Computer Science (Theory) for Class 11 (NEB)

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1. Computer System

1.1 Introduction of Computer

A computer is an electronic device, operating under the control of instructions stored in its own memory that can accept data (input), process the data according to specified rules, produce information (output), and store the information for future use.
The physical parts that make up a computer (the central processing unit, input, output, and memory) are called hardware. Programs that tell a computer what to do are called software. A set of instructions that perform a particular task is called a program, software program, or software. Peripherals are any hardware device connected to a computer, any part of the computer outside the CPU and working memory. Some examples of peripherals are keyboards, the mouse, monitors, printers, scanners, disk and tape drives, microphones, speakers, joysticks, plotters, and cameras. Computer is an advanced electronic device that takes raw data as input from the user and processes these data under the control of set of instructions (called program) and gives the result (output) and saves output for the future use. It can process both numerical and non-numerical (arithmetic and logical) calculations.

1.1.1 Definition, Characteristics and Application of Computer

Definition of Computer

A computer can be more accurately defined as an electronic device that takes data as input, stores and processes it and displays the output according to either the given instructions or the instructions stored in their memory unit.

The major characteristics of a computer can be classified into speed, accuracy, diligence, versatility, and memory which are as follows:

- Speed: The computer can process the data and give the output in fractions of seconds such that required information is given to the user on time enabling the user to take the right decisions at the right time. A powerful computer can execute about 3 million calculations per second.
- Accuracy: Inspire of its high speed of processing, the computers accuracy is consistently high enough which avoids any errors. If there are any errors, they are due to errors in instructions given by the programmer or input data.
- Versatility: The computer is versatile in nature in the sense of working and purpose. What that means is we can use the computer in any way we want. For example, if we need some graphics work, we can install the graphics software and we can design and accomplish our graphics work at the same time. Later if we need some report writing we can certainly install the word processing software and accomplish that also on the same computer we have used as a graphics designer. Similarly, we can do any work if the application for the same is available to us. That's why the computer is said to be versatile.
- Automation: Once the instructions are fed into the computer it works automatically without any human intervention until the completion of execution of program until meets logical instructions to terminate the job.
- Reliability: The output generated by the computer is very reliable, but it is reliable only when the data which is passing as input to the computer and the program, which gives instructions are correct and reliable.
- Diligence: A computer can perform millions of tasks or calculations with the same consistency and accuracy. It doesn't feel any fatigue or lack of concentration. Its memory also makes it superior to that of human beings.
- Storage: The computer has a provision to store large volumes of data in the small storage devices, which have the capacity to store huge amounts of data and help the retrieval of data an easy task.

1.1.2 Evolution of Computer Technology

The computer is well-known to us, the first counting device our ancestors used in the early decades. But also, before that, they utilized sticks, bones, and stones as their counting implements. As the evolution of the human mind and technology improved with time, the existence of more computing devices increased. In this section, we will get to know details on the History of computers and the Timeline according to the subsequent years.

First Computer Design

In the 19th century, a renowned Mathematician Charles Babbage developed and partly built a Victorian-era computer named the Analytical Engine. The fundamental component of the oldest machine was the input, having the programs and data that the user had to provide to the Analytical Machine through punched cards, a technique being employed at the time to handle mechanical looms like the Jacquard loom. The creation of the design of the Analytical Engine; was initiated by the year 1833. The computer was born not for amusement or email but out of a requirement to solve a complicated number-crunching crisis. By 1880, the U.S. population had expanded so vastly; that it bore more than seven years to tabulate the U.S. Census consequences. The government pursued a quicker method to acquire the job done, offering an upgrade to the punch-card-based computers that grabbed up total room space. From the 19th century to the present day, the role of the computer in its users' life is crucial. However, in today's generation, this computer may work a little differently and more advanced than in the 19th century. But it served the purpose it is to its users and remained the same. This tutorial describes various generations of computers in detail.

List of Five Generations of Computers

The journey of five generations of computers begins with vacuum tube circuitry from the 1940s and goes beyond the methods and approaches of artificial intelligence (AI) to the present day. These are as follows:

By the year 1940, Vacuum tubes, an electronic device that regulates the flow of electrons in a vacuum, were used. These were the first computer systems that the users utilized for circuitry and magnetic drums and were usually massive, capturing up an entire room. These computers were very costly to operate in the spare of employing a great deal of electricity. At that time, the most common computer language that the first-generation computers depended on was the machine language, the lowest-level programming language that the computers understood for executing operations. The UNIVAC and ENIAC computers are specimens of the first-generation computing devices.

Characteristics of First Generation of Computers

- The main electronic component of first-generation computers is the vacuum tubes.
- It operated in machine language.
- Its primary memories were the Magnetic tapes and magnetic drums.
- It employed its Input/output devices as Paper tape and punched cards.

Second Generation of Computers

In 1956, the technology of transistors replaced the bulkier generation of vacuum tubes. After the invention of these transistors, the dimensions of the computer also reduced. Second-generation computers evolved smaller in size compared to first-generation computers. Second-generation computers developed from enigmatic binary machine language to representational symbolic systems, or assembly languages, that authorized the programmers to appoint instructions in words or phrases. IBM1400 series, PDP-8, IBM 7090 and 7094, UNIVAC 1107, CDC 3600, etc., are a few examples of the Second-generation.

Characteristics of Second Generation of Computers

- The main electronic component of second-generation computers is electronic transistors.
- It operated in Machine language and assembly language.
- Its primary memories were the Magnetic core and magnetic tape or magnetic disk.
- Its Input/output devices were the Magnetic tape and punched cards.

Third Generation of Computers

This generation started developing integrated circuits in 1964. Instead of using punch cards and printouts, users were able to interact with third-generation computers via keyboards and monitors and interfaced with an operating system. For the first time, computers reached a mass audience, as they were smaller and cheaper than the past prototypes. Jack Kilby of Texas Instruments and Robert Noyce of Fairchild Semiconductor developed integrated circuits by 1950.

Characteristics of Third Generation Computers

- The main electronic component of third-generation computers is integrated circuits.
- It operated in High-level language.
- Its primary memories were the large magnetic core and magnetic tape/disk.
- Its Input/output devices were the Magnetic tape, monitor, keyboard, printer, etc.

By 1971, users operated the first microprocessors, the Large-Scale Integration (LSI) circuits created on one chip called microprocessors. The microprocessor was conducted in the fourth generation of computers, as developers built thousands of integrated circuits onto a single silicon chip. What if the first generation served an entire room that could currently accommodate within a palm? The Intel 4004 chip, developed in 1971, located all the computer components from the Central Processing Unit and memory to input or output authorities on a single chip.

Characteristics of Fourth Generation of Computers

- The main electronic component of fourth-generation computers is Very Large-Scale Integration (VLSI) and the microprocessor (VLSI contains thousands of transistors inside a single microchip).
- It operated in High-level language.
- Its primary memories were the semiconductor memory (mainly RAM, ROM, etc.)
- Its Input/output devices were the pointing devices, optical scanning, keyboard, monitor, printer, etc.

Fifth Generation of Computers

The technology on which the fifth generation of computers relies is AI. It authorizes computers to conduct like humans. Today's computers are so developed; that the users utilize them in every distinct field, primarily accounting, constructing buildings, space research, engineering technologies, and other types of analysis. The principal purpose of fifth-generation computing is to create devices that react to natural language input, competent in learning and self-organizing.

Characteristics of Fifth Generation of Computers

- The main electronic component of fourth-generation computers is Ultra Large-Scale Integration (ULSI) and the parallel processing technique.
- It operated in natural human language.
- Its Input/output devices were the Trackpad, touch screen, pen, speech input, light scanner, etc.

1.1.3 Measurement unit of processing speed and storage unit

The central processing unit (CPU) of a computer is the part of the machine that retrieves and executes instructions. An arithmetic and logic unit (ALU), a control unit, and multiple registers make up the system. The processor is a common term for the central processing unit (CPU). These are also called the unit of electromagnetic (EM) wave frequency.

The different measurement units and their relationship are as follows:
1,000 Hz = 1 Kilo Hertz (103 Hz)
1,000 KHz = 1 Mega Hertz (106 Hz)
1,000 MHz= 1 Giga Hertz (109 Hz)
1,000 GHz= 1 Tera Hertz (1012 Hz)

The size of the device in computers does not reflect the space available to store data in it. There are larger devices that can store only a few data were as many tiny devices as possible that store an unbelievable amount of data. It is also one type of measurement unit. Hence, we need to find some other way to measure space. All the digital computers use binary numbering systems (though there are some exceptions). The binary numbering system consists of only two digits – 0 and 1 to represent any quantity. 10 in binary is equal to the 2 and 100 to 5. Everything in computers is represented in strings of binary numbers. For example, capital A is interpreted by the computer as 0100 0001 and B is 0100 0010. All characters, numbers, symbols, images, sounds, animations, videos, and everything is converted into suitable binary code to store on a computer or processed by computer. So, if there is any device that can store one binary digits is called a nibble (4 bits = 1 Nibble). Similarly, a group of 8 bits is called a byte (1 byte = 8 bits). As you have seen in the example above, each character requires 8 bits which are 1 byte. So, 1 character requires 1-byte space. Now, if you have a text file whose size is 32 bytes, it means there are 32 x 8 binary digits (0s and 1s) stored in it. Following table lists the different units and their values:

Storage Measurement Units	Units Equivalent
0 or 1	1 Bit
4 Bits	1 Nibble
8 Bits	1 Byte
1024 Bytes	1 Kilobyte (KB)
1024 Kilobytes	1 Megabyte (MB)
1024 Megabytes	1 Gigabyte (GB)
1024 Gigabytes	1 Terabyte (TB)
1024 Terabytes	1 Petabyte (PB)
1024 Petabytes	1 Exabyte (EB)

1.1.4 Super, Mainframe, Mini and Microcomputers

Super Computer

They are the most expensive of all the computers. These computers are big general-purpose computers capable of executing more than 10,000 million instructions per second and have storage capacities of millions of bits per chip. These computers are used to solve multi- variate mathematical problems such as atomic nuclear and plasma physics seismology, aerodynamics etc. Supercomputers are typically capable of handling hundreds of millions of floating points operations per second (MFLOPS). The speed of super computers generally measured in “FLOPS” (Floating Point Operations Per Second). Super computers are used for highly calculation- intensive tasks such as weather forecasting, climate research, molecular modeling, physical simulation, and cryptanalysis and military and Scientific agencies are heavy users. Some super computers are – Cray 1, Cray 2, Cray 3 perform 10 billion operation per second, Param, Cyber 810&830 etc.

Mainframe Computer

They are very big in size and offer the maximum computing power. Many peripherals can be attached to them. They are generally used in large networks of computers with the mainframe being the model point of the network. They used satellites for networking. A typical application is the airline system. It has a mainframe computer at their head office where information on all the fights is stored. Small computers are installed at the booking offices are attached to central data bank, so that up-to-date information of all flights is always available. Some computers are – Univac 1100/10, Univac 1100/60, Honeywell DSP 88/860, IBM 270/168 etc.

They are smaller versions of the mainframes. Generally, they offer the same computing power as bigger counterparts. The most important advantage of a minicomputer over the main frame is that it is cheaper in cost, smaller in size and reliable. It does not require air conditioning and can be operated in room temperature. Main used of these systems is in education in local government word processing etc. in business they are being used for involving stock payroll etc. it is generally used as server system on networks with personal computers as nodes. Some typical machines– TDC 316, PDP 11/70, Honeywell (XPS-100), HCL-4.

Micro Computer

A microcomputer is a computer whose CPU is a microprocessor. A microprocessor is a processor all whose components are on a single integrated circuit chip. Personal computers are a kind of kind of microcomputer. Personal computers are called so because they are designed for personal use of individual or individual small business units' office automation unit or professionals. Pc can be used for variety of applications like computer literacy, fun and games, business applications, programming etc. Types of Micro Computer or personal computers

- Desktop Computer
- Laptop Computer
- Palmtop Computer, Digital Diary, Notebook, PDAs.

1.1.5 Mobile Computing and it's Application

Mobile computing is human–computer interaction in which a computer is expected to be transported during normal usage, which allows for the transmission of data, voice, and video. Mobile computing involves mobile communication, mobile hardware, and mobile software. Communication issues include ad hoc networks and infrastructure networks as well as communication properties, protocols, data formats, and concrete technologies. Hardware includes mobile devices or device components. Mobile software deals with the characteristics and requirements of mobile applications: -

Main Principles –

- Portability: Devices/nodes connected within the mobile computing system should facilitate mobility. These devices may have limited device capabilities and limited power supply but should have a sufficient processing capability and physical portability to operate in a movable environment.
- Connectivity: This defines the quality of service (QoS) of the network connectivity. In a mobile computing system, the network availability is expected to be maintained at a high level with a minimal amount of lag/downtime without being affected by the mobility of the connected nodes.
- Interactivity: The nodes belonging to a mobile computing system relate to one another to communicate and collaborate through active transactions of data.
- Individuality: A portable device or a mobile node connected to a mobile network often denotes an individual; a mobile computing system should be able to adopt the technology to cater to the individual needs and to obtain contextual information of each node.

1.2 Computer System and IO Devices

1.2.1 Concept of Computer Architecture and Organization

Architecture in the computer system, same as anywhere else, refers to the externally visual attributes of the system. That's why Computer Organization and Architecture is the study of internal working, structuring, and implementation of a computer system.

All computers, no matter their size, are based around a set of rules stating how software and hardware join together and interact to make them work. This is what is known as computer architecture. In this article we're going to delve into what computer architecture actually is.

Computer architecture is the organisation of the components which make up a computer system and the meaning of the operations which guide its function. It defines what is seen on the machine interface, which is targeted by programming languages and their compilers.

1.2.2 Components of Computer System: Input unit, Output unit, Processing unit, Memory unit and Storage

A computer comprises of some basic elements. These include hardware, software, programmes, data and connectivity. No computer can function in the absence of these elements. Apart from these elements, a computer system comprises of three basic components. These components are responsible for making computers actually function. Let's take a look at them in detail.

Every computer system has the following three basic components:

- Input unit
- Central processing unit
- Output unit

While there are other components as well, these three are primarily responsible for making a computer function. They must work in complete synergy because that will ensure smooth overall functioning. Hence, we can even call them building blocks of a computer system.

Input Unit: These components help users enter data and commands into a computer system. Data can be in the form of numbers, words, actions, commands, etc. The main function of input devices is to direct commands and data into computers. Computers then use their CPU to process this data and produce output.

For example, a laptop's keyboard is an input unit that enters numbers and characters. Similarly, even a mouse can be an input unit for entering directions and commands. Other examples include barcode readers, Magnetic Ink Character Readers (MICR), Optical Character Readers (OCR), etc.

Output Unit The third and final component of a computer system is the output unit. After processing of data, it is converted into a format which humans can understand. After conversion, the output units displays this data to users.
Examples of output devices include monitors, screens, printers and speakers. Thus, output units basically reproduce the data formatted by the computer for users' benefit.

Central Processing Unit (CPU) After receiving data and commands from users, a computer system now has to process it according to the instructions provided. Here, it has to rely on a component called the central processing unit. The CPU further uses these three elements:

1. Memory Unit

   Once a user enters data using input devices, the computer system stores this data in its memory unit. This data will now remain here until other components of CPU process it. The memory unit uses a set of pre-programmed instructions to further transmit this data to other parts of the CPU.

2. Arithmetic and Logic Unit

   This part of the CPU performs arithmetic operations. It does basic mathematical calculations like addition, subtraction, division, multiplication, etc. Further, it can even perform logical functions like the comparison of data.

3. Control Unit

control unit collects data from input units and sends it to processing units depending on its nature. Finally, it also further transmits processed data to output units for users.

1.2.3 Microprocessor: basic concepts, clock speed, word length, components and functions

A Microprocessor is an important part of a computer architecture without which you will not be able to perform anything on your computer. It is a programmable device that takes in input performs some arithmetic and logical operations over it and produces the desired output. In simple words, a Microprocessor is a digital device on a chip that can fetch instructions from memory, decode and execute them and give results.

Basics of Microprocessor – A Microprocessor takes a bunch of instructions in machine language and executes them, telling the processor what it has to do. Microprocessor performs three basic things while executing the instruction:

- It performs some basic operations like addition, subtraction, multiplication, division, and some logical operations using its Arithmetic and Logical Unit (ALU). New Microprocessors also perform operations on floating-point numbers also.
- Data in microprocessors can move from one location to another.
- It has a Program Counter (PC) register that stores the address of the next instruction based on the value of the PC, Microprocessor jumps from one location to another and takes decisions.

Clock Speed Every microprocessor has an internal clock that regulates the speed at which it executes instructions and also synchronizes it with other components. The speed at which the microprocessor executes instructions is called clock speed. Clock speeds are measured in MHz or GHz where 1 MHz means 1 million cycles per second whereas 1 GHz equals to 1 billion cycles per second. Here cycle refers to single electric signal cycle.

Currently microprocessors have clock speed in the range of 3 GHz, which is maximum that current technology can attain. Speeds more than this generate enough heat to damage the chip itself. To overcome this, manufacturers are using multiple processors working in parallel on a chip.

Word Size or Word length Number of bits that can be processed by a processor in a single instruction is called its word size. Word size determines the amount of RAM that can be accessed at one go and total number of pins on the microprocessor. Total number of input and output pins in turn determines the architecture of the microprocessor.

First commercial microprocessor Intel 4004 was a 4-bit processor. It had 4 input pins and 4 output pins. Number of output pins is always equal to the number of input pins. Currently most microprocessors use 32-bit or 64-bit architecture.

Microprocessor Components Compared to the first microprocessors, today's processors are very small but still they have these basic parts right from the first model –

- CPU
- Bus
- Memory

CPU CPU is fabricated as a very large scale integrated circuit (VLSI) and has these parts −

Instruction register − It holds the instruction to be executed.

Decoder − It decodes (converts to machine level language) the instruction and sends to the ALU (Arithmetic Logic Unit).

ALU − It has necessary circuits to perform arithmetic, logical, memory, register and program sequencing operations.

Register − It holds intermediate results obtained during program processing. Registers are used for holding such results rather than RAM because accessing registers is almost 10 times faster than accessing RAM.

microprocessor

Data Bus – Lines that carry data to and from memory are called data bus. It is a bidirectional bus with width equal to word length of the microprocessor.

Address Bus – It is a unidirectional responsible for carrying address of a memory location or I/O port from CPU to memory or I/O port.

Control Bus – Lines that carry control signals like clock signals, interrupt signal or ready signal are called control bus. They are bidirectional. Signal that denotes that a device is ready for processing is called ready signal. Signal that indicates to a device to interrupt its process is called an interrupt signal.

Memory Microprocessor has two types of memory

RAM – Random Access Memory is volatile memory that gets erased when power is switched off. All data and instructions are stored in RAM.

ROM – Read Only Memory is non-volatile memory whose data remains intact even after power is switched off. Microprocessor can read from it any time it wants but cannot write to it. It is preprogrammed with most essential data like booting sequence by the manufacturer.

Functions Among various functions of microprocessor some are as follows

- Controlling all other parts of the machine and sending timing signals.
- Transferring data between memory and I/O devices
- Fetching data and instructions from memory
- Decoding instruction
- Performing arithmetical and logical operations
- Executing programs stored in memory
- Performing communication among the I/O devices etc.

1.2.4 Bus System: data bus, address bus and control bus

The electrically conducting path along which data is transmitted inside any digital electronic device. A Computer bus consists of a set of parallel conductors, which may be conventional wires, copper tracks on a PRINTED CIRCUIT BOARD, or microscopic aluminum trails on the surface of a silicon chip. Each wire carries just one bit, so the number of wires determines the largest data WORD the bus can transmit: a bus with eight wires can carry only 8- bit data words, and hence defines the device as an 8-bit device.

- The bus is a communication channel.
- The characteristic of the bus is shared transmission media.
- The limitation of a bus is only one transmission at a time.
- A bus which is used to provide communication between the major components of a computer is called a System bus.

Data Bus A data bus is a computer subsystem that carries the data between the processor and other components. The data bus is bidirectional that allows for the transferring of data from one component to another within a computer system or between two computers.

This can include transferring data to and from the memory, or from the central processing unit (CPU) to other components. Each one is designed to handle so many bits of data at a time. It is the main part of a system bus that allows the actual transmission of data.

A typical data bus is 32-bits wide. This means that up to 32 bits of data can travel through a data bus every second. Newer computers are making data buses that can handle 64-bit and even 128-bit data paths. At the same time, they are making data buses to handle more bits and can handle those higher bitrates.

such as primary storage to input/output devices.

The address bus is unidirectional. It is used to transfer data between devices that are identified by the hardware address of the physical memory (the physical address), which is stored in the form of binary numbers to enable the data bus to access memory storage.

The address bus is used by the CPU or direct memory access (DMA) enabled device to locate the physical address to communicate read/write commands. All address busses are read and written by the CPU or DMA in the form of bits.

Control Bus A control bus is a computer bus that is used to carries control signals from the processor to other components. It also carries the clock's pulses which are used by the CPU to communicate with devices that are contained within the computer.

In the computer system, the CPU transmits a variety of control signals to components and devices. This occurs through physical connections such as cables or printed circuits.

The control bus is bidirectional and is comprised of interrupt lines, byte enables lines, read/write signals, and status lines.

After data being processed, the control bus carries commands from the CPU and returns status signals from the devices. For example, if the data is being read or written to the device, the appropriate line (read or write) will be active (i.e. logic one).

1.2.5 Primary Memory:

Primary memory is a segment of computer memory that can be accessed directly by the processor. In a hierarchy of memory, primary memory have access time less than secondary memory and greater than cache memory. Generally, primary memory has a storage capacity lesser than secondary memory and greater than cache memory.

This organization of memory in a stepwise manner is known as Memory Hierarchy.

Classification of Primary Memory Primary memory can be broadly classified into two parts:

- Read-Only Memory (ROM)
- Random Access Memory (RAM)

Read-Only Memory Any data which need not be altered are stored in ROM. ROM includes those programs which run on booting of the system (know as a bootstrap program that initializes OS) along with data like algorithm required by OS. Anything stored in ROM cannot be altered or changed.

Types of ROM:

ROM can be broadly classified into 4 types based on their behavior:

- MROM: Masked ROM are hardwired and pre-programmed ROM. Any content that is once written cannot be altered anyhow.
- PROM: Programmable ROM can be modified once by the user. The user buys a blank PROM and writes the desired content but once written content cannot be altered.
- EPROM: Erasable and Programmable ROM Content can be changed by erasing the initial content which can be done by exposing EPROM to UV radiation. This exposure to ultra-violet light dissipates the charge on ROM and content can be rewritten on it.
- EEPROM: Electrically Erasable and Programmable ROM Content can be changed by erasing the initial content which could be easily erased electrically. However, one byte can be erased at a time instead of deleting in one go. Hence, reprogramming of EEPROM is a slow process.

Random Access Memory Any process in the system which needs to be executed is loaded in RAM which is processed by the CPU as per Instructions in the program. Like if we click on applications like Browser, firstly browser code will be loaded by the Operating system into the RAM after which the CPU will execute and open up the Browser.

Types of RAM:

RAM can be broadly classified into SRAM (Static RAM) and DRAM (Dynamic RAM) based on their behavior:

transistors and electric charge leaks from capacitors and DRAM needs to be charged periodically. DRAM is widely used in home PCs and servers as it is cheaper than SRAM.

- SRAM: Static RAM or SRAM keeps the data as long as power is supplied to the system. SRAM uses Sequential circuits like a flip-flop to store a bit and hence need not be periodically refreshed. SRAM is expensive and hence only used where speed is the utmost priority.

Cache Memory A faster and smaller segment of memory whose access time is as close as registers are known as Cache memory. In a hierarchy of memory, cache memory has access time lesser than primary memory. Generally, cache memory is very smaller and hence is used as a buffer.

Data in primary memory can be accessed faster than secondary memory but still, access times of primary memory are generally in few microseconds, whereas CPU is capable of performing operations in nanoseconds. Due to the time lag between accessing data and acting of data performance of the system decreases as the CPU is not utilized properly, it may remain idle for some time. In order to minimize this time gap new segment of memory is Introduced known as Cache Memory.

Buffer In computer science, a data buffer (or just buffer) is a region of a memory used to temporarily store data while it is being moved from one place to another. Typically, the data is stored in a buffer as it is retrieved from an input device (such as a microphone) or just before it is sent to an output device (such as speakers). However, a buffer may be used when moving data between processes within a computer. This is comparable to buffers in telecommunication. Buffers can be implemented in a fixed memory location in hardware—or by using a virtual data buffer in software, pointing at a location in the physical memory. In all cases, the data stored in a data buffer are stored on a physical storage medium. A majority of buffers are implemented in software, which typically use the faster RAM to store temporary data, due to the much faster access time compared with hard disk drives. Buffers are typically used when there is a difference between the rate at which data is received and the rate at which it can be processed, or in the case that these rates are variable, for example in a printer spooler or in online video streaming. In the distributed computing environment, data buffer is often implemented in the form of burst buffer that provides distributed buffering service.

1.2.6 Secondary Memory:

You know that processor memory, also known as primary memory, is expensive as well as limited. The faster primary memory are also volatile. If we need to store large amount of data or programs permanently, we need a cheaper and permanent memory. Such memory is called secondary memory. Here we will discuss secondary memory devices that can be used to store large amount of data, audio, video and multimedia files.

Characteristics of Secondary Memory These are some characteristics of secondary memory, which distinguish it from primary memory −

- It is non-volatile, i.e. it retains data when power is switched off
- It is large capacities to the tune of terabytes
- It is cheaper as compared to primary memory

Depending on whether secondary memory device is part of CPU or not, there are two types of secondary memory − `fixed` and `removable`.

Magnetic Disk A magnetic Disk is a type of secondary memory that is a flat disc covered with a magnetic coating to hold information. It is used to store various programs and files. The polarized information in one direction is represented by 1, and vice versa. The direction is indicated by 0.

Magnetic disks are less expensive than RAM and can store large amounts of data, but the data access rate is slower than main memory because of secondary memory. Data can be modified or can be deleted easily in the magnetic disk memory. It also allows random access to data.

Hard Disk Drive Hard disk drive is made up of a series of circular disks called platters arranged one over the other almost ½ inches apart around a spindle. Disks are made of non-magnetic material like aluminum alloy and coated with 10-20 nm of magnetic material.

Standard diameter of these disks is 14 inches and they rotate with speeds varying from 4200 rpm (rotations per minute) for personal computers to 15000 rpm for servers. Data is stored by magnetizing or demagnetizing the magnetic coating. A magnetic reader arm is used to read data from and write data to the disks. A typical modern HDD has capacity in terabytes (TB).

Optical Drive CD stands for Compact Disk. CDs are circular disks that use optical rays, usually lasers, to read and write data. They are very cheap as you can get 700 MB of storage space for less than a dollar. CDs are inserted in CD drives built into CPU cabinet. They are portable as you can eject the drive, remove the CD and carry it with you. There are three types of CDs −

- CD-ROM (Compact Disk – Read Only Memory) − The data on these CDs are recorded by the manufacturer. Proprietary Software, audio or video are released on CD-ROMs.
- CD-R (Compact Disk – Recordable) − Data can be written by the user once on the CD-R. It cannot be deleted or modified later.
- CD-RW (Compact Disk – Rewritable) − Data can be written and deleted on these optical disks again and again.

DVD stands for Digital Video Display. DVD are optical devices that can store 15 times the data held by CDs. They are usually used to store rich multimedia files that need high storage capacity. DVDs also come in three varieties – read only, recordable and rewritable.

Flash Memory Flash Memory is a portable memory device that uses solid state memory rather than magnetic fields or lasers to record data. It uses a technology similar to RAM, except that it is nonvolatile. It is also called USB drive, key drive or flash memory or memo stick.

External storage More commonly called an external drive, external storage is storage that's not part of the internal parts (external) of a computer. These drives often connect to the computer using USB, eSATA, or FireWire connection

1.2.7 Input Devices:

In computing, an input device is a piece of equipment used to provide data and control signals to an information processing system, such as a computer or information appliance. Examples of input devices include keyboards, mouse, scanners, cameras, joysticks, and microphones.

Keyboard A keyboard is a human interface device which is represented as a layout of buttons. Each button, or key, can be used to either input an alphanumeric character to a computer, or to call upon a particular function of the computer. It acts as the main text entry interface for most users. Keyboards are available in many form factors, depending on the use case. Standard keyboards can be categorized by its size and number of keys, and the type of switch it employs. Other keyboards cater to specific use cases, such as a numeric keypad or a keyer. Desktop keyboards are typically large, often have full key travel distance, and features such as multimedia keys and a numeric keypad. Keyboards on laptops and tablets typically compromise on comfort to achieve a thin figure.

Mouse A Mouse allows a user to input spatial data to a computer. It is commonly used as a simple and intuitive way to select items on a computer screen on a graphical user interface (GUI), either by moving a mouse pointer, or, in the case of a touch screen, by physically touching the item on screen. Common pointing devices include mouse, touchpads, and touch screens.

Whereas mouse operate by detecting their displacement on a surface, analog devices, such as 3D mouse, joysticks, or pointing sticks, function by reporting their angle of deflection.

Scanner scanner, also called optical scanner, computer input device that uses a light beam to scan codes, text, or graphic images directly into a computer or computer system. Bar-code scanners are used widely at point-of-sale terminals in retail stores. A handheld scanner or bar-code pen is moved across the code, or the code itself is moved by hand across a scanner built into a checkout counter or other surface, and the computer stores or immediately processes the data in the bar code. After identifying the product through its bar code, the computer determines its price and feeds that information into the cash register. Optical scanners are also used in fax machines and to input graphic material directly into personal computers. Flatbed scanners have a top that lifts up, and the operator has to change manually the materials being scanned. Sheetfed scanners can be loaded with multiple loose pages, which are passed over the scanner by rollers.

Light Pen A light pen is a light-sensitive computer input device, basically a stylus, that is used to select text, draw pictures and interact with user interface elements on a computer screen or monitor. The light pen works well with CRT monitors because of the way such monitors scan the screen, which is one pixel at a time, giving the computer a way to keep track of the expected scanning time by the electron beam and infer the pen’s position based on the latest timestamp of the scanning.

collecting data from "fill-in-the-bubble" types of questions on student tests, surveys, ballots, assessments, evaluations, and many other types of forms. OMR can be confused with other types of recognition including: OCR (Optical Character Recognition) – reading machine printed characters, and ICR (Intelligent Character Recognition) – reading handwritten characters

Optical Mark Recognition enables the respondent to select an answer to a question by filling in a "bubble" or "mark" associated with an answer choice. For instance, in the image on the right the respondent selected Excellent in a box to indicate that the location was Excellent.

OCR Optical character recognition or optical character reader (OCR) is the electronic or mechanical conversion of images of typed, handwritten or printed text into machine-encoded text, whether from a scanned document, a photo of a document, a scene-photo (for example the text on signs and billboards in a landscape photo) or from subtitle text superimposed on an image (for example: from a television broadcast).

Widely used as a form of data entry from printed paper data records – whether passport documents, invoices, bank statements, computerized receipts, business cards, mail, printouts of static-data, or any suitable documentation – it is a common method of digitizing printed texts so that they can be electronically edited, searched, stored more compactly, displayed on-line, and used in machine processes such as cognitive computing, machine translation, (extracted) text-to-speech, key data and text mining. OCR is a field of research in pattern recognition, artificial intelligence and computer vision.

language which is Business Card Reader in software and in computer assembly language that is Backspace card reader. BCR stands for Barcode Reader for laptop enter devices. Barcodes are an aggregate of black and white strains. These strains comprise numbers and dates that may be effortlessly studied via the means of a barcode scanner. And these records may be effortlessly entered into your laptop. This is machine-readable code withinside the shape of numbers and strains, which might be basically parallel and are published on all merchandise. Barcode structures have been validated to be very beneficial in all businesses. With the assistance of those huge corporations, costs and stock tiers in their merchandise may be leveled and tracked.

Widely used as a form of data entry from printed paper data records – whether passport documents, invoices, bank statements, computerized receipts, business cards, mail, printouts of static-data, or any suitable documentation – it is a common method of digitizing printed texts so that they can be electronically edited, searched, stored more compactly, displayed on-line, and used in machine processes such as cognitive computing, machine translation, (extracted) text-to-speech, key data and text mining. OCR is a field of research in pattern recognition, artificial intelligence and computer vision.

MICR Scanner Magnetic ink character recognition code, known in short as MICR code, is a character recognition technology used mainly by the banking industry to streamline the processing and clearance of cheques and other documents. MICR characters are printed on documents in one of the two MICR fonts, using magnetizable (commonly known as magnetic) ink or toner, usually containing iron oxide. In scanning, the document is passed through a MICR reader, which performs two functions: magnetization of the ink, and detection of the characters. The characters are read by a MICR reader head, a device similar to the playback head of a tape recorder. As each character passes over the head, it produces a unique waveform that can be easily identified by the system.

MICR readers are the primary tool for cheque sorting and are used across the cheque distribution network at multiple stages. For example, a merchant will use a MICR reader to sort cheques by bank and send the sorted cheques to a clearing house for redistribution to those banks. Upon receipt, the banks perform another MICR sort to determine which customer's account is charged and to which branch the cheque should be sent on its way back to the customer. However, many banks no longer offer this last step of returning the cheque to the customer. Instead, cheques are scanned and stored digitally. Sorting of cheques is done as per the geographical coverage of banks in a nation.

Touch Screen A touchscreen or touch screen is the assembly of both an input ('touch panel') and output ('display') device. The touch panel is normally layered on the top of an electronic visual display of an information processing system. The display is often an LCD, AMOLED or OLED display while the system is usually used in a laptop, tablet, or smartphone. A user can give input or control the information processing system through simple or multi-touch gestures by touching the screen with a special stylus or one or more fingers.[1] Some touchscreens use ordinary or specially coated gloves to work while others may only work using a special stylus or pen. The user can use the touchscreen to react to what is displayed and, if the software allows, to control how it is displayed; for example, zooming to increase the text size.

Microphone A microphone, colloquially called a mic or mike is a transducer that converts sound into an electrical signal. Microphones are used in many applications such as telephones, hearing aids, public address systems for concert halls and public events, motion picture production, live and recorded audio engineering, sound recording, two-way radios, megaphones, and radio and television broadcasting. They are also used in computers for recording voice, speech recognition, VoIP, and for other purposes such as ultrasonic sensors or knock sensors.

Several types of microphone are used today, which employ different methods to convert the air pressure variations of a sound wave to an electrical signal. The most common are the dynamic microphone, which uses a coil of wire suspended in a magnetic field; the condenser microphone, which uses the vibrating diaphragm as a capacitor plate; and the contact microphone, which uses a crystal of piezoelectric material. Microphones typically need to be connected to a preamplifier before the signal can be recorded or reproduced.

Digital Camera A digital camera is a camera that captures photographs in digital memory. Most cameras produced today are digital, largely replacing those that capture images on photographic film. Digital cameras are now widely incorporated into mobile devices like smartphones with the same or more capabilities and features of dedicated cameras (which are still available). High-end, high-definition dedicated cameras are still commonly used by professionals and those who desire to take higher-quality photographs.

Digital and digital movie cameras share an optical system, typically using a lens with a variable diaphragm to focus light onto an image pickup device. The diaphragm and shutter admit a controlled amount of light to the image, just as with film, but the image pickup device is electronic rather than chemical. However, unlike film cameras, digital cameras can display images on a screen immediately after being recorded, and store and delete images from memory. Many digital cameras can also record moving videos with sound. Some digital cameras can crop and stitch pictures and perform other elementary image editing.

1.2.8 Output Devices:

An output device is any piece of computer hardware equipment which converts information into a human-perceptible form or, historically, into a physical machine-readable form for use with other non-computerized equipment. It can be text, graphics, tactile, audio, or video. Examples include monitors, printers, speakers, headphones, projectors etc.

Monitor (LCD, LED) A monitor is a standalone display commonly used with a desktop computer, or in conjunction to a laptop as an external display. The monitor is connected to the host through the use of a display cable, such as HDMI, DisplayPort, VGA, and more.

Older monitors use CRT technology, while modern monitors are typically flat panel displays using a plethora of technologies such as TFT-LCD, LED, OLED, and more.

LCD

A liquid-crystal display (LCD) is a flat-panel display or other electronically modulated optical device that uses the light-modulating properties of liquid crystals combined with polarizers. Liquid crystals do not emit light directly but instead use a backlight or reflector to produce images in color or monochrome. LCDs are available to display arbitrary images (as in a general-purpose computer display) or fixed images with low information content, which can be displayed or hidden. For instance: preset words, digits, and seven-segment displays, as in a digital clock, are all good examples of devices with these displays. They use the same basic technology, except that arbitrary images are made from a matrix of small pixels, while other displays have larger elements. LCDs can either be normally on (positive) or off (negative), depending on the polarizer arrangement. For example, a character positive LCD with a backlight will have black lettering on a background that is the color of the backlight, and a character negative LCD will have a black background with the letters being of the same color as the backlight. Optical filters are added to white on blue LCDs to give them their characteristic appearance.

LED

A LED display is a flat panel display that uses an array of light-emitting diodes as pixels for a video display. Their brightness allows them to be used outdoors where they are visible in the sun for store signs and billboards. In recent years, they have also become commonly used in destination signs on public transport vehicles, as well as variable-message signs on highways. LED displays are capable of providing general illumination in addition to visual display, as when used for stage lighting or other decorative (as opposed to projection screens, and they can be used for large, uninterrupted (without a visible grid arising from the bezels of individual displays) video walls. microLED displays are LED displays with smaller LEDs, which poses significant development challenges.

Printer (Dot Matrix, Inkjet, Laser)

A printer is an external hardware output device that takes the electronic data stored on a computer or other device and generates a hard copy. For example, if you created a report on your computer, you could print several copies to hand out at a staff meeting. Printers are one of the most popular computer peripherals and are commonly used to print text and photos. The picture is an example of an inkjet computer printer, the Lexmark Z605.

Dot Matrix IBM created the first dot matrix printer in 1957. However, the first dot matrix impact printer was introduced by Centronics in 1970. To create letters and images, the print head, which contains pins, sits over an ink ribbon. This ribbon rests above a piece of paper. As the print head moves across the ribbon (usually horizontally), the pins press into the ribbon to imprint ink onto the page (like a typewriter). As these pins print several dots, you can see where this printer got its name.

shutterstock.com · 1039414429

Inkjet While inkjet printers started being developed in the late 1950s, it wasn't until the late 1970s that they were able to reproduce decent digital images. These higher-quality inkjet printers were developed by multiple companies, including Canon, Epson, and Hewlett-Packard. Inkjet printers are similar to dot matrix printers in that the images they create are composed of dots. However, the dots on an inkjet printer are shot onto the page rather than using a ribbon and pins. Furthermore, an inkjet printer's dots are smaller, and their print speed is faster. See our inkjet printer page for further information about this printer.

Laser In the early 1970s, Gary Starkweather invented the laser printer while working at Xerox by modifying one of their model 7000 copiers. However, it wasn't until 1984, when Hewlett-Packard introduced the HP LaserJet, that laser printers became more widely available and affordable. The following year, Apple introduced the Apple LaserWriter, which introduced PostScript technology to the printer market. Laser printers are more complex than their predecessors. For information on how they work, see our laser printer definition.

Speaker

A speaker is an output device that produces sound through an oscillating transducer called a driver. Speakers are plugged into a computer's sound card via a myriad of interfaces, such as a phone connector for analog audio, or SPDIF for digital audio. While speakers can be connected through cables, wireless speakers are connected to the host device through radio technology such as Bluetooth.

Speakers are most often used in pairs, which allows the speaker system to produce positional audio. When more than one pair is used, Certain models of computers includes a built-in speaker, which may sacrifice audio quality in favor of size. For example, the built-in speaker of a smartphone allows the users to listen to media without attaching an external speaker.

1.2.9 Hardware Interfaces:

A hardware interface specifies the plugs, sockets, cables and electrical signals that pass through each line between the CPU and a peripheral device or communications network. It also stipulates which data trigger which functions, and the control software that “drives” the hardware is also part of the hardware interface.

Parallel Port A parallel port is another type of computer port to connect a peripheral device to the computer system. As its name implies, a parallel port can transmit multiple bits of data all together at the same time. Therefore, in the case of parallel ports, the rate of data transmission is relatively high as compared to series ports because these transmit data without any hold-up.

Parallel ports are mainly used to connect those computer peripheral devices that require high bandwidth. The most common examples of such devices are printers, monitors, projectors, etc.

Serial Port Serial Ports provide an interface to connect serial lines to prepare a serial communication. Serial ports are the types of computer ports through which the data bits are transmitted as a single stream of binary 0s and 1s in the form of electric signals. Serial ports provide only a single transmission path that can be a single wire, a pair of wires, or a single channel in case of wireless communication.

Serial ports are the oldest communication interfaces that are mainly used to connect printers and modem to the computer system. But in modern computers, serial ports are used to connect modern devices like flat-screen monitors, security cameras, GPS devices, etc. Serial ports are sometimes also called COM Ports (or Communication Ports).

USB Ports
The most widely used hardware interface for attaching external devices to computers is USB. It connects keyboards, mice, printers, cameras, music players, flash drives and external storage drives. A USB port is a standard cable connection interface for personal computers and consumer electronics devices. USB stands for Universal Serial Bus, an industry standard for short-distance digital data communications. USB ports allow USB devices to be connected to each other with and transfer digital data over USB cables. They can also supply electric power across the cable to devices that need it.

HDMI Short for High Definition Multimedia Interface, HDMI is a connector and cable capable of transmitting high-quality and high-bandwidth streams of audio and video between devices. The HDMI technology is used with devices such as an HDTV, Projector, DVD player, or Blu-ray player. The picture is an example of an HDMI cable from Mediabridge.

The HDMI ports are found either on the video card or motherboard on the back of the computer. It is important to note that not all computers and video cards have HDMI connectors.

Expansion Slots Alternatively known as a bus slot or expansion port, an expansion slot is a connection or port inside a computer on the motherboard or riser card. It provides an installation point for a hardware expansion card to be connected. For example, if you wanted to install a new video card in the computer, you’d purchase a video expansion card and install that card into the compatible expansion slot.

You’re most likely only going to encounter AGP, PCI, and PCI Express when working with computers today.

2. Number System and Conservation Boolean Logic

2.1 Number System and Conversion

A numeral system (or system of numeration) is a writing system for expressing numbers; that is, a mathematical notation for representing numbers of a given set, using digits or other symbols in a consistent manner.

number eleven in the decimal numeral system (used in common life), the number three in the binary numeral system (used in computers), and the number two in the unary numeral system (e.g. used in tallying scores).

The number the numeral represents is called its value. Not all number systems can represent all numbers that are considered in the modern days; for example, Roman numerals have no zero.

Ideally, a numeral system will:

- Represent a useful set of numbers (e.g. all integers, or rational numbers)
- Give every number represented a unique representation (or at least a standard representation)
- Reflect the algebraic and arithmetic structure of the numbers.

For example, the usual decimal representation gives every nonzero natural number a unique representation as a finite sequence of digits, beginning with a non-zero digit.

Numeral systems are sometimes called number systems, but that name is ambiguous, as it could refer to different systems of numbers, such as the system of real numbers, the system of complex numbers, the system of p-adic numbers, etc. Such systems are, however, not the topic of this article.

2.1.1 Decimal, Binary, Octal, Hexadecimal Number system and Conversion

Binary Number System

A binary number is a number expressed in the base-2 numeral system or binary numeral system, a method of mathematical expression which uses only two symbols: typically “0” (zero) and “1” (one).

The base-2 numeral system is a positional notation with a radix of 2. Each digit is referred to as a bit, or binary digit. Because of its straightforward implementation in digital electronic circuitry using logic gates, the binary system is used by almost all modern computers and computer-based devices, as a preferred system of use, over various other human techniques of communication, because of the simplicity of the language and the noise immunity in physical implementation.

Counting in binary

Counting in binary is similar to counting in any other number system. Beginning with a single digit, counting proceeds through each symbol, in increasing order. Before examining binary counting, it is useful to briefly discuss the more familiar decimal counting system as a frame of reference.

Decimal counting

Decimal counting uses the ten symbols 0 through 9. Counting begins with the incremental substitution of the least significant digit (rightmost digit) which is often called the first digit. When the available symbols for this position are exhausted, the least significant digit is reset to 0, and the next digit of higher significance (one position to the left) is incremented (overflow), and incremental substitution of the low-order digit resumes. This method of reset and overflow is repeated for each digit of significance. Counting progresses as follows:

> 000, 001, 002, … 007, 008, 009, (rightmost digit is reset to zero, and the digit to its left is incremented)
> 010, 011, 012, …
> …
> 090, 091, 092, … 097, 098, 099, (rightmost two digits are reset to zeroes, and next digit is incremented)
> 100, 101, 102, …

Binary counting follows the exact same procedure, and again the incremental substitution begins with the least significant digit, or bit (the rightmost one, also called the first bit), except that only the two symbols 0 and 1 are available. Thus, after a bit reaches 1 in binary, an increment resets it to 0 but also causes an increment of the next bit to the left:

> 0000, 0001, (rightmost bit starts over, and next digit is incremented)
> 0010, 0011, (rightmost two bits start over, and next bit is incremented)
> 0100, 0101, 0110, 0111, (rightmost three bits start over, and the next bit is incremented)
> 1000, 1001, 1010, 1011, 1100, 1101, 1110, 1111 …

Binary Number Conversion

Binary to Decimal

In the binary system, each bit represents an increasing power of 2, with the rightmost bit representing 2^0, the next representing 2^1, then 2^2, and so on. The value of a binary number is the sum of the powers of 2 represented by each "1" bit. For example, the binary number 100101 is converted to decimal form as follows:

> $(100101)_2 = (1 * 2^5 + 0 * 2^4 + 0 * 2^3 + 1 * 2^2 + 0 * 2^1 + 1 * 2^0)_{10}$
> $(100101)_2 = (1 * 32 + 0 * 16 + 0 * 8 + 1 * 4 + 0 * 2 + 1 * 1)_{10}$
> $(100101)_2 = (3710)_{10}$

Decimal number	Binary number
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101
14	1110
15	1111

So far we have only looked at whole numbers (integers), we need to understand how computers represent fractions.

You should have learned at Primary School how a decimal fraction works:

10^1	10^0		10^{-1}	10^{-2}
10	1		$\frac{1}{10}$	$\frac{1}{100}$
1	2	.	7	5

As you can see, the column headings have been extended to $10^{-1} = \dfrac{1}{10}$ and $10^{-2} = \dfrac{1}{100}$. We can do the same thing in binary with the column headings $2^{-1} = \dfrac{1}{2}$, $2^{-2} = \dfrac{1}{4}$, and so on. The number 12.75 in 8 bit binary with 4 bits after the binary point is therefore $8 + 4 + 0.5 + 0.25$:

Decimal to Binary Conversion

An easy method of converting decimal to binary number equivalents is to write down the decimal number and to continually divide-by-2 (two) to give a result and a remainder of either a "1" or a "0" until the final result equals zero.

Steps to convert the decimal to binary equivalent

- Divide the decimal number by 2 and store remainders in array.
- Divide the quotient by 2.
- Repeat step 2 until we get the quotient equal to zero.
- Equivalent binary number would be reverse of all remainders of step 1.

> So for example. Convert the decimal number 294_{10} into its binary number equivalent.
> Number is 294
> divide by 2
> result 147 remainder **0** (LSB)
> divide by 2
> result 73 remainder **1**
> divide by 2
> result 36 remainder **1**
> divide by 2
> result 18 remainder **0**
> divide by 2
> result 9 remainder **0**
> divide by 2
> result 4 remainder **1**
> divide by 2
> result 2 remainder **0**
> divide by 2
> result 1 remainder **0**
> divide by 2
> result 0 remainder **1** (MSB)

This divide-by-2 decimal to binary conversion technique gives the decimal number 294_{10} an equivalent of 100100110_2 in binary, reading from right to left. This divide-by-2 method will also work for conversion to other number bases.

You can convert the decimal number in to binary with the similar process done before but with an extra work for the fractional part of the given number. Repeat the process done before for the integer part of the given number and follow these extra step to convert the fraction part:

- Multiply the fractional decimal number by 2.
- Integral part of resultant decimal number will be first digit of fraction binary number.
- Repeat step 1 using only fractional part of decimal number and then step 2.
- And finally combine both integral and fractional part of binary number.

Let's take an example for n = 4.47
Step 1: Conversion of 4 to binary

Calculations	Remainder	Quotient
$4/2$	Remainder = 0	Quotient = 2
$2/2$	Remainder = 0	Quotient = 1
$1/2$	Remainder = 1	Quotient = 0

So equivalent binary of integral part of decimal is 100.
Step 2: Conversion of $.47$ to binary

Calculations	Remainder	Quotient
$0.47 * 2$	0.94	Integral part: 0
$0.94 * 2$	1.88	Integral part: 1
$0.88 * 2$	1.76	Integral part: 1

So equivalent binary of fractional part of decimal is $.011$.
Step 3: Combined the result of step 1 and 2.
Final answer can be written as:
$$ 100 + .011 = 100.011 $

2.1.2 Calculation in binary addition, subtraction

`Binary addition` is one of the binary operations. To recall, the term "Binary Operation" represents the basic operations of mathematics that are performed on two operands. Basic arithmetic operations like addition, subtraction, multiplication, and division, play an important role in mathematics.

The binary addition operation works similarly to the base 10 decimal system, except that it is a base 2 system. The binary system consists of only two digits, 1 and 0. Most of the functionalities of the computer system use the binary number system. The binary code uses the digits 1's and 0's to make certain processes turn off or on. The process of the addition operation is very familiar to the decimal system by adjusting to the base 2.

Rules of Binary Addition Binary addition is much easier than the decimal addition when you remember the following tricks or rules. Using these rules, any binary number can be easily added. The four rules of binary addition are:

1 + 0 = 1

1 + 1 =10

A few examples of binary additions are as follows:

Example 1: 10001 + 11101 Solution:

</> Plaintext

```
          1  Carry
    1 0 0 0 1
(+) 1 1 1 0 1
 ______________
  1 0 1 1 1 0
```

Example 2: 10111 + 110001

Solution:

</> Plaintext

```
          1 1 1  Carry
        1 0 1 1 1
    (+) 1 1 0 0 0 1
    ________________
      1 0 0 1 0 0 0
```

2.1.3 One's and Two's Complement methods of binary subtraction

Binary subtraction is one of the four binary operations, where we perform the subtraction method for two binary numbers (comprising only two digits, 0 and 1). This operation is similar to the basic arithmetic subtraction performed on decimal numbers in Maths. Hence, when we subtract 1 from 0, we need to borrow 1 from the next higher order digit, to reduce the digit by 1 and the remainder left here is also 1.

Can you subtract binary numbers? The answer is yes. Subtraction of binary numbers is an arithmetic operation similar to the subtraction of decimal numbers or base 10 numbers. For example, 1 + 1 + 1 = 3 in base 10 and 1 + 1 + 1 = 11 in binary number system. When you add and subtract binary numbers, you will need to be careful when borrowing as these will take place more often.

When you subtract several columns of binary digits, you must take into account the borrowing. When 1 is to be subtracted from 0, the result is 1 where 1 is borrowed from the next highest order bit or digit.

Rules and tricks: Binary subtraction is much easier than the decimal subtraction when you remember the following rules:

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```
0 – 0 = 0
0 – 1 = 1 ( with a borrow of 1)
1 – 0 = 1
1 – 1 = 0
```

Now, look at the example of the binary subtraction: `101` from `1010` .

Procedure to do Binary Subtraction: `1010` (-) `101`

Step 1: First consider the 1's column, and subtract the one's column,(0 – 1) and it gives the result 1 as per the condition of binary subtraction with a borrow of 1 from the 10's place.

</> Plaintext

```
     1 Borrow
  1 0 1 0
(-) 1 0 1
---------
        1
```

Step 3: So, subtract the value in the 10’s place, (0 – 0) = 0.

</> Plaintext

```
     1 Borrow
  1 0 1 0
(-) 1 0 1
------------
     0 1
```

Step 4: Now subtract the values in 100’s place. Borrow 1 from the 1000’s place (0 – 1) = 1.

</> Plaintext

```
  1   1 Borrow
  1 0 1 0
(-) 1 0 1
----------
  0 1 0 1
```

So, the resultant of the subtraction operation is `0101` .

When you cross-check the binary subtraction resultant value with the decimal value, the resultant value should be the same.
The binary value 1010 is equal to the decimal value 10, and 101 is equivalent to 5.
So, `10 – 5 = 5` . Therefore, the decimal number 5 is equal to the binary number `0101` .

Binary Subtraction Using 1’s Complement

- The 0 in the MSB for singed binary represents the positive sign
- The 1 in the MSB for singed binary represents the negative sign

Procedures for Binary Subtraction by 1’s Complement

- Write the 1’s complement of the subtrahend.
- Then add the 1’s complement subtrahend with the minuend.
- If the result has a carryover, then add that carry over in the least significant bit (LSB).
- If there is no carryover, then take the 1’s complement of the resultant, and it is `negative` .

Example $(110101)_2$–$(100101)_2$

Solution: $(110101)_2$ = 5310_{10}

$(100101)_2$ = 3710_{10} – subtrahend

Now take the 1’s complement of the subtrahend and add with minuend.

</> Plaintext

```
(+) 0 1 1 0 1 0
------------------
   0 0 1 1 1 1
       (+)  1 carry
------------------
   0 1 0 0 0 0

Therefore, the solution is 010000
```

Decimal equivalent of $(010000)_2 = 1610_{10}$

Subtraction using 2's complement

2's complement of a number can be found by adding a 1 to the 1's complement of a number. These are the following steps to subtract two binary numbers using 2's complement

- In the first step, find the 2's complement of the subtrahend.
- Add the complement number with the minuend.
- If we get the carry by adding both the numbers, then we discard this carry and the result is positive else take 2's complement of the result which will be negative.

Example:

(i) $110110_2 - 10110_2$

The numbers of bits in the subtrahend is 5 while that of minuend is 6. We make the number of bits in the subtrahend equal to that of minuend by taking a `0' in the sixth place of the subtrahend.

Now, 2's complement of `010110` is (`101101 + 1`) i.e. `101010` . Adding this with the minuend.

</> Plaintext

```
              1 1 0 1 1 0      Minuend
          (+) 1 0 1 0 1 0      2's complement of subtrahend
          ------------------
   Carry over 1   1 0 0 0 0 0      Result of addition
```

After dropping the carry over we get the result of subtraction to be `100000` .

(ii) 10110 – 11010

Solution:

2's complement of `11010` is `(00101 + 1)` i.e. `00110` . Hence

</> Plaintext

```
                  Minued -          1 0 1 1 0
2's complement of subtrahend -          0 0 1 1 0
---------------------------------------------------
          Result of addition -          1 1 1 0 0
```

As there is no carry over, the result of subtraction is negative and is obtained by writing the 2's complement of `11100` i.e. `(00011 + 1)` or `00100` .

Hence the difference is `- 100` .

Logic Functions are the algebraic functions of boolean variables or so called binary variables also being algebra as a boolean algebra. In short they are also reffered as a boolean logic functions or Logic Gates.

A gate is an electronic device that produces a result based on two or more binary input values.

Boolean algebra is algebra for the manipulation of objects that can take on only two values, typically true and false. It is common to interpret the digital value 0 as false and the digital value 1 as true.

- Boolean Expression: Combining the variables and operation yields Boolean expressions.
- Boolean Function: A Boolean function typically has one or more input values and yields a result, based on these input value, in the range {0, 1}.
- A Boolean operator can be completely described using a table that list inputs, all possible values for these inputs, and the resulting values of the operation. A truth table shows the relationship, in tabular form, between the input values and the result of a specific Boolean operator or function on the input variables.

2.2.1 Introduction to Boolean Algebra

Boolean algebra is the algebra of logic that deals with the study of binary variables and logical operations. It makes possible to transform logical statements into mathematical symbols and to calculate the truth or falsity of related statements by using rules. It is named after George Boole, a 19th-century Mathematician and Philosopher, who was the first to try and to formalize what we call logic or reasoning.

In computer science field, binary logic is referred as 'Digital Logic' which is considered as the heart of the operation of all modern digital computers. It shows the logical relationship between two or more logical functions. Instead of the use of T and F for true and false (which is frequently used for the truth tables) for the indication of the state of the sentences, Boolean algebra usually denotes it by 1 and 0 respectively. It is a branch of algebra in which the values of the variables are the truth values; true or false respectively.

2.2.2 Introduction to Boolean values, Truth table, Boolean expression and Boolean function

A boolean variable is the variables which have only two states i.e. true/ false or right/ wrong or on/off or 0/1. As a computer is a binary system, it operates on an electronic signal which has only 2 possible states.

The signal that does not change its state with time is called constant signal and its value always remains the same i.e. either 1 or 0 whereas a variable signal continuously changes its state according to the time. At some point, the value of the variable signal may be 1 and at some another point, it might be 0.Therefore, these variables which consist of only two values i.e. 1 and 0 are Boolean variables or logic variables. These variables are denoted by English capital letters like A, B, X, Y, etc.

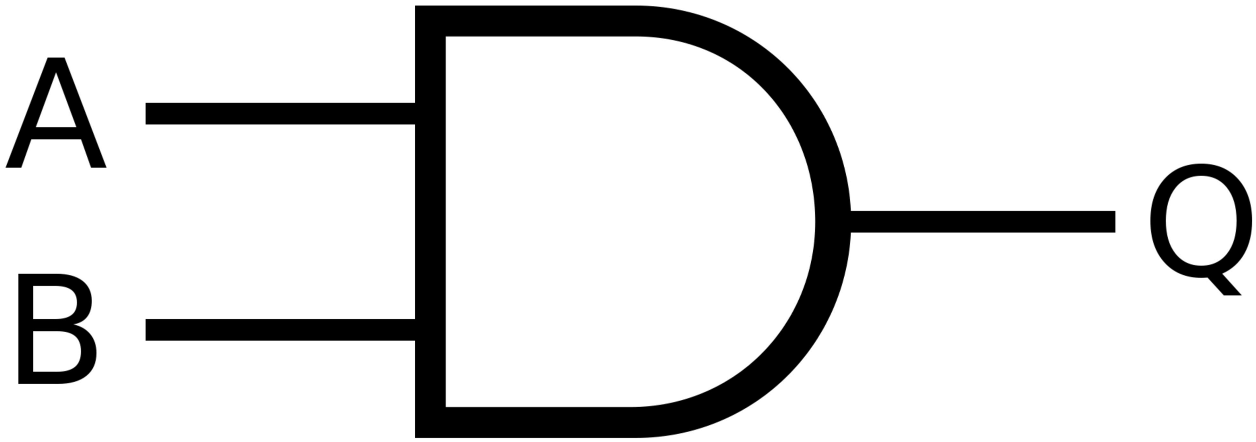
A truth table is a mathematical table used in logic—specifically in connection with Boolean algebra, boolean functions.

A truth table has one column for each input variable (for example, P and Q), and one final column showing all of the possible results of the logical operation that the table represents (for example, P XOR Q). Each row of the truth table contains one possible configuration of the input variables (for instance, P=true Q=false), and the result of the operation for those values. See the examples below for further clarification. Ludwig Wittgenstein is generally credited with inventing and popularizing the truth table in his Tractatus Logico-Philosophicus, which was completed in 1918 and published in 1921. Such a system was also independently proposed in 1921 by Emil Leon Post. An even earlier iteration of the truth table has also been found in unpublished manuscripts by Charles Sanders Peirce from 1893, antedating both publications by nearly 30 years.

2.2.3 Logic Gates - AND, OR, NOT, NAND, NOR, XOR and XNOR

AND

The `AND` gate is so named because, if `0` is called `false` and `1` is called `true`, the gate acts in the same way as the logical *and* operator. The following illustration and table show the circuit symbol and logic combinations for an AND gate. (In the symbol, the input `false`. In other words, the output is `1` only when both inputs A `AND` B are `1`.



`AND` Operation truth table:

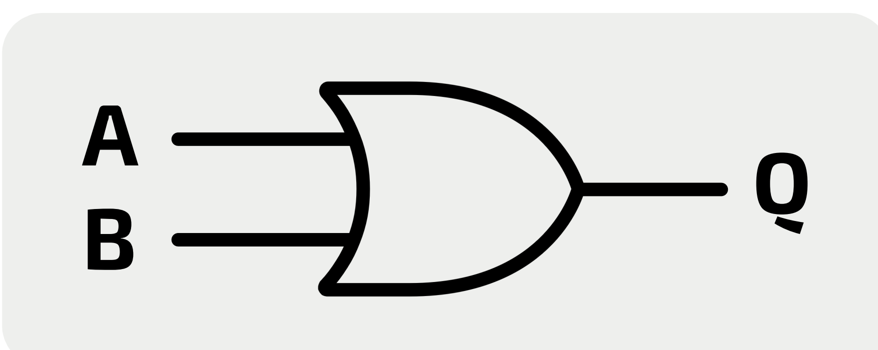
A	B	$Q = A \cap B$
F	F	F
F	T	F
T	F	F
T	T	T

In ordinary language terms, if both A and B are `true`, then the conjunction $A \cap B$ is `true`. For all other assignments of logical values to A and to B the conjunction $A \cap B$ is false.

It can also be said that if A, then $A \cap B$ is B, otherwise $A \cap B$ is A.

OR

The `OR` gate gets its name from the fact that it behaves after the fashion of the logical inclusive `or`. The output is `true` if either or both of the inputs are `true`. If both inputs are `false`, then the output is `false`. In other words, for the output to be `1`, at least input A `OR` B must be `1`.

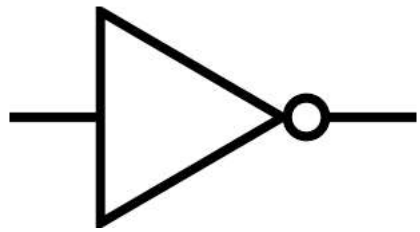


`OR` Operation truth table

F	F	F
F	T	T
T	F	T
T	T	T

NOT

A logical inverter, sometimes called a `NOT` gate to differentiate it from other types of electronic inverter devices, has only one input. It reverses the logic state. If the input is `1`, then the output is `0`. If the input is `0`, then the output is `1`.

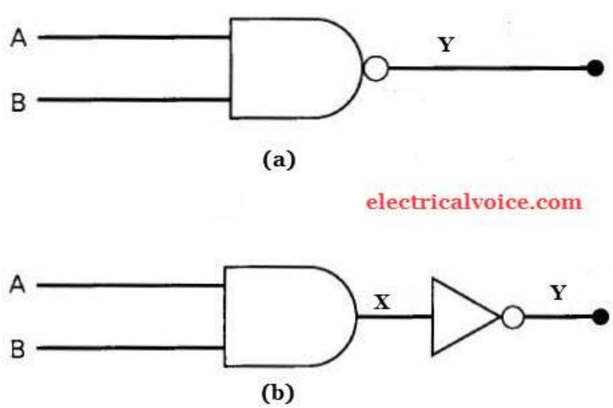


`NOT` Operation truth table

A	$Q = \overline{A}$
F	T
T	T

NAND

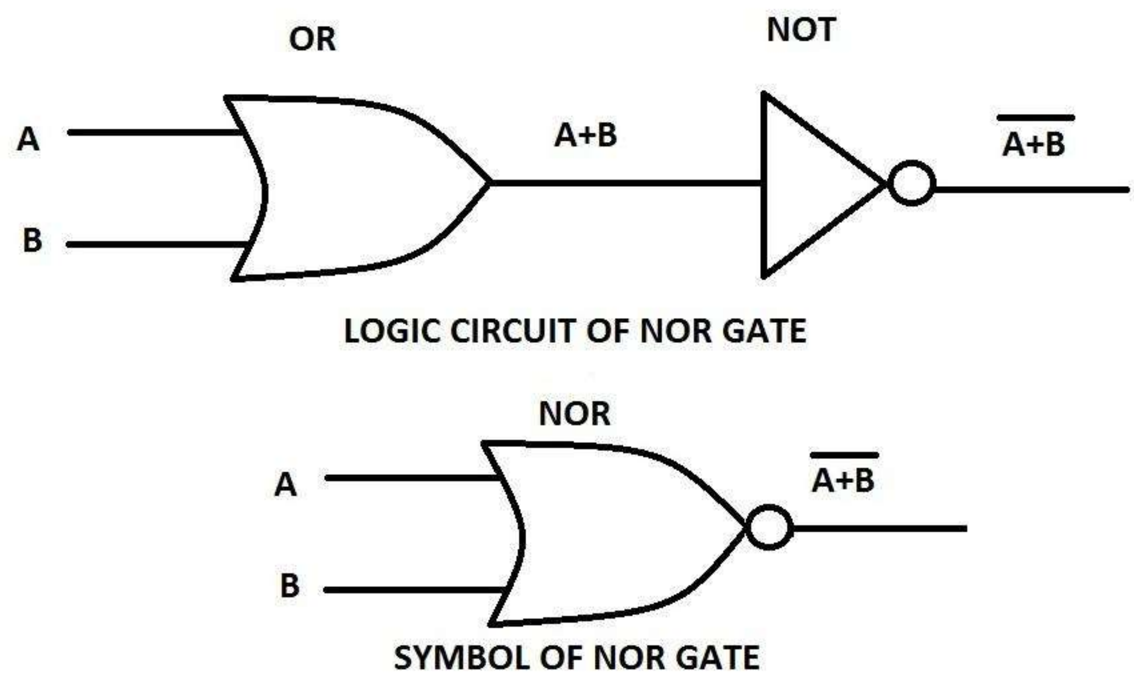
The `NAND` gate operates as an `AND` gate followed by a `NOT` gate. It acts in the manner of the logical operation *and* followed by negation. The output is `false` if both inputs are `true`. Otherwise, the output is `true`.



`NAND` Operation truth table

A	B	$X = A{\cdot}B$	$Y = \overline{X} = \overline{A{\cdot}B}$
F	F	F	T
F	T	F	T
T	F	F	T
T	T	T	F

The NOR gate is a combination OR gate followed by an inverter. Its output is `true` if both inputs are `false`. Otherwise, the output is `false`.

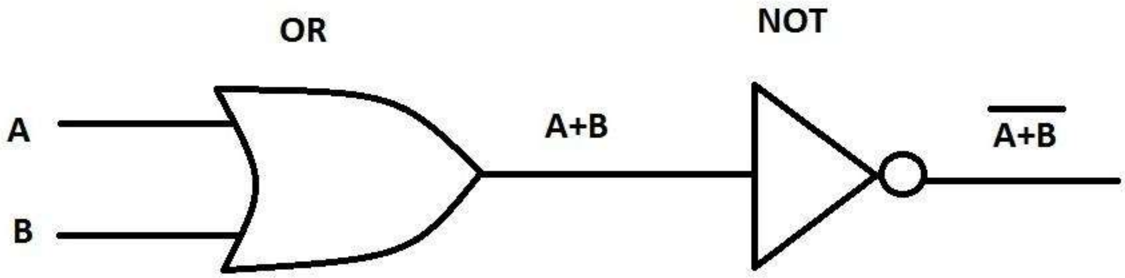


`NOR` Operation truth table

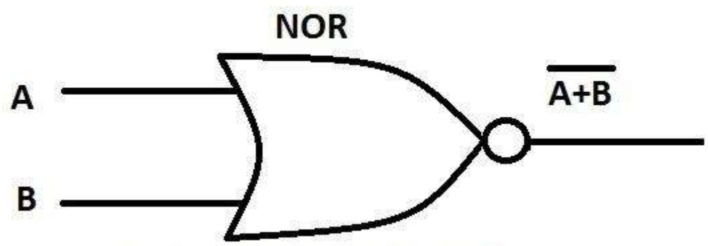
A	B	$X = A + B$	$Y = \overline{X} = \overline{A + B}$
F	F	F	T
F	T	T	F
T	F	T	F
T	T	T	F

NOR

The `NOR` gate is a combination `OR` gate followed by an inverter. Its output is `true` if both inputs are `false`. Otherwise, the output is `false`.



LOGIC CIRCUIT OF NOR GATE



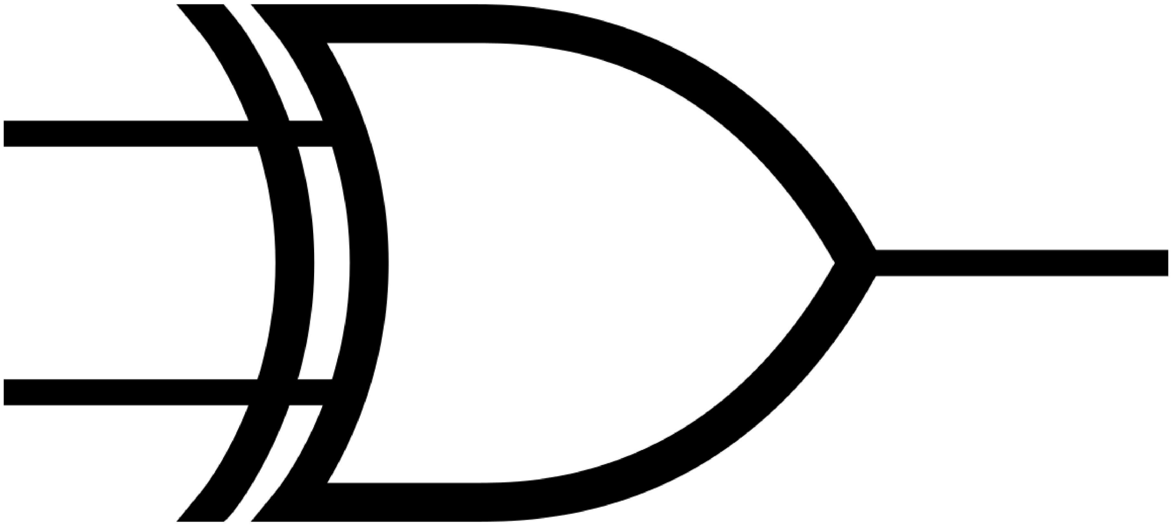
SYMBOL OF NOR GATE

`NOR` Operation truth table

A	B	$X = A + B$	$Y = \overline{X} = \overline{A + B}$
F	F	F	T
F	T	T	F
T	F	T	F
T	T	T	F

XOR

The `XOR` (`exclusive-OR`) gate acts in the same way as the logical `either/or` . The output is `true` if either, but not both, of the inputs are `true` . The output is `false` if both inputs are `false` or if both inputs are `true` . Another way of looking at this circuit is to observe that the output is `1` if the inputs are different, but 0 if the inputs are the same.

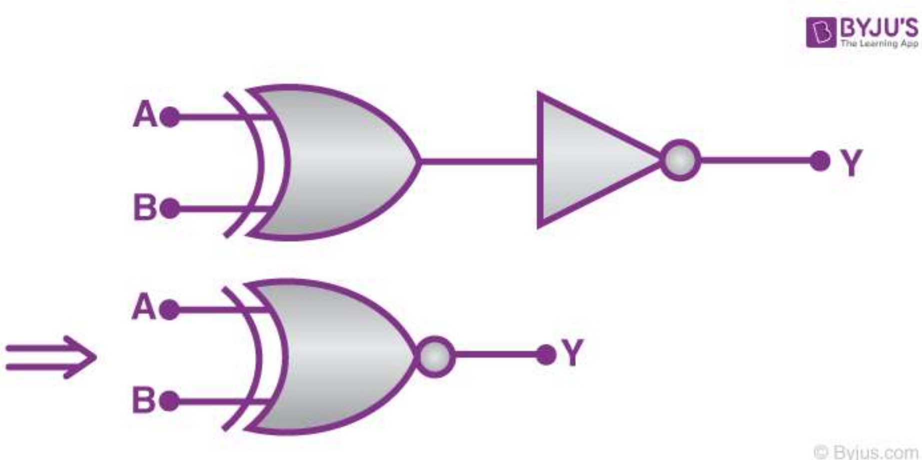


`XOR` Operation truth table

A	B	$X = A \oplus B$
F	F	F
F	T	T
T	F	T
T	T	F

XNOR

The `XNOR` (`exclusive-NOR`) gate is a combination `XOR` gate followed by an inverter. Its output is `true` if the inputs are the same, and `false` if the inputs are different.



`XNOR` Operation truth table

A	B	$X = A \oplus B$	$Y = A \odot B = \overline{X} = \overline{A \oplus B}$
F	F	F	T
F	T	T	F

T	F	T	F
T	T	F	T

2.2.4 Lasws of Boolean Algebra

Like normal algebra, Boolean algebra has several beneficial identities. An "identity" is merely a relationship that is always true, regardless of the values that any variables involved might take on; similar to laws or properties. Many of these can be analogous to normal multiplication and addition, particularly when the symbols {0,1} are used for {FALSE, TRUE}. However, while this can be useful, some identities are different and that causes confusion for many people. We will be sure to highlight these as we encounter them.

To begin with, Table below summarizes these identities, outlines the expressions, and then examines each in detail.

Boolean Identities

IDENTITY	EXPRESSION	
Logical Inverse	$\overline{0} = 1; \overline{1} = 0$	
Involution	$\overline{\overline{A}} = A$	
	OR	**AND**
Dominance	$A + 1 = 1$	$A.0 = 0$
Identity	$A + 0 = A$	$A.1 = A$
Idempotence	$A + A = A$	$A.A = A$
Complement	$A + \overline{A} = 1$	$A.\overline{A} = 0$
Commutative	$A + B = B + A$	$A.B = B.A$
Associative	$(A + B) + C = A + (B + C)$	$(A.B).C = A.(B.C)$
Distributive	$A + (B.C) = (A + B).(A + C)$	$A.(B + C) = (A.B) + (A.C)$
Absorption	$A.(A + B) = A$	$A.(A + B) = A$
DeMorgan's	$\overline{A + B} = \overline{A}.\overline{B}$	$\overline{A.B} = \overline{A} + \overline{B}$

2.2.5 Statement and Verification of Laws of Boolean algebra using truth table

DeMorgan's Law Verification

Statement: Demorgan's law says the complement of addition (OR operation) of two boolean variables are the product (AND operation) of the complement of individual variable. Mathematically,
$\overline{A + B} = \overline{A}.\overline{B}$

A	B	$\overline{A}$	$\overline{B}$	$A + B$	$\overline{A + B}$	$\overline{A}.\overline{B}$
F	F	T	T	F	T	T
F	T	T	F	T	F	F
T	F	F	T	T	F	F
T	T	F	F	T	F	F

Statement: Demorgan's law also says the complement of product (AND operation) of two boolean variables are the addition (OR operation) of the complement of individual variable. Mathematically,
$\overline{A \cdot B} = \overline{A} + \overline{B}$

A	B	$\overline{A}$	$\overline{B}$	$A \cdot B$	$\overline{A \cdot B}$	$\overline{A} + \overline{B}$
F	F	T	T	F	T	T
F	T	T	F	F	T	T
T	F	F	T	F	T	T
T	T	F	F	T	F	F

Here from the above table it is evident that $\overline{A \cdot B} = \overline{A} + \overline{B}$

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