Transistors

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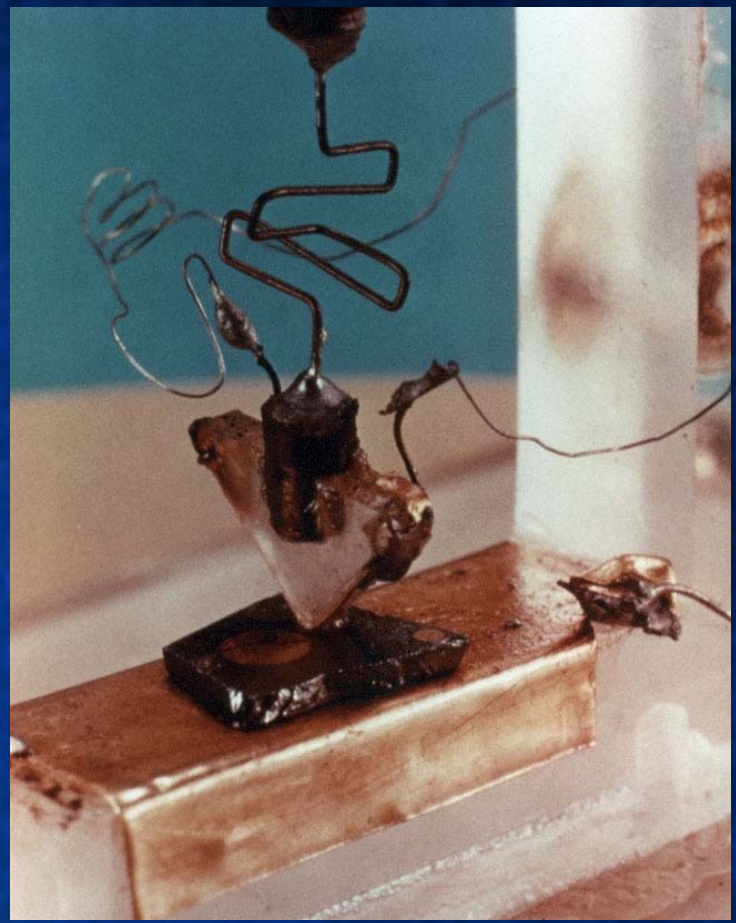
HAPPY 60th BIRTHDAY!

History

- First conceived and patented in 1928 by Julius Lilienfeld
- During WWII, research into semiconductors like geranium and silicon intensified
- First transistor was made by John Bardeen, Walter Brattain in 1947

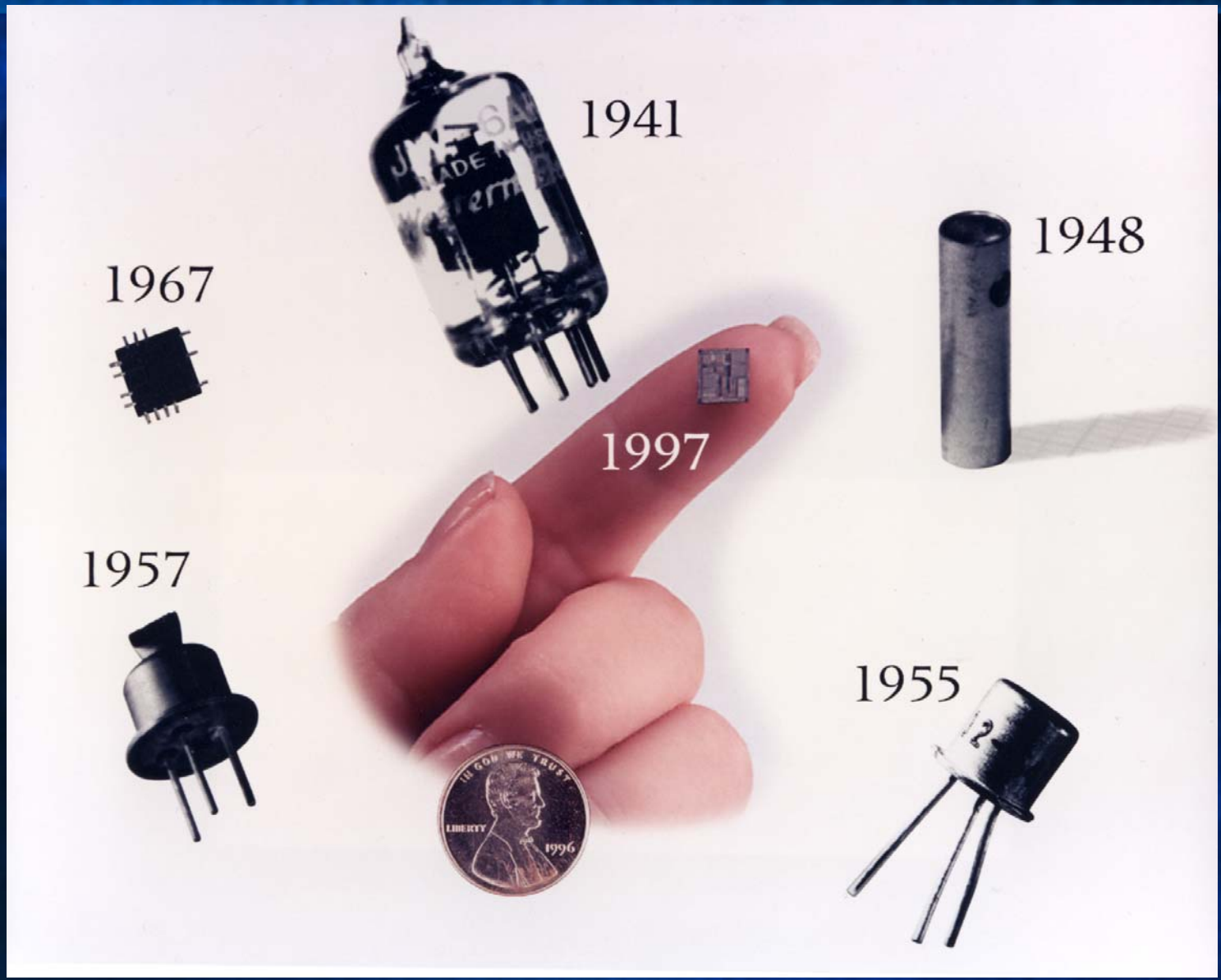


http://www.ieee.org/portal/cms_docs_sscs/sscs/07Spring/HR-1stTransistor.jpg

More History

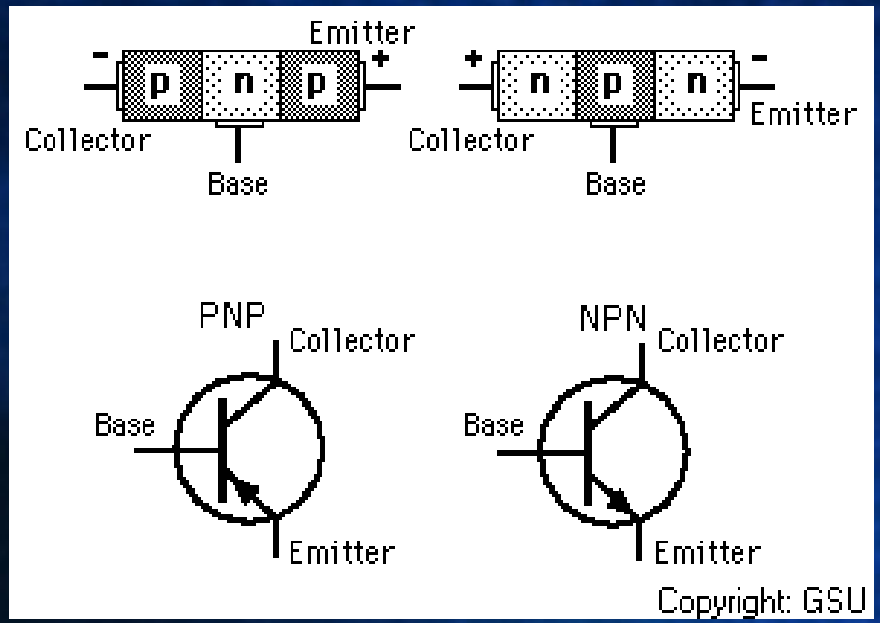
- William Shockley led the effort in the creation of the junction transistor in the early 1950s

http://th.physik.uni-frankfurt.de/~jr/gif/phys/bsb.jpg


1941
1948
1967
1997
1957
1955
IN GOD WE TRUST
LIBERTY
1996

How Transistors Work

Bipolar Junction Transistors

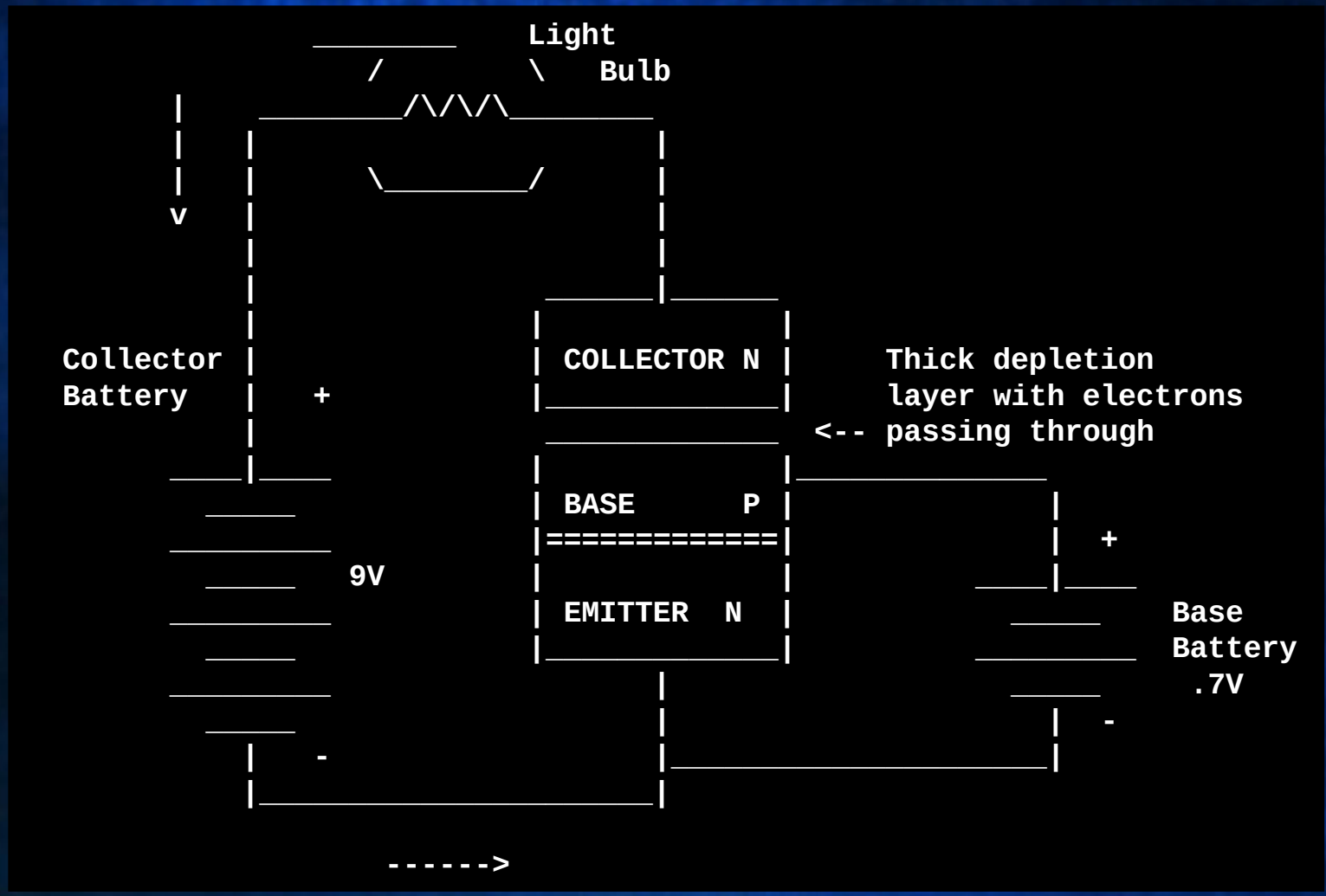


- NPN (most common) – uses electrons as carrier of current.
- PNP – uses the lack of electrons (“holes”).

The Physics of It

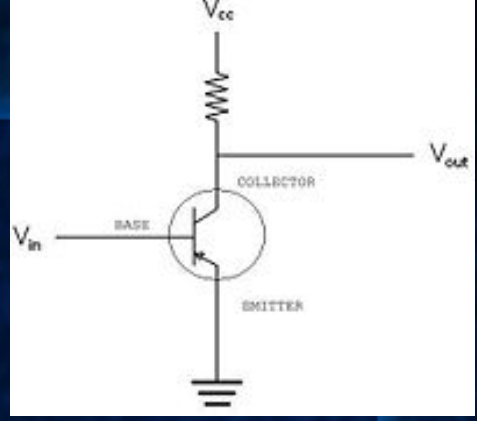
- An insulating effect occurs where the P-type and N-type are in contact. This interface is called a ‘depletion zone’.
- This insulating effect decreases when a voltage of the correct polarity is applied
- Apply a voltage across the collector and emitter.
- There’s a depletion zone between collector and base.
- Electrons which wander across the base are forced across the upper depletion zone by the applied voltage.
- The base depletion zone thus controls the collector battery current.
- This base depletion zone is controlled by the base voltage.

Diagram



Source of diagram: http://amasci.com/amateur/transis2.html

Transistors as Amplifiers



- The base/input voltage controls how much of the current supplied by the supply voltage (labeled ‘Vcc’) flows through the transistor itself, and how much acts as V_{out}.
- Small changes in the base voltage will produce large changes in V_{out}.
- You can think of a transistor like a valve: the base/input voltage controls how much of the supply voltage is allowed through.
- The ratio between the current through the collector and the current through the base is defined as h_{FE}.
- Unless the transistor is saturated, the current gain equals h_{FE}.
- Typically h_{FE} is 100.
- “Darlington pair” is when multiple transistors are connected, thus $h_{FE} = h_{FE1} \times h_{FE2}$.

Transistors as Switches

- Once the base voltage reaches a certain level, no additional current will flow
  - This level is referred to as ‘saturation’
- The input voltage can therefore be chosen so that the output is in one of only two possible states (ON or OFF)
- This allows transistors to be used as switches

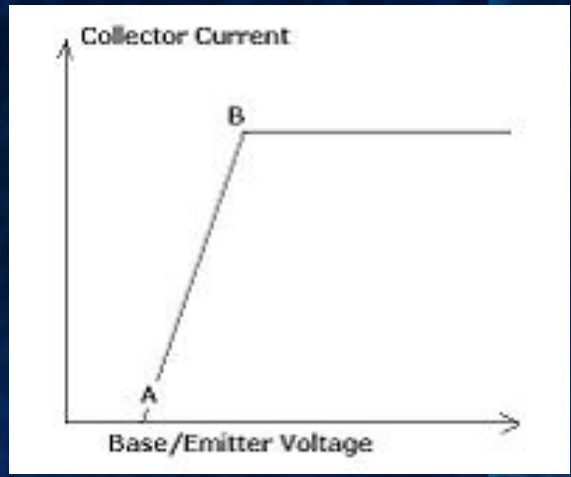
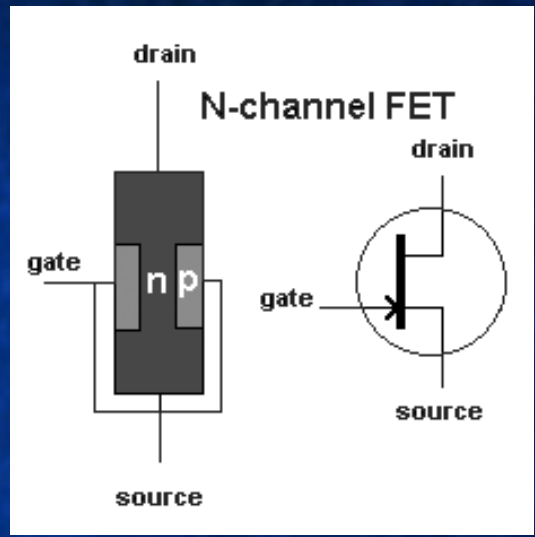


Diagram: http://en.wikipedia.org/wiki/How_a_Transistor_Works

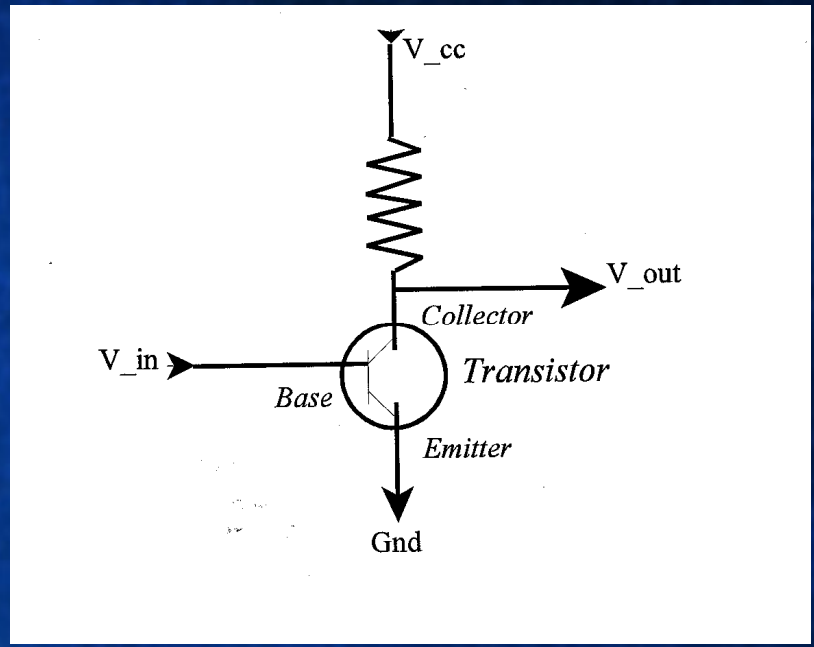
Field Effect Transistors

- Only has two layers of semiconductor material.
- Electricity flows from one layer called the channel to the other layer called the gate.
- The voltage across the gate interferes with the current, thus controlling its strength.



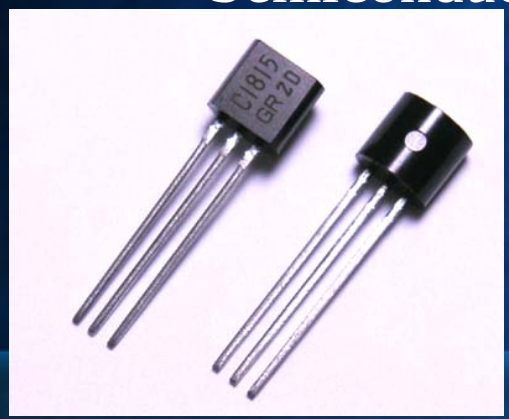
Logic Gates

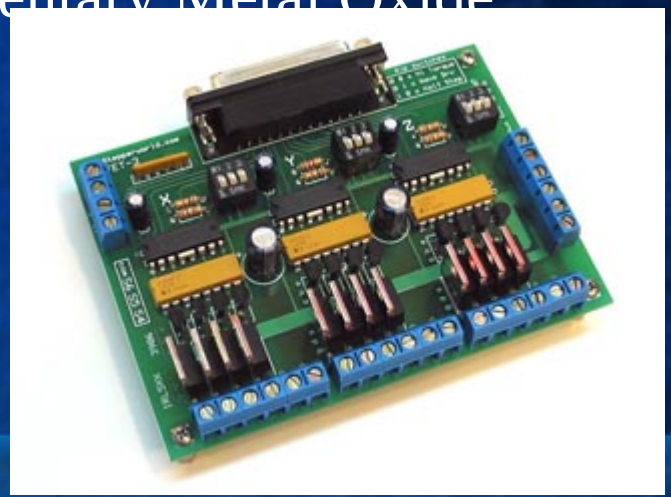
- When high voltage is applied to the *base*, the transistor behaves like a switch allowing current to flow from the collector to the emitter.
- If the collector is connected to the resistor, and a high voltage is applied to the base, current flows through the transistor causing a voltage drop across the resistor. In this case V_{out} is low.
- So if V_{in} has high voltage, V_{out} has low voltage.
- If V_{in} has low voltage, current does not flow through the resistor. Thus there is no voltage drop across the resistor and high voltage accumulates at Vout**.**
- So if V_{in} is low, V_{out} is high.
- This arrangement of transistors acts as a NOT-gate.
- Other arrangements can act as other logical gates.
- Using such gates in series allows for the construction of computers.



Main technologies for Transistor Design

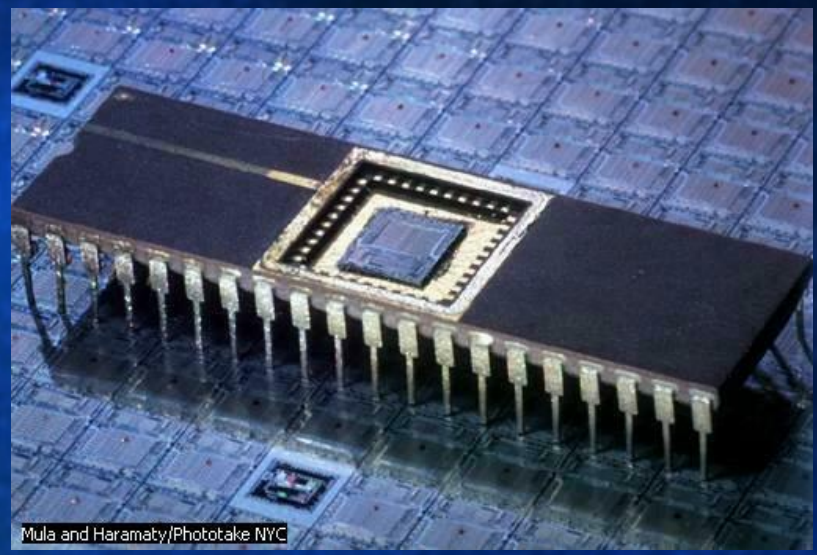
Silicon-Germanium (SiGe)	Usually refers to bipolar devices in SiGe technology, although SiGe FETs are also viable
MOS	Metal Oxide Semiconductor
Bipolar	Bipolar is a term used to describe a junction based transistor as distinct from a field effect transistor
BiCMOS	Bipolar Complementary Metal Oxide Semiconductor





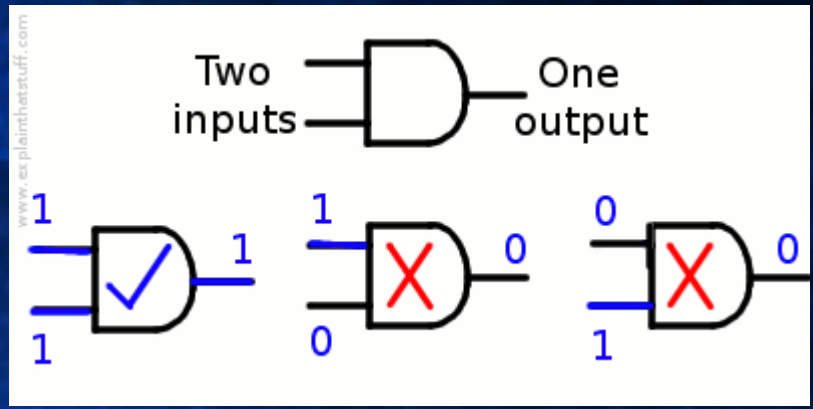
Distinct Characteristics of the Modern Applications

- 2 improvements made on the BJTs and FETs
- Used more in digital circuits than analog circuits. e.g. RAM,
- Transistors tend to be integrated into integrated circuits – digital output



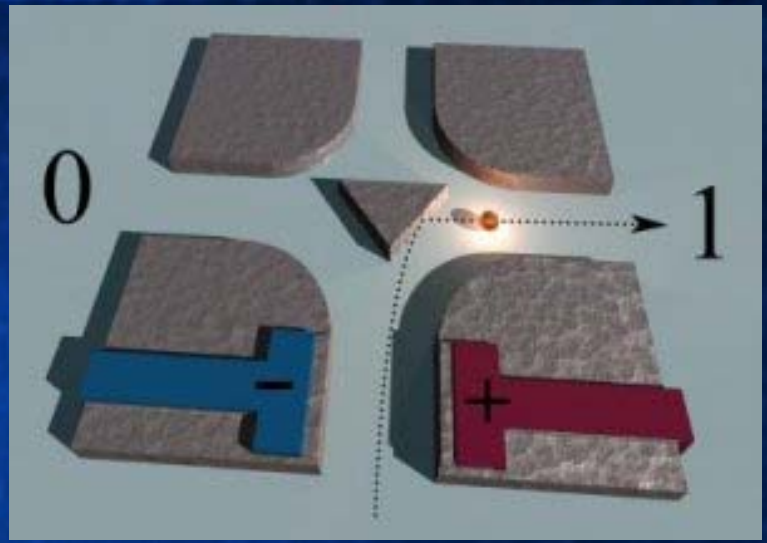
Examples

- temperature censors (analog output)
  - Ic rises exponentially with base-emitter voltage (0.6-0.7V for Si)
  - Usable when containing >1 transistor, or in an ideal device
  - Not useful alone, as Ic depends on voltage as well as outdoor temperature
- calculators of log and other functions
  - Transistors store binary numbers by switching electric currents on and off
  - Logic gates; compares 2 currents



Future Design

- Twisted Ballistic Transistor
- Electrons follow a ballistic trajectory into and out of junction (bumper)
- How it works
- gate structure crossroads design
- electric field at center of y-shaped non-conductive intersection
- inertia; electric field around the block; ballistic trajectory
- Electrons apply varying voltage differential
- an indium gallium arsenide-indium aluminum arsenide substrate increases electron flow and produces conduction
- current need not be present due to magnets
- Binary 1s and 0s
- semiconductor sheet 2D electron gas



Moore's Law

- The conjecture that the most cost-effective number of transistors per unit area on an integrated circuit will double every 12-24 months is known as Moore's Law.
- This has proven true!
- The development of transistors has allowed for this phenomenal increase in density, and thus SPEED.