, PLZT, TGS, TGSe and PVF₂ make MFS devices. For this purpose, these films were deposited on an n-type Si wafer by solution casting or evaporation technique. Thereafter applying a bias voltage of ± 30 V carried out the C-V characteristic. All the films have shown memory behavior when the
measurements are undertaken in the step of ± 2 Volts. The effect of depletion capacitance $C_0$ for each film has also been noticed for all the devices. All the material chosen for studies are characterized by C-T and C-P curves obtained by various circuit connections interfaced to computer.

The section I contains the dielectric study of PZT and PLZT samples of various forms. The capacitances on different temperature on constant frequency are measured. The capacitances become maximum at around $T_c$ (215°C for PZT and 242°C for PLZT). This was C-T characterization of PZT and PLZT starting from room temperature to 350°C. PZT $9 \mu$ film and $10.5 \mu$ films capacitance obtained maximum $24 \times 10^{-10}$ farad and $38 \times 10^{-10}$ farad respectively. PLZT $12.5 \mu$ film and $15 \mu$ films capacitance obtained maximum $95 \times 10^{-10}$ farad and $110 \times 10^{-10}$ farad respectively at constant frequency. The C-P characterization variations of capacitance at different pressure were found for films $5 \mu$ PZT1 and $15 \mu$ PZT2 from 86 nf to 172 nf for high pressure of 2.5 tones to 30 tones and 106 nf to 182 nf respectively. Similarly for films $10 \mu$ PLZT1 and $20 \mu$ PLZT2 from 136 nf to 188 nf for high pressure of 2.5 tones to 30 tones and 166 nf to 202 nf respectively.

The PZT MFS (metal-ferroelectric-semiconductor) device has shown $C_{max}$ around 98 pico-farad and with a $C_{min}$ on opposite voltage side (-Ve voltage region) around 42 pico-farad. and a shift of ±5volts in hysteresis has been seen towards +Ve voltage region. This shift in +Ve voltage side is explained due to the presence of some more immobile charges. The counter clockwise direction of hysteresis loop is found. The thickness of films is around 5.5/6cm and the estimated value of dielectric constant is found around 220.

In II section we used Kynar product PVF$_2$ powder and to obtained their saturated solution in solvents dimethyl form amide. The solution of these material were slowly evaporated and after the evaporate the temperature of the concentrated solution was maintained between 60 to 70°C while the rotating substrate was heated up to 75°C. The speed of rotation of the substrate was set around 4000 rpm. For application of low pressure from 100 Kg/m$^2$ to 1300Kg/m$^2$
on all samples of PVF$_2$, some are showing the value capacitance of PVF$_2$1 is 56.3 nF at 700 kg./m$^2$ for 29 µ film. The value capacitance of PVF$_2$2 is 47.3 nF at 700 kg./m$^2$ for 16µ film. The value capacitance of PVF$_2$3 is 40 nF at 700 kg./m$^2$ for 9µ film. In all the observation values of capacitances are increases with pressure with constant slope. This shows sensitivity of material towards pressure.

A retraceable hysteresis in C-V plot was observed by changing the bias voltage from +25V to -25V and again -25V to +25V, in step of 5 volts. An accumulation layer appears at the positive voltage side. An equal fault band shifts toward the positive and negative voltage side. Negative and positive side plot looks like mirror image of each other. This is quite symmetrical in both directions. The minimum capacitance for PVF$_2$ film is 58 nF and $e_{max}$ is found to be 92nF. All the justification for the memory behaviors fall of the capacitance and rotation of the hysteresis curve is that higher doping density of n-type Si-wafer provides better compensation of the polarization.

Triglycine sulphate and triglycine selenate are relatively new ferroelectric material. In this III section these material show their ferroelectric behavior near the room temperature ($T_c$ for TGS is 49°C and $T_c$ for TGSe is 22°C and $T_c$ for LATGS is 51°C). Films were prepared by spin coating disc method. TGS 22.5µ film and TGSe 12.5 µ films capacitance obtained maximum 1800 pico-farad and 2000 pico-farad respectively for temperature variation 10°C to 70°C. The C-P characterization variations of capacitance at different pressure were found for films 5µ TGS and 2.5µ TGSe from 86 nF to 172 nF for high pressure of 2.5 tones to 30 tones and 106 nF to 182 nF respectively. Similarly for films 10µ TGS and 20µ from 136 nF to 188 nF for high pressure of 2.5 tones to 30 tones and 166 nF to 202nF respectively.

A 4µm thickness of TGSe film, which is deposited on Si wafer, has shown TGS MFS device like behavior. The $C_{max}$ and $C_{min}$ values are found 87 and 42 pf respectively. The estimated value of dielectric contact is found 206.
CHAPTER IV

This chapter is based on hysteresis study on computer. Another closed loop circuit has been connected to card to obtain hysteresis curve on computer using Sawyer-Tower circuit. It has been observed that modification needed in circuit for crystal and film analysis, for that two different circuits developed. The aim was to design new circuit using digital components, which was compatible with card and computer. An integrating linear capacitor is placed in series with ferroelectric material. The value of C is chosen large enough so that most of the voltage drop in the circuit occurs across the FE material. The electrical non-linearity displayed as function of the driving signal is called Hysteresis. The main module of connection is Sawyer-Tower circuit. For obtaining hysteresis for crystal and for film different types of circuit was made. Buffer amplifies unit was made by TL 084. High voltage amplifier made by MCE 2E and power amplifier UJT 510. Sample and hold LF 356 implemented circuit. The necessary software developed to generate sine wave through software on DAC channel to Sawyer-Tower circuit.

In next part for films the output of Sawyer-Tower circuit was connected to spontaneous polarization current measurement circuit which consists of current to voltage converter unit and different type gain amplifier, controlled on circuits was made through 16 bit digital output unit of card.

Polarization field measurement a circuit was implemented by amplifies and CMOS 4031 multiplex chip. A modified hysteresis study was done on computer. All necessary hardware and software have been developed in laboratory.

Spontaneous polarization and coercive field were calculated for PZT, PLZT, PVF₂, TGS, and TGSP on different temperature and on different bias voltages. Curves for pure TGS at different temperature confirmed second order nature of phase transition was taking place. Hysteresis curves of phosphate doped TGS crystals with two different concentrations have been traced on computer. The
Spontaneous polarizations have been determined at different temperature. It was found that the transition temperature shifted towards lower values with increasing concentration of the dopants.

CHAPTER V

Special attempt was made to introduce some simple type of circuit designing which employ direct read out digital technique. Upto now circuits were interfaced with computer and graphs were plotted on computer. In following two chapter circuits were designed to measure required parameter by direct digital technique. First circuit was digital technique developed for measurement of frequency. Digital monitoring system consists of 555 timer chip in astable mode operation. The ferroelectric material capacitor is incorporated in place of one of the input capacitor of astable multivibrator Frequency of astablation is changed by applying weight, force on FE capacitor transducer. The piezoelectric capacitor is placed at input. The capacitance of piezoelectric material changes by applying weight by virtue of this resultant frequency is changing. Altered frequency is also observed when temperature of sample is raised.

Change of frequency is directly fed to digital counter and display system made up of IC CD 4033 counter and FND 543. PZT, PVF2 material crystal and films under stress were studied using IC 555.

Another system is based on development of novel circuit designing with 555 for measurement of dielectric constant by direct read out by digital technique. Detail of circuit description is attached. measurement is compared with existing instrument in laboratory. The main modules of system were square wave generator, sample holder, peak detector, amplifier, power supply, display unit, decoder and driver. The variation of dielectric constant with temperature at different frequencies of the applied a.c. field for flux grown was observed for all material. The dielectric constant is observed to vary from 714.6 to 990.8 at room temperature in the frequency range of 50 kHz-10MHz for PZT pellet.
Another experiment performed using 555-timer astable mode operation for measurement of capacitance. The ferroelectric capacitor is interfaced with circuit. It was observed the frequency of operation is altered as soon as ferroelectric material inserted in circuit. Astable multivibrator is used to produce single time period in response to an input-trigging single. Frequency is read out by digital technique. This circuit consist of four ICs first one is IC 555 timer, NAND gate IC CD4011 one decode counter IC CD4017 and one $\frac{1}{2}$ stage Binary counter IC CD 4040.

Capacitance is linearly proportional to the time constant when a capacitor is charged by a constant current source and discharge through a fixed resistance. By similar procedure we use 555 timers IC along with some digital test equipment to measure capacitance. Capacitances of samples were taken on 50 KHz to 10MHz for all samples by direct values shown.

The PZT pellet and PVF$_2$ readymade Kureha films were used for such studies. PZT pellets were made of tetraethyl lead or beta lead diketones. The remnant polarization was over 40$\mu$ coulomb/cm$^2$ and coercive field was below 10 Kv/cm.

CHAPTER VI

This chapter is continuation of frequency measurement technique with modification this circuit is developed to measure vibration. Special type of holder is designed for PZT capacitor, which is compression type accelerometer. Brief review of vibration measurement also presented relevant to circuit description. Impedance matching is obtained using LM 108 circuit. LM 324 IC is used for integrator and amplifier circuit. In addition to this closed loop contains ADC chip ICCD7106 and RMS detector again obtained using 324 IC. Vibration pickup by transducer is amplified by true RMS converter it is used to convert signal in DC signal is directly converted in digital form which can be displayed by display unit. Two amplifiers then amplify it. This signal is converted to digital form using an ADC. Further signal can be taken to display unit. Separate power
supply using IC 7660 is made for all individual chips. Digital measurement circuit
does system vibration analysis of piezo crystal. This circuit is made on computer
on Workbench software. The computer simulation study of vibration transducer is
done through it.

CHAPTER VII

This chapter describes the various conclusions investigation made in
the present studies. Further suggestions for future of transducer material for
different electronic application of materials are dealt. The future of various circuit
designs for electronics applications also discussed.