# FACTFILE:
# GCE TECHNOLOGY & DESIGN

## 1.17 ELECTRONIC SYSTEMS: PART 1

Rewarding Learning

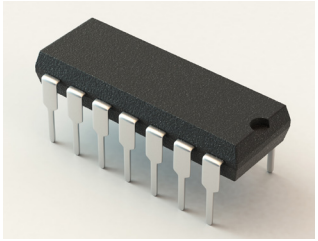
## Logic Gates

### Learning Outcomes

- demonstrate knowledge and understanding of the following systems:
  - AND and OR arrangements of SPST switches;
  - truth tables with a maximum of three variables;
  - logic gates AND logic function (AND), OR function (OR), Exclusive OR logic function (EOR), NOT logic function (NOT), NOT AND logic function (NAND), NOT OR logic
  - function (NOR), exclusive NOT OR logic function (ENOR);
  - incorporate these devices into applications to meet specified criteria.

### Course Content

These are digital switching circuits that respond to digital input signals and produce a digital output. Each gate has one or more inputs and one output. A logic gate processes the signals at its inputs by performing simple logical operations. The behaviour of logic gates can be summarised in truth tables in which input and output signals are denoted by `0' (low) and `1' (high).



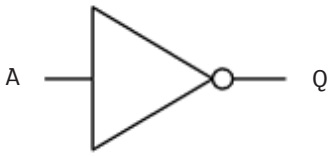
**NOT GATE**

This gate has a single input. The output, Q is always the inverse of the input A i.e. when the input is `0' (low), the output is `1' (high) and vice versa. This is sometimes called an inverter.

**Truth table**

| A | Q |
|---|---|
| 0 | 1 |
| 1 | 0 |

**Symbol**



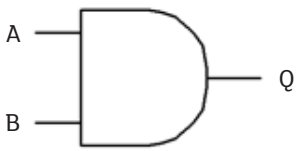

**AND GATE**

For a 2 input AND gate, the output Q is only `1' (high) when input A is `1' AND input B is ` 1'.

**Truth table**

| A | B | Q |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

**Symbol**

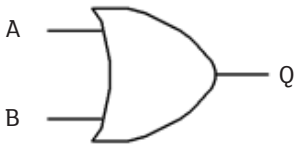


**OR GATE**
For a 2 input OR gate, the output Q is `1' (high) when input A is '1' OR input B is '1' OR both.

**Truth table**

| A | B | Q |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

**Symbol**

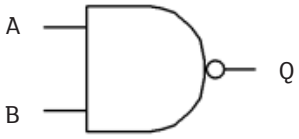



**NAND GATE**
For a 2 input NAND gate, the output Q is `1' (high) for all input combinations EXCEPT when input A is `1' NAND input B is `1'.

**Truth table**

| A | B | Q |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

**Symbol**

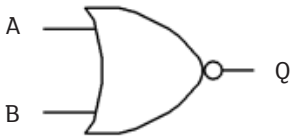



**NOR gate**
For a 2 input NOR gate, the output Q is '0' (low) when A NOR B is 1 OR when both are 1.

**Truth table**

| A | B | Q |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

**Symbol**

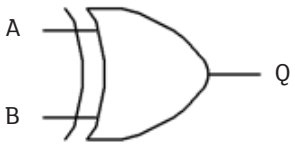



**EOR gate (Exclusive OR)**
For a 2 input EOR gate, the output Q is '1' (high) when A OR B is 1 but not when both are 1. This is sometimes called a true OR gate as the output is only 1 when either input is high but not both.

**Truth table**

| A | B | Q |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

**Symbol**



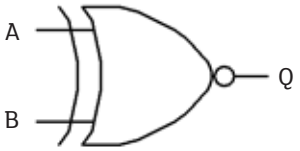

Another way of looking at this is to say that the output is high when the inputs are different.

**ENOR gate (Exclusive NOR)**
For a 2 input ENOR gate, the output Q is '0' (low ) when A OR B is 1 but not when both are 1 or both are 0.

**Truth table**

| A | B | Q |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

**Symbol**

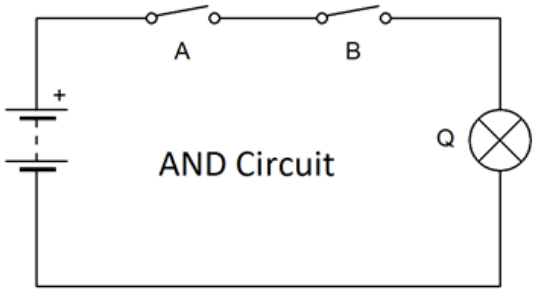



Another way of looking at this is to say that the output is high when the inputs are the same or that it is inverse for EOR.

## Logic Gates using switches

Switches may be used to construct simple digital electronic circuits. Their behaviour can be described by truth tables.

**AND Circuit**



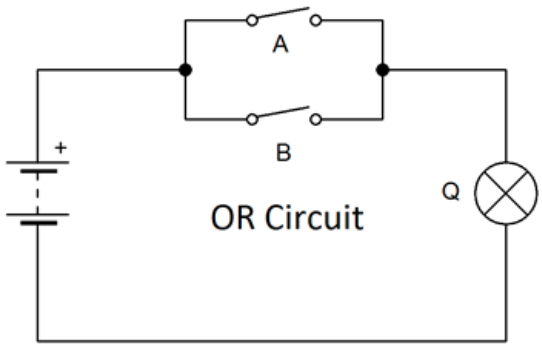

*Source: Circuit drawn by Noel Moore*

| A | B | Q |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

In this circuit, the bulb, Q, will light only when switch "A" is pressed AND switch "B" is pressed. This is called an AND circuit. A desk lamp will only light when the switch at the plug is switched on AND the switch on the lamp is switched on.

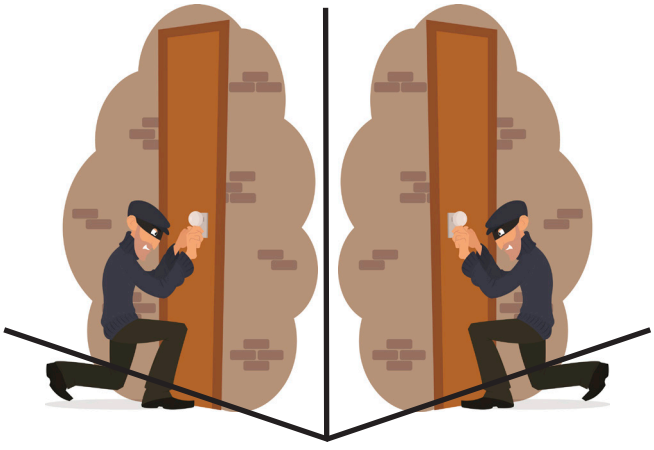
Hedge clippers will only operate when the left hand is pressing a switch AND the right hand is pressing the other switch. Why are hedge clippers designed like this?

**OR Circuit**



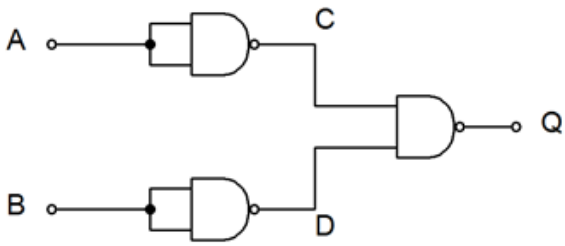

| A | B | Q |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

In this circuit, the bulb, Q will light when switch "A" is pressed OR switch "B" is pressed OR both. This is called an OR circuit. In a simple alarm system, the alarm will be activated when an intruder opens the front door OR the back door (OR both!).



## Combinational Logic

Logic gates may be joined together to form a combinational logic circuit. Truth tables can be drawn for such circuits and in many cases the circuit may be simplified by drawing the truth table.




This combinational logic circuit has inputs A and B and output Q. Columns representing the logic levels at the intermediate points C and D are included to help in the completion of the truth table.

| Inputs | | Intermediate Logic Levels | | Output |
|---|---|---|---|---|
| A | B | C | D | Q |
| 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 | 1 |

Observation shows that this logic circuit could be replaced by a 2-input OR gate since this would fulfill the same logic function.

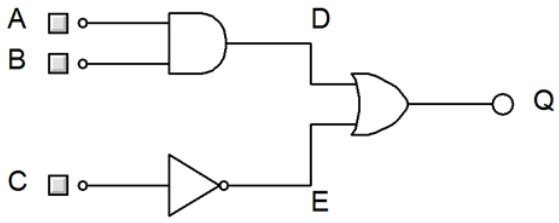
## Truth Tables with 3 variables

It is necessary to be able to construct truth tables for logic systems with 3 variables. Generally, the number of rows in a truth table is $2^n$ where n is the number of inputs or variables. Hence for 1 variable, 2 rows are required; for 2 variables, 4 rows are required; and for 3 variables, 8 rows are required.

Inputs or variables for a 3-input logic system

| A | B | C |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |
| 1 | 1 | 1 |

**Worked Example**
A logic circuit is shown below. The logic inputs to the circuit are provided by 3 switches labelled A, B and C.




Draw a truth table for all input combinations of A, B and C and the corresponding output Q for the logic circuit.

**Solution**
Draw a truth table showing the 8 possible combinations of the inputs A, B and C.

| A | B | C |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 0 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |
| 1 | 1 | 1 |

To complete the truth table, it is necessary to add additional columns corresponding to intermediate points in the circuit. Also, the intermediate points should be labelled in the figure.

Switches A and B are connected as inputs to an AND gate. Let us call the output of the AND gate D. Now add this Column to the truth table and determine the value of D.

| A | B | C | D |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 |

Switch C is connected as an input to a NOT gate. Let us call the output of the NOT gate E. This will always have the opposite state to C. Now add this Column to the truth table. Complete the truth table by adding a column corresponding to the output Q. Since D and E are connected as inputs to an OR gate, Q will be 1 if D = 1 OR E=1 OR both = 1.

| A | B | C | D | E | Q |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 0 | 1 | 1 |
| 0 | 1 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 1 | 0 | 0 | 0 |
| 1 | 1 | 0 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 0 | 1 |

## Revision Questions

**1** A logic gate is shown in Figure 1.

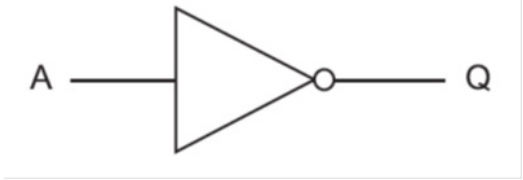



*Figure 1*

(i) Name the logic gate shown in Figure 1 and draw its truth table.

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(ii) With the aid of circuit diagrams, show how SPST switches can be arranged to provide:
- AND logic
- OR logic.

## Revision Questions

**2** A logic circuit is shown in Figure 2. The logic inputs to the circuit are provided by 3 switches labelled A, B and C.

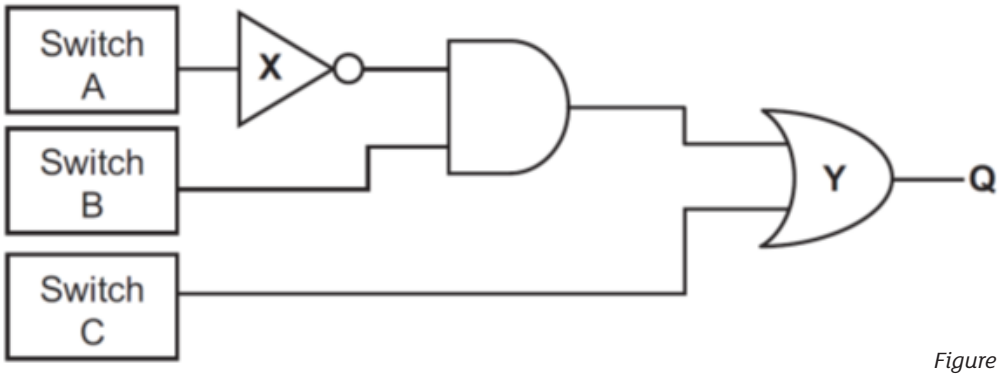


*Figure 2*

(i) Name the logic gates labelled X and Y in Figure 2.

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.....

(ii) Draw a truth table for all input combinations of A, B and C and the corresponding output Q for the logic circuit shown in Figure 2.

## Revision Questions

**3** Two logic gates are shown in Figure 3.

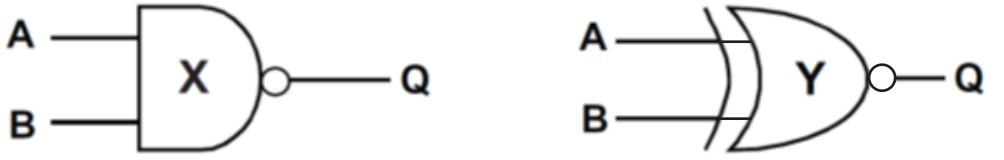


*Figure 3*

(a) (i) Name the logic gates labelled X and Y in Figure 3.

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(ii) Draw truth tables for each of the logic gates shown in Figure 3.

(b) Switches which are used to create logic functions can be incorporated into circuits as shown in the alarm circuit in Figure 3(b).

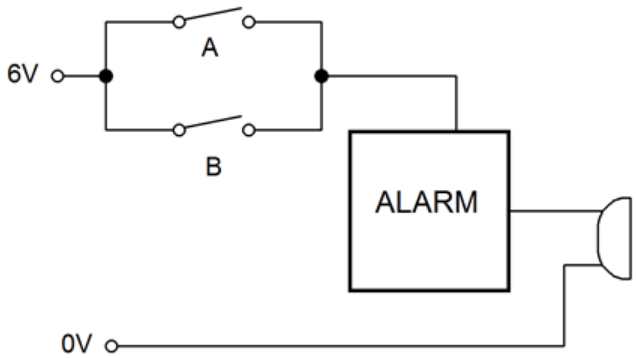


*Figure 3b*

(i) State the logic function achieved by the arrangement of the two switches A and B in Figure 3 (b) and explain how this logic function is achieved.

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## Revision Questions

**5** (a) An arrangement of logic gates is shown in Figure 4.

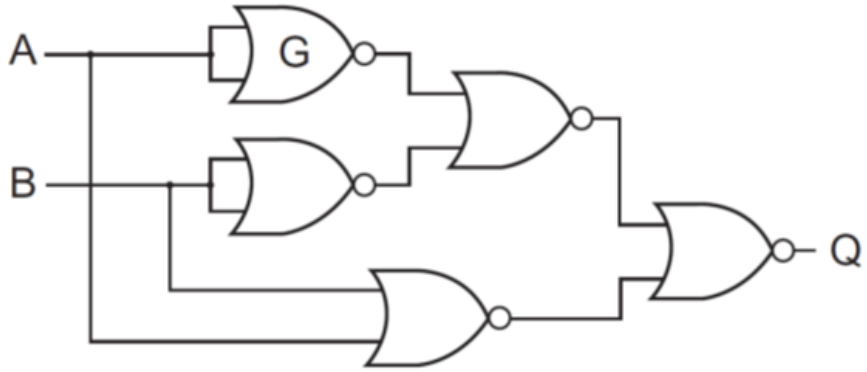


*Figure 4*

(i) Name the logic gate labelled G shown in Figure 4.

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(ii) Draw a logic truth table showing all input combinations of A and B and the corresponding output Q for the arrangement of logic gates shown in Figure 4.

(iii) Name and draw **one** logic gate that could be used to replace all 5 logic gates shown in Figure 4.

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