Indira Gandhi National Open University
School of Computer and Information Sciences

Commonwealth of Learning

INTRODUCTION TO MOBILE ARCHITECTURE

Mobile Hardware

3

Introduction to Mobile Architecture

School of Computer and Information Sciences
Indira Gandhi National Open University

Commonwealth *of* Learning

Block

3

MOBILE HARDWARE

INTRODUCTION TO MOBILE ARCHITECTURE

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BLOCK INTRODUCTION

This is the third block of the Course. This block introduces the learner to hardware in mobile devices.

The capabilities of a mobile device significantly increase with addition of new hardware. Indeed, the hardware of a smart phone is significantly different from earlier versions which do not fall under the category of smart phones. For example, addition of touch screens, high resolution cameras, front camera, and bothie etc. were result of additional hardware and software.

The units in this block will focus on hardware in mobile devices, namely, processors, memory, sensors and I/O.

This block consists of four units and is organized as follows:

Unit 8 introduces mobile processors. The unit covers most categories of processors in mobile devices. It starts with Qualcomm's Snapdragon and explains different mobile processors including ARM and x86 processors.

Unit 9 deals with memory in mobile devices. Indeed, knowing about memory in a PC should not be mistaken as knowing about memory in a mobile device. The unit covers MROM, PROM, EPROM, EEPROM apart from volatile and non-volatile memories. Also, explained are Flash memories.

Unit 10 introduces sensors in mobile devices. It particularly explains about gyroscope, accelerometers, compass and proximity sensor.

Unit 11 discusses about I/O devices in mobiles. It covers display, camera, speakers and microphone which are part of almost every mobile device and are becoming increasing sophisticated with high resolution cameras, LEDs, stereo speakers etc.

UNIT 8 MOBILE PROCESSORS

Structure

8.0 INTRODUCTION

The word "processor" is used interchangeably with the term "CPU". But, CPU is not the only processor in a computer. There are a lot of things in the computer that have the responsibility to process. In a personal computer, the processor is often called as microprocessor. This simply means that the processor's elements are embedded in a single integrated circuitry(IC) chip. The four basic functions of a processor are-fetch, decode, execute, and write back.

Let us know about the major elements of a processor:

- **ALU**- It stands for Arithmetic Logic Unit. It is responsible for carrying out arithmetic and logic operations.
- **FPU**- It stands for Floating Point Unit, also known as numeric coprocessor. This can manipulate large numbers more quickly than the basic microprocessor.
- **Register**- Register is used for store data and instructions. It sends the operands to the ALU and stores the result of operations.
- **L1 and L2 Cache memory**- It is a kind of memory which stores the data that is frequently accessed. It saves time compared to having to get data from Random Access Memory (RAM).

Mobile processors are usually found in handheld devices like mobile computers and cell phones. A processor can execute anything whatever you

want your Smartphone to do. Thesetypes of processors are generally accommodated in smaller chip package. These small chips usually use lower voltages as compared to the Desktop's embedded CPU chips. And, it also has more "sleep mode" capability. Let us now know something about the functioning of "sleep mode". Mobile processors can be easily throttled down to different levels of power. And, when not in use, these processors can be turned off entirely.

When the load on the processor is low, the clock frequency may be slowed down, so that the power and battery life of the processor could be saved for further use.

8.1 OBJECTIVES

After going through this unit, you should be able to know about

- various mobile processors
- ARM processors
- x86 processor

8.2 MOBILE PROCESSORS

The following sections describe various mobile processors.

8.2.1 Qualcomm Snapdragon

A US based organization Qualcomm Technologies is occupied with creating distinctive innovations, for example, planning of semiconductors for cell phones, tracing gadgets, Virtual Reality, satellite phones, remote charging, and communications and so on. Qualcomm is presently celebrated for its Snapdragon image which is fundamentally responsible for releasing Long Term Evolution (LTE) modems and mobile processors. The majority of the mobile and tablet makers, utilizes Snapdragon processors in their items except Apple iPhone. These processors are referred to for its execution as it proficiently handles multitasking and can likewise effectively oversee high end processing which is very critical for gaming. An awesome favourable position of these processors is that they deliver less warmth when contrasted with different processors. In any case, they are costlier than some other processor. Snapdragon processor was first developed by Qualcomm and uses its own architecture, but, now Snapdragon processor uses ARM architecture which is becoming popular in smart phones. ARM processors have high multimedia capability and can easily decode HD videos of high resolutions. Snapdragon processors along with HD videos also cater to the GPS navigation system, 3D Video recording, and high performance graphics.

Table 8.1 lists the processor frequencies in the corresponding mobile devices which have Qualcomm Snapdragon processor.

Table 8.1: Mobile devices with Qualcomm Snapdragon processors

Mobile Devices	Processor
HTC	600-800 MHz
Samsung Galaxy Ace Plus, Nokia Lumia 610	800-1000 MHz
HTC Desire S, HTC Incredible S, Sony Xperia ARC	1 GHz
Blackberry Bold 9900, Blackberry Torch 9860	1.2 GHz
HTC Titan, Nokia Lumia 800, Samsung Galaxy S Plus	1.5 GHz
Samsung Galaxy S 2	1.2 GHz Dual Core

8.2.2 Samsung Exynos

It is a series of ARM-based system-on-chips which is manufactured by Samsung Electronics. Previously , Samsung developed the series of S3C, S5L, and S5P line of systems on chip (SoC). Its unique method helps in power savings. Samsung's Exynos processors have significantly 30-40% less power consumption than the competition. Some of the processors in the arrangement are Exynos 7 Dual, Exynos 7420, Exynos 7 Octa 7580, and Exynos 7 Octa 7870. Exynos 8 Octa 8890 is the most recent from Exynos. Exynos 8 Octa 8890 is utilized as a part of Samsung Galaxy S6 and S6 edge. Samsung haven't made any declarations about any new model after Exynos 8 Octa 8890. Snapdragon processors are currently utilized by Samsung smart phones and tablets.

Table 8.2 lists the processor frequencies in the corresponding mobile devices which have Samsung Exynos processor.

Table 8.2: Mobile Devices with Samsung Exynos processors

Mobile Devices	Processor
Samsung Galaxy S line, Samsung GT-S8500 Wave, Samsung Wave II S8530, Nexus S, Meizu M9, Samsung Galaxy Tab, Samsung Droid Charge, Exhibit 4G, Samsung Infuse	1 GHz
Samsung Galaxy S II, Samsung Galaxy Note, Samsung Galaxy Tab 7.7, Samsung Galaxy Tab 7.0 Plus, Hardkernel ODROID-A, Meizu MX, Cotton Candy by FXI Tech	1.2 GHz Dual Core

8.2.3 NVIDIA Tegra

- This is an US based innovation organization which manufactures processing units for gaming, graphics and cell phones. It additionally

creates chips for smart phones, tablets and cell phones under the name of brand Tegra. Tegra processors utilized as a part of smart phone and tablets which are mainly Tegra 4/ 4i / Tegra K1.

- Tegra 4 is utilized by HP Slate book, Xiaomi Mi3, Asus Transformer PAD,XOLO Play Tegra Note and Toshiba Excite.
- Tegra 4i is used by Blackphone.
- Tegra K1 is utilized by Google Nexus 9, Acer Chromebook 13and 14, Navi Big Tab, and NVIDIA Shield Tablet.

When it comes to mobile gaming, NVIDIA Tegra is considered best. The processing of Graphic is best in contrast with any other mobile processors. Be that as it may, there are couple of disadvantages of Tegra, it reduces the battery life with heat generation. Tegra processors are bit costlier than different processors.

NVIDIA processors were known for graphics for the desktop. They entered into smart phones and mobile devices very late and their first product was Zune music player in 2008. It is the first to bring a quad core processor in market with the HTC One X. The main feature of NVIDIA Tegra is its graphic processing capability. Table 8.3 lists the processor frequencies of the corresponding mobile devices which have NVIDIA Tegra processor.

Table 8.3: Mobile Devices with NVIDIA Tegra processors

Mobile Devices	CPU
Motorola Atrix 4G, Motorola Droid X2, Samsung Galaxy R, LG Optimus 2X, Micromax Superfone A85, LG Optimus Pad, Notion Ink Adam tablet,, Motorola Xoom,Samsung Galaxy Tab 10.1, Lenovo ThinkPad Tablet, Sony Tablet S	1 GHz dual core
Samsung Galaxy S II, Samsung Galaxy Note, Samsung Galaxy Tab 7.7, Samsung Galaxy Tab 7.0 Plus, Hardkernel ODROID-A, Meizu MX, Cotton Candy by FXI Tech	1.4 GHz quad core

8.2.4 More Mobile Processors

The following are some more mobile processors:

- **Apple Mobile Processors-**Apple does not make any microprocessors. Rather, they make contracts with microprocessor making organizations essentially Taiwan Semiconductor Manufacturing Company (TSMC)and Samsung for making custom assembled processors that suits their outline and performance expectations.
- **Intel Atom and core M processors-**Intel is an American multinational organization which manages PC and microchips. Atom is the name allotted to the less power consuming and minimal cost 32/64 bit chips designed for utilizing as a part of smart phones and tablets. **Intel Core M** microprocessors were introduced by Intel which are ultra-low voltage intended for ultra-thin notebooks, smart phones and two in one convertibles. The microprocessor expends less power and along these lines

has long battery life. With the arrival of Intel Core M processors, 40% lift in CPU and graphics performance are also offered. This version is more productive than previous versions. All manufacturers supported Intel Atom processors. Manufacturers like Microsoft, HP, Dell, Asus, Lenovo, uses the latest Atom Processor. The one and only smart phone which uses Atom processor is Asus Zenfone series.

- **MediaTek-**Taiwanese semiconductor organization MediaTek, is providing chips to cell phones, HDTVs and other electronic devices.MediaTek microprocessors are based on 64 bit ARM design.The most recent MediaTek processor is capable to manage up to 3 GHz speed and comes in variety of cores, for example, Dual Core (Two core), Quad Core (Four core), Hexa Core (Six core) and Deca Core (Ten core).The most recent processor from MediaTek are Helio X20 and X25 which are utilized as a part of smart phones and tablets. Mostly Chinese manufacturers deal with MediaTek processors. MediaTek processors are used by Xiaomi, Meizu, LeEco Le, Yu etc on Smart phones. There are some more manufacturers like Acer, Asus, Lenovo, Amazon Fire HD, and QMobile who use this processor on their tablets. There are numerous advantages of MediaTek processor. MediaTekPowerVR GPU is superior to different processors. It creates less heat when contrasted with different processors. These processors are less expensive and are offered with great execution.
- **HiSilicon-**It is a Chinese company and specializes in manufacturing semiconductors. Huaweiis the owner of this company. Chips produced by this company are based on the ARM architecture which we will study in detail in the next section. There are various processors released by HiSilicon are K3V1, K3V2, K3V2E, Kirin 620, Kirin 650, Kirin 910, Kirin 920, Kirin 930, Kirin 950 and destined to be released Kirin 960.

8.3 ARM PROCESSORS

ARM stands for Advanced RISC Machine, and was previously known as Acorn RISC Machine. It is combination of RISC (Reduced Instruction Set Computing) architectures for computer processors. The processors based on RISC architecture require fewer transistors as compared to personal computers having complex instruction set computing x86 processors. Processors based on RISC reduces cost, heat and power use. These are the reasons because of which RISC architecture is supported in light, portable, battery-powered devices including tablets, smart phones, and laptops. The basis of every ARM processor is formed by ARM architecture. When, various components are included ARM engineering so that the developing interest for new usefulness, incorporated security highlights, elite and the necessities of new and developing markets are satisfied. The ARM design is like a Reduced Instruction Set Computer (RISC) engineering, as it joins these common RISC engineering highlights:

- A uniform register file load/store engineering, where information preparing works just on register contents, not straightforwardly on memory contents.
- Basic addressing modes, with all load/store addresses decided from register contents and direction fields as it were.

Improvements to an essential RISC engineering empower ARM processors to

accomplish a decent adjust of superior, little code measure, low power utilization and little silicon region. An ARM processor is developed by Advanced RISC Machines (ARM). It is based on the RISC architecture. ARM makes RISC multi core processors of 32-bit and 64-bit. RISC processors are fundamentally intended to perform a smaller number of types of computer instructions with the goal that they can keep running at a higher speed, performing millions of instructions in a second (MIPS).RISC processors evacuate repetitive guidelines with the goal that it can without much of a stretch upgrade its execution on account of CISC (Complex Instruction Set Computing) gadgets. Gadgets, for example, smart phones, tablets, and interactive media players utilize ARM processors.ARM requires fewer transistors because it is based on the reduced instruction set approach and therefore ARM processors use the Integrated Circuitry (IC) chip which is relatively small when compared to the transistors. ARM is compatible with miniaturized devices because of its salient features like smaller size, reduced complexity, and lower power consumption.

8.3.1 Features of ARM Processor

The following are features of a ARM processor:

- The architecture of ARM processor is kind of Load/Store.
- It is designed with a view to enhance power saving.
- Single cycle execution is implemented in this processor.
- It supports hardware virtualization.
- In need of high performance, it can execute 64-bit and 32-bit states.

Developers think that it’s simple to code for ARM processors due to its exceptional features like more proficiency and multi core processing. At the point when the developers deal with x86 processors, they don't have an indistinguishable throughput as of ARM processors, in any case, once in a while ARM processors surpass the execution of x86 processors for applications that exist on both architectures.

8.3.2 ARM Architecture

The ARM design was initially created by ACORN Computers in 1980s. 32-bit Reduced Instruction Set Computer (RISC) stack, store design is utilized as a part of ARM machines. The manufacturers rely on ARM machines because of its relative simplicity for low power applications like mobile, embedded and microcontroller applications and small microprocessors. This architecture uses registers to manipulate memory as it is not possible to directly manipulate the memory. The main focus of the instruction set of this architecture is on reducing the number of cycles per instruction featuring mostly single cycle executions. Figure 8.1 depicts ARM architecture.

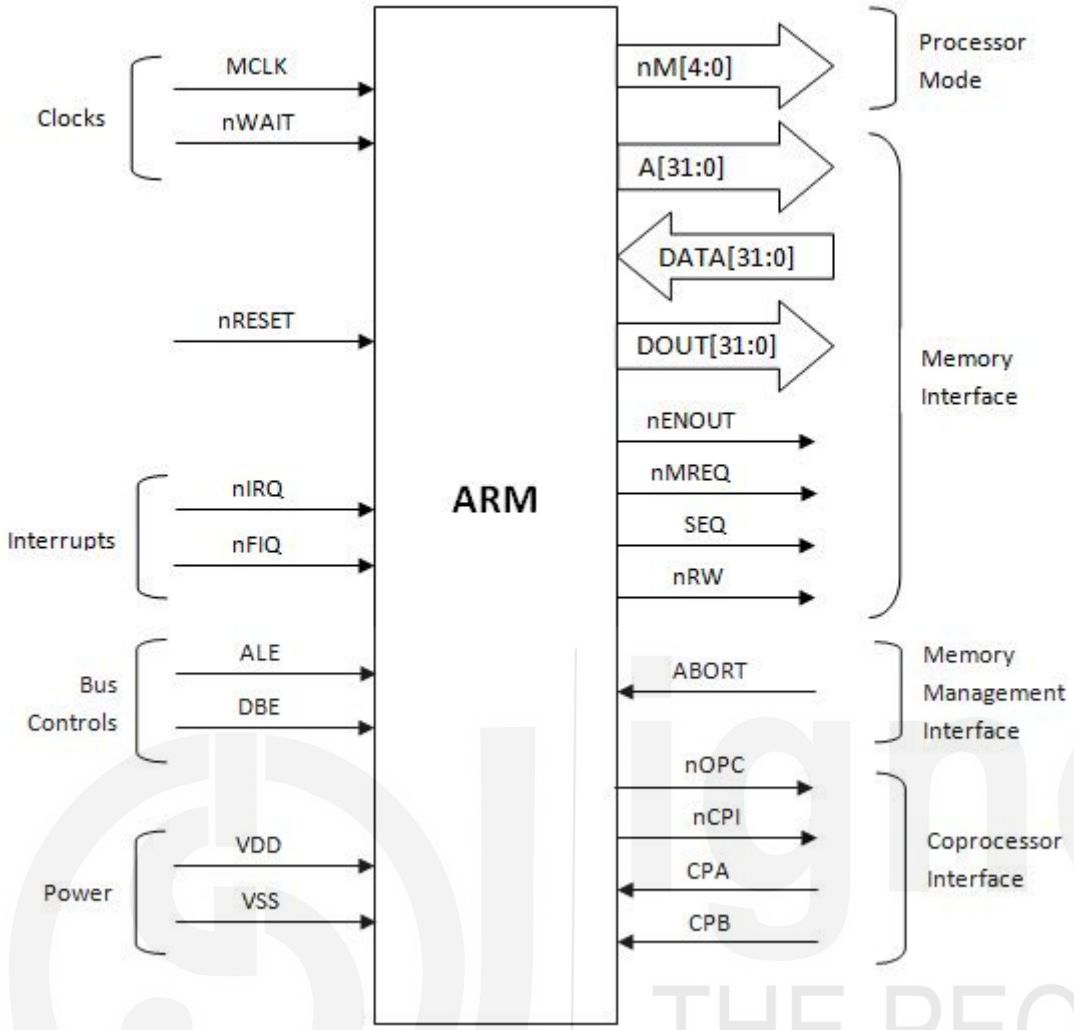

Figure 8.1: ARM Processor Architecture

8.4 x86 PROCESSORS

x86 is the mix of backward-compatible instruction set architectures in view of the Intel 8086 CPU and Intel 8088. Intel 8086 was first presented in 1978 , it was 16-bit based microchip and was the expansion of Intel's 8-bit based 8080 chip. In Intel 8086, more memory can be tended to with the assistance of memory divisionx86 architecture has been executed in processors of AMD, Intel, Cyrix, VIA and numerous different organizations. Till now the laptops and computers sold in the emerging markets are majorly based on x86 architecture. Intel 8086 was primarily developed for single user computers, small multi user or embedded systems but gradually it grew in features and processing power. Today, x86 is also used in workstations, servers, mid range computers or super computer clusters. The x86 architecture depends on CISC (Complex Instruction Set Computing) plan with primary concentrate on backward compatibility. The instruction set of this design is the augmented form of the 8-bit 8008 and 8080 architectures. Byte addressing is empowered in this design and words are put away in memory with little little-endian byte arrange. For all substantial word sizes, memory access to unaligned addressed is permitted. The biggest size for memory locations is 16, 32 or 64 bits.

8.4.1 Basic Design of x86 Processor

The following is basic information related to x86 processor:

- A place where all the calculations and logic operations are being done, is known as CPU (Central Processing Unit). There are numerous things that are stored in CPU like storage location, registers, high frequency clock, a control unit, and arithmetic logic unit.
- The synchronization of the internal operations of the CPU and other components in the system is a responsibility of the clock.
- Control Unit (CU) is responsible for arranging the sequence of steps involved in executing system instructions.
- The arithmetic operations such as addition and subtraction and logical operations such as AND, OR, and NOT are done by ALU (Arithmetic Logical Unit).
- The CPU and the rest of the computer is connected to each other via pins that are attached to the CPU socket in the computer's motherboard. Most of the pins on the CPU are connected to Data Bus, control bus, and the address bus. The instructions and data are temporarily stored in the memory storage unit while a computer program is running. The CPU sends a request for data to the storage unit, then it transfers all data stored from Random Access Memory (RAM) to the CPU, and finally transfers data from the CPU to memory. In CPU all the data processing takes place, so before execution of any command, programs that exist in memory must be copied into the CPU.

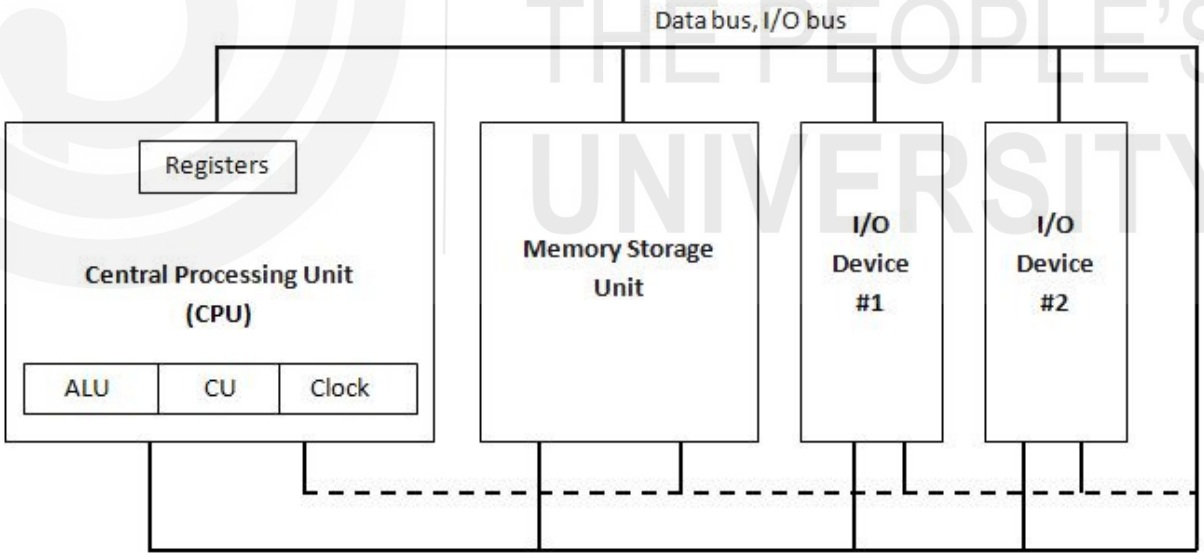

Figure 8.2: Block Diagram of Microcomputer

- A Bus is a combination of parallel wires that is responsible for transferring data from one part of the computer system to another. There are four types of buses in a computer system i.e. DATA, Input & Output (IO), Control, and Address. The **Data Bus** is responsible for transferring instructions and data between the CPU and memory. The **IO Bus** is responsible for transferring data between the CPU and the devices that have input/output command. The **Control Bus** is used to

synchronise actions of any device that is connected to the system Bus. The addresses of instructions and data are stored in the **Address Bus** which transfers data between the CPU and memory.

Figure 8.2 shows block diagram of a Microcomputer.

8.4.2 Instruction Execution Cycle

Instruction execution cycle is a sequence of individual operations that are separated from the execution of a single machine instruction. Before any execution, a program is loaded into memory. There is an instruction pointer that contains the address of the next instruction to be executed.

Fetch The Control Unit fetches the next execution instruction from the instruction set and increment the Instruction Pointer (IP) which is also known as Program Counter (PC).

Decode Control Unit decode the function of the instruction to determine what the instruction will do. The input operands of the instruction are passed to the ALU, and signals are sent to the ALU indicating the operation to be performed.

Execute At last, the ALU uses the registers as operands and executes the instructions and then forward the output to registers/memory.

8.4.3 Differences between ARM and x86 Processors

The following are differences between ARM and x86 processor:

The first and foremost difference between ARM and x86 processors is that ARM processors are based on RISC (Reduced Instruction Set Computer) architecture, whereas x86 processors are based on CISC architecture. In ARM processors, instructions are executed in one clock cycle whereas x86 processors' instructions are mostly complex and take multiple CPU cycles to execute each instruction. Explicit load and store model is followed in ARM processors whereas in x86 processors, the load and store register is in built. Therefore, CISC processors have more hardware logic to decode and execute the complex instructions.

Check Your Progress 1

1) ---------- developed Snapdragon processor.

2) RISC stands for ----------.

3) ----------,---------- and Execute form part of Instruction Execution Cycle.

8.5 SUMMARY

A processor executes what you need your smart phone to do. Early cell phones were basically cousins of conventional landline phones. Smart phones, in any case, are convenient PCs that happen to have phone capacities implicit. Underneath that astounding touch screen show is an undeniable PC, in charge of advising your applications how to work, your GPS how to get you home and you who to approach on the phone. The processor is the brains of the operation.

It's a component found in the fundamental processor that peruses and executes instructions. Gadgets started with a single-core processor, however builds made

all the more effective gadgets by incorporating more cores in one gadget. That prompted dual-core gadgets. Before long there were quad-core processors (as in four cores), and now there are hexa (six) and octa-core (eight) smart phones and tablets.

The more cores, the quicker they can divvy up the work you're requesting that the phone to do. That implies various cores make your experience smart; Apps load rapidly. You can capture high-quality photographs or HD video and after that peruse through your phone gallery immediately. Animations and recordings play easily without stammering. Games don't get stalled. There are special cases, yet for the most part, the more cores the better the execution.

No. An octa-core processor is speedier than a quad-core processor just when it's running an application that exploits its capacities or when you're multitasking. For instance, one core might be grinding away on your web browsing while another is standby. A call comes in, and the second core gets the chance to work. Both your web browsing and your phone call proceed easily, however not really twice as quick.

There are numerous—the processor is just a single segment of your brilliant gadget (consider it like all the parts of your auto's motor). There's likewise a graphics handling unit, RAM for short-term memory, antennas for Wi-Fi and GPS. These cooperate as a unit and all should be considered when you purchase a smart phone or tablet.

When looking for a smart phone or tablet, the processor specs are helpful to get a feeling of what the gadget can do. In case you're searching for speed, pull out all the stops with a multi-core processor.

In this era of technology, most of the population is engaged in the usage of smart phones. The sales of smart phones is rapidly increasing. There are numerous companies who are engaged in manufacturing and selling smart phones like Microsoft, Apple, Samsung, Asus, etc. These companies release upgraded versions of their products after time to time. Mostly these upgrades are in processors of mobiles, tablets, Laptops, etc. Processors in smart phones are manufactured by different companies and under the name of different brands. Some of them are:

- Qualcomm-Snapdragon
- Samsung Exynos
- Texas Instruments
- NVIDIA-Tegra

8.6 SOLUTIONS/ANSWERS

1) Qualcomm

2) Fetch, Decode

3) Reduced Instruction Set Computing

8.7 FURTHER READINGS

- Smart Phone and Next Generation Mobile Computing by Pei Zheng and Lionel Ni;Morgan Kaufmann; ISBN-13: 978-0-12-088560-2, ISBN- 10: 0-12-088560-3
- Handbook of Research in Mobile Business : Technical, Methodical and Social Perspectives by Bhuvan Unhelkar;Information Science Reference; ISBN-10: 1605661562, ISBN-13: 978-1605661568
- https://en.wikipedia.org/wiki/Mobile_processor
- https://www.qualcomm.com/products/mobile-processors
- https://en.wikipedia.org/wiki/Exynos
- http://www.samsung.com/semiconductor/minisite/exynos/
- https://en.wikipedia.org/wiki/Apple-designed_processors
- http://www.NVIDIA.com/object/tegra-4-processor.html
- https://en.wikipedia.org/wiki/HiSilicon
- https://en.wikipedia.org/wiki/MediaTek
- https://www.intel.in/content/www/in/en/processors/processor-numbers.html
- https://www.intel.com/content/www/us/en/products/processors/atom.html
- https://www.intel.com/content/www/us/en/products/processors/core/m3-processors.html

UNIT 9 MEMORY

Structure

9.0 INTRODUCTION

Memory resembles a human cerebrum. We can store information and instructions in it. When we discuss memory as far as PC, a storage room is accessible in a PC where information to be processed and instructions required for processing are put away. The memory is partitioned into little parts called cells. Every cell has a special address; the address can store the value from 0 to memory measure minus 1.

For example, if PC has 64K words, then the memory has 64*1024=65536 memory areas; then the address may lie in the range of 0 and 65535.

There are three types of memory available:

- Primary Memory
- Secondary Memory
- Cache Memory

Primary Memory

It is also known as main memory. It contains the current data and instructions on which computer is working. In primary memory, data is lost whenever power supply breaks down. All the information i.e. data and instructions required to be processed resides in this memory. This memory is made up of semiconductor. There are two types of memories which come under the category of Primary Memory i.e. RAM and ROM.

RAM stands for random access memory, is one of the basic segments of the smart phone alongside the processing cores and dedicated graphics. Without RAM in any kind of electronic gadget like this your smart phone would neglect to perform basic operations in light of the fact that getting to documents would be surprisingly slow. This kind of memory is a center man between the file-system which is put away on the ROM, and the processing cores, serving any kind of data as fast as could reasonably be expected. Basic files that are required by the processor are temporarily saved in the RAM, expecting to be processed. These files could be things, for example, OS components, application information and game designs; or usually anything that requires to be fetched at quicker than other storage can provide.RAM utilized part of smart phones is in fact DRAM, where D stands for Dynamic. The structure of DRAM is with the end goal that every capacitor on the RAM board stores a bit, and the capacitors leak charge and require consistent "refreshing"; thus the "dynamic" way of the RAM. It likewise implies that the content of the DRAM module can be changed rapidly and effectively to store diverse files. The benefit of the RAM not being static is that the capacity can change to adapt to whatever assignments the system is attempting to perform. On the off chance that a whole operating system was, say, 2 GB on disk, it wouldn't make sense or be effective for the RAM to archive the whole thing, particularly when smart phones with lower space of RAM (like 512 MB) can't bear.RAM is diverse to the blaze style ROM storage on the gadget in that at whatever point power is separated from the RAM module, the contents are lost. This is known as volatile memory, and it mostly helps the access time of the RAM to be so quick. It likewise clarifies loading screens: data from the slower ROM must be passed to the speedier RAM, and the restricting variable much of the time is the perused speed of the ROM. At the point when the system is fueled off, the content of the RAM is lost thus at the following boot, the RAM should be filled yet again from the content on the slower storage. Figure 9.1 depicts RAM.

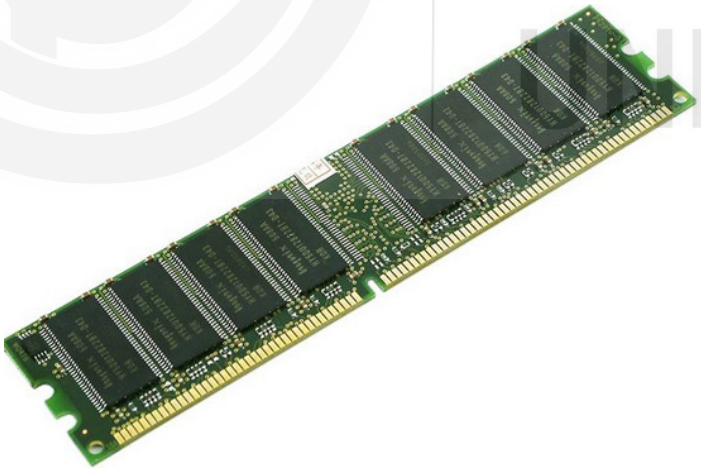

Figure 9.1: RAM

Secondary Memory

It is also known as non-volatile or External Memory. It permanently stores data and instructions. It is slower than Primary Memory. CPU access these memories via input output devices as it cannot access these memories directly. Firstly, contents of secondary memory are transferred to main memory, after that the CPU can access it. For example: CD-ROM, DVD, Disk etc. These memories are magnetic and optical. It is also known as backup memory. Secondary memory is non volatile in nature. Figure 9.2 depicts CD-ROM.

Figure 9.2 : CD-ROM

Cache Memory

It is made up of semiconductor device. It is used to increase the speed of CPU. This memory acts like a buffer between main memory and the CPU. Most frequently used data and program by CPU resides in this memory. Firstly, the information and program is exchanged from disk to cache memory, from where CPU can get to it.

Merits of Cache memory

- It stores data for temporary use.
- It is faster than primary memory.
- It generally keeps those instructions that can be executed inside a brief timeframe.
- As compared to main memory, access time of cache memory is less.

Demerits of Cache memory

- It has restricted limit.
- It is extremely costly.

9.1 OBJECTIVES

After going through this unit, you should be able to know about

- ROM (Read Only Memory);
- Flash memory; and
- Other types of memories in a mobile device.

9.2 MEMORY IN A MOBILE PHONE

In this era of technology, Smartphone is a device which is used by every second person of the population. There are a huge number of brands available of Smartphone. Every Smartphone have some memory associated with it. Basically, Smartphone uses two major types of memories i.e. volatile memory and non-volatile memory. In every Mobile phone, there are three memories,

namely, phone memory, memory on SD card and RAM. SD card memory is optional. The sizes of memories can be found by tapping on *settings* and other options that follow.

Now, let's learn more about volatile and non-volatile memories.

9.2.1 Volatile Memory

Volatile memory will not hold its content after the power supply is off. It loses the data it holds after the device is powered off. Volatile memory is like RAM(Random Access Memory). In RAM, each memory location has its own unique address that can be easily read or written independently. Advantage of using this memory is that the access time is very less. This memory acts like the run-time memory of software applications(device's operating system).RAM is also used as a storage drive in which part of it is reserved/allocated, this is known as RAM disk. RAM disk is available in smartphones as D-drive. Because, this is a volatile memory, data is lost when the device is switched off, therefore only small and temporary data should be stored in this.

9.2.2 Non-Volatile Memory

Unlike Volatile memory, non-volatile memory doesn't lose its data even if the power/device is switched off. Non-volatile memory always retains its state.

The following are basically two types of non-volatile memories-

- **ROM :** It stands for Read-only Memory. Usually, it is based on flash memory.
- **Flash RAM :** It is a kind of ROM, however it stores the data related to the Operating System and other applications. It stores that data which is not to be erased.

ROM can be seen as Z-drive on smart phones. This drive can only be view/read but it is not permissible to write. In new devices, this drive could not be accessed by unprivileged third party applications. Another type of non-volatile memory is Flash-RAM. It is based on the flash memory technology and it has write permission also along with read and view. This memory is also known as "user memory" or "phone memory". This device stores system software i.e. operating system like C-drive in computer. While initializing, the C drive needs that files/data which is used by the operating system for various purposes. This is the memory where various by default things are stored such as contacts, messages or photos.

9.3 MEMORY CARD

As depicts by its name, it is another kind of memory. Nowadays, almost every smart phone comes with the slot given for memory card to increase its memory space. Memory cards are available in different memory size like 8GB, 16GB, and 32GB etc.

Different types of memory card are:

- **MMC:** It stands for Multi Media Card. MMC is used in portable devices from which it can easily be removed. For example, it is used in digital camera for storing image files. A user can copy the pictures of digital

camera to his/her computer with the help of MMC reader. MMCs are available up to 512GB in size. Figure 9.3 depicts MMC card.

Figure 9.3 : MMC

- **SD Card:** It stands for Secure Digital Card. SD cards are slightly thicker and have some extra connectors as compared to MMCs. They also support extra security features and can also be used for peripherals.
- **RSMMC:** It stands for Reduced Size Multi Media Card. It is almost half of the MMC in size. These are also known as high voltage RSMMC cards because they can be operated at a voltage range of approximately 3.3 volt. Figure 9.4 depicts RSMMC.

Figure (D): RSMMC

- **Micro SD:** It is smaller in size as compared to SD cards and consumes different power than SD cards.

In every smart phone, by tapping on settings and other appropriate options, storage on the device can be known.

9.4 ROM

ROM is non-volatile memory which is used in computers, mobiles and other electronic devices. The data which is stored in ROM, cannot be modified easily, therefore it is mainly used for storing firmware or application software's. The instructions that are required to start a computer are stored in ROM.

The following are different types of ROM:

9.4.1 MROM

It stands for Mask ROM. These sorts of ROMs were first hard wired. They contain preprogrammed set of information or instructions to be processed.

9.4.2 PROM

It stands for Programmable Read Only Memory. It can be modified only once. Contents can be written on it only one time using PROM program and then it cannot be modified or erasable. There are small fuses in this ROM which are burnt open during programming. Figure 9.4 depicts PROM

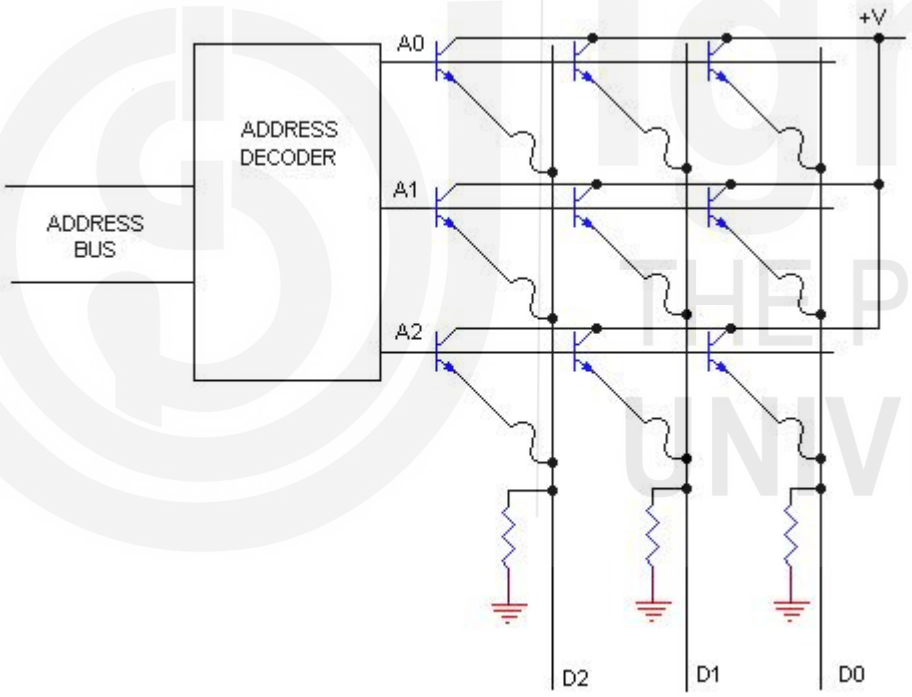

Figure 9.4 : PROM

9.4.3 EPROM

It stands for Erasable and Programmable Read Only Memory. The content of EPROM can be wiped off by presenting it to ultra-violet light for 40 minutes. During programming, in insulated gate region an electric charge is trapped which can be retained for more than 10 years because it has no leakage path. This charge can be erased by passing the ultra violet light through quartz crystal window. Figure 9.5 depicts EPROM.

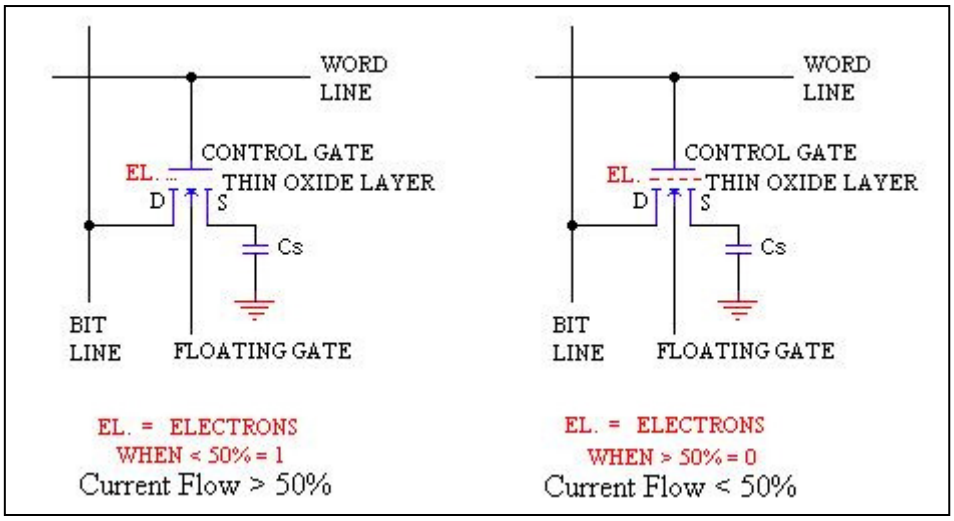

Figure 9.5 : EPROM

9.4.4 EEPROM

It stands for Electrically Erasable and Programmable Read Only Memory. On this ROM, erasing and programming can be done electrically. User can erase and re-program this memory about 10 thousand times. Approximately the whole process of erasing and programming take about 4-10 milliseconds. We can easily erase and program a selected location in EEPROM. It doesn't wipe off the whole chip at once, notwithstanding it delete one byte at any given moment. Subsequently, re-writing computer programs is adaptable in EEPROMs.

The following are advantages of ROM:

- It is non-volatile in nature.
- It cannot be changed accidently.
- They are easy to test
- They are cheaper and more reliable than RAMs.

9.5 FLASH MEMORY

Flash Memory is another kind of storage medium that can easily be erased and programmed. This memory is non-volatile in nature. It does not lose the data even when there is breakdown in power supply. It was first developed by Toshiba in 1980, but it was released in the market in 1984 and it was named as EEPROM (Electrically Erasable Programmable Read-only Memory). There are basically two types of flash memories which are based on the concept of NAND and NOR logic gates. The characteristics of both the memories reflect the internal characteristics of respective gates. It is used in devices like USB flash drives, digital cameras and video games. In NAND-type flash memories, data can be written and read in blocks, and the size of these blocks are much smaller than the size of entire device. Whereas, NOR-type flash memories can independently read or write single machine word (byte). Examples of both types of flash memories are video games, digital audio players, digital cameras, mobile phones, scientific instrumentation, industrial robotics etc. Along with its non-volatile nature, it also offers fast access time; however, it is not as fast as RAM or ROM. Also, there is a limitation on write cycles in flash memory.

User can read data n number of times from flash memory but it will stop working once the limitation of 'write' operation is exceeded. Approximately 1, 00,000 to 10, 00,000 write operations can be done on flash memory.

Flash memory stores data and instructions in an array like structure of memory cells, these cells are made up of floating-gate transistors. There are various types of devices that are made up of these cells, for example, single-level cell (SLC) devices are made up of single cell and each cell stores one bit of information, whereas, multi-level cell (MLC) devices are made up of multiple cells and they can store more than one bit per cell.

In flash memory, which is made up of one transistor, each memory cell shows the characteristics of a standard MOSFET (metal-oxide-semiconductor field-effect transistor). On the top of the memory cell, there is a control gate and below the control gate, there is a floating gate which is insulated by an oxide layer. The floating gate is placed between the Control gate and the MOSFET channel.

Low-level access of flash memory is quite different from other types of storage devices such as DRAM, ROM, and EEPROM. Flash memory supports alteration of bits i.e. 0 to 1 and 1 to 0 and it also supports random access through external buses. For reading and programming, NOR memory has an external address bus, and NAND memory do it page-wise.

9.5.1 NOR Memories

NOR flash and RAM follow the same process of reading. For proper execution of the process of reading, the data and address bus should be mapped correctly. User can directly execute the programs stored in NOR flash without copying the data into the RAM first. Just like reading, NOR flash can be programmed in a random-accessed manner. In programming, bits change from 1 to 0, and the bits that are already zero remain unchanged.

9.5.2 NAND Memories

NAND flash architecture was first introduced by Toshiba in 1989. NAND flash is generally used as block devices, such as hard disks. Each block contains number of pages. The size of each page is about 512, 2048, or 4096 bytes. With every page, few bytes are attached for the storage of error correcting code (ECC) checksum. NAND devices use ECC for compensating for the bits that may spoil/fail during normal device operation. Table 9.1 gives differences between NOR and NAND flash memories.

Table 9.1 : Differences between NOR and NAND flash memories

NOR Flash	NAND Flash
It allows Random-access for reading	It allows page access only
In this, cells are connected in parallel to the bit lines, so that cells can be read and programmed individually	In this, cells are connected in series, similar to NAND gate
It consumes more space as compared to NAND flash	It consumes less space as compared to NOR flash
Cost is high	Cost is low
The size of each cell is comparatively larger than NAND flash.	The size of each cell is smaller than the corresponding cells of NOR flash memory

Check Your Progress

1) _____ memory loses data if the device is powered off.

2) MMC stands for _____.

3) In EEPROM, _____ and _____ can be done electronically.

4) NOR flash memory allows _____ access for reading.

9.6 SUMMARY

While considering the memory particulars of any smart phone, it is vital to comprehend the distinction amongst internal and external (or expandable) memory. Internal memory is the pre-installed memory space provided along-with the phone, generally 16, 32 or 64GB, where the working framework, pre-introduced applications and other system applications are installed. The space of internal memory can't be expanded or diminished by the user, so if your phone has just 16GB of internal capacity and not expandable further, this is all the storage room you will ever have numerous gadgets which include a Micro SD card space are sold with a card as of now embedded. Be that as it may, not all phones will have this additional storage space included, and not all phones even have the feature to include external memory. iPhone, for instance, has never given users the capacity to include more storage space by utilizing a SD card, neither have both of the LG Nexus gadgets. In the event that storage, for music, pictures, or other user files, is essential to you, the capacity to include another 32 or even 64GB sensibly economically ought to be an imperative thought.

Cloud Space

To conquer the issue of lessened internal storage space, a few top of the line smart phones are sold with free cloud storage accounts. This offered space could be 10, 20 or even 50GB. While this is a decent additional, remember that not all information and files can be stored to cloud storage (applications for instance). You will likewise be not able get to files put away in the cloud on the off chance that you don't have a Wi-Fi or active mobile data pack.

Increasing Internal Storage Space

There are two or three conceivable approaches to make some additional space in your internal storage, contingent upon the mobile phone you have.

Impair Bloatware

Not all cell phones will give you a chance to do this, but rather on the off chance that you have an Android phone running form 4.2 or later, the procedure is genuinely simple. Although disabling 100MB pre-introduced application won't free up a relating measure of memory, it ought to positively make some additional space.

Backup and Clean Photographs

This is a decent practice to get into regardless of the possibility that storage space on your phone is not an issue. Utilize the sync program that is important

to your handset to reinforcement your photographs to your PC routinely. You are then ready to erase the photographs off of your phone (or possibly some of them) to free up some space.

For example, Cleanmaster is an application to clear unneeded or undesirable documents from your phone, frequently at the touch of a button. Once more, this measure won't free up immense measures of space, yet it can have some effect.

Un-installing-necessary or un-used Apps

In the event that you are anything like me, you will be liable of downloading the most recent prevailing fashion application, utilizing it always for half a month and afterward disregarding as you move onto the following. Check through your applications list and uninstall those you never again utilize. This is effectively done through the settings menu of a wide range of smart phone, or by utilizing an application like Cleanmaster.

In today's world of electronics, memory technology is an essential element. With the use of semiconductor technology, any device which uses processor embeds memory to store data/information. As the new devices in market come with the microprocessors, correspondingly the need for semiconductor memory is also increasing. Therefore, new and advanced semiconductor memory technologies are being researched. With the increased growth for semiconductor memories, there are a number and types of memories that emerged in the market. Some of them are- RAM, ROM, PROM, EPROM, EEPROM, and Flash memory, DRAM, SRAM, SDRAM and MRAM etc. Each kind of memory has its own advantages and features. Semiconductor memories technology is moving forward with pace. With the increase in the size of the memories, data density is also improving. Various new forms of memories are also introduced in the past few years like MRAM (Magneto resistive Random Access Memory). As the requirements for larger, faster and lower power consuming memories are increasing, the area of this technology will be one of the most dynamic in the electronics industry.

9.7 SOLUTIONS/ANSWERS

1) Volatile
2) Multi Media Card
3) Erasing, Programming
4) Random

9.8 FURTHER READINGS

- How Computers Work: Processor and Main Memory by Roger Young; Create space Independent; ISBN-13: 9781442113985, ISBN-10: 1442113987.
- Media and Memory (Media Topics) by Joanne Garde-Hansen; Edinburgh University Press; ISBN-10: 0748640339, ISBN-13: 978-0748640331.
- https://en.wikipedia.org/wiki/File:15-04-29-MMC-Karte-RalfR-dscf4734-d.jpg
- http://www.electronics.dit.ie/staff/tscarff/memory/prom.gif

- http://www.electronics.dit.ie/staff/tscarff/memory/eprom.gif
- https://en.wikipedia.org/wiki/Memory
- https://en.wikipedia.org/wiki/Computer_memory
- https://en.wikipedia.org/wiki/MultiMediaCard

UNIT 10 SENSORS

Structure

10.0 INTRODUCTION

In our everyday life, we see many articles, for example, touch-sensitive elevator and lights which diminish or light up by touching the base, other than various uses of which the vast majority are never aware. With fast improvement in the field of smaller scale hardware and simple to-utilize micro-controllers, the employments of sensors have extended beyond the traditional fields of temperature, pressure or flow estimation. Moreover, analog sensors like potentiometers and force-sensing resistors are still usually utilized. You may utilize sensors in assembling and apparatus, planes and aviation, autos, medicine, robotics and numerous aspects of our everyday life. A sensor is a device, module, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a Computer processor. A sensor is always used with other electronics, whether as simple as a light or as complex as a computer.. A sensor is constantly utilized with different electronic gadgets, regardless of whether as basic as a light or as complex as a PC. To the extent specialized meaning of sensor is considered, sensors are refined gadgets that are every now and again used to recognize and react to electrical or optical signs. Let's consider the case of temperature. In the glass thermometer, mercury extends and gets the fluid to change over the deliberate temperature which can be perused by a viewer on the adjusted glass tube. At the end of the day, a sensor is a gadget that identifies and reacts to some sort of contribution from the physical condition.

Figure 10.1 shows working of touch screen of a mobile device.

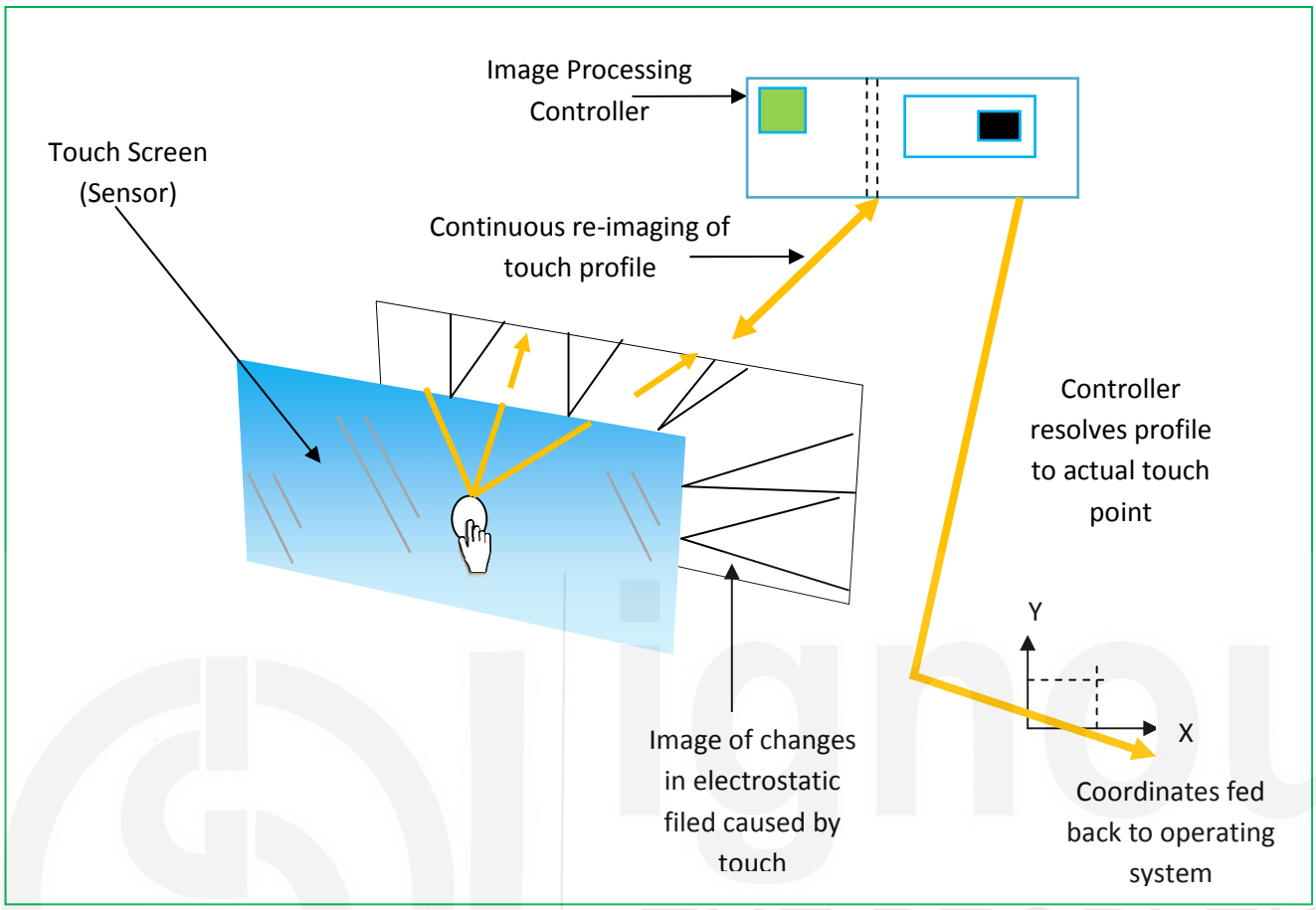

Figure 10.1 : Working of a Touch Screen of a Mobile Device

10.1 OBJECTIVES

After studying this unit, you should be able to know about:

- Gyroscope
- Accelerometer
- Compass
- Proximity sensor

10.2 GYROSCOPE

A gyroscope is a device used for measuring or maintaining orientation and angular velocity.

It's a device which is used to determine orientation with the help of Earth's gravity. The design of gyroscope comes up with a freely-rotating disk known as a rotor, mounted onto a spinning axis in the center of a larger and extra balanced wheel. As the axis turn, the rotor remains stationary to imply the central gravitational pull, and thus which direction is down. The degree of strength of the gyroscope can be maintained by measuring its rate of rotation round a particular axis. When estimating the rate of revolution around the roll

axis of an aircraft, it places an actual value until the object stabilizes out. Applying the central principles of angular momentum, the gyroscope helps indicate orientation.

Applications of gyroscopes include the inertial route systems where attractive compasses would not act, consistently in the Hubble telescope, or inside the steel structure of a submerged submarine, or would not be adequately right. Because of their accuracy, gyroscopes are likewise utilized as a part of gyrotheodolites to maintain direction in tunnel unearthing. Gyroscope can be utilized to develop gyrocompasses, which supplement or supplant magnetic compasses (in boats, flying machine and shuttle, vehicles by and large), to aid stability (Hubble Space Telescope, bikes, motorcycles, and ships) or be utilized as a major aspect of an inertial navigation system. A gyroscope would be applied in an aircraft to assist in indicating the rate of revolution about the aircraft roll axis. As an aircraft rolls, the gyroscope will measure non-zero values until the platform leaves out, whereupon it would record a null value to designate the direction of "down." The best example of reading a gyroscope is that of the attitude indicator on typical aircrafts. It is typified by a circular display with the screen divided in half, the top half being blue in color to indicate sky, and the bottom being red to indicate ground. As an aircraft banks for a spell, the orientation of the display will transfer with the bank to account for the actual direction of the Earth. Figure 10.2 shows gyroscope.

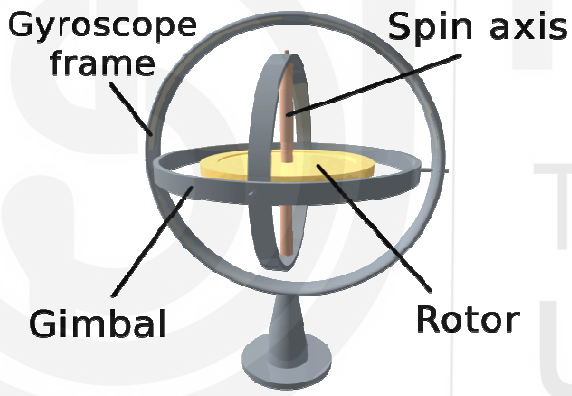

Figure 10.2 : Gyroscope

A gyroscope sensor has the following basic specifications:

- Measurement scale
- Sensing axes
- Non-linearity
- Operating temperature scale
- Shock sustainability
- Transmission Speed
- Noise Measurement
- Bias
- Bias Drift
- Bias Instability

Table 10.1: Describes various specifications of a Gyroscope.

Specification	Description
Measurement scale	This parameter decides the greatest angular speed with which the sensor can quantify, and is typically in degrees per second (˚/Sec).
Sensing axes	Gyroscopes are available that measure angular rotation in 1, 2, or 3 axes. Multi-axis detecting gyros have various single-axes gyros arranged orthogonal to each other. Vibrating plan gyroscopes are usually single-axis gyros or double-axis gyros, and revolving and visual gyroscope systems usually measure rotation in 3 axes.
Non-linearity	Gyroscopes deliver a voltage which is equal to the detected angular rate. Non-linearity is a bar of how near to linear the outputted voltage is in respect to the real angular rate. By not considering the non-linearity of a gyro, estimation can bring about some mistake. Estimation of non-linearity is figured as a rate error from a linear fit over the full-scale extend, or a mistake in parts per million.
Operating temperature scale	The greater part of the gadgets works just in some scope of temperatures. Working temperatures for gyroscopes are very substantial; their working temperatures go from generally - 40˚C to anyplace between 70 and 200˚C and have a tendency to be quite linear with temperature. Numerous gyros are accessible with a locally available temperature sensor, and afterward one doesn't have to stress over temperature related adjustment issues.
Shock sustainability	In frameworks where both linear acceleration and angular rotation rate are measured, it is vital to perceive how much force the gyroscope can withstand before breaking. Luckily gyroscopes are extremely rich, and can hold up a big container (over a short span) without ceasing. This is normally measured in g's (1g = earth's acceleration because of gravity), and at times the fourth dimension with which the most extreme g-force can be given before the unit fails is likewise displayed.
Transmission Speed	The data transfer capacity of a gyroscope regularly measures what number of measurements can be drawn every second. Hence the gyroscope transmission capacity is typically cited in Hz.
Angle Random Walk	Angle random walk (ARW) is a noise determination, in units of deg/hr1/2 that is specifically appropriate to angle computations. ARW depicts the normal deviation or mistake that will happen when you incorporate the signal. The "Random walk" is utilized as a part of statistics to portray a circumstance where

	the output of a system is driven by arbitrary, uncorrelated "steps".
Bias	At the point when there is no rotation, the bias, or bias error, of a rate gyro is the signal output from the gyro Even the absolute best gyros in the world have mistake sources and bias is one of these wrongdoings. Bias can be appeared as a voltage or a percent of full scale output, yet basically it speaks to a rotational speed (in degrees every second). Once more, in a perfect universe, one could make allowance for a fixed bias error. Unfortunately a bias error has a tendency to differ, both with temperature and over time. The bias error of a gyro is because of various parts: • Calibration blunders • Switch-on to switch-on • bias drift • effects of shock (g level) Single estimations of bias are excessively influenced by noise, which is the reason an important bias measurements is always an averaged series of measurements.
Bias Drift	This alludes particularly to the change of the bias after some time, acquiring every single other segment stay constant. Fundamentally, this is a warm-up impact, prompted by the self heating of the gyroscope and its related mechanical and electrical parts. This force would be required to be more dominating over the initial few moments after change on and to be nearly non-existent after (say) five minutes.
Bias Instability	Bias Instability is a simple paradigm of the "goodness" of a gyroscope. It is indicated as the base point on the Allan Variance curve, typically measured in °/hr. It outlines the best bias security which could be achieved for a given gyroscope expecting that bias averaging executes in the period recognized as the Allan Variance least 9.

10.3 ACCELEROMETER

An accelerometer is a device that measures proper acceleration. It's used to quantify the best possible acceleration which is not like coordinate acceleration. For example, an accelerometer at rest on the airfoil of the Earth will measure acceleration because of Earth's gravity, straight upwards (by definition) of g ≈ 9.81 m/s2. By complexity, accelerometers in free fall (going down toward the core of the world at a rate of roughly 9.81 m/s2) will measure zero. Accelerometers have different applications in industry and scientific discipline. Exceedingly delicate accelerometers are parts of inertial route navigation systems for aircraft and rockets. Likewise they are utilized to oversee screen vibration in rotating apparatus. Accelerometers are utilized as a part of tablet PCs and digital cameras so that pictures on screens are constantly

shown upright. Accelerometers are utilized in drones for flight adjustment. Coordinated accelerometers can be utilized to measure differences in appropriate acceleration, especially gravity, over their partition in space; i.e., gradient of the gravitational field. This gravity gradiometry is valuable since supreme gravity is a weak impact and relies on upon local density of the Earth which is quite variable. Single-and multi-axis models of accelerometer are accessible to recognize magnitude and direction of the proper acceleration, as a vector amount, and can be utilized to detect orientation (since direction of weight changes), organize acceleration, vibration, shock, and falling in a resistive medium (a situation where the best possible acceleration changes, since it begins at zero, then increments). Small scale machined accelerometers are progressively present in convenient electronic gadgets and computer game controllers, to recognize the position of the gadget or accommodate game input.

Types of Accelerometer

There are few unique standards whereupon an analog accelerometer can be constructed. Two exceptionally common types use capacitive sensing and the piezoelectric effect to detect the displacement of the evidence mass relative to the applied acceleration. Table 10.2 explains them in detail.

Table 10.2 : Capacitative and Piezoelectric Accelerometer

Capacitive	Accelerometers that execute capacitive sensing output a voltage subject to the distance between two planar surfaces. Either of these "plates" is charged with an electrical current. Changing the gap between the plates changes the electrical limit of the system, which can be measured as a voltage output. This strategy for detecting is known for its high precision and stability. Capacitive accelerometers are additionally less prone to noise and variation with temperature, normally disseminates less power, and can have larger transfer speeds because of inner feedback circuitry.
Piezoelectric	Piezoelectric detecting of acceleration is normal, as acceleration is straightforwardly corresponding to force. At the point when certain sorts of crystal are compressed, charges of inverse polarity accumulate on inverse sides of the crystal. This is known as the piezoelectric effect. In a piezoelectric accelerometer, charge aggregates on the crystal and is translated and amplified into either an output current or voltage. Piezoelectric accelerometers just react to AC phenomenon, for example, vibration or shock. They have a wide powerful range, however can be costly relying upon their quality. Piezo-film based accelerometers are best used to measure AC phenomenon, for example, vibration or shock, as opposed to DC phenomenon, for example, the acceleration of gravity. They are cheap, and react to other phenomenon, for example, temperature, sound, and pressure.

Table 10.3: Describes accelerometers that are less used in audio applications.

Piezoresistive	Piezoresistive accelerometers (otherwise called Strain gage accelerometers) work by measuring the electrical resistance of a material when mechanical anxiety is connected. They are favored in high shock applications and they can measure acceleration down to 0Hz. Be that as it may, they have a constrained high frequency reaction.
Hall effect	Corridor impact accelerometers work by measuring the voltage varieties brought about by the change in magnetic field around them.
Heat transfer	Warm move accelerometers comprise in a solitary heat source focused in a substrate and suspended across cavity. They incorporate similarly separated thermoresistors on the four side of the heat source. They measure the inward changes in heat because of acceleration. At the point when there is zero acceleration, the heat gradient will be symmetrical. Otherwise, under acceleration, the heat gradient will become asymmetrical because of convection heat exchange

The following are other types of accelerometer:

- Null-balance
- Servo force balance
- Strain gauge
- Resonance
- Optical
- Surface acoustic wave (SAW)

10.3.1 Specifications of an Accelerometer

A typical accelerometer has the following basic specifications:

- Analog/digital
- Number of axes
- Output range (maximum swing)
- Sensitivity (voltage output per g)
- Dynamic range
- Bandwidth

- Amplitude stability
- Mass

Analog and Digital accelerometers The most essential detail of an accelerometer for a given application is it's kind of output. Analog accelerometers output a constant factor variable relying upon the measure of acceleration applied. Earlier digital accelerometers output a variable frequency square wave, a technique known as pulse-width modulation. A pulse width modulated accelerometer takes readings at a fixed rate, regularly 1000 Hz (however this might be user-configurable in light of the IC selected). The value of the acceleration is corresponding to the pulse width (or obligation cycle) of the PWM signal. Newer digital accelerometers will probably output their value utilizing multi-wire digital protocols, for example, I2C or SPI.

For use with ADCs generally utilized for music collaboration systems, analog accelerometers are typically preferred.

Number of axes Accelerometers are accessible that measure in 3 dimensions. The most well-known kind of accelerometer measures across two axes. However, three-axis accelerometers are progressively normal and economical.

Output range To quantify the acceleration of gravity for use as a tilt sensor, an output scope of ±1.5 g is adequate. For use as an effect sensor, a standout amongst the most widely recognized melodic applications, ±5 g or more is desired.

Sensitivity A marker of the measure of progress in output signal for a given change in acceleration. A sensitive accelerometer will be more exact and most likely more precise.

Dynamic range The range between the smallest acceleration is discoverable by the accelerometer to the largest before distorting or clipping the output signal.

Bandwidth The data transmission rate of a sensor is typically measured in Hertz and demonstrates the capacity of the near-unity frequency reaction of the sensor, or how frequently a reliable reading can be taken. People can't make body movement much beyond the scope of 10-12 Hz. Thus, a data transmission of 40-60 Hz is sufficient for tilt or human movement detecting. For vibration estimation or exact reading of impact forces, transmission capacity ought to be in the scope of hundreds of Hertz. It ought to likewise be noticed that for some older microcontrollers, the data transmission rate of an accelerometer may extend beyond the Nyquist frequency of the A/D converters on the MCU, so for higher transmission rate sensing, the advanced signal might be associated. This can be resolved with simple passive low-pass filtering before sampling, or by basically picking a superior microcontroller. It is important that the data transmission rate or bandwidth may change by the way the accelerometer is mounted. A stiffer mounting will support to maintain a higher usable frequency range and the inverse will diminish it.

Mass The mass of the accelerometer ought to be fundamentally smaller than the mass of the system to be observed with the goal that it doesn't change the characteristic of the object being tested.

The following are some of the other details associated with accelerometer:

- Zero g balance (voltage output at 0 g)
- Noise (sensor least resolution)

- Temperature scale
- Bias drift with temperature (impact of temperature on voltage output at 0 g)
- Sensitivity drift with temperature (impact of temperature on voltage output per g)
- Power utilization

10.3.2 Output of an Accelerometer

An accelerometer output value is a scalar relating to the magnitude of the acceleration vector. The most widely recognized acceleration, and one that we are always presented to, is the acceleration that is a consequence of the earth's gravitational pull. This is a typical reference value from which every single other accelerations are measured (known as g, which is ~9.8m/s^2).

Digital output Accelerometers with PWM output can be utilized as a part of two diverse ways. For most exact outcomes, the PWM signal can be input directly to a microcontroller where the obligation cycle is perused in firmware and converted into a scaled acceleration value. (Check with the datasheet to acquire the scaling component and required output impedance.) When a microcontroller with PWM information is not accessible, or when different methods for digitizing the signal are being utilized, a simple RC reconstruction channel can be utilized to get a analog voltage proportional to the acceleration. At rest (half obligation cycle) the output voltage will show no acceleration, higher voltage values (coming about because of a higher obligation cycle) will show positive acceleration, and lower values (<50% obligation cycle) show negative acceleration. These voltages can then be scaled and utilized as one may the output voltage of an analog output accelerometer. One weakness of a digital output is that it takes somewhat more timing resources of the microcontroller to measure the obligation cycle of the PWM signal. Correspondence protocols could utilize I2C or SPI.

Analog output At the point when contrasted with most other modern sensors, analog accelerometers require small conditioning and the correspondence is basic by just utilizing an Analog to Digital Converter (ADC) on the microcontroller. Regularly, an accelerometer output signal will require a offset, amplification, and filtration. For analog voltage output accelerometers, the signal can be a positive or negative voltage, contingent upon the course of the acceleration direction. Additionally, the signal is persistent and relative to the acceleration force. Similarly as with any sensor bound for a analog to digital converter, the value must be scaled or potentially increased to maximize the range of acquisition. Most analog to digital converters utilized as a part of melodic applications acquire signals in the 0-5 V range.

The picture at right depicts an amplification and offset circuit, including the on-board operational amplifier in the ADXL105, limiting the requirement for extra IC components. The gain connected with output is set by the proportion R2/R1. The balance is controlled by biasing the voltage with variable resistor R4. Accelerometers output bias will float as indicated by surrounding temperature. The sensors are adjusted for operation at a particular temperature, commonly room temperature. However, in most brief length indoor applications the balance is generally consistent and stable, and in this way does not require modification. If the sensor is proposed to be utilized as a part of different situations with varying surrounding temperatures, the bias capacity ought to be adequate for analog alignment of the gadget. In the event that the ambient

temperature is liable to uncommon changes through the span of a solitary use, the temperature output ought to be summed into the bias circuit. Brilliant sensors may even think about this.

The resolution of the information gained is at last controlled by the analog to digital converter. It is conceivable, in any case that the noise floor is over the base resolution of the converter, diminishing the resolution of your system. Accepting that the noise is similarly circulated over all frequencies, it is conceivable to channel the signal to just incorporate frequencies inside the scope of operation. The channel required relies on both kind of acquisition and the location of the sensor. The transfer speed is essentially impacted by the three distinct methods of operation of the sensor.

10.3.3 Applications of an Accelerometer

The following are some of the applications of an accelerometer:

- The sensor can be executed in a system that identifies speed, position, shock, vibration, or the acceleration of gravity to decide orientation.
- A system comprising of two orthogonal sensors which are equipped for detecting pitch and roll. This is helpful in catching head movements. A third orthogonal sensor can be added to the network to acquire orientation in three dimensional space. This is proper for the detection of pen angles, and so forth. The detecting abilities of this network can be advanced to six degrees of spatial measurement freedom by the expansion of three orthogonal gyroscopes.
- As a shock detector, an accelerometer is searching for changes in acceleration. This jerk is detected as an over damped vibration.

Data transmissions related with different usage of accelerometers as input devices were illustrated in Table 10.4.

Table 10.4 : Data transmission rates with accelerometers

Location	Usage	Frequency	Acceleration
Head	Tilt	0-8 Hz	xx
Hand , Wrist, Finger	Cont.	8-12 Hz	0.04-1.0 g
Hand, Arm, Upper Body	Cont.	0-12 Hz	0.5-9.0 g
Foot, Leg	Cont.	0-12 Hz	0.2-6.6 g

Depending upon the sensitivity and dynamic range required, the cost of an accelerometer can increase to thousands of dollars. In any case, exceptionally accurate reasonable sensors are available.

10.4 COMPASS

A Compass is an instrument used for navigation and orientation that shows direction relative to the geographic cardinal directions (or points). The advanced compass that is typically in light of a sensor called magnetometer gives cell phones a straightforward orientation in connection to the Earth's magnetic field. Accordingly, your smart phone dependably knows which way

is North so it can auto rotating your digital maps relying upon your physical orientation. The cell phones have a little magnetometer implicit, which can measure the Earth's magnetic field. This data is consolidated with an accelerator that gets data in regards to the phone's position in space. It can pinpoint the phone's position from solid state sensors inside the phone that can measure their tilt and movement. The data given by these gadgets implies that the compass application can show cardinal directions regardless of which orientation the phone is in, as indicated by the algorithmic software development organization Sensor Platforms. The compass can decide north and south because of the magnet's association with the Earth's magnetic field. The reason for the magnetic field is not unmistakably known, but rather geologists have made speculations with respect to the phenomenon by analyzing the layers of the Earth. The Earth is comprised of an outer crust, trailed by the upper mantle, the inward mantle, the outer core, and after that at long last the inner core at the very center. The inner core is made up for the most part of liquid iron, however the extreme center of the inner core is under so much pressure that the liquid iron is in a solid form. It is trusted that the rotation of the Earth and the tremendous warmth from the core make the iron move in a rotational manner. This rotational manner might be the source of the magnetic field that we see on Earth. The field created is extremely feeble, be that as it may, which is the reason the needle on the compass should be exceptionally lightweight and on a surface with minimal friction.

10.5 PROXIMITY SENSOR

A proximity sensor is a sensor that is able to detect the presence of nearby objects without any physical contact. A proximity sensor regularly transmits an electromagnetic field or a beam of electromagnetic radiation (infrared, for example), and searches for alterations in the field or return signal. The object being sensed is regularly concerned to as the proximity sensor's target. Distinctive proximity sensor targets request different sensors. Like for a plastic target, capacitive or photoelectric sensor may be reasonable and for a metal target, an inductive proximity sensor is constantly required. This sensor can detect maximum distance up to its defined "nominal range". Proximity sensors can have a high reliability and long functional life due to the absence of mechanical parts and absence of physical contact between sensor and the detected object. Proximity sensors are usually utilized on mobile phones to detect and skip incidental touchscreen taps when held to the ear amid a call. They are likewise utilized as a part of machine vibration checking to measure the variation in distance between a shaft and its support bearing. This is basic in large steam turbines, compressors, and engines that utilize sleeve-type bearings. International Electrotechnical Commission (IEC) characterizes the specialized subtle elements of proximity sensors. A proximity sensor changed in accordance with a short range is regularly utilized as a touch switch.

Check Your Progress 1

1) A _____ is a device, module, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor.

2) A _____ is a device used for measuring or maintaining orientation and angular velocity.

3) An _____ is a device that measures proper acceleration.

4) A _____ is an instrument used for navigation and orientation that shows direction relative to the geographic cardinal directions.

5) A _____ is a sensor that is able to detect the presence of nearby objects without any physical contact

10.6 SUMMARY

Now a day, mobile phones accompanied with variety of sensors that simplify or automate our day to day assignments. This field considers the presence of an accelerometer, a compass, a gyroscope and a barometer.

Accelerometers in smart phones are utilized to recognize the orientation of the phone. The gyroscope, adds an extra dimension to the data provided by the accelerometer by following rotation or twist. Linear acceleration of movement is measured by accelerometer whereas gyroscope measures the angular rotational speed. Both sensors measure rate of progress; they simply measure the rate of progress for various things. Both sensors measure rate of progress; they simply measure the rate of progress for various things. In practice, accelerometer will quantify the directional movement of a gadget however won't have the capacity to determine its lateral orientation or tilt during that movement precisely unless a gyro is there to fill in that data. With an accelerometer you can either get a truly "loud" information output that is responsive, or you can get a "spotless" output that is slow. In any case, when you join the 3-pivot accelerometer with a 3-axis gyro, you get an output that is both perfect and responsive in a similar time.

The digital compass that is generally in view of a sensor called magnetometer gives cell phones a basic orientation in connection to the Earth's magnetic field. Thus, your phone dependably knows which way is North so it can auto rotating your digital maps relying upon your physical orientation.

Lastly, you may see a gadget sporting a barometer in its specification sheet. As opposed to what you may recommend, it has nothing to do with climate. Rather, the barometer is there to help the GPS chip inside the gadget get a quicker lock by immediately conveying altitude information.

10.7 SOLUTIONS/ANSWERS

1) Sensor
2) Gyroscope
3) Accelerometer
4) Compass
5) Proximity sensor

10.8 FURTHER READINGS

- Introduction to Sensors by John Vetelino and Aravind Reghu;CRC press; ISBN-10: 143980852X, ISBN-13: 978-1439808528.
- Sensors and Transducers by Ian Sinclair; Newnes; Third edition; ISBN-10:0080516998, ISBN-13:978-008051699.

- https://en.wikipedia.org/wiki/Sensor
- https://en.wikipedia.org/wiki/Gyroscope
- https://en.wikipedia.org/wiki/Accelerometer
- https://en.wikipedia.org/wiki/Compass
- https://en.wikipedia.org/wiki/Proximity_sensor
- http://www.te.com/usa-en/products/sensors.html
- https://science.howstuffworks.com/gyroscope.htm
- https://www.gsmarena.com/glossary.php3?term=accelerometer
- http://www.machinedesign.com/sensors/proximity-sensors-compared-inductive-capacitive-photoelectric-and-ultrasonic
- http://www.sensorwiki.org/doku.php/sensors/accelerometer

UNIT 11 INPUT-OUTPUT

Structure

11.0 INTRODUCTION

Any information or data which is sent to a computer/mobile device for processing is considered input. Input is most often sent to the device using an input device, the following pictures are examples of input being sent from the computer keyboard to the computer and using touchpad or virtual keyboard to mobile.

An output device is referring to a device or electronic equipment which is utilized for getting information from another gadget, however it can't send information to another gadget, for example, PC screen, projector, and speakers, which can get information (output) from the PC, yet they can't send data (input) to the PC. Similarly, in mobile phones, output device is the display screen of the phone where you see result of the action performed, like watching videos, viewing pictures etc. Hence we can say an input/output device is the device that can send data to a system for processing, and reproduces or displays the results of that processing. The output is depends upon on the interaction, a device can be both, referred to as an input/output or I/O device.

11.1 OBJECTIVES

After going through this unit, you should be able to:

- know about various input/output operations;
- understand different input/output interfaces; and
- understand the technology behind I/O devices.

11.2 DISPLAY

Display is the most important interface between humans and machines, with the ability to present information in terms of text, graphics, animation, and video. Historically, the display industry was stuck in neutral compared to the rest of the high tech sector, which has evolved at warp speed. For more than

eight decades, CRT (Cathode Ray Tube) was the king of display that has quickly changed now. Today, display devices, such as LCD, Plasma, DLP (digital light processing), LCoS (Liquid crystal on silicon), and SED (Surface-conduction electron-emitter display) have suddenly emerged. Driven by computers, high definition TV (HDTV), and mobile devices (including cell phones), the display industry is evolving at a much faster rate than ever before. With so many options, choosing the best display solution for you mobile device has become a real challenge. First, let's start by asking which display features and parameters are favorable to the application. Next, let's define some important general display performance attributes, as shown in the following table. Table 11.1 also describes some important mobile display performance attributes.

Table 11.1 : Mobile display performance attributes

Display Attribute	Description
Resolution	Number of pixels in X by Y dimensions For example, 1024 x 768
Screen size	Size of image area, as measured diagonally in inches For example, 16" or 42"
Contrast ratio	Brightest color (white) over darkest color (black) of display luminance
Brightness	Luminance
Response time	Display update transition time
Uniformity	Evenness in brightness and color
Pixel or color depth	Number of bits per pixel
Color gamut	Subset of colors that can be accurately represented
Refresh rate	Number of vertical scans per second (This is different from the Frame rate, which usually refers to the number of frames the host renders to the display device per second.)
Viewing angle	Maximum angel at which the display is properly visible, in horizontal and vertical directions.

As mobile and handheld devices grow exponentially, so do mobile displays. In general mobile displays are smaller than general displays, but size is not the only thing that matters. The previous section defined performance attributes of general displays. But mobile displays have additional requirements and attributes as outlined in table 11.2.

Table 11.2 : Attributes of a mobile display

Mobile Display Attribute	Description
Low power	Critical to save battery power
Thin	Low profile mobile form factor
Lightweight	Easy to carry around
Outdoor reading	Readable even in sunlight
Durable	Robust
Bi-stability	Retains image without refreshing and even without power. This can conserve significant power for still image display.
Pixel density	High ppi (pixel per inch) is needed for short-distance viewing

Presently, we can discover fast change since the days mobile displays required just to show the number of the individual calling. When we included messaging and emails, we require more space to perceive what we'd composed. We added color to give them more intrigue. When we began including cameras to the mobile phones, we needed the display to be sharper, so that we could view the pixelated VGA photographs we'd taken. Once the capacity to keep video reached, we required them to be smooth, with great refreshing rates. In the period of touch screen cell phones, we anticipate them will be on a par with PC display, providing crisp text, dynamic pictures, obscure free video and sufficient brightness to view outdoors, all via a responsive touch screen. Typically, a wide range of choices have emerged, particularly with regards to top of the line smart phones.

We've gathered all the essential data about various mobile screens which are explained in table 11.3.

Table 11.3 : Types of mobile screens

Screen Type	Description
TFT-LCD	TFT-LCD is the most well-known kind of display screen utilized as a part of mobile phones which ranges from smart phones like the HTC Desire C to first class tablets, like the Google Nexus 7. The thin-film transistor liquid crystal display known as TFCT-LCD; and there are varieties of ways for manufacturing LCD screens. Practically speaking, low-budget mobile screens will generally show dull colors, and have narrow viewpoint angles i.e. if you see at them from off-center; it ends up noticeably thick to perceive what's on-screen. LCD screens with High quality will have radiant, perfect colors and with lucidity from pretty much any angle.

AMOLED (Active-matrix organic light-emitting diode)	AMOLED displays don't require a backdrop illumination - every pixel generates its own light - so smart phones utilizing them can possibly be slimmer. It likewise implies that a generally dark screen will utilize next to no power, and genuine blacks while playing videos, instead of the dim some LCD screens deliver. Notwithstanding, AMOLED screens have demonstrated exorbitant and hard to produce in an indistinguishable numbers from LCD, a reality that prompted the HTC Desire powered by AMOLED display; replaced with Super-LCD part of the way through its assembling life. AMOLED utilizes a fluctuated subpixel course of action to LCD, so that pictures that don't seem quite as sharp.
Super-AMOLED	Super AMOLED is extended form of AMOLED screen that really comprise of capacitive touch screen innovation i.e. it doesn't need to be laminated later. It offers expanded brightness and minimal power utilization over prior AMOLED screens.
Super-AMOLED Plus	This is another innovation initially utilized by the Samsung in their Samsung Galaxy S2 Handset. The huge change is in the subpixel development, changing to something substantially nearer to that utilized by LCD, which implied sharper, clearer pictures.
Super AMOLED HD	Super AMOLED HD is essentially a HD (720 x 1280 or higher) display innovation. In an odd move Samsung disposed of the subpixel development from super AMOLED Plus and returned rather to a standard Super AMOLED subpixel arrangement for this display, asserting that it was more dependable. It was first utilized as a part of the Samsung Galaxy Note. Obviously, the Samsung Galaxy S3 likewise has a screen of this type.
Retina display	A showcasing term brought by Apple, a Retina display is a display with a pixel thickness sufficiently high that the human eye can't make out any individual pixels at a typical review separate. As it were it's a show with no pixilation by any means. Retina show fluctuates between gadgets as it is reliant on viewpoint seeing distance. iPhone X, which would be held near the face, has 458 pixels for every inch, while an iPad pro just had 264 pixels for each inch.
Super-LCD	This is a particular sort of TFT-LCD screen, and has been broadcasted as matching AMOLED for picture quality. It gives bring down power

	utilization than most LCD advancements, yet without trading off any photo quality.
Mobile BRAVIA Engine	BRAVIA is a Sony mark and has for some time been utilized for their TVs, it remains for Best Resolution Audio Visual Integrated Architecture which. The mobile BRAVIA Engine is comprised of various picture handling advancements and is intended to enhance pictures and videos by making them more sharper and diminishing noise. It likewise intends to enhance the contrast and make more natural colors. It's but rather a screen sort a suite of post-preparing impacts which can be turned on or off. The mobile BRAVIA Engine is utilized solely in Sony handsets, for example, the Sony Xperia S.
NOVA	LG utilizes this LCD-determined screen innovation in their Optimus Black phone which offers immensely expanded shine while being highly power saver.

Table 11.4 shows resolutions of various types of mobile displays.

Table 11.4 : Resolutions of mobile displays

Mobile Phone Display Resolutions	
QVGA (240 x 320)	QVGA remains for 'Quarter Video Graphics Array'; it is generally utilized for economical phones. Its resolution is quarter the resolution of VGA. The HTC Wildfire and the Samsung Galaxy Y supports this resolution.
WQVGA	WQVGA is characterized as the display that has similar height from QVGA (240) however a more prominent width. The "W" here stands for wide. The Sony Ericsson Aino has a WQVGA resolution of 240x432.
HVGA (320 x 480)	The "H" here stands for "Half" or 'half size' VGA. It alludes to a modest bunch of resolutions, yet the most well-known one is 320 x 480, which is 1/2 the size of VGA. The iPhone 3GS has a resolution of 320 x 480 thus too does the HTC Wildfire S.
nHD (360 x 640)	This resolution is not ordinarily utilized by phones, but rather can be seen on the Nokia N97 or the later Nokia 808 PureView.
WVGA	It remains for "Wider" VGA (Video Graphics Array) and alludes to any display with a height of 480 pixels however a width more prominent than 640 pixels. The most widely recognized WVGA resolution is 480 x 800 and this can be found on heaps of smart phones like Samsung Galaxy S2, Nokia Lumia 900 and so on.

FWVGA (480 x 854)	FWVGA remains for 'Full Wide' VGA and not at all like WVGA it doesn't require to be trimmed to deliver an aspect ratio of 16:9.This resolution can be found on the Sony Ericsson Xperia Arc S.
qHD (540 x 960)	The "q" here stands for One fourth of a full HD outline; these sorts of high-resolution displays are being utilized by smart phones as screens are getting bigger and bigger in size. The HTC Sensation is an ideal case of this kind of resolution in action.
DVGA (640 x 960)	The "D" here stands for Double VGA, this is a high resolution for phones and is utilized by the iPhone 4 and iPhone 4S and is named Retina display by Apple. This stands for 'Extended Graphics Array' and isn't generally utilized as a part of phones; however the forthcoming LG Optimus Vu has a XGA display.
HD (720 x 1280)	HD remains for high definition resolution which is alluded to as 720p. It is most strikingly utilized by the Samsung Galaxy S3 and HTC One X.
WXGA	The "W" here stands for 'Wide Extended Graphics Array', this, as you may have speculated, is an enlarged XGA resolution. Various resolutions fall under the WXGA flag, yet the main smart phone to at present have a resolution this high is the Samsung Galaxy Note, which has a 800 x 1280 display.

Apple utilizes high pixels per inch count for its display, instead of a specific innovation, though Sony Ericsson's Reality display with mobile Bravia screen utilizes for software enhancements to the video to get great outcomes. In both circumstances, it is really the LCD innovation powering things. On the off chance that you might want to watch motion pictures and play games on your phone then AMOLED may be the better decision as it offers the tremendously better contrast ratio compared to LCD. In the event that web browsing and working on a file is more, LCD will be better as it offers somewhat crisper content and make it easier to read text.

11.3 CAMERA

A camera is an optical instrument for recording or capturing images, which may be stored locally, transmitted to another location, or both. A camera phone is a mobile phone which is able to capture photographs and often record video using one or more built-in digital cameras. Sharp Corporation brought the first camera phone J-SH04 in the commercial market. The camera phone J-SH04 had built-in CCD sensor, with the Sha-Mail (Picture-Mail in Japanese) infrastructure developed in collaboration with Kahn's LightSurf venture, and marketed from 2001 by J-Phone in Japan today owned by Softbank. Initials phones were equipped with Internet connectivity, working web browsers and email-programs but the phone menu offered no way of including a photo in an email or uploading it to a web site. Modern smart phones have almost unlimited connectivity and transfer options with photograph attachment features. During 2003 as camera phones were gaining popularity in Europe some phones without cameras had support for MMS and

external cameras that could be connected with a small cable or directly to the data port at the base of the phone. The external cameras were comparable in quality to those fitted on regular camera phones at the time, typically offering VGA resolution. In 2013-2014 Sony and other manufacturers announced add-on camera modules for smart phones called lens-style cameras which can be mounted to an Android or iOS phone or tablet and use its display and controls.

Now a days, Camera in a mobile phone is very much common. You can easily find mobile phones which are coming up with in-built camera. It let users to take decent quality photographs and record a video; they are quite simpler than any digital camera. In most of the smart phones; you'll discover a menu to begin a camera application and an on-screen button to empower the shutter. For convenience, some of phones have a specific camera button. You can likewise discover phones which are particularly intended to resemble separate low-end digital compact cameras in appearance and to some degree in features and image quality, and are marked as both mobile phones and cameras. The fundamental advantage of camera phone is cost and portability; to be sure for a user who carries a mobile phone anyway, the expansion is irrelevant. smart phones with camera may run mobile applications to include abilities, for example, geotagging and picture stitching. Also the touch screen in smart phones can be used to direct their camera to focus on a specific object in the field of view; in any case, the touch screen, being a universally useful control, does not have specific camera's buttons and dial. Most of the camera phones use CMOS (complementary metal-oxide-semiconductor) image sensors, due to largely reduced power consumption compared to CCD (Charge Coupled Device) type cameras, which are also used, but in few camera phones. Some of the camera phones even use more expensive Back Side Illuminated CMOS which uses energy lesser than CMOS, although more expensive than CMOS and CCD. In smart phones, cameras are used as input devices in various research projects and commercial applications. The use of QR Codes attached to physical objects is a commercially successful example of camera in smart phones. Camera senses the QR Code and provides an according link to related digital content, usually a URL. Another approach is using camera images to recognize objects. The recognition of physical objects such as advertisement posters to provide information about the object can be done via content-based image analysis. Hybrid approaches use a combination of unobtrusive visual markers and image analysis. Some of the smart phones can provide an augmented reality overlay for 2D objects and to recognize multiple objects on the phone using a stripped down object recognition algorithm as well as using GPS(Global Positioning System) and compass. A few can translate text from a foreign language. Geotagging (also written as GeoTagging) is the process of adding geographical identification metadata to various media such as a geotagged photograph or video, websites, SMS messages, QR Codes[1] or RSS feeds and is a form of geospatial metadata. This data usually consists of latitude and longitude coordinates, though they can also include altitude, bearing, distance, accuracy data, and place names, and perhaps a time stamp.

Auto-geotagging can show the location where a picture is taken. Front camera (of lesser performance as compared to rear camera) of smart phones can be used for purposes like self-portraiture (selfie) and videoconferencing.

In Android phones, camera applications can be started by touching the Camera app icon as shown in figure 11.1.

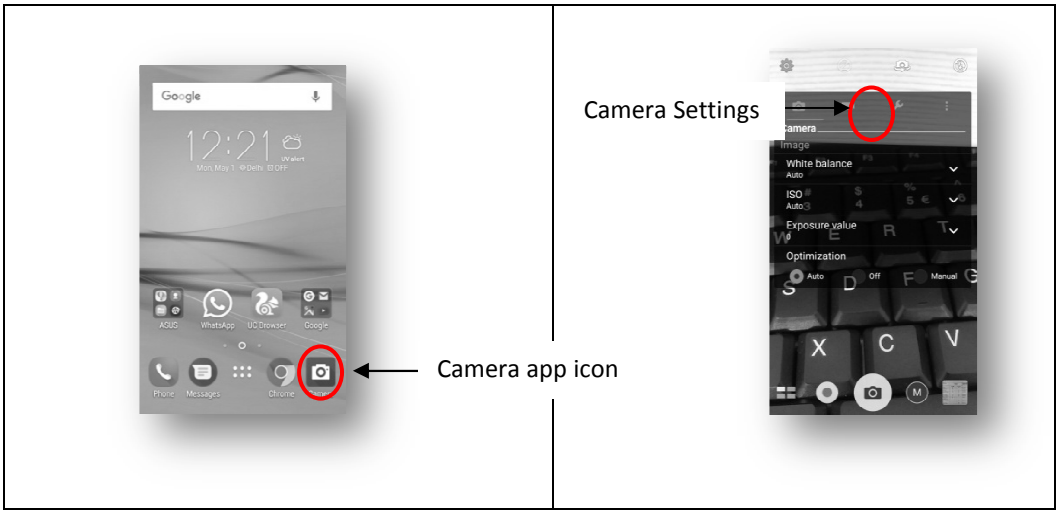

Figure 11.1: Camera app icon and settings

Over the years, camera phone technology has progressed a lot, the design of lens has evolved from a Cooke triplet or simple double Gauss to many molded plastic aspheric lens elements formed with varying dispersion and refractive indexes. The current generation of phone cameras also applies distortion (optics), vignetting, and various optical aberration corrections to the image before it is compressed into a .jpeg format. Most camera phones have a digital zoom feature. A few have optical zoom. An external camera can be added, coupled wirelessly to the phone by Wi-Fi. Images are usually saved in the JPEG file format, except for some high-end camera phones which have also RAW feature and the Android 5.0 Lollipop has facility of it. Microsoft Windows Phones can be configured to use as a camera even if the phone is asleep. An external flash can be employed, to improve performance. By default, phones stores videos and pictures in a folder called /DCIM. Storage can be changed to external memory.

11.4 SPEAKERS

Computer speakers, or multimedia speakers, are speakers sold for use with computers, although usually capable of other audio uses. Most of the speakers have built-in amplifier and simultaneously require a power supply, which may be by a primary power supply, USB port or batteries.

Wireless Bluetooth speakers need no physical connections at all as they are battery-powered. A wireless speaker receives audio signals using radio frequency (RF) waves rather than over audio cables. We can categorize speakers into following two types:

- Active Speakers
- Passive Speakers

11.4.1 Active Speakers

The crossover components in an active speaker which splits the frequency band of the sound signal into smaller parts which are then sent to individual speaker

drivers configured to handle those frequencies. These speakers are, themselves "powered." This is why active and powered are often used synonymously.

Active speakers are suitable for home entertainment and home theater solutions. In larger home theater settings, the crossover components and amps can be outside of the speaker. Active speaker system refers to active crossover and two or three separate amplifiers for the separate drivers. According to Bart LoPiccolo, National sales manager for Genelec, Inc., Genelec's speakers are active because, "they have active electronic crossovers before the amps, they have dedicated amps for each driver, each channel has protection, and there are room response controls per driver." Active speaker proponents like LoPiccolo believe that an active speaker system has certain advantages over a passive system due to the fact that the crossover components, amps, drivers, and speaker enclosures are all manufactured with one another in mind.

11.4.2 Passive Speakers

In comparison to the active speaker, passive speakers have following features:

- Here crossover components splits the audio signal and send each band directly to the loudspeaker drivers
- A separate individual amp is used for driving the signals
- Here components are typically consists of capacitors, resistors and inductors which splits the signal and send each frequency part to the drivers
- a separate power amplifier sends the full audio signal to the speaker

Passive Speaker user has the freedom to upgrade the amplifier, or swap it out at any time, where in an active speaker scenario the amps are part of the speaker package i.e. what you hear is what you get, generally speaking. But, the producers of amplifiers don't know what speaker system will be matched with their product, which is why amplifiers are over-built to accommodate a wide range of speakers, a step that results in extra expensive and more power consuming amplifiers.

A powered speaker is technically one that has its own in-built amplifier, and therefore plugs into a nearby power outlet. However, a powered speaker is not essentially an active one, as the crossover components within a powered speaker may be passive. Powered speaker systems have the edge of being a bit more compact, streamlined and portable—most of the speaker systems are designed for desktop home computers, laptops, single-room application, wireless multi-room application (like Sonos), and easy all-in-one iPod-docking-and-speaker-solution fall into the "powered" speaker category. In reality, a powered speaker can still have the "amp-passive crossover-driver" chain feature of any passive speaker scenario. According to Logan Pabor, Distribution Manager at Audioengine, "Powered speakers can cut costs, and reduce clutter," The built-in amplifier characteristic of a powered speaker, enables wireless speaker scenarios, and eliminates the requirement for extra, expensive components.

It will be a big debate, if we try to find out one technology as superior over another in the active vs. passive speaker vs. powered or unpowered speaker. Every system has some pros and cons, and ways of perfecting (as nearly as possible) one system to "match" the performance of another. The mobile market for audio products is expanding, creating freedom for sound designers,

content providers, and record companies. Due to an insatiable driven consumer demand, audio technologies for mobile devices are being developed and deployed at a spectacular rate. The feature to personify cell phones with audio (particularly in the form of ringtones) is a great motivational factor for consumers to spend money, which generates extra revenue options for carriers eager to recoup their massive infrastructure investments. However, the plethora of file formats and operating systems makes audio content creation and delivery a difficult and inefficient proposition. Content providers have to maintain multiple catalogs in different formats and resolutions. Game audio designers and programmers must either re-invent the wheel for each mobile title, or forgo complex interactive soundtracks altogether. Although Java-based systems attempt to address some of these problems, audio is still severely limited by limited bandwidth constraints and cross-platform incompatibilities. The ultimate quality of any sound system depends upon the speakers.

In android phones, sound/audio can be configured though settings menu as shown in figure 11.2.

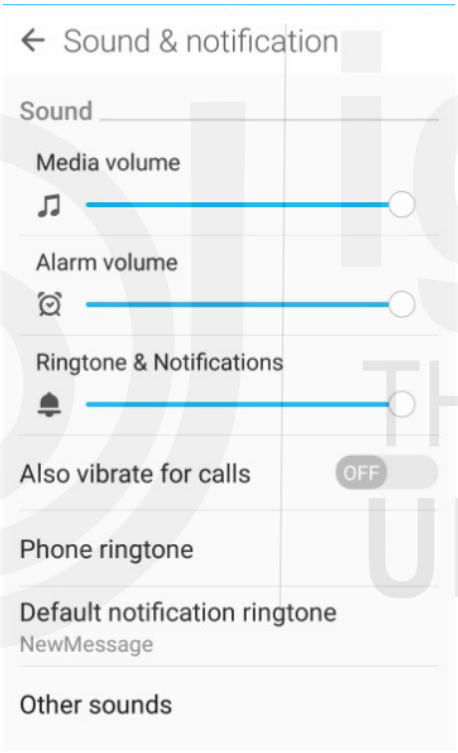

Figure 11.2 : Audio settings in an Android phone

11.5 MIC

A microphone, colloquially nicknamed mic or mike is a transducer that converts sound into an electrical signal. Numerous applications utilizes microphones, for example, phones, amplifiers, open address systems for show corridors and open occasions, movie generation, live and recorded sound designing, sound recording, two-way radios, TV broadcasting, and in PCs for recording voice, speech recognition, VoIP, and for non-hearing reasons, for example, ultrasonic sensors or knock sensors. There are a few unique sorts of microphones which are utilized to employ distinctive ways to deal with change over the air pressure deviations of a sound wave to an electrical signal. The

dynamic microphones are most regular as they uses a coil of wire suspended in an attractive field; the vibrating diaphragm is utilized by the condenser microphone as a capacitor plate, and the piezoelectric microphone, that uses a precious stone of piezoelectric material. Sound is an amazing thing. All of the different noises we hear are caused by minute pressure differences in the air around us. Amazing fact about it is that the air disseminates those pressure changes so well -- and so accurately -- over relatively long distances.

The First microphone was a metal diaphragm attached to a needle, and this needle scratched a pattern onto a piece of metal foil. The pressure in the air; is noticeable all around that happened when somebody talked toward the diaphragm moved the diaphragm, which moved the needle, which then recorded on the foil. At the point when the needle was later keep running back over the foil, the vibrations scratched on the foil would then move the diaphragm and re-make the sound. The fact that this purely mechanical system works shows how much energy the vibrations in the air can have. All the latest microphones are trying to achieve the equivalent thing as the original, but do it electronically rather than mechanically. A microphone wants to take varying pressure waves in the air and convert them into varying electrical signals. Table 11.5 describes various types of mics, including one of the first invented by Alexander Graham Bell.

Table 11.5: Types of Microphones

Microphone	Description
Liquid Microphones	It is imagined by Alexander Graham Bell and Thomas Watson, were among the principal working microphones to be designed, and they were an antecedent to what might later turn into the condenser microphones. The underlying fluid microphones designed utilizing a metal glass loaded with sulfuric acid and water. A diaphragm was set over the container with a needle on the getting side of the diaphragm. Sound waves would make the needle move in the water. A little electrical current raced to the needle, which was tweaked by sound vibrations. The fluid microphone was not at all a particular working gadget; however it shapes a huge analysis.
Carbon Microphones	It uses carbon dust technology which is used in the first telephones and is still used in some telephones today. The carbon dust has a thin metal or plastic diaphragm on one side. When sound waves hit the diaphragm, they shrink the carbon dust, which transforms its resistance. By running a current through the carbon, the changing resistance changes the amount of current that flows.
Fiber-Optic Microphone	Fiber-Optic Microphone uses super-thin strands of glass to disseminate message instead of traditional metal wires. Unlike conventional microphones, which are often big and transmit an electrical signal, fiber optic microphones can be extremely small, and they can be used in electrically sensitive environments. Also they can be produced with no metal, which makes them very

	fruitful in magnetic resonance imaging (MRI) applications and other situations where radio frequency interference is a problem.
Dynamic microphone	It takes edge of electromagnet effects. When a magnet moves past a wire (or coil of wire), the magnet activates current to discharge in the wire. Diaphragm in a dynamic microphone moves either a magnet or a coil when sound waves hit the diaphragm, and the movement generates a small current.
Electret microphones	They are the most widely used microphones in the consumer market as they're cheap and relatively simple. They are used in cell phones, computers and hands-free headsets. It is a type of condenser microphone where outside charge is replaced with an electret material which is known as permanent state of electric polarization.
Ribbon Microphone	It is a thin ribbon usually aluminum, duraluminum or nanofilm which is suspended in a magnetic field. Sound waves move the ribbon that changes the current flowing through it. They are bidirectional as they pick up sounds from both sides of the mic. The first ribbon microphone was RCA PB-31 which was produced in 1931, and brought the change in the audio and broadcasting industries as it set a new standard when it came to clarity.
Laser Microphone	It uses a laser beam to identify sound vibrations in a remote object. From window, the laser beam is directed into the room which reflects off the object and returns to a receiver (e.g. a solar panel) which converts the beam to an audio signal. The beam may also be bounced off the window itself. According to recent research, a new type of laser microphone which operates by streaming smoke across a laser beam which is intended at photocell, and then converted to an audio signal.
Condenser Microphone	Condenser microphone uses one plate of the capacitor which moves in response to sound waves. The movement changes the capacitance of the capacitor, and these changes are amplified to create a measurable signal. Usually, condenser microphones required a small power battery to deliver a voltage across the capacitor.
Cardioid Microphone	Cardioid microphone is used to record sound which is located in front of and on the sides of the microphone but not behind it. A polar plot of the gain for cardioid is heart-shaped (hence the name), with the highest sensitivity located directly in front of the mic, and slightly less on the sides. Cardioid microphones are suitable for recording live performances without capturing too much crowd noise. There are many

	handheld microphones used to amplify vocals are cardioid microphones.
Crystal Microphones	It uses a thin strip of piezoelectric material which is attached to a diaphragm. When the crystal is deflected by the diaphragm, the two sides of the crystal acquire opposite charges, which are proportional to the amount of deformation and disappear when the stress on the crystal disappears.

Check Your Progress

1) AMOLED stands for _____ .

2) _____ is the process of adding geographical identification metadata to various media such as a geotagged photograph or video, websites, SMS messages, QR Codes or RSS feeds and is a form of geospatial metadata.

3) A _____ is a mobile phone which is able to capture photographs and often record video using one or more built-in digital cameras.

4) Most of the speakers have _____.

5) A microphone, colloquially nicknamed mic or mike is a transducer that converts _____ into _____.

11.6 SUMMARY

An input/output (I/O) gadget is characterized as the equipment gadget which has the ability to take inputted, outputted or other prepared information. Additionally it can procure separate media information as info sent to smart phone or send mobile information to storage media as storage output. Input gadgets give input to a mobile, while output gadgets give a route to a mobile to output information for communication with users or other mobile. An I/O gadget is a gadget with both functionalities. Thus, I/O gadget information is bi-directional; such gadgets are typically arranged under storage or communications. Some of cases of I/O storage gadgets are MMC/SD Cards; USB streak drives and so forth. Thus, a portion of the cases of communication I/O gadgets are network connectors, Bluetooth connectors/dongles and modems.

11.7 SOLUTIONS/ANSWERS

1) Active Matrix Organic Light Emitting Diode
2) Geotagging
3) Camera phone
4) Built in amplifier
5) Sound, electric signal

11.8 FURTHER READINGS

- http://www.bestartech.com/base_mount.html
- http://www.voicecouncil.com/vcs-brief-guide-mic-pick-up-patterns/
- https://www.howstuffworks.com/
- https://en.wikipedia.org/wiki/Geotagging
- https://en.wikipedia.org/wiki/Camera
- https://en.wikipedia.org/wiki/Camera_phone
- https://en.wikipedia.org/wiki/Computer_speakers
- https://en.wikipedia.org/wiki/Microphone
- https://en.wikipedia.org/wiki/Display
- https://en.wikipedia.org/wiki/Display_device