

How
computers
perform
logical

unit 16

INTRODUCTORY ELECTRONICS

STUDENT LEARNING OUTCOME

After studying this chapter you should be able to

- ✓ explain the process of thermionic emission emitted from a filament.
- ✓ describe the simple construction and use of an electron gun as a source of electron beam.
- ✓ describe the effect of an electric field on an electron beam.
- ✓ describe the effect of a magnetic field on an electron beam.
- ✓ describe the basic principle of CRO and make a list of its uses.
- ✓ differentiate between analogue and digital electronics.
- ✓ state the basic operations of digital electronics.
- ✓ identify and draw the symbols for the logic gates (NOT, OR, AND, NOR and NAND).
- ✓ state the action of the logic gates in truth

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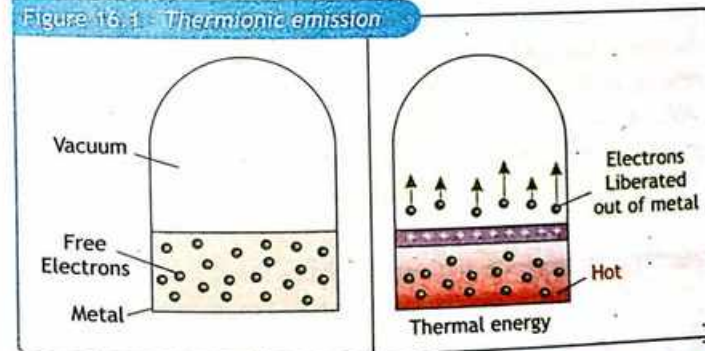
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	16.2 Electron gun
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	(a) Deflection by electric field
	(b) Deflection by magnetic field
	16.4 Cathode Ray Oscilloscope (CRO)
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	16.7 Logic gates
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We have used electronic equipment of one type or the other. Most of our homes have radio and television as standard domestic equipment. Mobile phones, personal computers and CD players provide further proof that electronics are vital to a developing economy like ours. This chapter will provide an introduction to electronics.

16.1 THERMIONIC EMISSION

Metals conduct electricity, this indicates that they contain some 'free' electrons that are not bound to a particular atom and free to move randomly through the metal as a whole. Most electrons in metals, particularly the 'core' electrons closest to the nucleus, are tightly bound to individual atoms; it is only the outermost 'valence' electrons that are somewhat 'free' and are termed as 'free electrons'. These free electrons are still bound to the material by a characteristic binding energy called the 'work function' and it represents the minimum energy that must be imparted to an electron in order to escape from the metal.

Figure 16.1 Thermionic emission



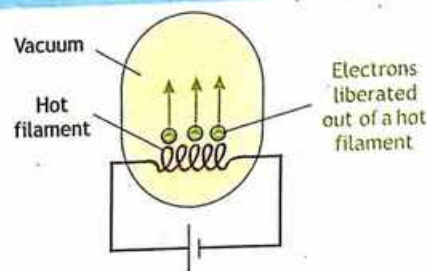
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If sufficient energy is given to the metal, the electrons taking this energy will be able to overcome the work function, causing electrons to be emitted from the metal.

If we increase the temperature of the metal, electrons start to move faster and some may have enough energy to escape from the metal as shown in figure 16.1. The higher the temperature, the higher will be the number of escaping electrons. The temperature induced electron ejection is called thermionic emission.

Thermionic emission can also be achieved by passing electric current through tungsten filament as shown in figure 16.2. The electric current heats up the filament and electrons are emitted.

Figure 16.2 Thermionic Emission from a filament



16.2 ELECTRON GUN

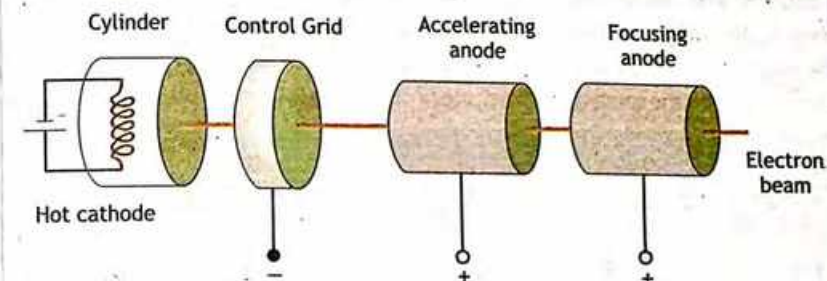
Electron gun is a source of focussed and accelerated electron beam. Electron gun is a versatile electrical component. It is an essential part for a number of devices, like Televisions, 3D printers, Scanning Electron Microscopes (SEM) and large synchrotrons.

Electron gun consists of a glass tube at very low pressure, with negatively charged electrode as cathode and positively charged electrode as anode as shown in figure 16.3. The electrons are emitted through the indirectly heated cathode. Indirectly heated cathode means the cathode surrounds the filament and emit electrons when the filament is heated up by the power applied. For getting the high emission of electrons at the moderate temperature, the layer of barium and strontium oxide is applied at the end of the cathode. The current and voltage required by the indirectly heated cathode are approximately equal to the 600 mA and 6.3V.

After exiting from the cathode, the electron passes through the control grid. The control grid is mostly made up of nickel material. The grid has negative biasing which controls the flow of electrons.

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Figure 16.3 Electron gun



By increasing the negative bias, one can decrease the number of electrons passing through and vice versa, thereby controlling the intensity (number of electrons) of the electron beam.

The electron which passes from the control grid is accelerated by the high positive potential which is applied across the accelerating anode. The electron beam is focused by the focusing anode.

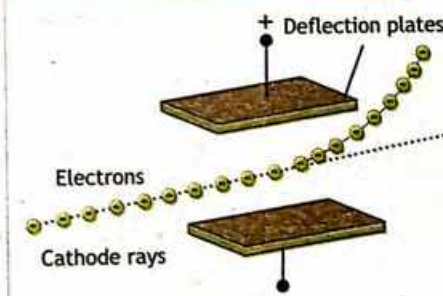
The beam after passing through the focusing anode passes through the deflection system and goes to the fluorescent screen.

16.3 CATHODE RAYS

Electron beam produced by electron gun is also called cathode rays as these rays are emitted from a negative electrode, also termed as cathode. Cathode rays can be effected by presence of an electric and magnetic field.

(a) Deflection by electric field: As cathode rays are composed of negatively charged electrons, therefore, the cathode ray beam is attracted by positive electrode and repelled by negative electrode as shown in figure 16.4. Thus, we can say that cathode rays are affected by presence of an electric field.

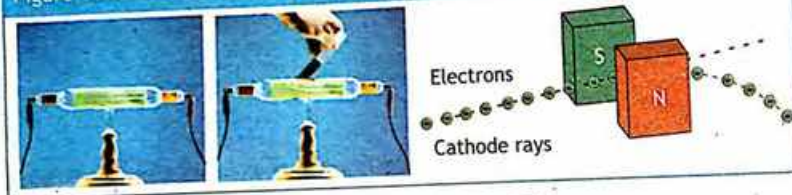
Figure 16.4 Electric field deflection



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(b) **Deflection by Magnetic field:** Since 'cathode rays' is stream of electrons. Electrons are negatively charged, and a magnetic field exerts forces on electrically charged particles that are in motion in any direction other than that of the magnetic field. To determine the direction of force and thus the deflection of electron beam, the same right hand rule III or Fleming left hand rule can be used.

Figure 16.5 - Deflection of electron beam in magnetic field



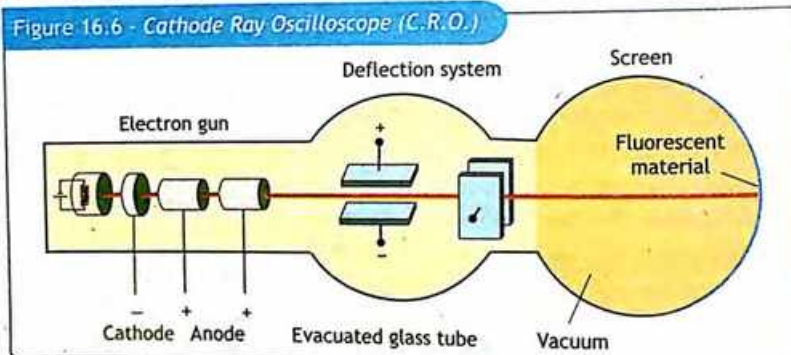
16.4 CATHODE RAY OSCILLOSCOPE (C.R.O.)

The Cathode Ray Tube (CRT) is used in computer monitors, TV sets and oscilloscope tubes. The main part of the C.R.O. is a highly evacuated glass tube, consisting of parts which generates a beam of electrons, accelerates them, shapes them into a narrow beam, and provides external connections to the sets of plates for changing the direction of the beam.

The CRO operates by firing an electron beam at a fluorescent material, which give off light as shown in figure 16.6. It consists of the following parts:

(a) **Electron gun:** The electron beam is generated at the cathode in the electron gun. As described earlier in electron gun, potential (voltage) is applied, which strips off and accelerates the electrons by accelerating anode.

Figure 16.6 - Cathode Ray Oscilloscope (C.R.O.)



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The electrons then travel to the electron beam focusing anode. An electrostatic mechanism is used to focus the beam.

(b) **Deflection system:** After the beam exits from the electron gun, it travels to the electron beam deflector. The deflector has two mechanisms, one to change the vertical direction and one to change the horizontal direction of the beam. This allows the electron beam to sweep over the entire screen.

(c) **Screen:** When an electron in the beam strikes a phosphor (such as Zinc Sulphide ZnS), it excites an electron in the phosphor. After being excited, the electron then releases the energy it got in form of a visible light, which is always the same for that phosphor. Phosphors emitting red, blue, and green light form a color image. The Cathode Ray Oscilloscope (CRO) is an electronic test instrument, used to observe the waveform of repetitive electric signal. This signal can be amplified or attenuated as required. Which enable its user to get the useful information about the electrical component attached to its in-put terminal.

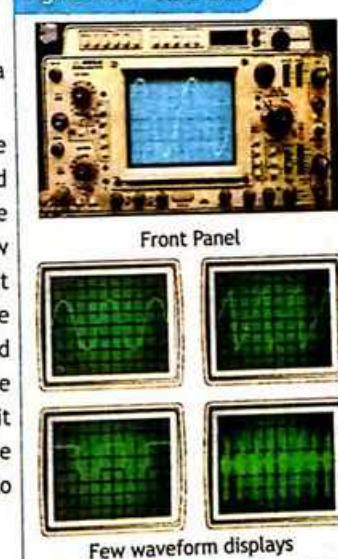
Uses of Cathode Ray Oscilloscope:

In a laboratory, a Cathode Ray Oscilloscope (CRO) can be used to

- display different types of wave form.
- measure short time interval.
- measure potential difference (as a voltmeter).

One of the most frequent use of oscilloscope is troubleshooting a malfunctioned electronic equipment because it has the advantage that it can graphically show signals. Using a voltmeter to study a circuit may show a totally unexpected intermediate voltage, an oscilloscope on the other hand can show the changes in the circuit voltage at various instants (showing that the circuit is oscillating). In such cases, the precise shape or timing of a pulse is important to troubleshoot the equipment.

Figure 16.7 - Basic CRO



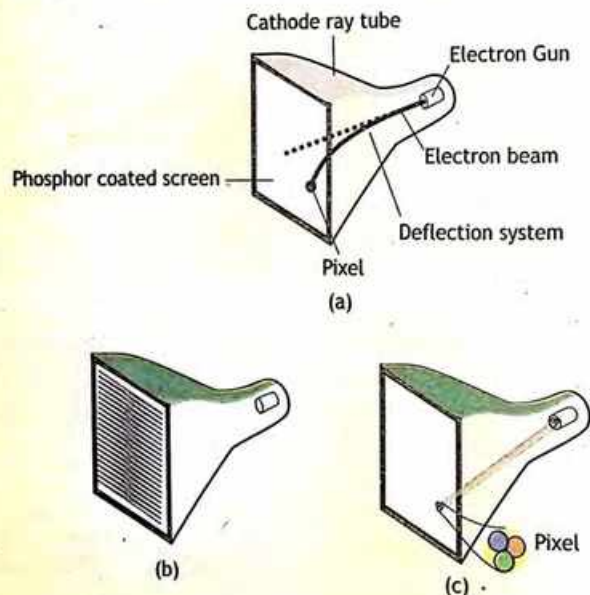
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Another use of oscilloscope is to check newly designed circuitry. Very often a newly designed circuit will misbehave because of design errors, bad voltage levels, electrical noise etc.

THE PHYSICS OF TELEVISION SCREENS

Some television sets and some computer display monitors have a cathode ray tube inside it. An electron gun sends a narrow beam of high-speed electrons toward the screen of the tube. The inner surface of the screen is covered with a phosphor coating, and when the electrons strike it, they generate a spot of visible light. This spot is called a pixel (a 'picture element').

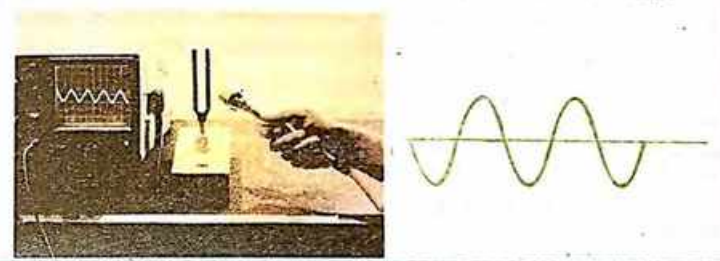
To create a black-and-white picture, the electron beam is scanned on the whole screen in sawtooth shape as shown in figure (b). As the beam scans the screen, brighter and darker spots are created by controlling electrons emitting from electron gun. A color TV operates with three electron guns i.e. red, green and blue colors as indicated in Figure c. Red, green and blue are primary colors, so virtually all other colors can be created by varying the intensities of the three beams focused on a cluster.



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TiBTS

'Seeing' Sound Waves: Cathode Ray Oscilloscope is used to display the form of electronic signals on a small monitor similar to a television screen. Sounds can be "seen" by using a microphone to convert them into electronic signals, an amplifier to amplify these signals, and an oscilloscope to display their form (see Figure 8.5). With an oscilloscope, you can visualize the difference between the sounds made by a variety of musical instruments. In figure below, an oscilloscope connected to a microphone can be used to display the wave form of a pure tone, created here by a tuning fork. The trace on the screen shows that the wave form is sinusoidal.



16.5 INTRODUCTION TO ELECTRONICS

The branch of physics and technology concerned with the design of circuits using transistors and microchips, and deals with the behaviour and movement of electrons in a semiconductor, conductor, vacuum, or gas is called electronics.

Electronics is widely used in information processing, telecommunication and signal processing. The ability of electronic devices to act as switches makes digital information processing possible.

Mathematical methods are integral part for the study of electronics. To become proficient in electronics, it is also necessary to become competent in the mathematics of circuit analysis. Due to the complex nature of electronics theory, laboratory experimentation is an important part of the development of electronic devices. These experiments are used to test or verify the engineer's design and detect errors. Historically, electronics labs have consisted of electronic devices and equipment located in a physical space.

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16.6 ANALOGUE AND DIGITAL ELECTRONICS

Analogue quantity is the one having continuous values. Therefore analogue signal is a continuously variable electrical or physical quantity. Most of the quantities that we deal in physical world are analogue quantities. There is an infinite amount of colors to paint an object (even if the difference is indiscernible to our eye), there is an infinite number of tones we can hear, and there is an infinite number of smells we can smell. The common theme among all of these analog signals is their infinite possibilities.

Digital systems on the other hand, operate on discrete digits that represent numbers, letters, or symbols. They deal strictly with ON and OFF states, which we can represent by 0 s and 1 s. A watch and voltmeter with both analogue measurement and digital measurements are shown in figure 16.8. The analogue measurement represents infinite possibilities whereas the digital watch is restricted only in its least count.

So why do we need to use digital representations in a world that is naturally analog? The answer is that if we want an electronic machine to interpret, communicate, process and store analog information, it is much easier for the machine to handle it if we first convert the information to a digital format. The conversion from one analogue to digital is achieved through circuit known as Analogue to Digital Converter (ADC) and converted back to analogue signals by Digital to Analogue Converter (DAC).

A digital value is represented by a combination of ON and OFF voltage levels that are written as a string of 1 s and 0 s.

Figure 16.8 - Analog Vs digital



Instead of dealing with the infinite span and intervals of analog voltage levels, all we need to use is ON or OFF voltages (usually +5 V = ON and 0 V = OFF).

A good example of the use of a digital representation of an analog quantity is the audio recording of music, Compact Disks (CDs) and Digital Versatile Disks (DVDs). Musical instruments and the human voice produce analog signals and the human ear naturally responds to these analog signals.

To accurately represent a complex musical signal as a digital string (a series of 1s and 0s), rather than gathering all the music on continuous basis, several samples of an analog signal must be taken, as shown in figure 16.9. It looks like an extra work but digital recordings have virtually eliminated problems such as electrostatic noise and the magnetic tape hiss associated with earlier methods of audio recording.

Figure 16.9: Analogue Wave

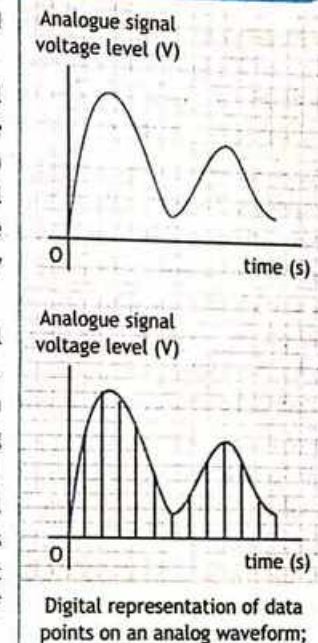
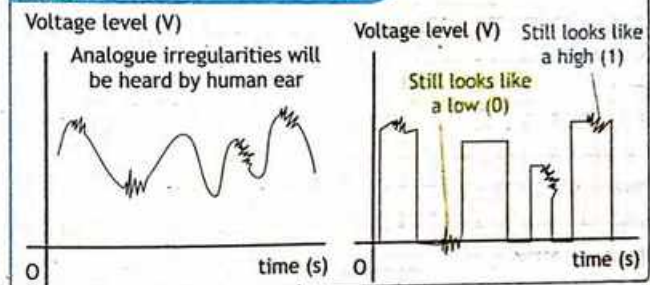


Figure 16.10 - Analogue Vs Digital



These problems have been eradicated because, when imperfections are introduced to a digital signal, the slight variation in the digital level does not change an ON level (high - 1) to an OFF level (0), whereas a slight change in an analog level is easily picked up by the human ear as shown in Figure 16.10.

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16.7 LOGIC GATES

Logic gates are the basic building blocks for forming digital electronic circuitry. A logic gate has one output terminal and one or more input terminals. Its output will be HIGH (1) or LOW (0) depending on the digital level(s) at the input terminal(s). Thus having the ability to perform a logical operation.

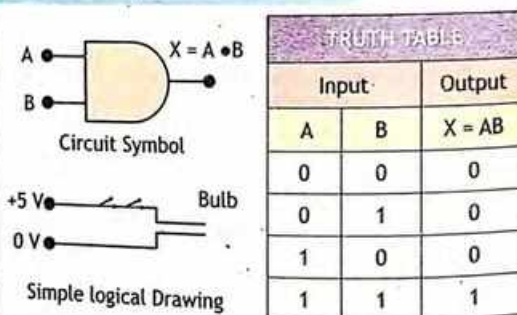
Proper understanding of logic circuits is vital for today's electrical and computer engineers. These circuits are the key ingredients of computers and are also used in many other applications. They are found in commonly-used products like music and video players, electronic games, digital watches, cameras, televisions, printers and many household appliances, as well as in large systems, such as telephone networks, internet equipment, television broadcast equipment, industrial control units, and medical instruments. In short, logic circuits are an important part of almost all modern products.

Digital logic circuits are simple. To depict algebraically the operation of a logic gate or a combination of logic gates, a **Boolean equation** is used. The operation of a logic gate or circuit can be represented in a table which contains all possible inputs and their corresponding outputs is called a **truth table**. The circuit symbols for the five basic logic gates AND, OR, NAND, NOR, and NOT gate (or inverter) are described below, along with their boolean equation and truth table.

AND GATE: The simplified AND gate has two inputs and will give high (1) output only if both inputs are high (1). In other words, if $A = 1$ AND $B = 1$, then $X = 1$. If either A or B or both are Low (0), the output will be Low (0). The Boolean equation for the AND function can

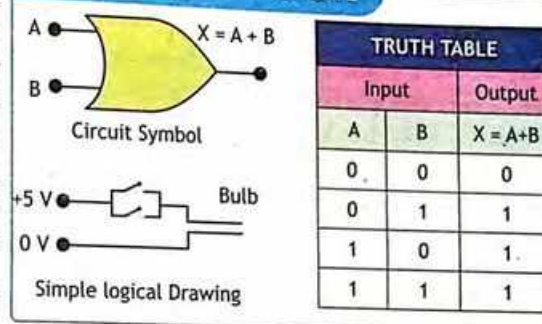
simply be written as $X = A \cdot B$ or just $X = AB$ (which is read as 'X equals A AND B'). AND gate performs the logical multiplication of the inputs. The circuit symbol for AND gate, its simple logical drawing and the truth table are shown in the figure 16.11.

Figure 16.11 - TWO INPUT AND GATE



OR gate: The simplified OR gate has two inputs and will give high (1) output at X whenever input A OR input B is HIGH or both are HIGH. As a Boolean equation, this can be written as $X = A + B$ (which is read as 'X equals A OR B'). Notice the use of the '+'

Figure 16.12 - TWO INPUT OR GATE

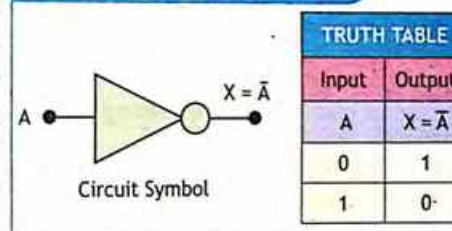


symbol to represent the OR function. OR gate performs the logical addition of inputs, the circuit symbol for two input OR gate, its simple logical drawing and truth table are shown in the figure 16.12.

NOT gate: NOT gate is used to complement or invert a digital signal therefore, it is also called inverter. It has a single input and a single output. If a High level (1) comes in, it produces a Low-level (0) output. If a Low level (0) comes in, it produces a High-level (1) output.

Figure 16.13 - NOT GATE (Inverter)

The symbol and truth table for the inverter gate are shown in Figure 16.13. The Boolean equation for an inverter is written $X = \bar{A}$ ($X = \text{NOT } A$). The bar over the A is an inversion bar, used to signify the complement.



NAND gate: The operation of the NAND gate is the same as the AND gate except that its output is inverted. You can think of a NAND gate as an AND gate with an inverter at its output. The symbol for a NAND gate is made from an AND gate with the inversion circle (bubble) at its output is shown in figure 16.14.

LAB WORK

To verify the truth table of OR, AND, NOT, NOR and NAND gates.
To make a burglar alarm/fire alarm using an appropriate gate.

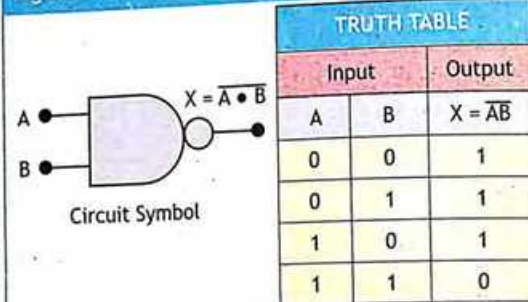
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The Boolean equation for the NAND gate is written $X = \overline{AB}$. The inversion bar is drawn over (A and B), meaning that the output of the NAND is the complementation of inputs (A and B) [NOT (A and B)].

Because we are inverting the output, the truth table outputs will be the complement of the AND gate truth table outputs. From truth table we can see that the output is low (0) when both inputs A and B are high (1). Also, the output is high (1) whenever either input is low (0).

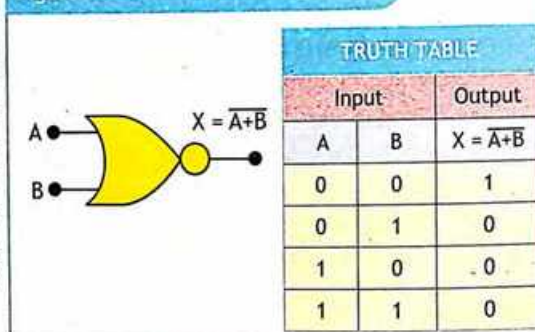
Figure 16.14 - TWO INPUT NAND GATE



NOR gate: The operation of the NOR gate is the same as that of the OR gate except that its output is inverted.

We can think of a NOR gate as an OR gate with an inverter at its output. The symbol for a NOR gate and truth table is shown in figure 16.15. The Boolean equation for the NOR function is $X = \overline{A + B}$. The equation is stated 'X equals not (A or B).'

Figure 16.15 - TWO INPUT NOR GATE

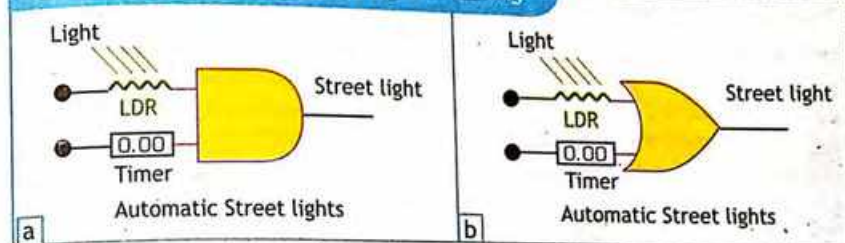


In other words, X is low (0) if A or B is high (1). Notice that the output column in the truth table is the complement of the OR gate truth table output column.

16.7.1 Uses of logic gates: Equipment and devices could be turned on and off automatically by using logic gates and their combinations.

(a) Automatic light bulb switching: If you desire to automatically switch the street lights on and off, after appropriate time and light level, you can use an AND gate.

Figure 16.16 - Automatic Street light switching

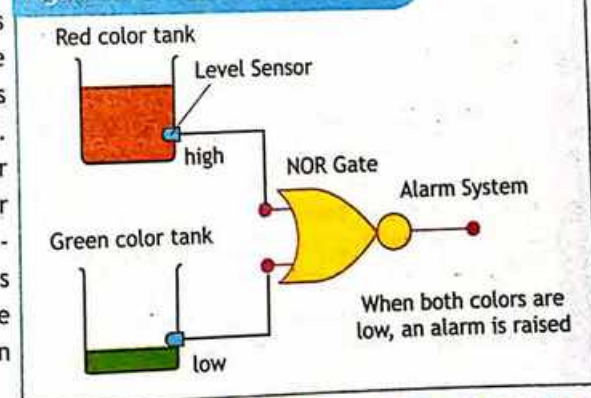


During day when light shines on Light Dependent Resistor (LDR), the resistance is high and current in the wire is low (0). In the evening when light fades out, the resistance of LDR decreases and it starts conducting and turns to high (1). But the light will not glow until the timer time is not reached after which it would also turn high (1). When both the terminals are high the street light will turn up. The schematic representation is shown in the figure 16.16 (a). On the other hand if we want to turn the light on when either light is low or timer time is reached, we can use an OR gate, as shown in figure 16.16 (b).

(b) Textile coloring plant: A textile coloring plant uses two tanks to store red color and green color. Each tank has a sensor that detects when the color level drops to 25% of full. The sensors produce a high level of 5 V when the tanks are more than one-quarter full. When the volume of color in a tank drops to one-quarter full or less, the sensor puts out a low level of 0 V. Manufacturer requires that an alarm is raised when both tanks are more than one-quarter empty. A NOR gate with its two

inputs connected to the tank level sensors and its output connected to the indicator alarm system is shown in figure 16.17. Such that if red color tank and green color tank are above one-quarter full, the signal is low (0 V), even if one tank reduces to less than 25% of full.

Figure 16.17 - Color level indicator



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As soon as both sensor outputs are low (0 V), indicating that both tanks are less than one-quarter full, the NOR gate output is high (5 V) and alarm is raised.

Here NAND gate circuitry can be used to indicate by a green light that both tanks are full.

Thermionic Emission: Temperature induced electron ejection.

Electron Gun: Source of focussed and accelerated electron beam (cathode rays).

Deflection of electron beam in electric and magnetic field: Electron beam is deflected in electric and magnetic field.

CRO: Cathode Ray Oscilloscope (CRO) is composed of electron gun, deflecting plates and florescent screen enclosed in an evacuated chamber. CRO works on the principle of deflection of electron beam in electric and magnetic field. CRO is used to

- estimate small intervals
- displays waveform of voltage and current

Analogue quantities and signals: Quantity having continuous values. Therefore, an analogue signal is a continuously variable electrical or physical quantity.

Digital quantities and signals: Quantity having discrete values that represent numbers, letters or symbols. Therefore digital signal deals strictly with ON and OFF states, which we can represent by 0s and 1s.

Logic gates: Basic building blocks for forming digital electronic circuitry.

Boolean equation: Algebraic depiction of the operation of a logic gate or a combination of logic gates.

Truth table: Table which contains all possible inputs and their corresponding outputs.

GROUP A 'AUTOMATIC WATER PUMP': Design logic circuit for automatic water pump. Pump will operate if there is an insufficient amount of water in the tank on the roof of house and sufficient amount of water in the well inside the house. Prepare a chart and present your finding to the class.

GROUP B 'AUTOMATIC FRONT GATE LIGHTING SYSTEM': What types of logic gates can you use to build an automatic lighting mechanism at front gate of your house. Identify the sensors required and the logic gates when a lamp outside your home front gate comes on automatically when it is dark and someone stands on the doormat outside the front door. Prepare a chart and give a brief presentation to your class fellows.

GROUP C 'CHART MAKING': Prepare a chart of symbols and corresponding truth table for NOT, OR, AND, NOR and NAND gates to be displayed in your classroom.

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GROUP D 'CRT': CRT technology is replaced with LED and LCD technology for television screens. Identify the main reason behind this shift. Also discuss where the research is still progressing in CRT technology. Document your finding in an article for your school magazine.

GROUP E 'TECHNOLOGY AND ELECTRONICS': Write an essay for your school magazine that modern world is the world of digital electronics. Identify by quoting examples that electronics is shifting from low-tech electrical appliances to high-tech electronic appliances. And that computers are the forefront of electronic technology.

EXERCISE

- MULTIPLE CHOICE QUESTIONS**
- ① Cathode rays are beam of
A. protons B. electrons C. ions D. neutrons
 - ② If electric field is applied parallel to the direction of electron beam, the electrons will
A. speed up B. slow down C. deflect D. not change its state
 - ③ If magnetic field is applied parallel to the direction of electron beam, the electrons will
A. speed up B. slow down C. deflect D. not change its state
 - ④ The electronic circuit that gives high (1) output when all its input are high (1) is called _____ gate.
A. AND B. OR C. NAND D. NOR
 - ⑤ The electronic circuit that gives high (1) output when one or more of its input are high (1) is called _____ gate.
A. AND B. OR C. NAND D. NOR
 - ⑥ The electronic circuit that gives low (0) output when all its input are high (1) is called _____ gate.
A. AND B. OR C. NAND D. NOR
 - ⑦ The electronic circuit that gives low (0) output when one or more of its input are high (1) is called _____ gate.
A. AND B. OR C. NAND D. NOR
 - ⑧ The Boolean equation for OR gate is
A. $X = AB$ B. $X = A + B$ C. $X = \overline{A}\overline{B}$ D. $X = \overline{A+B}$
 - ⑨ The Boolean equation for NAND gate is
A. $X = AB$ B. $X = A + B$ C. $X = \overline{A}\overline{B}$ D. $X = \overline{A+B}$

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