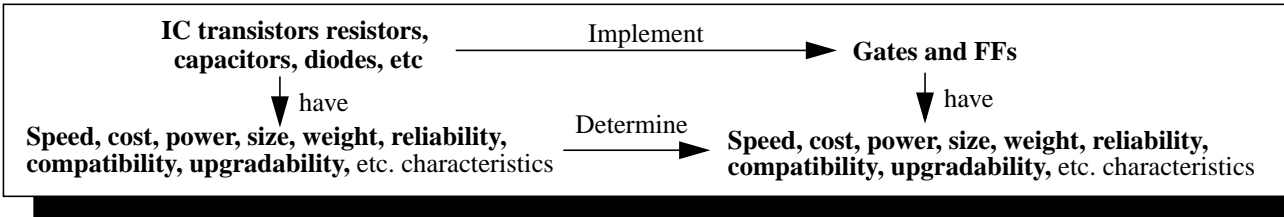
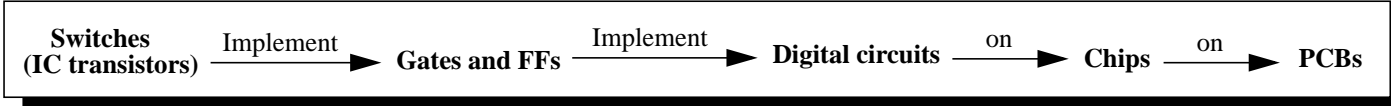
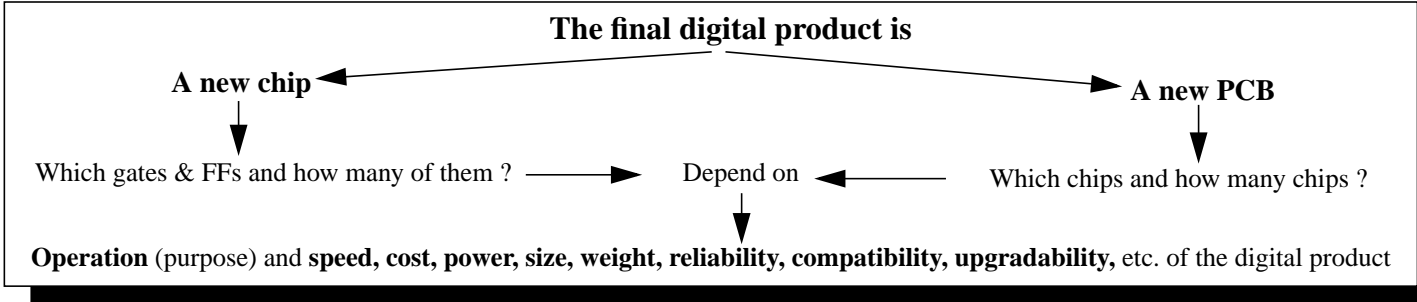
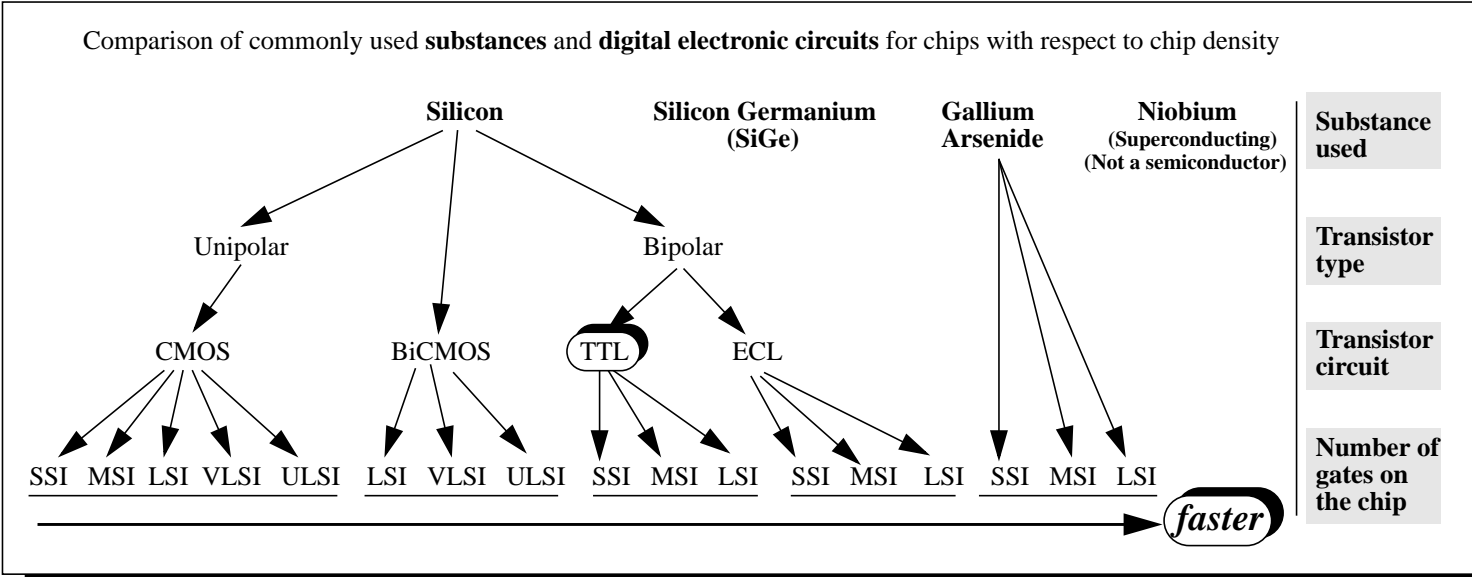


**A BRIEF LOOK AT THE SEMICONDUCTOR TECHNOLOGY**



- Therefore, we need to study
  - ⇒ **Substances** used for IC transistors, resistors, capacitors, diodes, etc.
  - ⇒ **Digital electronic circuits** that use IC transistors, resistors, etc. and implement gates and FFs



**Table 1: Chip densities** for various scales of integration

Scales of Integration (chip density)	Siewiorek et al (1982)	Burger et al (1982)
Small Scale Integration (SSI)	< 10 gates	< 64 components
Medium Scale Integration (MSI)	< 100 gates	< 2K components
Large Scale Integration (LSI)	< 10,000 gates	< 64K components
Very Large Integration (VLSI)	< 100,000 gates	< 2M components
Ultra Large Scale Integration (ULSI)	> 100,000 gates	> 2M components

**Table 2: The state of the silicon technology**

Characteristic	Silicon
Densest chip transistor circuit	CMOS
Transistors/chip (density)	600,000,000
Gate delay	50 - 500 ps
Process	45 nanometer

**Table 3: Summary of characteristics** for three commonly used IC logic families

Parameter	TTL	CMOS	ECL
Switching speed (gate delay)	Medium	Low	Good
Power consumption	Medium	Low	High
Chip density	Medium	High	Low
Cost	Low	Medium	High

### Transistor-Transistor Logic (TTL) features

- TTL families : 7400 series : 74 (Standard), 74H (High speed), 74L (Low-power), 74S (Schottky), 74LS (Low-power Schottky), 74AS (Advanced Schottky), 74ALS (Advanced Low-power Schottky), 74F (Fast)
- Unused gate inputs : can be left unconnected (floating), but should be tied to a used input to be safe. Also, can connect to 1 or 0 depending on the input characteristic, via a pull-up resistor or pull-down resistor, respectively
- Gate output circuits :
  - Totem-pole (do *not* short circuit gate outputs)
  - Tri-state (gate outputs can be short circuited if only one gate is enabled)
  - Open-collector (an external pull-up resistor needed. Gate outputs can be short circuited)

### Complementary Metal Oxide Semiconductor (CMOS) features

- CMOS families : 4000 series ; 7400 series : 74HC (High-speed CMOS), 74HCT (High-speed CMOS, TTL compatible), 74AC (Advanced CMOS), 74ACT (Advanced CMOS, TTL compatible), 74FCT (Fast CMOS, TTL compatible), 74FCT-T (Fast CMOS, TTL compatible with TTL  $V_{OH}$ )
- Unused gate inputs : do *not* leave them unconnected (floating). Tie them to a used input. Also, can connect to 1 or 0 depending on the input characteristic, via a pull-up resistor or pull-down resistor, respectively
- Gate output circuits :
  - Regular (do *not* short circuit gate outputs)
  - Tri-state (gate outputs can be short circuited, if only one gate is enabled)
  - Open-drain (an external pull-up resistor needed. Gate outputs can be short circuited)
- Electrostatic discharge can **damage** CMOS chips. Unless properly grounded, one should *not* touch CMOS chips