IC Technology

What advantages do ICs have over discrete components?

- **Size:** Sub-micron vs. millimeter/centimeter.

- **Speed and Power:** Smaller size of IC components yields higher speed and lower power consumption due to smaller parasitic resistances, capacitances and inductances.
  
  Switching between ‘0’ and ‘1’ much faster on chip than between chips.
  
  Payoff at the system level:
  
  Systems are physically smaller, e.g. cell phones.
  
  Lower power consumption ripple effect => less heat => cheaper power supplies => reduced system cost.

- Integrated circuit manufacturing is versatile.
  
  Simply change the mask to change the design.
  
  However, designing the layout (changing the masks) is usually the most time consuming task in IC design.
A Sample of Integrated Circuit technologies:

**MOS**
- CMOS
- PMOS-only
- NMOS-only

**Bipolar**
- Transistor-transistor logic (TTL)
- Integrated Injection Logic (I^2L)

**Gallium Arsenide (GaAs)**

**Silicon Germanium**

**BiCMOS**

**Superconducting technologies**
**Brief History**

- **1958**: First Integrated Circuit
  
  Flip-flop using two transistors  
  Built by Jack Kilby at Texas Instruments

- **2004**
  
  Intel Pentium 4 microprocessor (~55 million transistors)  
  512 Mbit DRAM (> 0.5 billion transistors)

- **53% compound annual growth rate over 45 years**
  
  No other technology has grown so fast so long

- **Driven by miniaturization of transistors**
  
  Smaller is faster, cheaper, lower in power  
  Revolutionary effects on society

- **Feature Size**: Smallest feature on an IC, currently the length of the transistor
  
  Current feature sizes: 130 nm/ 90 nm
Annual Sales

$10^{18}$ transistors manufactured in 2003
100 million for every human on the planet
Invention of the transistor

Vaccum-tubes ruled in the first half of 20th century.
Large, expensive, power-hungry, unreliable

1947: First point contact transistor
John Bardeen and Walter Brattain at Bell Labs
**MOS Integrated Circuits**

1970’s processes usually had only nMOS transistors
Inexpensive, but consume power when idle

1980’s present: CMOS processes for low idle power
**Why CMOS?**

Power consumption (heat) of bipolar circuits reduce level of integration.

- Multiple ICs offset advantage of faster speed of bipolar since intra-chip signal propagation is much smaller than inter-chip propagation.
- On-chip wires suffer capacitance and resistance. However, off-chip wires suffer from capacitance and inductance (ringing effects).

CMOS advantages:

- Low power.
- Fully restored logic levels.
- Rise and fall transition times are of the same order.
- Very high levels of integration.
- High performance.
**Moore's Law**

1965: Gordan Moore plotted transistor on each chip

Fits straight line on a semilog plot

*Transistor count doubles every 18-26 months*
Corollaries

Many other factors grow exponentially (clock frequency, processor performance, ...)

Cost of building a semiconductor fab is doubling every three to four years.