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.

IC Technology

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)

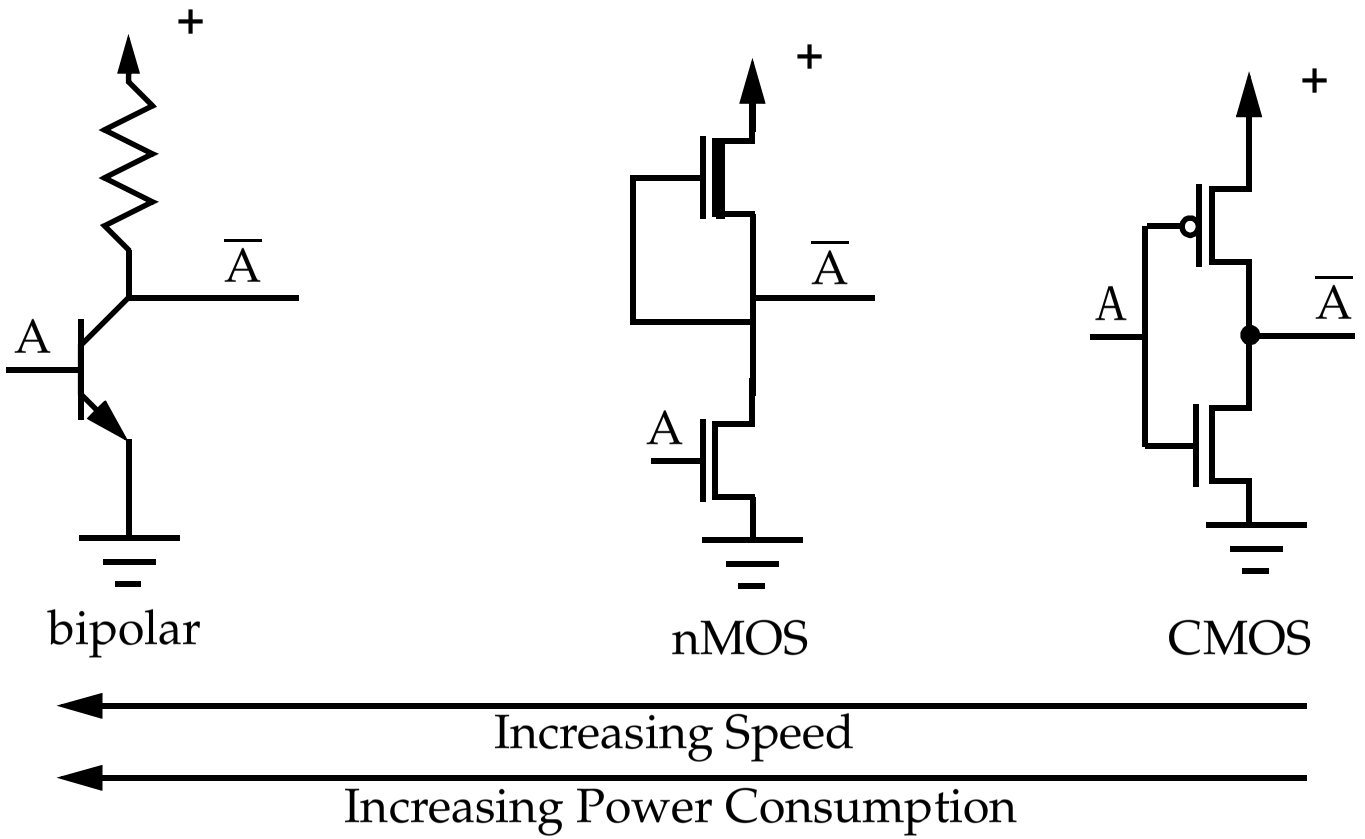
Silicon Germanium

BiCMOS

Superconducting technologies

IC Technology

Trade-offs among a few of the choices:



Changing the value of a physical variable requires more power as you change it more quickly.

CMOS Technology

Why use CMOS?

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

- Reducing chip size increases physical size of the system.
- 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.

Technology Generation

Technology generation defined by:

Feature size: Size of the smallest features on an IC, usually the length of the transistor channel.

Current feature size: **180 nm**.

What are the leading obstacles in reducing feature size?

Photolithographic tools:

Current optical techniques: **248 nm** wavelength good to **180 nm**.

Next (and probably last) generation of optical lithography: **193 nm** wavelength can reduce feature size to 130 nm, possibly down to 100 nm.

Contending solutions for 100 nm and below (*Spectrum*, "Solid state", Jan. 1998):

X-ray, extreme ultraviolet, projection electron-beam and ion projection.

Technology Generation Forecast

Moore's Law (Intel Chairman, 1965, Gordon Moore)**:**

# of transistors in IC will double every 18 months.

Table 1: Technology Roadmap for Semiconductors

	1997 (250 nm)	1999 (180 nm)	2002 (130 nm)	2005 (100 nm)	2008 (70 nm)	2011 (50 nm)
DRAM (bits)	256M	1G	4G	16G	64G	256G
MPU transistors/cm^2	3.7M	6.2M	18M	39M	84M	180M
DRAM chip size (mm^2)	280	400	560	790	1120	1580
MPU chip size (mm^2)	300	340(3.4cm^2)	430	520	620	750

MPU growth is a little slower:

Number of transistors: 2-3X every three years (DRAM about 4X%).

Die size: 20% every three years (DRAM about 40%).

Example: 6.2 million * 3.4 cm^2 = 21.1 million transistors.

Accurate for last 30 years.

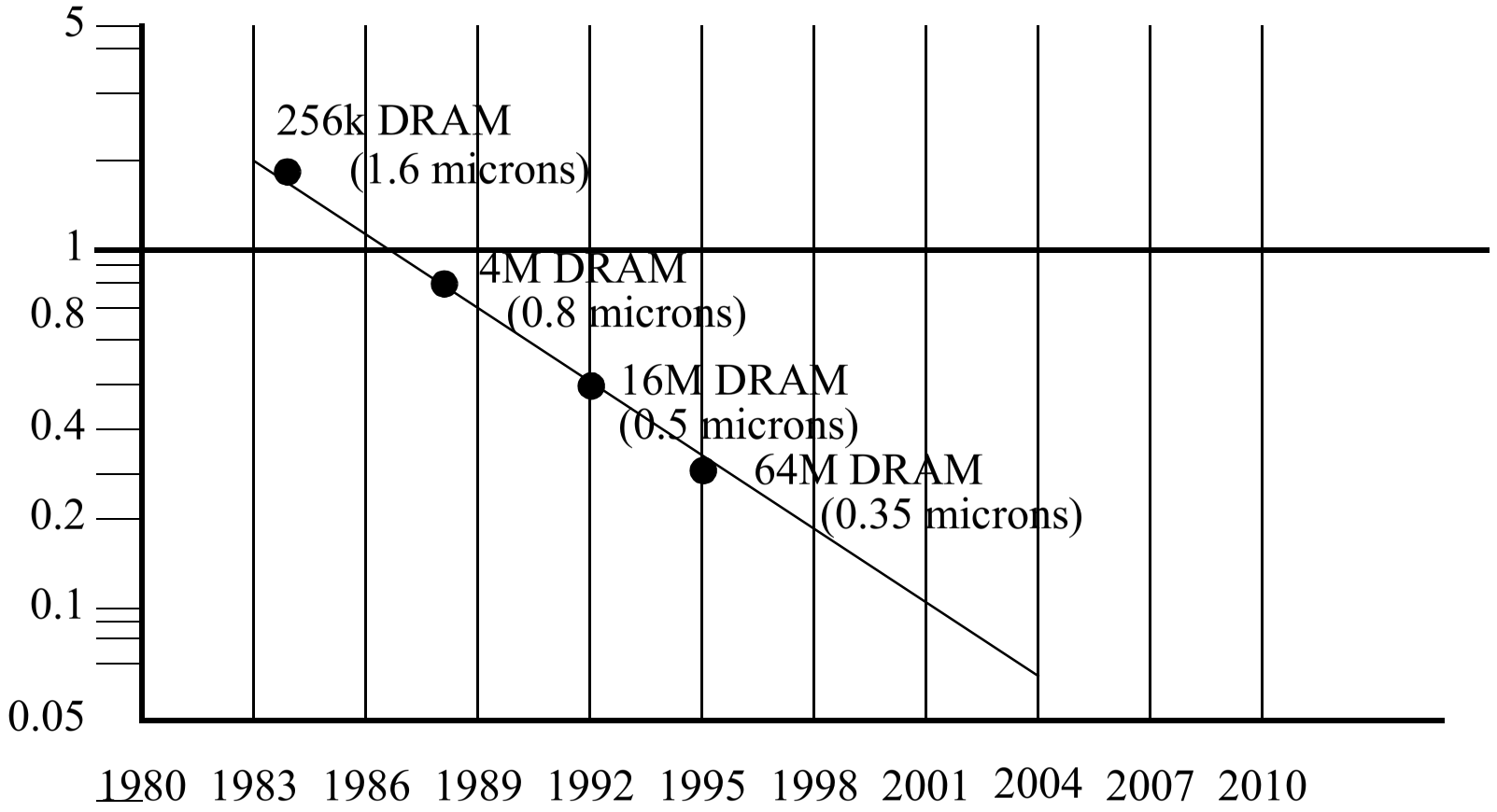
Will it hold for the next 15 years? Will it fail due to physics or economics?

Lithographic limits, design and test complexity and/or fabrication costs.

Technology Generation Forecast

Moore's Law:

Minimum transistor feature size must decrease by a factor of 0.7 every three years:



Technology Generation Forecast

Moore's Second Law:

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

In 1995, approximately 50 fabs in operation all over the world.
Another 50 in some state of completion.

Current cost > $1 billion

Toshiba predicts cost of building mega-fabs may slowdown Moore's first law.

Companies joining forces.

- IBM/Siemens(64Mbit technology)
- IBM/Siemens/Toshiba(256Mbit)

Technology Examples: Microprocessors

Pentium III Processor Characteristics:

Speed: 1GHz

Number of transistors: ~30 million

Supply voltage: <=2.0 system

Technology: 180 nm

Peak Power: ~35 Watts

System bus speed: 125 MHz

Other examples available on the web from:

- HP (Vectra)
- DEC (Alpha)
- IBM (PowerPC)
- Sun (SPARC)
- SGI
- Apple
- Motorola