User's Manual

STUDY OF DIELECTRIC CONSTANT

Model: DEC-01

(Rev : 01/04/2019)

Manufactured by:

SES Instruments Pvt. Ltd.

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ISO 9001:2015
Certified Company

CONTENTS

COPYRIGHT AND WARRANTY

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COPYRIGHT NOTICE

LIMITED WARRANTY

SES Instruments Pvt. Ltd warrants this product to be free from defects in materials and workmanship for a period of one year from the date of shipment to the customer. SES Instruments Pvt. Ltd will repair or replace, at its option, any part of the product which is deemed to be defective in material or workmanship. This warranty does not cover damage to the product caused by abuse or improper use. Determination of whether a product failure is the result of manufacturing defect or improper use by the customer shall be made solely by SES Instruments Pvt. Ltd. Responsibility for the return of equipment for warranty repair belongs to the customer. Equipment must be properly packed to prevent damage and shipped postage or freight prepaid. (Damage caused by improper packaging of the equipment for return shipment will not be covered by the warranty). Shipping costs for returning the equipment, after repair, will be paid by SES Instruments Pvt. Ltd.

EQUIPMENT RETURN

Should this product have to be returned to SES Instruments Pvt. Ltd, for whatever reason, notify SES Instruments Pvt. Ltd BEFORE returning the product. Upon notification, the return authorization and shipping instructions will be promptly issued.

Note : No equipment will be accepted for return without an authorization.

When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage by improper packing. To be certain the unit will not be damaged in shipment, observe the following rules:

1. The carton must be strong enough for the item shipped.
2. Make certain there is at least two inches of packing material between any point on the apparatus and the inside walls of the carton.
3. Make certain that the packing material can not displace in the box, or get compressed, thus letting the instrument come in contact with the edge of the box.

SAFETY INFORMATION

This Section addresses safety considerations and describes symbols that may appear on the Instrument or in the manual.

A **Warning** Statement identifies conditions or practices that could result in injury or death. A **Caution** statement identifies conditions or practices that could result in damage to the Instrument or equipment to which it is connected.

 **Warning**

To avoid electric shock, personal injury, or death, carefully read the information in Table-1, "Safety Information," before attempting to install, use, or service the Instrument.

GENERAL SAFETY SUMMARY

This equipment is Class 1 equipment tested in accordance with the European Standard publication EN 61010-1.

This manual contains information and warnings that must be observed to keep the Instrument in a safe condition and ensure safe operation.

To use the Instrument correctly and safely, read and follow the precautions in Table 1 and follow all safety instructions or warnings given throughout this manual that relate to specific measurement functions. In addition, follow all generally accepted safety practices and procedures required when working with and around electricity.

SYMBOLS

Table 2 lists safety and electrical symbols that appear on the Instrument or in this manual.

Table 2. Safety and Electrical Symbols

Symbols	Description	Symbols	Description
	Risk of danger. Important information. See Manual.		Earth ground
	Hazardous voltage. Voltage >30Vdc or ac peak might be present.		Potentially hazardous voltage
	Static awareness. Static discharge can damage parts.		Do not dispose of this product as unsorted municipal waste. Contact SES or a qualified recycle for disposal.

Table 1. Safety Information

⚠ ⚠ **Warning**

To avoid possible electric shock, personal injury, or death, read the following before using the Instrument:

- **Use the Instrument only as specified in this manual, or the protection provided by the Instrument might be impaired.**
- **Do not use the Instrument in wet environments**
- **Inspect the Instrument in wet environments.**
- **Inspect the Instrument before using it. Do not use the Instrument if it appears damaged.**
- **Inspect the connecting lead before use. Do not use them if insulation is damaged or metal is exposed. Check the connecting leads for continuity. Replace damaged connecting leads before using the Instrument.**
- **Whenever it is likely that safety protection has been impaired, make the Instrument inoperative and secure it against any unintended operation.**
- **Have the Instrument serviced only by qualified service personnel.**
- **Always use the power cord and connector appropriate for the voltage and outlet of he country or location in which you are working.**
- **Never remove the cover or open the case of the Instrument before without first removing it from the main power source.**
- **Never operate the Instrument with the cover removed or the case open.**
- **Use only the replacement fuses specified by the manual.**
- **Do not operate the Instrument around explosive gas, vapor or dust.**
- **When servicing the Instrument, use only specified replacement parts.**
- **The equipment can remain Switched on continuously for five hours**
- **The equipment must remain Switched off for at least fifteen minutes before being switched on again.**
- **The equipment is only for the intended use**
- **Use the equipment only as specified in this manual.**

Unpacking and Inspecting the Instrument

Every care is taken in the choice of packing material to ensure that your Instrument will reach you in perfect condition. If the Instrument has been subject to excessive handling in transit, there may be visible external damage to the shipping container and packing material for the carrier's inspection.

Carefully unpack the Instrument from its shipping container and inspect the contents for damaged or missing items. If the Instrument appears damaged or something is missing, contacts the carrier and SES immediately. Save the container and packing material in case you have to return the Instrument.

Storing and Shipping the Instrument

To prepare the Instrument for storage or shipping, if possible, use the original shipping container alongwith thermocoal corners, as it provides shock isolation for normal handling operations. If the original shipping container is not available, use any good cardboard box which is at least 2-3 inches bigger than the instrument on all sides, with cushioning material (thermocoal or styrofoam etc) that fills the space between the Instrument and the side of this box.

To store the Instrument, place the box under cover in a location that complies with the storage environment specification described in the "Environment Sections" below.

Environment

Temperature

Operating …………………………………. 0°C to 50°C

Storage …………………………………… 40°C to 70°C

Warm Up …………………………………15 min to full uncertainty specification

Relatively Humidity (non-condensing)

Operating …………………………………Uncontrolled (<10°C)

<90 % (10°C to 30°C)

<75 % (30°C to 40°C)

<45 % (40°C to 50°C)

Storage………………………………….. -10°C to 60°C <95 %

Power Considerations

The Instrument operates on varying power distribution standards found throughout the world and must be set up to operate on the line voltage that will power it. The Instrument is packed ready for use with a line voltage determined at the time of ordering.

Replacing the Fuses

The Instrument uses one fuse to protect the line-power input and two fuses to protect current-measurement inputs.

Line-Power Fuse

The Instrument has a line-power fuse in series with the power supply. Table 3 indicates the proper fuse for each of the four line-voltage selections. The line-power fuse is accessed through the real panel.

1. Unplug the power cord.
2. Rotate the fuse holder cap to the right until the fuse POPS out.
3. Remove the fuse and replace it with a fuse of an appropriate rating for the selected line-power voltage. See Table 2.

Warning

To avoid electric shock or fire, do not use makeshift fuses or short-circuit the fuse holder.

Table 2. Line Voltage to Fuse Rating

Line Voltage Selection	Fuse Rating
220/ 240 V	1A, 250V (Slow blow)
100/ 120 V	2A, 250 V (Slow blow)

Connecting to Line Power

Warning

To avoid shock hazard, connect the factory supplies three conductor line power cord to a properly grounded power outlet. Do not use a two-conductor adapter or extension cord, as this will break the protective ground connection. If a two conductor power cord must be used, a protective grounding wire must be connected between the ground terminal and earth ground before connecting the power cord or operating the Instrument.

1. Verify that the Line voltage is set to the correct setting.

2. Verify that the correct fuse for the line voltage is installed.

3. Connect the power cord to a properly grounded three-prong outlet. See Figure 1 for line-power cord types available from SES. Refer to Table 2 for description of the line-power cords.

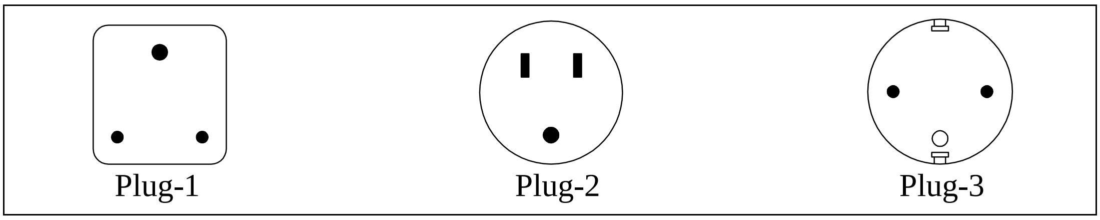

Figure 1. Line-Power Cord Types Available from SES

Table 3. Line-Power Cord Types Available from SES

Type	Voltage/Current	SES Model Number
India	240 V/ 5 A	Plug-1
North America	120 V/15 A	Plug-2
Universal Euro	220 V/16 A	Plug-3

Turning Power On

The On-Off switch on the front panel when points towards "ON" signs, indicates that the equipment has been switched on.

Cleaning the Instrument

⚠ ⚠ **Warning**

To avoid electric shock or damage to the Instrument, never get water inside the Instrument.

⚠ **Caution**

To avoid damaging the Instrument's housing, do not apply solvents to the Instrument.
If the Instrument requires cleaning, wipe it down with a cloth that is lightly dampened with water or a mild detergent. Do not use aromatic hydrocarbons, alcohol, chlorinated solvents, or methanol-based fluids when wiping down the Instrument.

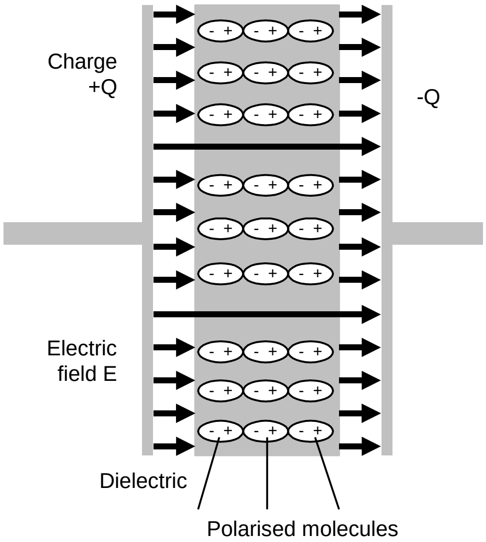
Charge
+Q
-Q
Electric
field E
Dielectric
Polarised molecules

Figure 2

STUDY OF DIELECTRIC CONSTANT AND CURIE TEMPERATURE MEASUREMENT OF FERROELECTRIC CERAMICS, DEC-01

INTRODUCTION

Research in the area of Ferroelectrics is driven by the market potential of next generation memories and transducers. Thin films of ferroelectrics and dielectrics are rapidly emerging in the field of MEMS applications. Ultrasonic micro-motors utilizing PZT thin films and pyroelectric sensors using micro-machined structures have been fabricated. MEMS are finding growing aplication in accelerometers for air bag deployment in cars, micro-motors and pumps, micro heart valves, which have reached the commercial level of exploitation in compact medical, automotive, and space applications. Extremely sensitive sensors and actuators based on thin film and bulk will revolutionize every walk of our life with Hi-Tech gadgets based on ferroelectrics. Wide spread use of such sensors and actuators have made Hubble telescope a great success story. New bulk ferroelectric and their composites are the key components for the defence of our air space, the long coastline and deep oceans.

The quest of human beings for developing better and more efficient materials is never ending. Material Scinece has played a vital role in the development of society. Characterization is an important step in the development of different types of new materials. This experiment is aimed to expose the young students to Dielectric and Curie Temperature Measurement techinque for Ferroelectric Ceramics.

Dielectric or electrical insulating materials are understood as the materials in which electrostatic fileds can persist for a long time. These materials offer a very high resisitance to the passage of electric current under the action of the applied *direct-current* voltage and therefore sharply differ in their basic electrical properties from conductive materials. Layers of such substances are commonly inserted into capacitors to improve their performance, and the term dielectric refers specifically to this application.

The use of a dielectric in a capacitor presents several advantages. The simplest of these is that the conducting plates can be placed very close to one another without risk of contact. Also, if subjected to a very high electric field, any substance will ionize and become a conductor. Dielectrics are more resistant to ionization than air, so a capacitor containing a dielectric can be subjected to a higher voltage. Also, dielectrics increase the capacitance of the capacitor. An electric field polarizes the molecules of the dielectric (Figure-1), producing concentrations of charge on its surfaces that create an electric field opposed (antiparallel) to that of the capacitor. Thus, a given amount of charge produces a weaker field between the plates than it would without the dielectric, which reduces the electric potential. Considered in reverse, this argument means that, with a dielectric, a given electric potential causes the capacitor to accumulate a larger charge.

The electrons in the molecules shift toward the positively charged left plate. The molecules then create a leftward electric field that partially annuls the field created by the plates. (The air gap is shown for clarity; in a real capacitor, the dielectric is in direct contact with the plates.)

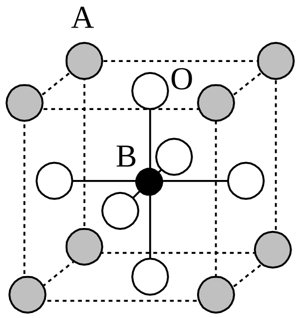

Figure 3 (a)

Figure 3 (a). Perovskite ABO_3 structure with the A and B cations on the corner and body center positions, respectively. Three oxygen anions per unit cell occupy the faces and form octahedra surrounding the B-site.

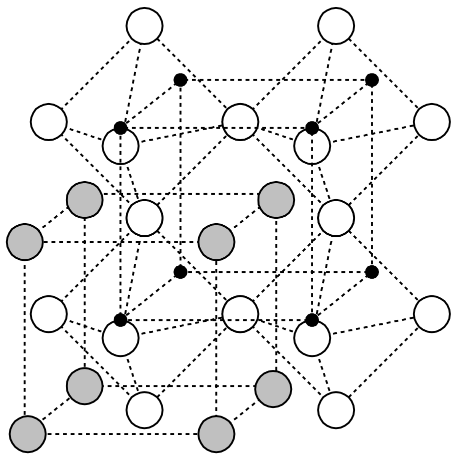

Figure 3 (b)

Figure 3 (b) Perovskite structure (Ba: Grey; Ti: Black; O: White)

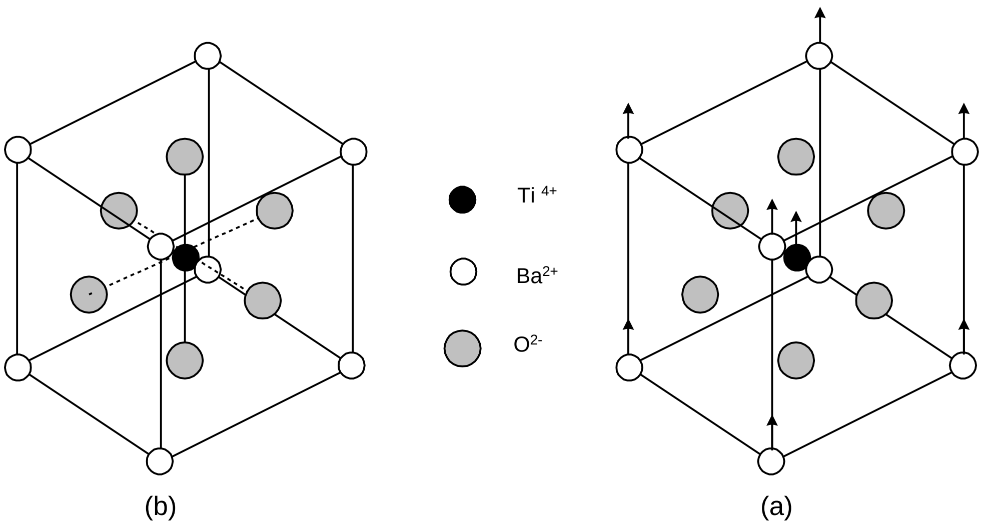

Figure 4 Perovskite unit cell and the displacements in its ions on the application of an electric field.

PACKING LIST

1. Study of Dielectric Constant, DEC-01: One
2. Probe Arrangement with RTD Sensor: One
3. Sample: One [Barium Titanate ($BaTiO_3$)]
4. Aluminium Foil: One
5. Dielectric Constant Oven: One

PEROVSKITE STRUCTURE

Perovskite is a family name of a group of materials and the mineral name of calcium titanate ($CaTiO_3$) having a structure of the type ABO_3. Many piezoelectric (including ferroelectric) ceramics such as Barium Titanate ($BaTiO_3$), Lead Titanate ($PbTiO_3$), Lead Zirconate Titanate (PZT), Lead Lanthanum Zirconate Titanate (PLZT), Lead Magnesium Niobate (PMN), Potassium Niobate ($KNbO_3$) etc. have a cubic perovskite type structure (in the paraelectric state) with chemical formula ABO_3 (figure 2 a, b).

As conventionally drawn, A-site cations occupy the corners of a cube, while B-site cations sit at the body center. Three oxygen atoms per unit cell rest on the faces. The lattice constant of these perovskite is always close to the 4 Å due to rigidity of the oxygen octahedral network and the well-defined oxygen ionic radius of 1.35 Å.

A practical advantage of the perovskites structure is that many different cations can be substituted on both the A and B sites without drastically changing the overall structure. Complete solid solutions are easily formed between many cations, often across the entire range of composition. Even though two cations are compatible in solution, their behavior can be radically different when apart from each other. Thus, it is possible to manipulate a material's properties such as Curie Temperature or dielectric constant with only a small substitution of a given cation.

All ferroelectric materials have a transition temperature called the Curie point (**T_c**). At a temperature $T > T_c$ the crystal does not exhibit ferroelectricity, while for $T < T_c$ it is ferroelectric. On decreasing the temperature through the Curie point, a ferroelectric crystal undergoes a phase transition from a non-ferroelectric (paraelectric) phase to a ferroelectric phase.

BARIUM TITANATE ($BaTiO_3$, BT)

Barium Titanate ($BaTiO_3$) has a ferroelectric tetragonal phase (Fig-3(a)) below its curie point of about 120°C and paraelectric cubic phase (Fig-3(b)) above Curie point. The temperature of the curie point appreciably depends on the impurities present in the sample and the synthesis process.

In the paraelectric cubic phase the center of positive charges (Ba^{2+}, Ti^{4+}) coincide with the center of negative charges (0^{-2} ion) and on cooling below T_c, a tetragonal phase develops where the center of Ba^{2+} and Ti^{4+} ions are displaced relative to the 0^{2-} ions, leading to the formation of electric dipoles.

As the BT ceramics have a very large room temperature dielectric constant, they are mainly used in multilayer capacitor applications. The grain size control is very important for these applications.

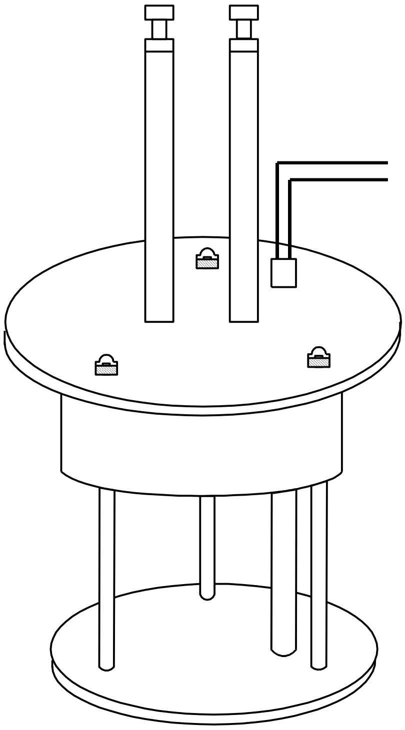

Fig. 5. Dielectric Constant Arrangement

DIELECTRIC CONSTANT

The dielectric constant (ε) of a dielectric material can be defined as the ratio of the capacitance using that material as the dielectric in a capacitor to the capacitance using a vacuum as the dielectric. Typical values of ε for dielectrics are:

Material	**DIELECTRIC CONSTANT (ε)**
Vacuum	1.000
Dry Air	1.0059
Barium Titanate	100-1250
Glass	3.8-14.5
Quartz	5
Mica	4-9
Water distilled	34-78
Soil dry	2.4-2.9
Titanium dioxide	100

Dielectric constant (ε) is given by

$$\varepsilon = \frac{C}{C_0}, \quad C_0 = \frac{\varepsilon_0 A}{t}$$

Where

- C = capacitance using the material as the dielectric in the capacitor,
- C_0 = capacitance using vacuum as the dielectric
- ε_0 = Permittivity of free space (8.85×10^{-12} F/m)
- A = Area of the plate/ sample cross section area
- t = Thickness of the sample

BRIEF DESCRIPTION OF THE APPARATUS

1. Probe Arrangement

As shown in Fig. 4, it has two spring loaded probes. These probe move in pipes and are insulated by teflon bush, which ensure a good electrical insulation. The probe arrangement is mounted in suitable stand, which also hold the sample plate and RTD sensor. The RTD is mounted in the sample plates such that it is just below the sample, separated by a very thin sheet of mica. This ensures the correct measurement of sample temperature. This stand also serves as a lid of the oven. The leads are provided for the connection to RTD and capacitance meter.

2. Sample

Barium Titanate ($BaTiO_3$) plate with top and bottom conducting surface.

3. Oven

This is a high quality temperature controlled oven. The oven has been designed for fast heating and cooling rates, which enhance the effectiveness of the controller.

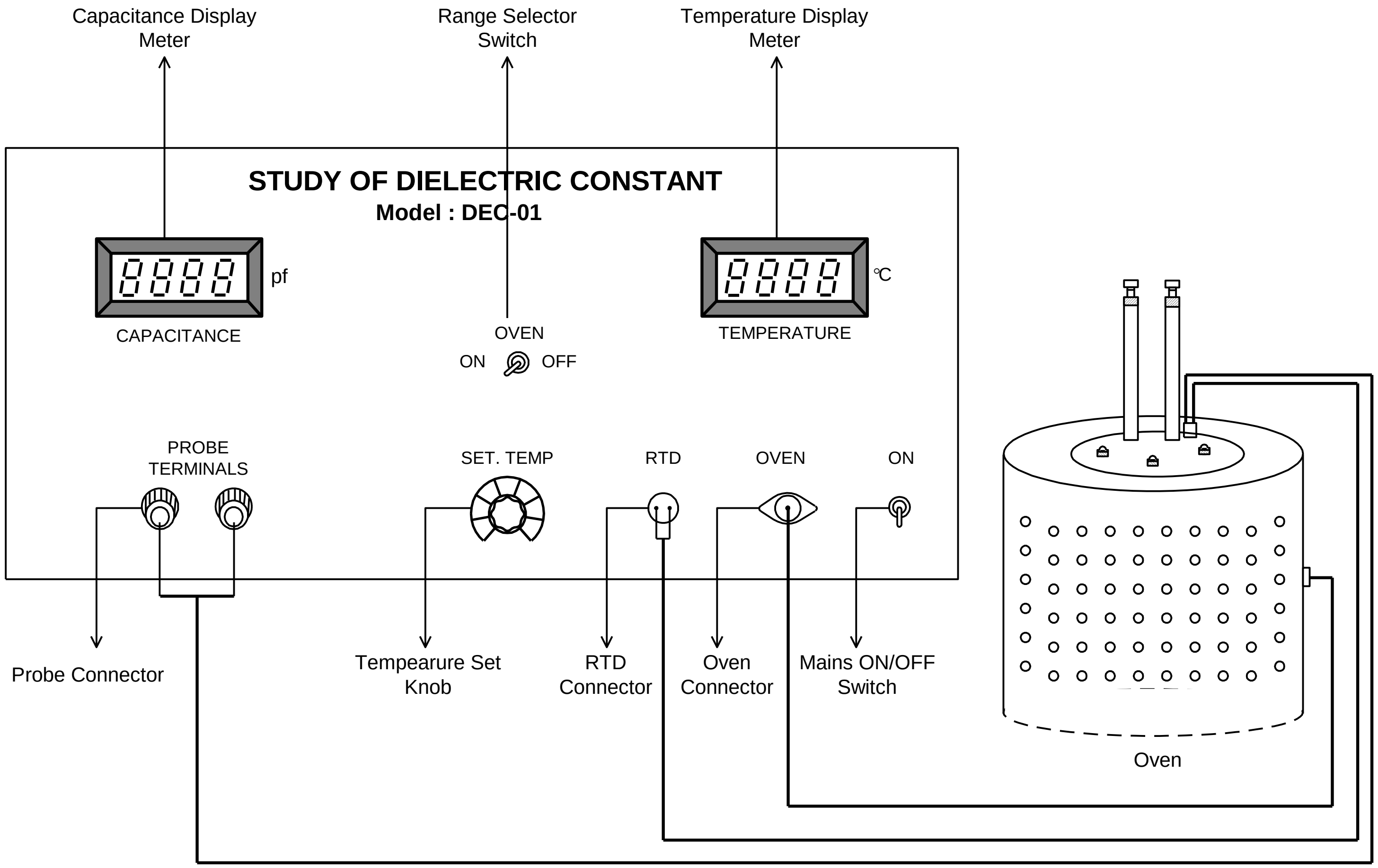

Fig. 6. Panel Diagram of Dieletric Constant Set-up, DEC-01

4. Main Units

The Set-up consists of two units housed in the same cabinet Fig. 5.

(i) Oven Controller

Platinum RTD (A class) has been used for sensing the temperature. A Wheatstone bridge and an instrumentation amplifier are used for signal conditioning. Feedback circuit ensures offset and linearity trimming and a fast accurate control of the oven temperature.

Specifications of the Oven	
Temperature Range	: Ambient to 200 °C
Resolution	: 0.1 °C
Stability	: ± .1 °C
Measurement Accuracy	: ± 0.5 °C
Oven	: Specially designed for Dielectric measurement
Sensor	: RTD (A class)
Display	: 3½ digit, 7 segment LED with autopolarity and decimal indication
Input	: 220±10%AC 50Hz
Power Dissipation	: 150W

(ii) Digital Capacitance Meter

This a compact direct reading instrument for the measurement of capacitance of the sample.

Specifications	
Range	: 50 to 6000 pf
Resolution	: 1pf
Display	: 3½ digit, 7 segment LED

EXPERIMENTAL PROCEDURE

1. Put a small piece of aluminum foil on the base plate. Pull the spring loaded probes upward, insert the aluminum foil and let them rest on it. Put the sample ($BaTiO_3$) on the foil. Again pull the top of one of the probe and insert the sample below it and let it rest on it gently. Now one of the probes would be in contact with the upper surface of the sample, while the other would be in contact with the lower surface through aluminum foil.
2. Connect the probe leads to the capacitance meter.
3. Connect the oven to the main unit and put the oven in OFF position.
4. Switch on the main unit and note the value of capacitance. It should be a stable reading and is obtained directly in pf.
   a. Switch ON the temperature Controller and approx adjust the set-temperature. The green LED would light up indicating the oven is ON and temperature would start rising. The temperature of the oven in °C would be indicated by the DPM.
   b. The controller of the oven would switch ON/OFF power corresponding to set-temperature. In case it is less then the desired, the set-temperature may be increased or vice versa.
   c. Because of thermal inertia of oven, there would be some over shoot and under shoot before a steady set-temperature is attained and may take 10 minutes for each reading.

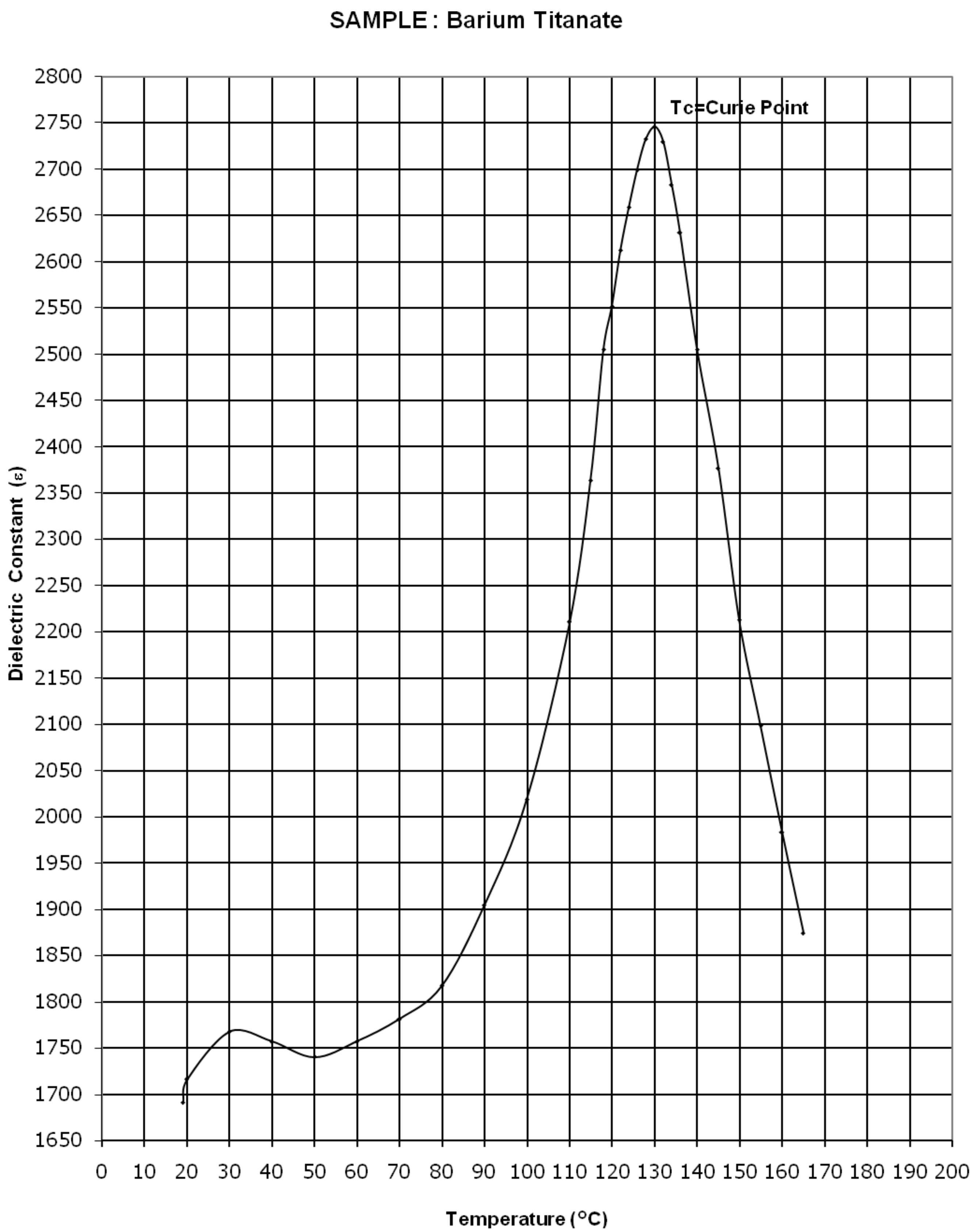

Fig. 7. A plot of temprature v/s dielectric constant

d. To save time, it is recommended to under adjust the temperature. Example, it is desired to set at 50°C, adjust the temperature set knob so that LED is OFF at 45°C. The temperature would continue to rise. When it reaches 50°C adjust the temperature set knob so that oven is just ON/OFF. It may go up 1 & 2°C, but would settle down to 50°C. Since the change in temperature at this stage is very slow and response of RTD and sample is fast, the reading can also be taken corresponding to any temperature without waiting for a steady state.

OBSERVATIONS AND CALCULATIONS

Sample : Barium Titanate ($BaTiO_3$)

Area (A) : 93.66 mm^2

Thickness (t) : 2.26 mm

Permittivity of Space (ε_0) : 8.85×10^{-12} F/m or 8.85×10^{-3} pf/ mm

$$\varepsilon = \frac{C}{C_0} \; ; \quad \text{where,} \quad C_0 = \frac{\varepsilon_0 A}{t} \Rightarrow \frac{8.85 \times 10^{-3} \times 93.66}{2.26} \Rightarrow 366.75 \times 10^{-3} \text{ pf}$$

S.No.	Temperature (°C)	Capacitance, C (pf)	Dielectric Constant, (ε)
1	19.1	619	1691
2	20	628	1716
3	30	647	1768
4	40	643	1757
5	50	637	1740
6	60	643	1757
7	70	652	1781
8	80	665	1817
9	90	697	1904
10	100	739	2019
11	110	809	2210
12	115	865	2363
13	118	917	2505
14	120	934	2552
15	122	956	2612
16	124	973	2658
17	126	988	2699
18	128	1000	2732
19	130	1005	2746
20	132	999	2730
21	134	982	2683
22	136	963	2631

S.No.	Temperature (°C)	Capacitance, C (pf)	Dielectric Constant, (ε)
23	140	917	2505
24	145	870	2377
25	150	810	2213
26	155	768	2098
27	160	726	1984
28	165	686	1874
29	170	653	1784

TYPICAL RESULTS

1. A plot of temperature v/s dielectric constant is shown in Fig. 7.
2. From the graph, **Curie Temperature** ($T_{c)}$ = 131°C

PRECAUTIONS

(1) The spring loaded probe should be allowed to rest on the sample very gently, other wise it may damage the conducting surface of the sample or even break the sample.

(2) The reading of capacitance meter should be taken when the oven is OFF. This would be indicated by the green LED. In ON position there may be some pick ups.

(3) The reading near the Curie temperature should be taken at closer intervals, say 1°C.

REFERENCE

Introduction to Solid State Physics – C. Kittle, Wiley Eastern Limited (5th Edition).

TECHNICAL SUPPORT

Feed Back

If you have any comments or suggestions about this product or this manual please let us know. **SES Instruments Pvt. Ltd.** appreciates any customer feedback. Your input helps us evaluate and improve our product.

To reach SES Instruments Pvt. Ltd.

* Phone : +91-1332-272852, 277118
* Fax : +91-1332 - 277118
* e-mail : **info@sestechno.com**; sestechno.india@gmail.com

Contacting for Technical Support

Before you call the SES Instruments Pvt. Ltd. Technical Support staff it would be helpful to prepare the following information:

- If you problem is with the SES Instruments Pvt. Ltd apparatus, note :
  - Model number and S. No (usually listed on the label at the backside of instrument).
  - Approximate age of the apparatus.
  - A detailed description of the problem/ sequences of events may please be sent by email or Fax.

- If your problem relates to the instruction manual, note;
  Model number and Revision (listed by month and year on the front cover).
  Have the manual at hand to discuss your questions.