DIGITAL ELCETRONICS

By the end of this chapter, you will be able to:

- Understand how resistors are used to make potential dividers in control and logic circuits.
- Understand elementary logic and memory circuits that exploits devices such as bistable and astable switches, logic gates and resistors as potential dividers.
- 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.

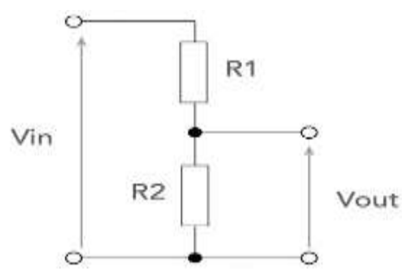
KEY WORDS

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

POTENTIAL DIVIDERS

A potential divider, also known as a voltage divider, is an electrical circuit arrangement used to produce an output voltage that is a fraction of the input voltage. It typically consists of two resistors connected in series across a voltage source, such as a battery or power supply. The output voltage is taken from the connection between the two resistors.

The output voltage V_{out} of a potential divider can be calculated using the voltage divider formula:



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

Where:

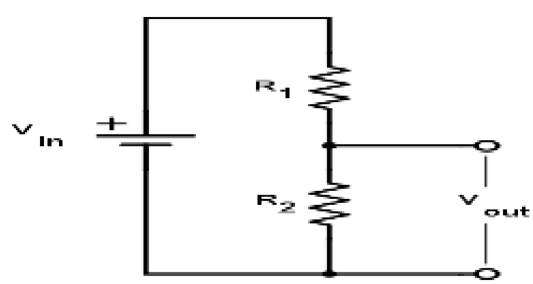
- V_{out} is the output voltage.
- V_{in} is the input voltage (across the entire potential divider).
- R_1 is the resistance of the first resistor.
- R_2 is the resistance of the second resistor.

APPLICATIONS OF POTENTIAL DIVIDERS

Potential dividers have a wide range of applications across various fields. Here are some common applications:

1. **Voltage Regulation:** Potential dividers are often used in voltage regulation circuits to provide a stable output voltage regardless of fluctuations in the input voltage. This is essential in many electronic devices to ensure consistent performance.
2. **Sensor Interfaces:** In sensor circuits, potential dividers are used to interface sensors with microcontrollers or other electronic systems. They help in scaling down the sensor output voltage to a suitable range for processing.
3. **Signal Conditioning:** Potential dividers are employed in signal conditioning circuits to adjust the amplitude or level of analog signals before further processing. This is useful in applications such as audio amplification and instrumentation.
4. **Battery Monitoring:** Potential dividers are utilized in battery monitoring circuits to measure the voltage of batteries. By scaling down the battery voltage to a suitable level, it can be accurately measured using analog-to-digital converters (ADCs).
5. **Temperature Sensing:** In temperature sensing applications, potential dividers are often combined with temperature-sensitive resistors (thermistors) or integrated temperature sensors to measure temperature-dependent voltage changes.
6. **Light Sensing:** Light-dependent resistors (LDRs) can be incorporated into potential divider circuits to create light sensors. The output voltage varies depending on the intensity of light falling on the LDR, making it useful in applications such as automatic lighting control and solar tracking systems.
7. **Feedback Networks:** In electronic amplifier circuits, potential dividers are used in feedback networks to set the gain or provide biasing. This helps in stabilizing the amplifier's operating point and achieving the desired amplification characteristics.
8. **Reference Voltage Generation:** Potential dividers can be employed to generate reference voltages for comparison purposes in circuits like voltage comparators or precision voltage sources.

Consider a potential divider circuit as shown below. A sensory device can be placed in the position of R_2

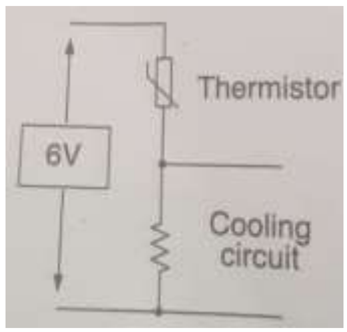


The voltage across sensory device (V_2on R_2) can be mathematically written as:

$$V_2 = \frac{R_2}{R_1 + R_2} x \ input \ voltage$$

Example

A potential divider circuit can be used inside a refrigerator to switch on the cooling circuit when the temperature is high (more than 30°C)



The characteristics of the thermistor are given in the table below. Let the voltage across the cooling circuit be V_{cc} and the resistance of the cooling circuit is 5kΩ. In order for the cooling circuit to operate, it needs a potential difference of 5V or more.

Temperature	Resistance of the thermistor
2°C	1500Ω
3°C	1000Ω
4°C	500Ω

Solution

Let the resistance of the thermistor be R_1 and that of the cooling circuit be R_2 and V_{cc} is the voltage across the cooling circuit.

$$V_{cc} = \frac{R_2}{R_1 + R_2} x \ input \ voltage$$

Therefore at 2°C,

$$V_{cc} = \frac{5000}{1500 + 5000} x \ 6 = 4.6 \ V$$

At 3°C

$$V_{cc} = \frac{5000}{1000 + 5000} x \ 6 = 5.0 \ V$$

At $4°C$,

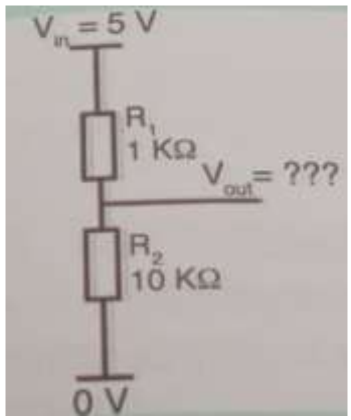
$$V_{cc} = \frac{5000}{500 + 5000} x\ 6 = 5.5\ V$$

Therefore, the sensory circuit switches on the cooling circuit when the voltage is 5 V or more.

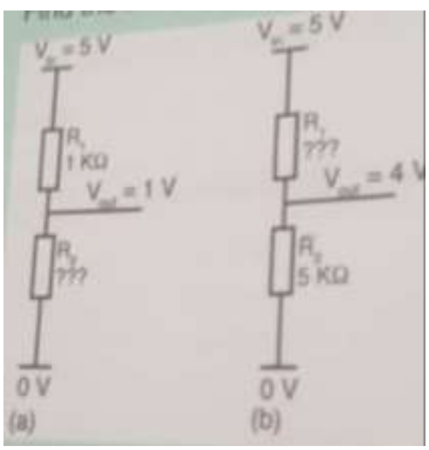
The above circuit can be modified to suit different applications. For example: switching off a heater when the temperature is above a certain temperature. This circuit can also be used for switching off lights in the daytime and switching them on at night (using LDR).

EXERCISE

Calculate the value of V_{out} for the circuit shown in the figure below,



Find the missing values in the figure below.



BINARY SYSTEM AND LOGIC GATES

A gate is a logic circuit with one output and one or more input. The output occurs only for certain combination of the inputs.

The various logic gates are “OR”, “AND”, “NOT”, “NOR”, “EXCLUSIVE-OR” gates, “NAND”.

Logic circuits can be classified into combinational and sequential logic circuit.

Combinational logic circuit is one where the output at any instant is a function of only the input at that instant.

Example: Gates like “AND”, “OR”, “NOT”, etc.

A sequential circuit can consist of a combinational circuit and memory which stores past inputs over a long period of time.

These combinational and sequential circuits are based on Boolean Algebra which is a way of analysing and designing logic circuit.

BOOLEAN ALGEBRA

It is an algebra where the variables are constrained and permitted to have only one of the two positive values. The possible two values may stand for “Truth” or “False” of a statement or “ON” or “OFF”. State in a switch or “PRESENCE” or “ABSENCE” of one of the two voltage values.

These Boolean variables are binary in nature. The binary values are designated “0” or “1”. Either of these binary values are denoted by “Bits”. Bit is derived from binary digits.

<u>Logic gate:</u>

Definition:

A gate is a logic circuit with one output and two or more inputs. The output signal occurs only for certain combinations of input variables.

The various logic gates are “OR”, “AND”, “NOT”, “NOR”, “EXCLUSIVE-OR” gates, “NAND”.

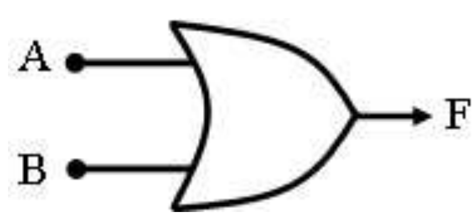
Truth-table:

Is a table which shows all the input and output possibilities for logic circuits. It gives what combinations of input that will produce outputs (Independent variables producing dependent variables).

Logic equation:

It is the relationship between independent logic input binary variables and logic output variables.
Basic gates:

1. **OR-gate** **symbol**

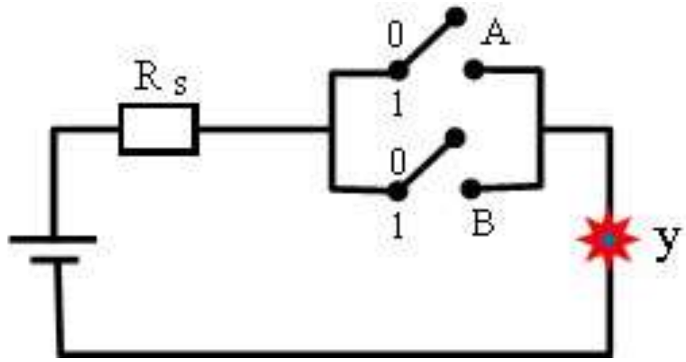


The logic equation: F = A+B

Truth Table

Input		Output
A	B	y
0	0	0
I	0	1
0	1	1
1	1	1

Circuit Analogy

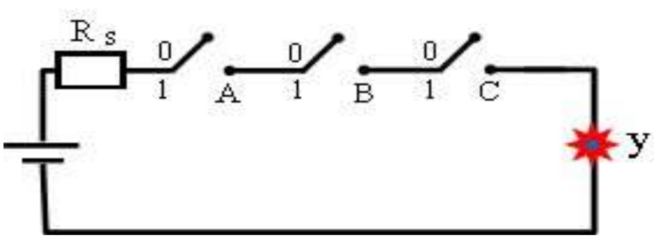


In the circuit analogy there is a parallel combination of the switches.

2. AND-gate symbol

The logic equation: F = ABC

Circuit analogy

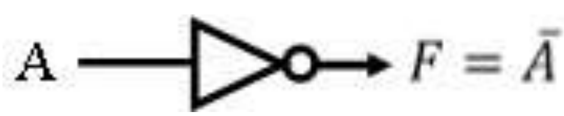


In this circuit analogy, there is series combination of switches.

3.NOT-gate:

This is an inverter. It has a single input and a single output. It inverts the input.

Symbol



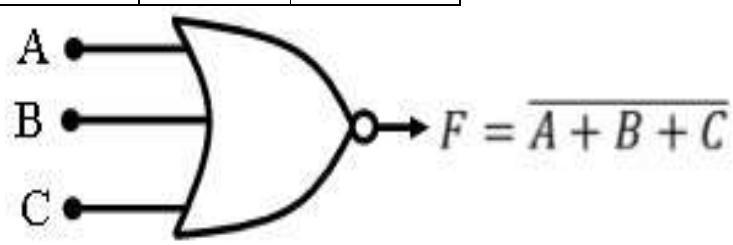
Truth table for NOT gate

Input	Output
0	1
1	0

Truth Table for the AND gate

input	input	input	Output
A	**B**	**C**	**Y**
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	0
1	1	1	1

4. When a **NOT-gate** is combined with the OR-gate in a cascade the result is known as a **NOR-gate** and the symbol is

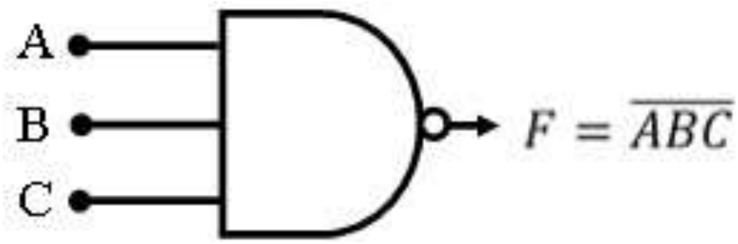


Truth Table for NOR gate

input	input	input	Output
A	**B**	**C**	**Y**
0	0	0	1
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0

5. NAND-gate

When the AND-gate is combined with a NOT-gate in a cascade, the resulting gate is known as a NAND gate.



Exercise

Draw the truth table for the above **NAND** equation

6. Exclusive-OR gate

The output of two inputs (Exclusive-OR gate) assumes state 1 if and only if, one variable assumes the state 1 but not both. Its logic equation is given by;

$F = A\bar{B} + \bar{A}B$

Symbol:

Exercise

Draw the truth table for the above **Exclusive-OR gate** equation.

APPLICATIONS OF LOGIC GATES

Logic gates are fundamental building blocks of digital circuits, and they find applications in various fields. Here are some common applications of logic gates:

1. **Digital Computers:** Logic gates form the basis of all digital computers. They are used extensively in the central processing unit (CPU) to perform arithmetic and logical operations, control the flow of data, and execute instructions.

2. **Digital Signal Processing (DSP):** Logic gates are used in DSP systems for tasks such as filtering, modulation, demodulation, and encoding/decoding of digital signals. They play

a crucial role in implementing algorithms for audio and video processing, telecommunications, and data compression.

3. **Memory Units:** Logic gates are utilized in memory units such as registers, flip-flops, and memory cells to store and retrieve digital data. They enable the implementation of various types of memory architectures, including random-access memory (RAM), read-only memory (ROM), and cache memory.

4. **Arithmetic and Logic Units (ALU):** ALUs are key components of CPUs responsible for performing arithmetic and logical operations on binary data. Logic gates are used extensively in ALUs to implement operations like addition, subtraction, multiplication, division, comparison, and bitwise manipulation.

5. **Control Units:** Logic gates are employed in control units to decode instructions, generate control signals, and coordinate the execution of operations within a CPU. They enable the fetch-decode-execute cycle and facilitate the proper sequencing of operations in a computer system.

6. **Digital Communication Systems:** Logic gates are essential in digital communication systems for tasks such as encoding, decoding, multiplexing, demultiplexing, and error detection/correction. They are used in devices like modems, codecs, encoders, decoders, and error-correcting codes (ECC).

7. **Industrial Automation:** Logic gates are widely used in industrial automation systems for controlling processes, monitoring sensors, and implementing logic-based decision-making. They are employed in programmable logic controllers (PLCs), motor control systems, robotic systems, and process control units.

8. **Consumer Electronics:** Logic gates are found in various consumer electronics products such as smartphones, tablets, digital cameras, televisions, gaming consoles, and home appliances. They enable functions like user interface interactions, data processing, signal conditioning, and control logic implementation.

9. **Security Systems:** Logic gates are used in security systems for tasks such as access control, authentication, encryption/decryption, and intrusion detection. They are employed in devices like keypads, biometric sensors, security cameras, and alarm systems.

10. **Automotive Electronics:** Logic gates are utilized in automotive electronics for functions like engine control, vehicle diagnostics, navigation systems, entertainment systems, and safety features (e.g., airbag deployment, anti-lock braking systems).

Logic Circuits

A logic circuit is a circuit that executes a processing or controlling function in a computer. This circuit implements logical operations on information to process it. It utilises two values for a given physical quantity for example voltage to denote the Boolean values true and false or 1 and 0 respectively. They have inputs with the corresponding outputs, which can be dependent on the inputs.

Types of logic circuits

1. Astable: This is a free running multivibrator that has No stable states but switches continuously between two states, this action produces a train of square wave pulses at a fixed known frequency.
2. Monostable: This is a one short multivibrator that has only ONE stable state as once externally triggered it turns to its stable state.
3. Bistable: This is a flip-flop that has TWO stable states producing a single pulse either HIGH or LOW in value.

Terms used in logic Circuitry.

1. Active HIGH: If the states change occurs from a **LOW** to a **HIGH** on clock's pulse rising edge or during the clock width.
2. Active LOW: If the states change occurs from a **HIGH** to a **LOW** on the clock's pulses falling edge.
3. Clock width: This is the time during which the value of the clock signal is equal to a logic **1** or **HIGH.**
4. Clock Period: This is the time between successive transition is the same direction i.e. between two rising or two falling edges.
5. Duty Cycle: This is the ratio of the clock width to the clock period.
6. Clock Frequency: This is the reciprocal of the clock period.

$$\boldsymbol{Frequency = \frac{1}{clock\ period} = \frac{1}{T}}$$

Compiled and prepared by Tr Moses Kusiima

Contact (0789298144) for any Facilitation in CBC