# PRACTICAL WORK BOOK
**For The Course**
## EE-221 Instrumentation

**For**

# Second Year
(Electrical & Electronic Engineering)

Name of Student: ______________________________________________

Class: ______________________________ Batch : ___________________

Discipline: ______________________________________________

Class Roll No.: _______________ Examination Seat No. ________________

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# EXPERIMENT # 1(a)

## OBJECT: -

**Measurement of Resistance by RCL Bridge and verify it by color code.**

## APPARATUS: -

1. RCL Bridge.
2. Different resistance.

## THEORY: -

*RESISTORS: -*

The device, which offers resistance to the flow of current, is called resistor.

RESISTANCE MEASURING INSTRUMENTS: -

There are following instruments used to measure resistance:

1. Potentiometer.
2. Kelvin doubles bridge.
3. Differential galvanometer.
4. Wheat Stone bridge.
5. RCL Bridge.

### *RCL BRIDGE: -*

RCL Bridge is a measuring instrument used to measure resistance as well as capacitance and inductance.

**CONSTRUCTION: -**

RCL Bridge is consisted on ports, for resistance, capacitance, and inductance. There are push buttons each for resistance, capacitance, and inductance.

The range multiplier switch knob is provided whose value can be determined by toothed scale on keeping the search button switch.

There is verneir scale, which is used to determine the numeric value of resistor, capacitor, or inductor by the maximum deflection of pointer on saw-toothed scale.

The Color Coded Chart are as follows:-

| COLOR | CODES |
|---|---|
| Black (B) | 0 |
| Brown(Br) | 1 |
| Red(R) | 2 |
| Orange(O) | 3 |
| Yellow(Y) | 4 |
| Green(G) | 5 |
| Blue(Bl) | 6 |
| Violet(V) | 7 |
| Gray(G) | 8 |
| White(W) | 9 |
| **TOLERENCE:** | |
| No color | ±20% |
| Silver | ±10% |
| Golden | ±05% |
| Red | ±02% |

## PROCEDURE: -

1. Turn the power on of RCL Bridge by pushing ON/OFF button.
2. Connect the resistor to be measured to port on RCL Bridge.
3. Press the R-Push button.
4. Keep the search button in press position with left hand and turn the range multiplier selector (RMS) knob, from button to top with right hand. While changing the range multiplier knob, observe the deflection of red pointer on saw toothed scale. When the red pointer come on saw toothed scale position, leave the RMS knob, on that position.
5. Now move the vernier scale black pointer (VSBP) by its knob verneir scale reading is 0 to 10.5, when move the VSBP the saw toothed scale pointer on dial also moves with it simultaneosly. Note down the reading of vernier scale, when pointer on saw toothed scale is come closer to null point and returned immediately. As this movement stops, note down the vernier scale reading.
6. Multiply the above observe reading with the range multiplier pointer value. This would be the measured value of the resistor.
7. Now calculate the resistor value by the digits, which are written on it or calculate it by the color-coding.
8. Compare the measured value of resistor by its calculated value and write down the difference.
   The value of resistance can be calculated by the color-coding table:

OBSERVATION: -

| S.No. | Colour of Resistors | Resistance in ohms | | |
|---|---|---|---|---|
| | | Measured value | Calculated value | Difference |
| 1<br>2<br>3<br>4<br>5 | | | | |

CALCULATIONS:-

RESULT:-

# EXPERIMENT # 1(b)

## OBJECT: -

Measurement of capacitance by RLC bridge and verify them by the numerical value.

## APPARATUS: -

(i) RCL bridge
(ii) Capacitor
(iii) 220 Volt, AC power supply.

## THOERY: -

The values of most electrolytic capacitors are clearly marked on them but those of ceramic or tantium capacitors are usually encoded in the form of a color code.
In case of a numerical coded capacitors, most of which are low values (usually below 1 micro farad), the first two digits show the value in Pico Farads and the third shows the multiplier as an exponent of ten. For example the value of 0.1μF, capacitor is denoted by marking showing the number 104 etc.
In case of the color-coded types, the values are read from the international capacitors color code table.

## PROCEDURE: -

1. Turn the power on, of RCL bridge by the push ON/OFF button.
2. Connect the capacitors to be measured to port on RCL bridge.
3. Press the C- push button.
4. Keep the search button in press position with left hand and turn the range multiplier selector (RMS) knob from bottom to top with right hand. When change the range multiplier knob, observe the deflection of red pointer on saw toothed scale. When the red pointer came on saw toothed scale position leave the RMS knob on the position.
5. Now move the vernier scale black printer (VSBP) by its know (which is on top side of RCL bridge). Vernier scale reading is 0 to 10.5. When move the vernier scale black printer the saw toothed scale pointer on dial is also move with it simultaneously. Note down the reading of vernier scale when the pointer on the saw-toothed scale is come closer to null point and returned immediately. At this moment note down the vernier scale reading.
6. Multiply the above observed reading with the range multiplier printed value. That would be the measured value of capacitors.
7. Now calculate the capacitor value by the digits, which are written on it.
8. Compare the measured value of capacitor by this calculated value and write down the difference.

OBSERVATIONS: -

| S.No. | Capacitor | Measured value μF | Calculated value μF | Difference μF |
|---|---|---|---|---|
| 1. | | | | |
| 2. | | | | |
| 3. | | | | |

CALCULATIONS: -

RESULT: -

It is observed that measured value and calculated value of the capacitors are approximately same.

# EXPERIMENT # 2(a)

## OBJECT: -

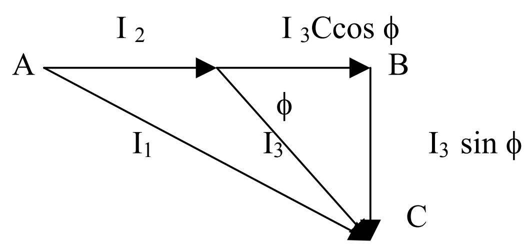
**To Measure the Power and Power Factor by three Ammeter method.**

## APPARATUS: -

- Given circuit board
- Three Ammeter.
- Power supply
- Connecting Wires
- 24 Volts Supply

## THEORY: -

On analyzing the given circuit, the total current $I_1$ is divided into $I_2$ & $I_3$. $I_2$ current is passing through resistor therefore it is in phase with applied voltage, while $I_3$ is passing through inductor therefore it is lagged by angle $\phi$ with respect to applied voltage. Graphically it can be represented as:




Resolve I into components & consider Δ ABC.

$(I_1)^2 = (I_2 + I_3 \cos\phi)^2 + (I_3 \sin\phi)^2$

$(I_1)^2 = I_2^2 + 2 I_2 I_3 \cos\phi + I_3^2 \cos^2\phi + (I_3 \sin\phi)^2$

$I_1^2 - I_2^2 = 2 I_2 I_3 \cos\phi + I_3^2 (\cos^2\phi + \sin^2\phi)$

Now,

$$\text{Cos}\,\phi = (I_1^2 - I_2^2 - I_3^2) / 2I_2I_3.$$

Now again consider above equation

$2I_2I_3 \cos\phi = ( I_1^2 - I_2^2 - I_3^2 )$

$2(V/R)\, I_3 \cos\phi = ( I_1^2 - I_2^2 - I_3^2 )$

$VI_3 \cos\phi = (I_1^2 - I_2^2 - I_3^2)R/2$

$P = (I_1^2 - I_2^2 - I_3^2) R/2.$

Real Power = $(I_1^2 - I_2^2 - I_3^2) R/2$

## OBSERAVTIONS: -

| V (Volts) | $I_1$ (Amp) | $I_2$ (Amp) | $I_3$ (Amp) |
|---|---|---|---|
| | | | |

## CALCULATIONS: -

## RESULT: -

(1)Power factor is found to be : ________

(2)Power is found to be : ___________

# EXPERIMENT # 2(b)

## OBJECT: -

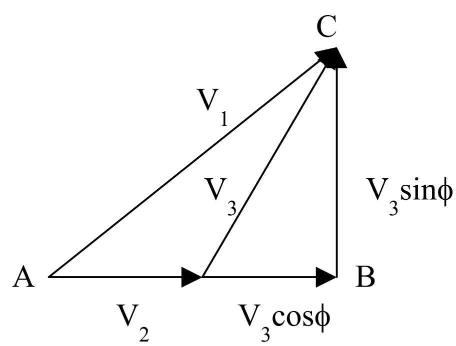
**Measurement of Power Factor by Three Voltmeter method.**

## APPARATUS: -

1. AC voltmeter.
2. 24 volt AC supply.
3. Circuit board.
4. AC ammeter.
5. Connecting wires

## THEORY: -

On analyzing the given circuit it is observed that the two elements, resistor, and inductor are connected in series i.e. the same amount of current is passing through each element. The voltage drop in inductor is leading the current which is graphically can be represented as:




Now from figure,
Apply Pythagorus theorem on Δ ABC.

$$V_1^{\,2} = (V_2 + V_3\cos\phi)^2 + (V_3\sin\phi)^2$$

$$V_1^{\,2} = V_2^{\,2} + 2V_2V_3\cos\phi + V_3^{\,2}\cos^2\phi + V_3^{\,2}\sin^2\phi$$

$$V_1^{\,2} - V_2^{\,2} - V_3^{\,2} = 2V_2V_3\cos\phi$$

$$\mathbf{\cos\phi = (V_1^{\,2} - V_2^{\,2} - V_3^{\,2}) / 2V_2V_3 \longrightarrow \quad Eq\ \#1}$$

**For real power: -**

$2V_2V_3 \cos\phi = V_1^2 - V_2^2 - V_3^2$

$2(IR)V_3 \cos\phi = V_1^2 - V_2^2 - V_3^2$

$V_3 I \cos\phi = (V_1^2 - V_2^2 - V_3^2)/2R$

**Real power = $(V1^2 - V2^2 - V3^2)/2R$ ⟶ Eq # 2**

OBSERVATIONS: -

I =

$V_1$=

$V_2$=

$V_3$=

CALCULATIONS: -

RESULT: -

- Real power is found to be = _______________Watts
- Power factor is found to be = ________________

# EXPERIMENT # 3

## OBJECT: -

**Measurements of power of Resistive load by Analogue Wattmeter and then calculate its power factor.**

## APPARATUS: -

1. Resistive load.
2. Voltmeter.
3. Ammeter.
4. Wattmeter.
5. Power supply 220 V
6. Connecting wires

## THEORY: -

The wattmeter is a measuring instrument use to measure electric power. The wattmeter is consists of a 'Pressure Coil' and 'Current Coil'. The current coil of the instrument carries the load current, while the pressure coil carries the current proportional to, and in phase with the voltage. The deflection of the wattmeter depends upon the current in these two coils and upon the power factor. Inductance in the pressure coil circuit should be divided as far as possible, since it causes the pressure coil current to lag behind the applied voltage. A high non-inductive resistance is connected in series with the pressure coil in order that the resultant of the coil itself shall be small in comparison, with the resistance of the whole pressure coil circuit taken by the pressure coil shall be small.

## PROCEDURE: -

1. Connect the voltmeter in parallel with the source.
2. Connect the ammeter in series with the source.
3. Connect the wattmeter according to the instruction already written on the labeled diagram.
4. Now vary the load, and measure voltage, current and power each time.
5. Finally measure power factor each time.

OBSERVATIONS: -

| Load | Power (Watt) | V (Volts) | I (Amp) | cosϕ (P/VI) |
|---|---|---|---|---|
| No load | | | | |
| 2 Bulbs ON | | | | |
| 4 Bulbs ON | | | | |
| 6 Bulbs ON | | | | |
| 8 Bulbs ON | | | | |
| 10 Bulbs ON | | | | |

CALCULATION:-

RESULT: -

The power & p.f by wattmeter has been measured.
We observed Unity P.f in case of Resistive load.

# EXPERIMENT # 4

## OBJECT: -

**Measurement of Electrical Energy by Electronic wattmeter and Energy meter(KWH).Also prove that E = P * t.**

## APPARATUS: -

1. Circuit board.
2. Energy meter.
3. Electronic wattmeter.
4. Stop watch.
5. Resistive Load.

## THEORY: -

**SINGLE PHASE WATT-HOUR METER**: -

Induction type meters are the most common form of AC meters. These meters measure electric energy in kilowatt-hour. The principle of these meters is practically the same as that of the induction wattcmeters. In these meters magnet and spindle is used.
The watt-hour meter consist on two main coils:

*(i)* *Pressure coil.*
*(ii)* *Current coil.*

The pressure coil is attached to the source while the current coil is attached to the load. In kilowatt-hour meter the breaking magnet is provided to control the speed of the disc. The breaking magnet decreases the breaking torque.

## FEATURES: -

1. They are induction type of instruments.
2. They are light in weight.
3. Torque to weight ratio is very small.
4. Temperature change has very small effect on the instrument.

ELECTRONIC WATTMETER: -

An electronic wattmeter is a power-measuring instrument. This instrument consists of a deflection scale, voltage adjustment knob and current adjustment knob as well. The electronic wattmeter is connected to the supply and voltage and current knob are adjusted. The pointer shows the deflection, which is to be noted. The power is calculated as:

***Power = deflection* Voltage range * Amperes range***

## PROCEDURE: -

1. First of all the connection is completed.
2. The voltage knob is adjusted at 500 volts.
3. The ampere knob is adjusted at 5 amp.
4. Deflection is measured from deflection scale.
5. Power is measured by above formula mentioned on Electronic Wattmeter.
6. Initially reading of kWh meter is noted and after 15 minutes the final reading is taken.
7. Change the time (which is in minute) into Hours.
8. The energy measured by electronic wattmeter should be equal to kWh meter.

## OBSERVATION: -

| S.No | Power (watt) Deflect. x V x I | Time (minutes) | kWh by calculations KWh = P x t | KWh by observations | | |
|---|---|---|---|---|---|---|
| | | | | Initially | Final | Diff. |
| | | | | | | |

## CALCULATION:-

## RESULT: -

It is observed that the energy measured by electronic wattmeter and kWh meter is same.

# EXPERIMENT # 5

## OBJECT: -

**Measure the Power (P), Power factor (Cos $\phi$), and VAR by Electronic wattmeter and Power Factor meter.**

## APPARATUS: -

1. Circuit kit.
2. 220 V supply.
3. Power factor meter.
4. Electronic wattmeter.
5. Ammeter.
6. Induction load.

## THEORY:

**AN ELECTRONIC WATTMETER:**

An electronic wattmeter is a power measuring device. This instrument constitutes of a deflecting scale, voltage adjusting knob and current adjusting knob. The electronic wattmeter is connected to the supply and voltage and current know is adjusted. The pointer shows the deflection which is to be noted. The power can be calculated as

**Power = Deflection * Voltage Range*Current Range**

**POWER FACTOR METER:**

The instrument is based on the dynamometer principle with spring control. The instrument has a stationary coil, which has a uniform field. There are two moving voltage coils having resitance, (R ) and inductance (L) in series. When the reistive load is increased or decreased the pointer shows the power factor, either leading or lagging.

## PROCEDURE:

1. First of all connections are completed.
2. The voltage knob is adjusted to 500 V
3. The ampere knob is adjusted depending on the load current.
4. Deflection is measured from deflection scale.
5. Power is measured by the above formula.
6. Power factor is measured with the help of power factor meter.

OBSERVATIONS:

| S. No | load | I (amps) | Cos Ø | Ø | P (watts) | V (volts) | VAR |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| 1 | No Load | | | | | | |
| 2 | R1 | | | | | | |
| 3 | R2 | | | | | | |
| 4 | R1 & R2 | | | | | | |

Observations For Io :

Io = No load current ( This current will flow in the primary of the transformer winding even at no load , this current is called as magnetizing current of the transformer, this current is necessary to maintain flux in the core).

Io = _________ amps

CALCULATIONS:

# EXPERIMENT # 6

## OBJECT:

**By making use of Cathode Ray Oscilloscope, Study the bridge rectifier to :-**

**(1) To calculate input frequency Vin**
**(2 ) To calculate Vrms, Vavg, Irms & Iavg.**

## APPARATUS:

- Vin = 24 V
- AC voltmeter (50V)
- DC Ammeter (5A)
- DC voltmeter (50 V)
- AC Ammeter (3A)
- Transformer step-down (220-24 volts)
- Oscilloscope (T/d = 5 s/div)
- Variable Load
  - R1 = 14.3 Ohm
  - R2 = 7.3 Ohm
  - R1// R2 =R3 = 4.83 Ohm

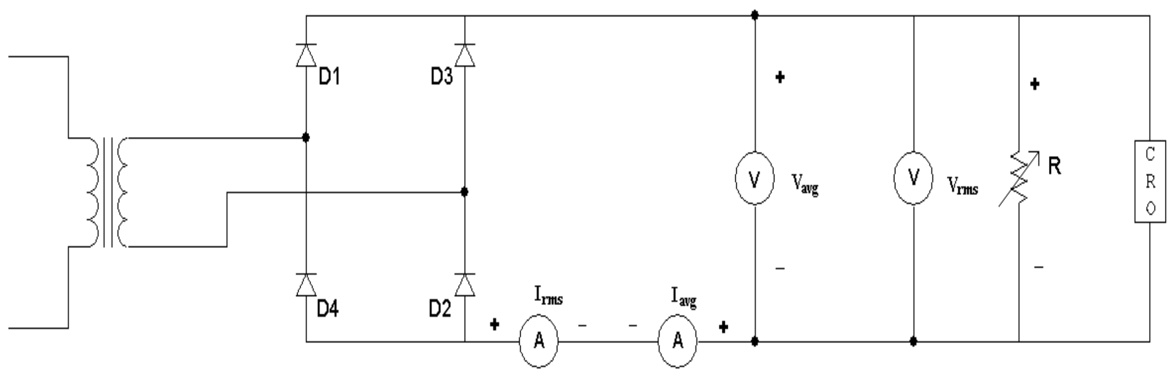
## Theory:

During the +ve, half cycle of input voltage the two diodes D1 & D2 are in conduction. D2 provides returning path to the current. In the negative half of the input voltage D3 & D4 become forward biased and they start conduction. The direction of current flow remains same during both conduction stages hence we get rectification in both cycles of input voltage.

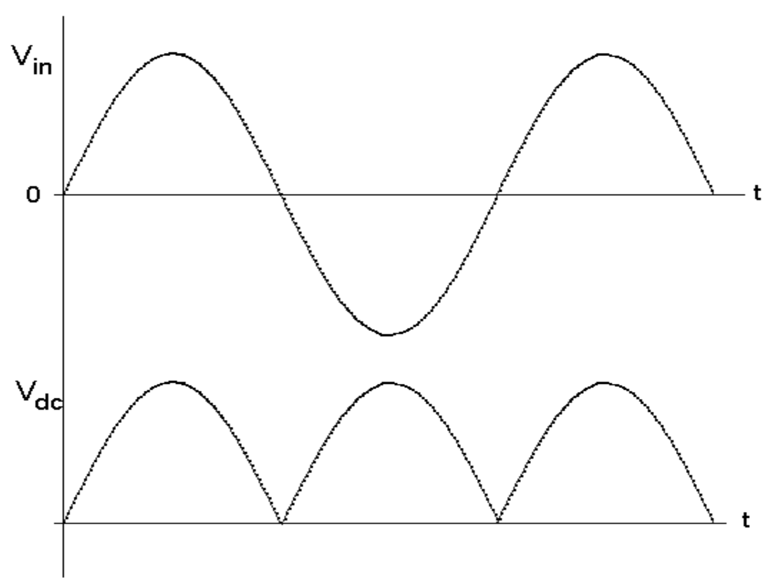
## Formulae Used in the Calculation:

1. $f = 1/T$
2. $V_{dc} = 0.636V_{max}$
3. $V_{rms} = 0.707V_{max}$

Circuit Diagram:




**Wave Forms:**




Procedure:-

- Connect the circuit element according to the diagram.
- Now turn on the load R1 and note the values of $I_{avg}$, $I_{rms}$, $V_{avg}$, and $V_{rms}$. Also observe their waveforms on the Oscilloscope.

- Now turn on R2 and repeat the above procedure.
- This time turn on both R1 & R2 simultaneously and measure the readings.
- Now Calculate the values of $I_{avg}$, $I_{rms}$, $V_{avg}$, and $V_{rms}$.

## Observations:-

The wave forms of the output voltage of a bridge rectifier are observed for a given frequency.

$$f = 1/T = 1/\quad ms = \quad Hz$$

| **S.No** | **Load** | $V_{max}$ | $V_{rms}$ | | | $V_{avg}$ | | | $I_{rms}$ | | | $I_{avg}$ | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | *Obs* | *Cal* | *Diff* | *Obs* | Cal | *Diff* | *Obs* | *Cal* | *Diff* | *Obs* | *Cal* | *Diff* |
| 1 | No load | | | | | | | | | | | | | |
| 2 | 14.3 Ω | | | | | | | | | | | | | |
| 3 | 7.3 Ω | | | | | | | | | | | | | |
| 4 | 14.3 Ω parallel with 7.3 Ω | | | | | | | | | | | | | |

## Result :-

We have noted the observations by and calculate the input frequency by making use of Cathode Ray Oscilloscope.

# Experiment # 7

## OBJECT:

To plot the characteristic curve of a photoresistor by varying levels of illumination.

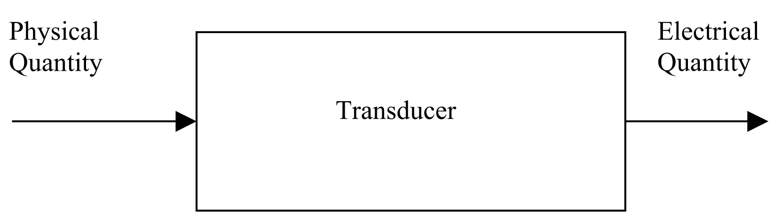
## EQUIPMENT REQUIRED:

- Module Holder
- Light Transducer and Control Module G13/EV
- Light Transducer Interface Unit TY13/EV
- PS1-PSU- Power supply unit
- Measurement unit IU9/EV.
- Connecting wires
- DIN Cable

## THEORY:

### LIGHT TRANSDUCER:

Transducers are devices that convert energy from one form to another. Here we use this term to define those devices that transform physical quantity into an electrical one. A typical block diagram of a transducer may be represented as




Light transducers are devices that transform the light radiation into an electrical quantity (resistance, current), where light radiation may be defined as that region of the electromagnetic spectrum that includes the infrared, visible and ultraviolet components. A part of the light radiations can be detected by the human eye and is defined as visible radiation or "light".

Interacting with a substance, the light radiation produces different effects. Among which, there is the **"Photoelectric Effect"** which consists of the liberation of electrons by electromagnetic radiation incident on a metal surface and in case of semiconductors, in the generation of electron hole pairs.

The first phenomenon is called photoemission and is applied to phototubes, photomultipliers etc. The second phenomenon, i.e. photoelectric effect on semi-conductors can be further divided into two:

(1) Photoconductive Effect:

The conductivity of a semiconductor bar depends on the intensity of the light radiation that strikes it.

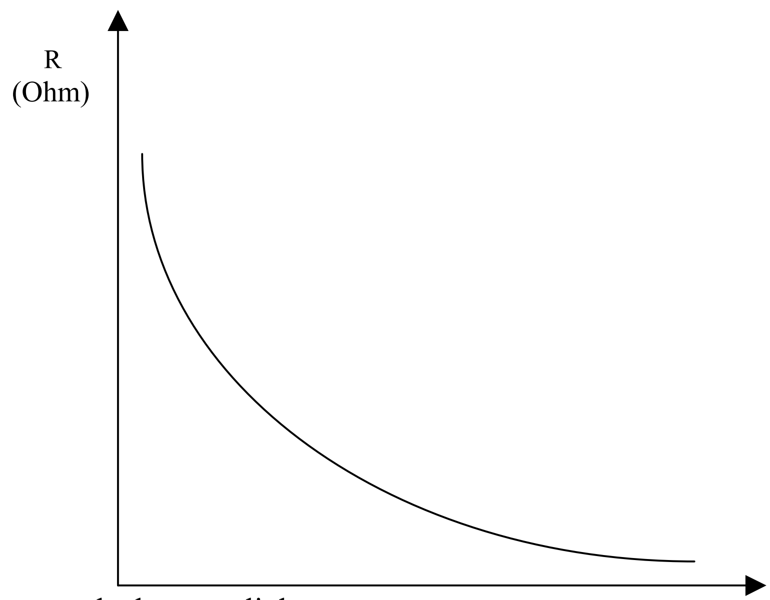
**(2) Photoelectric effect on the junction (Photovoltaic Effect):**

The current across a reversely biased P-N junction depends on the intensity of the light radiation. If the junction is not biased, an electromotive force is generated across it (Photovoltaic effect).

Devices belonging to the first category are called photoresistors, while those belonging to the second are called photodiodes, photoelectric cells and phototransistors.

**PHOTORESISTORS:**

A photoresistor is a passive semiconductor component without a junction. The resistance – illumination characteristic curve of a photoresistor may be given as




When crossed by a light radiation, it varies its resistance as a result of the photoconductive effect. The resistance drops when the light increases.

In dark conditions, the photoresistor practically acts as an insulting piece, as it has resistance values measured in MΩ (dark resistance); if strongly illuminated it has very low resistance values measured up to some tens of Ω.

The material used for a photoresistor determines the wavelength at which the device presents the maximum sensitivity. The following materials are used as photosensible materials: crystals of cadmium sulphide or lead for sensors within the visible range and crystal of cadmium selenide for sensors in the infrared range.

The photoresistor used in unit TY13/EV has the following main characteristics:

- **Resistance (10.76 Lux): 100 KΩ**
- **Resistance (1076 Lux): 2400 Ω**
- **Minimum dark resistance: 4 MΩ**
- **Maximum voltage peak: 250 V**
- **Maximum dissipable power: 100 mW.**
- **Maximum sensitivity: 0.55 µm**

SIGNAL CONDITIONER:

**Usually the output, electrical quantity of a transducer cannot be directly manipulated, for e.g., the output voltage range may not be the wished one, the supplied signal power may be too low, the electrical quantity may not be the one requested and so on. For these reasons, the transducer is never supplied alone but with a signal conditioner. The signal conditioner is an instrument converting an electrical quantity into another electrical one that is more suitable to the specific application.**

## PROCEDURE:

1. Connect jumper 2 to 11 as shown in the figure and connect module G13 to unit TY13/EV.
2. Set the switch of the **"**Photoresistor Conditioner" block to position A so as to isolate the photoresistor from the circuit and measure its resistance (With switch **I**1 in the position A, the transducer is disconnected from the rest of the circuit so that it can be analyzed without the influence of the other components.)
3. Set the multimeter to measure the resistance and connect it between terminals 16 and 17.
4. Connect module G13 to all the necessary supplies.
5. Set the lamp to the maximum distance with the slide.
6. Set the potentiometer of the SET-POINT block to the maximum value (300 Lux).
7. Move the lamp near the light transducers with the slide in correspondence to the divisions shown on the panel of unit TY13/EV, read the resistance value indicated by the multimeter and report them in table (column OHM).
8. Plot a graph with illumination on the x-axis and resistance on the y- axis and draw the points detected. The characteristic curve of the transducer is obtained by joining these points.
9. Remove the multimeter form terminals 16 and 17 and set the switch of the "Photoresistor Conditioner" block to B. Now insert the multimeter, selected as voltmeter for DC voltage, between terminal 18 and ground.
10. Repeat all the last measurements: in this case measure the response of the transducer together with the signal conditioner.
11. Plot a graph with illumination on the x-axis and voltage on the y-axis and draw the points detected.

12. The characteristic curve of the transducer together with its signal conditioner is obtained by joining these points.
13. Confront the quality of the two graphs.

*OBSERVATION:*

| S. No | **LUX** | **OHM** | **VOLT** |
|---|---|---|---|
| 1. | 57 | | |
| 2. | 68 | | |
| 3. | 83 | | |
| 4. | 104 | | |
| 5. | 133 | | |
| 6. | 177 | | |
| 7. | 248 | | |
| 8. | 370 | | |
| 9. | 612 | | |
| 10. | 1200 | | |

**RESULT:**

The characteristic curve of photoresistor is drawn and studied.

# Experiment # 8

## OBJECT:

Plot the characteristic curve of photodiode at variation of illumination.

## EQUIPMENT REQUIRED:

1. Module Holder
2. Light Transducer and Control Module G13/EV
3. Light Transducer Interface Unit TY13/EV
4. PS1-PSU- Power supply unit
5. Measurement unit IU9/EV.
6. Connecting wires
7. DIN Cable

## THEORY:

The photodiode is a device, which is similar in structure to a common semiconductor diode, with a P-N junction, and, for this kind of use, it is reverse biased.

In dark conditions the photodiode operates as a common semiconductor diode, while when the junction is crossed by a light radiation, the reverse current increases. Fig shows a typical relation between illumination and reverse current together with the symbol of the device.

The reverse current of photodiodes can take values ranging inside some nA and some tens of mA. The mostly used semiconductor materials are silicon, germanium, gallium arsenide and other semiconductor compounds.

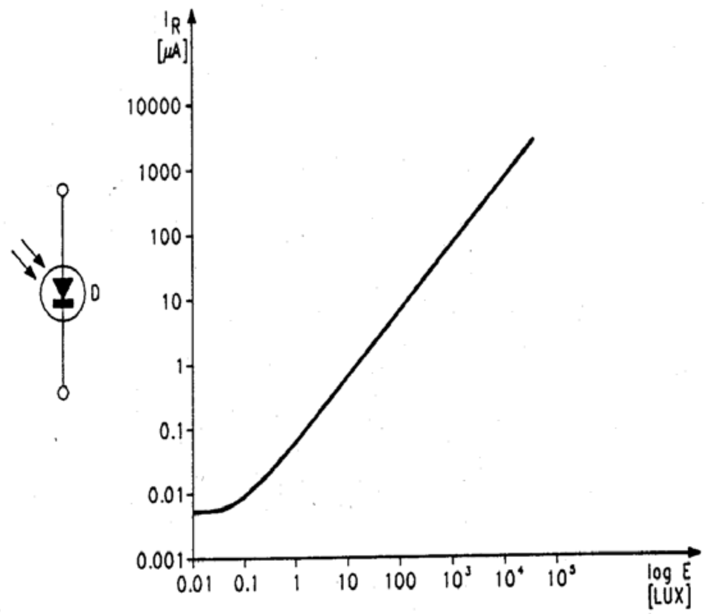
If a photodiode, which is not biased and without load is illuminated, it is crossed by a voltage generated inside the junction by the interaction between the light radiation and the semi conductive material (photovoltaic effect). If, then a load is applied to the photodiode, there is a passage of current and in this way generation of electrical energy takes place. The said is the operating principle of "**Photovoltaic cells".**

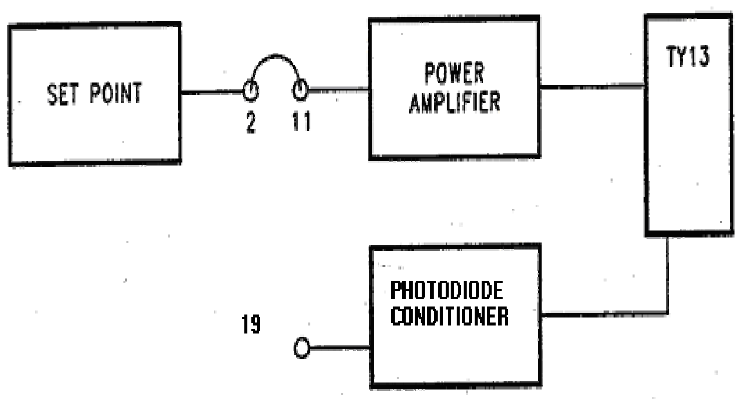
The typical parameters of photodiodes, beside the characteristic curve are:

- The maximum reverse voltage that can be applied across it.
- The maximum power that can be dissipated.
- Maximum switching speed (rise and fall times).

The photodiode used in unit TY13/EV is P-I-N silicon type and has the following characteristics (see data sheet for details):

- Maximum reverse voltage: 32 volts DC
- Maximum sensitivity: 0.9 µm
- Maximum dark current: 30 nA.
- Reverse current with illumination equal to 1mW/cm$^2$: 50 µA.
- No-load voltage (1000 lux): 350 mV
- Rise and fall times: 50 ns




PROCEDURE

1. Carry out the circuit of figure and connect module G-13 to unit TY13/EV as in figure
2. Set the switch of the "Photodiode Conditioner block to position A (with switch in position A, the transducer is disconnected from the operational amplifier and connected to resistor R7 so that it can be analyzed without the influence of the other components).
3. Set the multimeter for voltage measurement and connect it between terminal 19 and ground. In this case although a current is generated by the transducer, it is preferable to measure the fall this current determines on the resistor R7 as the same current is a very small.

4. Connect module G13 to all the necessary supplies.
5. Set the lamp to the maximum distance with the slide.
6. Set the potentiometer of the SET-POINT block to the maximum value (300 Lux).
7. Move the lamp near the light transducers with the slide and in correspondence to the divisions shown on the panel of unit TY13/EV, read the voltage values indicated by the multimeter and report them in table
8. Plot a graph with illumination on the x-axis and voltage of the diode cathode on the y-axis and draw the points detected.
9. The characteristic curve of the transducer is obtained by joining these points.
10. Remove the voltmeter from terminal 19, take the switch to B and insert the voltmeter between terminals 22 and ground.
11. Repeat all the last measurements: in this case measure the response of the transducer together with the signal conditioner.
12. Plot a graph with illumination on the x-axis and voltage on the y-axis and draw the points detected.
13. The characteristic curve of the transducer together with one of its signal conditioner is obtained by joining these points.
14. Confront the quality of the two graphs.

**OBSERVATION**

| LUX | $V_{out}$ (19) | $V_{out}$ (22) |
|---|---|---|
| 57 | | |
| 68 | | |
| 83 | | |
| 104 | | |
| 133 | | |
| 177 | | |
| 248 | | |
| 370 | | |
| 612 | | |
| 1200 | | |
| 3330 | | |

RESULT:

The characteristic curve of photodiode is drawn and studied.

# Experiment # 9

## OBJECT:

Plot the characteristic curve of Phototransistor at variation of illumination.

## EQUIPMENT REQUIRED:

1. Module Holder
2. Light Transducer and Control Module G13/EV
3. Light Transducer Interface Unit TY13/EV
4. PS1-PSU- Power supply unit
5. Measurement unit IU9/EV.
6. Connecting wires
7. DIN Cable

## THEORY:

### Phototransistor

The phototransistor is a device with a structure similar to the one of a standard transistor, but with a photo sensible base. It is generally NPN kind, it is powered with a positive voltage between collector and emitter while the base can be left open or connected to the emitter with a resistor.

In the second case, the sensitivity of the phototransistor can be adjusted by varying the value of the resistor used. In dark conditions, the current of the collector Ic is minimum and increases with illumination. Figure shows the symbol with the typical diagram of the connection of the phototransistor; furthermore it shows the characteristic curve with the relation between the variations of Ic and the variations of the illumination. The main parameters of a phototransistor, in addition to the characteristic curve, are:

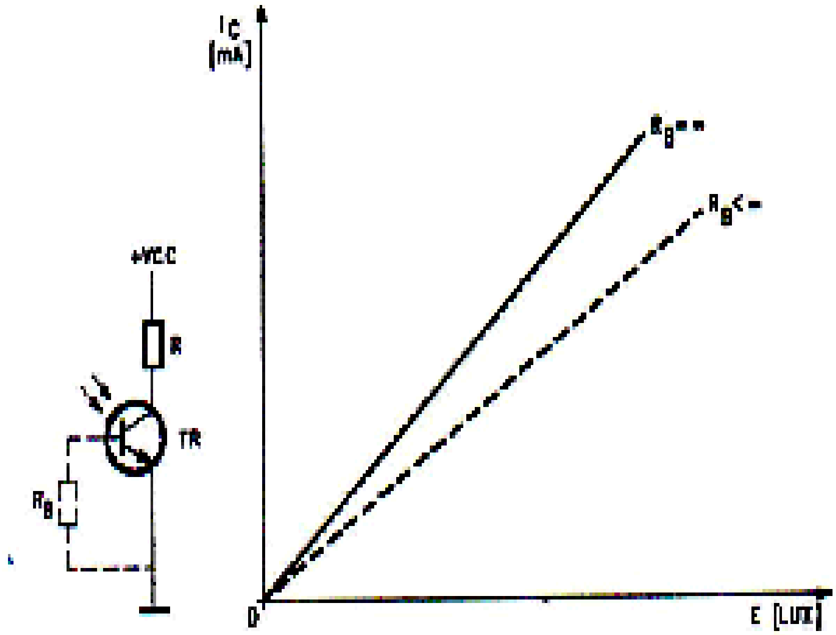
- The maximum dark current.
- The wavelength of maximum sensitivity.
- The switching speed (rise and fall times).
- The maximum admitted values of current, voltage and power**.**

The phototransistor used in the equipment has the following main characteristics:

- Dark current: 20 μA
- Rise time: 8 μs
- Fall time: 6 μs
- $V_{ce}$ max: 30 V DC

PROCEDURE:

- Carry out the circuit of figure and connect module G-13 to units TY13/EV as in figure
- Set the switch of the PHOTODIODE CONDITIONER block to the position A, set the multimeter for D.C. current measurement and connect it between terminals 23 and ground.
- Connect module G13 to all the necessary supplies.
- Set the lamp to the maximum distance with the slide.
- Set the potentiometer of the SET-POINT block to the maximum value (300 Lux).
- Move the lamp near the light transducers with the slide, and in correspondence to the divisions shown on the panel of unit TY13/EV, read the current values indicated by the multimeter and report them in table
- Plot a graph with illumination on the x-axis and current on the y-axis and draw the points detected.
- The characteristic curve of the transducer is obtained by joining these points.
- Set the switch to B and insert the multimeter, selected as voltmeter for D.C. voltage, between terminal 28 and ground.
- Repeat all the last measurements: in this case measure the response of the transducer together with the one of the signal conditioner.
- Plot a graph with illumination on the x-axis and voltage on the y-axis and draw the points detected.
- The characteristic curve of the transducer together with its signal conditioner is obtained by joining these points.
- Confront the quality of the two graphs.




**OBSERVATION:**

| Lux | Ampere | Volt |
|---|---|---|
| 57 | | |
| 68 | | |
| 83 | | |
| 104 | | |
| 133 | | |
| 177 | | |
| 248 | | |
| 370 | | |
| 612 | | |
| 1200 | | |
| 3330 | | |

RESULT:

The characteristic curve of Phototransistor is drawn and studied.

# Experiment # 10

## OBJECT:

(a) Plot the characteristic curve of Silicon transducer on a graph paper.
(b) Also determine STT linearity.

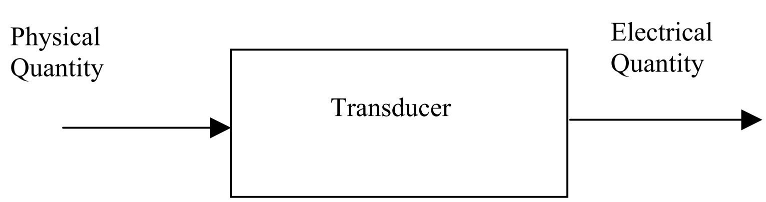
## EQUIPMENT REQUIRED:

1. Module Holder
2. Module for transducer control G34/ EV
3. PS1-PSU- Power supply unit
4. Transducer attachment TY 34/EV
5. Measurement unit IU9/EV.
6. Connecting wires
7. STT DIN cable.

## THEORY:

### General concepts regarding transducers:

Devices, which convert a physical quantity of one type into a physical quantity of a different type, are generally referred to as Transducers. Here this term refers to a specific type of device designed to transform a physical quantity into an electrical quantity, i.e. those that are designed to function as SINSORS. The general block diagram of a transducer is shown in fig. The electrical quantity output by a transducer may be a voltage, current, resistance etc.




Transducers are categorized as analog or digital according to the nature of the electrical quantity, which they output. When a continuous physical quantity is input to an analog transducer, the output is a continuous physical quantity that is proportional to the input, while in case of a digital transducer the output is a series of digital signals.

In general, this conversion absorbs a certain quantity of energy; as a result, the presence of a transducer represents a disturbance to the process being analyzed.

Each type of transducer has a series of characteristics, some of which are specific to that type of transducer, others being common to more than one type. These include:

- **Range**

This is the interval between the minimum and maximum physical quantities that the transducer can measure.

- **Proportionality constant**

The proportionality constant is the relationship between the values of the output and the input quantities.

- **Linearity error**

The linearity error is the shift from the proportionality constant between the input and output quantities and is expressed as a percentage of the maximum output value.

- **Accuracy (measurement error)**

The accuracy of a transducer indicates the maximum difference between the measured value and the true value. Accuracy is expressed as a percentage of the full-scale value.

- **Speed of response**

This is the speed with which the output quantity follows the variations in the input quantity.

- **Stability**

The stability indicates the degree to which the relationship between input and output remains constant in all operating conditions.

- **Repeatability**

This is the tolerance relative to the values for a given measurement (expressed as a fraction of the precision)

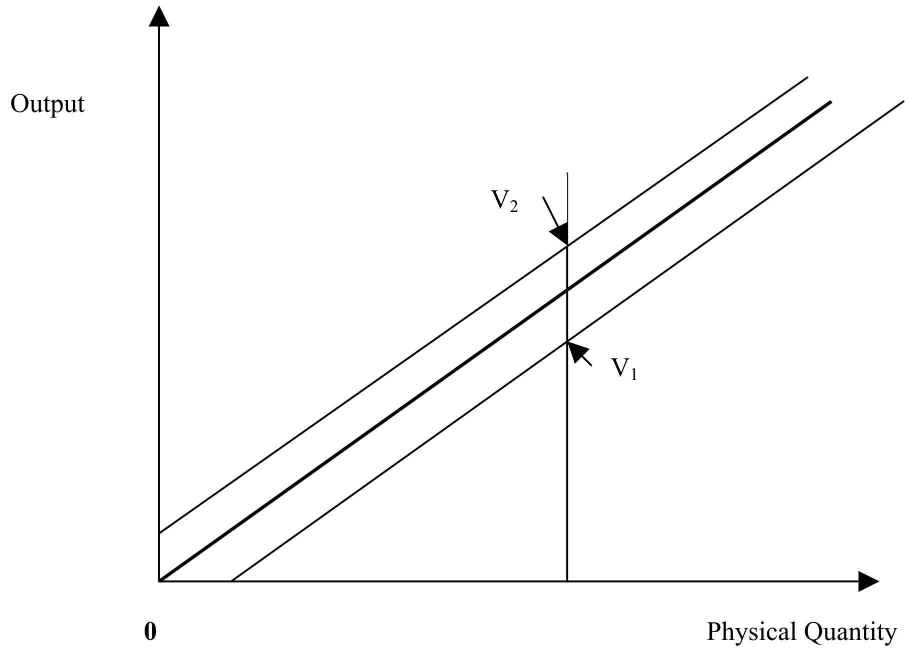
## Determining the linearity of a transducer

Most transducers are linear. One of the most important characteristics determined experimentally is the linearity. The procedure required to determine the linearity is the same for all types of transducers.

In order to plot the input/output characteristic curve of a transducer, it is necessary to measure the quantities output by the transducer in response to a series of input physical quantities. When these values have been plotted on a graph, the line that best represents the average measurement can be drawn. This is the best-fit straight line for the transducer. Plot two lines equidistant from and parallel to the best-fit straight line; these lines must encompass all the values plotted on the graph.

Next, plot a vertical line parallel to the y-axis. The points of intersection with the parallel external lines are called $V_1$ and $V_2$ (see fig). The percentage linearity of the transducer with respect to the full-scale value is given by the following equation:

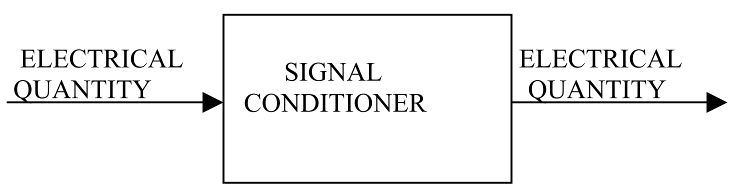
$$\textbf{Lin.[\%]} = \pm \frac{1}{2} \frac{V_2 - V_1}{V_{f.s.}} \cdot 100$$




## Signal conditioners

It is not normally possible to manipulate the electrical output of a transducer directly. For example, the range of output voltages may not be suitable, or the output signal may be too weak, or perhaps the electrical quantity is not the one required for the system, etc. For this reason, transducers are never installed without a device known as signal conditioner. A signal conditioner is a device (generally electronic), which converts one physical quantity into another that is more suitable for the specific application

In most cases, the output is a voltage. The block diagram relative to the signal conditioner is shown in fig.




## Temperature Transducers:

When energy is supplied to a physical system in any form, the state of the system inevitably changes. Temperature is one of the indicators, which represent the state of the system. The unit of temperature used in the international system is the Kelvin (K). In the Kelvin temperature scale, absolute zero corresponds to 0 K (-273 degrees centigrade).

Two other temperature scales are normally used: the Celsius or centigrade scale (°C) and the Fahrenheit scale (°F) the relationship between these scales is shown in fig. Note the difference in the intervals on the Fahrenheit scale.

Conversion from Centigrade to Fahrenheit is base on the following equation:

$$^{0}F = 9/5\ ^{\circ}C + 32$$

| ⁰K | ⁰C | ⁰F |
|---|---|---|
| 0 | -273.1 | -460 |
| \| | \| | \| |
| 273.1 | 0 | +32 |
| \| | \| | \| |
| 273.1 | 100 | +212 |
| \| | \| | \| |
| 1273 | 1000 | 1832 |

We will use the centigrade scale, which is perhaps the most practical of the three, as 0 ˚C corresponds to the temperature of melting ice and 100 ˚C to the boiling-point of water at sea-level. In industrial and domestic applications, temperature is measured with different types of transducers of varying complexity and accuracy.

The most commonly used are semiconductor transducers, thermo-resistances and thermocouples as these offer a high degree of accuracy together with simple construction and ease of use. These types of transducers can also be very small, and are therefore easy to insert directly into the process.

## Semiconductor Temperature Transducers (STT):

Semiconductor temperature transducers are based on the high degree of sensitivity of semiconductor materials to temperature. The temperature coefficient of a semiconductor temperature transducer (STT) is much higher than that of a thermo-resistance, and it is much cheaper to produce. Its main disadvantage lies in a limited temperature range and lower linearity.

Devices of this type may have one or two terminals and are classified as follows:

- Semiconductor resistive block
- Junction between two semiconductors doped P and N (diodes)
- Integrate circuit

The first type of devices are the most simple in structural terms, and may have a positive of negative temperature coefficient of approximately 0.7% / °C and linearity of ±0.5 % with in a temperature range of -65 °C to + 200 °C.

The law by which resistance varies with temperature is, in approximate terms, as follows:

$$\mathbf{R_T = R_o (1 + \alpha T)}$$

The transducer and signal conditioner are generally connected by two wires. As the temperature to which these wires are subjected varies, the overall resistance on the transducer and wires also varies. However the measurement error caused by the wires is, in most cases, negligible.

The wires which carry the transducer output are always made using the same material and are always of the same length, and their resistance R' is therefore identical. As a result, using a differential amplifier, it is possible to obtain a voltage, which varies only with the resistance R.

## PROCEDURE:

1. Connect the transducers to module G34 inserting the DIN cables into the related plugs.
2. Insert the required transducer and the mercury thermometer into the related holes of unit TY34.
3. Connect HEATER and COOLER terminals of G34 to HEATER and COOLER terminals of TY34.
4. Connect the output of the SET-POINT block terminal 2 to the set-point input of the ERROR AMPLIFIER block terminal 3 and Temperature meter input 10.
5. Connect the output of the ERROR AMPLIFIER 5 to the input of the PID controller 6.
6. Connect the output of the PID CONTROLLER 9 to the input of the HEATER AMPLIFIER 11.
7. Connect the output of the STT Conditioner 22 to the ERROR AMPLIFIER feedback input 4.
8. Set up the connection of the power supply with the console.
9. Set potentiometers p2 and p3 on the PID CONTROLLER to the halfway position
10. Connect the multimeter to the output of the signal conditioner, and set to 20V DC.
11. Short Jack 7 & 8.
12. Set Temperature meter switch at STT.
13. Starting from ambient temperature (temperature of the surrounding), adjust the Set-Point knob in order to increase the temperature of the oven in $10^0$C steps (i.e. bring the voltage on jack 2 to a value which corresponds to ambient temperature, then increase this voltage by a quantity which corresponds to a $10^0$C temperature increase). Measure the output voltage of the signal conditioner as soon as the temperatures stabilized. The reference temperature is given by a precision mercury thermometer (Centigrade Scale)
14. **N.B. Be careful to avoid exceeding the maximum temperature that the transducer can withstand ($175^0$C). For safety, do not exceed $150^0$C.**
15. Make a table listing the values measured and use these measurements to plot a graph with the temperature on the x-axis and the output voltage of the transducer on the y-axis.

OBSERVATION:

| S. No. | T ($^0$C) | Output Voltage of STT Sensor (V) |
|---|---|---|
| 1 | 30$^0$C | |
| 2 | 40$^0$C | |
| 3 | 50$^0$C | |
| 4 | 60$^0$C | |
| 5 | 70$^0$C | |
| 6 | 80$^0$C | |
| 7 | 90$^0$C | |
| 8 | 100$^0$C | |
| 9 | 110$^0$C | |
| 10 | 120$^0$C | |
| 11 | 130$^0$C | |

RESULT:

1. The characteristic curve of Silicon transducer is observed.
2. The linearity of STT sensor is found to be _________ %.

# Experiment # 11

## OBJECT:

Plot the characteristic curve of J type thermo couple and to determine thermo conditioner Couple linearity.

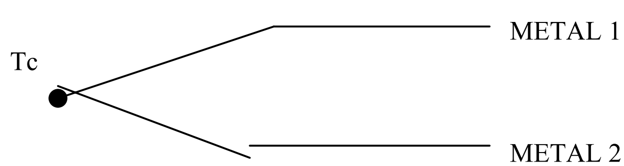
## EQUIPMENT REQUIRED:

1. Module Holder
2. Module for transducer control G34/ EV
3. PS1-PSU- Power supply unit
4. Transducer attachment TY 34/EV
5. Measurement unit IU9/EV.
6. Connecting wires
7. Thermo Couple DIN cable.

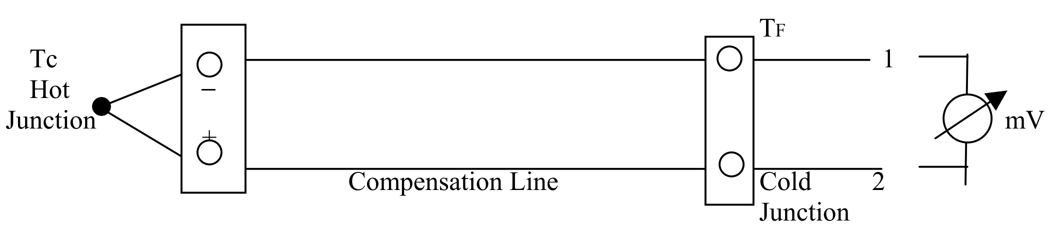
## THEORY:

### Thermocouple:

Thermocouples consist of two different metallic conductors, which are joined at one end by a galvanic contact (i.e. soldered) as shown in fig below.




The thermocouple (or hot junction) is introduced into the surrounding where the temperature is to be measured (e.g. inside an oven) and the conductors are brought to the point of measurement (cold junction), which is at a different temperature (see fig.). This circuit generates a thermoelectric E.M.F. (Electromotive force), which varies according to the difference between $T_C$ and $T_F$ (Seebeck effect)



By measuring this electromotive force, and as the temperature TF is a known quantity, it is possible to calculate the value to Tc. Since it is necessary to know the value of TF in order to calculate Tc, it is necessary to extend the wires of the thermocouple with compensating wires to a point at which the temperature is constant and known.

The most important of the thermocouples available in the market are as follows:

- **Fe-Constantan (type J)**
- **Ni-NiCr (type K)**
- **Cu-Constantan (type T)**

The E.M.F. of the Fe-Constantan thermocouple (J type) is much greater than that of the other types; its linearity is good, and it is inexpensive. One disadvantage is that the maximum temperature is limited by the iron element (700-800 °C).

The thermocouple examined in this case is of the Fe-Constantan type (type J), and has the following main characteristics:

- Transduction constant: 53 $\mu$V/°C
- Error: $\pm$2.2°C in the 0 - 270°C range
  $\pm$0.75% in the 270 - 760°C range
- Protected against atmospheric agents by metallic sheath

## PROCEDURE:

- Set up the apparatus as described in the previous experiment replacing the signal conditioner for the (STT) with the signal conditioner for the thermocouple.
- Starting from ambient temperature, adjust the Set-Point knob in order to increase the temperature of the oven in 10°C step (i.e. bring the voltage on jack 2 to a value which corresponds to ambient temperature, then increase this voltage by a quantity which corresponds to a 10°C temperature increase). Measure the output voltage of the signal conditioner as soon as the temperature is stabilized.

  If the temperature exceeds 150°C, remove the semiconductor transducer in order to avoid the possibility of damages.
- The reference temperature is given by a precision mercury thermometer (Centigrade scale)
  - Compile a Voltage/Temperature table and then plot the characteristic curve on a graph
  - Calculate the linearity of the thermocouple as described in the previous experiment.

**OBSERVATION**

| S. No. | T (°C) | Output Voltage of STT Sensor (V) |
|---|---|---|
| 1 | 30 °C | |
| 2 | 40 °C | |
| 3 | 50 °C | |
| 4 | 60 °C | |
| 5 | 70 °C | |
| 6 | 80 °C | |
| 7 | 90 °C | |
| 8 | 100 °C | |
| 9 | 110 °C | |
| 10 | 120 °C | |
| 11 | 130 °C | |

RESULT:

3. The characteristic curve of thermocouple is determined and studied.
4. The linearity of thermocouple is found to be _________ %.