Introduction:

Integrated circuit (IC) is the most significant technological development of the 21st century if I may say. It has forever transformed the world of electronics. It has reduced the size of electronics from a refrigerator size to palm size electronics or even less.

ICs dissipate less heat and as consumes less energy compared to vacuum tubes. It is very reliable. ICs have changed the fate of electronics. It has cut down the prices of electronics; it also changed the design of electronics from the use of discrete (separate) electronic components to hybrid solid-state devices which combine discrete components with ICs. ICs are so small that you cannot see the connections between them unless with the help of a microscope. Thus ICs are immensely in use in our electronics and almost all control devices.

Integrated Circuits:

Integrated circuit is defined as the circuit that comprises of elements that are inseparable and interconnected electrically in such a way that the integrated circuit (IC) cannot be separated for the reason of commerce and construction.

Although four basic types of constructions are employed in the manufacture of integrated circuits, namely: Monolithic, thin film, thick film and hybrid. But monolithic ICs are by far the most common type used in practice. Therefore, today what we call an IC, was originally known as a monolithic integrated circuit. It is believed that *Kilby* created the first working IC back in 1958 and he won the Nobel Prize in Physics in 2000 for his hard work.

Integrated circuit, sometimes called as a chip or microchip, is a semiconductor wafer on which a thousand or millions of tiny resistors, capacitors, and transistors are fabricated. An IC can be a function as an amplifier, oscillator, timer, counter, computer memory, or microprocessor.

IC is very small in size. In IC chips, the fabrication of circuit elements and their interconnections are done at same time. It has so many advantages such as extremely small size, low power consumption, low cost, high processing speed, easy replacement, and small weight.

A particular IC is categorized as ;

1. **Linear or Analog IC:** Linear IC is one which is gives us continuously variable output on the basis of given input signal level. The analog integrated circuits works by tackling continuous signals and is capable of performing tasks such as a filtering, amplification, demodulation and modulation etc. Sensors, OP-AMP’s are essentially Analog ICs.
2. **Digital IC:** Digital IC is one which operates at only fixed defined levels or states. This kind of IC has two defined levels: 1’s and 0’s that implies that they work on binary mathematics where in 1 stands for on and 0 stands for off. Such ICs are accomplished diligently as they contain more than millions of flip flops, logic gates and what not, all incorporated onto a single chip. Examples of digital IC include microcontrollers and microprocessors.
3. **Mixed IC:** The integrated circuits that are obtained by the combination of analog and digital ICs on a single chip are called as Mixed ICs. These ICs functions as Digital to Analog converters, Analog to Digital converters (D/A and A/D converters) and clock/timing ICs. The circuit depicted in the above figure is an example of mixed integrated circuit which is a photograph of the 8 to 18 GHz self healing radar receiver. This mixed-signal Systems-on-a-chip is a result of advances in the integration technology, which enabled to integrate digital, multiple analog and RF functions on a single chip.

Fabrication Process of IC:

Fabrication of integrated circuits needs a lot of sequential process steps. The most important steps used in the fabrication are:

1. Wafer production
2. Masking
3. Lithography
4. Etching
5. Doping
6. Metallization
7. Assembly and Packaging

Steps Required for Fabrication of IC:

1. **Wafer production:** The first step is wafer production. The wafer is a round slice of semiconductor material such as silicon. It is the base or substrate for entire chip.
   - Purification of polycrystalline silicon from the sand.
   - Heating it to produce molten liquid.
   - A small piece of solid silicon is dipped on the molten liquid and solid silicon is slowly pulled from the melt.
   - The liquid is cooled down to form single crystal.
   - A thin round wafer of silicon is cut using wafer slicer having thickness about 0.01-0.025 inches.
   - Damaged surface is smoothened by polishing.
   - The wafers are cleaned using high purity low particle chemicals.
   - The silicon wafers are now exposed to ultra pure oxygen.
2. **Masking:** Second step is masking, to protect some area of wafer when working on another area.
   - Photolithographic process is used.
   - Photographic mask and photo etching.
   - Application of photoresistive film on the wafer.
   - The alignment of wafer to a mask using photo aligner.
   - Exposing wafer to ultraviolet light through mask using automatic tools for alignment purpose.
3. **Lithography:** Lithography is used to transfer a pattern from a photomask to the surface of the wafer.
   - The gate area of a MOS transistor is defined by a specific pattern.
   - The pattern information of MOS transistor is recorded on a layer of photoresist, which is applied on the top of the wafer.
   - Exposing in light, photoresist changes its physical properties.
   - Depending on the type of resist is positive or negative; the pattern defined by the mask is either removed or remained after development.
   - The developed photoresist can act as an etching mask for the underlying layers.
4. **Etching:** Third step is Etching in which removal of material selectively is done from the surface of wafer to create patterns.

- Protection of the parts of material by etching mask.
- Wet or dry (chemical or physical) etching used for removal of the unmasked material.
- For faster etching, anisotropic etching is used.
- Liquid solvents are used in wet etching.
- Gases are used in Dry etching.
- The remaining part of photoresist is removed using additional chemicals.
- Now wafer is inspected to make sure that the image is transferred from mask to the top layer of wafer.

Anisotropic etching: It is a subtractive micro-fabrication process in which removal of a material is done in specific directions to obtain flat shapes.

Isotropic etching: It is a method which is used in semi-conductor technology to remove extra material from a substrate by a chemical process using an etchant substance. Etching is done horizontally as well as vertically into the surface of the substrate.

5. **Doping:** Process of adding some impurity atoms in the semiconductor.
    - P and N regions are created by adding dopants into the wafer.
    - The wafers are placed in an oven made up of quartz and surrounded with heating elements.
    - Wafers are heated at a temperature of about 1500-2200°F.
    - The dopant chemical is carried by inert gas.
    - The gas and dopant is passed through the wafers.
    - Dopant will be deposited on the wafer.
6. **Metallization:** Process for creating contact silicon and its interconnections on chip.
    - Deposition of thin layer of aluminum over the whole wafer.
    - Making successive layers.
    - The process such as etching, masking and doping are repeated for each successive layers until all IC’s are completed.
    - Silicon dioxide is used as insulator between the components.
    - Aluminum is deposited to make contact pads.

- The fabrication includes about three layers which are separated by dielectric layers. For electrical and physical isolation, solid layer of dielectric is surrounded in each component for purpose of isolation.
- Final dielectric layer is deposited to avoid damage and contamination of circuit.
- The individual IC is tested again for electrical function.
- Then by checking the functionality of each chip on wafer, those chips are not passed in the test will be rejected.

7. **Assembly and Packaging:** Each of the wafers contains lots of chips. These chips are separated and packaged by method known as cleaving and scribing.
   - The wafer is similar to a piece of glass and diamond saw is used for cutting the wafer into single chips.
   - For separation of the individual chips through the rectangular grid, diamond tipped tool is used.
   - Those chips are discarded which are failed in electrical test.
   - Observation under microscope before packaging.
   - The good chip is then sent for packaging.
   - For protection, thin wire is connected using ultrasonic bonding.
   - The chip is tested again before delivered to customer.
   - There are three configurations available for packaging.
     a. Metal can package
     b. Dual in line package.
     c. Ceramic flat package
   - The chip is assembled in ceramic packages for military applications.
   - This complete IC's are sealed in anti static plastic bags.

Integration

Based on the number of components used (typically based on the number of transistors used), they are as follows

- **Small-scale integration** consists of only a few transistors (tens of transistors on a chip), these ICs played a critical role in early aerospace projects.

- **Medium-scale integration** consists of some hundreds of transistors on the IC chip developed in the 1960s and achieved better economy and advantages compared to the SSI ICs.
- **Large-scale integration** consists of thousands of transistors on the chip with almost the same economy as medium scale integration ICs. The first microprocessor, calculator chips and RAMs of 1Kbit developed in the 1970s had below four thousand transistors.
- **Very large-scale integration** consists of transistors from hundreds to several billions in number.(Development period: from 1980s to 2009)
- **Ultra large-scale integration** consists of transistors in excess of more than one million, and later wafer-scale integration (WSI), system on a chip (SoC) and three dimensional integrated circuit (3D-IC) were developed.

All these can be treated as generations of integrated technology.

ICs are also classified based on the fabrication process and packing technology. There are numerous types of ICs among which, an IC will function as timer, counter, register, amplifier, oscillator, logic gate, adder, microprocessor, and so on.

The conventional Integrated circuits are reduced in practical usage, because of the invention of the nano-electronics and the miniaturization of ICs being continued by this Nano-electronics technology. However, the conventional ICs are not yet replaced by nano-electronics but the usage of the conventional ICs is getting diminished partially.

Applications of Integrated Circuits

The applications of an ICs includes the following

- Radar
- Wristwatches
- Televisions
- Juice Makers
- PC

- Video Processors
- Audio Amplifiers
- Memory Devices
- Logic Devices
- Radio Frequency Encoders and Decoders

Advantages of ICs

ICs have advantages over those that are made by interconnecting discrete components some of which are its small size. It is a thousand times smaller than the discrete circuits. It is an all in one (components and the interconnections are on a single silicon chip). It has little weight.

Its cost of production is also low. It is reliable because there are no soldered joints. ICs consume little energy and can easily be replaced when the need arises. It can be operated at a very high temperature. Due to which, different types of ICs are widely applied in our electrical devices such as high power amplifiers, voltage regulators, TV receivers and computers etc.

Limitation for different types of ICs

Despite the advantages that ICs provide us with, it have limitations some of which are:

- Limited power rating
- It operates at low voltage
- High grade of PNP is not possible
- It produces noise during operation
- Its components such as resistors and capacitors are voltage dependent
- It is delicate i.e. it cannot withstand rough handling etc.