# Experiment-5

## OPTOCOUPLERS AND THEIR CHARACTERISTICS

### BACKGROUND INFORMATION:

An optocoupler (or an optoelectronic coupler) is basically an interface between two circuits which operate at (usually) different voltage levels. The key advantage of an optocoupler is the electrical isolation between the input and output circuits. With an optocoupler, the only contact between the input and the output is a beam of light. Because of this it is possible to have an insulation resistance between the two circuits in the thousands of megohms. Isolation like this is useful in high voltage applications where the potentials of two circuits may differ by several thousand volts.

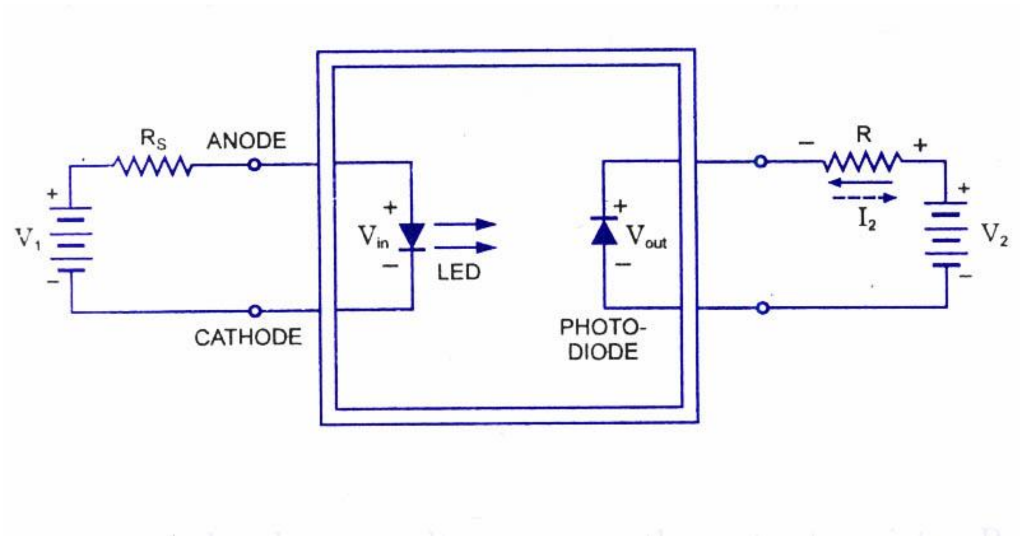
The most common industrial use of the optocouplers (or optically-coupled isolators) is as a signal converter between high-voltage devices (limit switches etc.) and low voltage solid-state logic circuits. Optical isolators can be employed in any situation where a signal must be passed between two circuits which are isolated from each other. Complete electrical isolation between two circuits (i.e. the two circuits have no conductors in common) is often necessary to prevent noise generated in one circuit from being passed to the other circuit. This is especially necessary for the coupling between high-voltage information-gathering circuits and low-voltage digital logic circuits. The information circuits are almost badly exposed to noise sources and the logic circuits cannot tolerate noise signals.

In many applications SCR and triac power circuits are under the control of sensitive electronic systems. For example, it is not unusual to have a microprocessor system programmed to turn motors, lights, and heaters on and off. To reduce the possibility of power-line noise being induced into the control electronics, and to protect it in the event of an SCR or triac failure, it is highly desirable to provide isolation.

The ideal isolation scheme should only allow signal flow in one direction, should respond to dc levels, and should offer an extremely large resistance between the input and output circuits. These features are available in a class of optoelectronic devices called *optocouplers* or *optoisolators.*

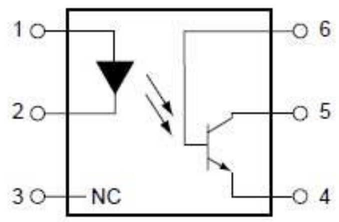
The optocouplers works well on either ac or dc high-voltage signals. For this reason, signal converters employing optical coupling are sometimes referred to the universal signal converters.

The optocoupler is a device that contains an infra-red LED and a photodetector (such as a photodiode, phototransistor, Darlington pair, SCR or triac) combined in one package.




IR-LED-phototransistor based optocouplers are most commonly used. Both the IRLED and Photo transistors are placed inside an IC as shown in Figure-1. The base terminal of the photo transistor is brought out as the 6th pin of the IC. However, it is not connected electrically.


**Functional Block Diagram**




PIN 1. ANODE
2. CATHODE
3. NO CONNECTION
4. EMITTER
5. COLLECTOR
6. BASE

The 4N25 family is an industry standard single channel phototransistor coupler. This family includes the 4N25/4N26/4N27/4N28. Each optocoupler consists of gallium arsenide infrared LED and a silicon NPN phototransistor.

**Optocoupler Characteristics**

Similar to discrete semiconductor device characteristics, optocoupler characteristics are set of curves that relate the voltage and current flowing through it. In an optocoupler we see two discrete devices, namely the diode at the input side and a photo transistor at the output side.

By drawing the individual characteristics curves one can identify the type of diode and photo detector used inside the IC. The input diode will have the input forward voltage ($I_F$) which depends on its material. For example, a silicon diode has 0.6V forward voltage and LEDs of different colors will have different forward voltages varying from 1V to 4V. Once the forward voltage and the wavelength are known, the semiconductor material can be identified. On the output side we have a photo transistor. The material of the photo transistor can be identified by its saturation voltage. Hence by the characteristics curves the material used in the optocoupler can be identified.

**Current Transfer Ratio (CTR)**

A npn or pnp device is characterized by its forward current gain $h_{FE}$ or β. Since there is no base current in the case of photo transistor, a new parameter similar to β is defined for an optocoupler. The Current Transfer Ratio (CTR) is an electrical parameter usually specified for an optocoupler. CTR is defined as the ratio of the output collector current (IC) caused by the light detected by the photodiode to the forward LED input current (IF) that generates the light, and is denoted as a percentage.

$$CTR = \frac{\text{Output collector current}}{\text{Forward LED input current}} \times 100 = \frac{I_C}{I_F} \times 100$$

The current transfer ratio (CTR) varies from 10% to 200% for devices of different makes. An optocoupler with 50% CTR is found to be extremely good in practice. As the light intensity increases, the collector current increases proportionately and becomes constant. Under this condition the transistor is conducting fully, or in other words it is saturated. This maximum collector current is denoted $Ic_{sat}$. In this case,

$$CTR = \frac{Ic_{sat}}{I_F} \times 100$$

**ELECTRICAL CHARACTERISTICS** ($T_A$ = 25°C unless otherwise noted)(1)

| Characteristic | | Symbol | Min | Typ(1) | Max | Unit |
|---|---|---|---|---|---|---|
| **INPUT LED** | | | | | | |
| Forward Voltage ($I_F$ = 10 mA) | $T_A$ = 25°C<br>$T_A$ = –55°C<br>$T_A$ = 100°C | $V_F$ | —<br>—<br>— | 1.15<br>1.3<br>1.05 | 1.5<br>—<br>— | Volts |
| Reverse Leakage Current ($V_R$ = 3 V) | | $I_R$ | — | — | 100 | µA |
| Capacitance (V = 0 V, f = 1 MHz) | | $C_J$ | — | 18 | — | pF |
| **OUTPUT TRANSISTOR** | | | | | | |
| Collector–Emitter Dark Current<br>($V_{CE}$ = 10 V, $T_A$ = 25°C | 4N25,25A,26,27<br>4N28 | $I_{CEO}$ | —<br>— | 1<br>1 | 50<br>100 | nA |
| ($V_{CE}$ = 10 V, $T_A$ = 100°C) | All Devices | $I_{CEO}$ | — | 1 | — | µA |
| Collector–Base Dark Current ($V_{CB}$ = 10 V) | | $I_{CBO}$ | — | 0.2 | — | nA |
| Collector–Emitter Breakdown Voltage ($I_C$ = 1 mA) | | $V_{(BR)CEO}$ | 30 | 45 | — | Volts |
| Collector–Base Breakdown Voltage ($I_C$ = 100 µA) | | $V_{(BR)CBO}$ | 70 | 100 | — | Volts |
| Emitter–Collector Breakdown Voltage ($I_E$ = 100 µA) | | $V_{(BR)ECO}$ | 7 | 7.8 | — | Volts |
| DC Current Gain ($I_C$ = 2 mA, $V_{CE}$ = 5 V) | | $h_{FE}$ | — | 500 | — | — |
| Collector–Emitter Capacitance (f = 1 MHz, $V_{CE}$ = 0) | | $C_{CE}$ | — | 7 | — | pF |
| Collector–Base Capacitance (f = 1 MHz, $V_{CB}$ = 0) | | $C_{CB}$ | — | 19 | — | pF |
| Emitter–Base Capacitance (f = 1 MHz, $V_{EB}$ = 0) | | $C_{EB}$ | — | 9 | — | pF |
| **COUPLED** | | | | | | |
| Output Collector Current ($I_F$ = 10 mA, $V_{CE}$ = 10 V) | 4N25,25A,26<br>4N27,28 | $I_C$ (CTR)(2) | 2 (20)<br>1 (10) | 7 (70)<br>5 (50) | —<br>— | mA (%) |
| Collector–Emitter Saturation Voltage ($I_C$ = 2 mA, $I_F$ = 50 mA) | | $V_{CE(sat)}$ | — | 0.15 | 0.5 | Volts |
| Turn–On Time ($I_F$ = 10 mA, $V_{CC}$ = 10 V, $R_L$ = 100 Ω)(3) | | $t_{on}$ | — | 2.8 | — | µs |
| Turn–Off Time ($I_F$ = 10 mA, $V_{CC}$ = 10 V, $R_L$ = 100 Ω)(3) | | $t_{off}$ | — | 4.5 | — | µs |
| Rise Time ($I_F$ = 10 mA, $V_{CC}$ = 10 V, $R_L$ = 100 Ω)(3) | | $t_r$ | — | 1.2 | — | µs |
| Fall Time ($I_F$ = 10 mA, $V_{CC}$ = 10 V, $R_L$ = 100 Ω)(3) | | $t_f$ | — | 1.3 | — | µs |
| Isolation Voltage (f = 60 Hz, t = 1 sec)(4) | | $V_{ISO}$ | 7500 | — | — | Vac(pk) |
| Isolation Resistance (V = 500 V)(4) | | $R_{ISO}$ | $10^{11}$ | — | — | Ω |
| Isolation Capacitance (V = 0 V, f = 1 MHz)(4) | | $C_{ISO}$ | — | 0.2 | — | pF |

1. Always design to the specified minimum/maximum electrical limits (where applicable).
2. Current Transfer Ratio (CTR) = $I_C/I_F$ x 100%.
3. For test circuit setup and waveforms, refer to Figure 11.
4. For this test, Pins 1 and 2 are common, and Pins 4, 5 and 6 are common.

## Experiment-5:

**AIM:** Determination of the transfer characteristics curve of the Optocoupler

**EQUIPMENT**

Power Supply

Oscilloscope

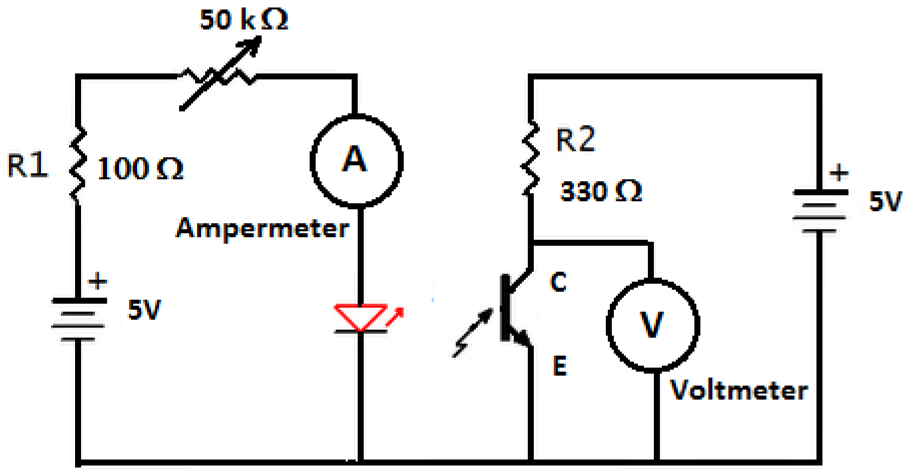
Voltmeter, Ampermeter

Optocoupler (4N25)

Resistors 100Ω, 330Ω, Variable Resistor 50kΩ,

**PROCEDURE:**

1. Build the circuit shown in the figure.

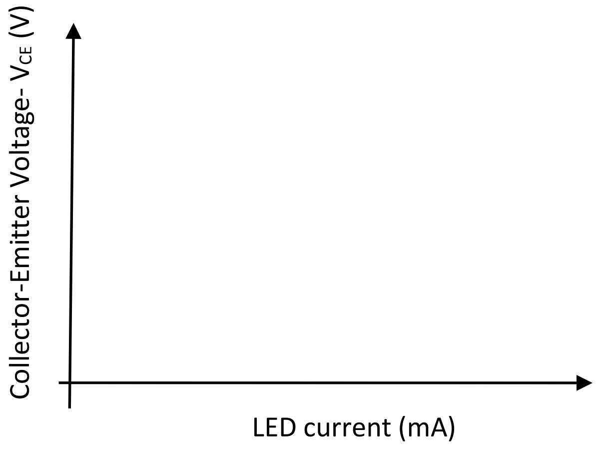



2. Set the LED current to values in the table by varying the variable resistor of 50 kΩ. Measure the voltage of $V_{CE}$ for different LED currents.

3. Complete the table by calculating the $I_{R2}$ and $V_{R2}$.

4. Calculate the current transfer ratio (CTR) in saturation case. For this process, set the LED current to minimum and increase slowly watching the voltmeter. LED current is increased until the VCE is minimum value. This indicated that the transistor is conducting fully or it is saturated. The LED current of $I_F$ that produces saturation and $V_{CE}$ are noted.

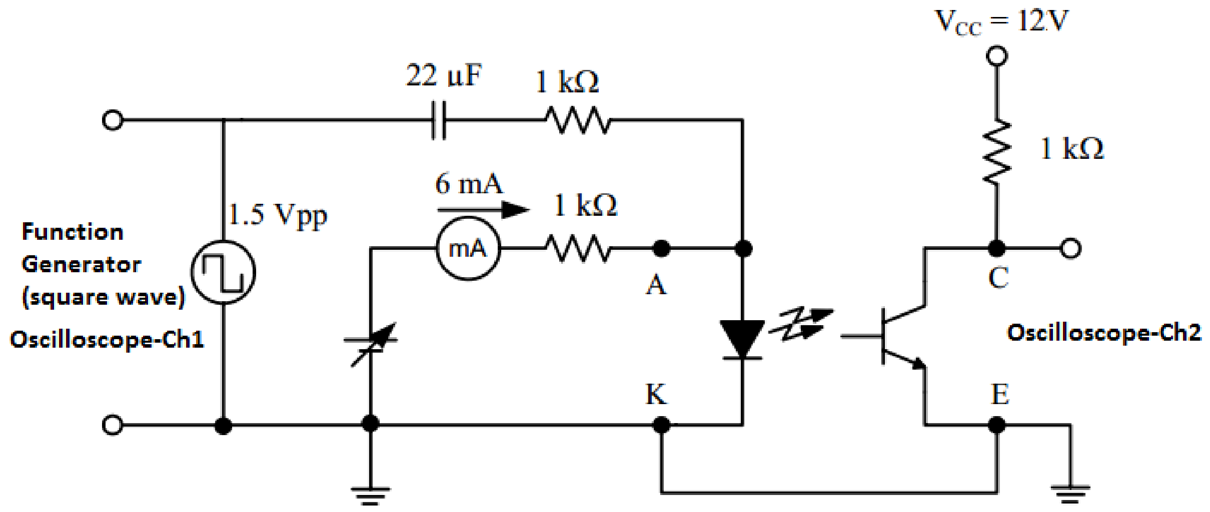
5. Draw the Transfer characteristics curve of the optocoupler by using the table.




| $I_{LED}$ (mA) | $V_{CE}$ (V) | $I_{R2}$ (mA) | $V_{R2}$ (V) |
|---|---|---|---|
| 0 | | | |
| 2 | | | |
| 4 | | | |
| 6 | | | |
| 8 | | | |
| 10 | | | |
| 12 | | | |
| 14 | | | |
| 16 | | | |

## Optocoupler: An Application

Connect the circuit as shown in the Figure. Set the DC supply of the phototransistor to be 12 V, adjust the DC supply of the LED circuit until the LED current equals to 6 mA (read from the ampermeter). Apply square wave with amplitude 1.5 Vp-p and frequency 1 kHz from a function generator to modulate the light intensity of LED. Use an oscilloscope to capture the waveform at the phototransistor collector compare to the square wave from the generator. Record the waveforms in AC and DC mode.




References:


1. http://kamaljeeth.net/uploaded_document_files/1347684563.pdf
2. http://pioneer.netserv.chula.ac.th/~tarporn/274/HandOut/OD.pdf