Course Title: Processing & Fabrication Technology
Course No.: EEE 489

VLSI Class lecture -6

Process Integration

Reference

TEXT BOOK

1. Fundamentals of Semiconductor Fabrication

-By **Garry S. May** and **Simon M. Sze**

2. Basic VLSI Design

-By **Douglas A. Pucknell** and **Kamran Eshraghin**

Introduction

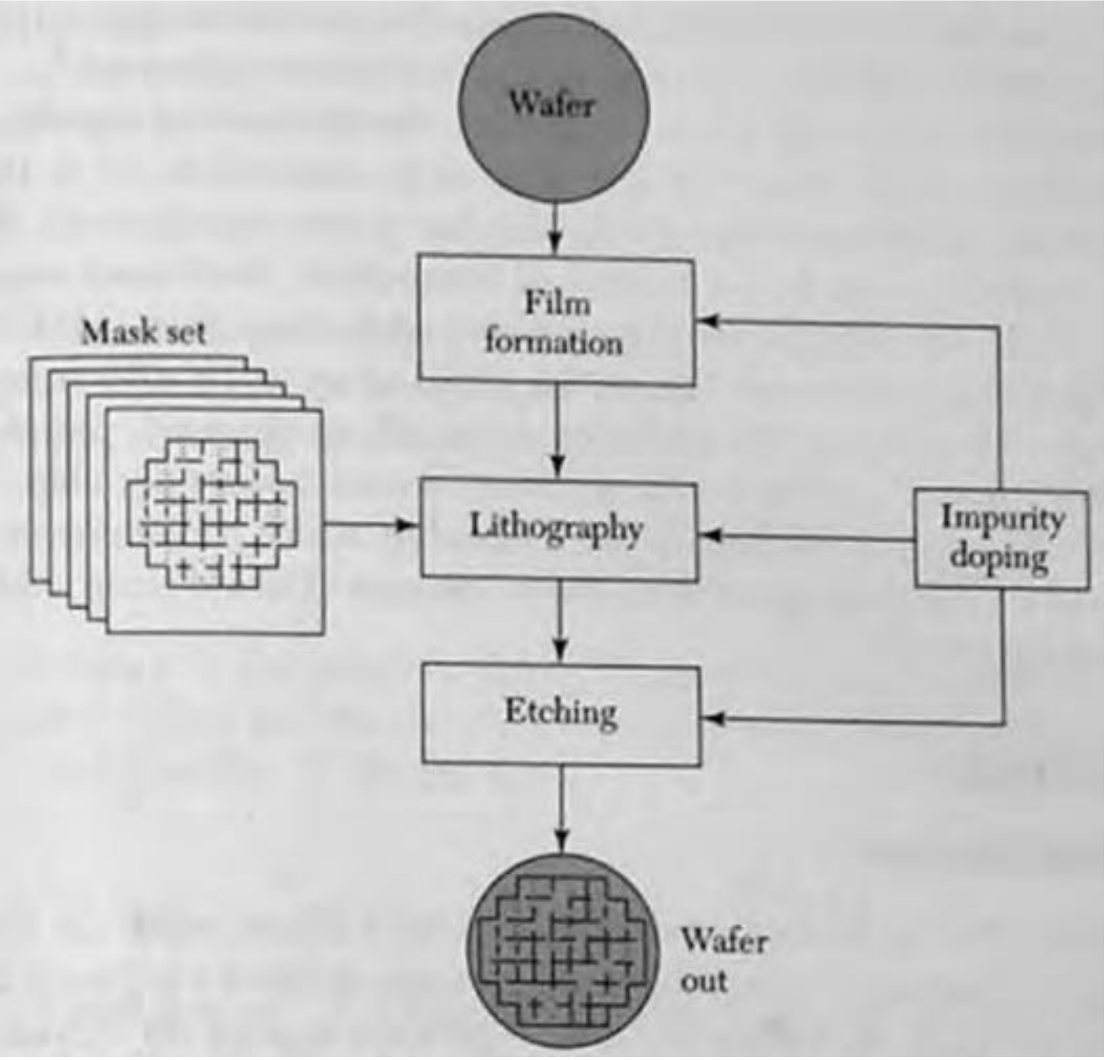
- Microwave, photonic and power applications generally employ discrete devices. However, most electronic systems are built on the *integrated circuit*, which is an ensemble of both active (e.g. transistor) and passive (e.g. resistor, capacitor and inductor) devices formed on and within a single-crystal semiconductor substrate and interconnected by a metallization pattern.
- ICs have enormous advantages over discrete devices connected by wire bonding.

Advantages

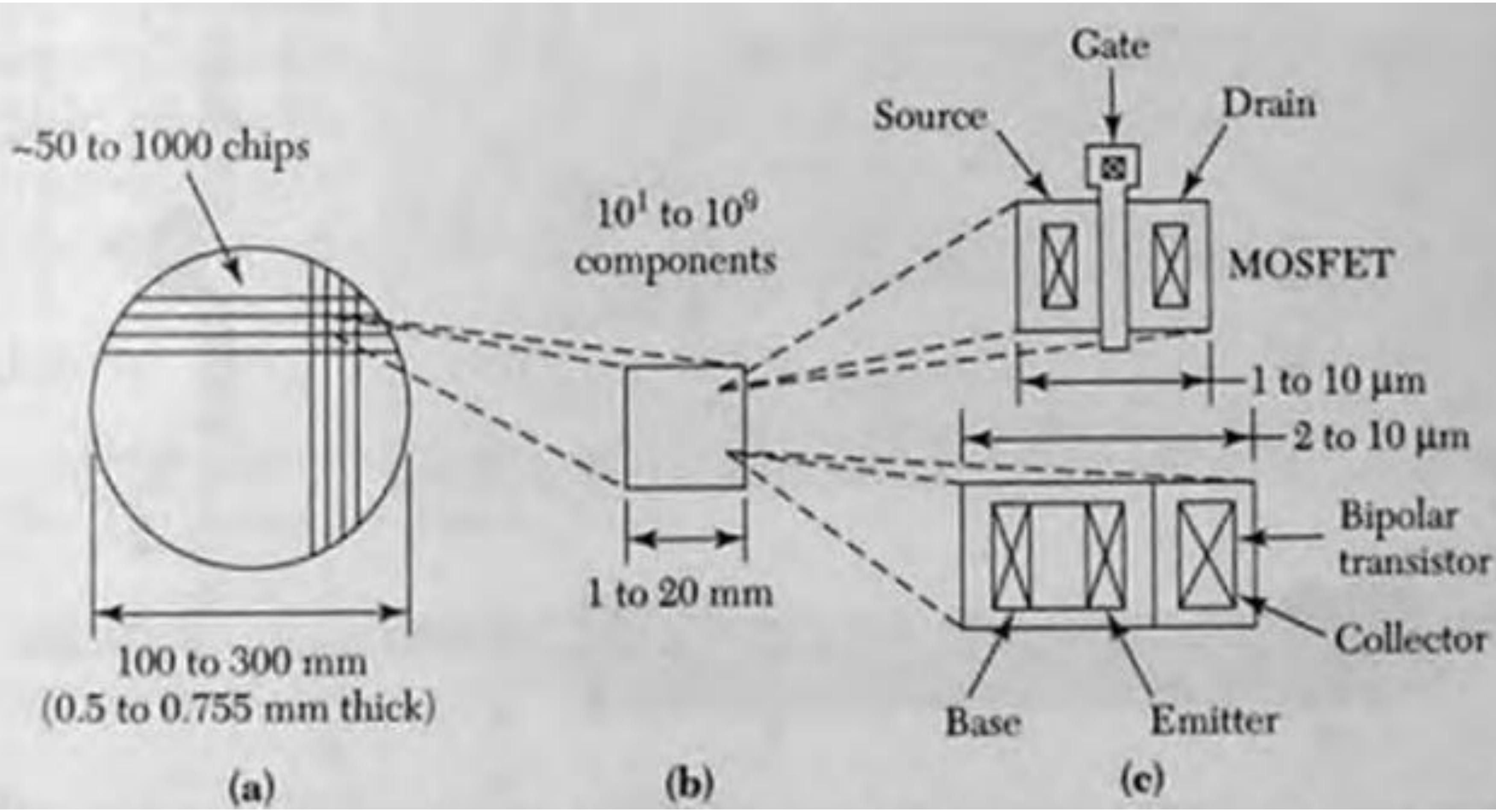
The advantages include -

- Reduction of the interconnection parasitics, because an IC with multilevel metallization can substantially reduce the overall wiring length.
- Full utilization of a semiconductor wafer’s area, because devices can be closely packed within an IC chip and
- Drastic reduction in processing cost, because wire bonding is a time-consuming and error-prone operation.

Schematic flow diagram of IC fabrication



Size comparison of a wafer to individual components



(a) Semiconductor wafer (b) Chip (c) MOSFET and Bipolar transistor

ICs trend

- IC chips may contain a few components (transistor, diodes, resistors, capacitors, etc.) or as many as a billion or more. We usually refer to the complexity of an IC as its level of integration.
- *Small-scale integration (SSI)*
  - refers to up to 100 components per chip,
- *Medium-scale integration (MSI)*
  - to up to 1000 components per chip,
- *Large-scale integration (LSI)*
  - to up to 100,000 components per chip,
- *Very large-scale integration (VLSI)*
  - to up to 10^7 components per chip, and
- *Ultra large-scale integration (ULSI)*
  - to larger numbers (over 2 billion) of components per chip.

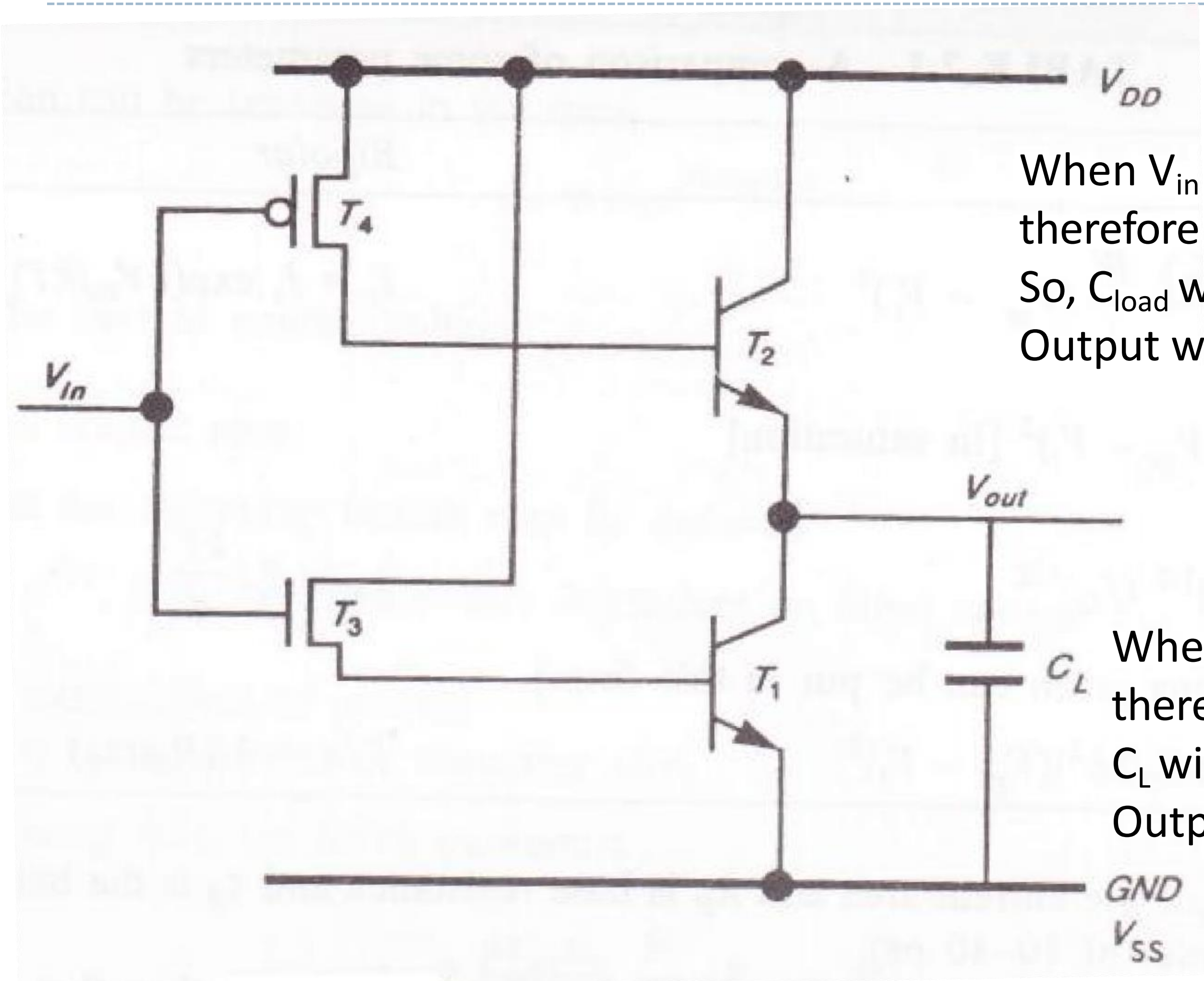
BiCMOS Technology

Why it is called BiCMOS?

- It consists of Bipolar transistor and CMOS.

- When designing with BiCMOS, the logical approach to use MOS switches to perform the logic function and bipolar transistors to drive the output loads.
- BJT provide some advantages, such as-
  - Higher gain
  - Better noise and high frequency characteristics

BiCMOS Inverters



When $V_{in} = 0$, T_4= ON, T_3=OFF,
therefore T_2=ON, T_1= OFF
So, C_{load} will charge towards 5V (V_{DD}).
Output will be $V_{out}= V_{DD}-(V_{BE})_2$

When $V_{in} = 5V$, T_4= OFF, T_3=ON
therefore T_2=OFF, T_1= ON
C_L will discharge towards 0V(GND)
Output will be $V_{out}= 0v+(V_{CEsat})_1$

A simple BiCMOS inverter

BiCMOS Inverters…

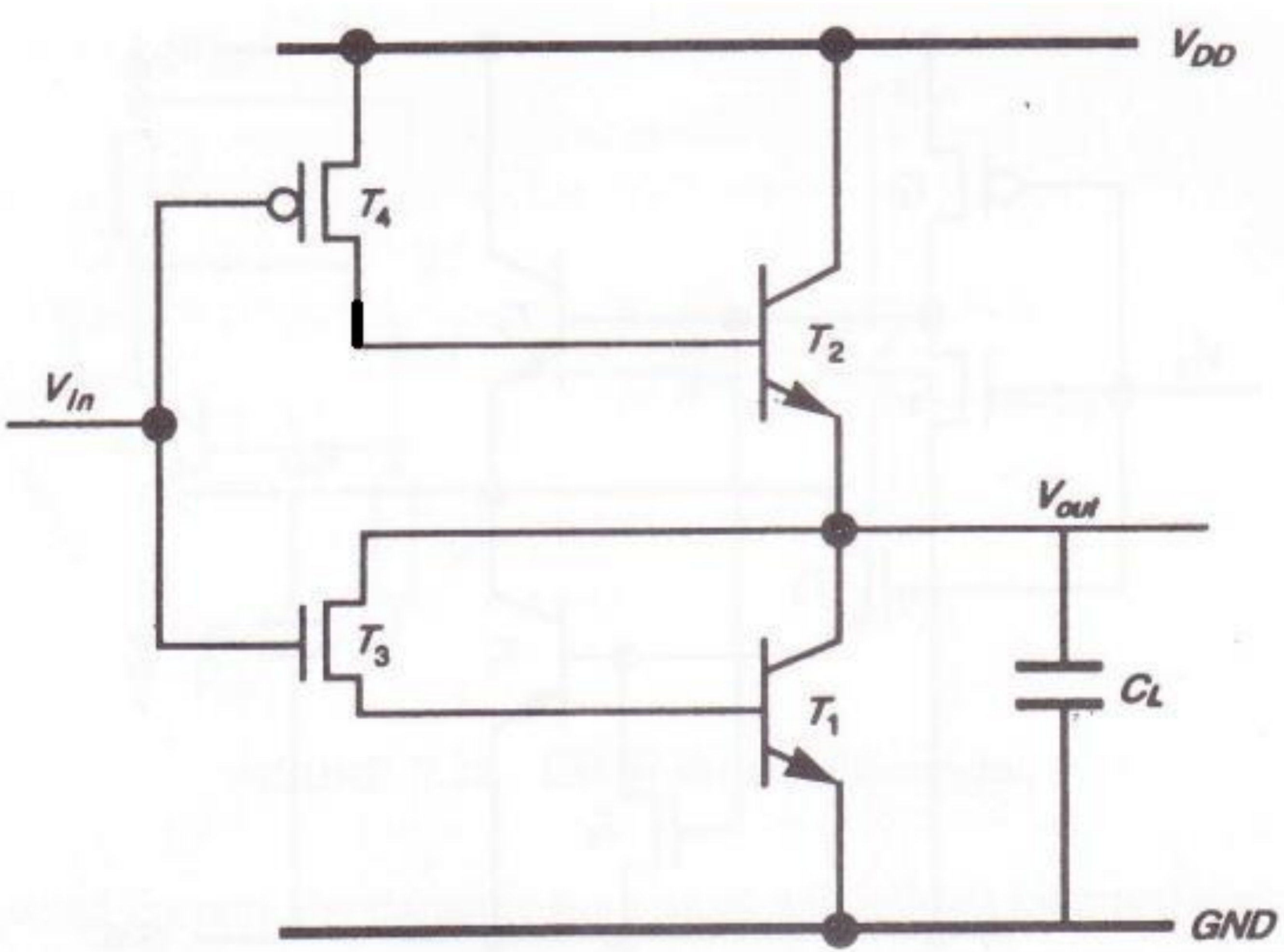
Advantages:

- High input and low output impedance
- High noise margin
- Almost 0V and 5V

Disadvantages:

- When V_{in}= HIGH (5V), there will be significant current flow through T_3 and T_1. Therefore this is not a good arrangement.
- There is no discharge path for current flow from the base of either transistor when it is being turned OFF. Discharge path is required, as junction capacitance (Stray capacitance) are formed.

BiCMOS Inverters…



BiCMOS inverter with no static current flow

BiCMOS Inverters…

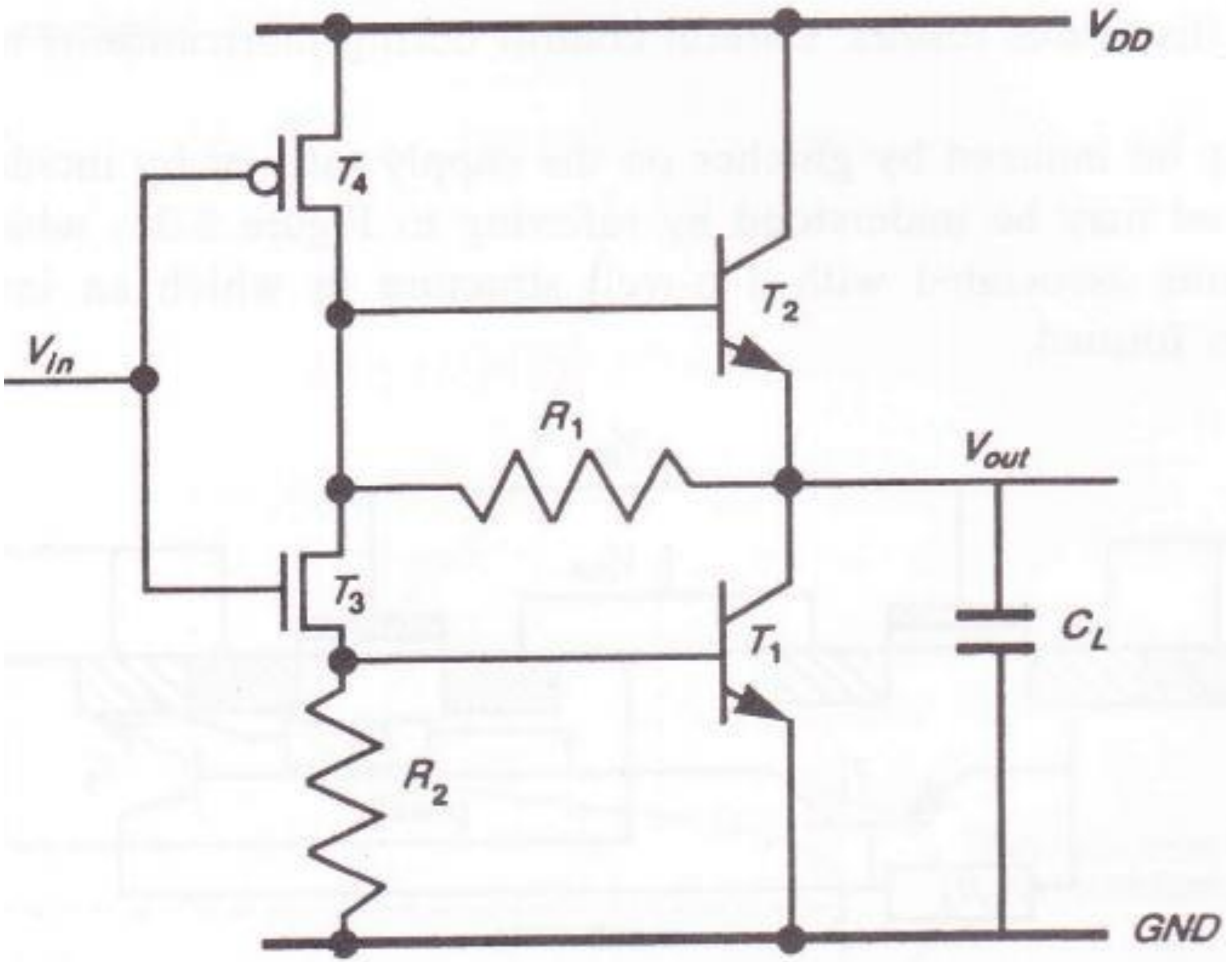
Advantages:

- DC path through T_3 and T_1 is eliminated. Therefore no static current flow through T_3 and T_1.

Disadvantages:

- Output voltage swing is reduced. Because when T_3 = ON, C_{Load}=Discharging, But $V_{out}= V_{BE} \neq 0$

BiCMOS Inverters…



BiCMOS inverter with better output logic levels

BiCMOS Inverters…

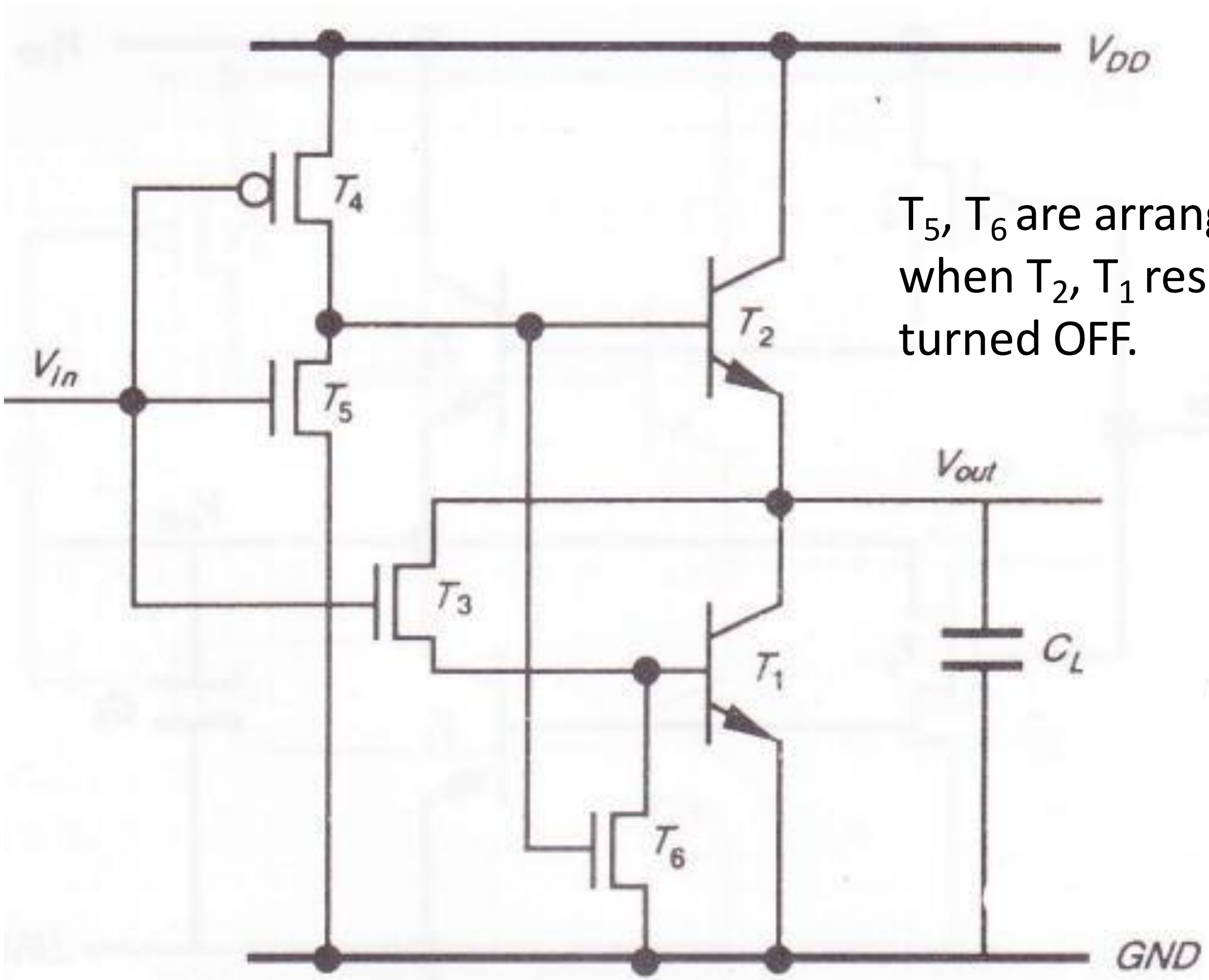
Advantages:

- Resistors provide the improved swing of output voltage when each bipolar transistor is OFF and also provide discharge paths for base current during turn-off.

Disadvantages:

- The provision of on chip resistors of suitable value is not always convenient and may be space consuming.

BiCMOS Inverters…



T_5, T_6 are arranged to turn ON, when T_2, T_1 respectively are being turned OFF.

BiCMOS inverter using MOS transistors

MEMS Technology

- Microelectromechanical systems (MEMS), also known as *microsystems technology* in Europe, or *micromachines* in Japan, are a class of devices characterized both by their small size and the manner in which they are made.
- MEMS devices are considered to range in characteristic length from one millimeter down to one micron – many times smaller than the diameter of a human hair.
- MEMS will often employ microscopic analogs of common mechanical parts and tools; they can have channels, holes, cantilevers, membranes, cavities, and other structures. However, MEMS parts are not machined. Instead, they are created using micro-fabrication technology similar to batch processing for integrated circuits.

MEMS Technology…

- Many products exist today that use MEMS technology, such as
  - micro heat exchangers,
  - ink jet printer heads,
  - micro-mirror arrays for high-definition projectors,
  - pressure sensors,
  - infrared detectors,
  - and many more.

SOI Technology

- Silicon-On-Insulator (SOI) is a semiconductor fabrication technique developed by IBM that uses pure crystal silicon and silicon oxide for integrated circuits (ICs) and microchips.
- An SOI microchip processing speed is often 30% faster than today's complementary metal-oxide semiconductor (CMOS)-based chips and power consumption is reduced 80%, which makes them ideal for mobile devices.
- SOI chips also reduce the soft error rate, which is data corruption caused by cosmic rays and natural radioactive background signals.

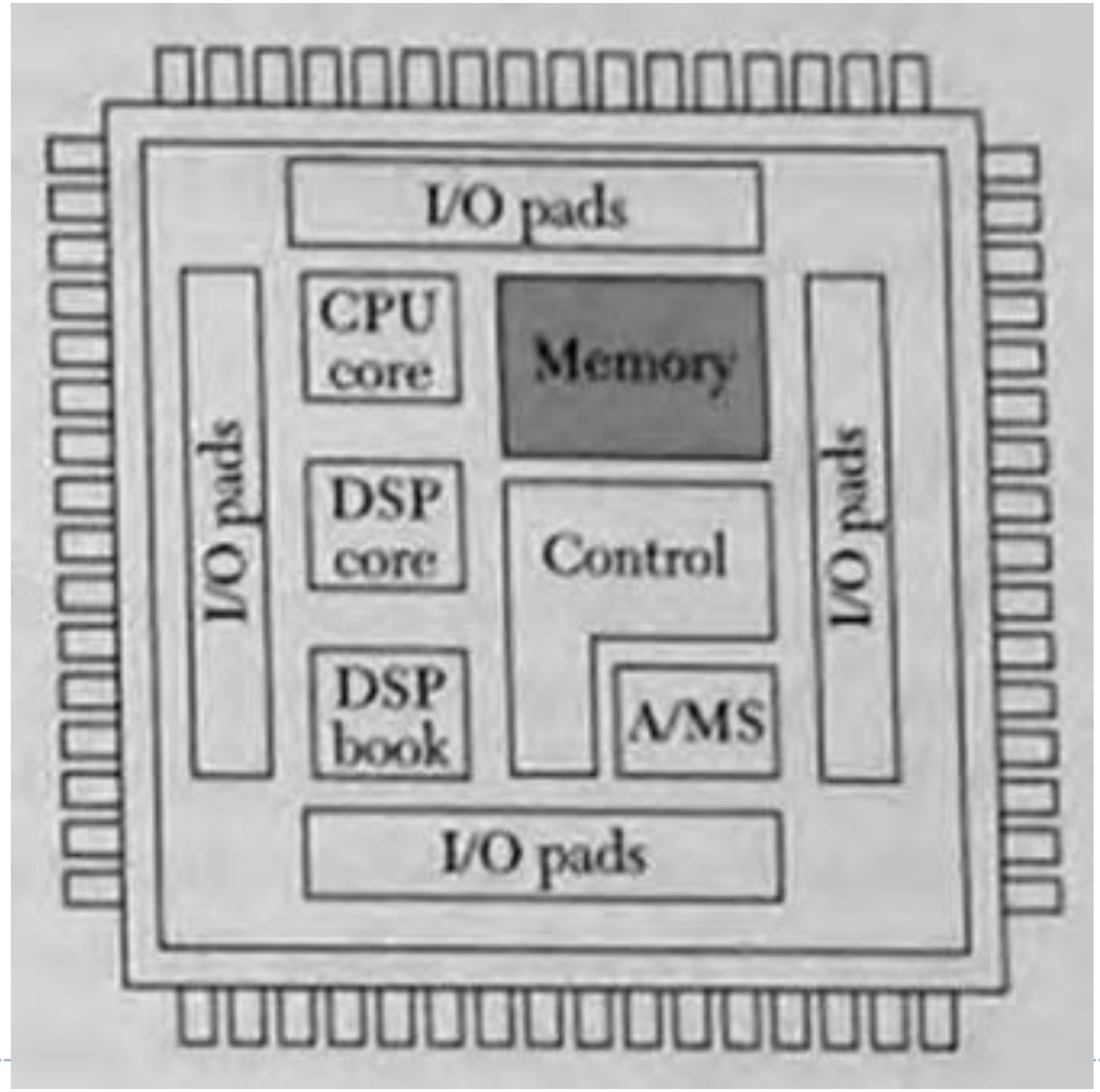
SOI Technology…

- A CMOS-based chip has impurities added to it, a process called "doping", that allows the chip to store an electrical charge called capacitance. In order to control the electrical currents needed, the capacitance must be discharged and recharged, which takes time and causes the transistors on the chip to heat up. This production of heat limits the speed at which microchips can operate. For this reason, microchips have poor yield rates above 1GHz and are not expected to attain future speeds above 5GHz. SOI microchips are not doped with impurities, which eliminates much of the capacitance and allows an SOI microchip to operate faster and cooler.

SOC Technology

- Increased component density and improved fabrication technology have helped the realization of the System-on-a-chip or System-on-chip (SoC or SOC).
- A SOC is an integrated circuit (IC) that integrates all components of a computer or other electronic system into a single chip. It may contain digital, analog, mixed-signal, and often radio-frequency functions—all on a single chip substrate. A typical application is in the area of embedded systems.

SOC Technology…



SOC of a conventional personal computer motherboard (virtual components).

SOC Technology…

- SOC technology is used in small, increasingly complex consumer electronic devices. Some such devices have more processing power and memory than a typical desktop computer.
- In the future, SOC - equipped nanorobots (robots of microscopic dimensions) might act as programmable antibodies to fend off previously incurable diseases.
- SOC video devices might be embedded in the brains of blind people, allowing them to see;
- SOC audio devices might allow deaf people to hear.
- Handheld computers with small whip antennas might someday be capable of browsing the Internet at megabit-per-second speeds from any point on the surface of the earth.

SOC Technology…

- But there are two obstacles in the realization of the SOC.
- The first is the huge complexity of the design. Another difficulty lies in fabrication.