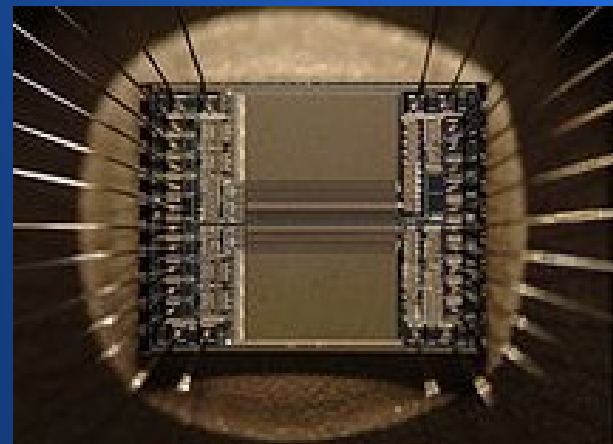
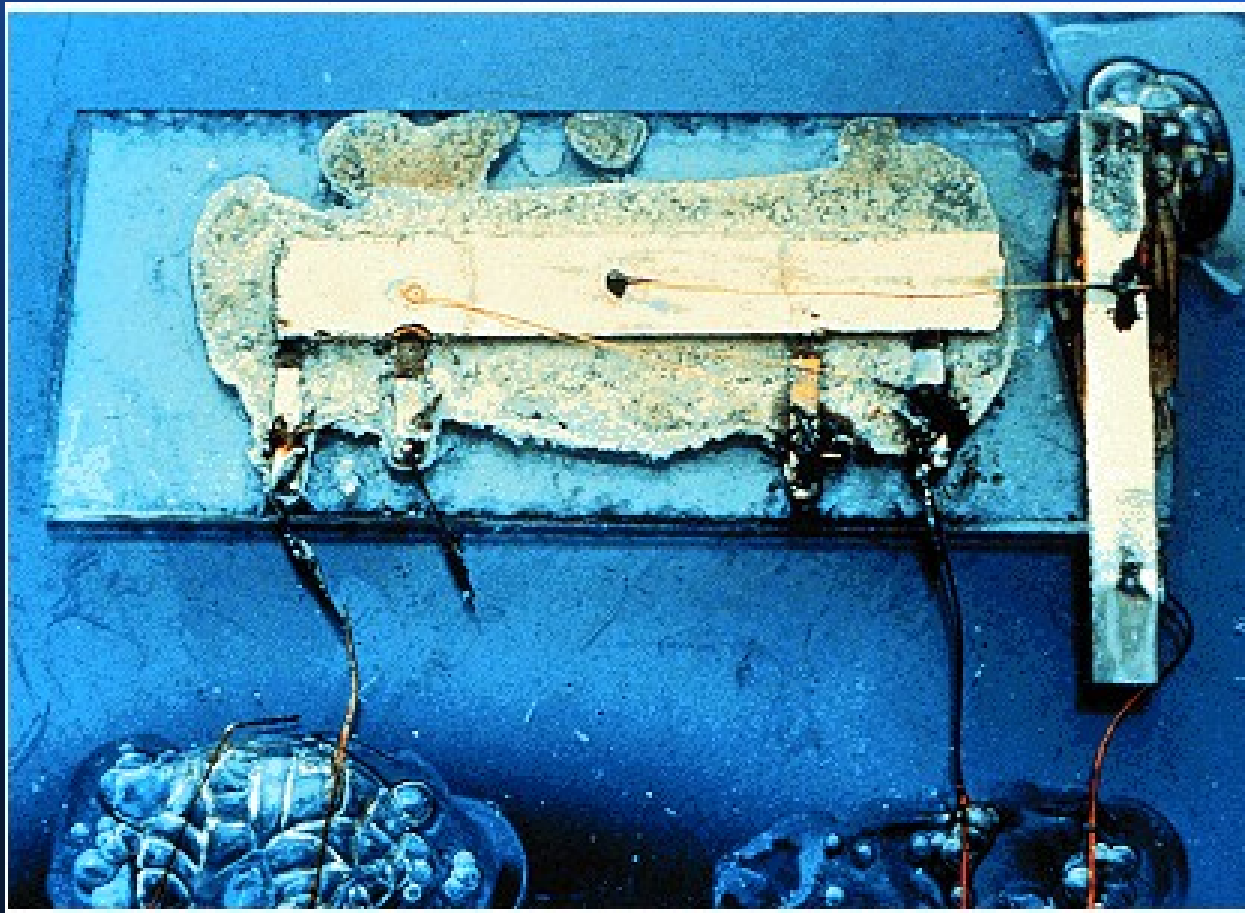


# Integrated Circuits

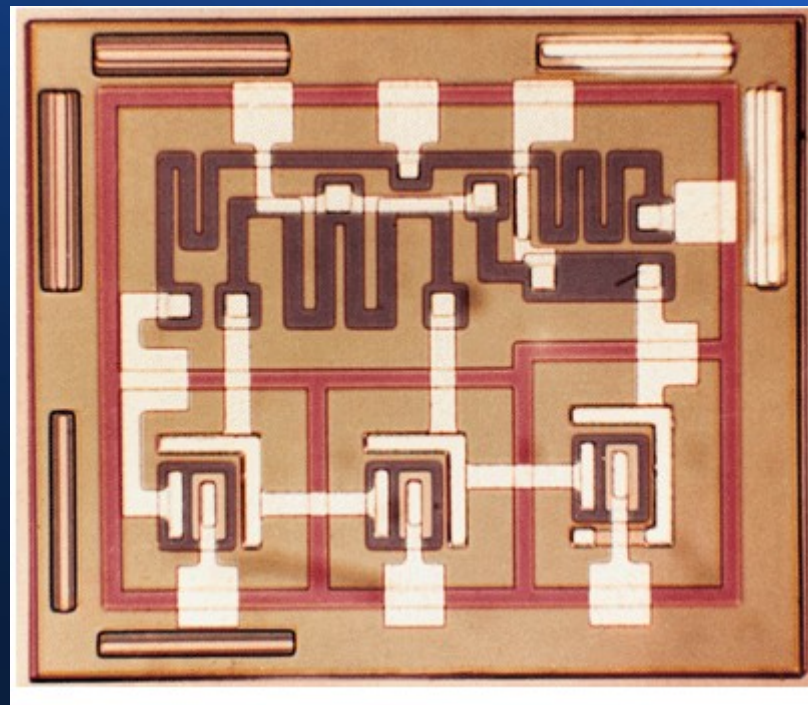
An integrated circuit (also referred to as an IC, a chip, or a microchip) is a set of electronic circuits on one small plate ("chip") of semiconductor material, normally silicon. This can be made much smaller than a discrete circuit made from independent components.



About a half inch wide, this archaic-looking collection of two transistors mounted on a bar of germanium was nonetheless the first integrated circuit. It was demonstrated by Texas Instruments, Inc. on September 12, 1958

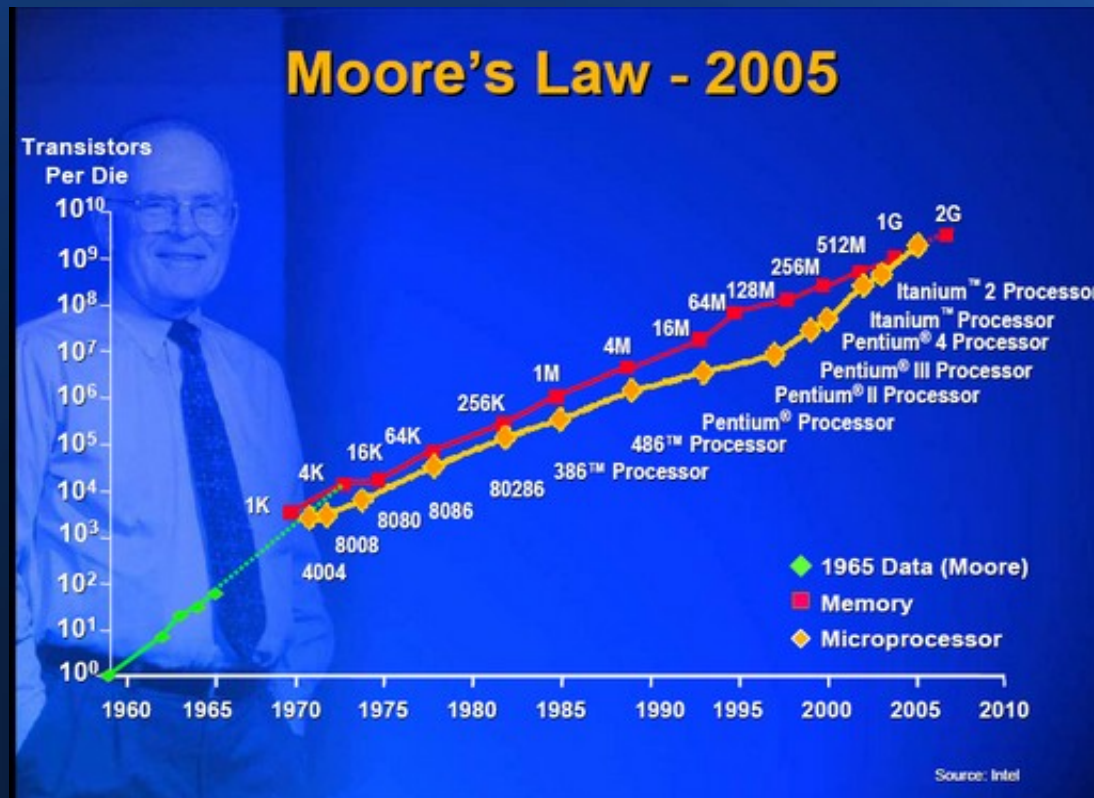


This amplifier circuit from Siemens was mass produced in 1965. Containing three transistors and five resistors on a 1.5 mm square chip



The transistor count of a device is the number of transistors in the device. Transistor count is the most common measure of integrated circuit complexity. According to Moore's Law, the transistor count of the integrated circuits doubles every two years.

On most modern microprocessors, the majority of transistors are contained in caches.



ICs can be made very compact, having up to several billion transistors and other electronic components in an area the size of a fingernail.

# Digital Logic Families

TTL transistor–transistor logic

ECL emitter-coupled logic

MOS metal-oxide semiconductor

CMOS complementary metal-oxide semiconductor



# Digital Logic Families

TTL is a logic family that has been in use for 50 years and is considered to be standard.

ECL has an advantage in systems requiring high-speed operation.

MOS is suitable for circuits that need high component density

CMOS is preferable in systems requiring low power consumption, such as digital cameras, personal media players, and other hand held portable devices.

Low power consumption is essential for VLSI design; therefore, CMOS has become the dominant logic family, while TTL and ECL continue to decline in use.

# Digital Logic Families

Fan-out specifies the number of standard loads that the output of a typical gate can drive

Fan-in is the number of inputs available in a gate

Power dissipation is the power consumed by the gate

Propagation delay is the average transition delay time for a signal to propagate from input to output

Noise margin is the maximum external noise voltage added to an input signal that does not cause an undesirable change in the circuit output.

## 7400 series – A standardized part numbering scheme

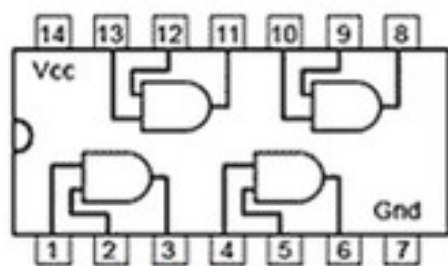
The 7400 series of transistor-transistor logic (TTL) integrated circuits are historically important as the first widespread family of TTL integrated circuit logic.

It was used to build the mini and mainframe computers of the 1960s and 1970s.

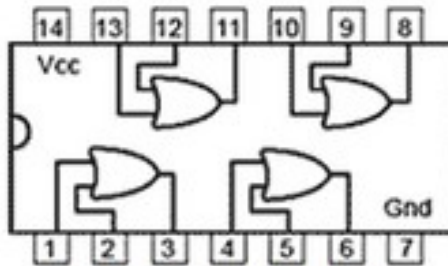
Several generations of pin-compatible descendants of the original family have since become de-facto standard electronic components

A two-figure arbitrary prefix, of which the two most common are "74", indicating a commercial temperature range device and "54", indicating an extended (military) temperature range.

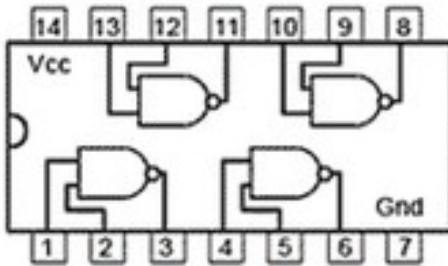




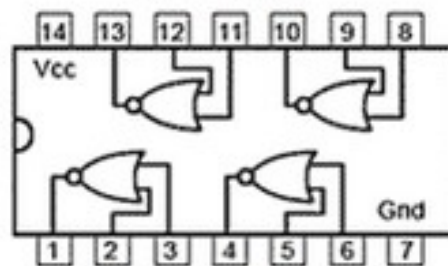
7408 Quad 2 input  
AND Gates



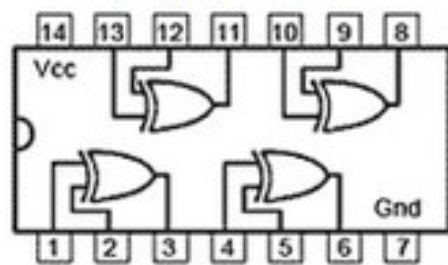
7432 Quad 2 input  
OR Gates



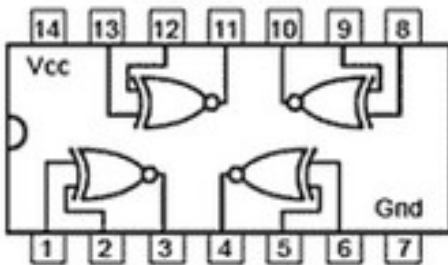
7400 Quad 2 input  
NAND Gates



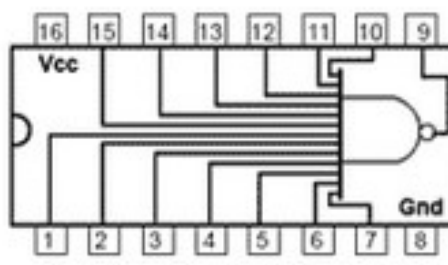
7402 Quad 2 input  
NOR Gates



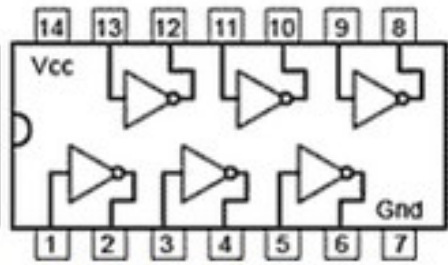
7486 Quad 2 input  
XOR Gates



747266 Quad 2 input  
XNOR Gates



74133 Single 13 input  
NAND Gate



7404 Hex NOT Gates  
(Inverters)

There is no pattern to the allocation of these numbers. The function and pin-out of the chip is nearly always the same for the same device number regardless of subfamily manufacturer

7400	quad 2-input NAND gate
741G00	single 2-input NAND gate
7401	quad 2-input NAND gate with open collector outputs
741G01	single 2-input NAND gate with open drain output
7402	quad 2-input NOR gate
741G02	single 2-input NOR gate
7403	quad 2-input NAND gate with open collector outputs
741G03	single 2-input NAND gate with open drain output
7404	hex inverter
741G04	single inverter
7405	hex inverter with open collector outputs
741G05	single inverter with open drain output
7406	hex inverter buffer/driver with 30 v open collector outputs
741G06	single inverting buffer/driver with open drain output
7407	hex buffer/driver with 30 v open collector outputs
741G07	single non-inverting buffer/driver with open drain output
7408	quad 2-input AND gate
.....	
.....	
.....	

Open-collector is a very common type of digital signal. Rather than providing 5 volts and ground, like the push-pull signal, an open-collector signal provides ground and High-impedance.

Open Drain and Open Collector are functionally equivalent, but Open Drain is implemented with FET technology while Open Collector is implemented with BJT technology.

The 7400 series contains hundreds of devices that provide everything from basic logic gates, flip-flops, and counters, to special purpose bus transceivers and Arithmetic Logic Units

Surface-mounted CMOS versions of the 7400 series are used in various applications in electronics and for glue logic in computers and industrial electronics.

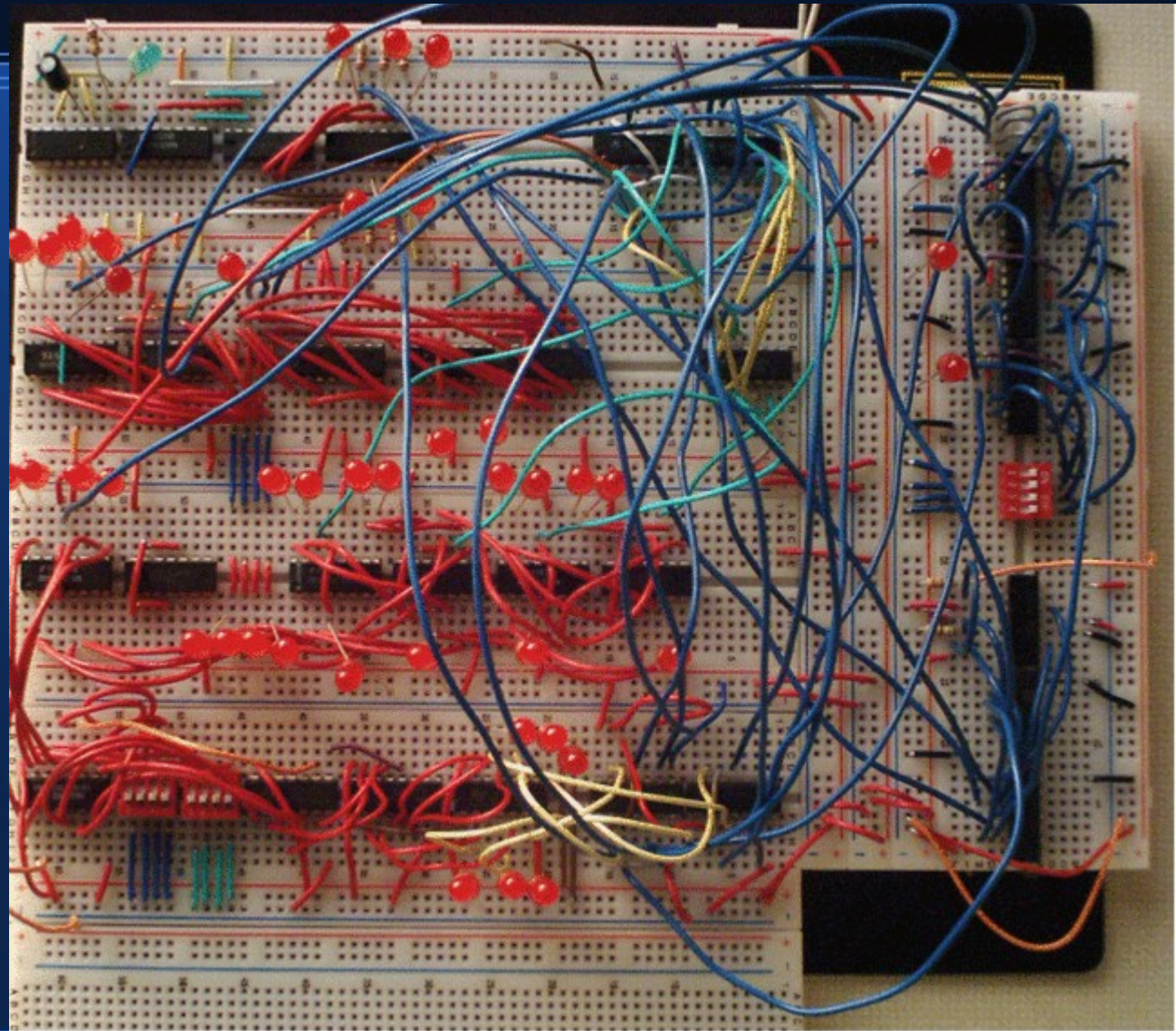
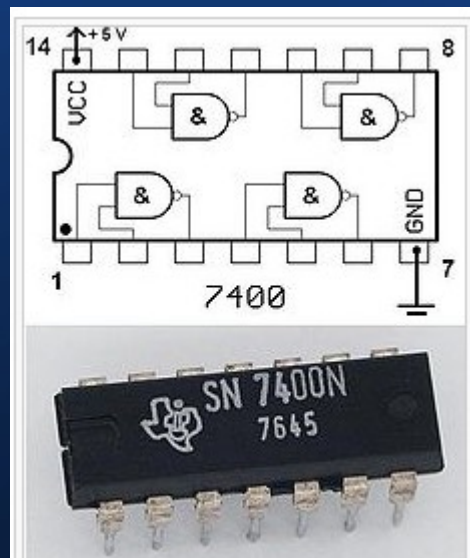
The original through-hole devices in dual in-line packages (DIP/DIL), which were the mainstay of the industry for many decades, are very useful for rapid breadboard-prototyping and education and so remain available from most manufacturers.

Hobbyists and students equipped with wire wrap tools, a 'breadboard' and a 5-volt power supply could also experiment with digital logic referring to how-to articles in Byte magazine and Popular Electronics which featured circuit examples in nearly every issue.

In the early days of large-scale IC development, a prototype of a new large-scale integrated circuit might have been developed using TTL chips on several circuit boards, before committing to manufacture of the target device in IC form.

This allowed simulation of the finished product and testing of the logic before the availability of software simulations of integrated circuits.

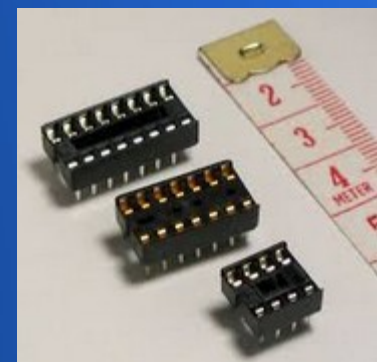
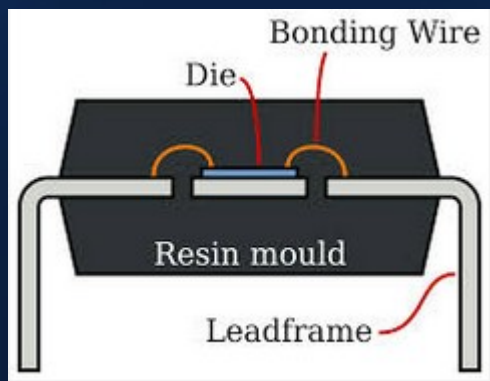




In microelectronics, a dual in-line package (DIP or DIL), or dual in-line pin package (DIPP) is an electronic component package with a rectangular housing and two parallel rows of electrical connecting pins.

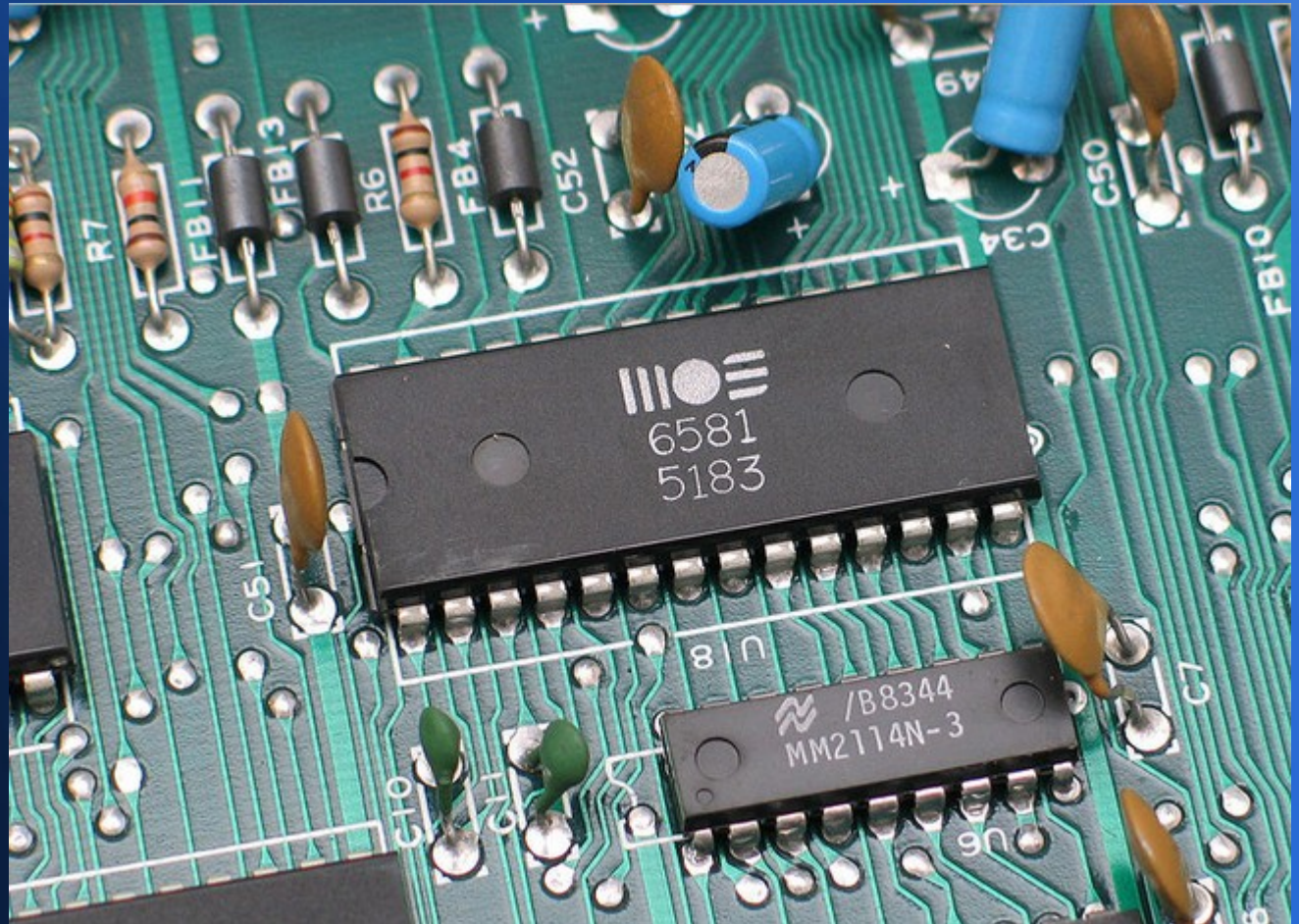
The package may be through-hole mounted to a printed circuit board or inserted in a socket.

Dual-in-line packages were developed in the 1960s when the restricted number of leads available on transistor-style packages became a limitation in the use of integrated circuits.





Through-hole technology, also spelled "thru-hole", refers to the mounting scheme used for electronic components that involves the use of leads on the components that are inserted into holes drilled in printed circuit boards (PCB) and soldered to pads on the opposite side either by manual assembly (hand placement) or by the use of automated insertion mount machines



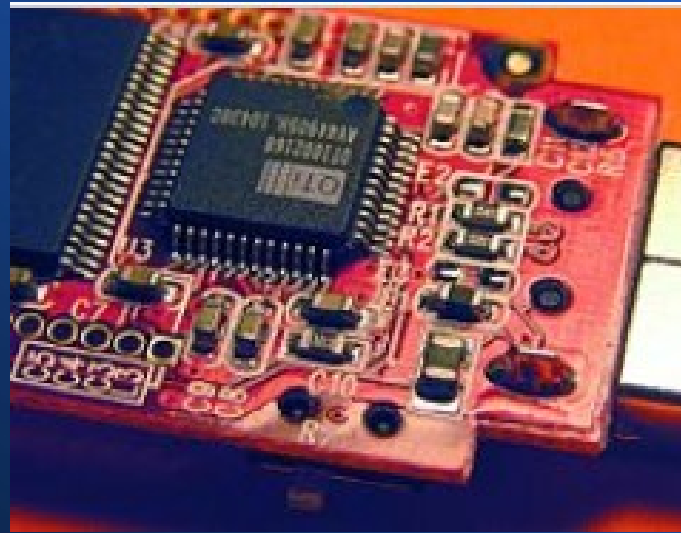
The fastest types and very low voltage versions are typically surface-mount only, however.

7400 series parts were constructed using bipolar transistors, forming what is referred to as transistor–transistor logic or TTL. Newer series, more or less compatible in function and logic level with the original parts, use CMOS technology or a combination of the two (BiCMOS). Originally the bipolar circuits provided higher speed but consumed more power than the competing 4000 series of CMOS devices. Bipolar devices are also limited to a fixed power supply voltage, typically 5 V, while CMOS parts often support a range of supply voltages.



Over 40 different logic subfamilies use this standardized part number scheme.

Surface-mount technology (SMT) is a method for producing electronic circuits in which the components are mounted or placed directly onto the surface of printed circuit boards (PCBs).



In the industry it has largely replaced the through-hole technology construction method of fitting components with wire leads into holes in the circuit board.

An SMT component is usually smaller than its through-hole counterpart because it has either smaller leads or no leads at all



# Semiconductor fabrication plant

A semiconductor fabrication plant (commonly called a fab) is a factory where integrated circuits are manufactured.

Fabs require many expensive devices to function. Estimates put the cost of building a new fab over one billion U.S. dollars with values as high as \$3–4 billion not being uncommon. Taiwan Semiconductor Manufacturing Company Limited TSMC invested 9.3 billion dollars in its Fab15 300 mm wafer manufacturing facility in Taiwan operational in 2012.

Intel Ireland's Leixlip campus, located in County Kildare, began operations in 1989.

Since then, Intel has invested over \$12.5 billion in turning the 360-acre former stud farm into the most technologically advanced industrial location in Europe.

The fabs at the Leixlip campus produce 300mm wafers on multiple process technologies (ie different materials, line widths etc) and the combined facilities constitutes one of Intel's most technologically advanced, high-volume manufacturing plants in the world.

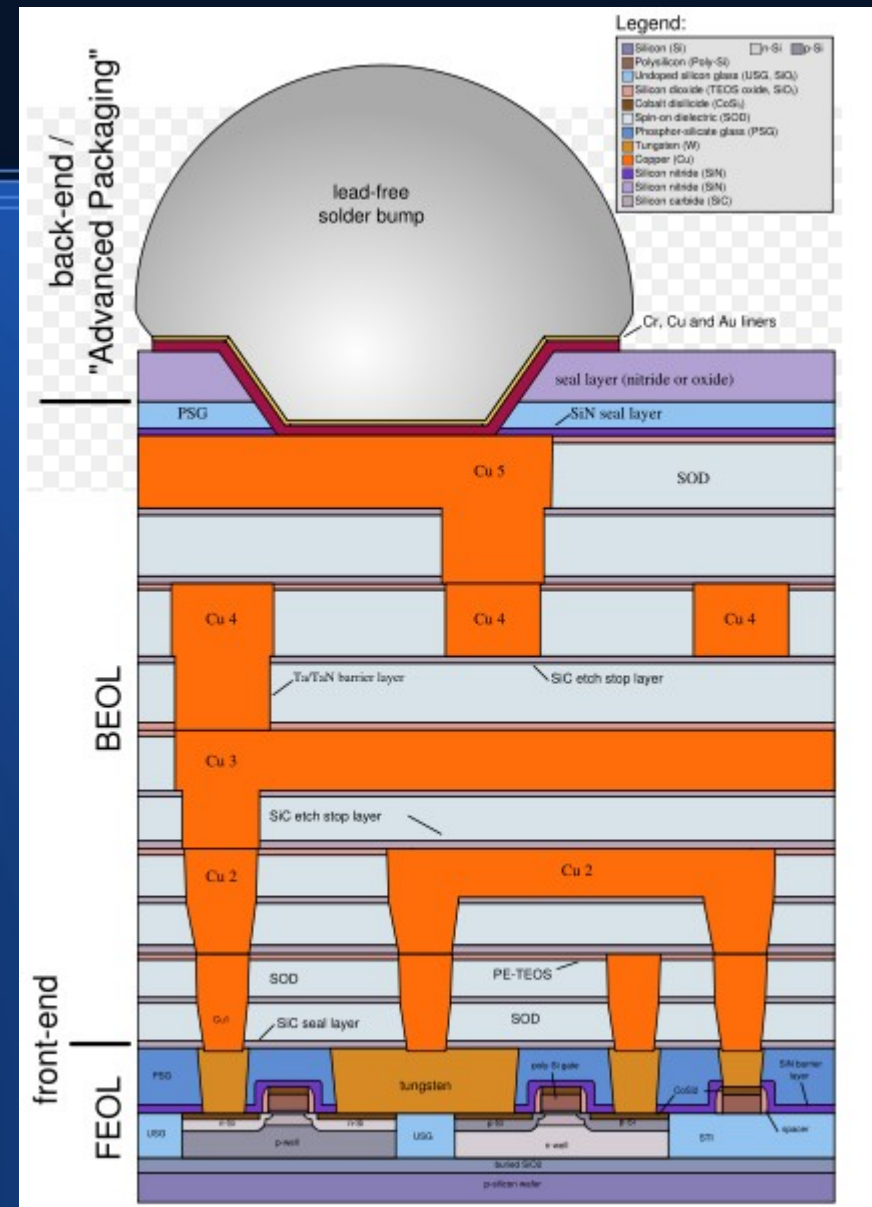
Different line width processes involve trade offs between performance, maximum memory size, power consumption, cost etc.

# Cmos chip structure

Schematic structure of a CMOS chip, as built in the early 2000s on an SOI (Silicon on insulator) substrate with five metallization layers and solder bump for flip-chip bonding.

Complementary metal–oxide–semiconductor (CMOS) is a technology for constructing integrated circuits.

It also shows the section for FEOL (front-end of line), BEOL (back-end of line) and first parts of back-end process.



The width of each conducting line in a circuit (the line width) can be made smaller and smaller as the technology advances; in 2008 it dropped below 100 nanometers and in 2013 it is in the tens of nanometers.

TSMC currently operates three 300-mm GIGAFAB facilities (Fab 12, Fab 14 and Fab 15), with a combined capacity reaching 3,936,000 12-inch wafers in 2012, supporting 0.13-micron, 90nm, 65nm, 40nm and 28nm process technologies.

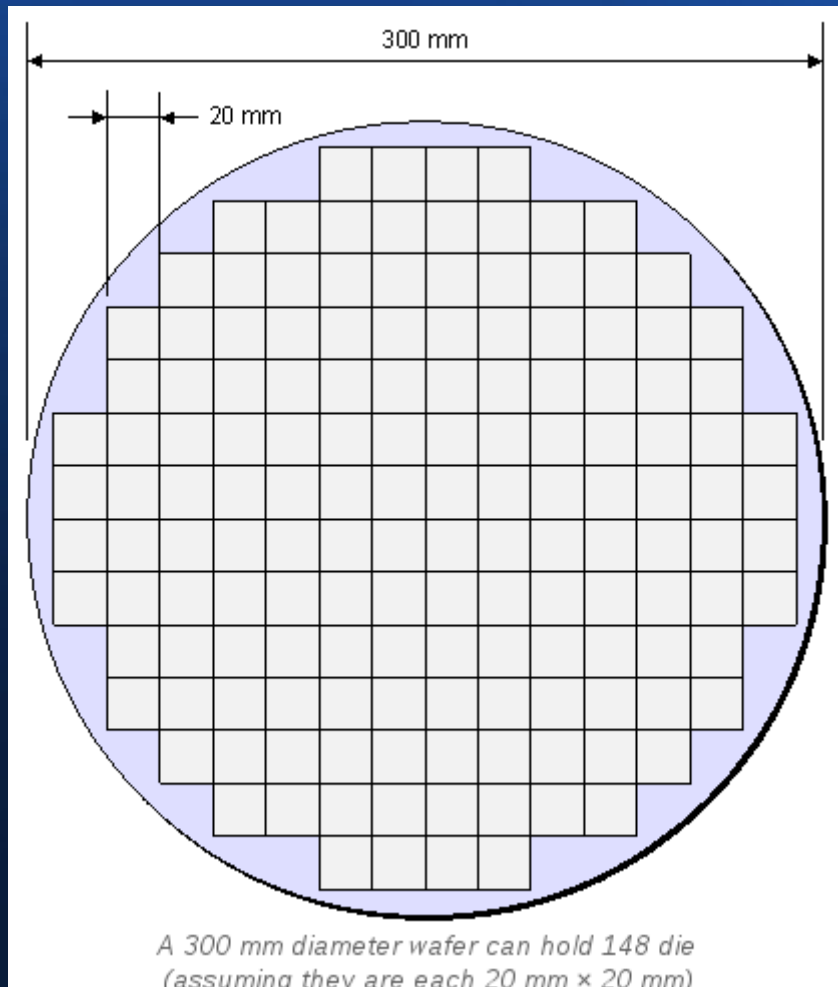
Part of the capacity is reserved for research and development work and currently supports 20nm and more advanced technology development.

Each device is tested before packaging using automated test equipment (ATE), in a process known as wafer testing, or wafer probing.



The wafer is then cut into rectangular blocks, each of which is called a die. Each good die (plural dice, dies, or die) is then connected into a package using aluminium (or gold) bond wires which are thermosonic bonded to pads, usually found around the edge of the die.





Suppose our die are each  $1\text{mm} \times 1\text{mm} = 1$  square millimeter; some of the die will be cut short by the curve of the circle, so we might expect say 70,000 die (each  $1\text{mm} \times 1\text{mm}$ ) on our 300 mm diameter wafer.

By comparison, if our die were each  $20\text{mm} \times 20\text{mm} = 400$  square mm, we will only get 148 of these on a 300 mm wafer as shown.

The central part of a fab is the clean room, an area where the environment is controlled to eliminate all dust, since even a single speck can ruin a microcircuit, which has features much smaller than dust. The clean room must also be dampened against vibration and kept within narrow bands of temperature and humidity. Controlling temperature and humidity is critical for minimizing static electricity.

The clean room contains the steppers for photolithography, etching, cleaning, doping and dicing machines. All these devices are extremely precise and thus extremely expensive. Prices for most common pieces of equipment for the processing of 300 mm wafers range from \$700,000 to upwards of \$4,000,000 each with a few pieces of equipment reaching as high as \$50,000,000 each (e.g. steppers). A typical fab will have several hundred equipment items.





15-Core Xeon Ivy Bridge-EX, Transistor count = 4,310,000,000  
22 nm Process, 23 mm x 23mm = 541 square mm

