FACTFILE:
GCE TECHNOLOGY & DESIGN

1.14 CALCULATIONS AND 1.17 ELECTRONIC SYSTEMS: PART 4

Rewarding Learning

Transistor

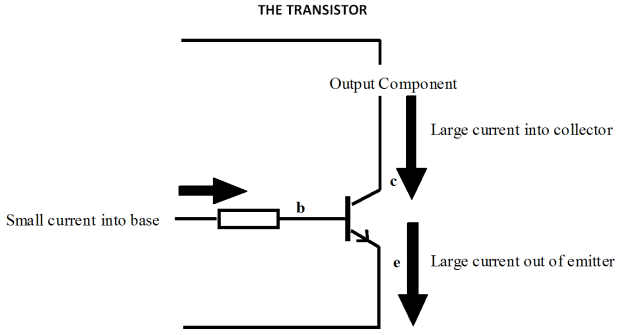
Learning Outcomes:

Students should be able to:

- demonstrate knowledge and understanding of the following systems:
  - transistor (npn in switching circuits only);
- and from 1.14 Calculations:
- use knowledge and understanding of formulas, and given information to complete calculations for:
  - transistor to include calculation of base resistor, h_{fe}, I_c (max)and Vbe.
  - incorporate these devices into applications to meet specified criteria.

Students need to know the relevant formulas as we will not provide these in the assessment.

Course Content



A transistor has 3 connections (or legs) called the Collector (c), the Emitter (e) and the Base (b). Transistors are housed in a plastic or metal case and the legs can be identified by looking at it from underneath and referring to a catalogue. Some transistors have a tag to help identify the legs.

The action of a transistor can be summarised as follows:

There are two paths for the electric current to pass through a transistor. The base current, Ib enters by the base, and the collector current, Ic by the collector. The combined current leaves by the emitter, so that the emitter current, Ie is the sum of the base and collector currents. Ie = Ib + Ic

The size of the collector current is controlled by the size of the base current. If no current flows into the base, then the collector current is also zero. A small base current results in a large collector current. Switching a small base current on and off will turn a large collector current on and off.

Switch-on voltage

It is found that for the transistor to switch on, the voltage at the base, Vbe should be about 0.6 V. The base can be connected to a voltage divider circuit which could include a sensor such as an LDR, so that the switching occurs automatically.

Precautions
To prevent damage to the transistor two precautions are necessary.

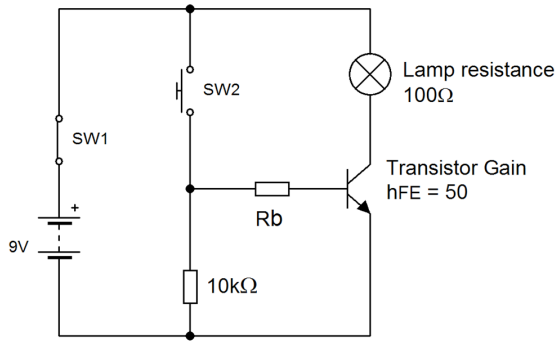
- a protective base resistor Rb must be present. Ohms law may be used to calculate the value of this;
- there must be an output device (load) between the collector and the positive supply

Current Gain (amplification)
Typically, the collector current is perhaps 50 or 100 times greater than the base current. The ratio of collector current Ic to base current Ib is denoted by hfe. hfe = Ic / Ib

Current flow through output devices
When the transistor is fully switched on, the collector voltage Vce = 0, meaning that the full supply voltage appears across the load. At this point, the collector current Ic (max) may be determined by dividing the supply voltage by the load resistance, Ic (max) = Vs/RL.

Transistor Calculations

Worked Example
Consider this simple transistor circuit.



(a) Calculate the current through the lamp when the transistor is fully "switched on" (saturated).

Answer: When the transistor is fully switched on, the collector voltage Vce = 0, meaning that the full supply voltage, 9 V, appears across the load. At this point, the collector current Ic (max) may be determined by dividing the supply voltage by the load resistance, Ic max) = Vs/RL.

Substituting, Vs/RL = 9/100 = 0.09A = 90 mA.

(b) Calculate the power dissipation in the lamp.

Answer: P = Vs x Ic (max). Substituting we obtain P = VI = 9 x 0.09 = 0.81W = 810 mW.

(c) Calculate the base current required to switch the transistor fully on.

Answer: The ratio of collector current Ic to base current Ib is denoted by hfe.
hfe = Ic / Ib or Ib = Ic / hFE.

Substituting we obtain Ib = Ic (max) / hfe = 90 mA/50 = 1.8 mA = 0.0018 A.

(d) Calculate the minimum value of base resistor required to switch on the transistor fully.

Answer: It is found that for the transistor to switch on, the voltage at the base, Vbe should be about 0.6V.

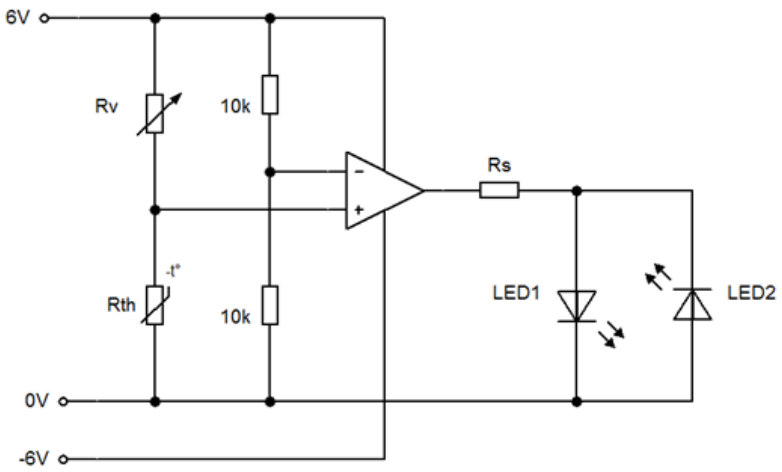
Hence the voltage across the base resistor when the push-to-make switch is pressed = 9-0.6 = 8.4 V

The value of the base resistor is determined using ohms law I = V/R or R = V/I

Substituting we obtain R = 8.4/0.0018 = 4666 Ω

Revision Questions

1



The frost warning circuit shown in the figure above is to be modified so that it will switch on a high voltage heater using a transistor and relay-based circuit. A table showing the available transistors is shown in the table below.

Transistor	Vbe	Ic(max)	hfe
Type 1	0.7	1 A	40
Type 2	0.6	800 mA	100
Type 3	0.6	400 mA	200

(i) Explain what is meant by the term Ic (max) when referring to transistors.

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(ii) Show, with the aid of a diagram, how a transistor and relay-based circuit can be used to enable the circuit shown in the figure above to turn on a high voltage heater.

Revision Questions

1 (iii) If a transistor with a supply voltage of 6 volts requires a base current of 8 mA to operate a relay with a coil resistance of 10 ohms, calculate the gain required for the transistor and choose an appropriate transistor from the table shown in the table above.

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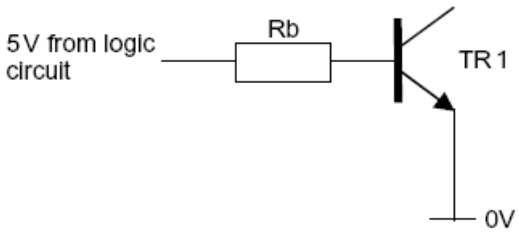
2 The output from a 5V logic circuit is to be used to switch on a 12 V motor using a transistor based driving circuit. Part of the driving circuit is shown in the figure below.



(i) Draw a circuit diagram to show how a 12 V motor would be controlled by the transistor shown in the figure above. Assume the transistor uses a 9 V power supply.

(ii) Explain how the circuit that you have drawn for (i) is used to control the motor, making reference to any additional components used.

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(iii) The transistor shown in the figure above has a current gain (h_{fe}) of 60 and a base/ emitter voltage (Vbe) of 0.7 V. If the collector current is to be limited to 420 mA, calculate the required value of resistor Rb.

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Revision Questions

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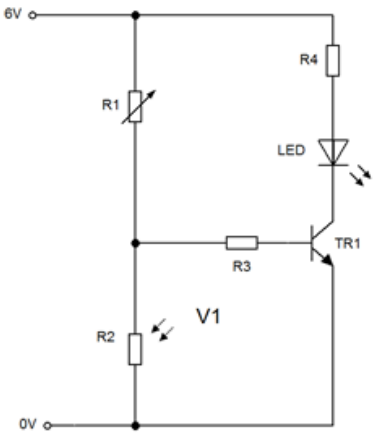

A prototype light sensing circuit is shown in the figure above which was found to respond to changes in the light conditions.

The maximum LED current in the figure above is limited to 20 mA when resistor R3 is 10 kΩ. Calculate a suitable gain (h_{fe}) for the transistor TR1. (Assume V1 is 4.2 V and Vbe is 0.6 V)

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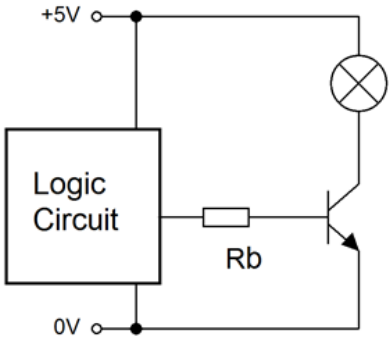
The output from a logic circuit is connected to a transistor and bulb arrangement as shown in the figure below. The bulb requires 80 mA in order to be illuminated.



If the transistor has a current gain of 100 and a VBE of 0.7 V, calculate the value of Rb needed to illuminate the bulb when the output from the logic circuit is high.

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