ECE 101

Fundamentals of Electronics

Electronics and Communication Engineering

Devices

- Transistors
- Diodes
  - Device Physics
  - Circuits

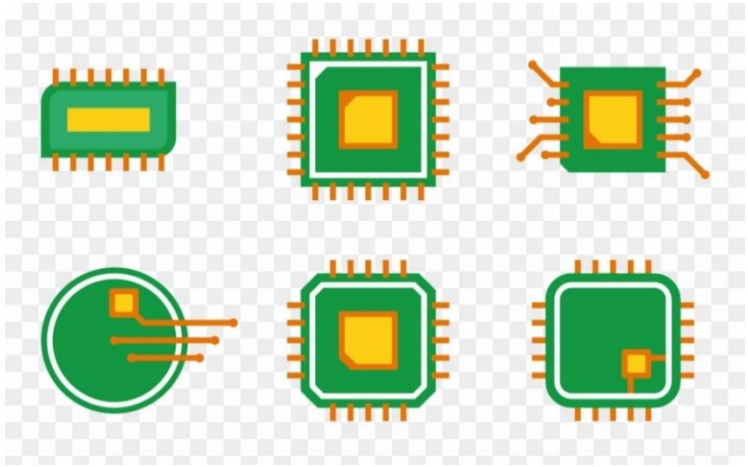
- Communication among the Devices
  - Internet
  - Internet of things

Algorithms, protocols, signal processing, modeling and simulations

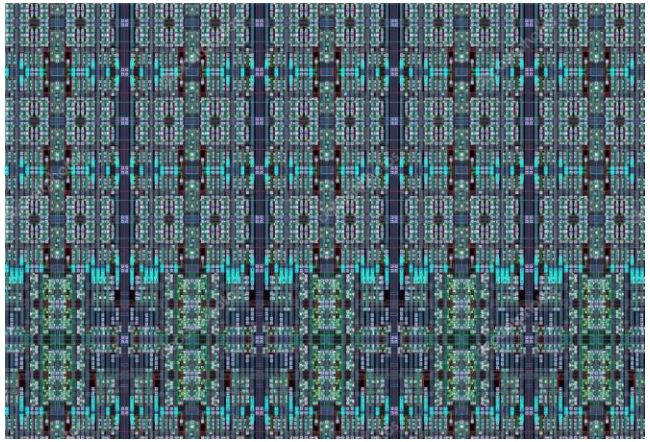
http://beta.nielit.gov.in/content/communication-technology

Introduction

Integrated circuits

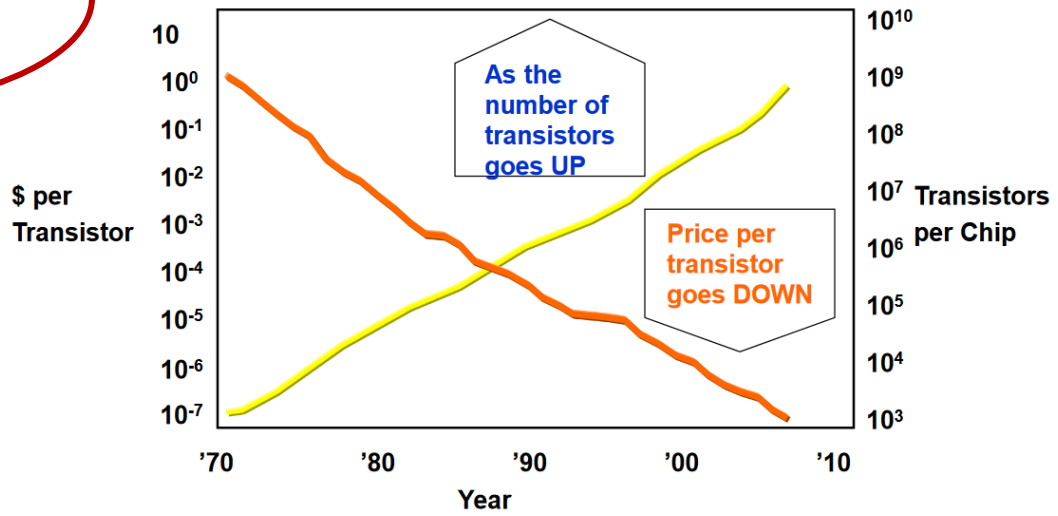


Game of electrons



Layout of a chip

https://www.dreamstime.com



Moore's law and Scaling

Number of transistors would double every 18 months.

The story of electronics is the story of conquest of the electron

History

Pre-electronics era

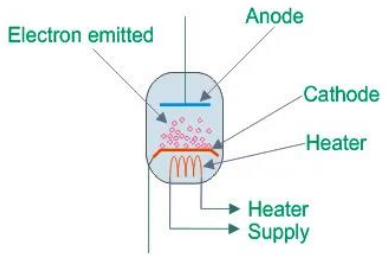
Pre-20th century,
Almost no electronics in common man's life

Electricity, Magnetism and technologies based on that

Vacuum tube electronics

Vacuum tube diode and triode invention,

Facilitated the invention of the first computer



Transistor era

The semiconductor era

Start with the birth of solid state triode - transistor

History – Summary

- Willian Gilbert, 16th Century
- Benjamin Franklin, 18th century
- Hans Christian Oersted
- Faraday
- Maxwell
  - Maxwell's equations for electromagnetic field.
  - Paved the way for the development of electric machines and communication systems.
- Edison
  - Electric bulb
  - DC
- Tesla
  - Induction motor
  - AC
- Alexandra Graham Bell, Elisha Gray
  - Telephone
- Henry Hertz
  - Radio waves (Method to transmit and detect)
- Indian Scientist J.C. Bose, Russian scientist Popov, Italian electrical engineer Marconi
  - Invented the radio and used antennas for radio communications.
- Electronic devices..
  - Vaccum tube etc.

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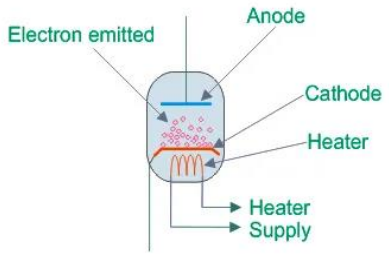


Transistor era

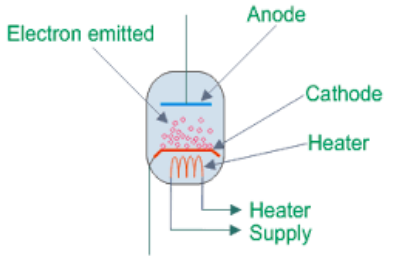
The semiconductor era

Start with the birth of solid state triode - transistor

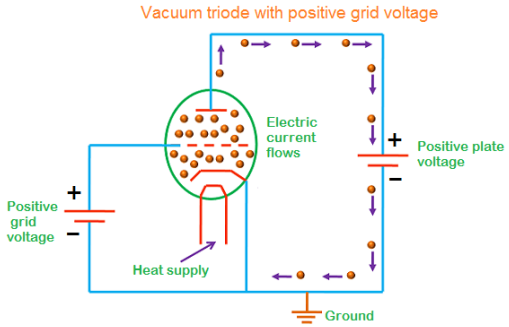
Vacuum tube electronics era, 20th century

- The first decade saw the invention of vacuum tube

- John Ambrose Fleming (UK), 1904
  - He developed a device he called an "oscillation valve" (because it passes current only in one direction). The heated filament, was capable of thermionic emission of electrons that would flow to the plate (or anode) when it was at a positive voltage with respect to the heated cathode.
  - Electrons, however, could not pass in the reverse direction because the plate was not heated and thus not capable of thermionic emission of electrons.
  - It worked as a very important part in radio communication – for AC to DC conversion
  - This is considered to be the birth of electronics.



- Lee De Forest (US), 1906
  - Invented triode
  - Besides anode and cathode, it had a third terminal as well (grid) which controls the flow of the electrons
  - It acted like amplifier – a key component in communication



Ref: https://ethw.org/w/images/8/87/Routray.pdf

Technological innovations: vacuum tube technology

- Diode
  - Rectifier
- Triode
  - Amplifier
- Radio communication technology
- Television
- Radar
- Computer

Electronics in 20th century

- Then came photoelectric effect and quantum mechanics
  - Our fundamental understanding of nature was revolutionized.
  - Planck, Einstein, Bohr, De Broglie, Heisenberg, Schrödinger and Dirac.

https://en.wikipedia.org/wiki/History_of_quantum_mechanics

- Then came world wars
  - The development of electronics saw huge jump
  - Due to the world wars, there was a big need of computers for war related tasks like code breaking.

Ref: https://ethw.org/w/images/8/87/Routray.pdf

History – the transistor era (solid state electronics)

- Transistor
  - Switching
  - Amplification

- The solid-state electronics goes back to the invention by Ferdinand Braun of the solid-state rectifier in 1874.
  - His work centered around the solid-state rectifier using a point contact based on lead sulfide.

- With the need for high frequency applications, the idea of point contact made a comeback.

- 1920s onwards, understanding of quantum mechanics played an important role in developing solid state electronics.

- Without QM, a good understanding of solids (metals, semiconductors, insulators) would have been impossible. – Electronic band structure came about due to that reason only.

- Development of the quantum theory of solids led by Peierls, Wilson, Mott, Franck, and others – electron conductivity in metals.

History – the transistor era (solid state electronics)

- Mervin Kelly, at Bell Labs, decided in 1936 that he should start a solid-state device group.

- It is interesting to note that by 1938, two Germans (Pohl and Hilsch) described a solid amplifier made using potassium bromide that had three metal leads.
  - However, this device turned out to have too low an operating frequency. Also, it was not a device that could be used in any true sense for electronics.

- By 1940, Russell Ohl had done a great deal of work, along with others at Bell Labs, in an attempt to understand silicon crystals.
  - Ohl learned that depending on how you prepared single crystals of silicon, you could get either n- or p-type silicon.

- Ohl actually was able to make a sample in which the top part was a p-type region and the bottom was n type, and he found that when light was shone on it, it actually developed a voltage.
  - Solar cell

- Ohl's piece was given to Brattain to re-measure it the voltage when light is shown over the sample.

- Impurities that were responsible for n-type and p-type character of material

History – the transistor era (solid state electronics)

- Post WW II, the solid-state group was again re-constituted.
  - Bardeen made important contributions to understand field effects transistor.
- The Field-Effect idea: the field can tune the conductivity of the material.
- By simple calculations, he showed how even a small concentration of surface states can screen the field from the interior.
- Bardeen and Brattain started attempts to clean the surface
- In Nov 1947, the transistor was improved in Dec 1947.
- In June 1948, they had a press conference with the circuit made from transistor and voices being amplified over it.

Transistor

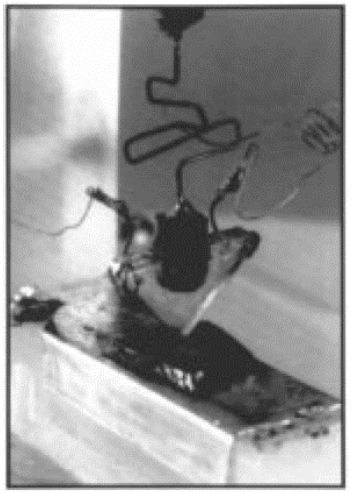
Transfer + varistor [transfer + resistor]

The idea

- **Three terminal device**
  - **Switch, amplifier**
  - Output across two terminals can be amplified by applying current/voltage across the other two terminals
  - BJT, **FET**

History

- **1947 – Bell Labs:** Shockley, Bardeen & Brattain
- **FET: 1926 –** conceptualized by Lilienfeld
- **Transistors as switch**

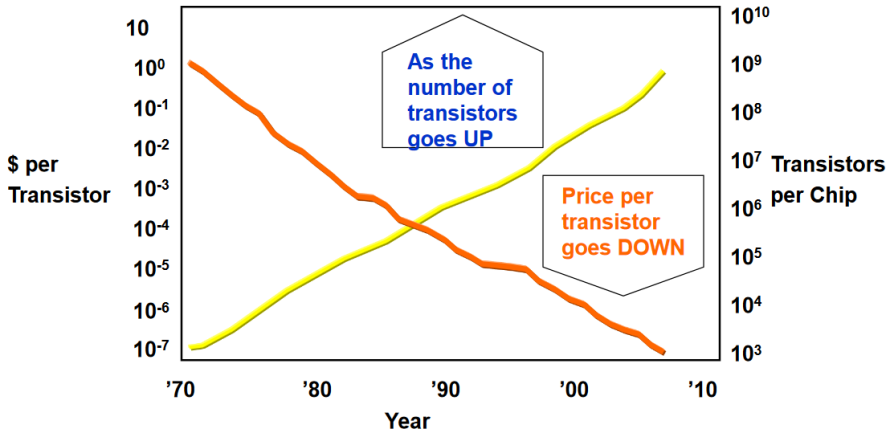


History: The transistor era – integration

- An IC is a set of electronic circuits on one small flat piece (or "chip") of semiconductor material, normally silicon.

- The integration of large numbers of tiny transistors into a small chip results in circuits that are orders of magnitude smaller, faster, and less expensive than those constructed of discrete electronic components.

- Integrated circuits were made practical by mid-20th-century technology advancements in semiconductor device fabrication.
  - Since their origins in the 1960s, the size, speed, and capacity of chips have progressed enormously
  - 1968 – Intel was founded.



Moore's law and Scaling

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Thank you