

COURSE ON

# Power Devices and Circuits

Master degree

Electronic Curriculum

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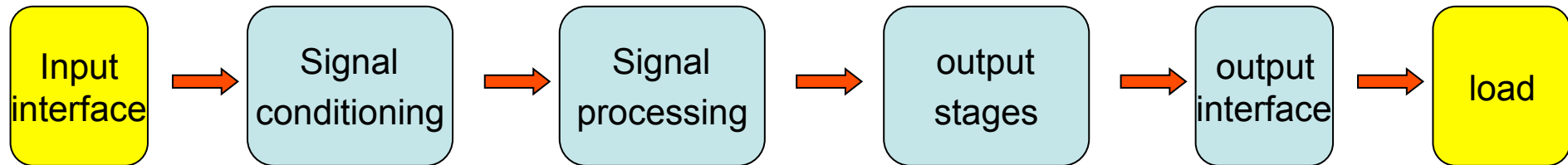
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# What is the scope of Power Electronics?

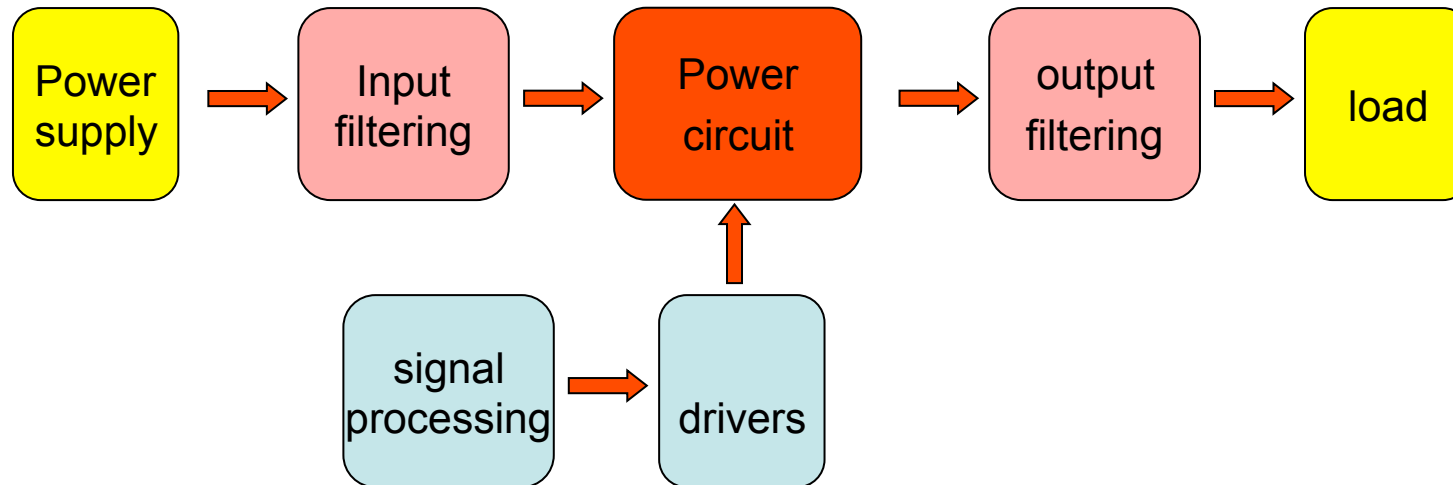
In many electronic systems, attention is given to the flow of the **information** (signal) from the input interface to the conditioning and processing stages, and finally to the output stages that should drive the external load, as schematically indicated in this figure:



**Power electronics** instead pay attention to the ways of changing, controlling, conditioning, the (unconditioned) **power** given by the external supply to the conditioned one required by the load.

The key aspect is the **efficiency** of power transfer from the supply to the load

A typical block chain for a power electronic system can be the one indicated in figure:



In the power circuit, the conditioned signal given by the (analog or digital) building blocks is applied (through some driver stages) to the power devices that actually are the core of any power circuit. The power circuit must then give the controlled power (current and voltage, changing with time) needed to drive the load.

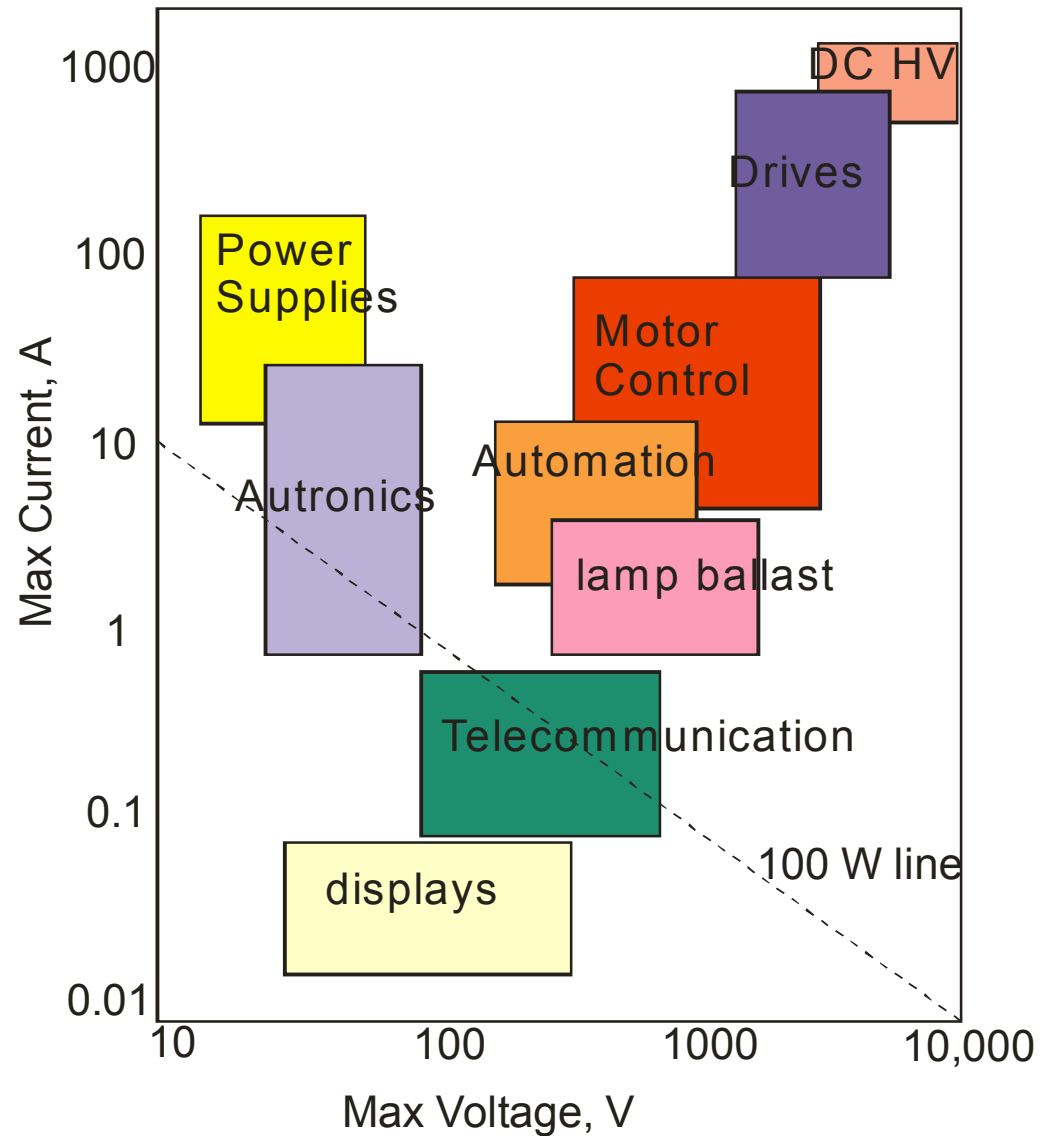
The loads can be very different, such as: Motors, Actuators, Ovens, Lamps, Electronic systems supply, Displays, Output antennas, Spark plugs, Pumps, and so on.

# MOST IMPORTANT APPLICATIONS OF POWER ELECTRONICS

Some most relevant applications for power electronic circuits are indicated in the following graph.

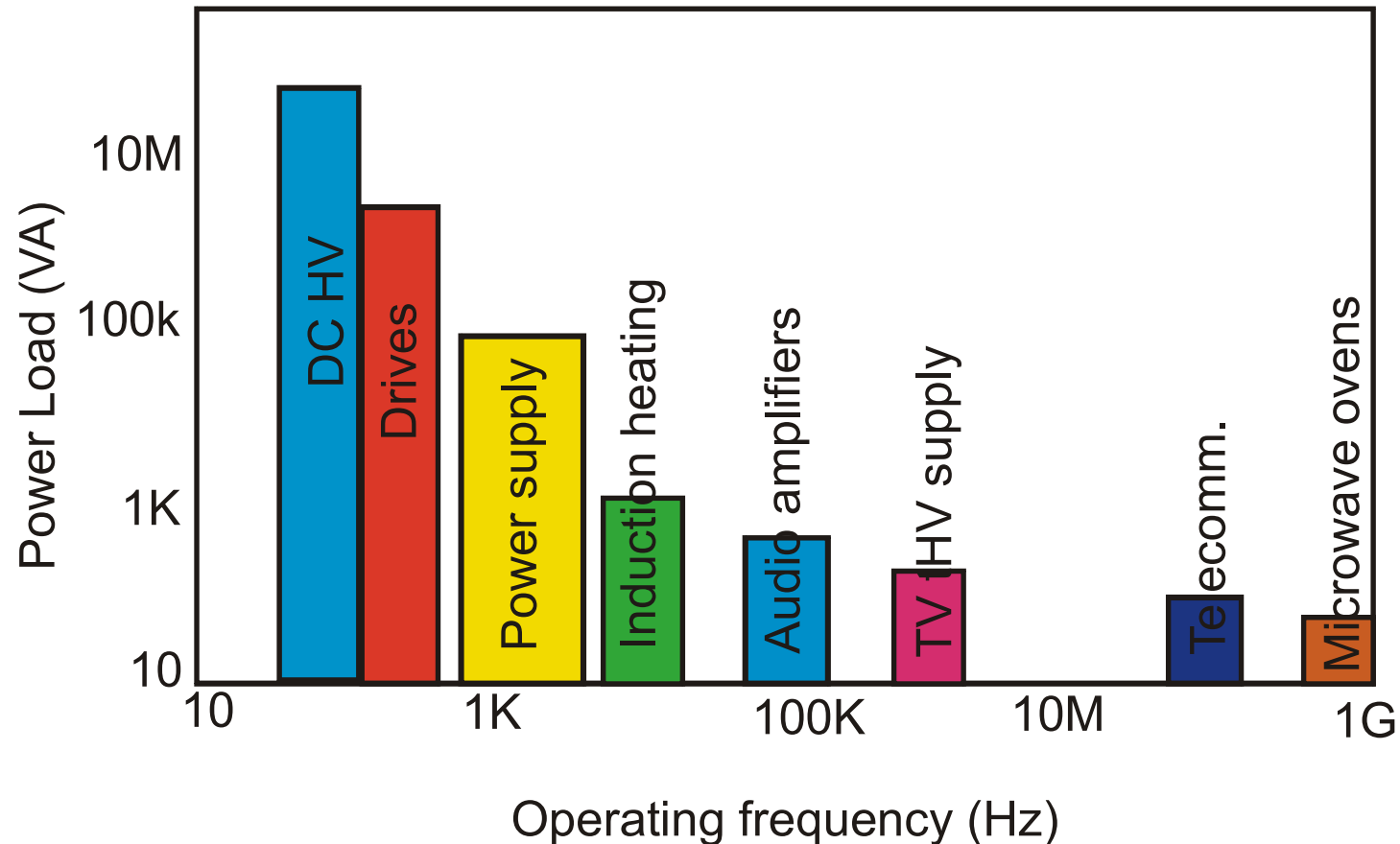
One can note the very different voltages and currents ratings needed for the different applications.

We span in power needs from the smallest ones (some watts) to the larger ones (some tens of MW)



# Operating Frequency

For most of these application fields, the power needs gets smaller when the operating frequency required is higher, so the requests for a fast dynamics of the devices needed for the power circuits is reduced at the high current and voltage ratings.

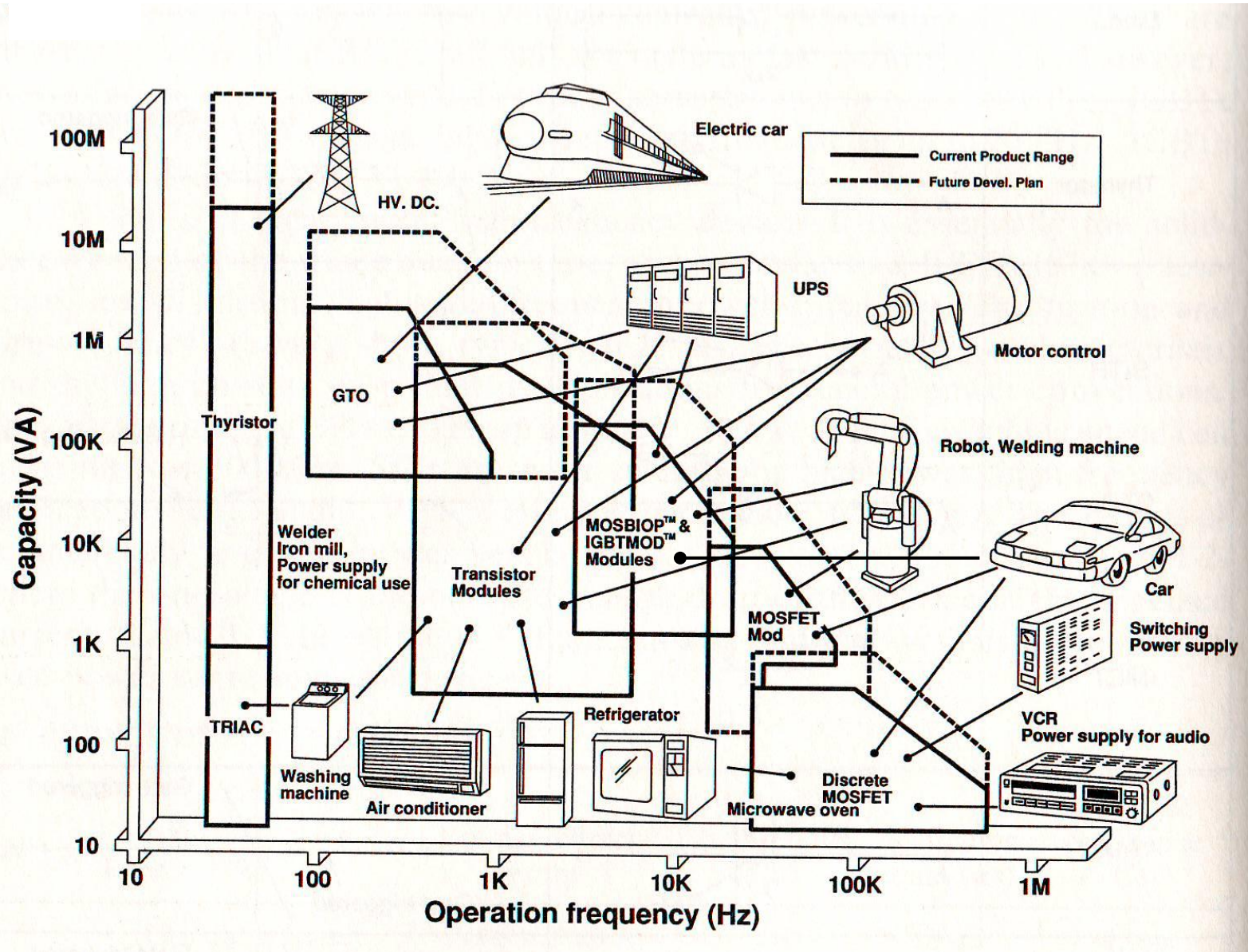


This will lead to **different types of power devices** to be used in the various power ranges required, as we will see in the following of the course.

# Power devices used in different applications

In this figure, the power and frequency requests for some of the key power applications are associated to the most used power devices, either in module or in discrete packages:

- *Bipolar transistor*
- *Power MOS*
- *IGBT*
- *Thyristor (SCR)*
- *GTO*



## Scope of the course

- The course will present and discuss the main **circuits** used for power conversion and power management, that can be used in the different applications seen before, with emphasis to the role played by the active devices used in these circuits.
- Then the different **power devices** available for power applications will be presented, and their operational principles will be discussed and analyzed, with reference to the limits of operation, Safe Operation Area, and static and dynamic performances.



## Course contents

### ***Basic principles of Power Electronic Circuits***

- *Power Amplifiers*

  - operating class A, B, D
  - power conversion efficiency
  - power dissipation

- AC/DC converters (rectifiers)

  - half and full bridge rectifier
  - bridge rectifier
  - diode ratings
  - capacitance and inductance filtering

- DC/DC converters (Step-down, step-up, bridge)

  - Ideal circuit schematic
  - Principle of operation
  - Input to output transfer function
  - Filter and ripple
  - Circuit realization with power devices
  - Efficiency vs current and frequency
  - Drive circuits



- *DC/AC converters* (inverters)
  - Principle of operation
  - Circuit realization with power devices
  - Driving circuits

### ***Devices power dissipation***

- *Static power losses*
- *Thermal characterization:*
  - thermal resistance: definition and modeling
  - thermal impedance: definition and modeling
  - device packages
- *Switching power losses*
  - Resistive and inductive load switching
  - Snubber circuits: turn-on and turn-off snubber networks



•**Power PIN diode:**

Breakdown voltage

Junction termination

I-V curve in high injection

generation and recombination lifetime

Dynamic behaviour (turn-on, turn-off)

Fast recovery diodes

•**Power Bipolar transistor (BJT)**

Device structure

Current gain and quasi-saturation region

Emitter current crowding

Thermal instability

Max rating voltages

Safe Operating Area

Drive circuits



- ***SCR and GTO devices***

- Device structure
- Output I-V curves
- Turn-on condition
- Turn-on dynamics
- GTO structure
- Turn-off gain

- ***Power MOS (VDMOS)***

- Device structure
- Output I-V curves
- On Resistance
- Planar and trench Power MOS
- Max voltage ratings
- Inductive load switching
- U.I.S. and S.C. testing
- Safe Operating Area



- ***Insulated Gate Bipolar Transistor (IGBT)***

  - Device structure

  - Output I-V curves

  - NPT and PT structures

  - Inductive load switching

  - U.I.S. and S.C. testing

  - SOA

- ***New materials for power devices***

- Laboratory work***

  - Power circuit simulations and analysis with Spice

  - Power device simulations with PC1D software

