Test Report & Test Result

FOUR PROBE SET-UP

MODEL DFP-02 # 2287

Manufactured by:

SES Instruments Pvt. Ltd.
452, Adarsh Nagar, Roorkee-247 667
Ph.: 01332-272852, Fax: 277118
Email: ses@sestechno.com
Website: www.sestechno.com

ISO 9001:2008
CERTIFIED COMPANY

INSTRUMENT : FOUR PROBE SET-UP, MODEL DFP-02 # 2287

1. Visible Inspection of Instrument Cabinet

(i) General Workmanship : O.K

(ii) Mechanical Dimensions (Non-critical): 305 mm (L) X 240 mm (B) X 120 mm (H)

(iii) Paint Quality : O.K

2. Insulation Resistance at 1000V : > 200 MΩ (Line to body with power OFF)

3. Power Supplies:

(a)	+5V (DVM) Output = + 4.92 V	Regulation : O.K.	Ripples/Noise : O.K.
(b)	-5V (DVM) Output = - 5.09 V	Regulation : O.K.	Ripples/Noise : O.K.
(c)	+5V (C.C.) Output = + 5.04 V	Regulation : O.K.	Ripples/Noise : O.K.
(d)	-5V (C.C.) Output = - 4.97 V	Regulation : O.K.	Ripples/Noise : O.K.

4. Millivoltmeter

S. No.	RANGE	DFP-02	Standard*	% Error
1.	X1	198.2 mV	198.15 mV	-
2.	X10	1.973 V	1.9729 V	-

5. Constant Current Generator

i) Calibration

S. No.	DFP-02	Standard*	Error	% Error
1.	19.88 mA	19.881 mA	-	-

ii) Open Circuit Voltage : ≅ 18 V at 220 V A.C. mains

iii) Minimum Current : 0.00 mA

iv) Maximum Current : 24.78 mA (out of scale)

v) Current Regulation (180-240 V) at 14.00 mA across 1 K load : O.K.

vi) Floating Supply : O.K.

* *Standard : Scientific 4½ digit Multimeter, Model : HM-5011-3, S.No. 0110859*

6. Oven Power Supply (at 220 V mains)

i) a) L : 40 V b) H : 44 V

ii) Is LED glow on load with oven : Yes

7. Oven

i) Heater Resistance : 36 Ω

ii) Maximum Temperature : 200 °C

iii) Operating Temperature : 175 °C

iv) Maximum Heater Voltage : 45 V

8. Sample : S. No. 1707, Batch: 03

Material : Ge single crystal type : n-type

Thickness : 0.50 m.m.

9. Four Probe Arrangement

Distance between probes : 2.00 mm ± 2% (Measured with travelling microscope)

Colour Codes

Voltage Probes : Yellow & Green

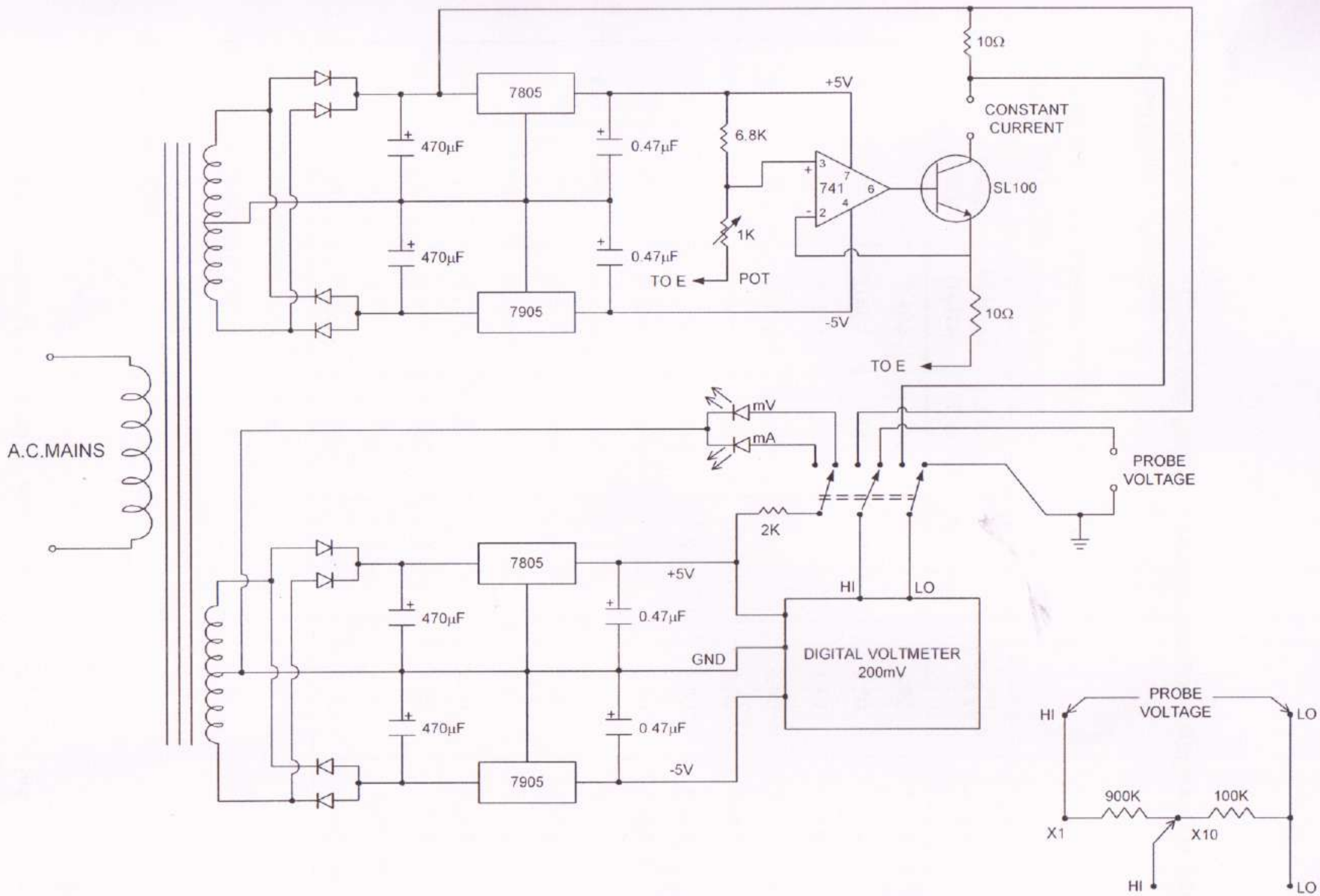
Current Probes : Red & Black

10. Temperature Measuring Device

Mercury Thermometer : 0-200°C

Passed for despatch: Yes **Dated**: 16.01.2018

Q.C. Engineer: U.S.Chauhan



Schematic Diagram of Four Probe Set-up, DFP-02

TEST RESULTS

EXPERIMENT

Determination of the band gap of a semiconductor : Germanium Chip; Four Probe Set-Up # 2287

OBSERVATION & TABULATION

Current (I) = 5.00 mA (Constant)

S.No.	Temp (°C)	Voltage (volts)	Temp (T in K)	ρ (Ω.cm.)	$T^{-1} \times 10^{-3}$	$Log_{10}\rho$
1	19	0.400	292	17.04	3.42	1.231
2	30	0.402	303	17.13	3.30	1.234
3	40	0.387	313	16.49	3.19	1.217
4	50	0.347	323	14.78	3.10	1.170
5	60	0.285	333	12.14	3.00	1.084
6	70	0.221	343	9.41	2.92	0.974
7	80	0.1602	353	6.82	2.83	0.834
8	90	0.1241	363	5.29	2.75	0.723
9	100	0.0894	373	3.81	2.68	0.581
10	110	0.0694	383	2.96	2.61	0.471
11	120	0.0506	393	2.16	2.54	0.334
12	130	0.0388	403	1.65	2.48	0.218
13	140	0.0293	413	1.25	2.42	0.096
14	150	0.0236	423	1.01	2.36	0.002

Distance between probes (S)= 0.200 cm

Thickness of the crystal (W)= 0.050 cm

CALCULATION

We know that $\rho_0 = \frac{V}{I} \times 2\pi S$

Since the thickness of the crystal is very small compared to the probe distance a correction factor for it has to be applied. In this present case the bottom surface is non-conducting so the correction factor would be :

$$\rho = \frac{\rho_0}{G_7(W/S)} p$$

Now substituting the proper values,

$$\rho_0 = \frac{V}{I} \times 2 \times 3.14 \times 0.200$$

$$\rho_0 = \frac{V}{I} \times 1.256$$

and the correction factor corresponding to G_7 (0.050/0.200) or G_7 (0.250) is 5.89 (obtained from table 1 on page 9)

$$\rho = \frac{\rho_0}{5.89} = \frac{V}{I}\left(\frac{1.256}{5.89}\right) = \frac{V}{I} \times 0.213$$

Putting I = 5.00 mA (constant for whole set of the readings)

$$\rho = \frac{0.213 \times V}{5.00 \times 10^{-3}} = 42.6 \times V$$

CALCULATION FOR ENERGY BAND GAP

We know, $E_g = 2k \frac{\text{Log}_e \rho}{\frac{1}{T}}$

Where k is the Boltzamann's constant = 8.6×10^{-5} eV/deg & T is temperature in kelvin.

From the graph, the slope of the curve is

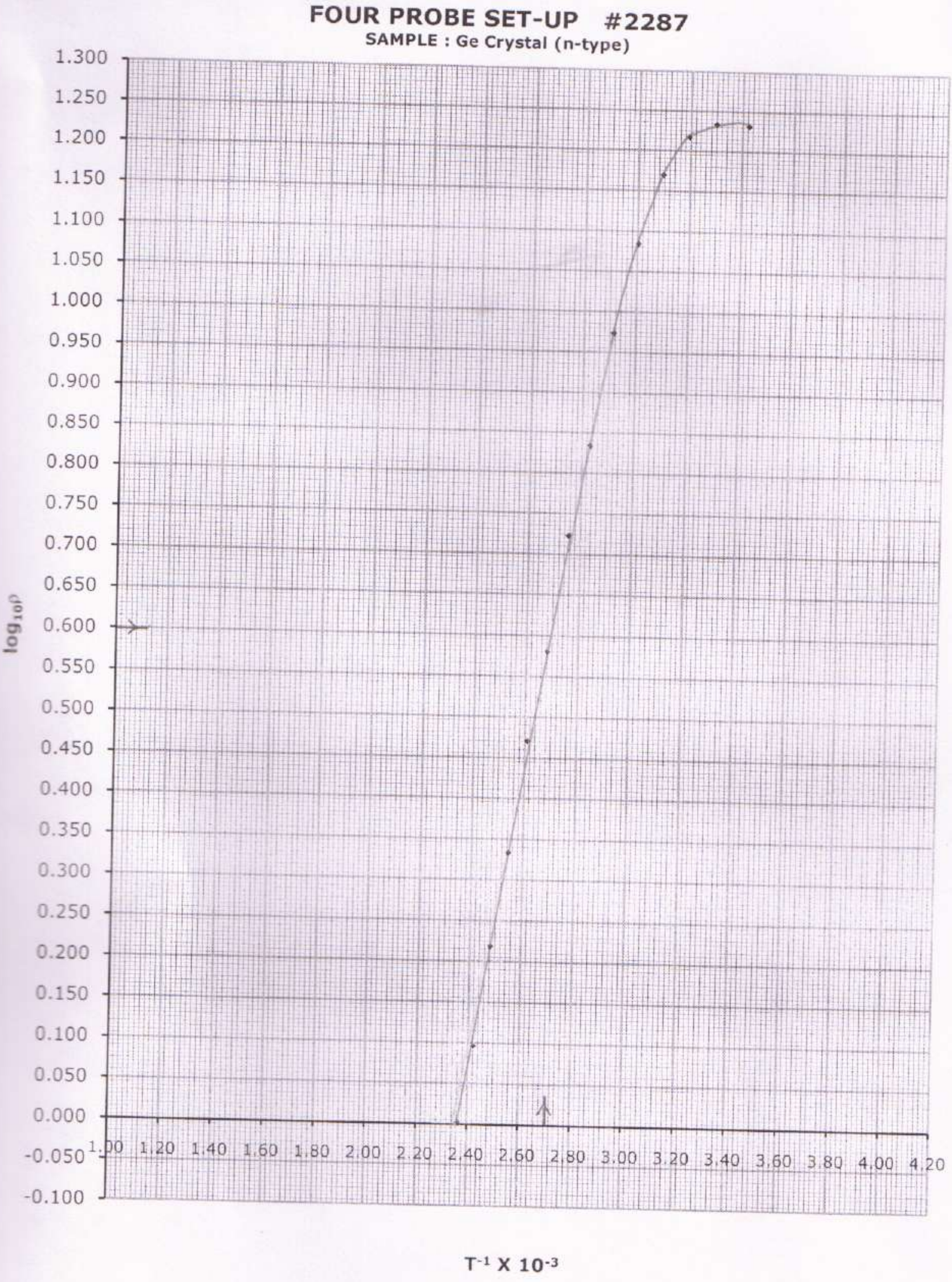
$$\frac{\text{Log}_e \rho}{\frac{1}{T}} = \frac{2.3026 \times \text{Log}_{10} \rho}{\frac{1}{T}} = \frac{2.3026 \times 0.60}{0.34 \times 10^{-3}} = 4063$$

Hence $E_g = 2 \times 8.6 \times 10^{-5} \times 4063$

$E_g = 0.70$ eV

Passed for despatch : Yes **Dated** 20.01.2018

Q.C. Engineer: U.S.Chauhan


FOUR PROBE SET-UP #2287
SAMPLE : Ge Crystal (n-type)
log10ρ
1.300
1.250
1.200
1.150
1.100
1.050
1.000
0.950
0.900
0.850
0.800
0.750
0.700
0.650
0.600
0.550
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
-0.050
-0.100
1.00 1.20 1.40 1.60 1.80 2.00 2.20 2.40 2.60 2.80 3.00 3.20 3.40 3.60 3.80 4.00 4.20
T-1 X 10-3

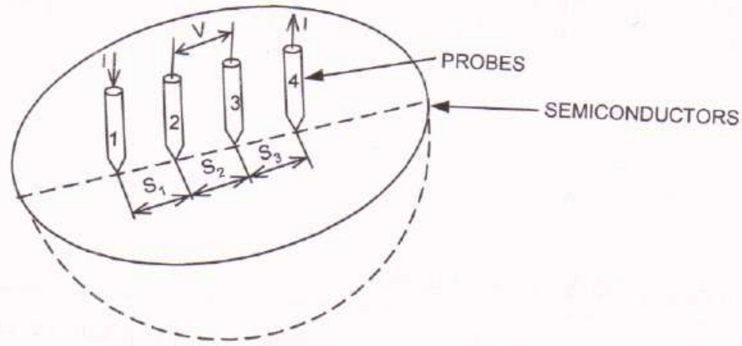


Fig 6. Model for the Four Probe resistivity measurement

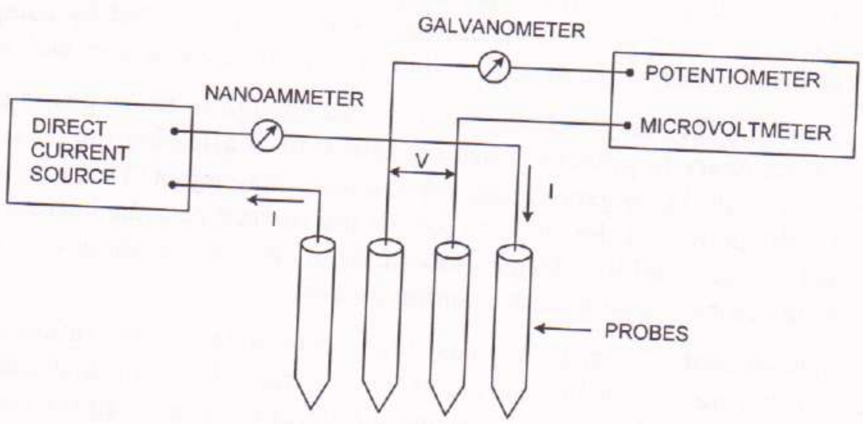
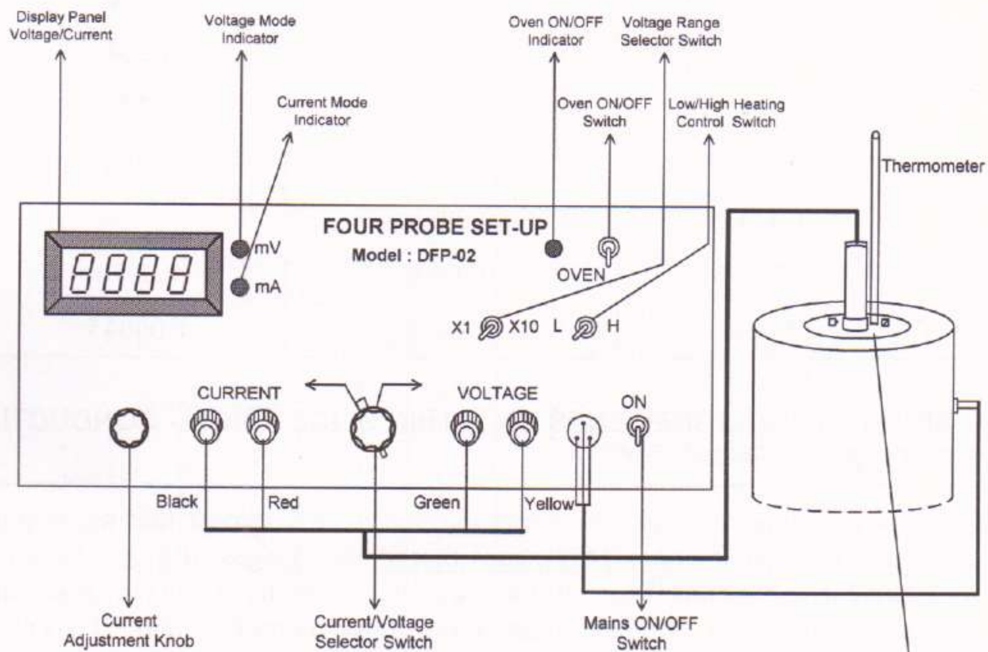
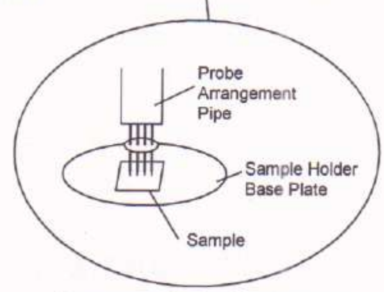


Fig 7. Circuit used for resistivity measurement



Panel Diagram of Four Probe Set-Up, DFP-02



Arrangement for keeping the sample

BRIEF DESCRIPTION OF THE APPARATUS REQUIRED

1. **Probe Arrangement** : It has four individually spring loaded probes. The probes are collinear and equally spaced. Individual spring ensure good electrical contact with the sample. The probes are mounted in a teflon bush, which ensure a good electrical insulation between the probe. A teflon spacer near the tips is also provided to keep the probes at equal distance. The whole arrangement is mounted on a suitable stand and leads are provided for current and volateg measurement.
2. **Sample** : Ge or Si crystal in the form of a chip/slice.
3. **Oven** : It is a small oven for studying the behaviour at different of temperatures of the crystal from room temperature to about 200°C.
4. **Four Probes Set-up : (Measuring Unit)** - It has three subunits all enclosed in one cabinet. It requires 230Vac ±10%, 50Hz input power

(i) Multirange Digital Voltmeter

In this unit intersil 3½ digit single chip A/D converter ICL 7107 has been used. It has high accuracy, auto zero to less than 10μV, zero drift-less than 1μV/°C, input bias current of 10pA and roll over error of less than one count. Since the use of internal reference causes the degradation in performance due to internal heating, an external reference has been used.

SPECIFICATIONS

Range	:	X1 (0 - 200.0mV) & X10 (0 - 2.000V)
Resolution	:	100μV at X1 range
Accuracy	:	± 0.1% of reading ± 1 digit
Impedance	:	10Mohm
Display	:	3½ digit, 7 segment, LED (12.5mm hieght) with auto polarity and decimal indication.
Overload Indicator	:	Sign of 1 on the left and blanking of other digits

(ii) Constant Current Generator

It is a IC regulated current generator to provide a constant current to the outer probes irrespective of the changing resistance of the sample due to change in temperatures.

The basic scheme is to use the feedback principle to limit the load current of the supply to preset maximum value. Variations in the current are achieved by a potentiometer included for that purpose. The supply is a highly regulated and practically ripple free d.c. source. The current is measured by the digital panel meter.

SPECIFICATIONS

Open circuit voltage	:	18V
Current range	:	0 - 20mA
Resolution	:	10μA
Accuracy	:	± 0.25% of the reading ±1 digit
Load regulation	:	0.03% for 0 to full load
Line regulation	:	0.05% for 10% changes

(iii) Oven Power Supply

Suitable voltage for the oven is obtained through a step down transformer with a provision for low and high rates of heating. A glowing LED indicates, when the oven power supply is 'ON'.

EXPERIMENTAL PROCEDURE

1. Put the sample on the base plate of the four probe arrangement. Unscrew the pipe holding the four probes and let the four probes rest in the middle of the sample. Apply a very gentle pressure on the probes and tighten the pipe in this position. Check the continuity between the probes for proper electrical contacts.

   CAUTION : The Ge crystal is very brittle. Therefore, use only the minimum pressure required for proper electrical contacts.

2. Connect the outer pair of probes (red/black) leads to the constant current power supply and the inner pair (yellow/green leads) to the probe voltage terminals.
3. Place the four probe arrangement in the oven and connect the sensor lead to the RTD connector on the panel.
4. Switch on the mains supply of Four Probe Set-up and put the digital panel meter in the current measuring mode through the selector switch. In this position LED facing mA would glow. Adjust the current to a desired value (Say 5 mA).
5. Now put the digital panel meter in voltage measuring mode. In this position LED facing mV would glow and the meter would read the voltage between the probes.
6. Connect the oven power supply. Rate of heating may be selected with the help of a switch Low or High as desired. Switch on the power to the Oven. The glowing LED indicates the power to the oven is 'ON'.

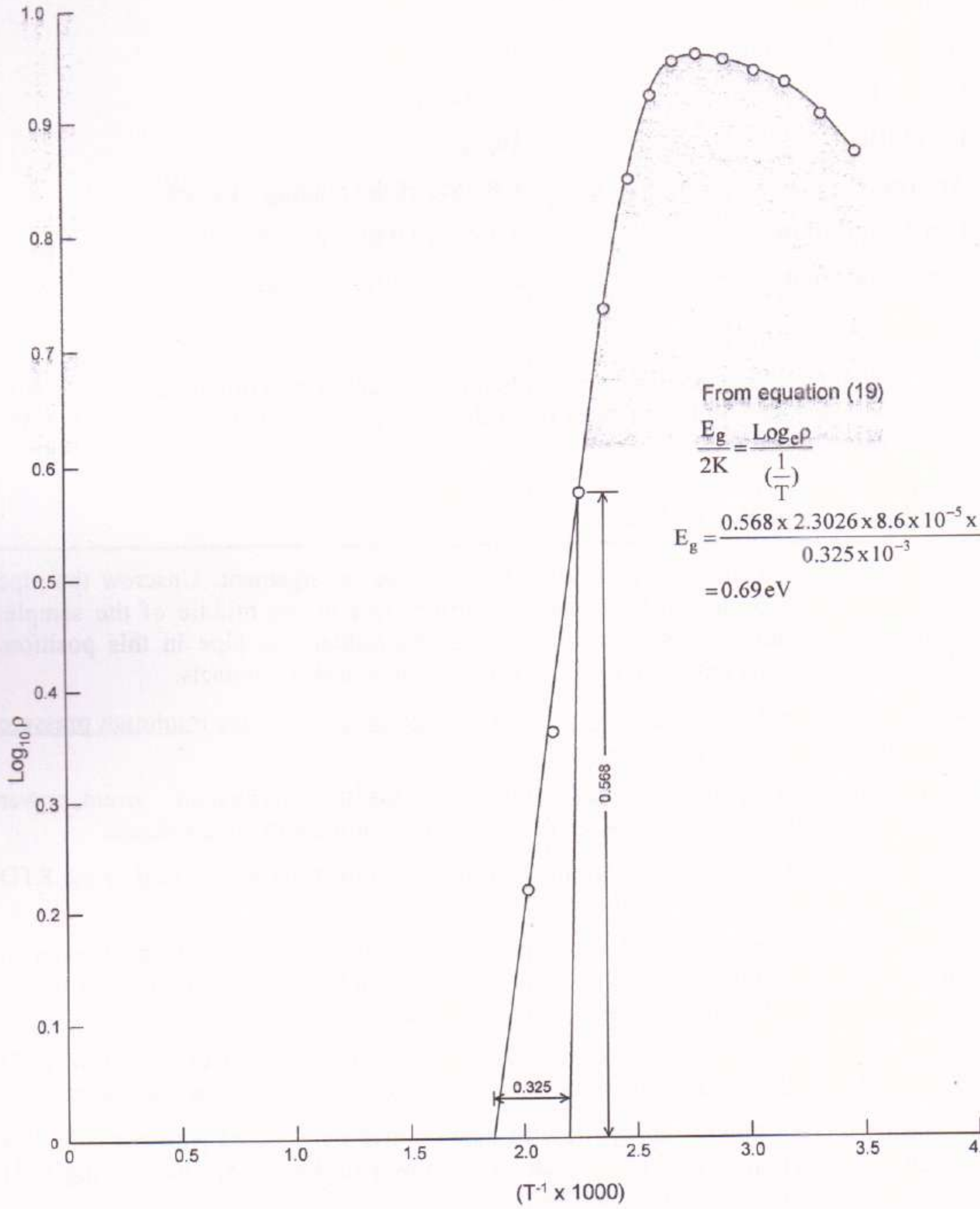


Fig. 10 The resistivity of a germinimum crystal as a function of inverse temperatu For this sample T < 363°K, conduction is due to the impurity carri (extrinsic region), for T > 363°K, conduction is due to electrons transferrec the conduction band (and the corresponding holes created in the valer band). This is the intrinsic region.

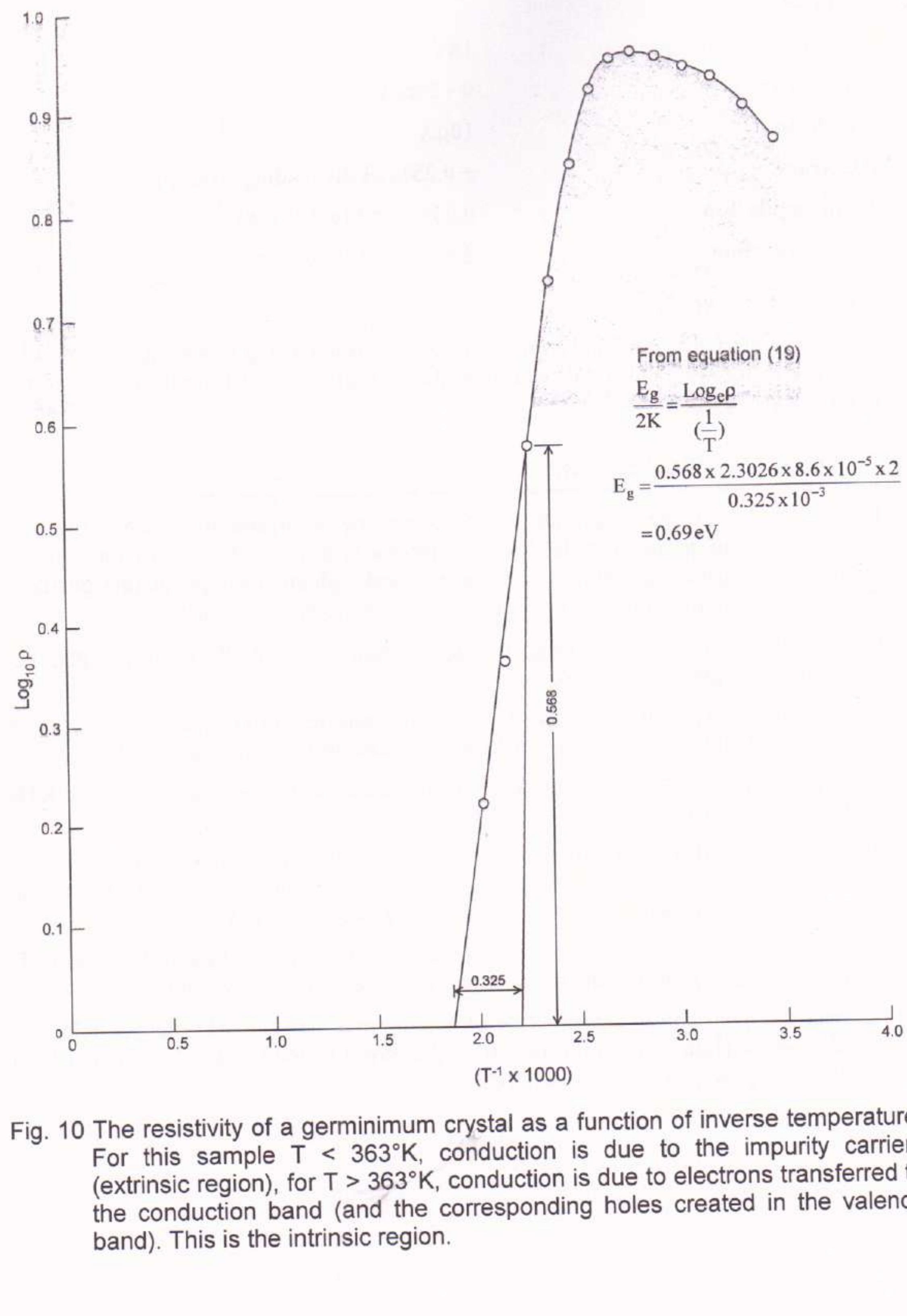


Fig. 10 The resistivity of a germinimum crystal as a function of inverse temperature. For this sample T < 363°K, conduction is due to the impurity carriers (extrinsic region), for T > 363°K, conduction is due to electrons transferred to the conduction band (and the corresponding holes created in the valence band). This is the intrinsic region.

OBSERVATIONS & TABULATION

Current (I) = mA (Constant)

S.No.	Temperature (°C)	Voltage (volts)	Temperature (T in K)	ρ (ohm. cm.)	$T^{-1} \times 10^3$	$Log_{10}\rho$

Distance between probes (S) = mm

Thickness of the crystal (W) = mm

CALCULATION

From Eq. (11)

$$\rho_0 = \frac{V}{I} \times 2\pi S$$

Since the thickness of the crystal is small compared to the probe distance a correction factor for it has to be applied. Further as the bottom surface is non-conducting in the present case, Eq. (17) will be applied.

$$\rho = \frac{\rho_0}{G_7(W/S)}$$

The function G_7 (W/S) may be obtained from Table-I or Fig. 9 for the appropriate value of (W/S). Thus ρ may be calculated for various temperature.

Plot a graph for $\log_{10}\rho$ vs. $T^{-1} X 10^{-3}$

Using Eq. (7) $\log_e \rho = \frac{E_g}{2kT} - \log_e K$

the slope of the curve is given by $\frac{\log_e \rho}{\frac{1}{T}} = \frac{E_g}{2k}$ (19)

Thus E_g may be obtained from the slope of the graph. Note that $\log_e x = 2.3026 \log_{10} x$ and the Eq. (7) is applicable only in the intrinsic region of the semiconductor. A typical graph is shown in Fig. 10.