

## Lesson 10

**Title of the Experiment:** Sensors connected to transistor switch  
(Activity number of the GCE Advanced Level practical Guide - 23)

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### Introduction:

Solid state switches are one of the main applications for the use of transistors, and transistor switches can be used for controlling high power devices such as motors, solenoids or lamps, but they can also be used in digital electronics and logic gate circuits. While there are limitations as to what we can switch on and off, transistor switches offer speed, lower cost and substantial reliability over conventional mechanical relays.

Sensing is the process of converting a particular physical property to a signal suitable for measurement or for further action. A device that performs sensing is called a sensor.

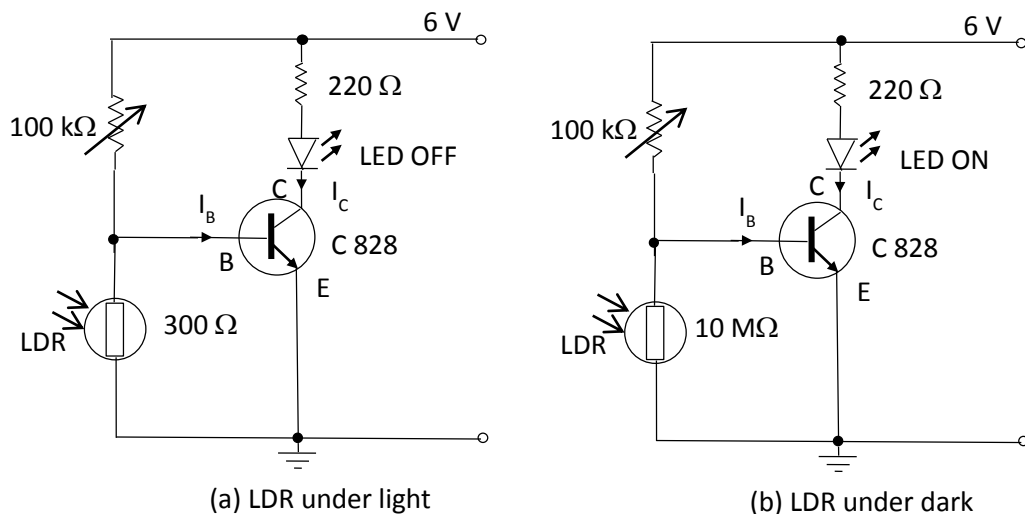
In this experiment, we will review the basic principles for transistor switches using common bipolar transistors and looking at how external variations in light, temperature or humidity (water) can be converted into a suitably changing electrical signal that can be processed by an electrical system. In this experiment we are going to concentrate on three types of input sensors (i) light dependent resistor (ii) positive and negative thermistor (iii) water sensor.

### Theory:

Let us go back to Lesson 09 figure (6) which presents the  $I_C - I_B$  curve. In this curve we identified three regions namely, cut off, active, and saturation regions.

As we have discussed in Lesson 09 when a transistor operates within only cut off and saturation regions, it functions as a switch.

This transistor switch reacts faster than a mechanical switch; It can be operated by increasing or decreasing the input voltage. The relevant input voltage ( $V_i$ ) can be provided by another circuit. Such an arrangement is presented in Figure 1.



**Figure 1:** Transistor switch at 'ON' and 'OFF' states.

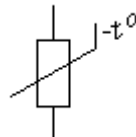
In Figure 1, we have a common emitter NPN transistor with a voltage divider circuit. In the circuit there is a **light dependent resistor (LDR)**. It is a sensor whose resistance changes with light. It is made from Cadmium Sulphide (CDS) and the resistance decreases as the brightness of light falling on the LDR increases. When the light falls on the LDR the resistance goes down (say to  $300\ \Omega$ ) (Figure 1(a)), and the total current flows through it.

$$\text{Therefore } I_B = 0 \text{ and } I_C = 0$$

As a result the bulb does not glow.

When there is no light (or when the LDR is in the dark) the resistance of the LDR increases (say upto  $10\ \text{M}\Omega$ ) (Figure 1(b)) and a high current of  $I_B$  flows into the transistor. Therefore  $I_C$  increases. Now the bulb glows. This circuit in Figure 1 is used to switch 'ON' and 'OFF' a bulb when the LDR is in the dark and under light, respectively.

The thermistor is a two leaved component that changes its resistance responding to a change in temperature. The symbol for a thermistor is shown below:



The '-t' alongside the symbol indicates that this is a negative temperature coefficient (or NTC) thermistor, which simply means that the resistance of the thermistor decreases as temperature increases. A positive temperature coefficient (PTC) thermistor does exist where the resistance increases as temperature increases. The symbol just has a '+t'.

The thermistor is used in a circuit in a similar way to the LDR as shown in figure 1 and you have to only replace LDR by the thermistor. If you understand the operation involving the LDR which is previously discussed, then you may have no problem to understand the operation with a thermistor. The circuit analysis will be exactly the same, the only difference is that instead of having a characteristic relating to light intensity values, here it is temperature.

### Learning outcomes:

At the end of this experiment you will be able to describe the operation of LDR, PTC, NTC and make a Bipolar Junction Transistor (BJT) as a simple switch, which will turn ON or turn OFF an electrical load.

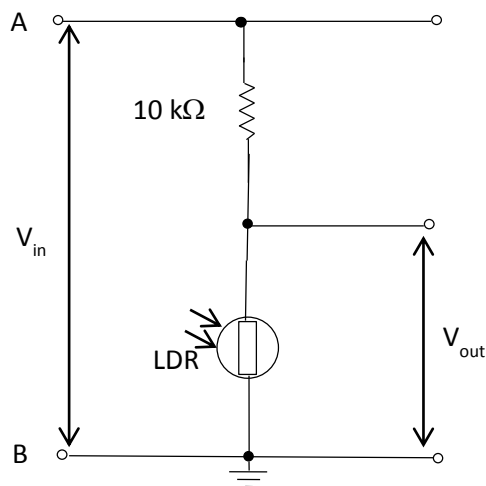
The load in the present experiment will be an LED, which is a low-power device and is thus very simple to incorporate in the circuit without requiring additional components such as a relay.

### Materials/Equipment:

C 828 transistor, Power supply (0-6 V), resistors ( $220\ \Omega$ ,  $10\ \text{k}\Omega$ ,  $1\ \text{k}\Omega$ ), variable resistor ( $100\ \text{k}\Omega$ ), LDR, PTC, NTC, LED, Multimeters, Bread board, connecting wires.

**Part I**

1. Measure the resistance across the given LDR under normal light.  
.....
2. Measure the resistance across the given LDR under bright light. (Note: Use the light source given.)  
.....
3. Construct the following circuit on the Breadboard using the given components. Connect 6 V supply across AB.



**Figure 2:** Test circuit for LDR

When LDR is dark

$V_{in}$  = .....

$V_{out}$  = .....

When LDR is bright

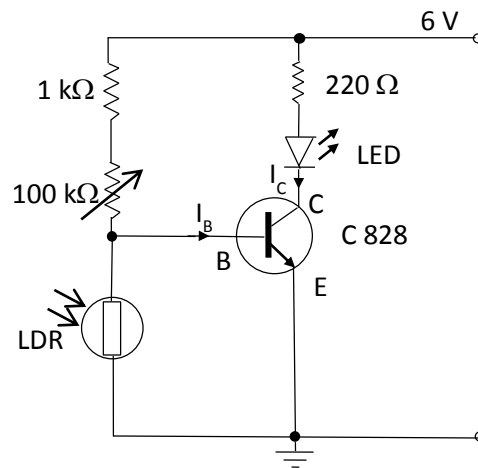
$V_{in}$  = .....

$V_{out}$  = .....

**Part (II) Light sensing switch**

Light sensors are devices that are used to detect light. There are different types of light sensors, each of which works in a slightly different way. They can be found in electronics such as computers and televisions to control the brightness of a television or computer screen.

In this part, a variable resistor is initially used to look for the switching point. The variable resistor and the LDR (Light Dependent Resistor) together form a voltage divider. The control voltage  $V_{BE}$  is set so that the base-emitter path just becomes nonconductive. Strong illumination onto the LDR increases its resistance so that the voltage rises at the base, and thus current flows through. In turn, current flows through the collector-emitter path and the LED glows.



**Figure 3:** Light sensing switch

**Procedure:**

- i. Connect the circuit shown in Figure 3.
- ii. Turn on the power supply and set the operating voltage to 6 V.
- iii. Arrange the circuit so that the LDR is uniformly illuminated, e.g. having it point toward a ceiling light.
- iv. The LDR's illumination should not be changed while setting the switching point.
- v. Set the variable resistor (100 kΩ) so that the LED just stops shining.
- vi. Cover the LDR and observe the LED. It should now shine.
- vii. Measure and tabulate base-emitter  $V_{BE}$  and collector-emitter  $V_{CE}$  voltages, and base current  $I_B$  and collector current  $I_C$  when the LDR is illuminated and when it is not.

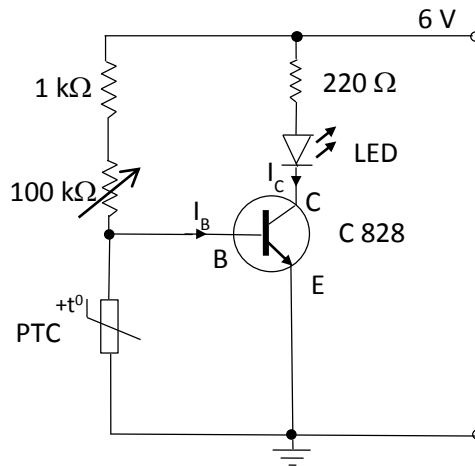
**Readings/Observations:**

LDR	$I_B$ ( $\mu A$ )	$I_C$ (mA)	$V_{BE}$	$V_{CE}$	LED
Under Dark					
Under Light					

**Part (III) Heat sensing switch**

In the third part, the experiment is conducted with a PTC (Positive Temperature Coefficient resistor).

In this lab an LED is automatically turned on when the ambient temperature level rises over a threshold. The threshold is determined by adjusting a variable resistor (potentiometer). The circuit contains a transistor that amplifies the current coming into its base. This current controls the LED.



**Figure 4:** Heat sensing switch

**Procedure:**

- i. Connect the circuit shown in the Figure 4.
- ii. Turn on the power supply and set the operating voltage to 6 V.
- iii. The PTC's temperature should not be changed while setting the switching point.
- iv. Set the variable resistor (100 k $\Omega$ ) so that the LED just stops shining at room temperature.
- v. Heat up the PTC by heating element and observe the LED. The LED should now shine. Depending on the thermal capacity, this can take some time.
- vi. Measure and tabulate base-emitter  $V_{BE}$ , collector-emitter  $V_{CE}$  voltages and base current  $I_B$ , collector current  $I_C$  for a cold PTC and a warm one.

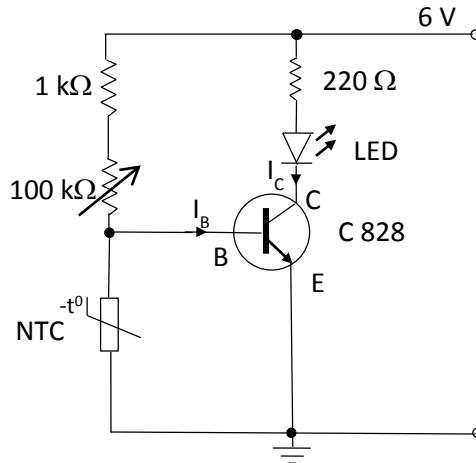
**Readings/Observations:**

PTC	$I_B$ ( $\mu A$ )	$I_C$ (mA)	$V_{BE}$	$V_{CE}$	LED
Room temperature					
High temperature					

**Part (IV) Cold sensing switch**

In the fourth part, the experiment is conducted with a NTC (Negative Temperature Coefficient resistor).

In this experiment an LED is automatically turned on when the ambient temperature falls below a threshold. The threshold is determined by adjusting a variable resistor (potentiometer). The circuit contains a transistor that amplifies the current coming into its base. This current controls the LED.



**Figure 5:** Cold sensing switch

**Procedure:**

- i. Connect the circuit shown in the Figure 5. Show the circuit to your demonstrator before turning on the power to the circuit.
- ii. Turn on the power supply and set the operating voltage to 6 V.
- iii. The NTC's temperature should not be changed while setting the switching point.
- iv. Set the variable resistor (100 kΩ) so that the LED just stops shining at room temperature.
- v. Cool down the NTC and observe the LED. The LED should now shine. Depending on the thermal capacity, this can take some time.
- vi. Measure and tabulate base-emitter  $V_{BE}$ , collector-emitter  $V_{CE}$  voltages and base current  $I_B$ , collector current  $I_C$  for a cold NTC and a warm one.

**Readings/Observations:**

NTC	$I_B$ ( $\mu A$ )	$I_C$ (mA)	$V_{BE}$	$V_{CE}$	LED
Room temperature					
Low temperature					

**Part (V) Water sensing switch**

In this experiment you use a transistor to amplify the signal from a water sensor. The water sensor works by electrical conductivity; when water contacts on the plates it forms a thin film that conducts electricity between the two plates. The Water sensor employs a simple mechanism to detect and indicate the water level in an overhead tank or any other water container.

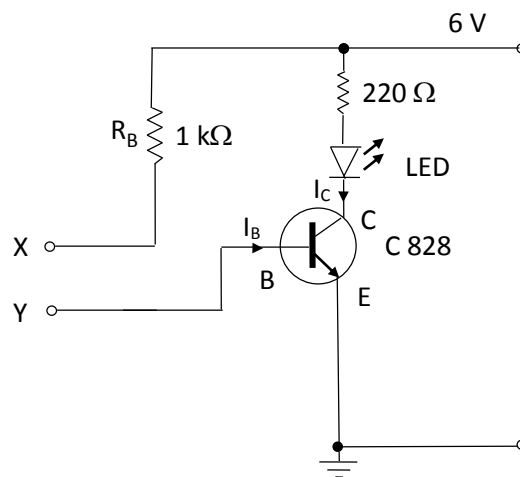


Figure 6: Water sensing switch

**Procedure:**

- i. Connect the circuit shown in the Figure 6.
- ii. Turn on the power supply and set the operating voltage to 6 V.
- iii. Now take a small cup (make sure it isn't made of metal), fill it half way with water, and place the two wires into the water but without touching each other.
- iv. Measure and tabulate base-emitter  $V_{BE}$ , collector-emitter  $V_{CE}$  voltages and base current  $I_B$ , collector current  $I_C$  when X Y wires in the water and out the water.

**Readings/Observations:**

XY wires	$I_B$ ( $\mu A$ )	$I_C$ (mA)	$V_{BE}$	$V_{CE}$	LED
Out the water					
In the water					

**Discussions:**

**Conclusions:**

**References:**

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Hambley, A. R., (2002). *Electrical Engineering: Principles and Applications* 3rd Edition, Prentice Hall

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