Basic Mechatronics Workshop

Module 2: Sensors

LAB-4

Sensor Interface,

NPN and PNP Type, Lamp control

(Practice)

Dr. Mohamed Abdalbar

Lecturer, Mechatronics Department,

Egyptian-Korean Faculty of Technological Industry and Energy,

Beni Suef Technological University

Email: mh_abd2001@yahoo.com

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Sensor Interface,
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Tasks

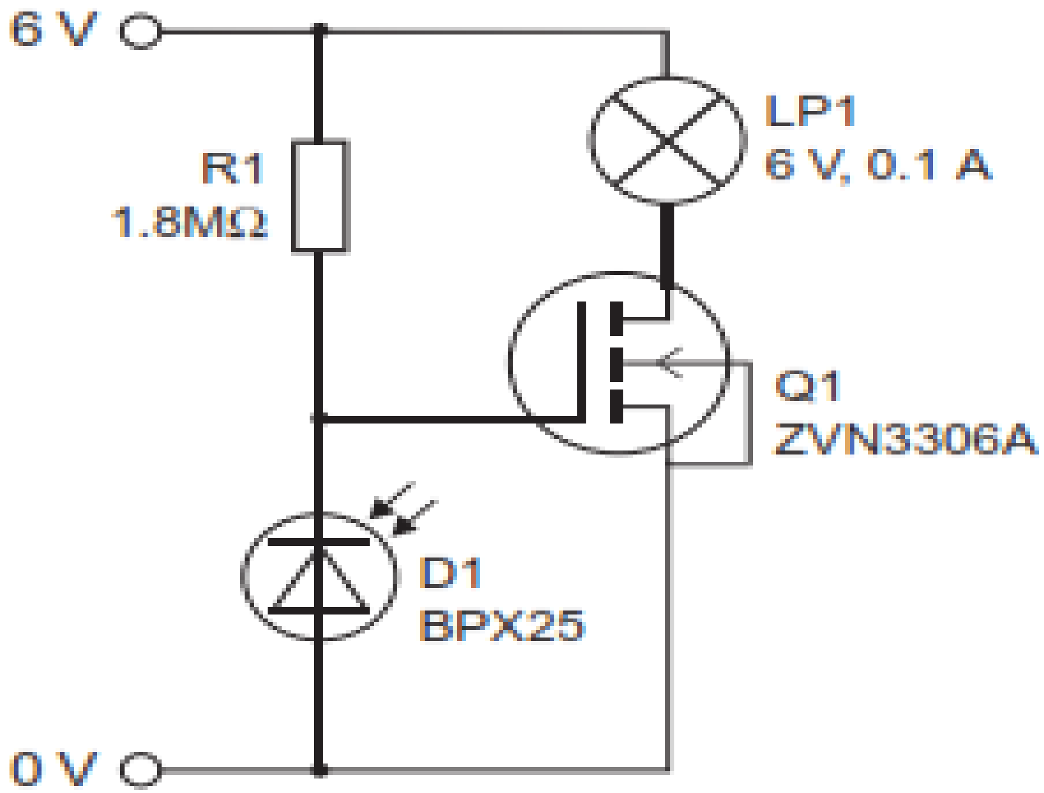
Upon completion of this lab, Student should be able to

1. Understand the MOSFET acts as a voltage-controlled switch
2. Design the switching lamp circuit by MOSFET transistor.
3. Design the light-sensitive alarm circuit by BJT transistor.
4. Use BJT transistor to control of high voltage loads such as heater switch .
5. Control of the indicator lamp circuit by BJT transistor.
6. Describe when PNP or NPN transistor is used

Switching lamp circuit

This circuit uses a MOSFET transistor for switching a lamp. We might use this to control a low-voltage porch lamp which is switched on automatically at dusk.

The sensor is a photodiode, which could be either of the visible light type or the type especially sensitive to infra-red radiation. It is connected so that it is reverse-biased. Only leakage current passes through it.



Switching lamp circuit *System Design*

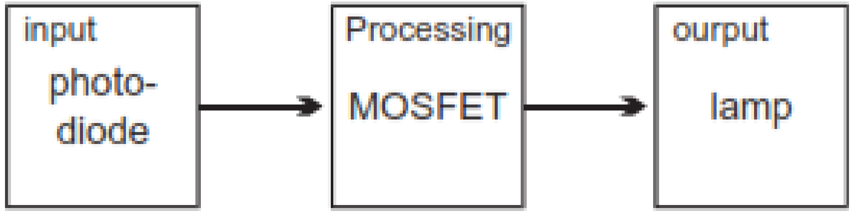
Electronic systems often consist of three stages. The first stage is the ***input*** stage. This is the stage at which some feature of the outside world (such as a temperature, the light level, or a sound) is detected by the system and converted into some kind of electrical signal.

The last stage is the ***output*** stage in which an electrical signal controls the action of a device such as a lamp, a motor, or a loudspeaker.

Connecting the input and output stages is the ***signal processing stage***. This may comprise several substages for amplifying, level-detecting, data processing, or filtering.

As a system, this circuit is one of the simplest. It has three sections:

The input section consists of the photodiode.



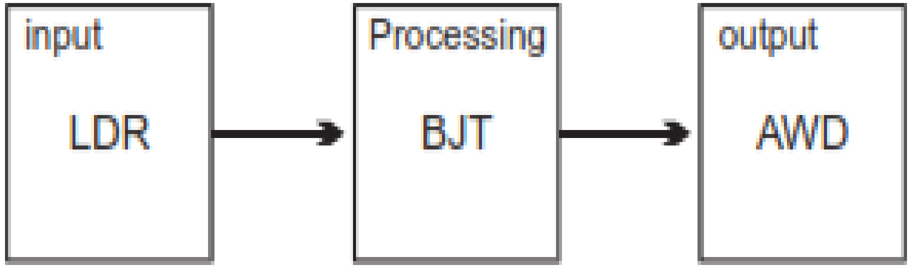
The processing section consists of R1 and Q1. R1 generates a voltage, which is fed to the gate of Q1, which is either turned ‘off’ or ‘on’.

The output section consists of the lamp, which is switched by Q1.

Three-stage systems are very common.

Light-sensitive alarm

This circuit uses a different type of light sensor, and a different type of transistor. It has a similar three-stage system diagram:



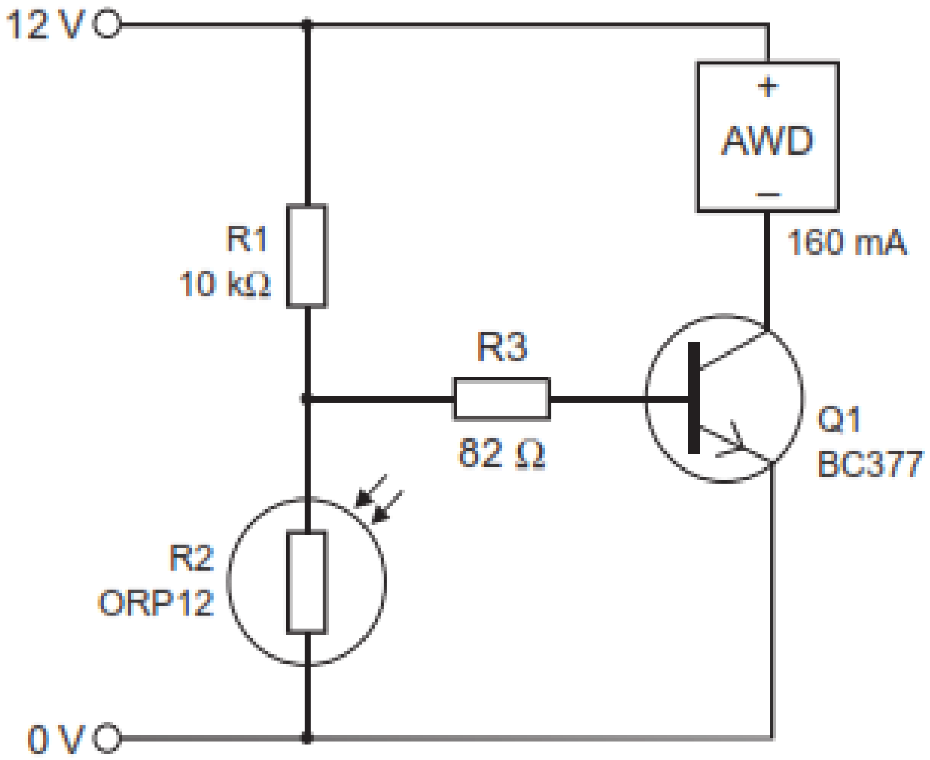
Input is accepted by a light-dependent resistor (or LDR). This is made from a semiconductor material such as cadmium sulphide. The resistance of this substance varies according the amount of light falling on it. The resistance of an LDR ranges between 100Ω in bright light to about $1M\Omega$ in darkness.

Processing uses a voltage divider (R1/R2) that sends a varying voltage to the bipolar junction transistor, Q1. The voltage at the point between the resistors is low (about 10 mV) in very bright light but rises to about 5 V in darkness. With LDRs other than the ORP12, voltages will be different, and it may be necessary to change the value of R1 or replace it with a variable resistor.

Output is the sound from an *audible warning device*, such as a siren.

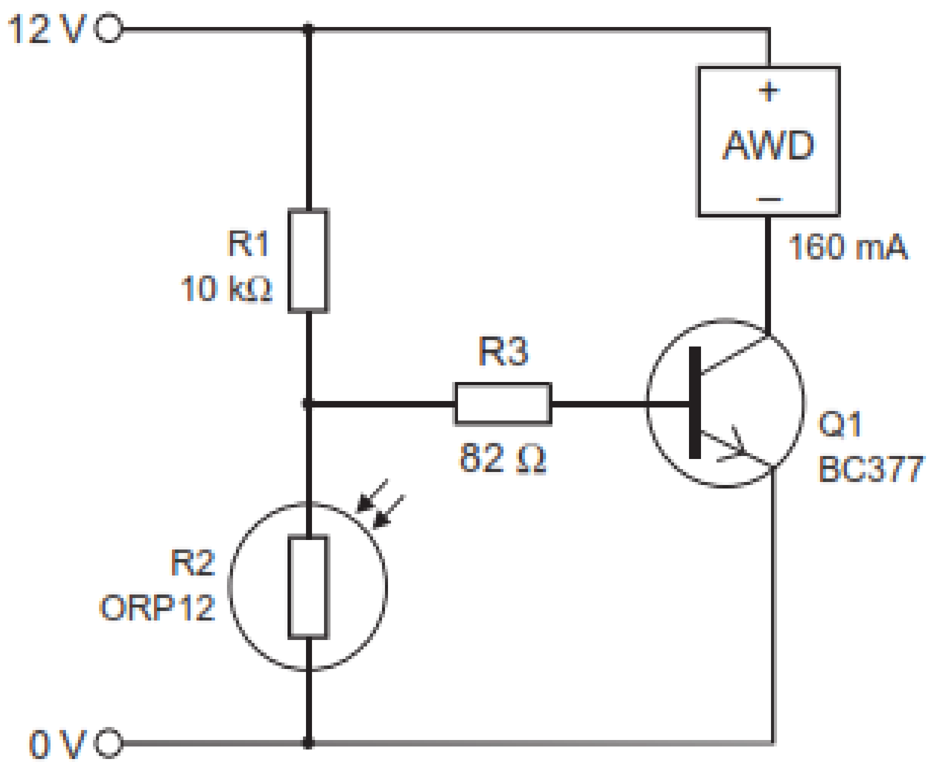
Light-sensitive alarm

The function of the circuit is to detect an intruder passing between the sensor and a local source of light, such as a street-light. When the intruder's shadow falls on the sensor, its resistance increases, raising the voltage at the junction of the resistors. Increased current flows through R3 to the base of Q1. This turns Q1 on and the siren sounds.



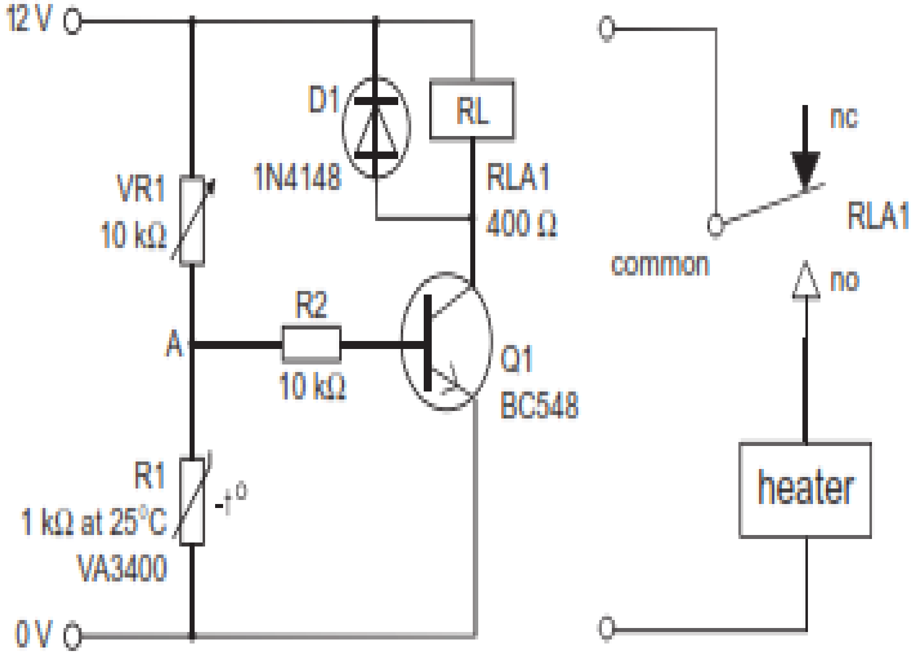
Light-sensitive alarm

This circuit uses a BJT; almost any NPN type will do, provided it is able to carry the current required by the audible warning device, which in this example is a piezo-electric siren. A typical ultra-loud (105 dB) warbling siren suitable for use in a security system takes about 160 mA when run on 12 V. The BC337 transistor is rated at 500 mA.



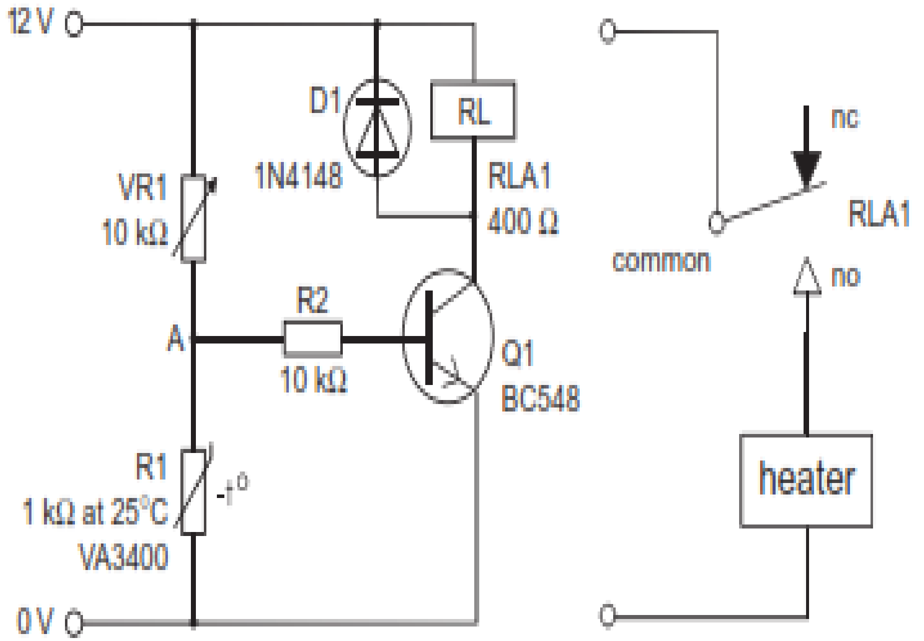
Heater Switch

The heater switch is a circuit for maintaining a steady temperature in a room, a greenhouse, or an incubator. The sensor is a thermistor, a semiconductor device. Its resistance decreases with increasing temperature, which is why it is described as a negative temperature coefficient (NTC) device. Thermistors are not ideal for temperature measuring circuits, because the relationship between temperature and resistance is far from linear. This is no disadvantage if only one temperature is to be set, as in this example.



Heater Switch

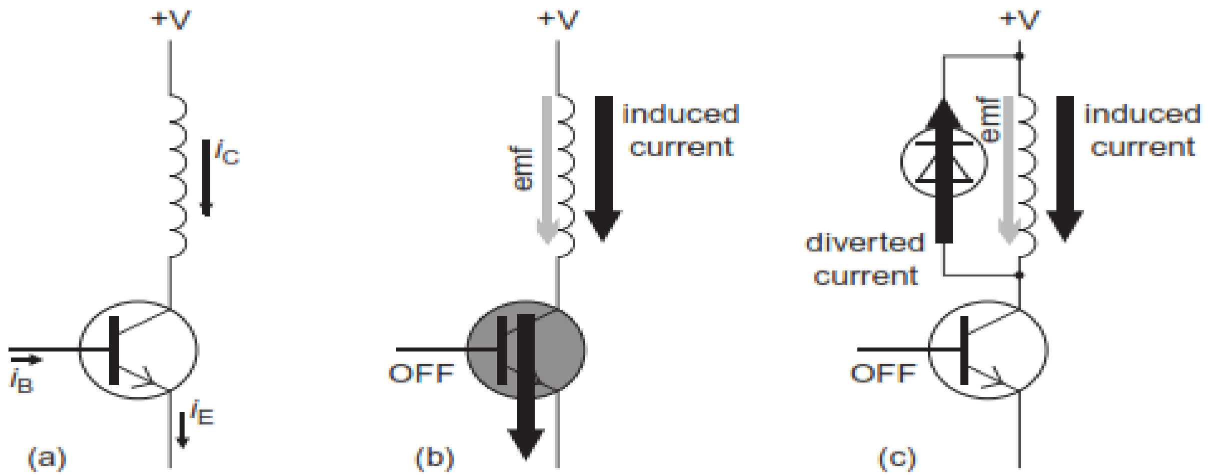
The switched device in this example is a relay. This consists of a coil wound on an iron core. When current passes through the coil the core becomes magnetized and attracts a pivoted armature. The armature is pulled into contact with the end of the core and, in doing so, presses two spring contacts together. Closing the contacts completes a second circuit which switches on the heater. When the current through the coil is switched off, the core is no longer magnetized, the armature springs back to its original position, and the contacts separate, turning off the heater.



Heater Switch *Protective Diode*

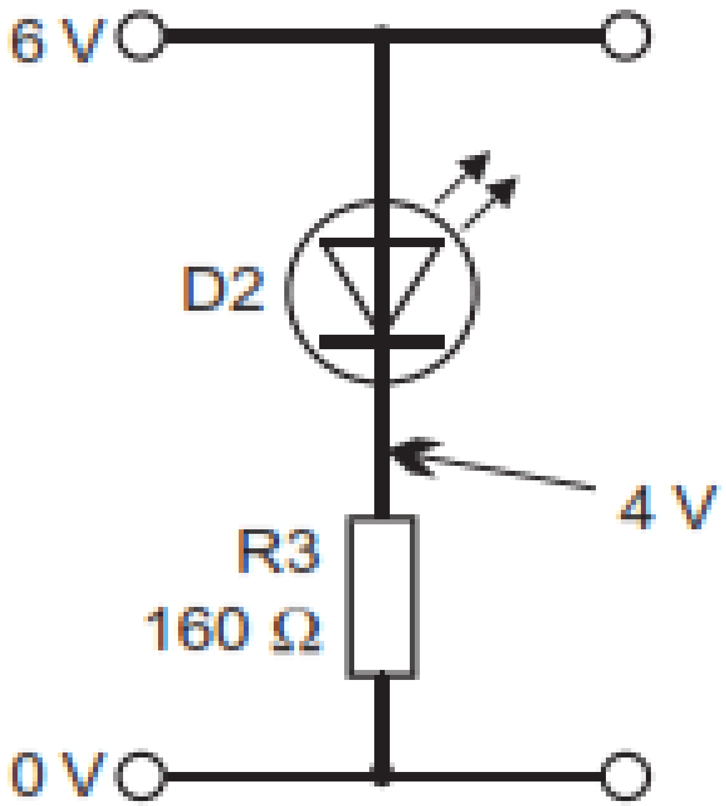
The diode D1 is an important component in this circuit.

At (a) below a transistor is controlling the current through an inductor. When the transistor switches off (b), current ceases to flow through the coil and the magnetic field in the coil collapses. This causes an emf to be induced in the coil, acting to oppose the collapse of the field. The size of the emf depends on how rapidly the field collapses. A rapid switch-off, as at (b), collapses the field instantly, resulting in many hundreds of volts being developed across the transistor. This emf produces a large current, which may permanently damage or destroy the transistor.



indicator lamp circuit

The idea is to have a lamp that comes on when the circuit is switched on. We could use a filament lamp (such as a 6 V torch bulb) but a light-emitting diode is generally preferred. This is because, for a given brightness, LEDs do not take as much current as filament lamps. Also, filament lamps do not last as long as LEDs. An LED needs a current of a few tens of milliamps. Often 20 mA or 25 mA makes the LED shine brightly. Like any other diode, an LED has a forward voltage drop across it when it is conducting. For most LEDs the drop is about 2 V.

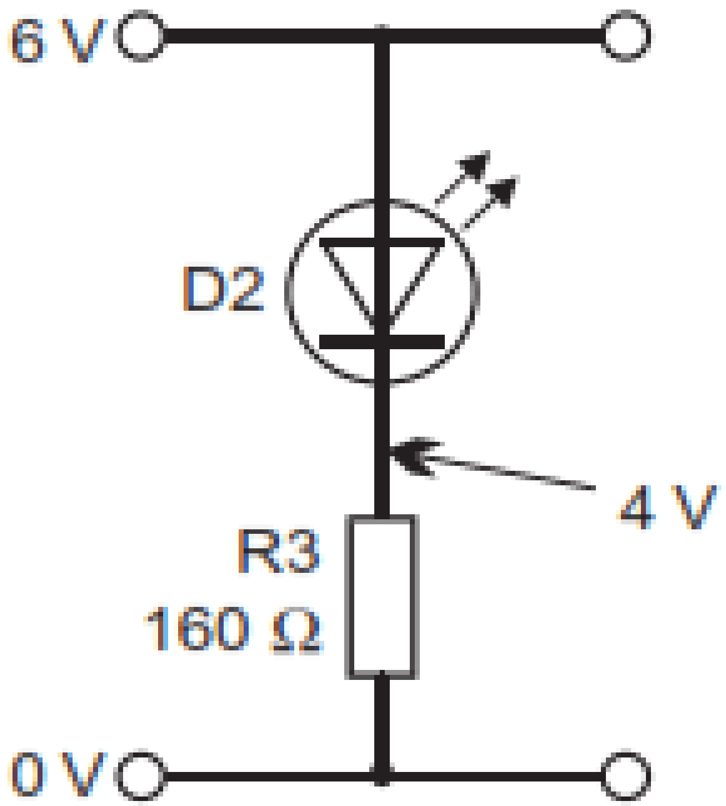


indicator lamp circuit

The LED will burn out if the voltage across it is much more than 2 V. If the LED is being powered by a supply greater than 2 V, we need a resistor (R3) in series with it. This drops the excess voltage.

In the diagram above, the supply is 6 V, so the excess voltage is 4 V. If we decide to have a current of 25 mA through the LED, the same current passing through R3 must produce a drop of 4 V across it. So, its resistance must be:

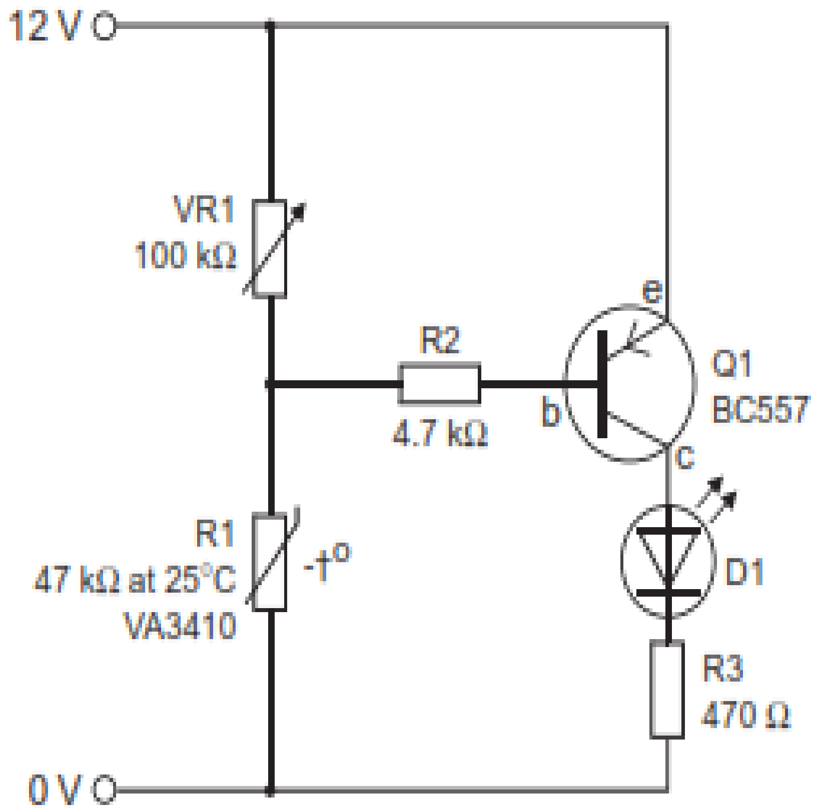
$$R_3 = \frac{4}{0.25} = 160\Omega$$



Overheating Alert

Previous circuits in this topic have used BJTs of the type known as NPN transistors. Here we use the other type of BJT, a PNP transistor. The action of a PNP transistor is similar to that of an NPN transistor. In particular, a small base current control a much larger collector current. However, the polarities are reversed:

- ✓ The transistor is connected with its emitter positive of its collector.
- ✓ Base current flows out of the base terminal instead of flowing into it.
- ✓ When the transistor is ‘on’, the base terminal is 0.7 V negative of the emitter.



a switching circuit using a PNP- BJT:

PNP OR NPN?

The inverse action can be achieved either by exchanging components or by using a PNP transistor. This illustrates a point about electronic circuits, that there are often two or more ways of doing the same thing. Sometimes both ways are equally effective and convenient. In other instances, we may have reason to prefer one way to the other.

In practice, NPN transistors are used far more often than PNP transistors. Although sometimes a resistor or logic gate may be saved in a circuit by using PNP, it is usually just as convenient to swap components to invert the action.

The main reason for using PNP is when we want a given signal to produce an action and its inverse at the same time. Then we use a pair of transistors, NPN and PNP, with equal but opposite characteristics.