S4 TERM 3 NOTES

Theme: Modern physics

TOPIC: DIGITAL ELECTRONICS

Competency: Learners should understand how electronic components combine in digital circuits.

LEARNING OUTCOMES

The learner should be able to:

a. understand how resistors are used to make potential dividers in control and logic circuits (u, s)

b. understand elementary logic and memory circuits that exploit devices such as bi-stable and a stable switches, logic gates and resistors as potential dividers (u, s)

c. know that logic circuits are able to store and process binary information and that this can be exploited in an increasingly wide variety of digital instruments (k, u, s)

Electronics is a branch of physics that deals with the study, design and use of devices that control the flow of electric current (or electrons) in certain components to perform electrical functions.

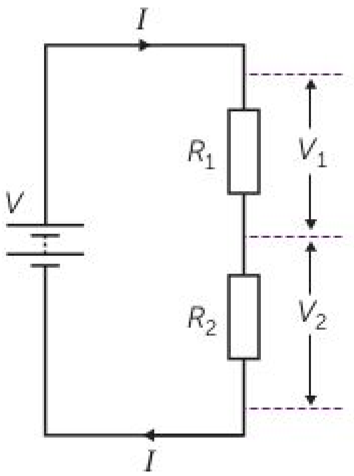
Digital electronics is a branch of both physics dealing with the study of digital signals and the design of electronic circuits that use them. It focuses on circuits that process information represented in binary form (0s and 1s),

THE POTENTIAL DIVIDER

A potential divider is used to supply a specified voltage from a fixed voltage supply.

A potential divider consisting of two resistors connected ins series to a fixed voltage supply.

The potential difference across each resistor is a fixed fraction of the potential difference across the two resistors.



From the figure, since the current I flows through a series connection of resistors, R_1 and R_2 then

$$I = \frac{V}{R_1 + R_2}$$

then the the p.d., across resistor $R_1, V_1 = IR_1 = \frac{R_1}{R_1 + R_2} V$

and the p.d, across resistor $R_2, V_2 = IR_2 = \frac{R_2}{R_1 + R_2} V$

WORKED OUT EXAMPLE

In the figure above, the supply voltage is 12V, $R_1 = 100\,\Omega$ and $R_2 = 150\,\Omega$.

Calculate V_1 and V_2

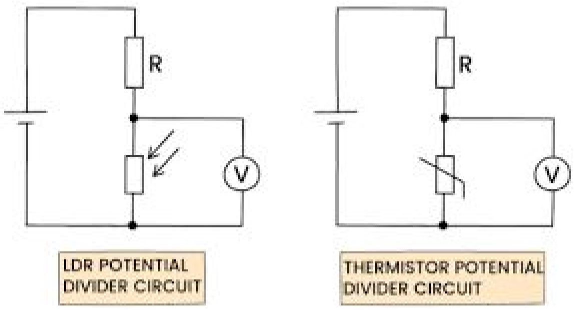
solution

$$V_1 = \frac{R_1}{R_1 + R_2} V = \frac{100}{100 + 150} x\, 12 = 4.8\, V$$

$$V_2 = \frac{R_2}{R_1 + R_2} V = \frac{1050}{100 + 150} x\, 12 = 7.2\, V$$

The potential divider always split the supplied voltage in the same proportion as the resistance values are fixed.

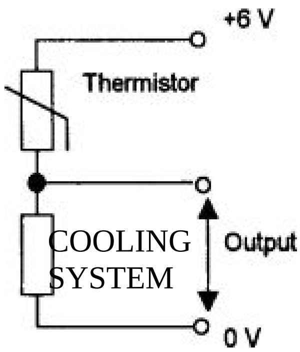
Potential dividers are particularly useful in sensory circuits with components like light-dependent resistors (LDRs) or thermistors. These components change their resistance based on external factors (light or temperature). By incorporating them into a potential divider, changes in resistance can be translated into measurable voltage changes, allowing the circuit to sense and respond to these changes



For example

A potential divider circuit is a refrigerator is made of a cooling system of resistance $5000\,\Omega$ and a thermistor the cooling system requires a voltage of 5V or more to automatically switch on. At what temperature will the system turn on when connected to a supply of 6 V and the characteristics of thermistor is shown

Temperature	Resistance of thermistor
2^0C	$1500\,\Omega$
3^0C	$1000\,\Omega$
4^0C	$500\,\Omega$



Solution

using $V_{out} = \frac{R_1}{R_1 + R_2} V$

$$At\, 2^0 C, V_{out} = \frac{5000}{5000 + 1500} x\, 6 = 4.6\, V$$

$$At\, 3^0 C, V_{out} = \frac{5000}{5000 + 1000} x\, 6 = 5.0\, V$$

$$At\, 4^0 C, V_{out} = \frac{5000}{5000 + 500} x\, 6 = 5.5\, V$$

the refrigerator will turn on at 3^0C

SEE *Exercise 7.2 page 91 fountain book4*

NOTE: A potentiometer acts as a potential divider. By adjusting the position of the sliding contact, the potentiometer divides the input voltage into a desired output voltage

APPLICATIONS OF POTENTIAL DIVIDERS

1. **Volume Control:** In audio systems, a potentiometer (a variable resistor) acts as one of the resistors in a potential divider. By adjusting the potentiometer, the output voltage, and thus the sound volume, can be controlled.

2. **Light Dimmer:** Similar to volume control, a potentiometer can be used to vary the voltage supplied to a light bulb, thus adjusting its brightness.

3. **Sensor Circuits:** Potential dividers are crucial in circuits using thermistors (temperature-sensitive resistors) or LDRs (light-dependent resistors). Changes in temperature or light alter the resistance of these components, which in turn changes the output voltage of the divider, allowing for detection and measurement of these environmental changes.

4. **Voltage Measurement:** In situations where you need to measure a voltage higher than the input range of a device (like a microcontroller), a potential divider can be used to scale down the voltage to a measurable level.

5. Power Supplies: Potential dividers can be used to create reference voltages within power supplies or to adjust voltage levels for different components.

BINARY SYSTEM AND LOGIC GATES

The binary system uses only two digits, 0 and 1, to represent information.

In digital circuits, these digits are typically represented by voltage levels: such as **low** voltage for 0 and a **high** voltage for 1.

This system is ideal for representing the "ON/ TRUE" (1) and "OFF/FALSE" (0) states of electronic switches

Logic Gates: Logic gates are electronic circuits that perform logical operations on binary inputs to produce a binary output.

They act as decision-making components in digital circuits, controlling the flow of information based on logical rules.

TRUTH TABLES:

A truth table is a table that shows all possible input combinations for a logic gate or circuit and the corresponding output(s) for each combination. It defines the behavior of a logic gate.

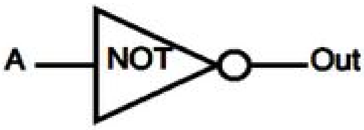
THE BASIC LOGIC GATES AND TRUTH TABLES

NOT gate:

For a single input NOT (Inverter) gate, the output is ONLY true when the input is “NOT” true, the output is the inverse or complement of the input giving the Boolean Expression of output is

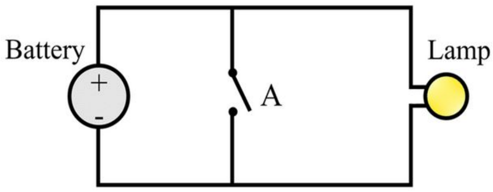
NOT A $= \overline{A}$.

The symbol of a NOT gate and the truth table



Truth Table	
INPUT	OUTPUT
0	1
1	0

The **switching circuit** diagram of the NOT gate is shown below:

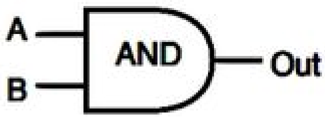


The switching circuit illustrates that the lamp will glow when switch A is open and will go off when the switch A is closed (making the current to go through the short circuited path).

AND gate:

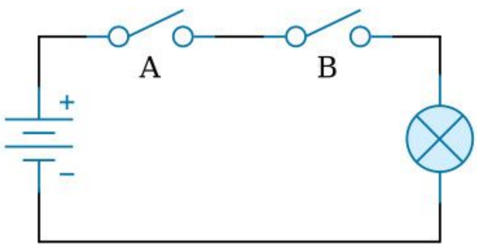
For a 2-input AND gate, the output is true if BOTH input A “AND” input B are both true, giving the Boolean Expression of **A.B**. The out put is false if any of the inputs is false

The symbol of a AND gate and the truth table



Truth Table		
INPUT A	INPUT B	OUTPUT=A.B
0	0	0
0	1	0
1	0	0
1	1	1

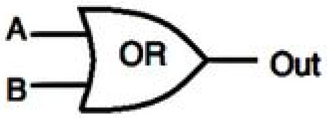
The **switching circuit** diagram of the AND gate is shown below:



OR gate:

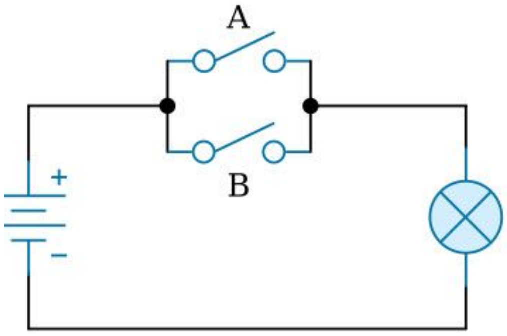
For a 2-input OR gate, the output is true if any of the input A “OR” input B true or both are true, giving the Boolean Expression of **A+ B**. The out put is false if both inputs are false

The symbol of a OR gate and the truth table



Truth Table		
INPUT A	INPUT B	OUTPUT=A+B
0	0	0
0	1	1
1	0	1
1	1	1

The **switching circuit** diagram of the AND gate is shown below:



NAND (Not AND) **gate:**

The **NAND gate** is another logic device commonly found in digital equipment. This gate is simply an AND gate with an inverter (NOT gate) at the output.

The output is NOT true if BOTH input A and input B are true. giving the Boolean Expression of $\overline{A.B}$

The symbol of a NAND gate and the truth table

Truth Table (Read as A AND B gives NOT)		
INPUT A	INPUT B	OUTPUT=$\overline{A.B}$
0	0	1
0	1	1
1	0	1
1	1	0

The NAND gate performs two functions, AND and NOT.

NOR (Not OR) **gate:**

The **NOR gate** is an OR gate with an inverter on the output. The NOR gate will have a true output only when all the inputs are False. This gives the Boolean Expression of $\overline{A+B}$

The symbol of a NOR gate and the truth table

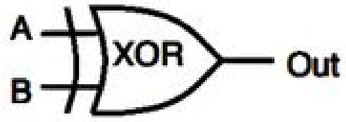
Truth Table (Read as A OR B gives NOT)		
INPUT A	INPUT B	OUTPUT=$\overline{A+B}$
0	0	1
0	1	0
1	0	0
1	1	0

The NOR gate performs two functions, OR and NOT.

XOR gate/EX-OR (Exclusive OR) Gate: The output is true if EITHER input A or if input B is true, but NOT both giving the Boolean Expression of: $A \oplus B$ =(A and NOT B) or (NOT A and B).

Output is 1 if the inputs are different and 0 if inputs are the same.

The symbol of a XOR gate and the truth table



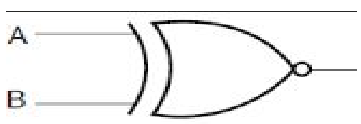
Truth Table		
INPUT A	INPUT B	OUTPUT=$A \oplus B$
0	0	0
0	1	1
1	0	1
1	1	0

XNOR EX-NOR (Exclusive NOR) Gate

The output Q is true if BOTH input A and input B are the same, either true or false, giving the Boolean Expression of: $\overline{A \oplus B}$ = (A and B) or (NOT A and NOT B).

Output is 1 if the inputs are the same

The symbol of a XOR gate and the truth table



Truth Table		
INPUT A	INPUT B	OUTPUT=$\overline{A \oplus B}$
0	0	1
0	1	0

1	0	0
1	1	1

APPLICATIONS OF LOGIC GATES IN CONTROL SYSTEMS

Performing calculations Logic gates are used to perform arithmetic functions like addition and subtraction in calculators.

Automatic Door Systems: Logic gates are used to detect when someone is near, opening or closing doors automatically.

Traffic Light Systems: Logic gates control the timing of traffic lights, helping traffic officers manage traffic flow

Designing computer processor: Logic gates are used in creating computer parts like control units and arithmetic logic units (ALUs) in CPUs.

Designing computer memory Systems: They are used to design storage systems like RAM (Random Access Memory), and ROM (Read-Only Memory) in computers.

Digital communication Systems: Logic gates are Used to send and receive data on different network channels. They perform tasks like encoding and decoding data e.g., in TV decoders.

Robotics: Logic gates control the decision-making and actions of robots thus helping them perform tasks based on user instructions

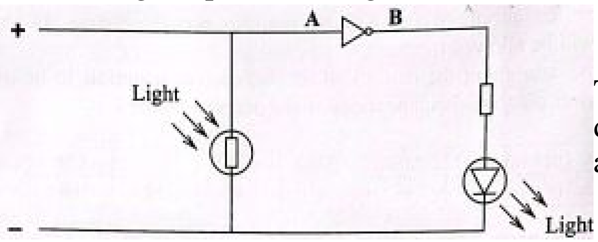
Digital Clocks and Timers: Logic gates are used to design digital clocks, timers, and other timing circuits.

Security Systems: They are used in designing alarm systems to detect thieves and intruder.

Car Engine Control Units: Logic gates control car engine functions, like managing fuel use.

SAMPLE SCENARIOS

ONE: After building his house in the village, The rich man worried on who will switch on the lights when he is away for a business trip. When contacted his electrician, it was suggested to use an automatic switching lamp whose design is as shown.



The business man couldn't understand how the design will work and as approached you for assistance.

TASK

As a physics student,
Help the business understand how the design will work (include truth table)

TWO: During a school project, student A wanted to design a fire alarm and extinguisher system using logic gates. This student approaches you for assistance. The system is need to work as follows

- Either smoke detected or temperature very high(above room temp), only alarm turns on
- Smoke detected, temp very high alarm turn on and extinguisher pours water

Student B made a made an automatic lamp which uses a potential divider. The lamp has an input voltage of 12 V and the bulb to be used has resistance of 100 Ω. The student requires an output of 4 V a cross the bulb and requires your guidance

Task: As a Physics student:

(a) Help student A to achieve his project (Include truth tables).

(b) i) Briefly describe to student B how the potential divider system works.

(ii) Offer guidance on that will enable the lamp to work

THREE: In a classroom activity, Senior five students of your school are presented with the learning aids shown in the figures

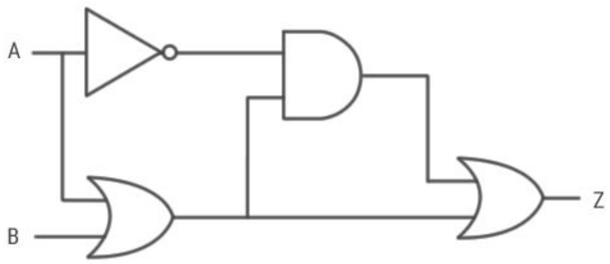


Figure 1

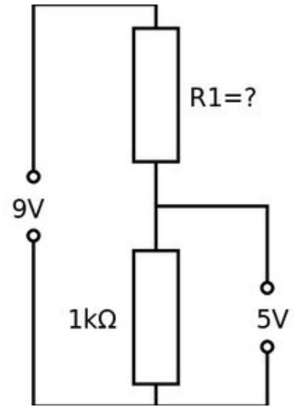


Figure 2

The students are required to

a) i) Explain the electronic devices used designing Figure 1.
ii) Obtain the possible outs at Z

b) i) Find the value of R1 for which the circuit in Figure 2 will operate
ii)Explain the effect of making R1 greater or equal to 1k Ω

c) Give two the applications of logic gates.

TASK:

Assist the students with the activity