TOPIC: DIGITAL ELECTRONICS

TR. TWINAMATSIKO DENIS

S4 PHYSICS

NEW CURRICULUM

FIRST EDITION

June 19, 2025

DIGITAL ELECTRONICS

- It is a branch of electronics that deals with digital signals to perform operations.
- It works with discrete values represented as 0's and 1's (binary).

KEY words

- Potential dividers
- Binary information
- Logic gates
- Astable switches
- Bistable switches

Scan for connection with the Author

A potential divider is an electrical circuit that produces an output voltage that is a fraction of the input voltage.

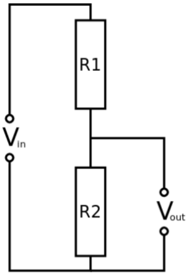


Figure 1: Potential divider

V_{in} - input voltage (voltage across the whole potential divider).
V_{out} - output voltage.
When the switch k is closed, same current flows through resistors R_1 and R_2 (series arrangement).

.

$$R = R_1 + R_2 \tag{1}$$

$$V_{in} = I(R_1 + R_2) \tag{2}$$

$$I = \frac{V_{in}}{R_1 + R_2} \tag{3}$$

The voltage across R2 is given by:

$$V_{out} = \frac{R_2 V_{in}}{R_1 + R_2} \tag{4}$$

The output voltage (V_{out}) is a fraction of the input voltage (V_{in}).

APPLICATIONS OF POTENTIAL DIVIDERS

1.Volume control of a radio. **2.Brightness control for lamps**

3.Light Sensing LDRs cobined with potential divider to create light sensors. The output voltage intensity of light falling on the LDR. Used in automatic lighting control.

4.Temperature Sensing potential dividers combined with thermistors to measure temperature-dependent voltage changes

1.Volume control of a radio.

- It uses a potentiometer. A potentometer is a variable resistor device with three terminals used to create a variable potential divider. It is a three terminal resistor with a sliding contact.

Mode of operation of a radio volume control

- Input signal (voltage) is applied across the two ends A and B of the potentiometer.
- The output signal (voltage) is taken from the slider (middle terminal) and end B.

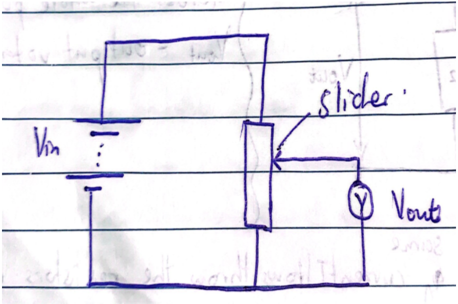
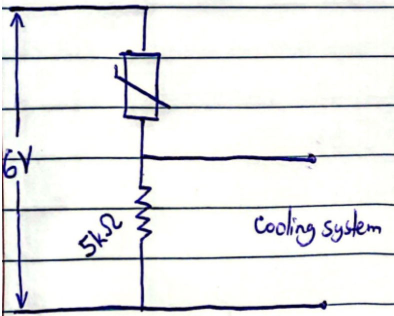


Figure 2: Radio volume control

.

- When the slider is moved upward, the resistance of the lower section increases and this increases output voltage (V_{out}).
- This adjusts volume since volume depends on the voltage applied.

Question A potential divider circuit is used inside a refrigerator to switch on the cooling system when the temperature is high (more than 30^{o}C). The cooling circuit has a resistance of 5k and it works when it has a pd of 5V or more. At what temperature will the cooling system work.



Temp (°C)	Resistance of thermistor (Ω)
2	1,500
3	1,000
4	500

Answer

$$At \quad 2^oC, \quad V_{out} = \frac{5000x6}{1500 + 5000} = 4.6V \tag{5}$$

$$At \quad 3^oC, \quad V_{out} = \frac{500x6}{1000 + 5000} = 5V \tag{6}$$

$$At \quad 4^oC, \quad V_{out} = \frac{5000x6}{1500 + 5000} = 5.5V \tag{7}$$

Let the voltage across the cooling system be Vout.
It will work at a temperature of 3 ^{o}C or more.
NB: The above circuit can be modified and used in:
-Switching off a heater when temperature is above a certain temperature.
-Switching off lights in daytime and on at night (LDR)

Binary system is a number system that uses only two digits 0's and 1's.
This system is used in all digital electronics eg computers and logic gates.
Digital circuits operate using two voltage levels.
0= Low voltage (eg 0V)
1= High voltage (eg 5V and 3.3V)
Binary values are derived from bits which are derived from digits.

LOGIC GATES

A gate is a logic circuit with one output and one or more input.
They include **AND, NAND, OR, NOR, NOT, EXCLUSIVE-OR**.
Logic gates are classified into:

1. Combinational logic circuit is one where the output depends on current inputs but not past inputs. eg Encoders and decorders.

2. Sequential logic circuit is one where the output depends on both current inputs and history of past inputs (It has a memory) eg counters

Logic equation

It is the relationship between independent logic binary variables and output variables.

Truth table

It is a table which shows all the input and output possibilities for logic circuits.

1. AND gate

The output is TRUE (or 1) if and only if all the inputs are TRUE.

2. NAND gate

The output is a 0 if and only if all the inputs are TRUE (1)

3. OR gate

The output is TRUE if atleast one of the inputs is TRUE (1).

4. NOR gate

The output is TRUE if all inputs are FALSE.

5. Exclusive-OR (XOR) gate

The output is TRUE if and only if one INPUT is true.

6. NOT / INVERTOR gate

It inverts the input signal. Eg Automatic street lights use the NOT gate. When sunlight is ON, lights are OFF.

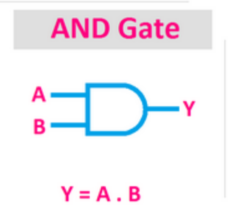


Figure 3: AND gate

INPUT		OUTPUT (Y)
A	B	
0	0	0
0	1	0
1	0	0
1	1	1

Figure 4: AND truth table

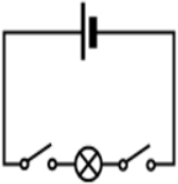


Figure 5: AND gate equivalent circuit

.

.

.

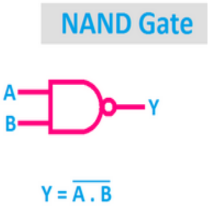


Figure 6: NAND gate

INPUT		OUTPUT (Y)
A	B	
0	0	1
0	1	1
1	0	1
1	1	0

Figure 7: NAND truth table

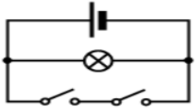


Figure 8: NAND gate equivalent circuit

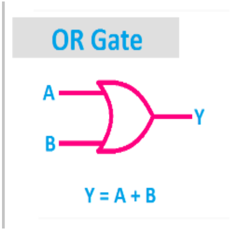


Figure 9: OR gate

INPUT		OUTPUT (Y)
A	B	
0	0	0
0	1	1
1	0	1
1	1	1

Figure 10: OR truth table

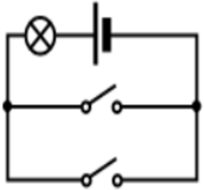


Figure 11: OR gate equivalent circuit

.

.

.

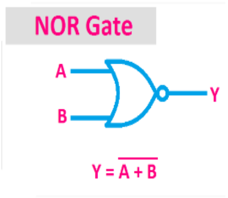


Figure 12: NOR gate

INPUT		OUTPUT (Y)
A	B	
0	0	1
0	1	0
1	0	0
1	1	0

Figure 13: NOR truth

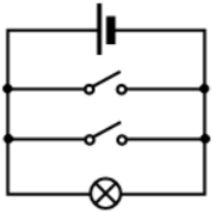


Figure 14: NOR gate

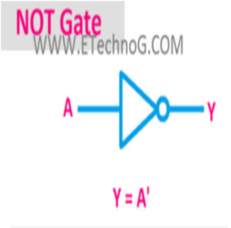


Figure 15: NOT gate

INPUT A	OUTPUT (Y)
0	1
1	0

Figure 16: NOT truth table

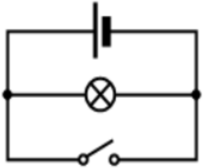


Figure 17: NOT gate equivalent circuit

.

.

.

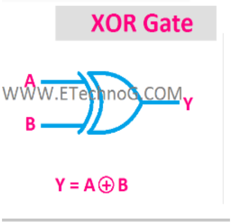


Figure 18: NOR gate

INPUT A	INPUT B	OUTPUT (Y)
0	0	0
0	1	1
1	0	1
1	1	0

Figure 19: XOR truth

Applications of logic gates

1. **Digital circuits and computers**

Form basis of microprocessors, memory units and computers

Perform arithmetic and logic operations (eg addition, comparisons)

2. **Calculators**. Used to build circuits that allow calculations.

3. **Control systems**. eg In traffic light control systems, gates decide the sequence and timing of lights.

4. **Alarms and security systems**. Used in burglar alarms and smoke detectors to trigger an alert.

5. **Gaming systems**. Video game consoles use logic gates in their internal electronics for processing game logic.

It is a circuit that performs a processing or controlling function in a computer. It implements logical operations on information to process it.

TYPES OF LOGIC-BASED/ MULTIVIBRATOR SWITCHES

- **Astable**
  It is a circuit with no stable states
  It continuously switches from HIGH to LOW (1 and 0) on its own.
  Application Used in blinking lights, timers, pulse generators.
- **Monostable**
  It has one stable state and one unstable state.
  When triggered by an input, it temporalily switches to unstable state and returns to stable state after a delay.
  Application Used in timers, producing a single pulse.
- **Bistable**
  It has two stable states.
  Can be set to one stable and remain there until changed by another input.
  Application Used in memory storage, toggle switches.

QUESTIONS

QN 1. Construct a bistable switch from two NOR gates

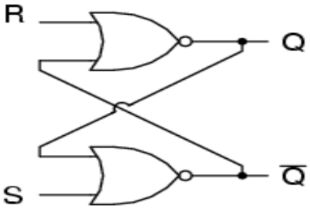
A bistable switch is also known as **SR flip flop** (Set-Reset latch)

It is constructed using two cross coupled NOR-gates.

The inputs are S (set) and R (Reset)

The outputs are Q and $\overline{Q}$

The output of each NOR gate is connected to one of the inputs of the other gate creating feedback.



S	R	Q	$\overline{Q}$
0	0	latch	latch
0	1	0	1
1	0	1	0
1	1	0	0

Figure 20: Bistable switch

QN 2. How is a bistable circuit used in binary counting circuit

A bistable circuit is used in binary counters which are used to count in binary (eg 0,1,10,11).

A binary counter is made by connecting multiple bistable circuits (flip flops) in series.

Each bistable circuit stores one bit of binary information either 1 0r 0.

How it works

A bistable counter has two stable states $Q=0$ or $Q=1$.

When used in a counter, each flip flop toggles its state on receiving a clock pulse.

The output of one flip flop can be used as the clock input for the next one.

This is called ripple counting.

Applications

$-Digitalclocks - Digitaltimers - Microprocessors - Frequencydividers$

QN 3. How are logic gates used in control circuits

A control circuit is a system that automatically monitors inputs (eg sensors or switches) and produces an output action based on logic. Control circuits use logic gates to make automatic decisions based on conditions.

eg (1)Start a motor only if Start button is pressed **AND** safety door is closed

(2)Alarm turns on if sensor A **OR** sensor B detects an intruder

QN 4. How do logic circuits process and store information

They store and process information using combinations of logic gates, flip flops and memory elements.

Processing information

Logic gates perform logical operations on binary inputs (0s and 1s) to produce inputs.

Multiple gates can be combined into combinational logic circuits to perform tasks eg addition

Storing information

A bistable circuit eg SR stores one bit of data.

Flip flops are the basic memory elements in digital systems.

In real devices:

- Microprocessors use millions of logic gates to process data.
- RAM and ROM use flip flops and other storage elements to store data and programs.
- A bit is stored as 1 or 0 in a flip flop . Bytes store large information.

QN 5. How do digital instruments display/use binary information

Digital instruments include calculators, digital thermometers.

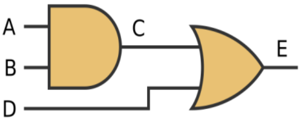
Humans don't read binary directly.

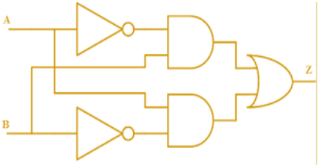
The steps are Binary Data Collection (ADC), Binary Processing (logic gates), Binary Storage(RAM and ROM) and Binary to Human-Readable Display (LCD or LED display).

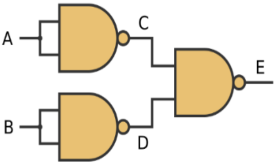
- Digital systems generate binary output (eg result of a calculation or measurement)
- Decoder or driver circuit converts binary values into signals that control segments, pixels, or characters.
- Display lights up or changes to show the value visually. Examples include: 7-segment display (Numeric Display), LCD, graphic displays (LCD panels)

Trial questions

Draw truth table for the following combinational logic circuits.

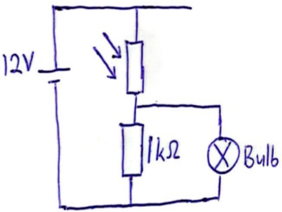






Qn. The table below shows the resistance of a certain LDR with changing external conditions.

Light condition	Resistance (Ω)
dark	10,000
light	2500
bright	20



1. Use the information to find the potential difference across the LDR when it is
(a) Dark
(b) light

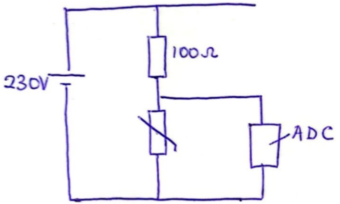
2. Explain the brightness of the bulb in bright, light and dark conditions.

3. Where can such a circuit be applied.

20/22

Qn. The table below shows the resistances of a thermistor with varying temperature.

temperature (°C)	Resistance (Ω)
10	4,000
40	1,980
100	200



1. Calculate the potential ~~pie~~ difference across the thermistor when it is
a) 10°C
b) 40°C

2. Explain the ~~bi~~ change in voltage output of the ADC with change in temperature.

NB: *The ADC (Analogue Digital converter) is connected to the temperature sensor to read the output voltage.

* This circuit can be used to monitor the temperature of the battery.

For solutions and feedback, use the link below.
https://forms.gle/hodmnHcxXJ5ZQ7UF8

END