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A basic review of integrated circuits and fabrication

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Abstract: This paper provides the review of how integrated circuits have dominated the market, changing trends in its development and research work conducted in the field of integrated circuits.

Keywords: transistors, ICs,integrated ,CMOS technology ,VLSI , semiconductors, microprocessors.

INTRODUCTION

ICs were made possible by experimental discoveries showing that semiconductor devices could perform the functions of vacuum tubes and by mid-20th-century technology advancements in semiconductor device fabrication. The integration of large numbers of tiny transistors into a small chip was an enormous improvement over the manual assembly of circuits using discrete electronic components. The integrated circuit's mass production capability, reliability, and building-block approach to circuit design ensured the rapid adoption of standardized integrated circuits in place of designs using discrete transistors[9].

ADVANTAGES

There are two main advantages of ICs over discrete circuits: cost and performance. Cost is low because the chips, with all their components, are printed as a unit by photolithography rather than being constructed one transistor at a time. Furthermore, much less material is used to construct a packaged IC die than to construct a discrete circuit. Performance is high because the components switch quickly and consume little power (compared to their discrete counterparts) as a result of the small size and close proximity of the components. As of 2012, typical chip areas range from a few square millimeters to around 450 mm2, with up to 9 million transistors per mm2.

HISTORY

Early developments of the integrated circuit go back to 1949, when the German engineer Werner Jacobi [5]filed a patent for an integrated-circuit-like semiconductor amplifying device[1] showing five transistors on a common substrate in a 3-stage amplifier arrangement.

The idea of the integrated circuit was conceived by a radar scientist working for the Royal Radar Establishment of the British Ministry Of Defence, Geoffrey W.A. Dummer(1909–2002). Dummer presented the idea to the public at the Symposium on Progress in Quality Electronic Components in Washington D.C. on 7 May 1952.[7] He gave many symposia publicly to propagate his ideas, and unsuccessfully attempted to build such a circuit in 1956.

GENERATIONS

In the early days of integrated circuits, only a few transistors could be placed on a chip, as the scale used was large because of the contemporary technology, and manufacturing yields were low by today's standards. As the degree of integration was small, the design process was relatively simple. Over time, millions, and today billions,[9] of transistors could be placed on one chip, and a good design required thorough planning. This gave rise to new design methods.

The final step in the development process, starting in the 1980s and continuing through the present, was "very large-scale integration" (VLSI). The development started with hundreds of thousands of transistors in the early 1980s, and continues beyond several billion transistors as of 2009.

ADVANCES in IC

Among the most advanced integrated circuits are the microprocessors or "cores", which control everything from computers and cellular phones to digital microwave ovens. Digital memory chips and application-specific integrated circuits (ASIC)s are examples of other families of integrated circuits that are important to the modern information society. While the cost of designing and developing a complex integrated circuit is quite high, when spread across typically millions of production units the individual IC cost is minimized. The performance of ICs is high because the small size allows short traces which in turn allows low power logic (such as CMOS) to be used at fast switching speeds.

ICs have consistently migrated to smaller feature sizes over the years, allowing more circuitry to be packed on each chip. This increased capacity per unit area can be used to decrease cost and/or increase functionality—see Moore's law which, in its modern interpretation, states that the number of transistors in an integrated circuit doubles every two years.

In general, as the feature size shrinks, almost everything improves—the cost per unit and the switching power consumption go down, and the speed goes up. However, ICs with nanometer-scale devices are not without their problems, principal among which is leakage current (see subthreshold leakage for a discussion of this), although these problems are not insurmountable and will likely be solved or at least ameliorated by the introduction of high-k dielectrics. Since these speed and power consumption gains are apparent to the end user, there is fierce competition among the manufacturers to use finer geometries. This process, and the expected progress over the next few years, is well described by the International Technology Roadmap for Semiconductors (ITRS).

In current research projects, integrated circuits are also developed for sensoric applications in medical implants or other bioelectronic devices. Particular sealing strategies have to be taken in such biogenic environments to avoid corrosion or biodegradation of the exposed semiconductor materials.[2] As one of the few materials well established in CMOS technology, titanium nitride (TiN) turned out as exceptionally stable and well suited for electrode applications in medical implants.[3][4]

BASIC IC TYPES

Analog versus digital circuits

Analog, or linear, circuits typically use only a few components and are thus some of the simplest types of ICs. Generally, analog circuits are connected to devices that collect signals from the environment or send signals back to the environment. For example, a microphone converts fluctuating vocal sounds into an electrical signal of varying voltage. An analog circuit then modifies the signal in some useful way—such as amplifying it or filtering it of undesirable noise. Such a signal might then be fed back to a loudspeaker, which would reproduce the tones originally picked up by the microphone. Another typical use for an analog circuit is to control some device in response to continual changes in the environment. For example, a temperature sensor sends a varying signal to a thermostat, which can be programmed to turn an air conditioner, heater, or oven on and off once the signal has reached a certain value.

A digital circuit, on the other hand, is designed to accept only voltages of specific given values. A circuit that uses only two states is known as a binary circuit. Circuit design with binary quantities, “on” and “off” representing 1 and 0 (i.e., true and false), uses the logic of Boolean algebra. The three basic logic functions—NOT, AND, and OR—together with their truth tables are given in the figure. (Arithmetic is also performed in the binary number system employing Boolean algebra.) These basic elements are combined in the design of ICs for digital computers and associated devices to perform the desired functions.[8]

CLASSIFICATION

Depending on the way they are manufactured, integrated circuits can be divided into two groups: hybrid and monolithic. Hybrid circuits have been around longer. If a transistor is opened, the crystal inside is very small. This means a transistor doesn't take up very much space and many of them can be fitted into a single Integrated Circuit. Most integrated Circuits are in a DIL package - Dual In Line, meaning there are two rows of pins. . The device is viewed from the top and the pins are numbered in an anti-clockwise direction. High power integrated circuits can generate a lot of heat and they have a metal tag that can be connected to a heatsink to dissipate the heat.

MANUFACTURING

The semiconductors of the periodic table of the chemical elements were identified as the most likely materials for a solid-state vacuum tube. Starting with copper oxide, proceeding to germanium, then silicon, the materials were systematically studied in the 1940s and 1950s. Today, silicon monocrystals are the main substrate used for ICs although some III-V compounds of the periodic table such as gallium arsenide are used for specialized applications like LEDs, lasers, solar cells and the highest-speed integrated circuits. It took decades to perfect methods of creating crystalswithout defects in the crystalline structure of the semiconducting material.

Semiconductor ICs are fabricated in a layer process which includes these key process steps:

- Imaging
- Deposition
- Etching

The main process steps are supplemented by doping and cleaning.

Mono-crystal silicon wafers (or for special applications, silicon on sapphire or gallium arsenide wafers) are used as the substrate. Photolithography is used to mark different areas of the substrate to be doped or to have polysilicon, insulators or metal (typically aluminium) tracks deposited on them.

- Integrated circuits are composed of many overlapping layers, each defined by photolithography, and normally shown in different colors. Some layers mark where various dopants are diffused into the substrate (called diffusion layers), some define where additional ions are implanted (implant layers), some define the conductors (polysilicon or metal layers), and some define the connections between the conducting layers (via or contact layers). All components are constructed from a specific combination of these layers.
- In a self-aligned CMOS process, a transistor is formed wherever the gate layer (polysilicon or metal) crosses a diffusion layer.
- Capacitive structures, in form very much like the parallel conducting plates of a traditional electrical capacitor, are formed according to the area of the "plates", with insulating material between the plates. Capacitors of a wide range of sizes are common on ICs.
- Meandering stripes of varying lengths are sometimes used to form on-chip resistors, though most logic circuits do not need any resistors. The ratio of the length of the resistive structure to its width, combined with its sheet resistivity, determines the resistance.

More rarely, inductive structures can be built as tiny on-chip coils, or simulated by gyrators

ICs and IC FAMILIES

- The 555 timer IC
- The 741 operational amplifier
- 7400 series TTL logic building blocks
- 4000 series, the CMOS counterpart to the 7400 series
- Intel 4004, the world's first microprocessor, which led to the famous 8080 CPU and then the IBM PC's 8088, 80286, 486 etc.
- The MOS Technology 6502 and Zilog Z80 microprocessors, used in many home computers of the early 1980s
- The Motorola 6800 series of computer-related chips, leading to the 68000 and 88000 series (used in some Apple computers and in the 1980s Commodore Amiga series).
- The LM-series of analog integrated circuits.

CONCLUSION

Integrated circuits are used in virtually all electronic equipment today and have revolutionized the world of electronics. Computers and mobile phones, and other digital home appliances are now inextricable parts of the structure of modern societies, made possible by the low cost of producing integrated circuits.

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