User's Manual

DEPENDENCE OF HALL COEFFICIENT ON TEMPERATURE

Model: HEX-22

(Rev: 01/04/2010)

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ISO 9001:2008
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. On receipt, 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 due to improper packing. To be certain that the unit will not be damaged in shipment, please observe the following:

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

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 lease 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 3.

⚠ ⚠ Warning

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

Table 3. Line Voltage to Fuse Rating

Line Voltage Selection	Fuse Rating
220/ 240 V	0.3A, 250V (Slow blow)
100/ 120 V	0.6A, 250V (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 3 for line-power cord types available from SES. Refer to Table 4 for description of the line-power cords.

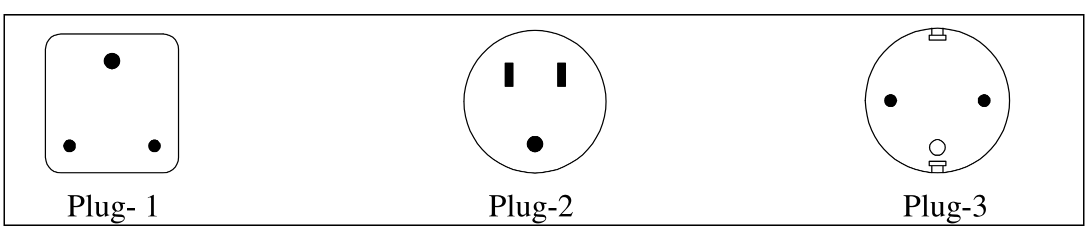


Figure 3. Line-Power Cord Types Available from SES

Table 4. 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.

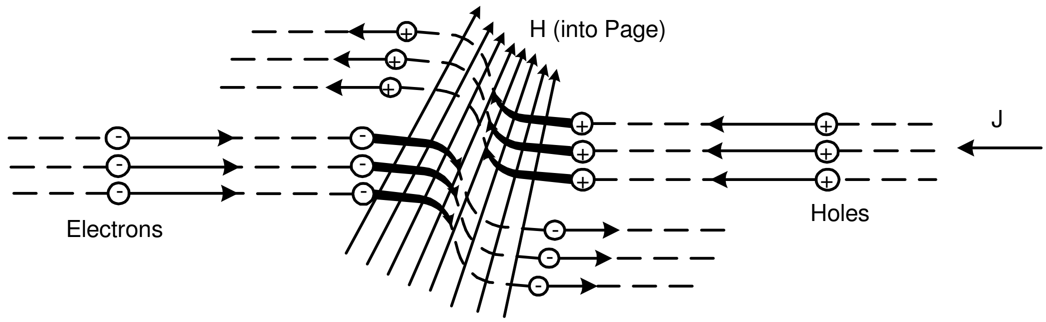


Fig. 1 Carrier separation due to a magnetic field

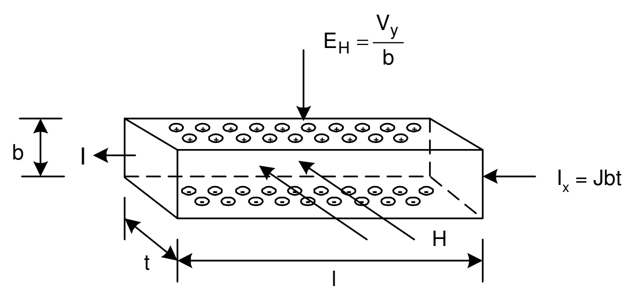


Fig. 2 Sample for studying Hall Effect

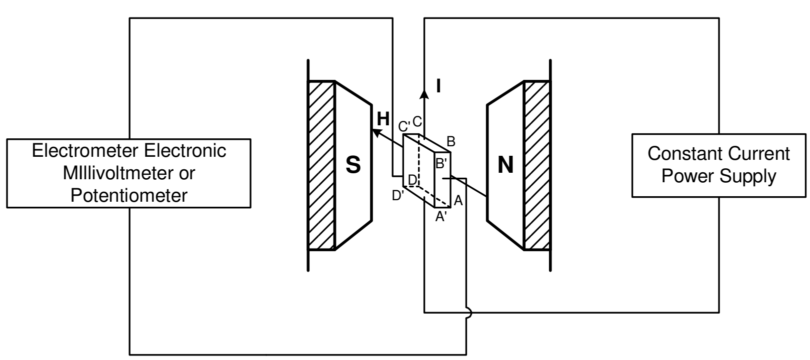


Fig. 3

INTRODUCTION

Conductivity measurements in semiconductors cannot reveal whether one or both types of carriers are present, nor distinguish between them. However, this information can be obtained from Hall Effect measurements, which are a basic tool for the determination of mobilities. The effect was discovered by E.H. Hall in 1879.

Consider a simple crystal mounted as in the Fig. 4, with a magnetic field H in the z direction perpendicular to contacts 1, 2 and 3, 4. If current is flowing through the crystal in the x direction (by application of a voltage V_x between contacts 1 and 2), a voltage will appear across contacts 3, 4 in the y- direction. It is easy to calculate this (Hall) voltage if it is assumed that all carriers have the same drift velocity. We will do this in two steps: (a) by assuming that carriers of only one type are present, and (b) by assuming that carriers of both types are present.

a) One type of carrier:

The magnetic force on the carriers is $\vec{F}_m = e\vec{E}_m = e\left(\vec{v} \times \vec{H}\right)$ and it is compensated by the force $\vec{F}_h$ due to the Hall field $\vec{E}_H$, $\vec{F}_H = e\vec{E}_H = \vec{F}_m$. As $\vec{v}$ is along the x- axis and $\vec{H}$ along the z-axis, the electric field $\vec{E}_m$ is along the y-axis and is given by $E_m = vH = \mu E_x H$ where μ is the carrier mobility given by $v = \mu E_x$ and E_x is the applied electric field along the x-axis. This electric field is related to the current density and conductivity, $\sigma E_x = J_x$. The Hall coefficient R_H is defined as

$$\left|R_H\right| = \frac{E_m}{J_x H} = \frac{\mu E_x}{J_x} = \frac{\mu}{\sigma} = \frac{1}{ne} \qquad (1)$$

We have used the relation $\sigma = ne\mu$. Hence for fixed magnetic field and fixed input current, the Hall voltage is proportional to 1/n. It follows that

$$\mu = R_H \sigma , \qquad (2)$$

providing an experimental measurement of the mobility. R_H is expressed in cm^3 $coulomb^{-1}$.

Experimentally the coefficient is given by

$$R_H = \frac{V_y b}{(I_x / bt)H} = \frac{V_y t}{I_x H}, \qquad (3)$$

where b and t are respectively the width and the thickness of the sample. In case the voltage across the input is kept constant, it is convenient to define the Hall angle as the ratio of applied and measured voltages:

$$\phi = \frac{V_y}{V_x} = \frac{E_m b}{E_x l} = \mu \frac{b}{l} H \qquad (4)$$

where l is the length of the crystal.

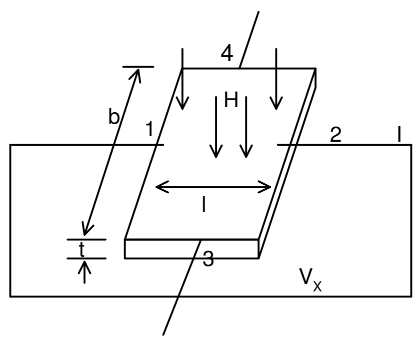


Fig. 4 Schematic arrangement for the measurement of Hall Effect of a crystal

The Hall angle is thus proportional to the mobility,

(b) **Two types of carriers**:

Now it is important to recognize that for the same electric field E_x, the Hall voltage for p carriers (holes) will have opposite sign from that for n carriers (electrons). (That is, the Hall coefficient R has a different sign.) Thus, the Hall field E_y will not be able to compensate for the magnetic force on both types of carriers and there will be a transverse motion of carriers; however, the net transverse transfer of charge will remain zero since there is no current through the 3, 4 contacts; this statement is expressed as

$$e(v_y{}^{+}p - v_y{}^{-}n) = 0$$

while

$$e(v_x{}^{+}p - v_x{}^{-}n) = J_x \quad \text{and} \quad e(\mu^{+}p + \mu^{-}n) = \sigma$$

where the mobility is always a positive number; however, $v_x{}^{+}$ has the opposite sign from $v_x{}^{-}$. It is given by

$$v_y = \frac{s}{\tau} = \left(\frac{1}{2}\frac{F}{m^{*}}\tau^{2}\right)\frac{1}{\tau} ,$$

where τ is mean time between collisions and m* is the effective of the carriers. Now for holes and electrons, we have

$$\vec{F}^{+} = e[(\vec{v}_x{}^{+} \times \vec{H}) - \vec{E}_H]$$

$$\vec{F}^{-} = -e[(\vec{v}_X{}^{-} \times \vec{H}) - \vec{E}_H]$$

If m_h and m_e are effective masses for holes and electrons, respectively, we get

$$v_y{}^{+} = \frac{1}{2}\frac{e}{m_h}\tau[(\mu^{+}E_x H) - E_H] = \mu^{+}(\mu^{+}E_x H - E_H)$$

$$v_y{}^{-} = \frac{1}{2}\frac{e}{m_e}\tau[(\mu^{-}E_x H) - E_H] = \mu^{-}(\mu^{-}E_x H + E_H)$$

and

$$\mu^{+}p(\mu^{+}E_x H - E_H) - \mu^{-}n(\mu^{-}E_x H + E_H) = 0$$

or

$$E_H = E_x H \frac{(\mu_h{}^{2}p - \mu_e{}^{2}n)}{\mu_h p + \mu_e n} , \qquad (5)$$

and for the Hall coefficient R_H

$$R_H = \frac{E_H}{J_x H} = \frac{E_H}{\sigma E_x H} = \frac{\mu_h{}^2 p - \mu_e{}^2 n}{e(\mu_h p + \mu_e n)^2} \qquad (6)$$

Equation 6 correctly reduces to Eq. 1 when only one type of carrier is present.

Since the mobilities μ_h and μ_e are not constants but functions of T, the Hall coefficient given by Eq. 6 is also a function of T and it may become zero and even change sign. In general $\mu_e > \mu_h$ so that inversion may happen only if $p > n$; thus ***"Hall coefficient inversion" is characteristic of only "p-type" semiconductors***.

At the point of zero Hall Coefficient, it is possible to determine the ratio of mobilities μ_e/μ_h in a simple manner.

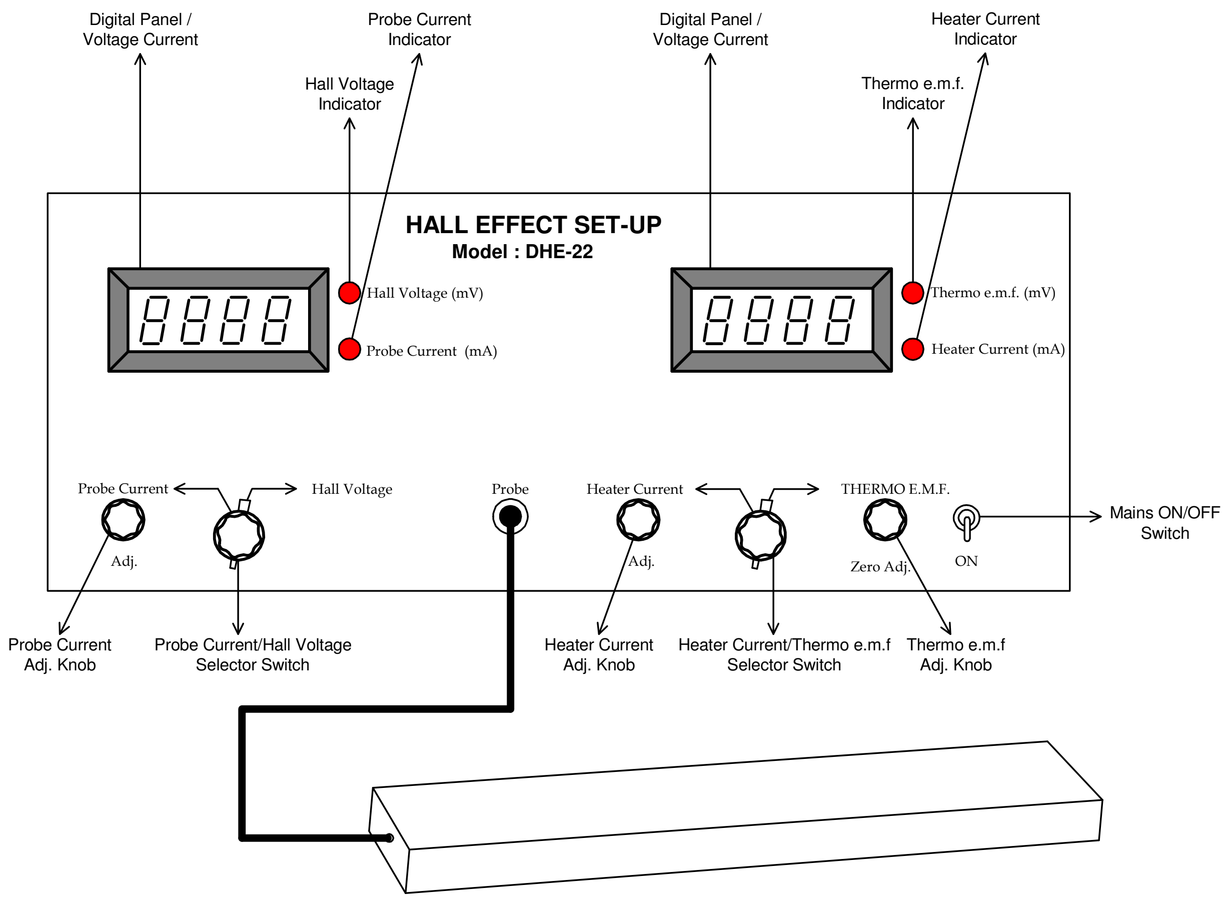
EXPERIMENTAL TECHNIQUE

(a) Experimental consideration relevant to all measurements on semiconductors

1. Soldered probe contacts, though very much desirable may disturb the current flow (shorting out part of the sample). Soldering directly to the body of the sample can affect the sample properties due to heat and by contamination unless care is taken. These problems can be avoided by using pressure contacts as in the present set-up. The principle draw back of this type of contacts is that they may be noisy. This problem can, however, be managed by keeping the contacts clean and firm.
2. The current through the sample should not be large enough to cause heating. A further precaution is necessary to prevent 'injecting effect' from affecting the measurement. Even good contacts to germanium for example, may have this effect. This can be minimized by keeping the voltage drop at the contacts low. If the surface near the contacts is rough and the electric flow in the crystal is low, these injected carriers will recombine before reaching the measuring probes.

(b) Experimental consideration with the measurements of Hall coefficient.

1. The Hall Probe must be rotated in the field until the position of maximum voltage is reached. This is the position when direction of current in the probe and magnetic field would be perpendicular to each other.
2. The resistance of the sample changes when the magnetic field is turned on. This phenomena called magneto-resistance is due to the fact that the drift velocity of all carriers is not the same, with magnetic field on, the Hall voltage compensates exactly the Lorentz force for carriers with average velocity. Slower carriers will be over compensated and faster ones under compensated, resulting in trajectories that are not along the applied external field. This results in effective decrease of the mean free path and hence an increase in resistivity.
3. In general, the resistance of the sample is very high and the Hall Voltages are very low. This means that practically there is hardly any current - not more than few micro amperes. Therefore, the Hall Voltage should only be measured with a high



Panel Diagram of Hall Effect Set-up, DHE-22

input impedance (≅1M) devices such as electrometer, electronic millivoltmeters or good potentiometers preferably with lamp and scale arrangements.

4. Although the dimensions of the crystal do not appear in the formula except the thickness, but the theory assumes that all the carriers are moving only lengthwise. Practically it has been found that a closer to ideal situation may be obtained if the length may be taken three times the width of the crystal.

PACKING LIST

1. Hall probe (Ge:p type)
2. Oven
3. Temperature sensor
4. Hall Effect Set-up, Model : DHE-22
5. Electromagnet, EMU-50V
6. Constant Current Power Supply, DPS-50
7. Digital Gaussmeter, DGM-102

1. HALL PROBE (GE : P-TYPE)

Ge single crystal with four spring type pressure contact is mounted on a glass-epoxy strips. Four leads are provided for connections with the probe current and Hall voltage measuring devices.

2. OVEN

It is a small oven which could be easily mounted over the crystal or removed if required.

Specifications

Size : 35 x 25 x 5 mm (internal size)

Temperature Range : Ambient to 100°C

Power requirement : 12W

3. TEMPERATURE SENSOR

Temperature is measured with Cromel-Alumel thermocouple with its junction at a distance of 1 mm from the crystal

4. HALL EFFECT SET-UP, MODEL : DHE-22

The set-up, DHE-22 consists of two sub set-ups, each consisting of further two units.

(i) Measurement of Probe Current & Hall Voltage

This unit consists of a digital millivoltmeter and constant current power supply. The Hall voltage and probe current can be read on the same digital panel meter through a selector switch.

(a) Digital Millivoltmeter

Intersil 3½ digit single chip ICL 7107 have been used. Since the use of internal reference causes the degradation in performance due to internal heating an external reference have been used. Digital voltmeter is much more convenient to use in Hall Experiment, because the input voltage of either polarity can be measured.

Specifications

Range : 0-200mV (100µV minimum)

Accuracy : ±0.1% of reading ± 1 digit

(b) Constant Current Power Supply

This power supply, specially designed for Hall Probe, provides 100% protection against crystal burn-out due to excessive current. The supply is a highly regulated and practically ripple free dc source.

Specifications

Current : 0-20mA

Resolution : 10µA

Accuracy : ±0.2% of the reading ±1 digit

Load regulated : 0.03% for 0 to full load

Line regulation : 0.05% for 10% variation

Input Supply : 220VAC ±10%

(ii) Measurement of Thermo emf and Heater current

The unit consists of a digital millivoltmeter and constant current power supply. The thermo emf of thermocouple and heater current can be read on the same DPM through a selector switch.

(a) Digital Millivoltmeter

Intersil 3½ digit single chip ICL 7107 have been used. Since the use of internal reference causes the degradation in performance due to internal heating an external reference have been used. Digital Voltmeter is much more convenient to use, because the input voltage of either polarity can be measured.

Specification

Range: 0 - 20 mV

Resolution: 10 µV equivalent to 0.25ºC in terms of thermo emf

Accuracy: ±0.1% of reading ± 1 digit

(b) Constant Current Power Supply

The supply is highly regulated and practical ripple free source.

Specifications

Current: 0 - 1A

Accuracy: ±0.2% of the reading ± 1 digit

Line regulation: 0.1% for 10% variation

Load regulation: 0.1% for 0 to full load

Input Supply : 220VAC ±10%

CALIBRATION TABLE
(CHROMEL-ALUMEL)

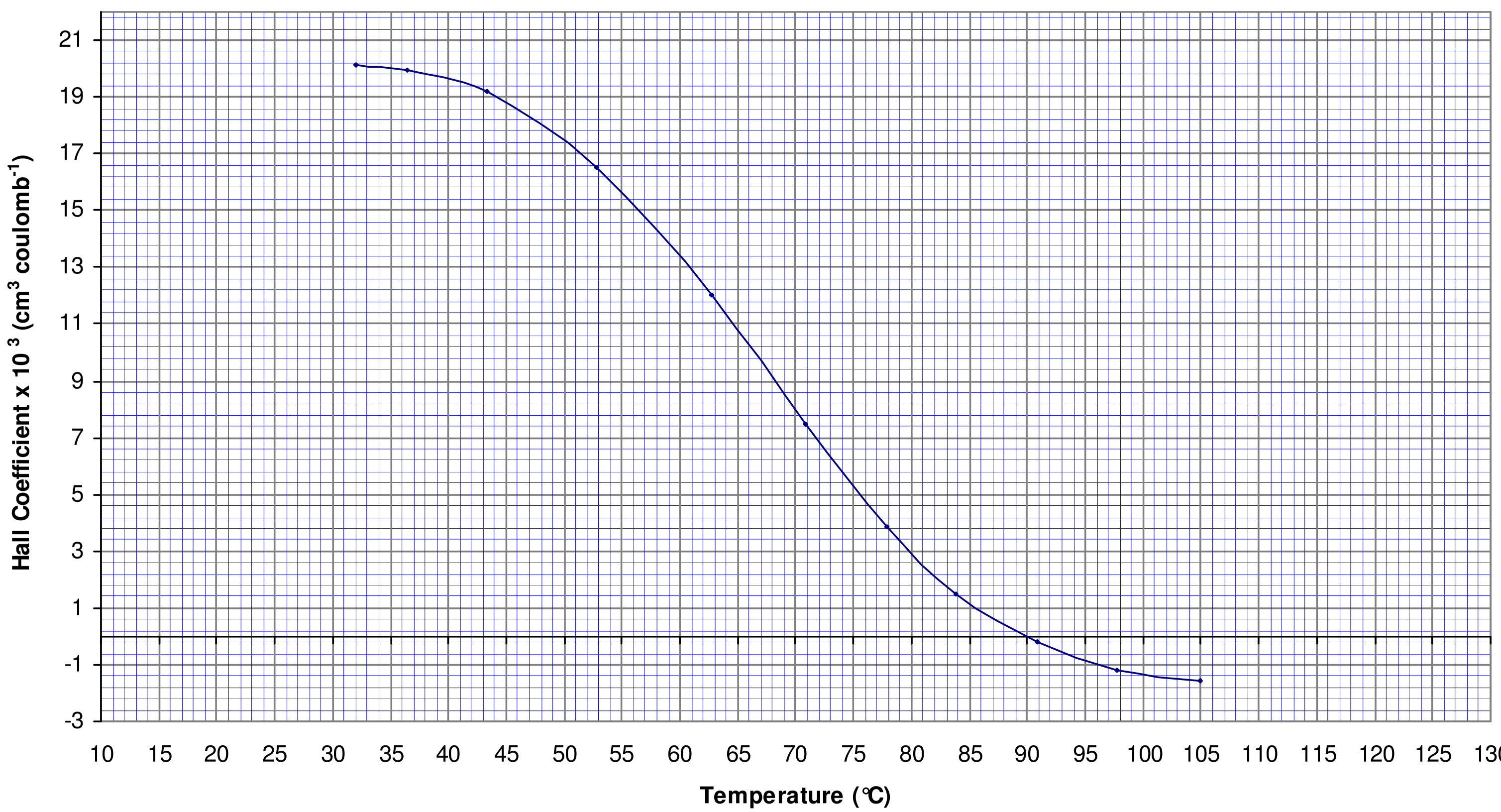
ºC	0	1	2	3	4	5	6	7	8	9
0	0.00	0.04	0.08	0.12	0.16	0.20	0.24	0.28	0.32	0.36
10	0.40	0.44	0.48	0.52	0.56	0.60	0.64	0.68	0.72	0.76
20	0.80	0.84	0.88	0.92	0.96	1.00	1.04	1.08	1.12	1.16
30	1.20	1.24	1.28	1.32	1.36	1.40	1.44	1.49	1.53	1.57
40	1.61	1.65	1.69	1.73	1.77	1.81	1.85	1.90	1.94	1.98
50	2.02	2.06	2.10	2.14	2.18	2.23	2.27	2.31	2.35	2.39
60	2.43	2.47	2.51	2.56	2.60	2.64	2.68	2.72	2.76	2.80
70	2.85	2.89	2.93	2.97	3.01	3.05	3.10	3.14	3.18	3.22
80	3.26	3.30	3.35	3.39	3.43	3.47	3.51	3.56	3.60	3.64
90	3.68	3.72	3.76	3.81	3.85	3.89	3.93	3.97	4.01	4.06
100	4.10	4.14	4.18	4.22	4.26	4.31	4.35	4.39	4.43	4.47
110	4.51	4.55	4.60	4.64	4.68	4.72	4.76	4.80	4.84	4.88

PROCEDURE

1. Note the ambient temperature.
2. Connect the widthwise contacts of the Hall Probe to the terminals marked 'Voltage' and lengthwise contacts to terminals marked 'Current'.
3. Switch 'ON' the Hall Effect set-up and adjustment current (say few mA).
4. Switch over the display to voltage side. There may be some voltage reading even outside the magnetic field. This is due to imperfect alignment of the four contacts of the Hall Probe and is generally known as the 'Zero field Potential'. In case its value is comparable to the Hall Voltage it should be adjusted to a minimum possible (for Hall Probe (Ge) only). In all cases, this error should be subtracted from the Hall Voltage reading.
5. Now place the probe in the magnetic field as shown in fig. 3 and switch on the electromagnet power supply and adjust the current to any desired value. Rotate the Hall probe till it become perpendicular to magnetic field. Hall voltage will be maximum in this adjustment.
6. Measure Hall voltage.
7. Measure the magnetic field by the Gaussmeter.
8. After every new setting of heater current, wait for about 7-8 minutes for the temperature to stabilize. This would be indicated by a stable thermo e.m.f. also.
9. After Hall voltage reading at a particular temperature, switch off the constant current power supply of the magnetic. Note down the off-set voltage at residual magnetic field and subtract it from the Hall voltage. This is very important.
10. There is no need to gradually increase/decrease the magnetic field. Just switch 'OFF' the supply for off-set voltage and switch 'ON' for the next reading.
11. Change of sign of Hall voltage on heating would occure for p-type sample only. This is explained in the Manual. There is no need to take further readings after the change of sign.
12. Allow about 10 minutes time for the thermal stabilization of the DHE-22 every time the experiment is to be performed.
13. Thermo emf (mV) reading if any at ambient temperature i.e. without heater current should be subtracted from the thermo emf reading to get the corresponding correct temperature from the calibration table provided with the set-up. It is assumed that the thermo-emf of the chromel-alumel thermocouple used with the heating arrangement varies linearly with the temperature difference between the two junctions of the thermocouple.

DEPENDANCE OF HALL COEFFICIENT ON TEMPERATURE

Sample : Ge (P-type) medium doping



Observations

Ambient temperature :

Sample : Ge (p-type) medium doping

Thickness : 0.50 mm

Residual Magnetic Field: 130 Gauss

Mag. Field : 3.13 KGauss

Probe Current (I): 4.00 mA

S.No.	Heater current (mA)	Thermo. e.m.f. (mV)	Temp (ºC)	Hall Voltage (mV)	Off-set voltage at residual (mV)	Corrected Hall Voltage (mV)	Hall Coefficient ($cm^3.coulomb^{-1}$)
1	0	0.00	17.0	54.6	-0.8	55.4	23.08
2	200	0.09	19.3	54.3	-0.9	55.2	23.00
3	300	0.29	24.3	54.8	0.29	54.5	22.71
4	400	0.59	31.8	53.1	-1.2	54.3	22.63
5	500	0.98	41.5	56.6	2.8	53.8	22.42
6	550	1.27	48.8	54.7	3.2	51.5	21.46
7	600	1.52	54.8	49.9	2.6	47.3	19.71
8	650	1.77	61.0	41.9	2.0	39.9	16.63
9	700	2.02	67.0	22.0	-8.7	30.7	12.79
10	750	2.25	72.0	14.4	-7.6	22.0	9.17
11	800	2.53	79.5	5.0	-7.4	12.4	5.17
12	850	2.82	86.5	-4.8	-8.6	3.8	1.58
13	900	3.05	92.0	-6.3	-6.7	-0.4	-0.17
14	950	3.54	100.8	-7.9	-5.2	-2.7	-1.13
15	1000	3.71	107.8	-7.8	-4.2	-3.6	-1.50

Note : Since Hall voltage at residual magnetic field form the part of Offset Voltage, the magnetic field for Hall Coefficient calculation would be = 3.13 - 0.13 = 3.00 KG

Variation of Hall Coefficient with temperature is shown in the graph

Formula used for calculation of Hall Coefficient (R)

$$R = \frac{V_y\ t}{I\,H}$$

where, V_y = Hall voltage

t = Thickness of the sample

I = Probe current

H = Magnetic field

Dependence of Hall coefficient on temperature for p-type and n-type Ge crystal are shown in graph enclosed.

CALCULATIONS

(a) From the graph Hall voltage vs. magnetic field calculate Hall coefficient.

(b) Determine the type of majority charge carriers, i.e. whether the crystal is n type or p type.

(c) Calculate charge carrier density from the relation

$$R = \frac{1}{nq} \Rightarrow n = \frac{1}{Rq}$$

(d) Calculate carrier mobility, using, the formula

$$\mu_n \text{ (or } \mu_p) = R\sigma$$

using the specified value of resistivity ($1/\sigma$) given by the supplier or obtained by some other method (Four Probe Method). *Typical calculations are shown in appendix*

QUESTIONS

1. What is Hall Effect?
2. What are n-type and p-type semiconductors?
3. What is the effect of temperature on Hall coefficient of a lightly doped semiconductor?
4. Do the holes actually move ?
5. Why the resistance of the sample increases with the increase of magnetic field?
6. Why a high input impedance device is generally needed to measure the Hall voltage?

REFERENCES FOR SUPPLEMENTARY READING

1. Fundamentals of semiconductor Devices, J.Lindmayer and C.Y. Wrigley, Affiliated East-West Press Pvt. Ltd., New Delhi.
2. Introduction to Solid State Physics, C. Kittel; John Wiley and Sons Inc., N.Y. (1971), 4th edition.
3. Experiments in Modern Physics, A.C. Melissios, Academic Press, N.Y. (1966).
4. Electrons and Holes, W. Shockley, D. Van Nostrand ,N.Y. (1950).
5. Hall Effect and Related Phenomena, E.H. Putley, Butterworths, London (1960).
6. *Handbook of Semiconductor Electronics, L.P. Hunter (e.d.) McGraw Hill Book Co. Inc., N.Y. (1962).*

TECHNICAL SUPPORT

Feed Back

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

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Contacting for Technical Support

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

- If your problem is with the our instrument:
  - 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;
  - Model number and Revision (listed by month and year on the front cover).
  - Have the manual at hand to discuss your questions.