Lesson 13

Title of the Experiment: Voltage comparator and its application as controller
(Activity number of the GCE Advanced Level practical Guide - 26)

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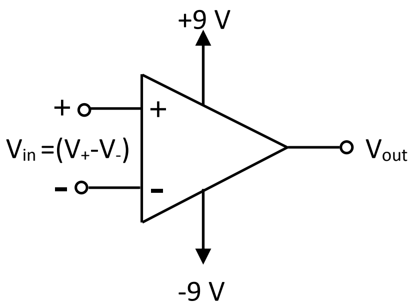
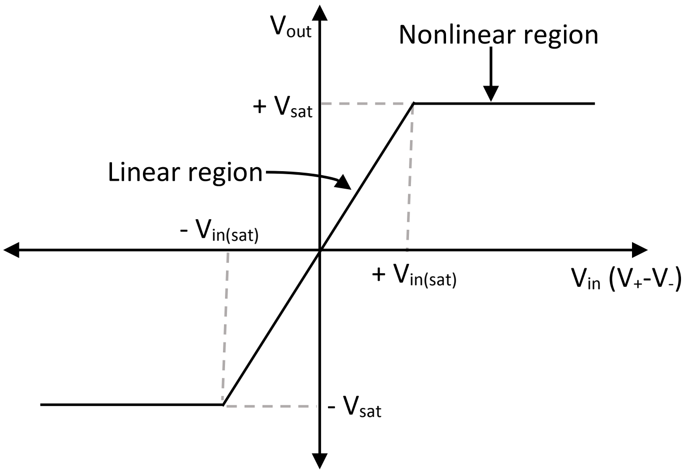
Introduction:
Recall the Op-Amp characteristics. The maximum amplitude of the op-amp output voltage is limited by the size of the power supply voltage connected to the Op-Amp bias terminals. Typically, the maximum amplitude is about 90% of the bias supply voltage. For example, using ±9 V bias voltages, the amplitude of V_{out} is limited to ±8 V; that is, $-8\text{ V} \leq V_{out} \leq +8\text{ V}$. However, V_{out} varies linearly with V_{in} ($V_{out}=A_{VOL}V_{in}$) over a very small range of V_{in} values and V_{out} saturates at either $+V_{sat}$ (+8 V) or $-V_{sat}$ (-8 V), depending on the polarity of V_{in} when the magnitude of V_{in} exceeds a certain limit. This is Op-Amp's characteristics which can be represent graphically by plotting V_{out} Vs V_{in}. Where V_{in} is ($V_+ - V_-$). Consider that typical open loop voltage gain of 741 Op-Amp is 200,000.





$V_{out} = A_{VOL}\, V_{in}$
$V_{in} = V_{out}/A_{VOL} = \pm 8\text{V}/200000 = \pm 40\ \mu\text{V}$

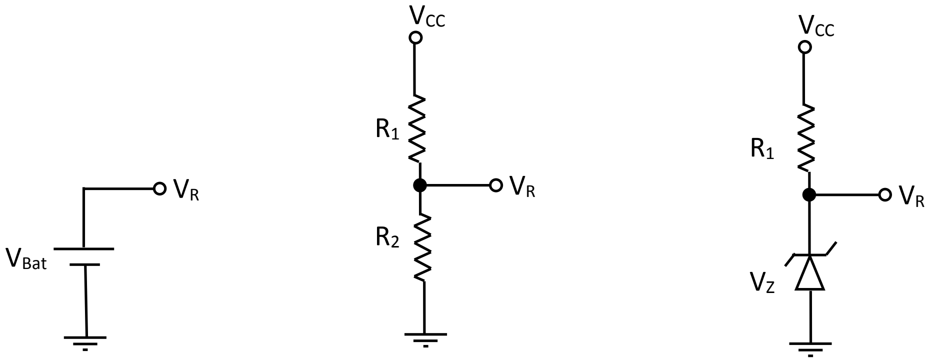
Figure 1: Typical 741 Op-Amp characteristics

The output voltage reaches its saturation level with a very low input voltage (i.e. ±40 µV). For 741 Op-Amp when bias voltage equals to ±9 V, Output voltage is either +8 V or -8 V depending on the $V_{in} \geq +40\ \mu\text{V}$ or $V_{in} \geq -40\ \mu\text{V}$ respectively.

Reference voltage sources
Reference voltages are used in many electronic circuits in order to set constant dc voltage level. In general reference voltage set by using a battery, a voltage divider and a resistor and zener diode arrangements as shown in Figure 2.

Light Dependent Resistors (LDRs)
LDRs are very useful especially in light/dark sensor circuits. Normally the resistance of an LDR is very high but the resistance drops dramatically when they are illuminated. The light-sensitive part of the LDR is a wavy track of cadmium sulphide as shown in Figure 3(a). Light energy triggers the release of extra charge carriers in this material, so that its resistance falls as the level of illumination increases. Figure 3(b) shows the symbol of LDR. A light sensor uses an LDR as part of a voltage divider as shown in Figure 3(c). In other words, this circuit gives a LOW output voltage when the LDR is in the light, and a HIGH output voltage when the LDR is in the shade. When the position of

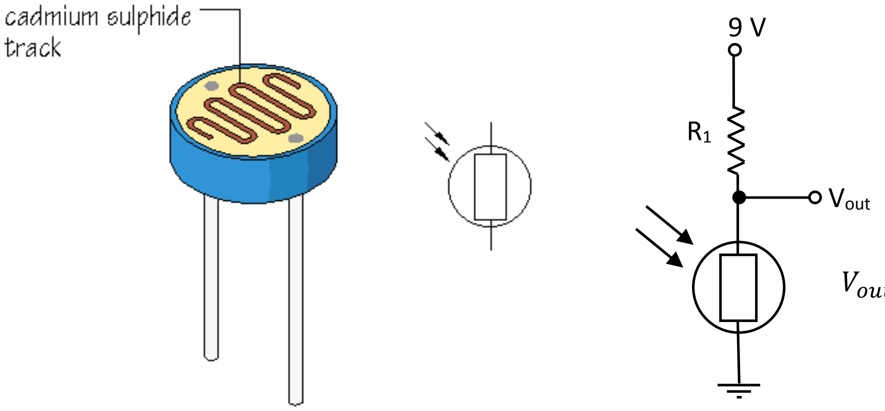
the LDR and the fixed resistor are swapped, circuit gives a HIGH output voltage when the LDR is in the light, and a LOW output voltage when the LDR is in the shade.



$V_R = B_{Bat}$ $\qquad$ $V_R = \left(\dfrac{R_2}{R_1 + R_2}\right) V_{CC}$ $\qquad$ $V_R = V_Z$

(a) (b) (c)

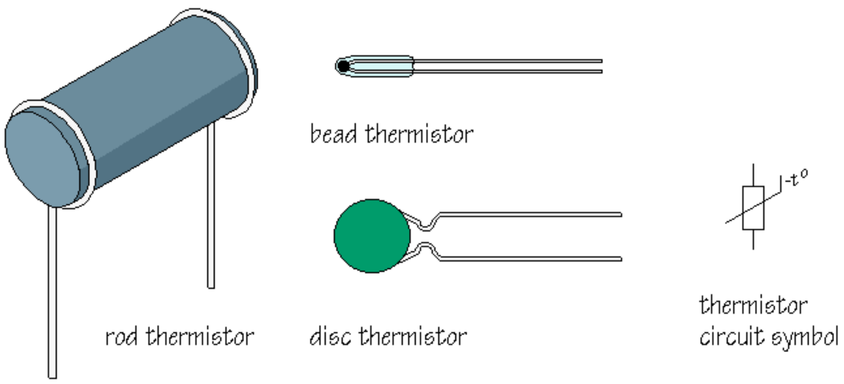
Figure 2: (a) Battery reference (b) Voltage divider reference and (c) Zener diode reference



$$V_{out} = \left(\frac{R_{LDR}}{R_{LDR} + R_1}\right) 9\,V$$

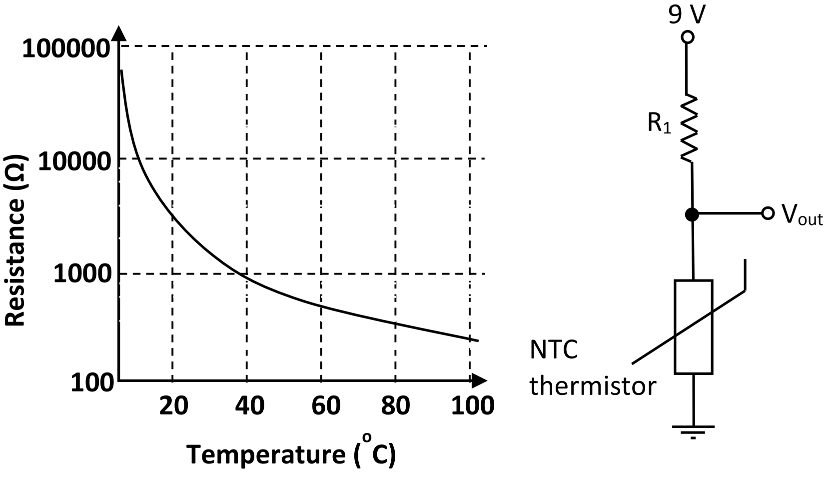
(a) (b) (c)

Figure 3: (a) LDR, (b) Symbol of LDR and (c) LDR as a part of a voltage divider



(a) (b)

Figure 4: (a) Different types of thermistors, (b) symbol of thermistor (NTC)



(c) (d)

$$V_{out} = \left(\frac{R_{LDR}}{R_{LDR} + R_1}\right) 9\,V$$

Figure 4: (c) typical characteristic curve of a thermistor and (d) thermistor as part of a voltage divider

Thermistor (NTC)

A temperature sensitive resistor is called a thermistor. There are several different types of thermistors commercially available as shown in Figure 4(a). Symbol of the NTC thermistor is shown in Figure 4(b). The resistance of most common types of thermistor decreases as the temperature rises. They are called negative temperature coefficient, or NTC, thermistors. Note the -t° next to the circuit symbol. Figure 4(c) shows characteristic curve for typical NTC thermistors. A temperature sensor uses a thermistor as part of a voltage divider as shown in Figure 4(d). This circuit gives a LOW output voltage when the NTC thermistor is in high temperature, and a HIGH output voltage when the NTC thermistor is in low temperature. When the position of the NTC thermistor and the fixed resistor are swapped, circuit produces output voltages other way round.

Theory:

In the voltage comparator, Op-Amp is operated under open-loop mode. The performance of a voltage comparator is easily understood according to the following relationship between the input and the output of an open circuit operational amplifier.

$$V_{out} = A_{VOL}(V_+ - V_-)$$

Where V_+ and V_- are potentials at noninverting and inverting inputs, respectively and A_{VOL} is the open loop voltage gain. Since typically value of A_{VOL} is very high, the output becomes saturated even for very small values of (V_+ - V_-). If $V_+ > V_-$, the output will be at its positive saturation value and if $V_+ < V_-$, the output will be at its negative saturation value, thus enabling the comparison of V_+ and V_- by measuring the output voltage.

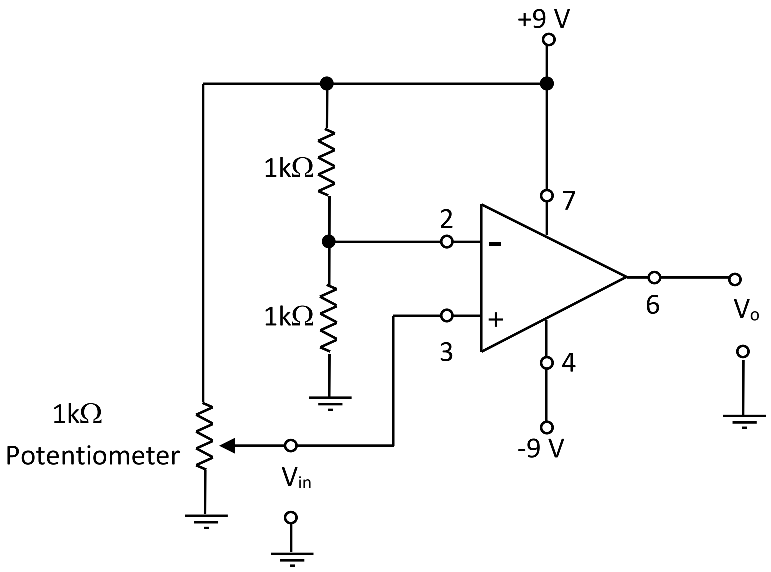


Figure 5: Circuit diagram of the voltage comparator

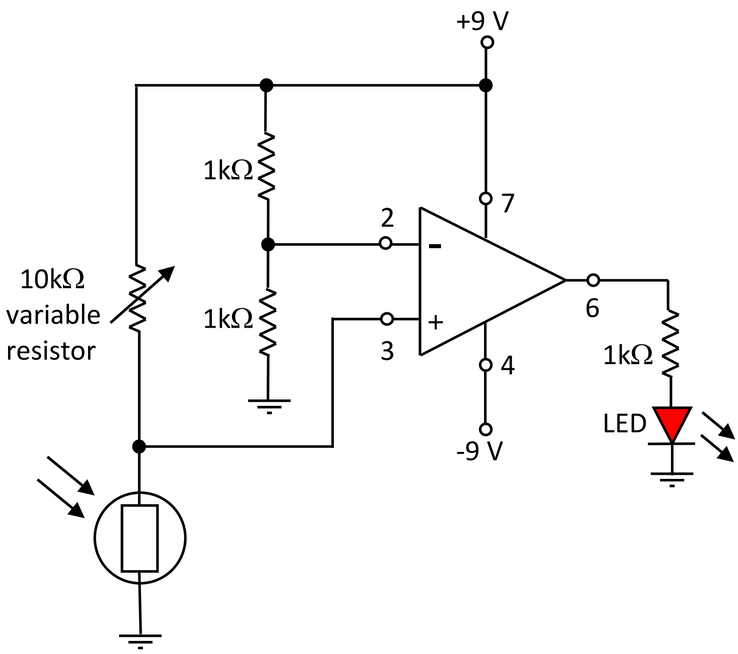


Figure 6: Circuit diagram of Light/dark sensor using a comparator

Learning outcomes:
In this experiment you will study the characteristics of a voltage comparator. At the end of this experiment you should be able to select the proper values of external components for designing a sensitive light and temperature sensors.

Materials/Equipment:
741 op-amp, ±9 V dual rail power supply, breadboard, voltmeter, three 1 kΩ resistors, one 1 kΩ and 10 kΩ potentiometers, LDR, NTC thermistor, LED connecting wires

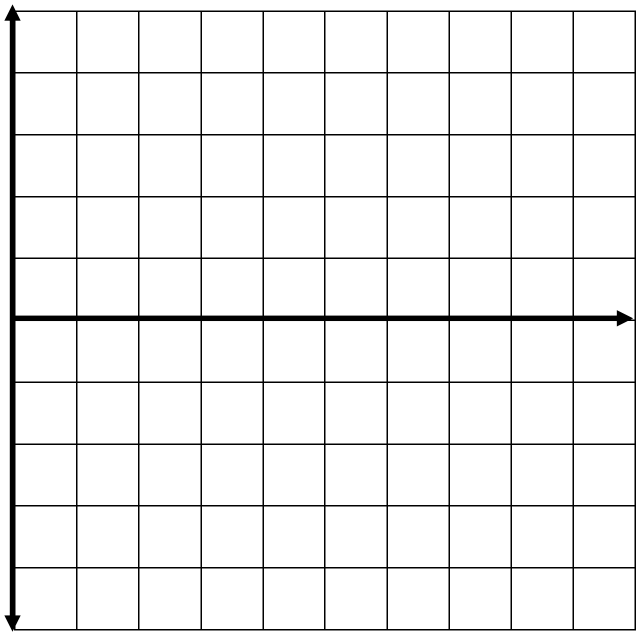
Methodology/Procedure:

1. Connect the circuit shown in Figure 5. Show the circuit to your demonstrator before turning on the power to the circuit.
2. Set the potentiometer in fully in clockwise direction. Measurer the voltage at pin 2 (input voltage), pin 3 (reference voltage) and pin 6 (output voltage) with respect to ground and record the measured voltages in the sample data sheet.
3. Very slowly turn the potentiometer in the anticlockwise direction while observing the output voltage. Stop turning when the output voltage suddenly changes polarity. At the 'switch-over' point, measure the voltage at pin 2 and pin 3 and compare two voltages. Record the measured voltages in the sample data sheet.
4. Turn the potentiometer fully anticlockwise and measure the voltages at pin 2, pin 3 and pin 6 with respect to ground and record the measured voltages in the sample data sheet.
5. Plot the V_o versus V_{in} curve for the comparator.
6. Connect the circuit shown in Figure 6.
7. By keeping the LDR in dark, adjust the variable resistor until the LED is light ON.
8. Illuminate the LDR and observe that the LED is light OFF.
9. Interchange the LDR and variable resistor in the circuit shown in Figure 6.
10. By illuminating the LDR, adjust the variable resistor until the LED is light ON.
11. Keep the LDR in dark and observe that the LED is light OFF.
12. Replace the LDR in NTC thermistor.
13. Increase the temperature of the NTC thermistor by using a lamp and adjust the variable resistor until the LED is light ON.
14. Keep the NTC thermistor in cool place and observe that the LED is light OFF.
15. Interchange the NTC thermistor and variable resistor.
16. Keeping the NTC thermistor in cool place, adjust the variable resistor until the LED is light ON.
17. Increase the temperature of the NTC thermistor and observe that the LED is light OFF.
18. Construct a circuit to light ON different LEDs at different temperatures using above circuit.

Readings/Observations:

Potentiometer	Voltage at Pin 2 (V) (Input Voltage)	Voltage at Pin 3 (V) (Reference Voltage)	Voltage at Pin 6 (V) (Output Voltage)
Fully clockwise			
Switch-over point			
Fully anticlockwise			

Diagrams/Graphs:



Discussions:

Conclusions:

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