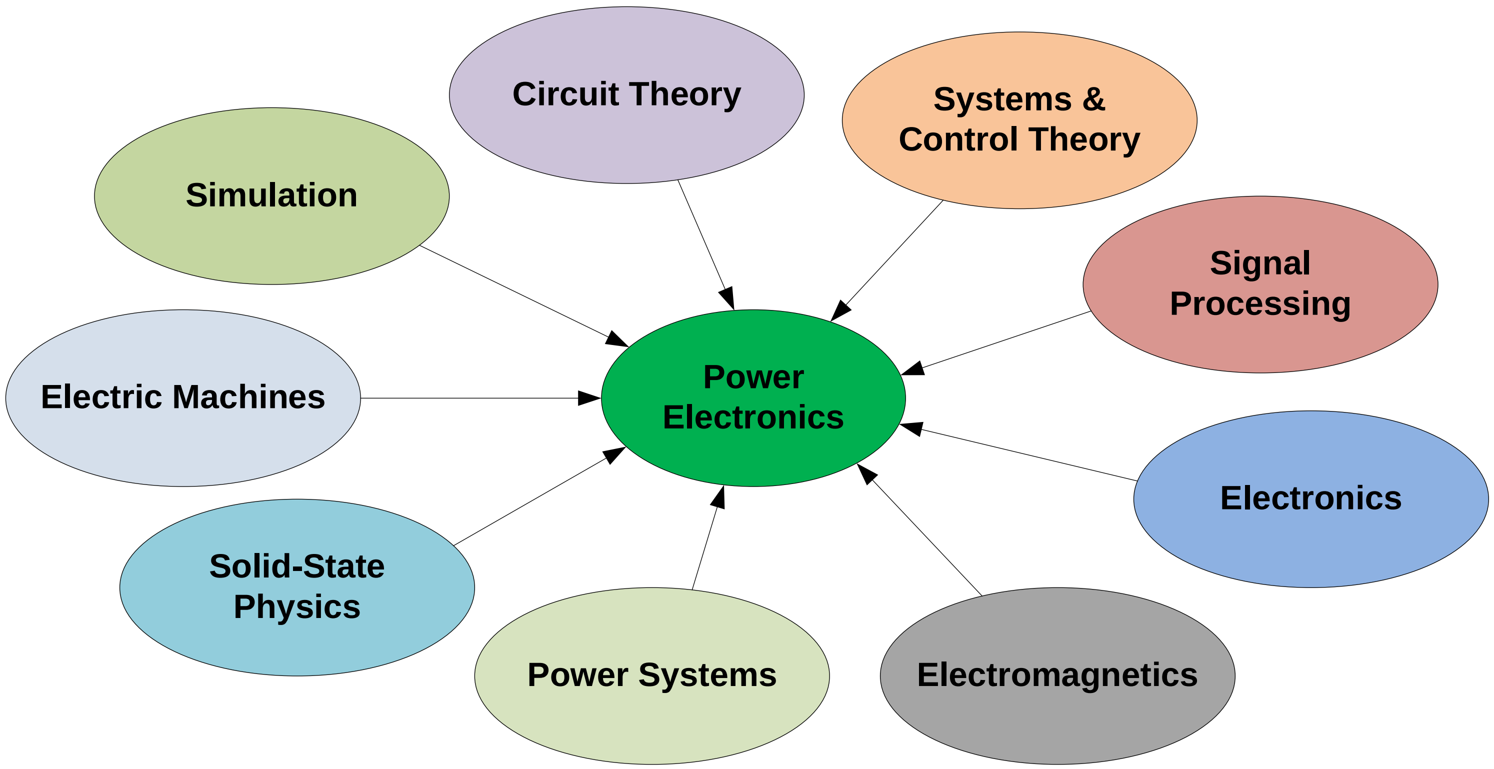
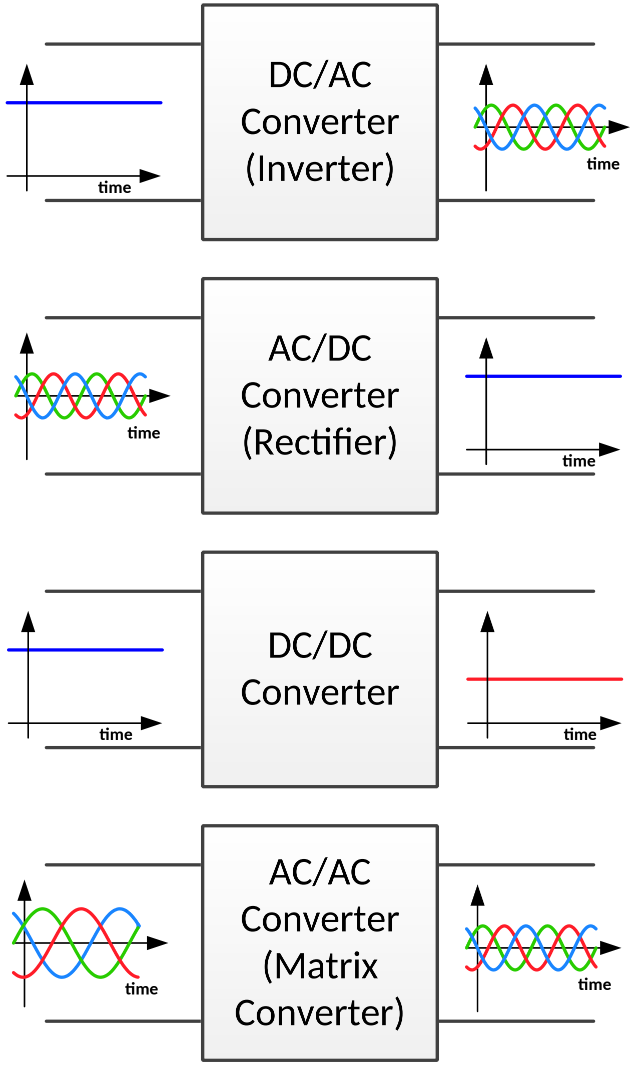
Power Electronics Overview

Overview – *Power Electronics*



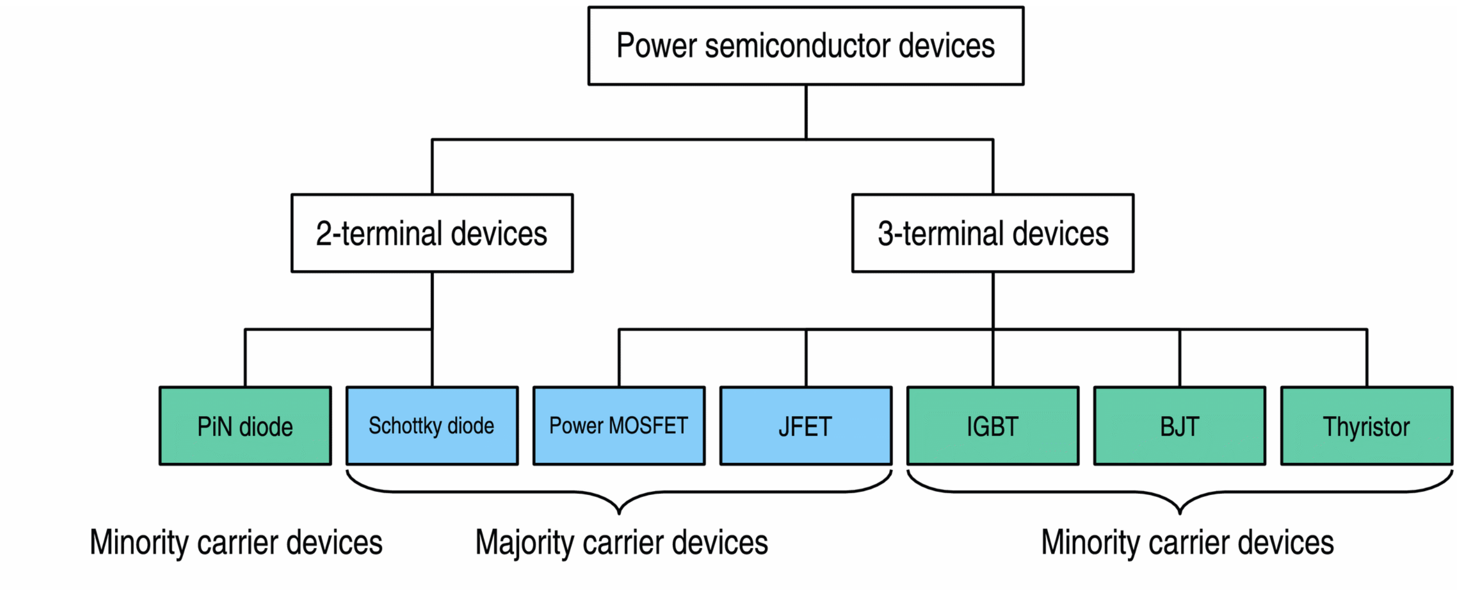
Interdisciplinary Nature of Power Electronics

Overview – *Converter Topologies*



electrical power processing

Semiconductors – *Power Electronics Devices*



Power Electronic Devices (copied from https://commons.wikimedia.org/wiki/File:Power_devices_family.png)

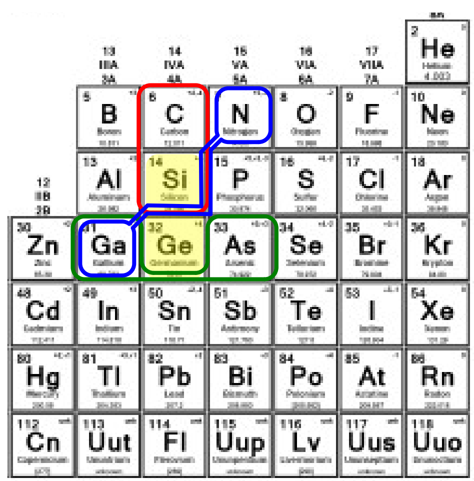
Semiconductors – *Power Electronics Devices*

Common Semicoductors:

Material	Symbol	Group
Germanium	Ge	IV
Silicon	S	IV
Gallium Arsenide	GaAs	III-V
Silicon Carbide	SiC	IV
Gallium Nitride	GaN	III-V
Gallium Phosphide	GaP	III-V

Elemental Semiconductors (Germanium, Silicon)

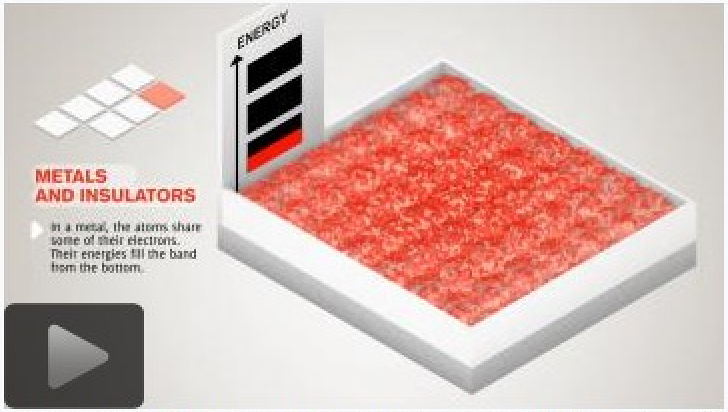
Compound Semiconductors (Gallium Arsenide, Silicon Carbide, Gallium Nitride, Gallium Phosphide)



Semiconductors – *Power Electronics Devices*

The Fermi-Dirac distribution function gives the probability that (at thermodynamic equilibrium) a state having energy ϵ is occupied by an electron:

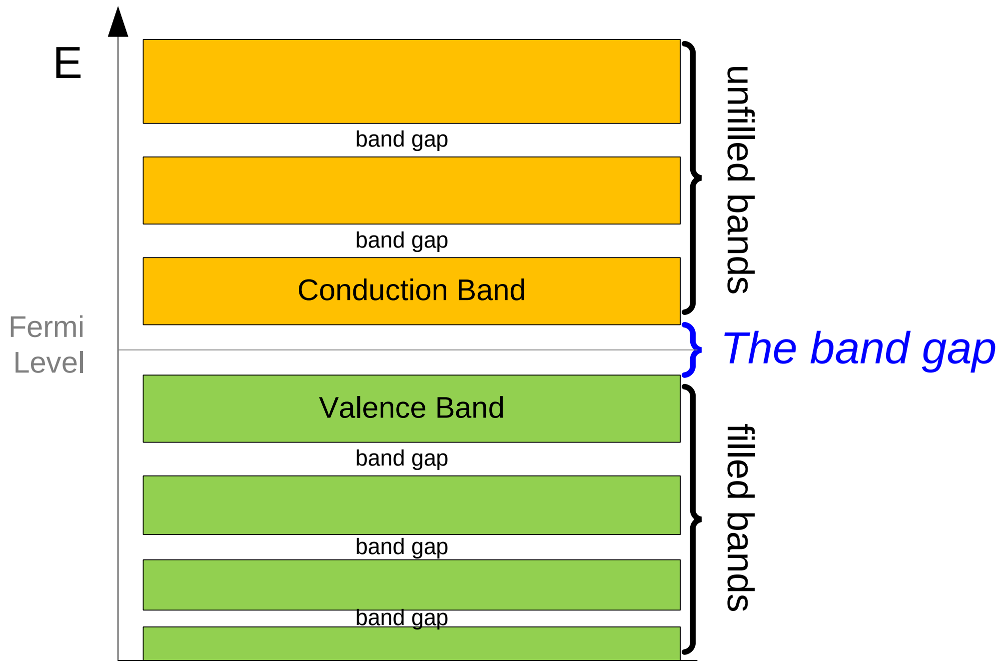
at Fermi Level



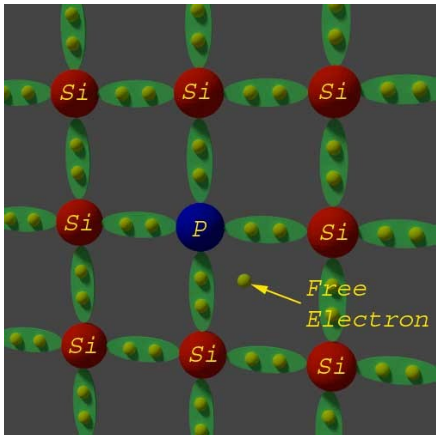
Animation of band formation and how electrons fill them in a metal and an insulator

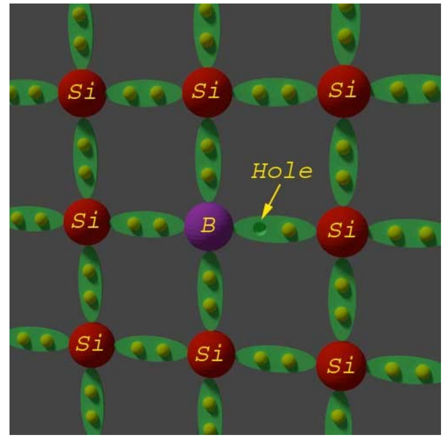
Copied from (https://en.wikipedia.org/wiki/Electronic_band_structure)

Semiconductors – *Power Electronics Devices*

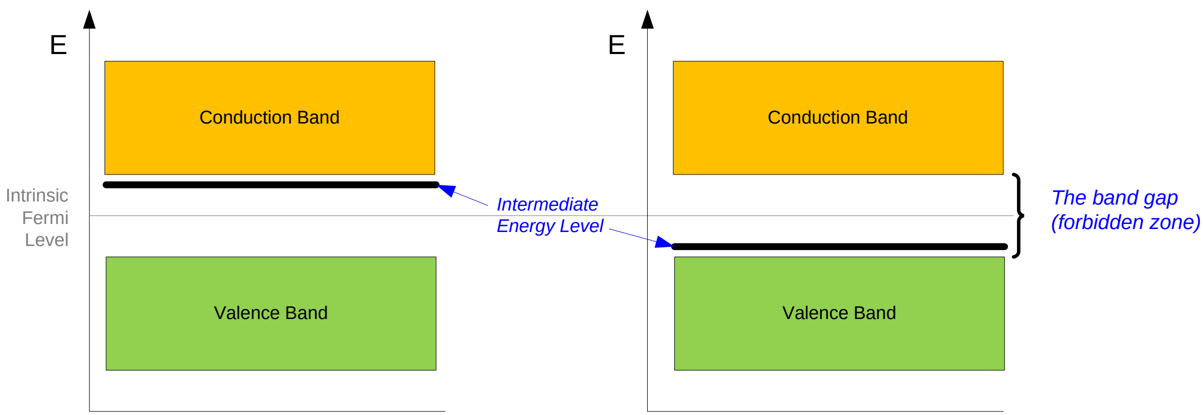


Semiconductors – *Power Electronics Devices*





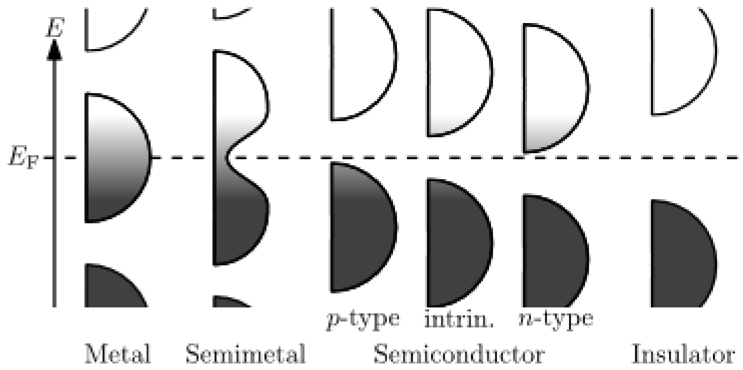
pictures from
http://www.electrical4u.com/donor-and-acceptor-impurities-in-semiconductor/



n-Type Material

p-Type Material

Semiconductors – *Power Electronics Devices*



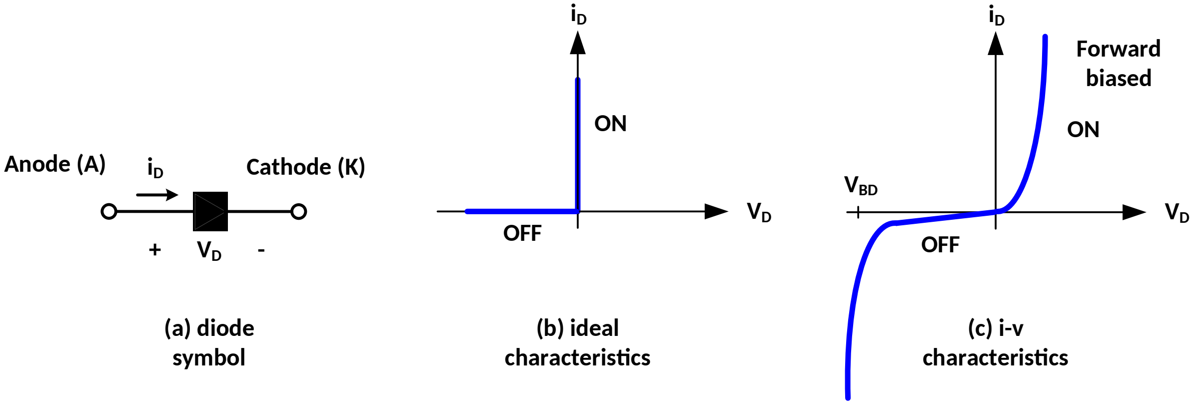
Filling of the electronic states in various types of materials at equilibrium. Here, height is energy while width is the density of available states for a certain energy in the material listed. The shade follows the Fermi–Dirac distribution (black = all states filled, white = no state filled). In metals and semimetals the Fermi level E_F lies inside at least one band. In insulators and semiconductors the Fermi level is inside a band gap; however, in semiconductors the bands are near enough to the Fermi level to be thermally populated with electrons or holes. (Copied from https://en.wikipedia.org/wiki/Fermi_level)

Semiconductors – *Power Diodes*

Power Diode

- First power diode developed in 1952
- Replaced mercury-arc converters

Diode

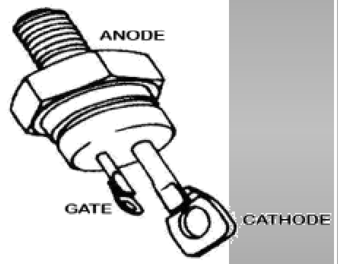


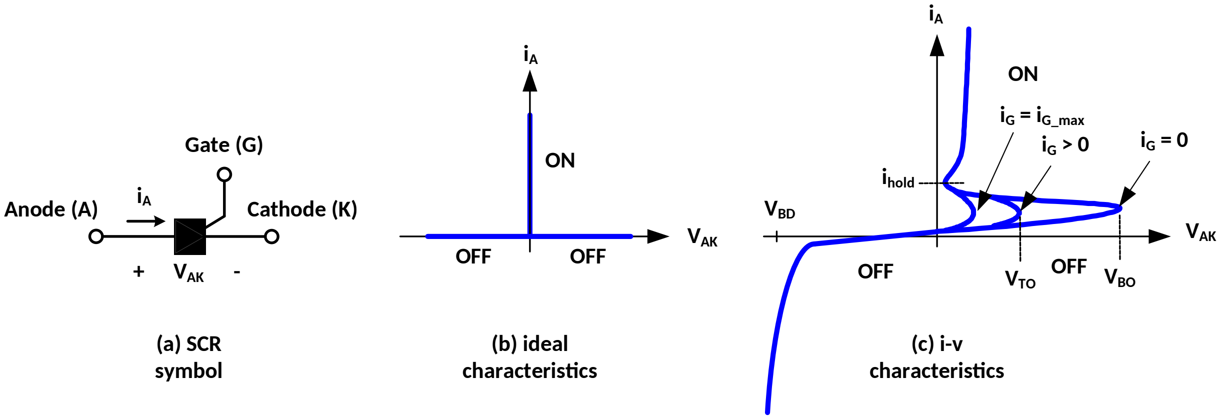
Diode Characteristics

Semiconductors – *Silicon Controlled Rectifier*

Thysristor – Silicon Controlled Rectifier (SCR)

- First commercially available power electronic device (GE – 1957)
- Was essentially the only viable power electronics device for the next 25 years
- Converts AC grid power to DC
  - DC machines (process industry, traction drives, etc.)
  - DC power supplies (welding, metal plating, battery chargers, etc.)
- Load Commutated Device (turns off when current goes to zero)
- Later developments in SCRs GTO, MCT, IGCT (Turn-off devices)



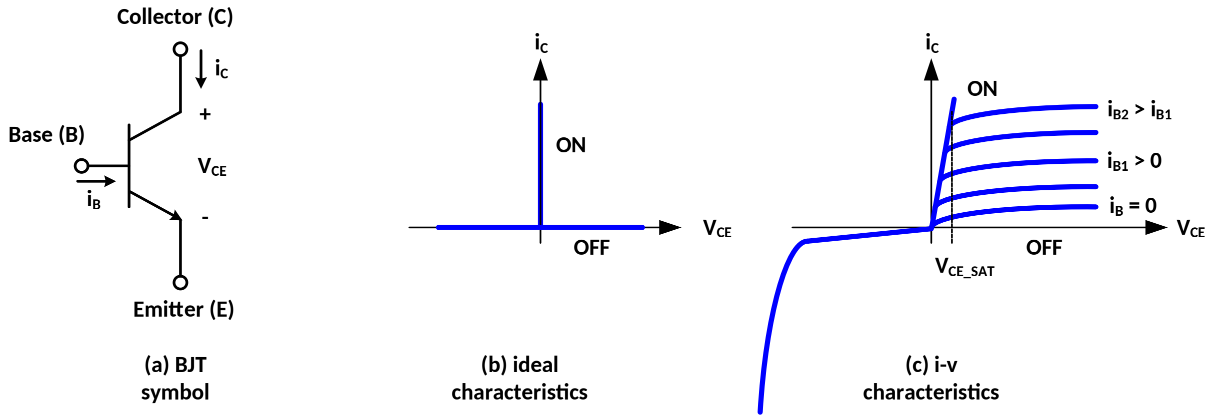


Thyristor Characteristics

Semiconductors – *Power BJT*

<u>Bipolar Junction Transistor</u>

- Developed in 1970
- Low to medium power and frequency
- Difficult base drive requirements (current controlled)
- <u>Essentially obsolete due to voltage controlled (FET) devices</u>



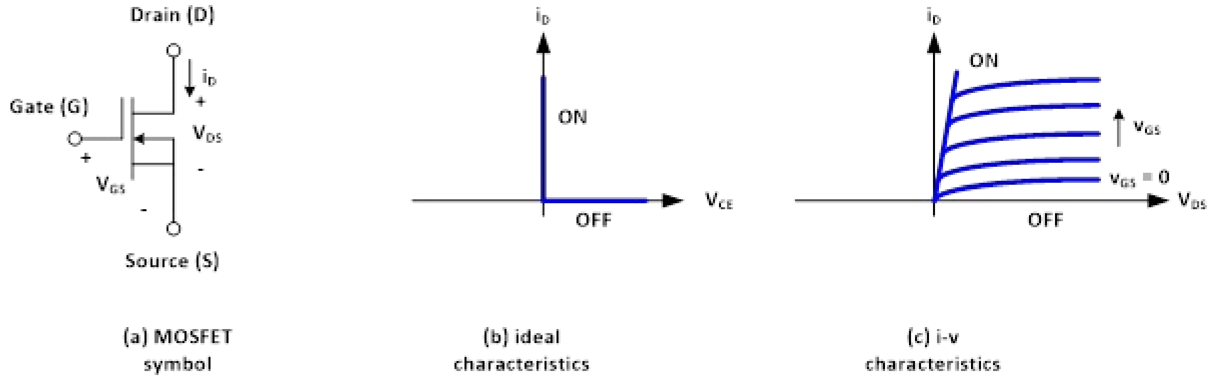
BJT Characteristics

Semiconductors – *Power MOSFET*

MOSFET

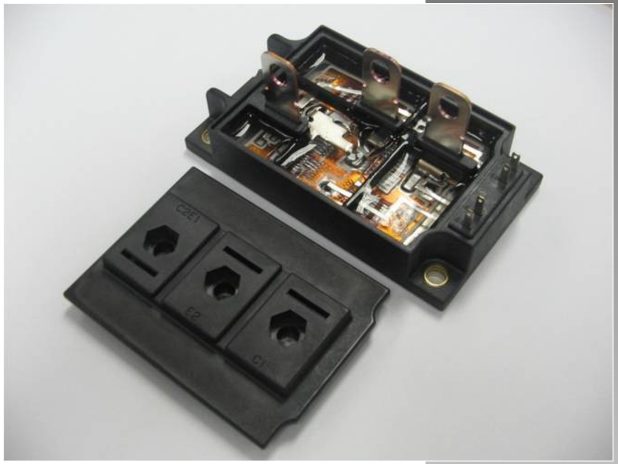
- Developed in 1978
- Voltage controlled gate low gate drive power required
- Used pervasively in low to medium power

Capable of very high frequency



MOSFET Characteristics

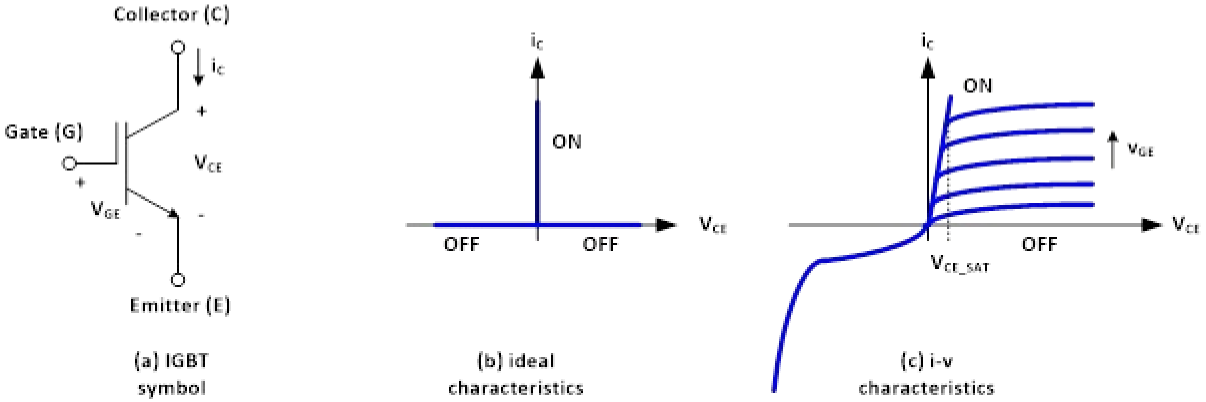
Semiconductors – *Insulated Gate Bipolar Transistor*



IGBT

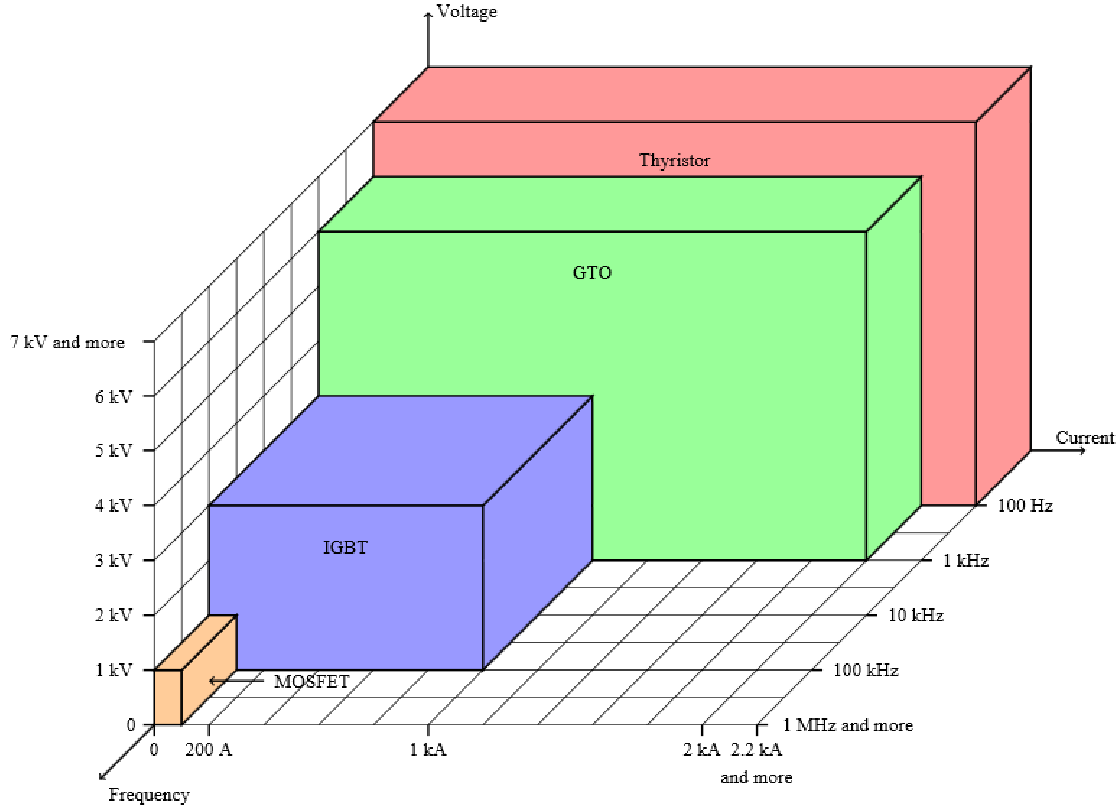
- Developed in 1983
- Combined power of BJT and gate control of MOSFET

Currently on 6th generation design



IGBT Characteristics

Semiconductors – *Power Range*



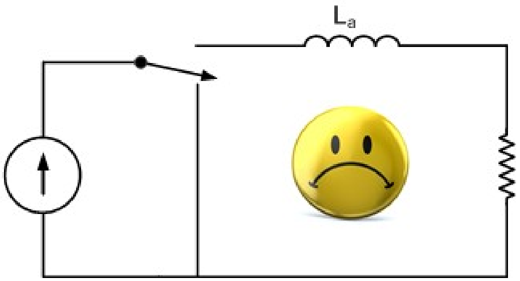
Current/Voltage/Switching Frequency Domains of Main Power Electronic Switches
(Copied from https://en.wikipedia.org/wiki/Power_semiconductor_device)

Semiconductors – *Golden Rules of Power Electronics*

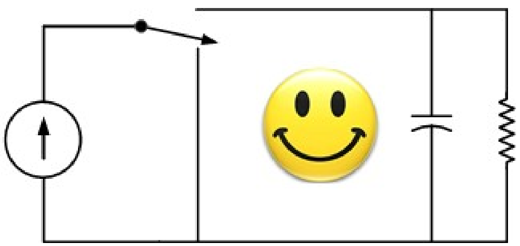
Power Electronics Review

Basic Rules of Power Electronics

- Inductor current cannot change instantaneously
- Capacitor voltage cannot change instantaneously
- Average voltage across an inductor = 0
- Average current through a capacitor = 0
- Energy is always conserved



Not good, cannot change current instantaneously through an inductor



No problem, capacitor current can change instaneously, voltage cannot