CHAPTER TWO
INTEGRATED CIRCUITS

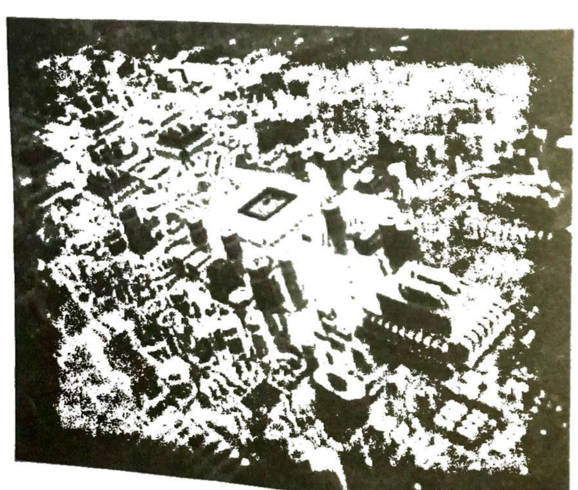
2-0 INTRODUCTION

In <u>theoretical computer science</u>, a **circuit** is a <u>model of computation</u> in which input values proceed through a sequence of gates, each of which computes a <u>function</u>. Circuits of this kind provide a generalization of <u>Boolean circuits</u> and a mathematical model for <u>digital logic</u> circuits. Circuits are defined by the gates they contain and the values the gates can produce. For example, the values in a Boolean circuit are <u>boolean</u> values, and the circuit includes <u>conjunction</u>, <u>disjunction</u>, and <u>negation</u> gates. The values in an <u>integer circuit</u> are <u>sets</u> of <u>integers</u> and the gates compute <u>set union</u>, <u>set intersection</u>, and <u>set complement</u>, as well as the <u>arithmetic operations</u> <u>addition</u> and <u>multiplication</u>.

Computer circuit - a circuit that is part of a computer. logic gate, gate - a computer circuit with several inputs but only one output that can be activated by particular combinations of inputs

integrated circuit, microcircuit - a microelectronic computer circuit incorporated into a chip or semiconductor; a whole system rather than a single component.

Computer circuitry, complete path or combination of interconnected paths for electron flow in a computer. Computer circuits are binary in concept, having only two possible states. A computer's speed of operation depends on the design of its circuitry.



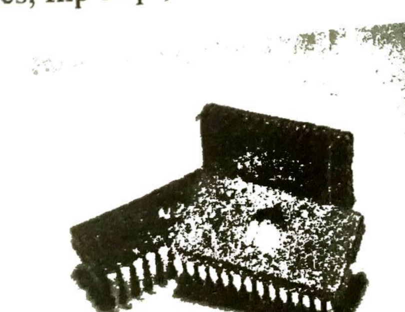
2.1 Circuit

In electronics, a circuit is a closed path that allows electricity to flow from one point to another. It may include various electrical components, such as transistors, resistors, and capacitors, but the flow is unimpeded by a gap or break in the circuit.

In computing, the term "circuit" is used more liberally and may be used to reference a circuit board or an **integrated circuit**. The internal workings of computers and other electronic devices are comprised of these components, which may each contain hundreds or thousands of individual circuits. The large number of circuits inside computers allow them to route data to different locations and perform complex calculations. For example, a chip may route graphics operations to the GPU and other operations to the CPU. These processors contain logic gates that can rapidly open and close circuits. Modern processors have so many circuits and transistors, they can perform billions of instructions every second.

2.2 Integrated Circuits

An integrated circuit (IC) is a small <u>electrical circuit</u> created using a <u>semiconductor</u> substance, such as <u>silicon</u>. An integrated circuit is also known as a chip or microchip. A integrated circuit is built with the primary objective of embedding as many transistors as possible on a single semiconductor chip with numbers reaching in the billions as of 2012. IC chips are found in nearly every modern electronic device, and allow compact technologies including computers and cell phones to be built. Integrated circuits can be classified into **analog, digital and mixed signal**, consisting of analog and digital signaling on the same IC. Digital integrated circuits can contain billions of logic gates, flip-flops, multiplexers, and other circuits in a few square millimeters.



Different Types of Integrated Circuits

- Integrated Circuits.
- Different Types of ICS.
- Digital Integrated Circuits.
- Analog Integrated Circuits.
- Mixed Integrated Circuits.
- Logic Circuits.
- Comparators.
- Switching ICs.

Below is the classification of different types of ICs basis on their chip size.

- SSI: Small scale integration. 3 – 30 gates per chip.
- MSI: Medium scale integration. 30 – 300 gates per chip.
- LSI: Large scale integration. 300 – 3,000 gates per chip.
- VLSI: Very large scale integration. More than 3,000 gates per chip.

2.2.1 Types of Integrated Circuits

There are five major types of integrated circuits.

A dynamic random access memory chip (DRAM) is a type of integrated circuit that is essential for modern computers. Most personal computers and laptops contain at least one DRAM integrated circuit, and many computers hold several. A DRAM circuit is able to store digital data while power is present. If power is cut, the information stored in the memory circuit is lost. DRAM integrated circuits commonly hold temporary computer information, such as words typed on a screen or data from a streaming video.

Microprocessor units (MPUs) are a type of integrated circuit that act as the central processing area for a computer or other device. A microprocessor circuit is usually programmed with instructions that cannot be easily deleted, even if power is lost. These core instructions allow a device to perform properly when various inputs are received. Devices such as cell phones use microprocessors to execute important tasks such as connecting to a cellular network, while

computers use microprocessor instructions to boot up and interface properly with attached hardware.

Another type of integrated circuit is the **application specific integrated circuit**, or ASIC. True to their name, an ASIC circuit contains digital instructions that are specifically customized to a certain purpose. ASICs contain essential programs and are similar to microprocessors, but are more specialized and limited than the chips used in computers. These types of integrated circuits are often used in single-purpose devices such as printers and car air bag units.

The **digital signal processor** (DSP) type of integrated circuit is specifically designed to process or interpret electronic signals. These circuits typically convert analog inputs into digital format, and filter out any signal that is not within a preset range. Signal processor microchips are common in audio devices such as cell phones and radios.

Programmable memory chips (EPROMs) are integrated circuits that are able to retain programs even if power is lost. Unlike ASICs or microprocessors, EPROM memory often receives programming only a single time, and keeps this single program for its entire use without any receiving any updates. Programmable memory circuits usually contain simple instructions for devices such as video games or handheld electronics.

2.2.2 Uses Of Integrated Circuits

Jack Kilby, a researcher at Texas Instruments in the United States, is credited with being one of the first people to see the potential benefits and uses of integrated circuits.

They are found in every electronic device that has some type of microprocessor control, from cell phones and portable music players to gaming systems, personal computers, and other digital devices. This is because an integrated circuit (IC) or chip by contemporary 21st century standards is an extremely sophisticated device, packing up to millions of electronic components like transistors, resistors, and capacitors into an area of a few square centimeters on a wafer of silicon.

The enormous leap that the IC chip gave to electronic circuit design is based on a limitation that electronics manufacturers were facing during the late 1950s. The transistor had replaced vacuum tubes, but basic electrical components for circuits like transistors, capacitors, and resistors could only be made so small, as holding them with a tweezers and soldering them onto a circuit board was becoming increasingly difficult as they became smaller and smaller.

While the very first integrated circuits were referred to as **small-scale integration** (SSI) circuits and contained only a few dozen components, they were vital to aerospace projects By 1968, uses of integrated circuits had begun to spread to consumer electronics, with their ability to process frequency modulated (FM) sound in televisions.

As the number of components that could be placed on a chip was scaled up, the uses of integrated circuits became much more widespread. **Medium-scale integration** (MSI) chip models contained hundreds of components by the end of the 1960s, and **large-scale integration** (LSI) could put multiple thousands of components on one chip five years later. From there, the growth of how many components could be packed into an area of a few square centimeters increased exponentially. **Very-large-scale integration** (VLSI) allowing for hundreds of thousands of connected components in the early 1980s, and three-dimensional integrated circuit (3D-IC) designs as of 2011 allow for millions or billions of components to be packed into a network that is interconnected both horizontally and vertically on multiple layers of semiconductor wafer.

As of 2011, the multiple control and mathematical processing functions that an integrated circuit can perform has made them ubiquitous devices in most consumer electronics from radios and televisions to calculators and digital watches. The uses of integrated circuits are widespread throughout industrial plants and in robotics, as well as for controls in automobile and aircraft systems. As they become more sophisticated and inexpensive to manufacture, they are also found in disposable items such as greeting cards that play music. Radio-frequency identification (RFID) tags on disposable consumer product packaging that retail stores use to track inventory are also a common location for IC chips, with RFID tags being added to other products like passports and credit cards as well.

2.2.3 Integrated Circuit Fabrication

Integrated circuit fabrication involves a process of creating very thin surface layers of semiconducting material atop a substrate layer, usually

made out of silicon, that can be chemically altered at the atomic level to create the functionality of various types of circuit components, including transistors, capacitors, resistors, and diodes. It is an advance over previous circuitry designs where individual components of resistors, transistors, and more were hand-attached to a connecting breadboard to form complex circuitry. An integrated circuit fabrication process works with components that are so small that billions of them can be created in an area of a few square centimeters as of 2011, through various photo lithography and etching processes in a microchip fabrication facility.

2.2.4 Functions of an Integrated Circuit

The function of an integrated circuit (IC) is to be a single component that can perform high-level tasks such as amplification, signal processing, or even sophisticated digital calculations as in the case of microprocessors. Also, the function of an integrated circuit includes miniaturization, cost reduction, and performance enhancement among others.

In terms of ***cost reduction***, the function of an integrated circuit is to provide a relatively cheap alternative to gathering a huge amount of semiconductor parts and electrical parts, and mounting on a circuit board and soldered.

The ***performance enhancement*** function of an integrated circuit is made possible by the specialized circuit implementation inside the chip. Several radio frequency applications were too expensive to implement as discrete components. When there was a high demand for a specific feature, the semiconductor industry finds a way to get funding and builds ICs for special applications. Another performance enhancement is the lowered power consumption for the same results, which brings higher power efficiency.

There are several ICs and even several microcomputers right inside computers, cell phones, and other digital devices. In a hand-held gaming gadget, there is a graphics processor that drives the colored screen. This processor is usually a large-scale integration (LSI) chip with its own miniaturized and super low-power digital processing system. Another computer – the main computer – handles the task of running user applications.

The trend in electronics has always been to ***miniaturize circuits***, while the bottom-line costs are low. Any popular equipment will usually justify the amount of resources spent in conceptualizing, designing, and implementing new integrated circuits meant to optimize the manufacture of products.

There are standard ICs that work as amplifiers, power regulators, and simple signal processors. These ICs usually range from 8-pin to about 16-pin packages. Bigger chips are used mostly for complex digital applications such as customized or application-specific IC (ASIC), which can contain an entire microcomputer for all kinds of applications in telecommunications, automation, and power control.

2.2.5 Generations of Integrated Circuits

According to their design assembly, integrated circuits have undergone several generations of advancements and developments such as:

- Small Scale Integration (SSI): Ten to hundreds of transistors per chip
- Medium Scale Integration (MSI): Hundreds to thousands of transistors per chip
- Large Scale Integration (LSI): Thousands to several hundred thousand transistors per chip
- Very Large Scale Integration (VLSI): Up to 1 million transistors per chip
- Ultra Large Scale Integration (ULSI): This represents a modern IC with millions and billions of transistors per chip

An IC can be further classified as being digital, analog or a combination of both. The most common example of a modern IC is the computer processor, which consists of billions of fabricated transistors, logic gates and other digital circuitry.

2.2.5.1 Small-scale Integration

Integration in which a complete major subsystem or system is fabricated on a single integrated-circuit chip that contains integrated circuits which have appreciably less complexity than for medium-scale integration.

2.2.5.2 Medium-Scale Integration (MSI)

Medium-scale integration is the process of embedding hundreds of transistors in one integrated circuit or microchip.

Medium-scale integration was developed in the early days of mainframe computers. In conventional microchip design, it has been replaced by successive integration methods such as large-scale integration, ultra-large-scale integration (USI) and very large scale integration (VLSI), as the ability to increase the number of transistors in integrated circuits improved. An IT theory known as Moore's Law has largely held out during the past two decades, showing that the number of transistors embedded in a single individual circuit has approximately doubled each year. With current technologies, engineers can embed billions of transistors in an integrated circuit.

Although medium-scale integration has been replaced by other methods for the regular creation of microchips, recent news shows that engineers have been using carbon nanotube methods to develop new kinds of microchips on a medium-scale integration level.

2.2.5.3 Large-Scale Integration (LSI)

Large-scale integration (LSI) is the process of integrating or embedding thousands of transistors on a single silicon semiconductor microchip. LSI is no longer in use. LSI defines the technology used to build powerful microchips or integrated circuits (IC) in a very small form factor. LSI technology was conceived in the mid-1970s when computer processor microchips were under development.

It succeeded small-scale integration (SSI) and medium-scale integration (MSI), which included tens to hundreds of transistors per microchip. LSI consists of thousands of transistors that are closely embedded and integrated with a very small microchip. One of the first components built on LSI technology was 1-K bit RAM, which contained 4,000 transistors. Later components and microprocessors held up to 10,000 embedded transistors.

2.2.5.4 Very Large-Scale Integration (VLSI)

Very large-scale integration (VLSI) is the process of integrating or embedding hundreds of thousands of transistors on a single silicon semiconductor microchip. VLSI technology was conceived in the late 1970s when advanced level computer processor microchips were under development. VLSI is a successor to large-scale integration (LSI), medium-scale integration (MSI) and small-scale integration (SSI) technologies

VLSI is one of the most widely used technologies for microchip processors, integrated circuits (IC) and component designing. It was initially designed to support hundreds of thousands of transistor gates on a microchip which, as of 2012, exceeded several billion. All of these transistors are remarkably integrated and embedded within a microchip that has shrunk over time but still has the capacity to hold enormous amounts of transistors. The first 1 mega byte RAM was built on top of VLSI design principles and included more than one million transistors on its microchip dye.

2.2.5.5 Ultra Large-Scale Integration (ULSI)

Ultra large-scale integration (ULSI) is the process of integrating or embedding millions of transistors on a single silicon semiconductor microchip. ULSI technology was conceived during the late 1980s when superior computer processor microchips, specifically for the Intel 8086 series, were under development. ULSI is a successor to large-scale integration (LSI) and very large-scale integration (VLSI) technologies but is in the same category as VLSI.

ULSI was designed to provide the greatest possible computational power from the smallest form factor of microchip or microprocessor dye. This was achieved by embedding and integrating integrated circuits (IC), which were formed with transistors and logic gates. The close placement and design architecture enabled faster resolution of tasks and processes. However, even though VLSI now contains more than millions of

transistors, any IC or microchip with more than one million transistors is considered a ULSI implementation. Intel 486 and the Pentium series of processors were built on ULSI principles.

2.3 Forms of Integrated Circuit

2.3.1 Analog Integrated Circuit

An analog integrated circuit (IC) is a basic component in most electronic devices, the most basic circuit that is a part of a larger electronic circuit. An analog integrated circuit will be made up of semiconductors, inductors, capacitors, and resistors. An analog integrated circuit involves an output signal that follows a continuous input signal.
Examples of analog integrated circuits are operational amplifiers, power management circuits, and sensors; the most well-known and long-lived analog integrated circuits are the 741 operational amplifier and the 555 timer. An analog integrated circuit is what makes computers, cell phones, and digital devices work, and it can be found inside almost every consumer electronics available to mankind today. It is still used when there is a need for higher power applications and wideband signals that need sampling rate requirements, and for user interface with a transducer.

2.3.2 Digital Integrated Circuit

A digital integrated circuit (IC) is a highly miniaturized electronic circuit, operating on individual voltage levels, fitted into a small package. It commonly operates with low-voltage direct current (DC) power supplies. Typical supply voltages are 5 and 3.3 volts (V). Earlier digital integrated circuits worked on 12 V power supplies.

Different types of semiconductors, resistors, and capacitors are used in the digital integrated circuit. The simplest digital integrated circuit could be a 14-pin dual-in-line package chip or microchip that has six built-in digital inverters. Each inverter uses a single pin for input and a single pin for output. The inverter outputs a "high" when a "low" is fed into the input, but when a "high" is fed into the input the output is "low." This is why it is called an inverter.

In electronics, computers, cell phones, and digital devices, there are so many types of digital integrated circuits that perform all kinds of functions including mathematical calculations using the binary number system. In an 8-bit microcomputer, a set of 8 bits is referred to as a byte. Each byte can represent a number from 0 to 255, or it can represent –128 to +127. In certain modes of computation known as the binary-coded decimal, the byte can represent a number from 00 to 99.

The digital integrated circuit, operating on digital levels, can distinguish the digital equivalent of analog signals by using a converter. The analog-to-digital (A/D) converter is a combined analog and digital circuit that inputs an analog level and outputs a multi-bit digital equivalent of the analog sample.

There are many circuits and equipment used in digital electronics. The microprocessor uses registers, which are sets of digital latches that retain a single bit. For memory applications, the density of semiconductors in memory chips has increased to contain more than just a few tens of gigabytes per square inch.

2.3.3. Application-Specific Integrated Circuit

An application-specific integrated circuit (ASIC) is a compactly packaged electronic circuit intended to simplify the overall circuit design. In some cases it also prevents reverse engineering of an existing product. For instance, many products use a single special-purpose chip to control the product. Almost all gadgets, like computers, cell phones, and other digital devices will be using at least one ASIC. This circuit differs significantly from a general-purpose integrated circuit (IC). The application-specific integrated circuit is often used in complex circuit applications. For instance, in the personal computer with a simple graphics adapter card, it may not be possible to successfully install a graphic-intensive game.

In data communications, the application-specific integrated circuit can be used in computers, hubs, switches, and routers. The network interface card (NIC) uses a customized chip, an ASIC that handles the physical and data link layer requirements of the local network segment. The ASIC in the NIC is responsible for the physical behavior of the NIC.

2.3.4 Integrated Circuit Amplifier

An integrated circuit amplifier is a compactly packaged collection of active and passive devices that may boost the voltage or current level of a signal. The active components are transistors, three-terminal semiconductor devices that are capable of current gain, wherein a small change in current produces a pro-rated change in the integrated circuit amplifier output. Discreet electronic circuits, which use separate transistors, resistors, and capacitors, were the earliest prototype of the integrated circuit. The integrated circuit amplifier or chip amplifier or microchip amplifier was the result of the attempt to reduce the weight and space requirements of fixed and portable electronic gadgets and equipment. Home computers that have sound cards with integrated circuit amplifiers that amplify sound are very popular in multimedia applications. The integrated circuit amplifier accepts the output from the digital-to-analog converter. This output is fed into another integrated circuit amplifier until the power level is enough to drive a speaker. In the opposite direction, when a microphone is used, the small signal from a microphone is amplified, or boosted, into a level sufficient to be detected by an analog-to-digital converter. Various electronic devices, such as cell phones, and digital devices, such as computers, use many types of integrated circuit amplifiers. There are even integrated circuit amplifiers that operate in the radio frequency (RF) band besides the audio frequency band.

Special features have been added for the integrated circuit amplifier. For battery operation, it may be useful to place an amplifier on standby, thus reducing power consumption in devices such as two-way radios used in rescue operations. Other features include audio noise cancellation that ensures voice messages are easily understood under adverse conditions.

2.3.5 Optical Integrated Circuit

An optical integrated circuit (IC) is a compactly packaged electronic circuit, chip, or microchip that processes light directly to perform various communication functions. The advantages in using an optical integrated circuit include the higher maximum data speed that can be sent over an optical link as compared to other means and the freedom from damage due to natural and man-made interference and transient energies. These energies include electromagnetic emissions and electrostatic discharge from clouds observed as lightning and seen as electromagnetic pulse (EMP) by electrical and electronic circuits.

The optical integrated circuit uses various types of electronics components such as semiconductors that act as optical sources, optical modulators, and optical detectors. The intensity of light from an optical source can be controlled to carry the message to the far end of an optical cable.

Systems that support communications via cell phones use various digital broadband communications equipment, which may be wire, wireless, or fiber based. The optical integrated circuit is usually used for fiber-based communications that make use of either single-mode or multi-mode fibers. Instead of a single optical signal, multi-mode fibers use two or more optical signals on the same optical fiber. Optical fibers are actually made up of a slightly flexible glass material that allows light to pass through with very little loss. This characteristic makes optical fiber communications ideal for long spans of cable, in many controlled locations.

The optical integrated circuit is used for data communications equipment for computers and other digital devices. For data rates up to a few hundred million bits per second (mbps), wire and wireless means of communications may be practical, but for higher speeds communication between nodes is more practical with high-speed optical data communications. The bit error rate (BER) for optical fiber links is the lowest among the possible options available.

Wireless radio links may experience signal fading and interference that can lead to increased BER. Wires may experience signal degradation due to undesired coupling between signals in separate cables, an occurrence called crosstalk. Optical fiber links are free from interference and crosstalk. The equipment for optical fiber links, however, can be more expensive.

2.3.6 Radio Frequency Integrated Circuit

A radio frequency integrated circuit is a compact electronic circuit that uses active devices for signal frequencies in the so-called radio frequency (RF) range. Radio frequency circuits include low- and high-power amplifiers, modulators, and demodulators. A...

voltage or power level of RF signals. The radio frequency integrated circuit makes use of dozens of semiconductors in a very small package to perform functions in popular gadgets such as cell phones.

Radio frequency integrated circuits solve many problems in designing and manufacturing receivers, transmitters, and RF test equipment. The relatively long wire causes a characteristic known as inductance. Inductance is the reaction caused by the resulting magnetic field in a current-carrying wire. Modern radio frequency integrated circuit offers the best performance features, which include low power consumption and good signal performance. Early RF devices were faced with problems of high power consumption leading to less standby and talk times for early portable communications equipment.

2.4 IC Fabrication Techniques

The manufacturing of Integrated Circuits (IC) consists of following steps. The steps includes 8-20 patterned layers created into the substrate to form the complete integrated circuit. The electrically active regions are created due to this layering in and on the surface of wafer. Hundreds of integrated circuits can be made on a single thin silicon. Then it is cut into individual IC chips.

Step 1 *Wafer production*

The first step is wafer production. The wafer is a round slice of semiconductor material such as silicon. Silicon is preferred due to its characteristics. It is more suitable for manufacturing IC. It is the base or substrate for entire chip. First purified polycrystalline silicon is created from the sand. Then it is heated to produce molten liquid. A small piece of solid silicon is dipped on the molten liquid. Then the solid silicon (seed) is slowly pulled from the melt. The liquid cools to form single crystal ingot. A thin round wafer of silicon is cut using wafer slicer. Wafer slicer is a precise cutting machine and each slice having thickness about .01 to .025inches. When wafer is sliced, the surface will be damaged. It can be smoothening by polishing. After polishing the wafer, it must thoroughly clean and dried. The wafers are cleaned using high purity low particle chemicals .The silicon wafers are exposed to ultra pure oxygen.

Step 2 *Masking*

To protect some area of wafer when working on another area, a process called **photolithography** is used. The process of photolithography includes masking with a photographic mask and photo etching. A photoresist film is applied on the wafer. The wafer is aligned to a mask using photo aligner. Then it is exposed to ultraviolet light through mask. Before that the wafer must be aligned with the mask. Generally, there are automatic tools for alignment purpose.

Step 3 *Etching*

It removes material selectively from the surface of wafer to create patterns. The pattern is defined by etching mask. The parts of material are protected by this etching mask. Either wet (chemical) or dry (physical) etching can be used to remove the unmasked material. To perform **etching** in all directions at same time, isotropic etching will be used. Anisotropic etching is faster in one direction. Wet etching is isotropic, but the etching time control is difficult. Wet etching uses liquid solvents for removing materials. It is not suited to transfer pattern with submicron feature size. It does not damage the material. Dry etching uses gases to remove materials. It is strongly anisotropic. But it is less selective. It is suited to transfer pattern having small size. The remaining photo resist is finally removed using additional chemicals or plasma. Then the wafer is inspected to make sure that the image is transferred from mask to the top layer of wafer.

Step 4 *Doping*

To alter the electrical character of silicon, atom with one less electron than silicon such as boron and atom with one electron greater then silicon such as phosphorous are introduced into the area. The P-type (boron) and N-type (phosphorous) are created to reflect their conducting characteristics. Diffusion is defined as the movement of impurity atoms in semiconductor material at high temperature.

Atomic diffusion

In this method *p* and *n* regions are created by adding dopants into the wafer. The wafers are placed in an oven which is made up of quartz and it is surrounded with heating elements. Then the wafers are heated at a temperature of about 1500-2200°F. The inert gas carries the dopant chemical. The dopant and gas is passed through the wafers and finally the dopant will get deposited on the wafer. This method can only be used for large areas. For small areas it will be difficult and it may not be accurate.

Ion implantation

This is also a method used for adding dopants. In this method, dopant gas such as phosphine or boron trichloride will be ionized first. Then it provides a beam of high energy dopant ions to the specified regions of wafer. It will penetrate the wafer. The depth of the penetration depends on the energy of the beam. By altering the beam energy, it is possible to control the depth of penetration of dopants into the wafer. The beam current and time of exposure is used to control the amount of dopant. This method is slower than atomic diffusion process. It does not require masking and this process is very precise. First it points the wafer that where it is needed and shoot the dopants to the place where it is required.

Step 5 *Metallization*

It is used to create contact with silicon and to make interconnections on chip. A thin layer of aluminum is deposited over the whole wafer. Aluminium is selected because it is a good conductor, has good mechanical bond with silicon, forms low resistance contact and it can be applied and patterned with single deposition and etching process.

Making successive layers: - The process such as masking, etching, doping will be repeated for each successive layers until all integrated chips are completed. Between the components, silicon dioxide is used as insulator. This process is called chemical vapor deposition. To make contact pads, aluminum is deposited. The fabrication includes more than three layers separated by dielectric layers. For electrical and physical isolation a layer of solid dielectric is surrounded in each component which provides isolation. It is possible to fabricate PNP and NPN transistor in the same silicon substrate. To avoid damage and contamination of circuit, final dielectric layer (passivation) is deposited. After that, the individual IC will be tested for electrical function. Check the functionality of each chip on wafer. Those chips are not passed in the test will be rejected.