COURSE GUIDE

CIT 210 COMPUTER HARDWARE

Course Team

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NATIONAL OPEN UNIVERSITY OF NIGERIA

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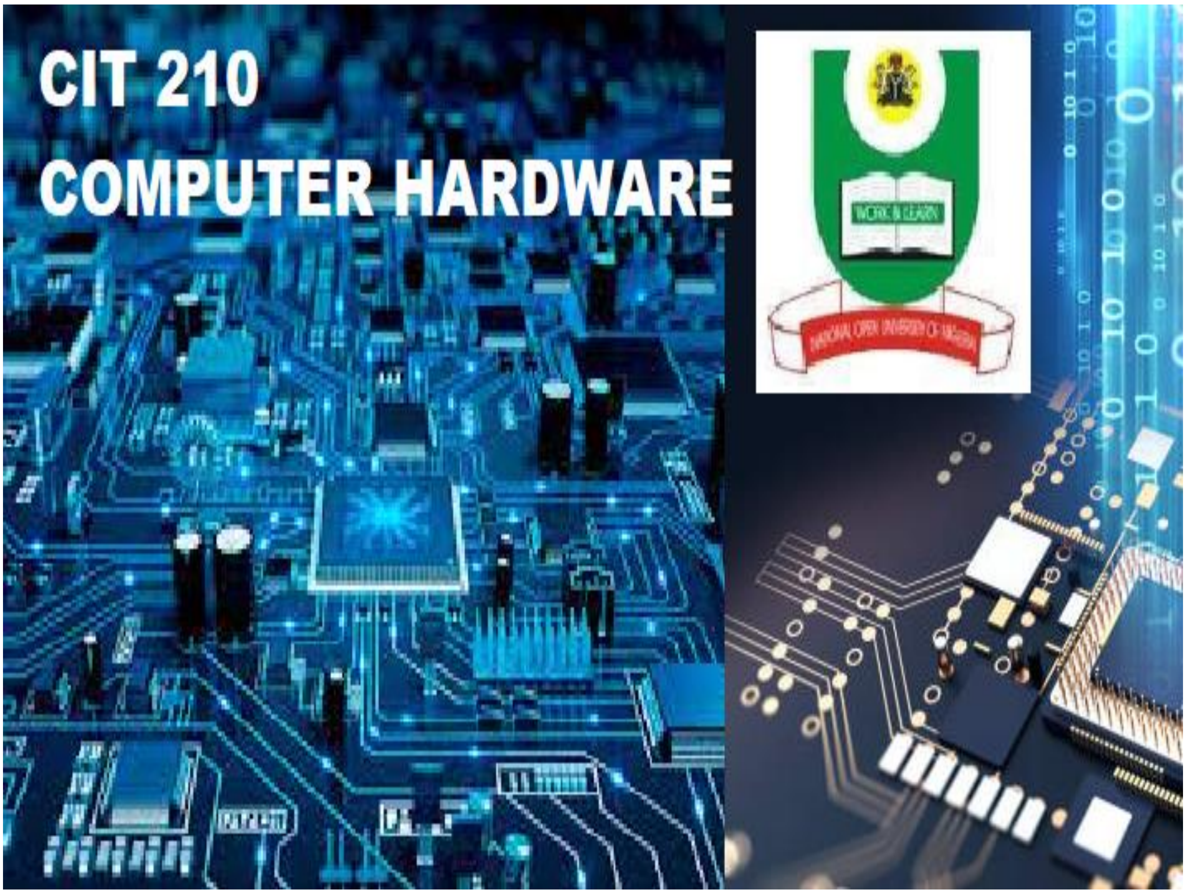
INTRODUCTION



NATIONAL OPEN UNIVERSITY OF NIGERIA

FACULTY OF SCIENCES

DEPARTMENT OF COMPUTER SCIENCE

Course Guide for CIT210

INTRODUCTION

CIT210 – Computer Hardware is a 3-credit unit course. The course is a compulsory course in the first semester. It will take you 15 weeks to complete the course. You are to spend 65 hours of study for a period of 13 weeks while the first week is for orientation and the last week is for end of semester examination.

You will receive the course material which you can read online or download and read off-line. The online course material is integrated in the Learning Management System (LMS). All activities in this course will be held in the LMS. All you need to know in this course is presented in the following sub-headings.

Course Competencies

By the end of this course, you will gain competency to:

Understand, use and work with computer hardware devices

Course Objectives

The course objectives are to:

- Understand the standard computer system hardware architecture as explained by John Von Neumman
- Be familiar with diver computer hardware devices, components, interconnectivity, and services
- Understand the future trends of computer hardware advancement
- Comprehend the fundamental computer hardware categories which include peripheral devices, processing units, and memory or storage devices.

Working through this Course

The course is broadly divided into Modules, and subsequently into Units. The modules are derived from the course competencies and objectives. The competencies will guide you through on the knowledge you would acquire at the end of this course. So, as you work through the course, reflect on the competencies to ensure mastery. The Units are components of the Modules. Each Unit is discussed under the following headings, viz; introduction, intended learning outcome(s), main content, self-assessment exercise(s), conclusion, summary, and further readings. The Introduction addresses the expectations from the Unit topic. The intended learning outcome(s) is the benchmark that evaluates your achievement at the end of the course. Therefore, review the intended learning outcome(s) before going to the main content and at the end of the unit, revisit the intended learning outcome(s) to check if you have achieved the learning outcomes. Work through each Unit again if you have not understood the pre-determined learning outcomes.

The main content is the body of knowledge in the Unit, which specifically addresses the theoretical framework. Self-assessment exercises are significant parts of the content which enable evaluation of the understanding of the course competencies. The conclusion expresses the final notes achieved, while the summary presents the brief overview of the knowledge discussed in the Unit. The last section on further readings provides sources of relevant literature, books, and journals.

The Modules and Units are hereby enumerated as follows:

Module 1: Introduction to Computer Systems

- Unit 1: Fundamentals of Computer Systems
- Unit 2: Computer Software

Module 2: Computer Hardware Architecture

- Unit 1: Von Neumann Computer Architecture
- Unit 2: Central Processing Unit
- Unit 3: Computer Data Storage and Memory Devices

Module 3: Computer Peripheral Devices

- Unit 1: Input Devices
- Unit 2: Output Devices

Module 4: Computer Hardware Components

- Unit 1: System board - Motherboard
- Unit 2: Microchips Technology

Module 5: Hardware Interconnectivity and Embedded Systems

Unit 1: Computer Networking

Unit 2: Multi-core Technology

Unit 3: Introduction to Embedded Systems

Module 6: Digital Systems

Unit 1: Introduction to Digital Systems

Unit 2: Cloud Computing

There are six modules and fourteen units in this course. Each unit represent a week of study or combined.

Presentation Schedule

The weekly activities are presented in Table 1 while the required hours of study and the activities are presented in Table 2. This will guide your study time. You may spend more time in completing each module or unit.

Table I: Weekly Activities

Week	Activity
1	Orientation and course guide
2	Module 1 Unit 1
3	Module 1 Unit 2
4	Module 2 Unit 1
5	Module 2 Unit 2
6	Module 2 Unit 3
7	Module 3 Unit 1
8	Module 3 Unit 1
9	Module 4 Unit 1
10	Module 4 Unit 2
11	Module 5 Unit 1
12	Module 5 Unit 2
13	Module 5 Unit 3
14	Module 6 Units 1 and 2
15	Revision and Response to Questionnaire
16	Examination

The activities in Table I include facilitation hours (synchronous and asynchronous), assignments, mini projects, and laboratory practical. How do you know the hours to spend on each? A guide is presented in Table 2.

Table 2: Required Minimum Hours of Study

S/N	Activity	Hour per Week	Hour per Semester
1	Synchronous Facilitation (Video Conferencing)	1	13
2	Asynchronous Facilitation (Read and respond to posts including facilitator’s comment, self-study)	3	39
3	Assignments, mini-project, laboratory	1	13

	practical and portfolios		
	Total	5	65

Assessment

Table 3 presents the mode you will be assessed.

Table 3: Assessment

S/N	Method of Assessment	Score (%)
3	Assignments 1-4 (best 3 will be chosen)	30
4	Final Examination	70
Total		100

Assignments

There are two aspects to the assessment of the course. First are the tutor marked assignments; second, is a written examination. In a case where NOUN e-learning platform is applicable, take the assignment and click on the submission button to submit. The assignment will be scored, and you will receive a feedback.

In tackling the assignments, you are expected to apply information and knowledge acquired during this course. The assignments must be submitted to your tutor for formal assessment in accordance with the deadlines stated in the Assignment File. The work you submit to your tutor for assessment will count for 30% of your total course mark.

At the end of the course, you will need to sit for a final three-hour examination. This will also count for 70% of your total course mark.

Examination

Finally, the examination will help to test the cognitive domain. The test items will be mostly application, and evaluation test items that will lead to creation of new knowledge/idea.

How to get the Most from the Course

To get the most in this course, you:

- Need a personal laptop or a desktop PC at home. The use of a smart mobile phone is not sufficient to grant you the desirable environment to work.
- Need regular, stable, and faster internet.
- Need to install the recommended software.
- Must work through the course step by step starting with the programme orientation.
- Must not plagiarise or impersonate. These are serious offences that could terminate your studentship. Plagiarism check will be used to run most of your submissions.

- Must do all the assessments following given instructions.
- Must create time daily to attend to your study.

Facilitation

There will be two forms of facilitation – synchronous and asynchronous. The synchronous will be held through video conferencing according to weekly schedule. During the synchronous facilitation:

- There will be one hour of online real time contact per week making a total of 13 hours for thirteen weeks of study time.
- At the end of each video conferencing, the video will be uploaded for view at your pace.
- You are to read the course material and do other assignments as may be given before video conferencing time.
- The facilitator will concentrate on main themes.
- The facilitator will take you through the course guide in the first lecture at the start date of facilitation

For the asynchronous facilitation, your facilitator will:

- Present the theme for the week.
- Direct and summarise forum discussions.
- Coordinate activities in the platform.
- Score and grade activities when need be.
- Support you to learn. In this regard personal mails may be sent.
- Send you videos and audio lectures, and podcasts if need be.

Read all the comments and notes of your facilitator especially on your assignments, participate in forum discussions. This will give you opportunity to socialize with others in the course and build your skill for teamwork. You can raise any challenge encountered during your study. To gain the maximum benefit from course facilitation, prepare a list of questions before the synchronous session. You will learn a lot from participating actively in the discussions.

Learner Support

You will receive the following support:

- Technical Support: There will be contact number(s), email address and chatbot on the Learning Management System where you can chat or send message to get assistance and guidance any time during the course.

- 24/7 communication: You can send personal mail to your facilitator and the centre at any time of the day. You should receive answer to you mails within 24 hours. There is also opportunity for personal or group chats at any time of the day with those that are online.

- You will receive guidance and feedback on your assessments, academic progress, and receive help to resolve challenges facing your studies.

COURSE INFORMATION

COURSE CODE	CIT210
COURSE TITLE	COMPUTER HARDWARE
COURSE UNIT	3
SEMESTER	SECOND
COURSE DURATION	13 WEEKS
REQUIRED HOURS FOR STUDY	65
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COURSE DETAILS

Module 1: Introduction to Computer Systems

Unit 1: Fundamentals of Computer Systems

CONTENTS

1.0 Introduction

Today, almost everyone uses computers directly or indirectly to solve diverse problems ranging from word processing to internet-based applications. For instance, your access to this course material is through the use of computers and computer applications. This course is about the study computer hardware, which is the physical part of the computer system. This module addresses the introductory theories about computer systems. It also deals with interconnectivity and relationship with the major modules of a standard computer system. In this Unit, we shall discuss some fundamental concepts relating to a computer system. The Unit also explains the computer device and system configuration.

2.0 Intended Learning Outcomes

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

- Understand the concepts of computer systems
- Observe the interconnectivity of subsystems in a computer system

3.0 Main contents

3.1 Definition of a Computer

A computer can be described as an electronic device that can receive data, process the data, and produce the result as the outcome. Conventionally, the received data is known as input while the result of the processing is known as output or information. A computer also has the capability of storing data and/or information in its memory for future use. This relationship is illustrated in Figure 1.

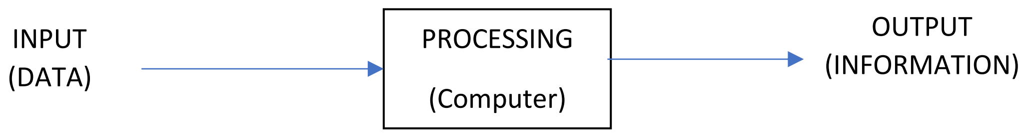


Figure 1 Computer Device Data Flow Process

Basically, a computer is divided into two major parts, namely, hardware and software. This configuration is like the division of human being into body and spirit/soul. That is, the body is the hardware while the software is the spirit or soul. While the hardware, the physical or most visible part is tangible, the software is intangible. Normally, the software resides and operates within the hardware. Essentially, hardware the physical part of the computer while the software is the code that runs on the computer.

Computers are capable of processing numerical data in form of 0's and 1's or simply in binary digital format. This digital format is the basis of the machine language which differs from human-readable languages. They can solve repetitive computational jobs with high level of accuracy and timeliness depending on the software capability.

3.2 Description of a Computer System

A computer system involves a complete suite of hardware and software resources as well as the users that operate the computer system. While a computer system does the basic function of a computer device, different kinds of computer systems can handle certain specific additional functionalities. This will be addressed later in this Module.

Ideally, a full-fledged computer system is made up of users, application software, systems software, operating system and hardware as shown in Figure 2.

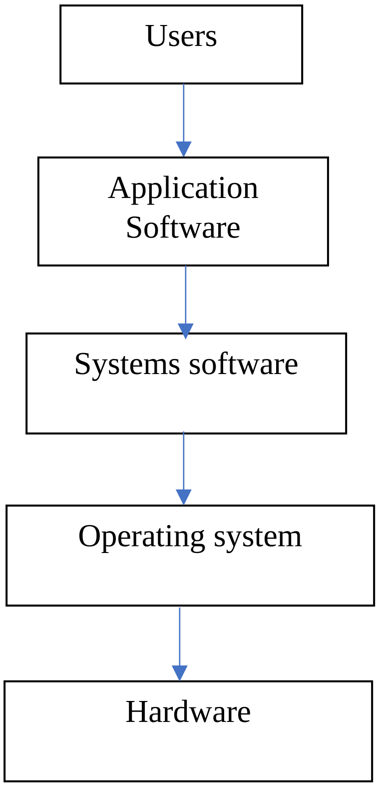


Figure 2 Architecture of a Computer System

In Figure 2, each of the computer system parts is known as a subsystem. In this case, a subsystem is made up of more than one component. For instance, the users' subsystem comprises expert users, programmers/developers, and end-users.

The main focus of this course is the hardware subsystem. It is the bedrock of other subsystems.

3.3 Classifications and Types of computers

You must have been aware that many kinds and types of computers exist for different applications and computational needs. Can you identify some of these? Essentially, computers while maintaining their basic functionalities, can be categorized according to their processing power, internal design, applicability, and physical size. These categories are as follows:

- Personal computers
  Personal computers, popularly shortened as PC, are common, cheaper, versatile, small and portable in sizes. They are single-user computer based on different kinds of microprocessors. Laptops are kinds of PCs that consume less power due to their miniaturized integrated internal components. We shall discuss about processors and their types later in this course.

Today, many students, office workers and business people use personal computer to carry out many tasks. Such tasks include word processing, graphical designs, desktop publishing, accounting operations, spreadsheets, video editing, teleconferencing among others.

It should be noted that the specifications of personal computers have evolved over the years due to explosion in human population, advancement in software and hardware components.

- Workstations
  These computers are relatively more powerful than PCs in terms of computational capability. They are also single-user based. Although, a workstation is like a personal computer, however it has a higher specifications and better quality. These high-end computers are often used to execute complex and large computational jobs in lesser time, so they are usually more costly than PCs. These types of computers are found in research laboratories, research institutions, universities, Space, automotive, and manufacturing industries.

Note that the specifications of workstation computers have also evolved over the years due to software and tasks requirements.

- Minicomputers
  Minicomputers are multi-users-based computers. They support a large array of users concurrently and are usually able to handle larger complex or/and large computational jobs. PCs and workstations are usually connected to minicomputers in a network for the joint execution of tasks, processes, and programs. Minicomputers are not portable, they belong to large organizations such as the Nigerian National Space Research and Development Agency (NASRDA), National Identity Management Commission (NIMC), Central Bank of Nigeria (CBN), national astronautics and space administration (NASA), European Space Agency (ESA), among others. During your next industrial training, you may wish to visit such organization to see such computers.

It should be noted that the specifications of minicomputers computers have also evolved over the years due to software and hardware advancement.

- Mainframe

Mainframe computers are larger, expensive and more powerful multi-user systems. They simultaneously support thousands of users than minicomputers. They have higher specifications in terms of processing speed and storage. They are quite huge and expensive. Mainframe computers are mostly found in large corporations, enterprises and government organizations where many IT professionals and workers use them simultaneously to solve grand challenge computational problems

They are designed to perform large numbers of calculations for governments and large enterprises

It should be noted that the specifications of mainframe computers have also evolved over the years. International Business Machine (IBM) is one of the earliest manufacturers of computer systems. Figure 3 shows the System z9 computer which was a line of mainframe manufactured by IBM in 2005.

Figure 3 IBM System z9

- Supercomputer
  Although, these computers are similar to mainframe, they are extremely the fastest and can be used to perform hundreds of millions of instructions per second. They are designed to solve grand challenge problems that are often data- and computationally intensive, such as DNA sequencing/human genome, Space exploration, Mars mission, national population census, national electoral system, national database systems, banking applications and database, health informatics, etc. A typical supercomputer can solve up to ten trillion individual calculations per second.

It is important to note that the specifications of supercomputers have also evolved over the years. Usually, supercomputers are the most powerful computers that exist at a time in human history. Today, China and USA are the leading manufacturers and users of supercomputers in the world. This fact is available at the https://www.top500.org/ website.

Till early 2021, Fugaku, the Chinese exascale systems was known to be the world's fastest supercomputer on Top500. As at this press time, the Intel and Cray of the Argonne National Laboratory is working hard on the design and development of

Aurora as the fastest supercomputer to be commissioned in late 2022. The project is under the sponsorship of the United States Department of Energy. Figure 4 show a typical structure of a computer system.

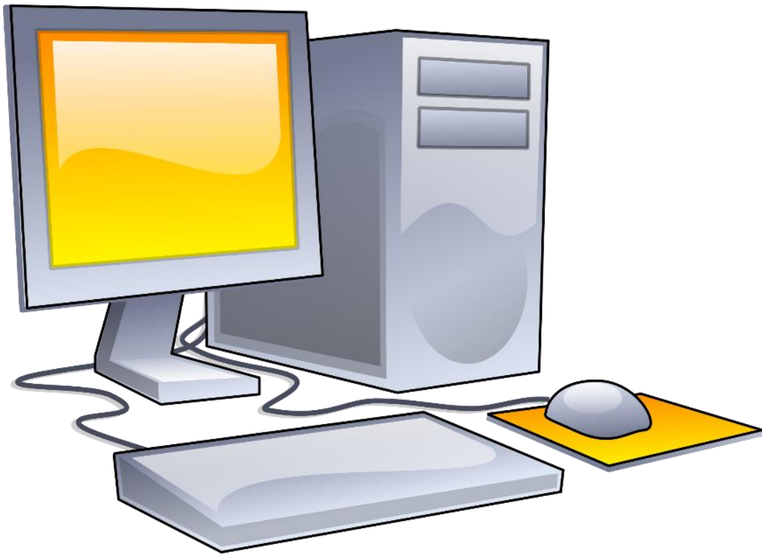


Figure 4 Computer system

These categories of computers spread across the generational phases and development of computer systems of all history.

3.4 Historical Generations Advancements of Computers

Computer history specifically dated back to 1833 when Charles Babbage, a mathematician, invented the first runner of digital programmable and general-purpose computers. Barely, a century later, Electronic Numerical Integrator and Computer (ENIAC) was invented by John W. Mauchly and J. Presper Eckert, this computer was the first general-purpose electronic computer.

Obviously, the entire history of mainly computer hardware advancements were distinctly partitioned into time-frame, periods, or generations according to a specific range of advancements. The generations are as follows:

a) First Generation: 1940-1956

This generation showcased the use of vacuum tubes for logic circuitry through the flow of electrical current. Magnetic drums were used for data transfer and storage. During this period, machine language was developed for systematic programming. ENIAC was among the systems developed during this period. The drawbacks of the systems include slower speed, excessive heat, and high cost. Figure 5 shows a typical first generation computer.

Figure 5 First Generation Computers

b) Second Generation: 1957-1963

In this generation, transistors were used as the major switching devices thus making computers smaller, faster and energy-efficient. The programming format was assembly languages. Figure 6 shows a typical second generation computer.

Figure 6 Second Generation Computer

c) Third Generation   1964-1971

Integrated circuits (IC) were developed and used as the switching devices for the flow of data. A single IC contains several numbers of transistors, capacitors, and resistors in the entire circuitry. Thus, computers became smaller in size, faster in processing and generally efficient. High level programming languages were also introduced during this period. Figure 7 shows a typical third generation computer.

Prominent computers in the third generation were PDP (Personal Data Processor), IBM-168/360/370 series, Honeywell-6000 series

Figure 7 Third Generation computer

d) Fourth Generation Computers 1972-1990

The fourth-generation computers were based on the successful invention and development of microprocessors as the central processing units (CPU). Personal and portable computers were manufactured due to the production of miniatured computing components. As a result, the Very Large Scale Integrated (VLSI) circuits technology was implemented in the design of the microprocessors and other kinds of switching devices. Intel was the first company to design and develop microprocessors. The details of microprocessor or CPU will be discussed later in this course. Efficient high-level programming languages were also developed such as Java, C++, C#, VB.NET among others. Figure 8 shows a typical example of the fourth Generation Computer.

Figure 8 Fourth Generation Computers

e) Fifth Generation Computers 1990 to date

The computers of this generation are designed based on superconductors, VLSI, miniaturized components, multi-core technologies, and artificial intelligence. Future computers will advance more on machine learning, expert systems, natural language processing, neural networks, advanced parallel computation, robotics, and fuzzy logic designs. Virtual reality, fault-tolerance, and artificial intelligence will dominate the hardware and software designs of fifth-generation computers.

The robots are being manufactured as computing devices that can replace human beings to work in difficult, dangerous, and boring environments with less human intervention. Examples of these robots are satellites, Sophia, robocop, mars rover, among others. Find out what these robots do and identify other kinds of robots. Figures 9 and 10 show examples of the fifth generation computers.

Figure 9 Fifth generation computer - Laptop

Figure 10 Fifth generation computer - Robot

3.5 Comparison between Hardware and Software

Table 1 in this section shows the comparison between hardware and software.

Table 1 The comparison of hardware to software

Hardware	Software
Hardware is a tangible physical parts computer system	Software is a set of instruction or codes that control the functions of a computer
Hardware devices are manufactured	Software are developed
Hardware cannot function without software.	software needs hardware to operate
As Hardware are physical electronic devices, we can see and touch hardware.	We can see and also use the software but can’t actually touch them.
Von Neumman architecture for computer framework	This adopts software models
computer viruses do not affect computer	Computer viruses can corrupt codes
Yes, hardware can do not bare metals	It can be downloaded, copy and transfer
If hardware is damaged, it can be replaced with a new one	When software is damaged, corrupt it can recovery from backup or the nendows
Examples include Keyboard, Mouse, Monitor, Printer, CPU, Hard disk, RAM, ROM etc.	Examples include Ms Word, Excel, Power Point, Photoshop, MySQL etc.

4.0 Conclusion

A computer has been described as an electronic device that is capable of receiving data, processing the data and generating the output result in a timely manner. A computer system comprises software and hardware. Some basic categories of computers include supercomputers, mainframe, minicomputer, desktop computers, and personal computers.

5.0 Summary

In this Unit, you have learned about some fundamental concepts of a computer system.

6.0 Self-Assessment Exercises

- What is a computer?
- Mention some tasks which computers can be used for
- Describe a computer system
- Advancements in computer hardware are the major causes of different generations in computer history. Discuss.

7.0 References / Literature

Price, Derek de S. (1984). "A History of Calculating Machines". IEEE Micro. 4 (1): 22–52. doi:10.1109/MM.1984.291305

Őren, Tuncer (2001). "Advances in Computer and Information Sciences: From Abacus to Holonic Agents" (PDF). Turk J Elec Engin. 9 (1): 63–70.

https://www.top500.org/

Unit 2: Computer Software

Content

1.0 Introduction

Do you realize that computer hardware cannot work without software? You have learned from the Unit 1 that software is the soul or intangible component of the computer system. When you drive your motor car, you are able to control the operations and direction of movement of the car. That is what a software does exactly to the computer hardware. In this Unit 2, we shall study about the detailed professional description of software and the types that are available to the users. It is certain that you have used some of several kinds of software directly or indirectly over the years. Relax well as we discuss this important subject matter in computer systems.

2.0 Intended Learning Outcomes

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

- Understand the definition and relevance of computer software
- Know some types of computer software

3.0 Main Content

3.1 Descriptions of Computer Software

Software can simply be described as a set of codes or programs involving a combination of well-defined instructions, scripts, procedures, documentations, and data that can manipulate and execute predefined tasks on a computer system. These tasks also include the control of functionalities of the computers or computing devices in handling jobs according to the programming. The computing devices include PCs, tablets, PDA, Automated teller machines, mobile phones, smart TVs, and other microcontroller-based embedded systems or smart devices.

Basically, computer hardware devices cannot operate or function without software. This inter-relationship between hardware and software is as shown in figure 2.0. You need to also understand that a software suite comprises programs, also known as a set of codes, design specifications, documentation, and users' manuals.

3.2 Types of Computer Software

Since the inception of the computer age, there are have been several kinds of software serving different purposes ranging from hardware control, users' operations, management of hardware to the entire system control. Most times, the users, developers, manufacturers and programmers determine the availability of different kinds of software that are used in the computer systems.

Generally, software can be classified into application software, system software utility software, operating system and firmware. All these forms of software are available in computer systems and software engineering environment so as to support ICT facilities, computer users, programmers, developers among others. Figure 11 shows the classifications of software. Let us go through all these now.

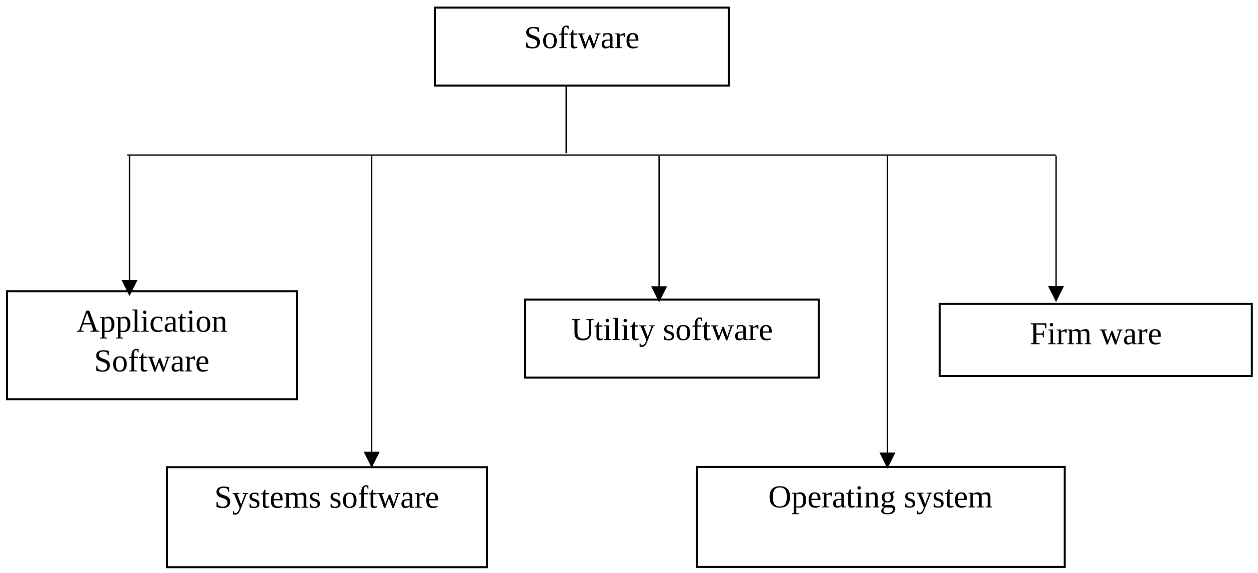


Figure 11 Classifications of Computer Software

Operating system

An operating system software is a software that interfaces between system hardware, application software and the users. It is analogous to a company secretary or receptionist that interact between the guests and other workers or offices of the organization. On arrival, the guests may be directed to appropriate employee or office that can meet the needs of the guests. Thus, without the roles of operating systems the computer hardware cannot be operated, controlled and manipulated by the users. The effective communication between hardware and users is very important for both parties.

Essentially, the operating systems enable the management of all the computer resources. These resources include memory, files, processes, peripheral devices, security features, processors, storage devices, networking functionalities, job scheduling among others.

Operating systems (OS) can be broadly categorized as single-users and multi-users. While a single-users OS allows one user at time, a multi-users OS allows more than one user to operate a computer at a time. We also have single-tasking and multi-tasking operating systems. Tasks are processes or jobs running by the computer central processing unit. Now, you should be able differentiate between single-tasking, and multi-tasking. A single-user OS may be either single-tasking e.g. (MS Windows 95) or multi-tasking (e.g. MS Windows 7, 8, 9,10,11). MS here means Microsoft, one of the prominent software developer companies in the world today.

Examples of single-users operating systems are MS-DOS, Windows 95, Windows NT, Windows 2000, Microsoft Windows 7, 8, 9, 10, 11, etc.

Examples of multi-users operating systems are Mainframes, IBM AS400, Linux & Unix Distributed OS, etc.

Application software

An application (app) software is a computer program suite specifically designed and developed to solve a certain problem, perform a job or execute an activity in various human endeavours. Mostly, applications manipulate or work on data, text, numbers, audio, graphics, and video with respect to the objectives of the operations.

Examples of application software are MS Word, Excel, PowerPoint, Google Chrome, Photoshop, MySQL etc.

Firmware

Firmware is a kind of software that enables the low-level control for a specific micro-controller-based hardware device. Firmware software are mostly used for embedded systems operations and control. Today, many electrical/electronic appliances such as washing machines, air conditioning units among others have firmware running in their computing systems.

4.0 Conclusion

It is important to note that a computer system or computing device is broadly divided into hardware and software. While hardware refers to the physical components or parts, the software is the soft part, non-tangible, or simply codes and programs that drive the hardware. The computer hardware machines cannot function without the software. Thus, the software helps to achieve the functions a computer. Types of software include systems software, operating systems, application software and utility software.

5.0 Summary

In this Unit, you have learned about software, types of software and software applications.

6.0 Self-Assessment Exercises

- ✓ Give some analogies of computer software
- ✓ What are the roles of computer software?
- ✓ State some examples of computer software
- ✓ Distinguish between firmware and operating systems

7.0 References and Further Reading

Stallings (2005). Operating Systems, Internals and Design Principles. Pearson: Prentice Hall.

Gagne, Silberschatz Galvin (2012). Operating Systems Concepts. New York: Wiley. p. 716. ISBN 978-1118063330.

https://www.webopedia.com/definitions/software/

Module 2: Computer Hardware Architecture

Unit 1: Von Neumann Computer Architecture

Content

1.0 Introduction

In the last Module, you learned about computers functions and the types of computers. In this module, we shall study deeper the architectural design, layout, nature, and structure of a computer system. In 1945, the well-known and most acceptable standard architecture for all digital computer systems was designed and published by John Von Neumann, a Hungarian mathematician who also doubled as a physicist. This man was thus the architecture is tagged Von Neumann architecture.

2.0 Intended Learning Outcomes

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

- Understand the marketecture of computer systems
- Peruse the detailed component of the computer system

3.0 Main Content

3.1 Von Neumann Computer Architecture

Von Neumann architecture described the digital-based computer hardware as a system comprising the following major parts

- System Unit
- System board
- Central Processing unit
- Ports
- Input Devices
- Output Devices
- Memory

- Secondary storage
- Communication devices

The functionality of these aforementioned parts is a similitude to the joint operation of the human body. Our brain is the central processing unit, our legs and hands are the input/output devices. Can you guess what the memory devices may refer to?

Figure 12 shows the pictorial description of the Von Neumann architecture that serves as the basis for all digital computer systems.

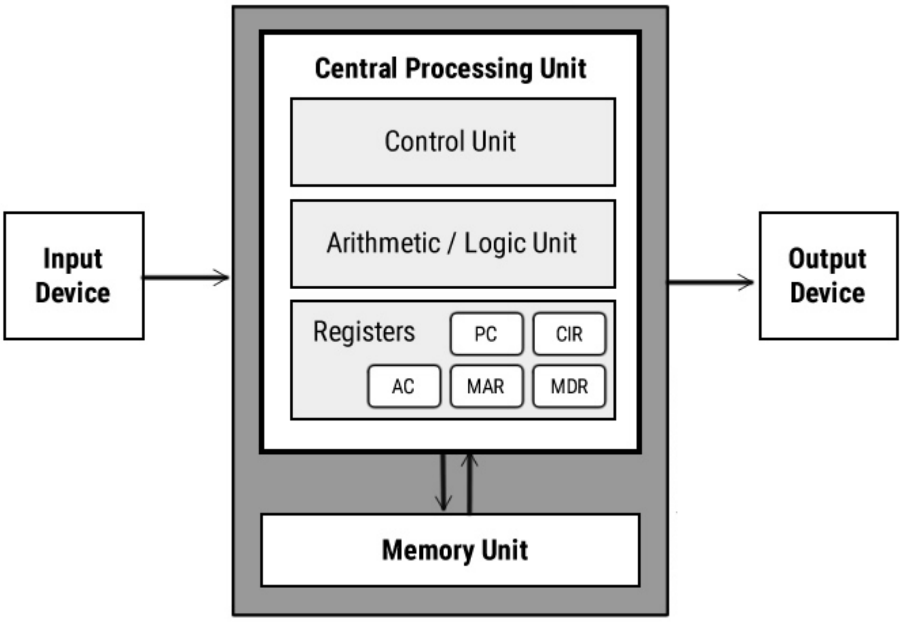


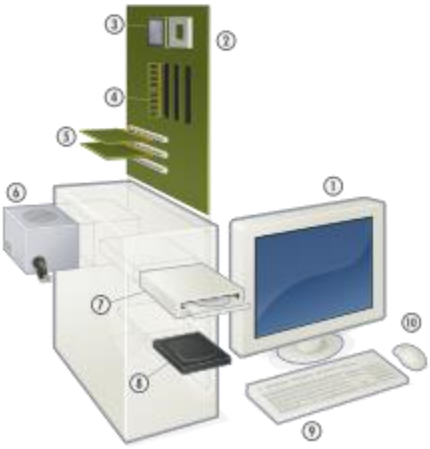
Figure 12 Von Neumann Computer Architecture

In Figure 12, the central processing unit, popularly known as CPU for short, comprises of the control unit, arithmetic/logic unit and processor registers. The computer system operations are also controlled by the peripheral devices which are basically known as the input and output devices.

We shall discuss the details of these component parts in the following modules

3.2 System Unit

The system unit houses all the internal components of a computer system. These internal components include the system board, also known as the motherboard, the power supply unit, fixed hard drives, communication buses among others. Figures 12 and 14 show the illustrations of computer system unit.



Label
1. Monitor
2. Motherboard
3. CPU
4. RAM
5. Expansion cards
6. Power supply
7. Optical disc drive
8. Hard disk drive
9. Keyboard
10. Mouse.

Figure 13 Personal computer hardware

Figure 14 System unit of a personal computer

The entire system unit of a personal computer is often located in a plastic or metallic case or enclosure. Such personal computers are desktops, laptops, and palmtops. The desktop PC case, which is usually designed to be placed on desks, can either be in the tower or flat shape. Nowadays, there are compact, all-in-one desktop system units having all the peripheral devices integrated together. Such all-in-one systems are manufactured by Dell, HP, and Apple (iMac). Most high-performance computer servers and workstations are available in bigger, rack and tower shapes.

Power supply unit

The computer power supply module which is located in the system unit case enables the conversion from 100-240V alternating current to low-voltage direct current voltage to power the internal components according to the requirement specifications. Some systems like laptops have the in-built batteries for power backup when utility power supply fails.

System upgrade

The computer system upgrade often refers to improvement on the hardware and software resource specifications so as to enhance the system capability and overall performance. For instance, in terms of hardware, the RAM size, HDD/SSD capacity, visual display unit, and CPU can be enhanced. In most cases the software and hardware advancements must match. For instance, it is advisable that the 64-bit software should run on the 64-bit processor, otherwise there may be a speed mismatch, error in computation, or operation failure.

An expansion card, which is a printed circuit board, can be inserted plugged via its socket into an expansion slot of a computer motherboard through the data bus according to the required need of the computer system. Graphics, visual display unit, sound, networks subsystems all have either in-built connections on the motherboard or expansion cards.

3.3 Computer Communication Buses

The name bus is an analogy derived from vehicle buses to transport human beings from one place to the other as shown in Figure 15. Computer bus lines, wire, or cables are electrical data paths through which bits of information are transmitted between the CPU and other components. They are communication cables and devices that enable data transfer among the internal and external components or parts of a computer system. Buses are also both hardware and software-based. Hardware buses include wires, optical fibre, etc. while software-based buses include communication protocols. The CPU word size, also known as the bus size refers to the number of bits that can be transmitted at once. In general, this should be the same as. Figures 16 and 17 show some common types of communication buses within computer systems.

Figure 15 A vehicle bus for human transportation

Figure 16 A computer bus for data transfer

Figure 17 Computer bus for data transfer between the motherboard and RAM

Historically, computer buses were initially made up of parallel electrical wires involving several connections of hardware devices. Today, computer communication buses also include parallel and serial physical arrangements that support the logical functions. Computer buses are simply wired in a daisy or multidrop arrangement as in universal serial bus or switch connections.

4.0 Conclusion

The Von Neumman computer architecture is the most acceptable standard of computer systems parts and connections upon which computer digital systems are based. The CPU, peripheral and storage devices are the main parts well revealed by this standard architecture. The computer communication buses are essential for data transfer among the computer hardware resources.

5.0 Summary

In this Unit, you have learned about computer hardware architecture. Lessons learned include the Von Neumann architecture with respect to the interconnectivity of the major parts of computers via different kinds of data buses.

6.0 Self-Assessment Exercises

With the aid of a well-annotated diagram, explain the main components of the Von Neumann computer architecture

Explain the concept of data communication buses

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Unit 2: Central Processing Unit

Content

1.0 Introduction

In this Unit, we shall explain the roles and functions of the main internal component of the computer system, which is the Central Processing Unit (CPU). The CPU is metaphorically referred to as the hearth-beat or brains of the computers. The CPU carries out the execution of computer instructions or programs and the manipulation of data. It also controls the functions of other parts of the computer so as to enable the smooth running of the entire computer system. The CPU is also known as the processor, microprocessor or central processor of the computer.

2.0 Intended Learning Outcomes

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

- Comprehend the central processing unit of the computer systems
- Understand the roles and functions of system CPU
- Know some types of CPUs

3.0 Main Content

3.1 Central Processing Unit

The central processing unit (CPU), also known as the processor is an electronic chip of an integrated circuit that control the computer and also performs arithmetic logical operations. The main function of the CPU in a computer system is to receive, implement and execute all the instruction codes received from the computer hardware and software. The CPU on the satellite onboard computer is popularly known as the central terminal unit. The CPU on the graphic adapter of an image processing computer system is known as the graphic processing unit. All these variants have the same functions and architecture. Figure 18 shows the computer CPU.

Figure 18 The computer CPU

The CPU comprises of the control unit (CU), arithmetic and logical unit (ALU), processor registers, and the program counter. Figure 19 shows the block diagram of the CPU and its internal components.

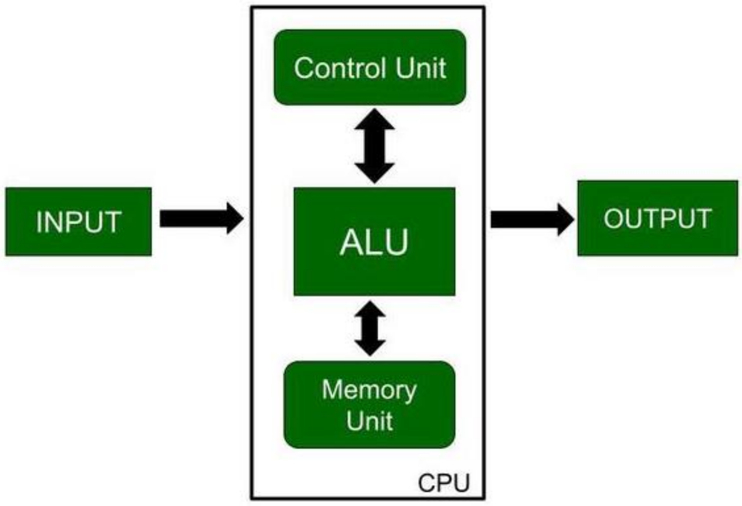

Figure 19 Block diagram of the CPU and its internal components.

How the CPU works

The figure shows that the CPU receives data through input devices and stores it in the memory. The control unit thereafter extracts the data from the memory according to the instructions. Consequently, the ALU executes necessary arithmetic and logical operations on the data manipulations. These operations include addition, subtraction, multiplication, and division. The result of the computations is stored in memory and finally sent out as output via the output devices. The control unit basically deciphers and carries out the pre-defined instructions or programs.

The word size refers to the number of bits of data a CPU can process at once. Today, due to advancement in hardware technology 64 bits is the standard word size for CPU's used in personal computers, the older CPU used 32 bits. The overall speed of a CPU in executing programs is proportional to its word size.

Different CPUs have different types of instructions, so software made for one type of CPU will not run on other kinds.

The Intel Pentium and PowerPC are common examples of processors for IBM-PCs and Macintoshes respectively.

Generally, the CPU is usually located at the center of the computer motherboard as shown in Figure 20. The CPU is usually cooled by a heat sink and fan often mounted on top of it. Most newer CPUs include an on-die Graphics Processing Unit (GPU) and co-processor for graphic and mathematical processing respectively.

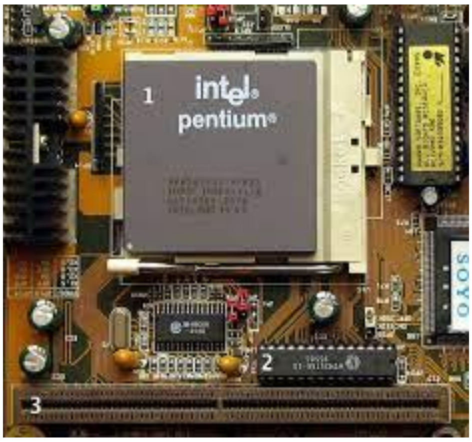

Figure 20 The CPU inside the computer motherboard

3.2 ALU

The arithmetic logic unit (ALU) component uses a combinational digital circuit to perform bitwise operations and arithmetic calculations on integer binary numbers. The ALU does not operate on other fixed- or floating-point numbers. It is a key component structure of several kinds of computing circuits, including the CPU and GPUs. The ALU operates on the operands and codes which are the inputs as the data for the system. Subsequently, this generates the output of the executed operations through the status input/output which provides information about the operations. This is achieved by the in-build external status registers.

3.3 Micro-controller or system-on-chip

The microcontroller is a complete computer on one chip, simply known as system-on-a-chip (SoC). It is a small chip with all the required electronic components, CPU, RAM, storage, and other circuitry in a specific device. Examples of the applications include a smartphone or portable computer, on a single slab of an integrated circuit, car, microwave, thermostat among others. For instance, arduino computer on a board has a microcontroller chip.

4.0 Conclusion

The CPU is an integral part of the computer hardware. It is conspicuously located at the centre of the motherboard. The computer CPU enables the control of the hardware resources and also carries out the arithmetic and logical operations of the system. The micro-controller is simply the complete computer on a small single slab of an electronic chip.

5.0 Summary
In this Unit, you have learnt about the CPU and micro-controller.

6.0 Self-Assessment Exercises
Describe the functionalities of the CPU
Identify the components of the CPU
Define a micro-controller

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Unit 3: Computer Data Storage and Memory Devices

Content

1.0 Introduction

In this Unit, we shall deal with computer data memory or storage devices. These are significant media components of the computer system used for recording or retaining all forms of digital data. Every computer system requires several different levels of memory for storing system data, users' data, programs, and instruction sets either temporarily or permanently. The two keywords here are memory and storage, which slightly refer to different things. While the memory devices store data for a short-term for immediate access, the storage devices store data long-term for permanent access. Long-term storage is also known as persistent storage duration. The data, in this case, refers to documents, applications, programs, codes, and operating systems.

Computer memory can be classified into either primary and secondary or fixed and removable devices.

2.0 Intended Learning Outcomes

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

- Understand the computer memory organization and architecture
- Know some types of memory storage devices

3.0 Main Content

3.1 Primary Main Memory

The rimary memory chips which are directly accessible by the CPU, is the main primary memory of the computer. The access speed of the main memory is faster than any other kinds storage devices. Examples of primary memory devices are Random Access Memory (RAM) and Read Only Memory (ROM). Both of them are made up of solid-state materials.

Figure 21 shows different types of memory and storage devices available in computer systems. Let us discuss some of these storage devices in detail.

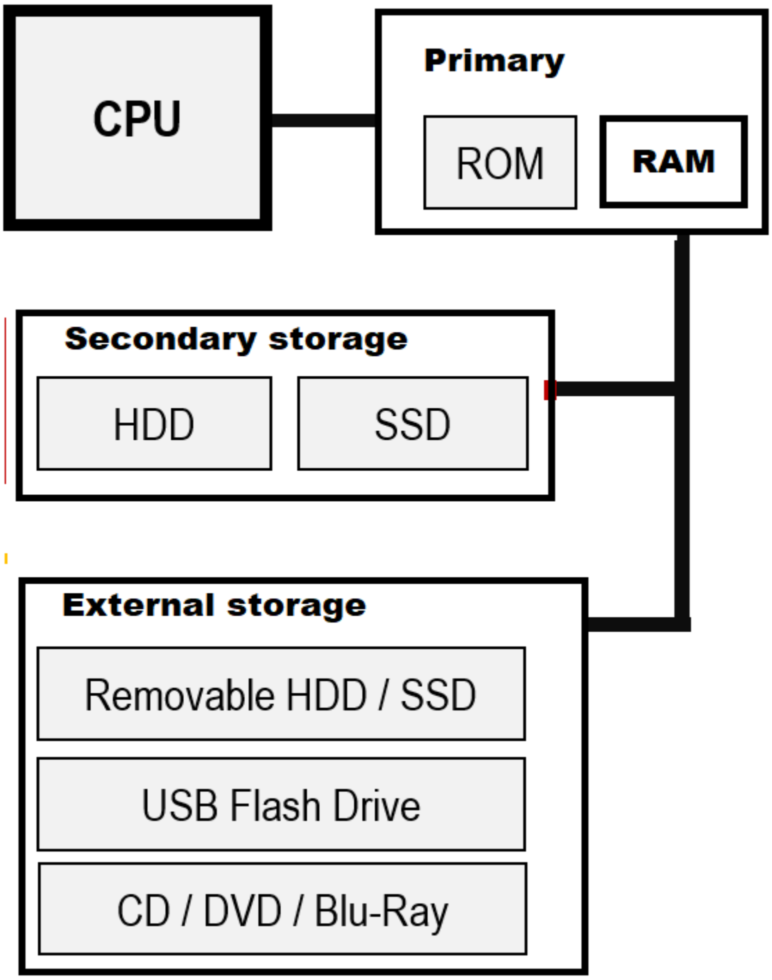

Figure 21 Computer memory and storage devices

Random Access Memory

Random Access Memory (RAM), is a main memory or primary storage that has capability of holding the loaded data, instructions, operating system and all running application, processes and other programs only during execution, that is, when the computer system is running and powered by electricity. RAM behaves like a scratchpad memory or whiteboard. temporary, it is a working storage area of bytes under the supervision of the CPU. RAM stores entire data temporarily. For instance, if you type your CV on MS Word without saving it with a file name, it remains inside the RAM while your computer keeps working. If the power is turned off in the process, your data and program will be erased automatically. Then you will lose your documents or data. This means RAM is not persistent, its contents are dependent on power supply. Therefore, always save up your document while working and making updates.

A good feature of RAM is about faster speed of access because its contents are being actively manipulated by the CPU. It is able to access and retrieve the value of any particular byte in a few nanoseconds (1 nanosecond is 1 billionth of a second). RAM is more than 1000x faster than the fastest secondary storage.

Usually, RAM is designed and manufacture with a few chips packaged together onto an integrated circuit, a popular example of this is the dual inline memory module (DIMM) that can be inserted into the motherboard socket as shown in Figure 22.

The two common types of RAM are static RAM (SRAM) and dynamic RAM (DRAM).

a) SRAM

This is a kind of RAM that uses flip-flops transistor or Mosfet (MOS) as switching devices. Its access speed is fast but more expensive. Example of SRAM is cache memory.

b) DRAM

Dynamic RAM uses capacitors as switching devices to store. The capacitors charges when data is 1 and do not charge when the data is 0. Unlike SRAM, DRAM requires refreshing circuits for the data refreshment so as to avoid current leakage. Usually, it is slower but cheaper thank SRAM. Most computer main memory is made up of DRAM due to higher access time.

Figure 22 Random Access Memory in a motherboard

Read-Only Memory

The Read-Only Memory (ROM) chip is a type of primary memory that stores the basic input/output system (BIOS) information that runs when the computer is booting or starting. They are non-volatile memory that generally contains instructions for booting the computer or loading the operating system. This information is in boot and power management firmware. Modern motherboards apply Unified Extensible Firmware Interface (UEFI) instead of BIOS.

The flash chips are non-volatile devices that do not require electricity. They are used in computers, cell phones, digital cameras, etc.

The cache memory is special high-speed memory that temporarily stores instructions and data that the CPU is using frequently, Thus speeding up the processing. The Level 2 or external caches generally range in size from 64 Kilobytes to 2 Megabytes.

3.2 Secondary Storage Devices

A secondary storage device can be described as a persistent or non-volatile medium that can save up data for a long time until it is overwritten, deleted, or corrupted. These storage devices can either be fixed or removable. Examples of secondary storage devices are Hard Disk Drive (HDD) and Solid State Drive (SSD). The removable USB flash drive and optical compact disks can be used to copy or transfer data between computers. The fixed drives are usually permanently connected to the system unit of the computer. HDD and SSD are often connected to the motherboard through communication cables. HDD is capable of using its read/write heads to store digital data on a magnetic surface of a rigid plate. HDD physical size is usually 3½ and 2½ inches for desktops and laptops respectively.

These types of storage devices shall be discussed as follows;

Compact Disc, DVD, Blu-ray are examples of optical external storage devices while USB Flash Drives are made up of solid-state materials. Flash drives as also known as thumb drives or USB-key.

Difference between Hard drives and Solid State Drives

A solid-state drive (SSD) is a secondary storage device that implements an array of integrated circuits to store data persistently. Hard disk drives are found in virtually all older computers, due to their high capacity and low cost, but solid-state drives are faster and more power-efficient but more expensive. Flash drives are removable and external SSD. They consume less power, and they are usually faster and cheaper than hard disk drives. Technologically, hard drives store bytes of data as a magnetic pattern on a spinning metal disk in high pitch spinning sound. The solid-state drives that store bytes on flash chips, do not have spinning parts but use silicon chips and electrons.

Today, high-performance computer clusters use disk array controllers for greater reliability, security, and massive storage. Figure 23 shows Hard Disk Drive for persistent storage.

Figure 23 Hard Disk Drive for persistent storage

Figure 24 and 25 shows USB flash drive or Optical disc which can be used to transfer data between computers via the USB port. They are compatible with most hardware and software specifications.

Figure 24 Removable Flash Drive for persistent storage

Figure 24 Removable Flash Drive for persistent storage

Flash drive

Figure 25 shows the SD Card which provides storage in devices like cameras. This looks similar to the USB flash drive.

Figure 25 SD memory flash

Other types of removable secondary storage devices are as follows

Compact disc (CD) is a circular thin platted glass and plastic polycarbonate material of a standard size of 12 cm with a hole in the center of about 1.5 cm and 1.2 mm in thickness. The CD has a storage capacity of 600 MB to 700 MB of data, this technological product is much older, the new ones will be discussed shortly. CD uses optical laser technology instead of magnetic technology to store its contents. Figure 26 shows bottom surface of a 12 cm compact disc.

Figure 26 Bottom surface of a 12 cm compact disc

Types of Compact discs are:

a) Compact disc Read-Only Memory (CD-ROM): The contents of the CD-ROM cannot be deleted by any means. Only the publisher is allowed to access the data imprinted on this CD. It is mostly used to store or copy small size documents or software applications.
b) CD-Recordable (CD-R): The contents can be stored once and read several times. Just like CD-ROM, its contents cannot be deleted or overwritten.
c) CD-RW (CD-Rewritable): The contents of CD-RW can be erased or rewritten several times.
d) Digital Video/Versatile Disc (DVD): This type has a higher storage capacity ranging from 4.7GB to 17GB depending on whether it is a single or dual-layer format. The storage capacity of a DVD with a one-sided layer is 4.7 GB, the one-sided double layer is 8.5 GB, the double-sided layer is 9.4 GB, and the double-sided double-layer is 17 GB.
e) DVD-ROM: The contents of this type of media cannot be written on or erased by the user. It is mostly used for distributing proprietary software or other kinds of applications.
f) DVD-R / DVD+R: These two different types of discs, DVD-R (DVD minus R) and DVD+R (DVD plus R) are recordable once.
g) DVD-RW / DVD+RW: The contents can be re-written several times.
h) DVD-RAM: This is a rewritable disc that can alter its contents several times. It functions like hard disks.

A Floppy disk is an old, portable, and removable platter storage device that was made of magnetizable mylar plastic. The data is stored in concentric rings called tracks on either side of the platter. The last kind of floppy disk was is a 3½ inches platter in a hard plastic case that holds 1.44 Megabytes of information. A Zip disk, on the other hand, could hold up to 250 Megabytes.

Magnetic tape, which was developed in Germany in 1928, is a medium for magnetic wire data recording. It was made of a thin, magnetizable coating on a long, narrow strip of plastic film. Tape recorders and video tape recorders are used to record and playback audio and video respectively. The tape drive stores computer data on magnetic tape.

4.0 Conclusion

The storage or memory devices are integral parts of a computer system. The devices can be categorized into primary and secondary which can be either fixed or removable. RAM and ROM are primary memory while HDD and SSD are types of secondary non-volatile storage devices. The removable storage devices are USB drives, flash drives, and compact disc drives. The required types and capacity of drives needed for a computer system is a function of the well-configured system specification, cost, and the desired performance.

5.0 Summary

In this Unit, you have learned about different kinds of memory and storage devices. Quite some examples were also stated.

6.0 Self-Assessment Exercises

Distinguish between persistent and non-persistent storage of data

Differentiate between Hard disk drive and solid-state drive

List some types of compact discs you know

Why is the manufacturing of floppy drives discontinued?

7.0 References and Further Reading

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Module 3: Computer Peripheral Devices

Unit 1: Input Devices

Content

1.0 Introduction

In the previous modules of this course, you have learned about various hardware parts of computer systems as shown in the John Von Neumman architecture. Peripheral devices, which involve input and output devices are significant parts of this standard architecture. The peripheral devices are connected externally to system unit of the computer through appropriate interface and ports.

2.0 Intended Learning Outcomes

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

- Understand the input devices and the functions in the computer system
- Identify various kinds of input devices

3.0 Main Content

3.1 Description of Input Devices

Input devices are parts of the computer system that enable the users to enter data and the required control parameters into the computer. The input data is thereafter converted and translated into a computer-readable format for subsequent processing by the central processing unit.

Input devices can be categorized into pointing, scanning, wireless, and cable devices. Pointing input devices are used to move a cursor on the screen, examples of these include the mouse, trackball, and touchpad. The category of scanning input devices are Optical Mark Recognition (OMR), scanners, Optical Character Recognition (OCR) devices, bar code readers among others. These pointing input devices can sense and read characters directly on papers, and other kinds of materials. Bar code readers are often used to scan bar code items in the supermarkets and different kinds of industrial products in the supply chain line.

Some of the input devices include the keyboard, mouse, touchpad, webcams, microphones, joysticks, image scanners among several others. Figure 27 shows Computer with Peripheral Devices.

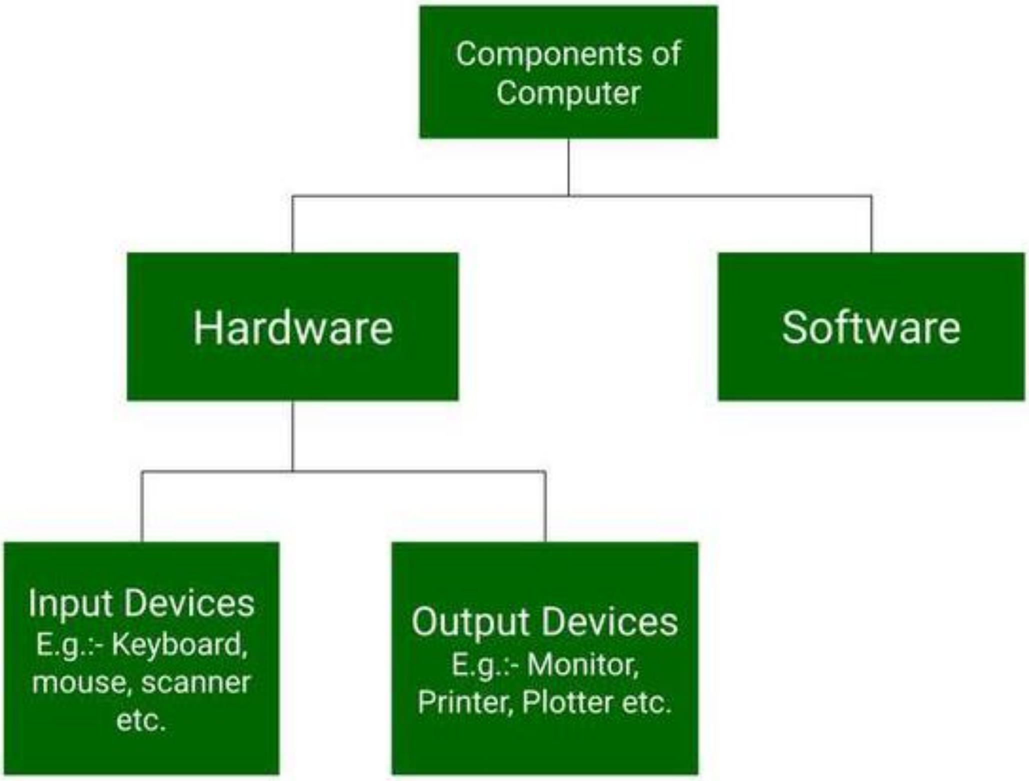

Figure 27 Computer with Peripheral Devices

3.2 Keyboard

The keyboard is the major and commonly used data entry device for different kinds of computers. Like the old typewriter machines, the keyboard is used to enter data into the computer by typing the necessary alphanumeric keys. There is a total of 104 numeric, alphabet, and function keys. The keyboard can be connected to the system unit via cable or wirelessly using Bluetooth.

Essentially, the keyboard typing keys include the following classes

- Upper and lower case alphabet keys from A-Z and a-z respectively
- Numeric keys from 0 to 9
- Special 12 function keys for specific purposes
- control (Ctrl) keys
- cursor and screen control keys are Arrow keys, page up, page down
- Alternate (Alt), Escape (Esc), Home, End, Insert, Delete
- Enter, backspace, num-lock, caps lock, shift, space bar, tab, scroll lock, sleep, print screen

Figures 28 and 30 show the illustration of computer keyboard.

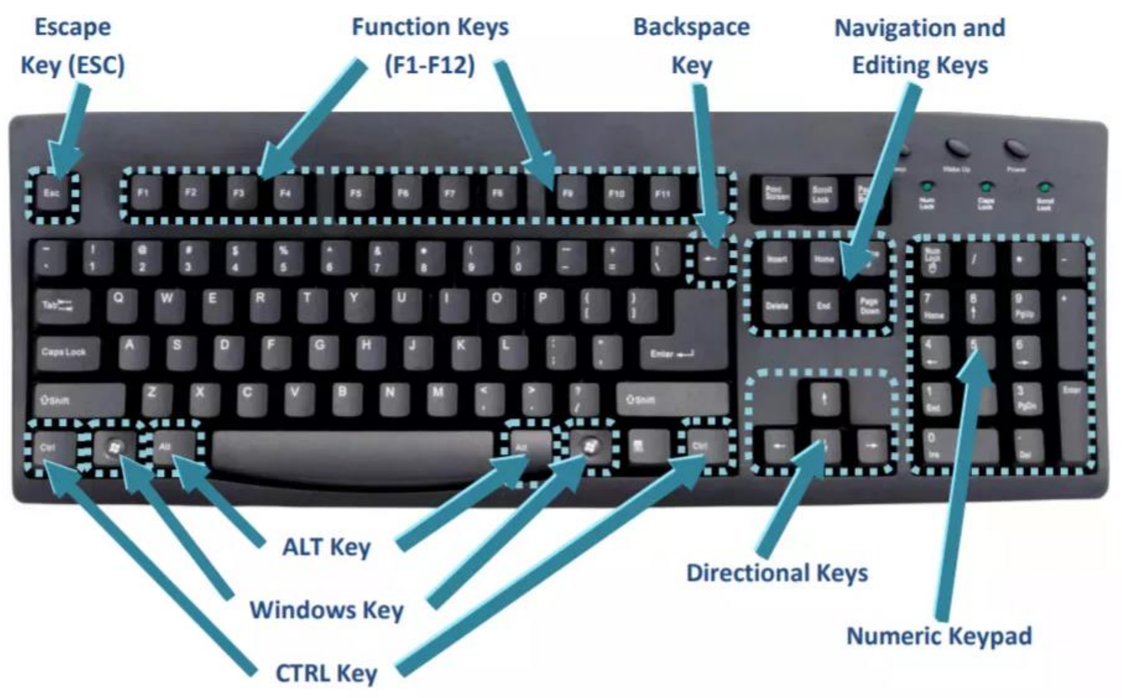

Figure 28 Description of computer keyboard

Figure 29 Computer keyboard

3.3 Mouse

A mouse is an input pointing device that is rolled over a smooth surface to control the cursor on the computer screen through its speed controlled sensor, operational clickable buttons on the left, middle, and right parts. The functions of the buttons can be customized to select and, open files or objects. Figures 30 and 31 show the wired and wireless mouse.

Figure 30 Wireless Mouse

Figure 31 Mouse

3.4 Image scanners

The image scanner is an input device that optically scans printed materials, objects, images, and documents and thereafter converts and store them in a digital format. The scanned document be edited for further application. Figure 32 shows a scanner.

Figure 32 Scanner

3.5 Track Ball

A trackball is a pointing device that holds a small ball held in its sensor-based socket. The sensor detects the rotational movement of the ball about its two axes. The device operates exactly like an upside-down mouse but uses space to rotate its ball. As the trackball remains stationary and the user moves the ball in various directions, it reflects activity on the screen as shown in Figure 33.

Figure 33 Track ball

3.6 Light Pen

Light pen is a light-sensitive input device that can be used to point and write or draw directly on the visual display unit, monitor, and screen. Light pen to detect raster on the screen as it passes on it with high precision. Light pen functions well like the touchscreen devices as shown in figures 34 and 35.

Figure 35 Light pen

Figure 34 Light pen on IPAD

3.7 Headsets and Microphone

Headsets or microphones are a kind of computer voice input devices that are able to record sounds by transmitting and converting human speech or voice into electrical signals. This electrical signal is processed by the computer and the word is recognized. Application areas include in customers' service, religious programmes and technical support centers, where the users can communicate with clients while entering or typing into a computer. Figure 36 shows a typical computer microphone.

Figure 36 Computer microphone

3.8 Optical Character Reader

Optical character recognition or optical character reader (OCR) uses a low frequency light source to detect and convert drawn images, alphanumeric characters, and printed text into machine-encoded text, pictures or scanned documents. The OCR, which operates like a scanner, absorbs light by the dark areas and is reflected by the light areas. Subsequently, it reflects and receives the light by the photocells as shown in figure 37.

Figure 37 Barcode Reader

3.9 Bar Code Reader

A barcode reader is an optical scanning device which is connected to a compute to read printed barcodes and decode the hidden data. The barcode reader which functions like a flatbed scanner, comprises of a light source, a lens and a light sensor translating for optical impulses into electrical signals. Most barcode readers contain decoder circuitry that can analyze the image data in the barcode via the sensor and thereafter send the contents of the barcode to the scanner output port.

Figure 38 and 39 show a barcode reader reading data that is coded into white and black lines.

Figure 38 Bar code reader

Figure 39 Bar code scanner

4.0 Conclusion

Several computer data input devices have been discussed. The input devices are part of peripheral devices that help users to enter data into the computer system via diverse kinds of port interfaces. Upon reception, data will be processed by the CPU for further action. Some common input devices are keyboard, mouse, scanner, optical character reader, barcode reader among others.

5.0 Summary

In this Unit, you have learned about some common data input devices.

6.0 Self-Assessment Exercises

What do you understand by peripheral devices?

List five types of data input devices

Discuss any 4 kinds of data input devices

Distinguish between scanner and barcode reader

7.0 References and Further Reading

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Unit 2: Output Devices

Content

1.0 Introduction

You have learned about input devices in Unit 1. In this Unit 2, you will learn more about computer peripheral devices, essentially, the output devices. These are the devices that are used to display, in human-readable form, the output of any task carried in the computer.

2.0 Intended Learning Outcomes

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

- Identify some output devices often used to enter data into computers
- Differentiate between input and output devices

3.0 Main Content

3.1 Description of Output Devices

An output device is any peripheral hardware that is connected to a computer either wired or wireless so as to display, project, or physically reproduce the results of data processed by a computer. It converts electronic information into a format, which can be understood by humans.

What differentiate an input from output device is that the input device transfers data to the computer, whereas the output data receives data from the computer. Input devices usage is mandatory to operate the computer, on the other hand, output devices may be optional.

Conventionally, the output devices can be grouped into data, print, visual, and sound hardware. Thus, various kinds of output hardware include visual display unit (monitor or screen), printer, plotter, headphones, computer speakers, projector, GPS, sound card, video card, braille reader, speech generating machine, among others.

3.2 Visual Display Unit

The visual display unit (VDU) popularly known as a monitor or display screen, is the main and well-known output device that displays output contents as picture elements (pixel) on the computer screen. These output contents include text, video, images, etc. The VDU looks much like a TV screen and they share similar resolution parameters.

The resolution of the monitor is determined by the number of pixels. Basically, the monitor resolution, smoothness or picture clarity, increases with more pixels. The two types of monitor screens are cathode ray tube monitors (CRT) and flat-panel screen monitors.

Cathode Ray Tube monitors, which were manufactured using old CRT technology, applied phosphorescent dots to generate pixels that form displayed images. CRT monitor screens, which were the same as the old TV CRT technology, were usually large and consumed more power. Figures 40 and 41 show LCD and CRT visual display units respectively.

Figure 40 LCD visual display unit

Figure 41 CRT visual display unit

Flat Panel Screen Monitors

Flat-panel screen monitors, which implement a thin panel design instead of CRT technology, are much lighter, thinner, and portable. They use liquid crystals or plasma technology to generate output as light passes through liquid crystals to form the required pixels.

The three types of Flat Panel screen monitors are Liquid Crystal Devices (LCD) monitors or Non-emissive displays, Light Emitting Diode (LED) monitors or Emissive displays, and Plasma monitors. Let us explain these three types of monitor screens.

a) Liquid Crystal Devices (LCD) monitors or Non-emissive displays
This type of flat panel display implements the light-modulating properties of liquid crystals. This technology is also replicated in LCD televisions, aircraft cockpit displays, ship cocktail screen, etc. An LCD monitor is more energy-efficient, and users' friendly. It is safer to dispose than the CRT monitors.

b) Light Emitting Diode (LED) monitors or Emissive displays
Although the technologies of LCD and LED are similar. The LED technology of LED is more advanced than the LCD monitor. The LED monitors are lighter, thinner, and less expensive. These monitors are more reliable as they have a more broad dimming range in terms of backlighting.

c) Plasma monitors
The picture elements in the plasma screen monitors are illuminated by a tiny bit of charged gas or plasma which is similar to a tiny neon light. These monitors are thinner, brighter, and better in performance than the Cathode ray tube, and liquid crystal display monitors.

3.3 Printing Devices

The printing devices are specialized computerized machines that can print information permanently on materials of different forms. They are usually stand-alone systems that can be connected to computers via cable, wirelessly, or cloud. Examples of printing devices include printers, plotters, 3D printers among others. This section discusses on some printing devices.

3.3.1 Printers

A printer is the most second common type of output device that permanently transfers the processed data from the computer into a printed format and thereby produces text or images hardcopy output on paper. Today, different kinds of printers can print texts, photos and graphics objects in coloured, monochrome, and black and white. Printers used in homes and offices have high dots per inch (DPI), which generates high-quality images.

The printers are classified into Impact, and Non-Impact printers.

a) Impact printer

This is old type of printer noisily prints characters by striking on the ribbon, and thereby imprint on the paper.

The impact printers can either be character or line printers.

i. Character printers

These types of printers are capable of printing text, and a single character at a time in the average speed is up to 300 lines per minute. The different types of character printers include chain, band, dot matrix, and daisy wheel printers. The commonly used printers are dot matrix and daisy wheel.

ii. Line Printers

Line printers can print and display output texts line by line. The two types of line printers are drum printers and chain printers. Basically, the drum printer has high speed and can print up to 300 to 2000 lines per minute.

b) Non-Impact printer

The non-impact printers can print without striking the ribbon. These include laser printers and inkjet printers.

i. Laser Printers

Laser printers which use a photoelectric drum, powdered ink, and laser light to produce dots to form the characters for printing. When a print command is given, a laser beam draws the document on a selenium-coated drum using an electrical charge, giving a clean copy of the image on the paper. They have fewer smearing problems than an inkjet printer since ink is not used. A laser printer uses the same technology and procedures like a copying machine. Figures 42 and 43 show LaserJet printers.

ii. Inkjet Printers

This printer generates output by spraying droplets of ink onto the paper through a small nozzle. Inkjet printers are the most widely used type of printer. There are expensive and inexpensive models available in the market. It was the most common type of printer in the olden days due to limited available technology. The printers are less expensive.

Figure 42 LaserJet Printer

Figure 43 Coloured Epson Printer

3.4 Graph Plotter

A plotter output device, which is similar to a printer, but usually bigger in size, can be used to draw large high quality, images, pictures and vector graphics.

A plotter is used to generate and draw hardcopy on papers large drawings, architectural blueprints, engineering drawings, graphic cards, cadastral maps, satellite imageries among others. Figure 44 shows a graph plotter.

Figure 44 Graph Plotter

3.5 **Computer Speakers**

Computer speakers are one of the most common output hardware used with a computer. The speakers receive audio as input from the computer via a sound card. The internal amplifiers of the speaker can be used to control or vary the volume or the amplitude of the sound. Connection of external speakers can be used to enhance the volume and other in-built parameters of the sounds. Figure 45 shows computer speakers.

Figure 45 Computer speakers

4.0 Conclusion

Computer output hardware are quite important in showing and revealing the results of processing by the CPU. Some common output devices are visual display units, printers and output accessories. A printer is a peripheral output device which produces a hardcopy of graphics or text from a computer usually on papers. While most output is human-readable, bar code printers are an example of an expanded use for printers. Different types of printers include 3D printers, inkjet printers, laser printers, and thermal printers.

5.0 Summary

In this Unit, you have learnt about some common computer output devices. Their usage enables the users to view and appreciate the results of processing.

6.0 Self-Assessment Exercises

Differentiate between CRT and flat panel screen monitors
Mention the three types of Flat Panel screen monitors

7.0 References and Further Reading

Morley, Deborah (April 2007). Understanding Computers: Today & Tomorrow, Comprehensive 2007 Update Edition. Cengage Learning. p. 164. ISBN 9781305172425.

https://www.tutorialspoint.com/basics_of_computer_science/basics_of_computer_science_types.htm

https://www.classmate4u.com/output-devices-of-computer/

Module 4: Computer Hardware Components

Unit 1: System board - Motherboard

Content

1.0 Introduction

In this Unit, you will learn about the system motherboard. The motherboard is the main circuit board firmly fixed inside a computer system unit to which all other internal electronic components and interfaces are connected via its ports. Among these are CPU, RAM slots, controllers, system chipset, ROMs, communication cables.

2.0 Intended Learning Outcomes

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

- Understand details about computer hardware components
- Get familiar with the design of computer motherboards

3.0 Main Content

3.1 Description of Motherboard

The motherboard is a major large integrated circuit component in the system unit. It is rectangular in shape and contains chipsets, switching devices, onboard ports, sockets, slots, ROM chips, and interfaces for interconnecting CPU, hard drives and optical drives, CMOS, data buses, cooling fan, power supply unit, and secondary storage devices. Different kinds of communication and power cables are used for appropriate connections. Expand cards and other peripheral card slots also provide connections to video, speakers, and sound interfaces. The cooling fans and heat sink prevent excessive heat radiation and thereby maintain the specified operating condition inside and outside the system unit.

Some popular manufacturers of the motherboard include Intel, ASUS, AOpen, ABIT, Biostar, Gigabyte, MSI. Figures 46 and 47 show computer motherboard.

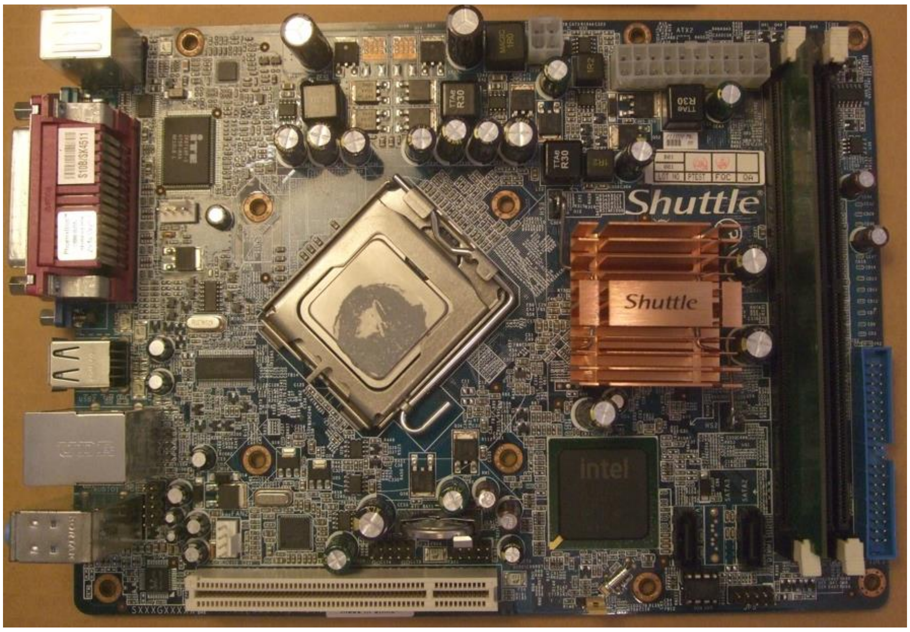

Figure 46 Computer motherboard

The chipset is one of the most important components in the motherboard. Older motherboards were designed with a lot of different chips scattered all the motherboard. There are chips for different things like chips for bus controller, memory controllers, keyboard controllers, etc. Thus, diver chips control different functions on the motherboard. A chipset is a smaller set of chips that has replaced a larger amount of chips so as to control data flow between the CPU, the peripherals, bus slots, memory, and other parts of computer.

Furthermore, the advancement in technology enable the chips manufacturers to reduce the number of chips and rather centralizes somewhere to execute same job and localize them to chipset. Buses connect the CPU to various internal components and to expand cards for graphics and sound. The CMOS battery attached to the motherboard provides the memory power backup for system clock, date, time and other system setup parameters in the BIOS chip. The CMOS battery is mostly CR2032.

It is important that video cards, hard disks, sound cards, power supply modules, and system unit cases are compatible and interoperable with the motherboard in order for the entire computer system to function properly as required.

Figure 47 Motherboard components layout

The computer system clock is an electrical pulse generator that sends out a pulse of electricity at regular intervals. The electronic components of the computer require these electric pulses in order to execute tasks. The more pulses sent out by the system clock in a cycle, the faster the CPU works. The first personal computers had clock speeds of 8 million pulses per second (8 MHz), but nowadays, the PCs have clock speeds greater than 3.2 billion pulses per second (3.2 GHz).

3.2 Computer Communication Ports

A computer port is a connecting interface point or socket between two electronic devices. These devices can either be both computers or a peripheral device and a computer. This connection point enables the use of various functionalities, such as the transmission of data, power, audio, and video. Plugging a printer into your computer, electrical charging of your phone, and storing or transferring data via a USB device are all instances of using computer ports.

Furthermore, computer ports grant easy power connection, charging of electronic accessories, Ethernet connections, external storage of documents or projects, projection of audio or visual media, and cable connection to peripheral devices, such as printers or scanners.

The use of computer ports is very essential in our homes, offices, or in the public due to the proliferation of different kinds of computers, peripheral devices, and applications that require the exchange of data and information. Ports and sockets are often located outside the system unit through the motherboard or interface board for the convenience of connecting or disconnecting communication cables.

The following figures will enable you to identify different types of computer ports so as to make use of them appropriately. This will help to improve your performance in your academic or career when dealing with hardware and software interfacing. Figures 48 – 51 show different kinds of computer communication ports.

Figure 48 Computer ports

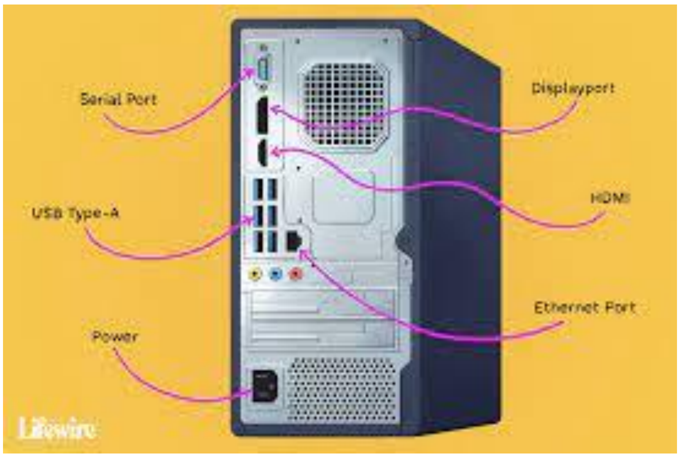

Figure 49 Computer Ports on the System Unit

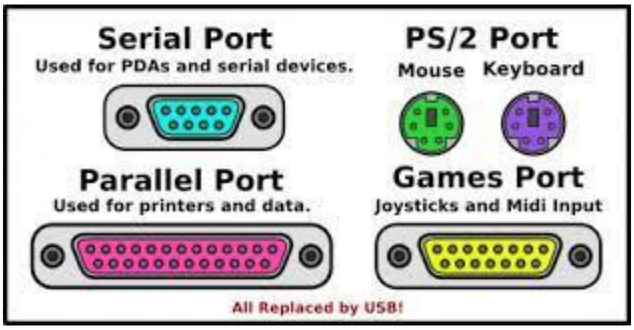

Figure 50 Additional Computer ports

Figure 51 Generic Computer Ports

Although, some ports technologies are relatively old, many of such old ports are still found on legacy computing equipment. Therefore, it is important for you to get familiar will all form of ports and sockets so as to be able to operate many kinds of computing hardware devices. Other ports such as Universal Serial Board (USB) on the motherboard provide connection to monitor, printer, mouse, keyboard, speaker, and network cables. The USB ports enable compatible devices to be connected in plug-in/plug-out scheme.

Types of Computer ports

Fundamentally, hardware ports are available in different types based on the signal transfer modes. Some common ports are:

Serial port, parallel port, PS/2 port, universal serial (USB) port, Video Graphic Adapter (VGA) port, Modem port, game port, ethernet port, Digital Video Interface (DVI) port, etc.

While serial ports transmit one bit of data at a time, the parallel ports transmit 8 bits of data at a time. The technology of universal serial bus (USB) ports is newer and the port is much faster than serial or parallel port. USB ports allow multiple devices to be connected to the same port.

4.0 Conclusion

You have learned about some computer hardware components in this Module. These include the system motherboard or main board, and communication ports. It is important for you get familiar with a large array of existing communication ports, their functionalities, and components interconnectivities. This will really enhance your studies and career in computing. Although, some ports are old, they still exist in some legacy systems and customized devices, which are readily available in manufacturing, satellite, and communication industries.

5.0 Summary

In this unit you have learned about computer communication ports. There are quite number of them. The literature provided will enhance further study on this.

6.0 Self-Assessment Exercises

Describe the usefulness of the computer system

Explain the function of computer communication ports

List some computer ports

7.0 References and Further Reading

Jan Axelson, USB Complete: The Developer's Guide, Fifth Edition, Lakeview Research LLC, 2015, ISBN 1931448280, pages 1-7

Hachman, Mark (2022). "The new USB4 spec promises a lot: Thunderbolt 3 support, 40Gbps bandwidth, and less confusion". PCWorld. Retrieved 26 January 2022.

Kars, Vincent (May 2011). "USB". The Well-Tempered Computer. Retrieved 7 May 2018. All operating systems (Win, OSX, and Linux) support USB Audio Class 1 natively. This means you don't need to install drivers, it is plug&play.

https://web.stanford.edu/class/cs101/hardware-1.html

Unit 2: Microchips Technology

Content

1.0 Introduction

In this Unit, you will learn about microchips and their application areas. Microchips are the main building structures of the digital systems and embedded computing devices. Microchips are the brain and bedrock of components miniaturization that enabled mobile or portable devices in our world today. All these digital systems and embedded devices are being used in most home, office and industrial devices to control integrated systems in the oil and gas, space, manufacturing industries, just to mention a few. These enable us to work, travel, stay fit and entertain ourselves conveniently. Remote controlled devices in our cars, phones, driverless cars, robots, and other automated systems are now becoming more possible.

2.0 Intended Learning Outcomes

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

- Understand the transistors and chips functionalities in the computer hardware
- Know the relevance of transistors and chips in hardware design

3.0 Main Content

3.1 Description of Microchips

A microchip is a set of electronic circuits with millions of miniatured transistors mounted on a small flat piece of silicon slab. Microchips which are also well known as chips or integrated circuits (IC), function basically as switching devices that can turn current on or off. The pattern of tiny switches is etched on the silicon wafer by adding and removing materials to form a multilayered lattice work of interconnected shapes.

Formation of Microchips

Silicon, a semiconductor material, is an active part of the transistor is made of silicon. Remember that a transistor being a solid state component, can change its electrical state when pulsed, that is, in its normal state, the transistor may be conductive or non-conductive, either impeding or allow current flow. Knowing fully that, when voltage is applied to the gate, the transistor changes its state.

You will recall from the knowledge of chemistry, that silicon, being a semiconductor can have its conductive properties increased by mixing it with materials like boron or phosphorus. Thus, silicon can be used as a switching component to turn on and off devices. This unique behaviour is preferred to metals whose main property is to conduct electrical currents. Therefore, silicon becomes a useful and effective material in the chip industry.

Very interestingly, silicon is made from sand, the second most abundant element next to oxygen. Silicon wafers are produced from silica sand, which is made of silicon dioxide. Wafers are slices of ingot, which is the melted sand which are cast into the form of a large. Microchips, the products of these silicon wafers are therefore available everywhere on several devices. The current advances in chips have spawned new products and transformed industries worldwide. A chip size is usually measured in nanometers, which is approximately one billionth of a meter, or a millionth of a millimeter.

Types of Chips

Logic chips and Memory chips are the types of microchips available.

Logic chips are very essential in all electronic devices to process the required information. Examples of logic chips are central processing units (CPU), graphical processing units (GPU), and neural processing units (NPU). The CPUs which were initially designed in the 1960s, are capable of handling all logical and mathematical computations, the GPU was dedicated for visual display performance and the NPU was designed for artificial intelligence works especially the deep and machine learning applications.

Memory chips, that are designed to store information include Random Access Memory RAM and Read-Only Memory. These types of memory storage devices have discussed in an earlier Module of this course.

Chips Computational Power

Constant improvements on chips technology have significant impact on advanced memory capacity and computational power since 1960 till date. The computational power, in terms of CPU clock speed and memory size have driven several innovative technologies in the space, automotive, communication, and manufacturing sectors. Space-based projects; Mars exploration, deep space exploration, satellites launched, 5G deployment, robotics, and artificial intelligence projects have been made possible because of the advancements in chips technologies.

Chips Manufacturers

We need to talk about some players in the chips technology industry. The Integrated device manufacturers (IDMs) such as Intel and Samsung both design and manufacture chips. Foundries, on the other hand, are companies that manufacture chips under contract for other companies. Taiwan Semiconductor Manufacturing Company (TSMC), Global foundries and United Microelectronics Corporation (UMC) are examples of this type of chipmaker. A third type of chipmaker is the 'fabless Taiwan semiconductor company' such as Qualcomm, Nvidia and Advanced MicroDevices (AMD), who avoid the high costs of building and maintaining production facilities by focusing only on chip design. These companies might farm out their production to a foundry.

Taiwan, USA and China are among the leading countries in the manufacturing of chips globally. Most of these countries have Semiconductor Manufacturing Companies, Silicon Valley, and chips markets.

Figure 52 shows a silicon chip enclosed in a plastic package with electrical connection pins. The plastic package encloses a fingernail sized silicon chip with several transistors and other components etched on its surface.

Figure 52 silicon chip in a plastic package

Modern computers use tiny electronic components which can be etched onto the surface of a silicon chip.

3.2 Moore's Law of Silicon Technology

In 1965, Gordon Earle Moore who was Intel co-founder, propounded a non-scientific law or theory about the forecast rate that the number of transistors in a dense integrated circuit would double up about every two years. Generally, the observed components in the dense integrated circuit include transistors, resistors, diodes, or capacitors. The implication of this law is that transistors get twice smaller about every two years. Conversely, the number of transistors doubles per chip due to advancement in chip etching technology. Today, as microchips are becoming more denser, tens of billions of transistors are available in a chip, thus making chips more computationally powerful and versatile. This miniaturization engineering has led to manufacturing of mobile, onboard, embedded, and smart devices. Examples of these include Internet-of-things, computerized machines, smart watches, high-performance phones, android-based devices, cars with onboard computer, etc.

Although, Moore's law, which was an observation, prediction or projection of an empirical relationship based on long-time experience of production still remain valid, however its relevance has diminished due to the novel methods of measuring overall processing power. The prediction has become a target for miniaturization in the semiconductor industry and has had a widespread impact in many areas of high technological advancement. This scaling has also significantly reduced the overall cost of memory and logic chips with higher performance.

Future of Chips Technology

Obviously, Moore's law validity cannot continue indefinitely. Technological and computational innovations will not end when transistor shrinking is no longer possible. The evolution of the new generation of chip designs now include advanced parallelism, 3D, and multi-core technologies. Some of these concepts will be discussed in the subsequent modules of this course.

The future generation of chips design will be amazing. They will enable and orchestrate the incredible big waves of innovations in areas of machine learning, robotics, automated transportation, smart cities, advanced AI, and fast connectivity with 5G. Figures 53 – 55 show illustration of Moore's law.

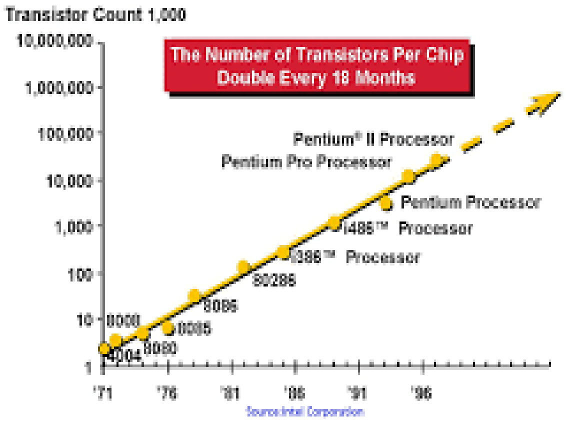

Figure 53 Moore's Law

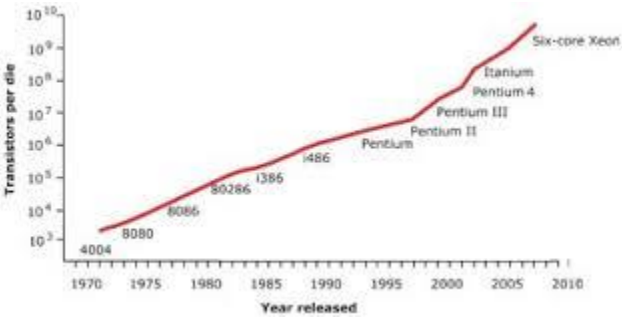

Figure 54 Moore's Law Explained

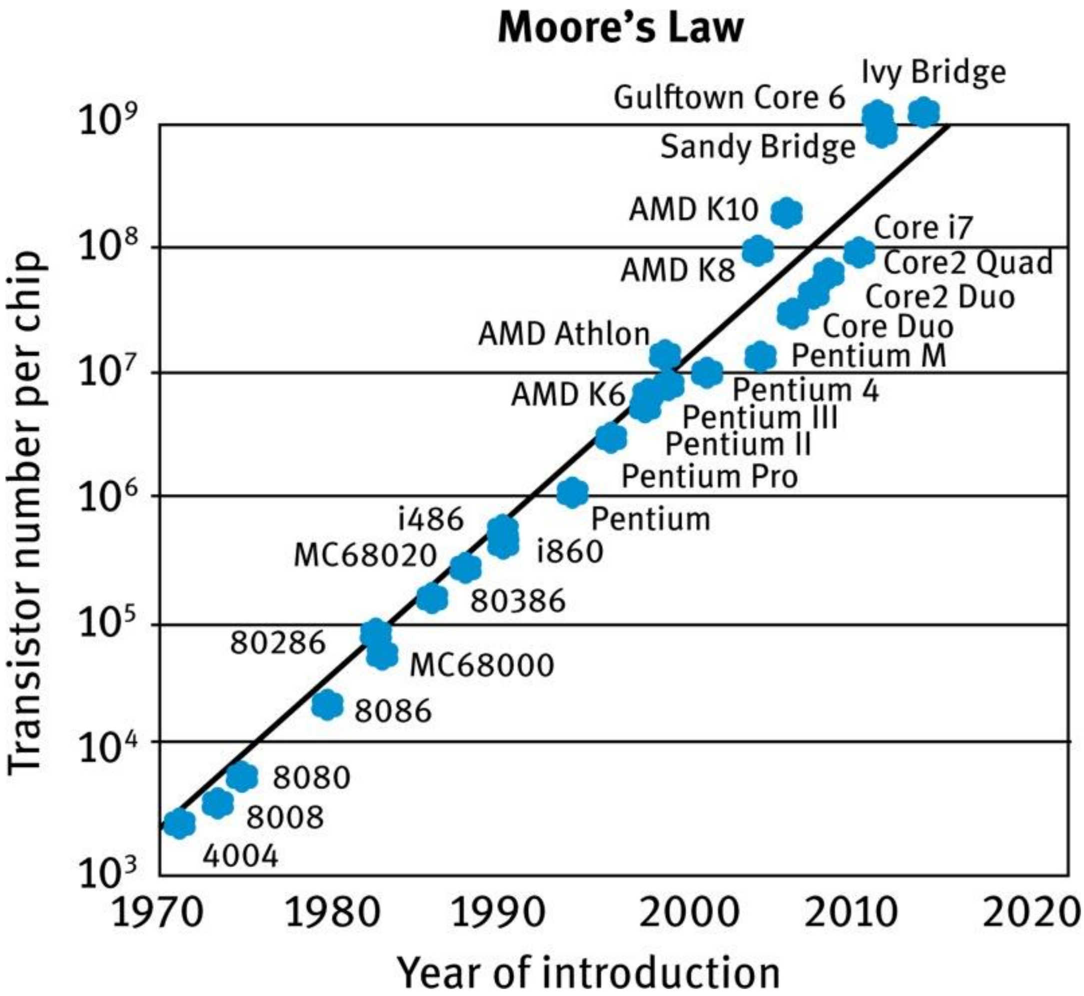

Figure 55 Moore's law on Microchips Technology

4.0 Conclusion

Microchips development has become the mainstream of technological advancement. Microscopic transistors are etched on the silicon chips. The silicon chip is just like the size of a fingernail of silicon. Chips, packaged in a plastic material, can contain billions of transistors. CPU chips, memory chips, flash chips, and other memory chips for various applications are simply some examples of chips.

The transistor, a semiconductor material, was invented in the 1950's to replace the vacuum tubes. Transistors, the most common and basic electronic component, function like amplifying valve for the flow of electrons. They serve as switching devices and can be used as building blocks for constructing complex electronic components. Transistors are solid state devices which means they do not have any moving parts. Since, its invention, the transistor has been made smaller continuously to allow many of them to be etched onto a silicon chip.

Gordon Moore, one of Intel's co-founders, observed that the number of transistors on a microchip was increasing rapidly, and thereby exponentially increasing the computing power while also decreasing the cost of the chips. He, therefore, proposed and formulated that the number of transistors on a silicon chip will double up nearly every two years. Moore's law has mainstreamed miniaturization of chips manufacturing for advanced technologies and innovative applications.

5.0 Summary

In this Unit, you have learned about the development of microchips technology as the bedrock of innovations and technological advancement.

6.0 Self-Assessment Exercises

What do understand about microchips technology?
What are the application areas of microchips?
State Moore's law. What is the impact of this law to our world today?

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http://www.cs.ucr.edu/~gusta/cs8w04/hardware.htm

Module 5: Hardware Interconnectivity and Embedded Systems

Unit 1: Computer Networking

Content

1.0 Introduction

In this Unit, you will learn about computer networking. Computer networking can be described as an interconnection of several computers and computing devices for the purpose of sharing resources in an effective manner. It is worth noting that computer networking is a critical part of computer hardware. Today, computer networking is the bedrock of advanced computing technology in our modern world. Access to the internet, intranet, social media, and the cloud is made possible by computer networking. Therefore, it is very important for you to understand this topic so as drive academic, job, and economic opportunities that are abound around you.

2.0 Intended Learning Outcomes

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

- Understand the concepts of system networking
- Identify hardware devices relevant to computer networks

3.0 Main Content

3.1 Description of Computer Networking

A computer network can be described as a system in which multiple computers and other types of computing hardware are interconnected so as to share data, information and resources. In a network, files or documents can be created, saved and stored in a computer such as server, and be accessed in another computer on the network irrespective of the distance. Scanners, printers, plotters and some other peripheral hardware can be shared over the computer network.

Computers on a network are called nodes or hosts. Multiple paths, wired or wireless, must be carefully designed to enable sending and receiving data as required. Computer networks include several network-enabled equipment to support communication over a long range, some of these network devices include routers, switches, hubs, and bridges. Figure 56 shows a typical computer networking structure.

Figure 57 Computer networking structure

3.2 Networking Devices

Routers, modems and network cards are the main networking hardware that allow computer systems to share data and other computing resources among themselves. Let us briefly compare the roles of modem and network card. While a modem sends information over a communication line, a network card sends information over a network cable. Modems are usually slow and susceptible to problems such as phone line static. Network cards can connect computers to a local area network (LAN) or to an Internet Service Provider (ISP) through a cable modem or DSL for the purpose of accessing the Internet access.

Network nodes, devices, hardware, components are computers and other computing resources available in a network. Basically, the computer network includes the following networking elements:

- More than one computer
- Network connectors
- Gateway devices – routers etc
- Transmission medium – wired or wireless
- Protocols, group policies and operational rules
- Network software

Network cables are the communication media used to connect the nodes on the network. The most commonly used cable is ethernet cable, coaxial cable, etc. examples of ethernet cables include category 5, CAT 6i with cable RJ-45 connectors as shown in figure 57. Figures 58 and 59 show a router and ethernet card respectively.

Figure 58 Network cables and connectors

Figure 59 Router

Figure 60 Internal network card

3.3 Types of computer networks

Major types of computer networks include local area network, metropolitan area network, wide area network. Table 1 shows the details about various types of computer networks.

Table 1 Types of Computer Networks

Type of Network	Explanation and features
Personal Area Network (PAN)	PAN is a computer network used for data transmission amongst devices like computers, telephones, tablets, iPAD and personal digital assistants via Bluetooth, WI-FI, TCP/IP connections
Local Area Network (LAN)	LAN is a type of computer network that interconnects computers within a local place or area. Such areas include residential buildings, school, laboratory, university campus, offices, NOUN premises
Virtual Local Area Network (VLAN)	This type of network involves two or more LANs that are configured and integrated as a segment to share resources
Wide Area Network (WAN)	WAN is a type of network that extends over a large geographical region. WANs are often established with leased telecommunication circuits. Corporate organization, business, education, government, telecommunication firms use WAN to relay data to staff, students, clients, buyers, and suppliers from various locations across the globe. The Internet may be considered a WAN.
Storage Area Network (SAN)	SAN is a network that provides access to a large integrated array or block level data storage. 21st Century in Lekki, Lagos and other multinational firms like HP, Dell Incorporation have SAN
Wireless Local Area Network (WLAN)	WLAN is a wireless distribution method for two or more devices that use high-frequency radio waves and often include an access point to the Internet. A WLAN allows users to move around the coverage area, often a home or small office, while maintaining a network connection
Internet	The Internet is the worldwide interconnection of many types of network that uses the Internet protocol suite (TCP/IP), web browsers to connect computers and computing devices. It is a network of networks that involves of both private and public sectors as well as academia, business, and government networks at local and international levels.
Extranet	An extranet, private network organization, is a specialized private network that allows access to specific authorized bodies,

	partners, vendors, suppliers, corporate organization. It is a subset of the information accessible from an organization's intranet. An extranet is a similitude to a DMZ in that it provides access to needed services for authorized parties, without granting access to an organization's entire network.
Virtual Private Network (VPN)	VPN extends a private network across a public network, and enables users to send and receive data across shared or public networks as if their computing devices were directly connected to the private network. Applications running across the VPN may therefore benefit from the functionality, security, and management of the private network.
Peer-to-peer (P2P)	P2P network is a distributed application architecture that partitions tasks or workloads between peers. Peers are equally privileged, equipotent participants in the application, thereby establishing a peer-to-peer network of nodes.

Scenario 1 Click to watch a video on further explanation about SAN

Scenario 2 Click to watch illustration about the Internet

3.4 Network topology

Network Topology is the physical arrangement and layout of the computing shared resources over the cabled or wireless networks.

The layout arrangement of the different devices in a network. Common examples include: Bus, Star, Mesh, Ring, and Daisy chain. Figure 60 show different types of computer network topology.

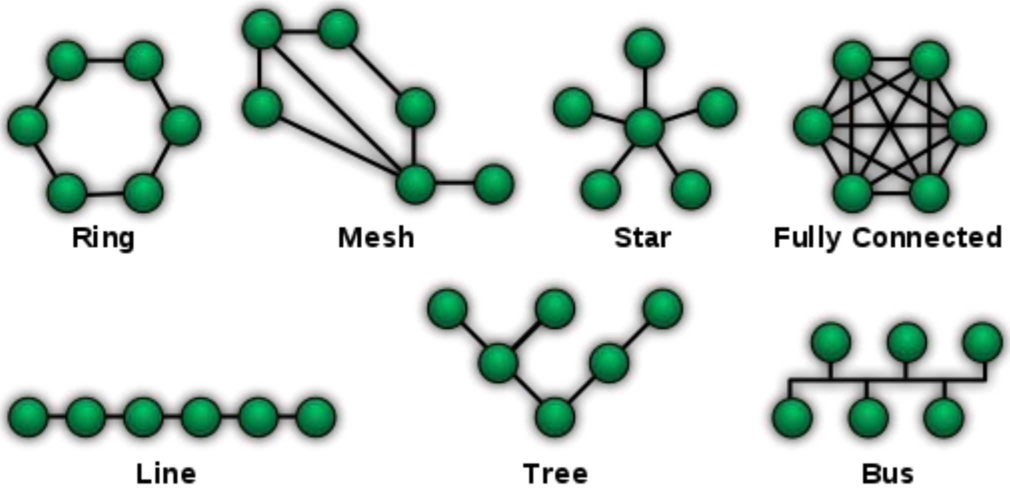

Figure 61 Types of Network Topology

3.5 Features of Computer Networks

The criteria or design considerations for having effective and good computer networks include accessibility, performance, security, and reliability. Performance is a function of the throughput, that the time elapse between request for a resource and its availability or response. The throughput involves the transit and response times. The shorter the throughput of a network the better the performance of such network. Basically, the network performance depends on the number of users, type of transmission medium, capacity of the nodes as well as the network operating system or software.

Network reliability and security are very essential too. Reliability is a function of failure rate, ability to recover from failures, and general robustness of operations. You can imagine when write computer-based test (CBT) may for job examination interview or so, it may be disastrous for the network breakdown to affect your computer or node allocated to you. For instance, the JAMB always ensures the CBT centres have reliable computer networks. Network security is also important to ensure that the network resources, data and hardware, are well protected from unauthorized access. Banks always provide adequate security to protect their customers' funds over the network operations.

4.0 Conclusion

Computer networking involves interconnections of computer hardware and software to share computing devices in a well-organized manner for optimizing resources, saving cost, and attaining good quality results. Computer networking has been very beneficial to us today. It has provided humanity with resounding socio-economic development, an improved education system among others. Detailed description of computer networking, Types of computer networks, networking topologies among others were discussed.

5.0 Summary

In this Unit, you have learned about computer networking.

6.0 Self-Assessment Exercises

Explain computer networking

Discuss some advantages of computer networking

Explain computer network topology and mention some types

Discuss the impact of computer networking on our socio-political system

Identify different types of networks.

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Unit 2: Multi-core Technology

Content

1.0 Introduction

In the previous Module, you learned about microchips technology and its impact in the modern technological achievement. In that Module, we also discussed Moore's law of rate of change on the number of transistors per silicon chip at the interval of about two years from 1965 till date. In this Unit, you will learn about multi-core technology as an improvement on the extent to which many more transistors can be mounted on silicon wafer on multiple networked CPUs. Simply, multi-cores assembly is about having a network of CPUs on one socket. A multi-core processor is an integrated circuit (IC) to which two or more processors have been attached for enhanced performance, reduced power consumption, and more efficient simultaneous processing of multiple tasks.

2.0 Intended Learning Outcomes

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

- Understand the concepts of multicore technology
- Know more about parallel computing

3.0 Main Content

3.1 Description of Multicore Technology

Multi-core technology can be described as the configuration, architecture and joint operation of two or more logical CPUs on the same processor chip. These processors are packaged into a single integrated circuit (IC) or a die. Multi-core can also refer to multiple dies assembled or packaged to function together. Multi-core technology which is available in desktops, mobile PCs, servers and workstations, enables the system to execute multiple tasks simultaneously resulting to a greater overall system performance for the benefit of the users.

For instance, a dual-core refers to a single chip or physical CPU that contain two separate processors or execution cores mounted on the same socket or integrated circuit so as to enhance access speed and general high capacity. The multi-core processors also include quad cores, dual quad cores, etc. Dual quad cores refer to two sockets having four CPUs each making the total of eight core processors. Technically, a dual core processor is about twice in performance than a single core processor. Multi-core systems ultimately minimize the power and heat.

Since 2005 AMD, ARM, Broadcom, Intel, and VIA are among the chip processors manufacturing companies that have implemented the multi-core utilization that can make use of multithreaded applications. Technically, it is obvious that the number of cores to be integrated in one chip would increase over time as their physical size and energy consumption drops. This, however, renders Moore’s law ineffective with the growing number of transistors. Multi-core technology is, therefore, an increasing advancement as single core processors rapidly reached the physical limit speed and miniaturization.

This technology is most commonly used in multicore processors, where two or more processor chips or cores run concurrently as a single system. Multicore-based processors are used in mobile devices, desktops, workstations and servers. Today, multi-core processors, where two or more processor chips or cores run concurrently as a single system, are commonly used across several fields and disciplines, such as health informatics, diseases simulation, general-purpose, embedded, robotics, network, digital signal processing, machine learning, and digital image processing. Multicore-based processors are used in mobile devices, desktops, workstations and servers.

Figure 61 shows a quad core processor, with four processors on a single integrated circuit.

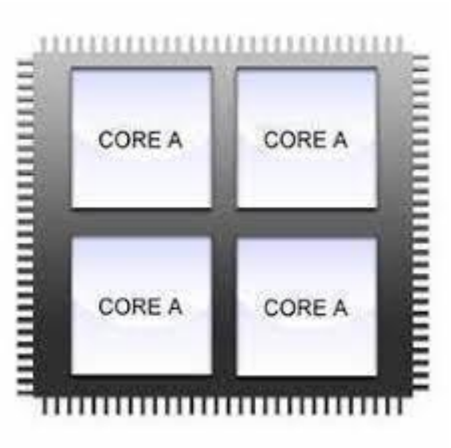

Figure 62 Multi-core processor - Quad core

Multi-threaded Software

Till date, most software and program codes are developed to function serially on one CPU at a time. It is somehow complex to split or parallelize a program into smaller modules for separate CPUs to execute different individual part without interfering with each other. However, multi-core technology has provided more than one processor for executing problems in parallel. Multithreaded software is a software capable of splitting large or complex tasks or computational jobs into a set of separate workloads or subtasks that could be processed and executed concurrently on each of the cores present. Many software operating system and applications development are now becoming multithreaded. Thus, multi-core processors work at their full potential can be used for such multi-threaded programs or software, thereby reducing execution time. Data-intensive or computational-intensive jobs are common in science and engineering fields, examples include human genome or DNA sequencing, advanced virtual manufacturing, video editing, encoding, 3D gaming, space exploration simulation and other types of grand challenge problems.

The parallelization of software programming to take advantage of multi-core hardware is a significant innovation. It is a fact that advancement in hardware is much ahead of software advancement.

3.2 Parallel Computing

The multi-core processor technology serves as the basis for parallel computing in terms of hardware and software deployment. Parallel computing cluster servers and parallel algorithms have capability to take advantage of multiple processors thereby increasing the speed, efficiency and the general performance of computers. While serial computing allows each process to run sequentially, the parallel computing technique allows multiple processes to be executed at the same time.

Parallel computing enables computers to solve extremely large and complex problems that would otherwise be impossible to process within a reasonable time frame. Such a problem must have divisible parts or modules that can run concurrently. Parallel computing enables all computer processes to run more efficiently, thereby saving time and money. While large problems are data-intensive, complex problems are more computationally-intensive. These kinds of problems are common in science and engineering fields.

Performance evaluation of a multi-core processor is a function of the software algorithms used and their implementation. In actual sense, the speedup is limited by the fraction of the software that can run in parallel on the available multiple cores.

Category of Parallel Computing Architecture

The four categories of parallel computers are:

- ✓ Bit-level parallelism,
- ✓ Instruction-level parallelism,
- ✓ Data parallelism,
- ✓ Task parallelism.

Many computers possess only one CPU, but some computer have many CPUs. Meanwhile, the single-CPU computers perform parallel processing a networking environment with the aid of distributed processing software. Parallel computing is the mainstream of high-performance computing.

Parallel software are more complex to program than sequential software, because concurrency introduces coding errors and bugs due to attendant race conditions and dead locks. These potential coding bugs do pose challenges on getting the required performance due to communication, intermittent results collation, and synchronization demands. Interestingly enough, many parallel programming languages have been developed to address these challenges.

4.0 Conclusion

Multicore architecture assembles multiple processor cores into a single physical processor chip or integrated circuit die so as to implement multiprocessing capability for high-performance computations. Parallel computing with multi-threaded software to solve complex and/or large problems in business, science and engineering will achieve high-performance computing that often showcases in cost effectiveness, reduction of execution time and high quality results.

5.0 Summary

In this Unit, you have learned about multicore technology and its relevance to technological achievement.

6.0 Self-Assessment Exercises

Define multicore technology
Distinguish between cores and CPUs
Compare advancement between software and hardware technologies with respect of parallel processing
Explain the relationship between Moore’s law and multicore technology

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Unit 3: Introduction to Embedded Systems

Content

1.0 Introduction

In Unit 2, you learned about the multi-core technology, parallel computing and multi-threaded software attributes. All of these have direct applications in embedded systems design. In this study, you will learn about embedded computing systems and their applications in our modern world. Precisely, cameras, phones, thermostats, pilot cockpit, etc are few examples of embedded computers comprising hardware and software.

2.0 Intended Learning Outcomes

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

- Understand the concepts of embedded systems
- Know more about micro-controller-based systems

3.0 Main Content

3.1 Introduction to Embedded systems

An embedded hardware device is a specialized computer system that exists as an in-built or integral part of a bigger equipment, machine or system, which can function with less human interaction. Usually, an embedded system has a processor, software, interface, input and output integrated components. The components are closely assembled together to provide various functionalities to the user. Technically, an embedded system is designed and implemented on a single microprocessor board with the programs stored in ROM.

Today, almost all electrical/electronic appliances have embedded devices with specialized digital interface. Examples of systems that use embedded computers are watches, microwaves, ATM machines, smart classroom boards, VCRs, cars, biomedical devices, satellites, pilot cockpits, televisions, and industrial robots. More specifically, the controller embedded in an elevator controls the motor to move the elevator to different floors, based on buttons that are pressed by the user. A decoder is embedded in a satellite television set-top box to read a signal from the dish and send input to the operate the TV. Usually, the embedded systems often operate within the pre-defined time, also known as real-time computing. Figure 62 shows some examples of embedded devices.

Figure 63 Examples of embedded systems

3.2 Embedded Software

Embedded software is a specialized kind of portable software that is used to operate in-built computers. Embedded software is a real-time software developed specifically to control the designed functions of the in-built devices. The components are usually limited in capacity. Some embedded systems include an application software, operating system, but many are so customized in such a way that all the entire logics are implemented as a single program.

There significant differences among embedded software, operating system, and firmware. The embedded software is a set of dedicated codes to control the functions a device. Firmware functions to complement the operations of the computer systems and applications. The normal computer operating system is a full-fledged software that control other resources in a computer.

Practically, device manufacturers design embedded software to execute the specific and exact purpose of the instructions. On the other hand, the normal operating systems can execute a wide range of optional instruction codes with much degree of flexibility with respect to the users' preferences.

3.3 On-board Computers

An on-board computer can be described as a computer or hybrid computing system that is specifically configured and installed in mobile objects or vehicles such as submarines, ships, aircraft, and spacecraft. The on-board computers are used to process information that is transmitted to, or received from mobile or remote objects through microwaves, radar, optical, and other types of radio-engineering so as to monitor the functions, health status, data handling, communications, navigation guidance, and other activities of the objects. On-board computers are manufactured and developed from miniaturized integrated circuits and other high-performance embedded electronic computing devices

Application areas include satellite autonomous on-board computers (OBC), remote terminal units, central terminal units (CTU), encryptors and decryptors. Most of these on-board computing devices, which provide processing functionality, are installed and in the avionics and on-board data handling subsystems of in-orbit spacecraft. The on-board software, including the operating system and applications run in the OBC under the control of the on-board processor, known as the CTU.

Obviously, you are familiar with the cars on-board computers. The on-board computer continuously and autonomously informs drivers about the functions and conditions of the car through voice, sound and display. Can you identify some of these information and feedbacks as shown in Figure 63? Figure 64 shows the cockpit on-board computer supporting the pilot to navigate and control the aircraft.

Figure 64 Car On-board Computers

Figure 65 Plane On-board Computer - Cockpit

4.0 Conclusion

Embedded systems are specialized integrated in-built computers. Embedded systems control many of the common devices in our homes, offices, institutions, companies, and communities, such as card readers in hotel door locks or several things in a car. They can control small things like an MP3 player or a digital camera, and large systems like ships, traffic light systems, airplanes, satellites, or assembly lines in a factory. On-board computers are usually installed on mobile and remote objects to control and monitor their behaviours and functionalities.

5.0 Summary

In this Unit, you have learned about embedded system description, application and examples.

6.0 Self-Assessment Exercises

Define the characteristics of embedded systems

How useful are embedded systems in our modern world today?

Mention some appliances or equipment with embedded system devices.

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Module 6: Digital Systems

Unit 1: Introduction to Digital Systems

Content

1.0 Introduction

In this Unit, you will learn about digital systems. A system could be described as a set of related components that function as a whole to achieve a definite goal comprising inputs, processors, and outputs in digital form.

They are found in a wide range of applications, including process control, communication systems, digital instruments, and consumer products.

A computer manipulates information in digital, or more precisely, binary form. A binary number has only two discrete values — zero or one. Each of these discrete values is represented by the OFF and ON status of an electronic switch called a transistor. All computers, therefore, only understand binary numbers. Any decimal number (base 10, with ten digits from 0 to 9) can be represented by a binary number (base 2, with digits 0 and 1).

The basic blocks of a computer are the central processing unit (CPU), the memory, and the input/output (I/O). The CPU of the computer is basically the same as the brain of a human. Computer memory is conceptually similar to human memory. A question asked to a human is analogous to entering a program into the computer using an input device such as the keyboard, and answering the question by the human is similar in concept to outputting the result required by the program to a computer output device such as the printer. The main difference is that human beings can think independently, whereas computers can only answer questions that they are programmed for.

2.0 Intended Learning Outcomes

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

- Understand the concepts of digital systems
- Make use of different digital system

3.0 Main Content

3.1 Digital Systems

A digital system represents information by using digits with optional entries such as in decimal (0 through 9), or binary (either 0 or 1). A digital clock display is in decimal format. A binary digit also known as a bit, is used in computers, digital communication such as the Internet. For example, a bit can represent 'Yes' or 'No'; 'True' or 'False'; or ‘On’ or ‘Off’. For instance, a string of bits of ‘0’ and ‘1’ can be used to represent data or information, such as image. This is useful in transmitting satellite image from an observation satellite from orbit to the ground station using affordable data rate within the limited visible time. Binary digit (Bit) has a value of either 0 or 1, and 1 byte (a Character) comprises of 8 bits.

ASCII (American Standard Code for Information Interchange) is one of the most common character encoding formats for text data in computers and on the internet. In standard ASCII-encoded data, there are unique values for 128 alphabetic, numeric or special additional characters and control codes. It is a code that assigns characters, such as 'a', 'b', etc. unique 8-bit values. This enables data generated on one computer to be understood by other computers.

Kilobyte: 1024 bytes (or 2^10 bytes).

Megabyte: 1024 * 1024 bytes (or 2^20 bytes), this is about one million bytes.

Gigabyte: 1024 * 1024 * 1024 bytes (or 2^30 bytes), this is about one billion bytes.

Terabyte: 1024 * 1024 * 1024 * 1024 bytes (or 2^40 bytes), this is about one trillion bytes.

3.2 Analog-to-Digital Converter

An Analog-to-Digital Converter (ADC) is an electronic device that converts an input analog voltage or current to a discrete digital number, that is, from analog signals into digital signals. The size of the number grows with increasing input voltage or current. Some non-electronic or partly electronic devices, such as rotary encoders, can also be identified as ADCs. A digital system is different than an analogue system, which represents information in a continuous way.

Analog information is transmitted by modulating a continuous transmission signal by amplifying a signal strength or varying its frequency to add or take away data. Digital information describes any system based on discontinuous data or events. Computers, which handle data in digital form, require analog-to-digital converters to turn signals from analog to digital before it can be read. One example is a modem which converts signals from digital to analog before transmitting those signals over communication lines such as telephone lines that transmit only analog signals. The signals are turned back into digital form or demodulated at the receiving end so that the computer can process the data in its pre-designed digital format. Figure 65 shows Analog-to-Digital Converter.

Figure 66 Analog-to-Digital Converter

Figure 66 shows computer system connection to MODEM.

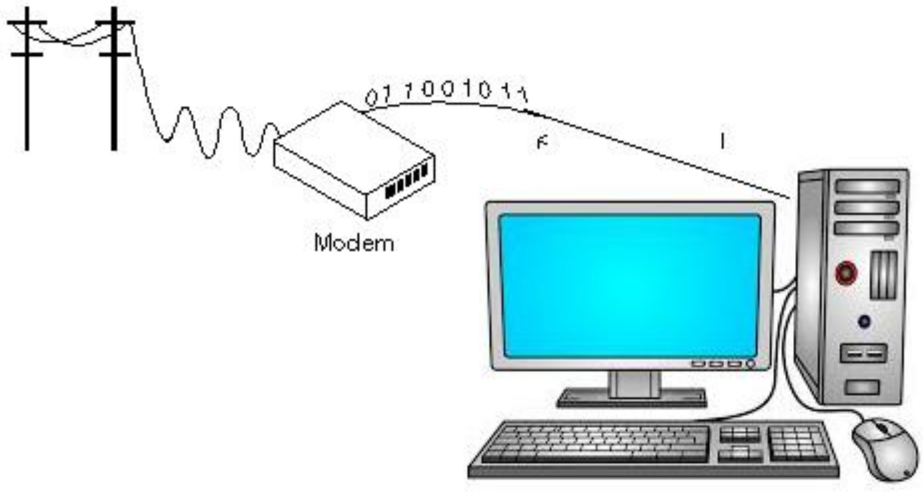

Figure 67 Computer system connection to MODEM

3.3 Digital-to-Analog Converter

The reverse operation of ADC is performed by a digital-to-analog converter (DAC). Digital-to-analog converter is a device on a single chip for converting binary digital code or data to analog signals such as current, voltage or electric charge.

Modems require a DAC to convert data to analog signals that can be carried by communication cables. For instance, video adapters also require DACs, commonly known as Random Access Memory DAC (RAMDAC), to convert digital data to analog signals suitable for Visual Display Units processing. RAMDAC combines DACs with small static random access memory useful for graphic controllers to generate voltage amplitude, analog signal for colour display. Figure 67 shows Digital-to-Analog Converter.

Figure 68 Digital-to-Analog Converter

4.0 Conclusion

Digital system is a field relevant to provide background understanding about the number formats used by the computing systems and computation parameters. Data values are usually converted into bit strings for easy computation. The analog-to-digital and digital-to-analog converters enable necessary values conversion for easy interoperability among diverse computing devices.

5.0 Summary

In this Unit, you have learned about analog-to-digital and digital-to-analog converters. These hardware devices are useful for converting one signal to the other for the purpose of compatibility in data processing.

6.0 Self-Assessment Exercises

Define the functions of an analog-to-digital converter

Distinguish between DAC and ADC hardware devices

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Unit 2: Cloud Computing

Content

1.0 Introduction

In earlier parts of this course, you have learned about computing hardware in several concepts. In this Unit, you will learn about the cloud of computing resources and its hardware devices. Cloud computing is a means of accessing, processing and saving computing hardware, software (data or programs) through the Internet. Application of cloud computing gives the flexibility of working anywhere where you can get an online connection. This is in contrast to how data and programs are normally accessed, which is locally through your computer's hard drive (or network). This means being committed to the physical device or network where your work and programs are saved. Similar to how the cloud hide the sky in the real world, the cloud in computing hides the computing infrastructure but are made available to the users via the Internet.

2.0 Intended Learning Outcomes

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

- Understand the concepts of cloud computing
- Identify hardware resources available in the cloud
- How to make use of the cloud computing

3.0 Main Content

3.1 Description of Computing

Cloud computing can be described as a collection computing resources, basically software and hardware infrastructures as well as services independently configured and deployed by an organization for use by a large array of clients, mostly for commercial purpose. Cloud computing is a similitude to provision of electricity by PHCN for consumers who pay for the service accordingly. Normally, the consumers do not bother about how the electricity is generated, transmitted or distributed. Thus, cloud computing involves information technology-based activities that are provided "as a service" which allow users to access the available services and resources through the Internet.

In fact, the IEEE explained cloud computing as a concept where information is hosted on computer servers accessible via the Internet to other devices, such as computers, laptops, handhelds, and sensors. It includes hardware as a platform, software as a service (SaaS), such as Web 2.0, that depend on the Internet to meet the computational needs of the users. It requires a well-configured high capacity infrastructure that can handle large and complex data processing. The user can simply use storage, computing power, or development environments, without having to worry how they work behind the scenes.

Examples of the cloud computing providers are Windows Azure, Google App Engine. For instance, Google has made several office suite apps which are accessed from a web browser. Unlike other software that does the same tasks, including Microsoft Office, the software and data are stored on Google's servers, not on the machine in which they are used. Figure 68 shows a typical cloud computing platform.

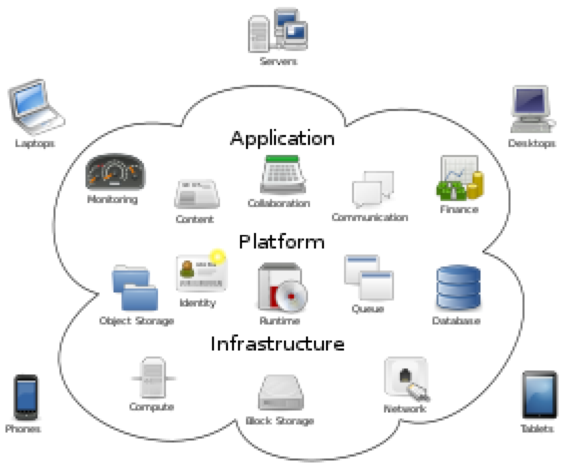

Figure 69 Cloud computing platform

Cloud computing is an on-demand service that has gained much support and interest from corporate online datacenters and professionals respectively. The cloud enables the datacenter to host online computing resources for the use remote clients. Such users can pay and access software applications and services via the Internet instead of using their hard drive and other local computing resources as desired. The cloud infrastructure providers are responsible to maintain their cloud computing platforms.

Cloud computing networks involve large groups of high-performance computing servers, WAN/LAN networks of systems, large bandwidth, faster Internet access, and cloud service providers that usually take advantage of low-cost computing technology, with specialized connections to deploy data-processing facilities. Virtualization and hyperthreading technologies are often deployed to maximize online processing power.

Cloud computing is much profitable and beneficial to small and medium enterprises (SME) who cannot afford all their required resources. In the SME sector there is often a limited number of resources in terms of time and financial resources to acquire, deploy and maintain the software, server and storage infrastructure. Thus, pay-as-you-browse subscription business method is designed to let SMEs easily add or remove services and resources as required.

3.2 Cloud Computing Infrastructure

Basically, the cloud computing platforms comprise of Software-as-a-Service (SaaS), Infrastructure-as-a-Service (IaaS), and Platform-as-a-Service (PaaS).

a) Software-as-a-Service

Software-as-a-Service (IaaS)refers to software that is available in the Cloud which the users can access based on subscription through the Internet and web browsers. The cloud computing provider manages the software update, licenses renewal, availability, and security. The remote users do not bother about all these, thus making the entire subscription cost more affordable than the cost of installing all the required software in a local hard drive.

Examples of SaaS include Google Apps, MailChimp, Office Online, Dropbox, among others.

Merits of SaaS include the following:

- ✓ Reduction in funds, time and stress expended in maintaining locally installed software
- ✓ Readily available on any device provided Internet connection exists
- ✓ Access to any desired software

Drawbacks and challenges of SaaS include the following:

- ✓ Downtime due to planned maintenance schedules
- ✓ Cybersecurity threats – compromise of sensitive data over the Internet
- ✓ Bandwidth overhead, constraints about Internet accessibility especially in the developing nations
- ✓ Inability to control the software, e.g. appearance, scheduled updates etc
- ✓ There Vendor Lock-In, this means users are tied to their vendors and to swap vendors is usually difficult sometimes. Transfer of data may be complex.

b) Infrastructure-as-a-Service

Infrastructure-as-a-Service (IaaS) are the resources made available as a cloud-based service, these include storage, networking, processing and virtualization. Thus, businesses can purchase resources on-demand. This is much preferred to buying and owing several hardware resources. This provides a highly flexible and scalable solution whereby specific hardware can be paid for based on the current needs of the business or project. Examples of IaaS include Rackspace, Amazon Web Services (AWS), Microsoft Azure, Cisco Metapod

c) Platform-as-a-Service

Platform-as-a-Service (PaaS) are hardware and software tools available over the Internet. PaaS is used to provide a platform for software creation. Using PaaS allows developers to focus on coding their applications and not worry about the OS, storage or hardware. It also allows many users to work on the same project together, and provide tools to help test and deploy applications.

PaaS (Platform as a Service) is a model that provides, among other things, the operating system, programming language execution environment, database, and web server as computing platforms. Examples of PaaS include Apache Stratos, AWS Elastic Beanstalk, Windows Azure, Heroku, Force.com, Google App Engine, etc.

4.0 Conclusion

Cloud computing refers to an Internet-based cloud of computational software, infrastructure, platform, and services that is remotely located away from the users. The cloud computing providers maintain and secure the resources while the users subscribe on-demand. This system is more affordable for the users, since they do not have to bother about the systems update, regular license subscription, ethical challenges, legal issues, and cost acquiring virtually all the resources. However, the vendors must conform with best practices, cybersecurity, regulatory, and standard frameworks.

5.0 Summary

In this Unit, you have learned about cloud computing, its designs, configurations, opportunities, and challenges.

6.0 Self-Assessment Exercises

Define cloud computing

List some cloud computing hardware

Identify some cloud computing platforms

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