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The Basics of Power Electronics

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Common Questions/FAQs

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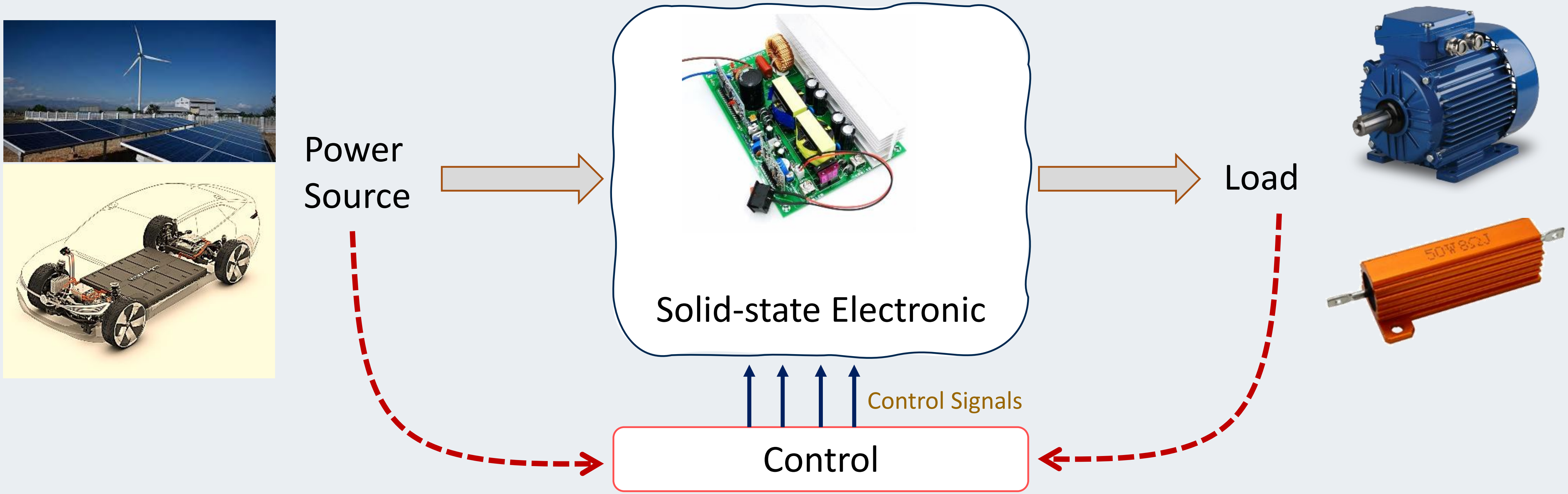
What is Power Electronics ?

The term power electronics refers to solid-state electronic devices used for the conversion and control of electric power.



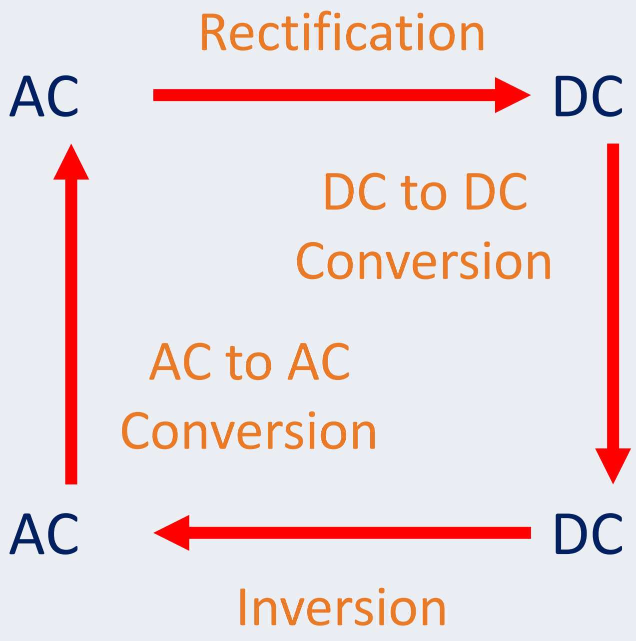
Power Electronics is a field which combines Electric Power, Electronics and Control

What does Power Electronics do ?

Efficient, flexible control and conversion of electrical energy

AC sources: single phase or three phase AC

AC loads: machines, power transmission and distribution systems



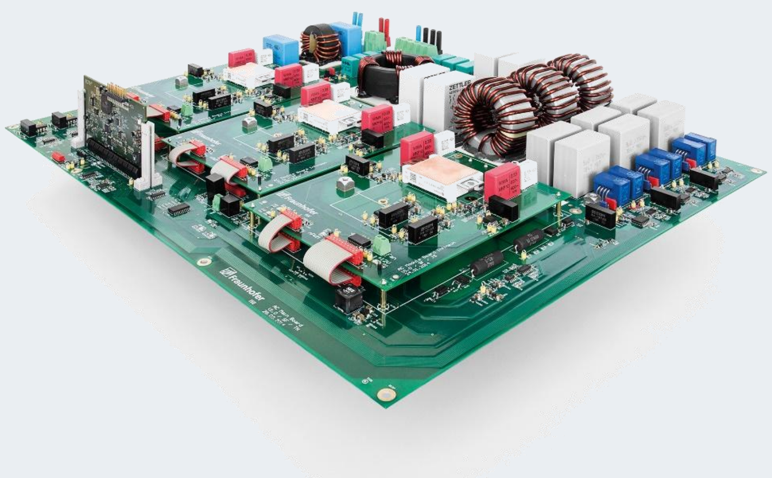
DC loads : heater, lamp, DC motor

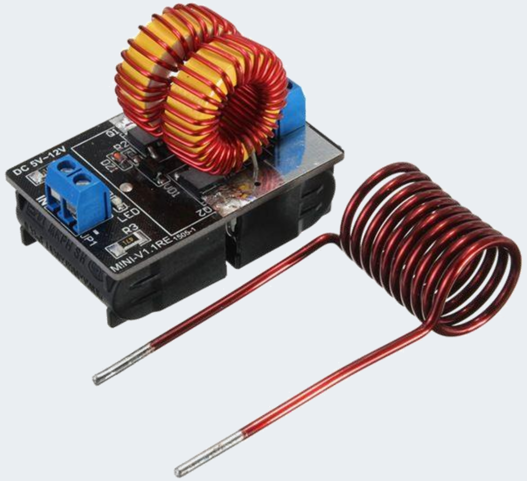
DC sources : batteries, solar panel, power supply

DC loads : electronic circuits, machines

Power Electronic Applications

- **Commercial/Industrial Applications**
  Heating Systems Ventilating, Air Conditioners, Central Refrigeration, Lighting, Computers and Office equipment, Uninterruptible Power Supplies (UPS), Elevators, and Emergency Lamps.





- **Domestic Applications**
  Cooking Equipment, Lighting, Heating, Air Conditioners, Refrigerators & Freezers, Personal Computers, Entertainment Equipment, UPS

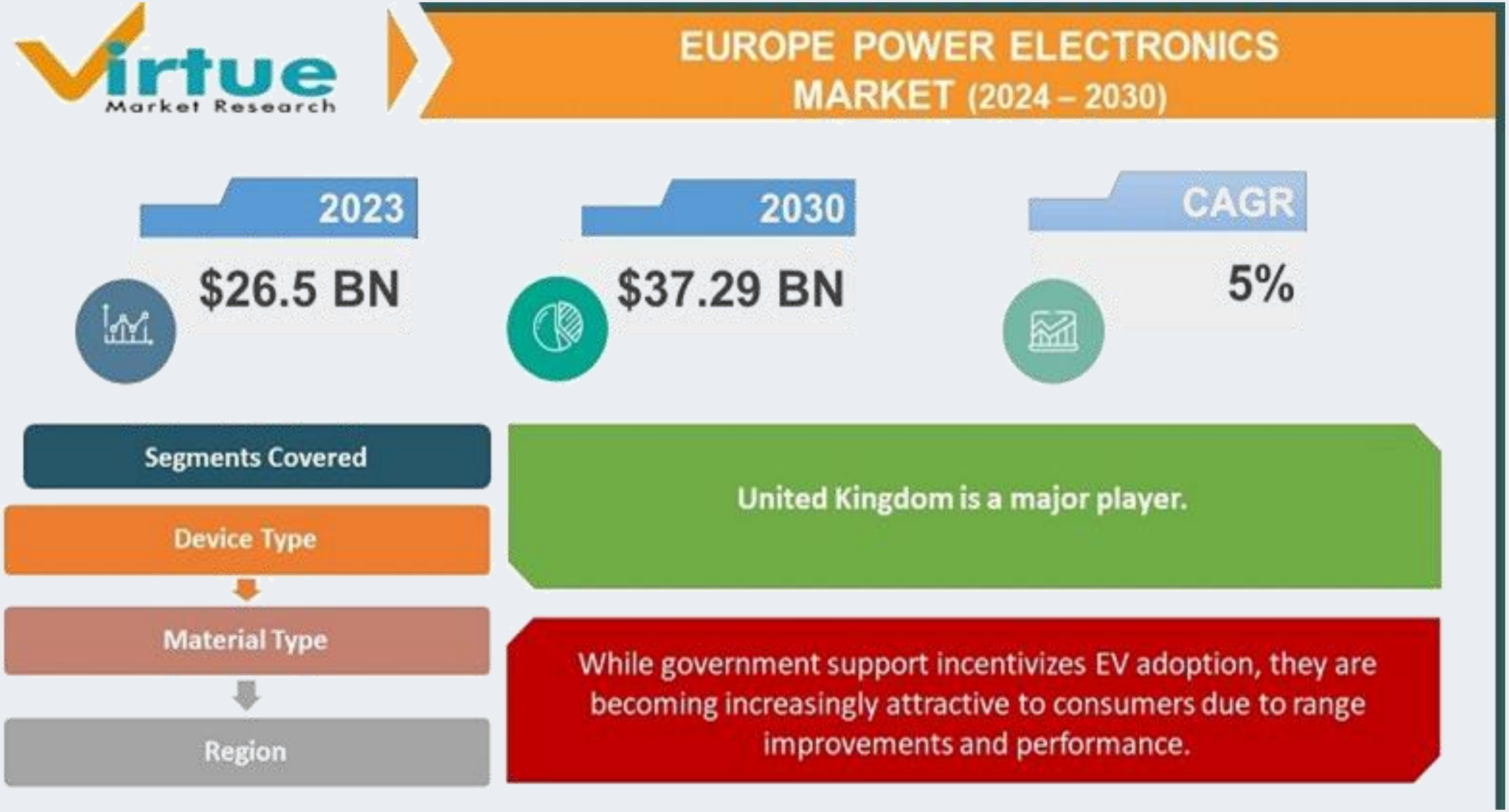
Power Electronic Applications

- **Aerospace Applications**
  Space shuttle power supply systems, satellite power systems, aircraft power systems.

- **Telecommunications**
  Battery chargers, power supplies (DC and UPS), mobile cell phone battery chargers.

- **Transportation**
  Traction control of electric vehicles, battery chargers for electric vehicles, electric locomotives, street cars, trolley buses, automobile electronics including engine controls.

The Market



Virtue
Market Research
EUROPE POWER ELECTRONICS MARKET (2024 – 2030)
2023
$26.5 BN
2030
$37.29 BN
CAGR
5%
Segments Covered
Device Type
Material Type
Region
United Kingdom is a major player.
While government support incentivizes EV adoption, they are becoming increasingly attractive to consumers due to range improvements and performance.

The Market

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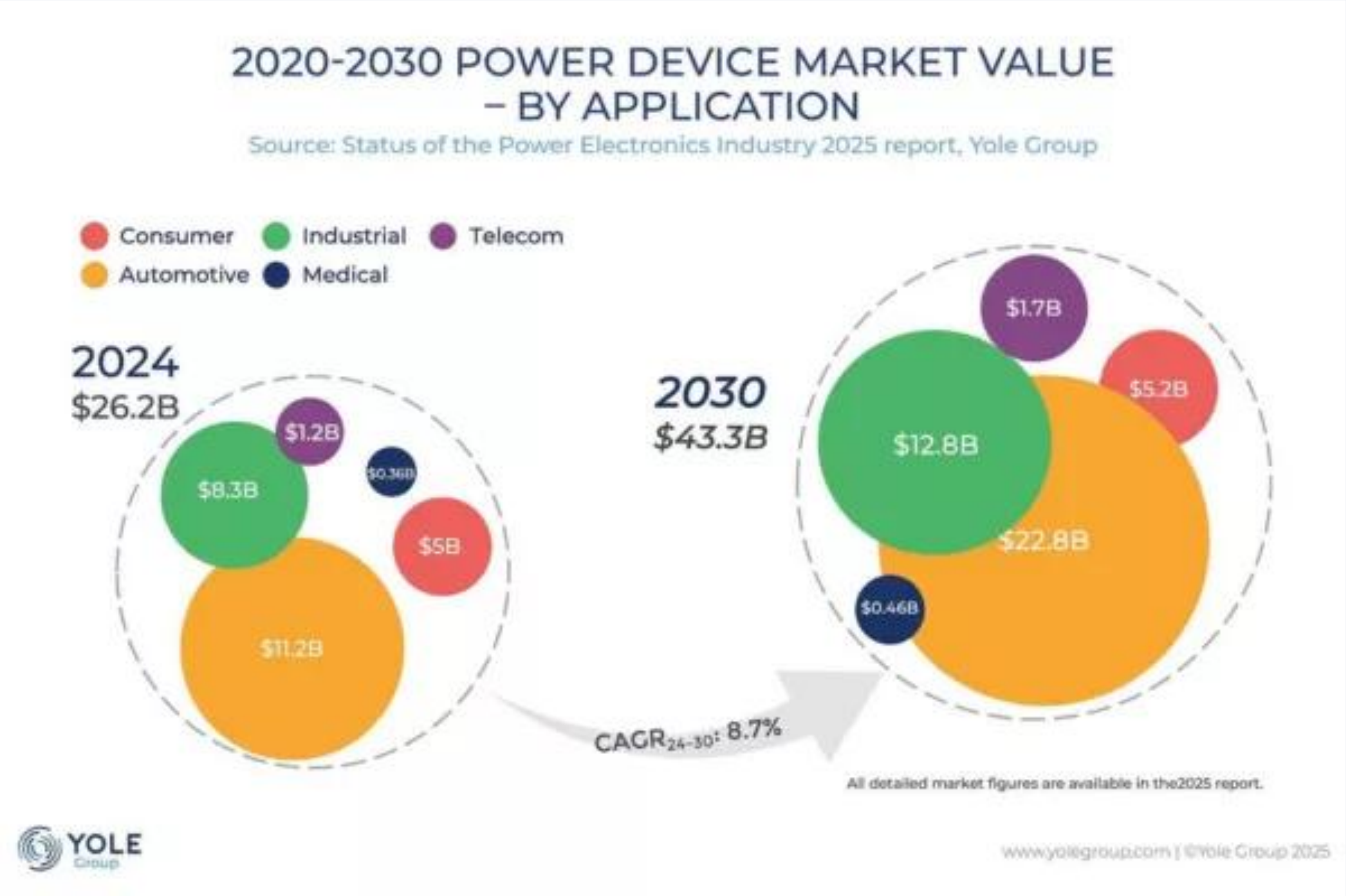


The Market

Job title:	Power Electronics Engineer (Systems Level Inverters & Drives)
Job type:	Permanent
Emp type:	Full-time
Functional Expertise:	Hardware Engineering
Skills:	Power Electronics, Inverters, DC-DC, AC-DC
Salary type:	Annual
Salary:	GBP £60,000.00
Location:	Woking
Job published:	20-01-2026

Job title:	Principal Power Electronics Engineer
Job type:	Permanent
Emp type:	Full-time
Salary type:	Annual
Salary:	GBP £75,000.00
Job published:	03-12-2025

Qualifications

- Bachelor's or Master's degree in Electrical Engineering, Power Electronics, or equivalent field.
- Minimum 5+ years of experience in design and development of power conversion systems, with emphasis on inverters and motor drives.
- Deep understanding of topologies (e.g., three-phase inverters, DC/DC converters, multilevel inverters) and related control strategies (FOC, PWM, DTC, etc.).
- Experience with SiC and GaN-based power devices and associated gate drive circuits.
- Strong analytical and modelling skills using tools like MATLAB/Simulink, PSIM, or PLECS.
- Familiarity with EMI/EMC design principles, thermal design, and safety standards (IEC, UL, ISO).
- Hands-on experience with hardware testing, lab instrumentation, and system commissioning.
- Excellent communication and cross-functional collaboration skills.

Requirements

Master's or PhD in Electrical Engineering, Power Electronics, or related field.

10+ years of experience in power electronics design, focusing on **DC/DC, AC/DC, and DC/AC conversion**.

Extensive expertise in **SiC and GaN-based power electronics** for high-efficiency designs.

Strong proficiency in **LTSpice, PLECS, MATLAB/Simulink, Altium, or similar tools**.

Experience with **high-frequency switching, EMI/EMC compliance, and thermal management**.

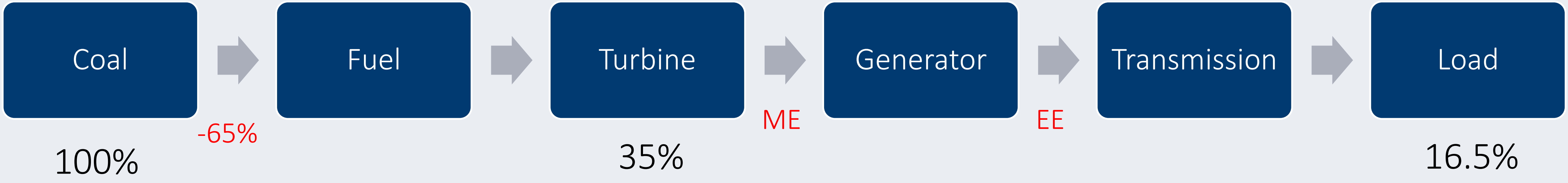
Hands-on experience with **PCB layout design for high-power circuits**.

Deep understanding of **control algorithms for power converters** (digital and analog).

Familiarity with **power magnetics, gate drivers, and high-voltage isolation techniques**.

Proven track record of **leading projects from concept to production**.

Why Power Electronics?



- Fossil fuel (Oil, natural gas and coal) still the most used energy source, >85%.
- In best scenarios, the fossil fuel energy sources will last for +150 years
- What will happen after 150 years ?   We don't know ……

But we can extend this period or even replace the traditional resources by:

1. Using it efficiently → Global warning still a problem
2. Improve the energy conversion efficiency
3. Promote more integrated renewable energy sources

} Role of Power Electronic circuits

Why Power Electronics?

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Coal → Fuel → Turbine → Generator → Transmission → Load

-65% ME EE

100% 35% 16.5%

6 : 1

100kW

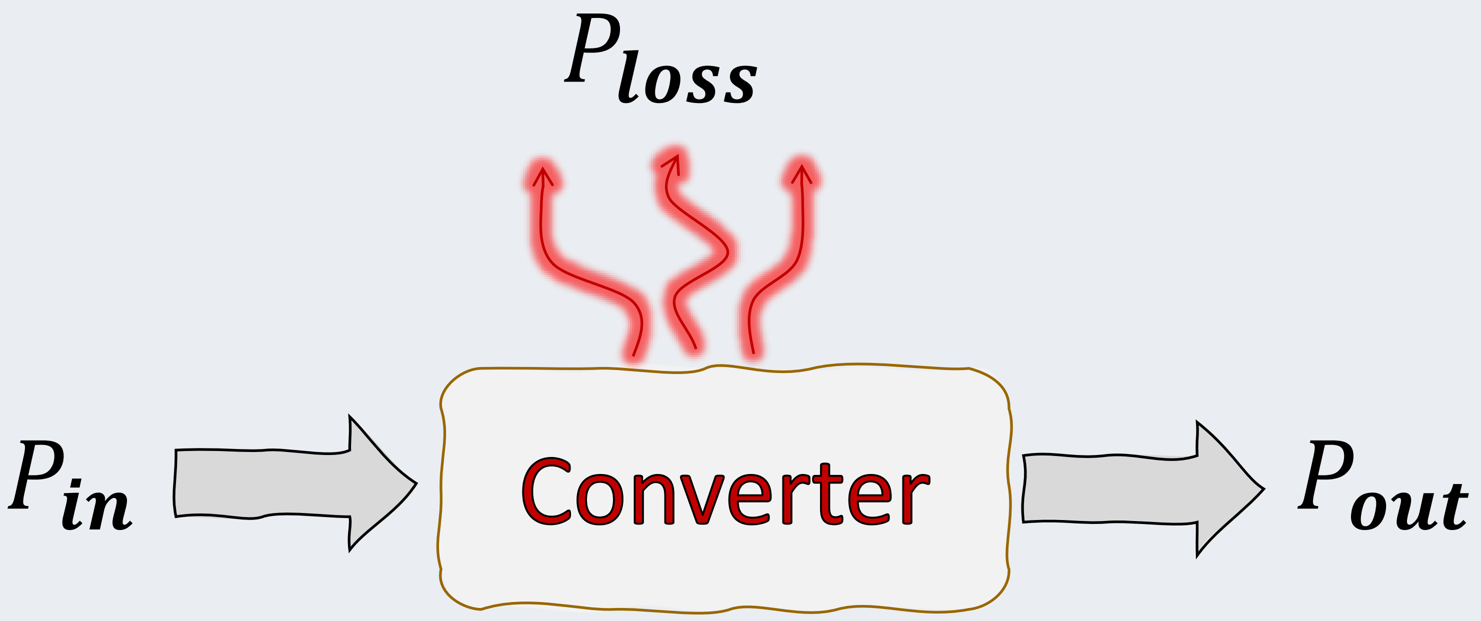
16.5kW

saving

6kW ← 1kW (6%)

So it is necessary to have higher efficiency drives, chargers and circuits for the loads …. Done by PE.

Why do we spend effort on the load side (i.e. Motor efficiency) when most of losses are at front end ?



$$\eta = \frac{P_{out}}{P_{in}}$$

$$P_{in} = P_{out} + P_{loss}$$

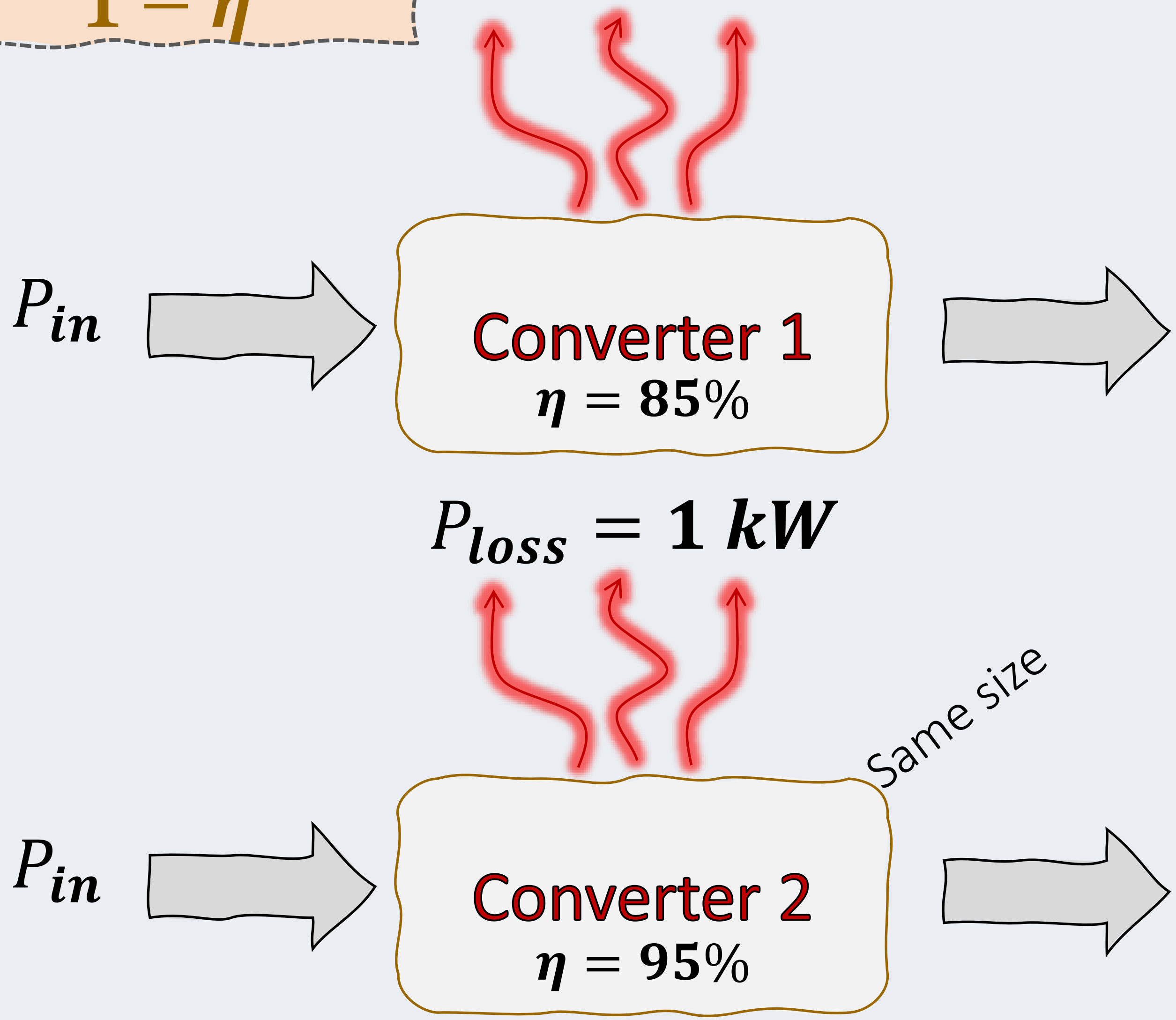
$$\eta = \frac{P_{out}}{P_{out} + P_{loss}}$$

$$\eta(P_{out} + P_{loss}) = P_{out}$$

$$P_{out} = \frac{\eta}{1-\eta} P_{loss}$$

$$P_{out} = \frac{\eta}{1-\eta} P_{loss}$$

$$P_{loss} = 1\ kW$$



$$P_{out1} = \frac{0.85}{1-0.85} \times 1k = 5.7kW$$

$$P_{out2} = \frac{0.95}{1-0.95} \times 1k = 19\ kW$$

x3

Higher Efficiency

Switches

Diodes, transistors, thyristors

Silicon, Silicon Carbide, GaN

Topologies

Interleaving, switched capacitors, etc

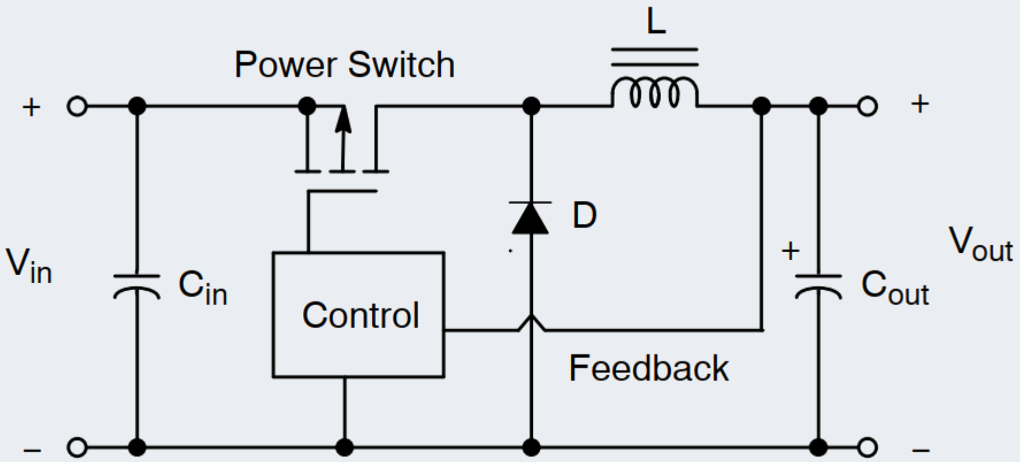
Hard and soft switching

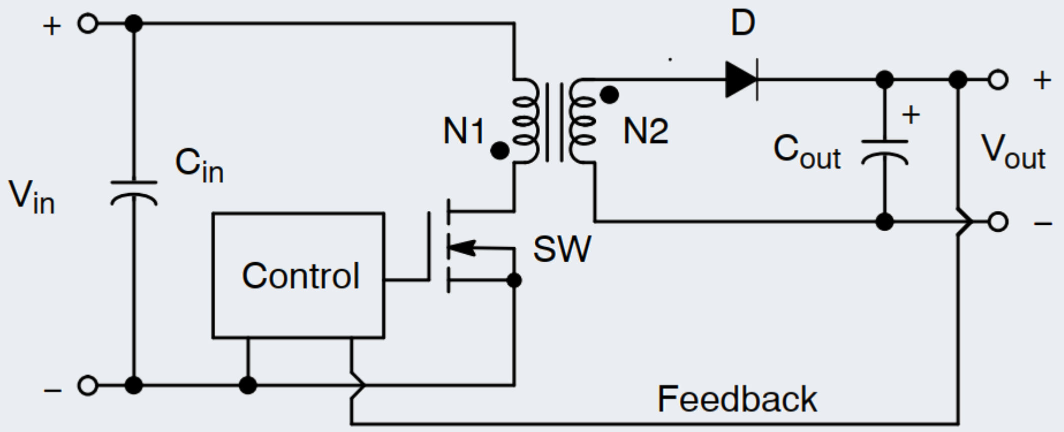
Power Semiconductor Devices

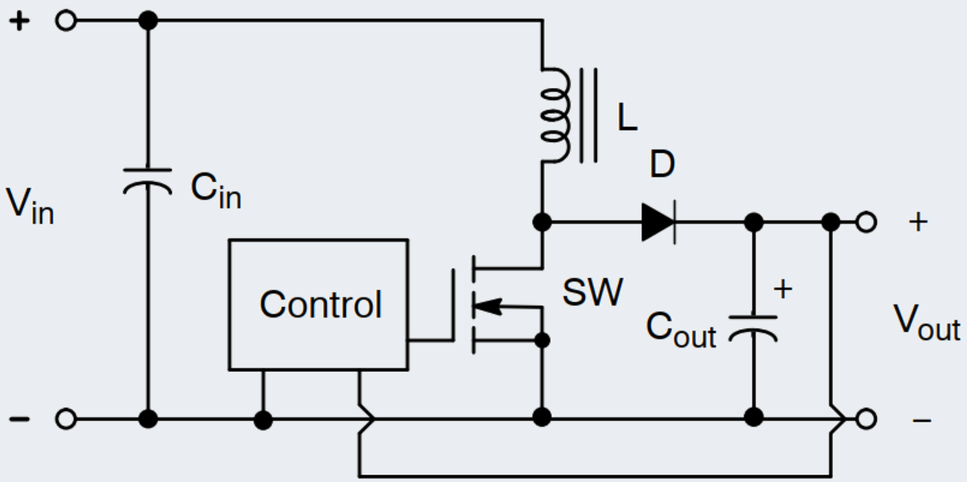
The power semiconductor devices are used as on/off switches in power control circuit. These devices are classified as follows.

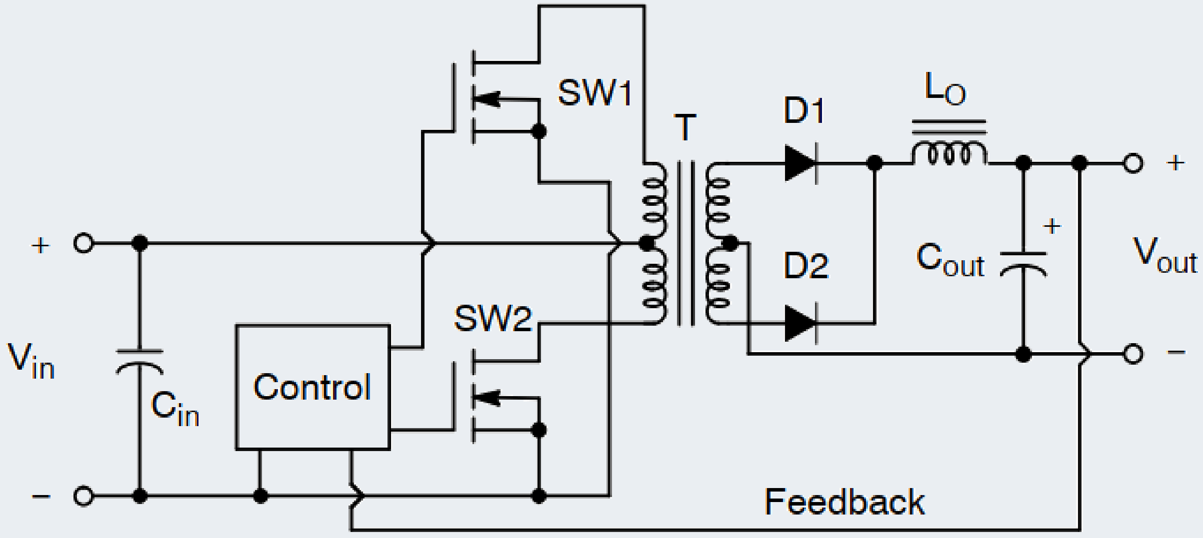
- Power Devices
  - Diodes
    - General purpose
    - High speed
    - Schottky
  - Transistors
    - BJT
    - MOSFET
    - IGBT
  - Thyristors
    - SCR
    - GTO
    - Triac
    - SITH

Power Semiconductor Topologies

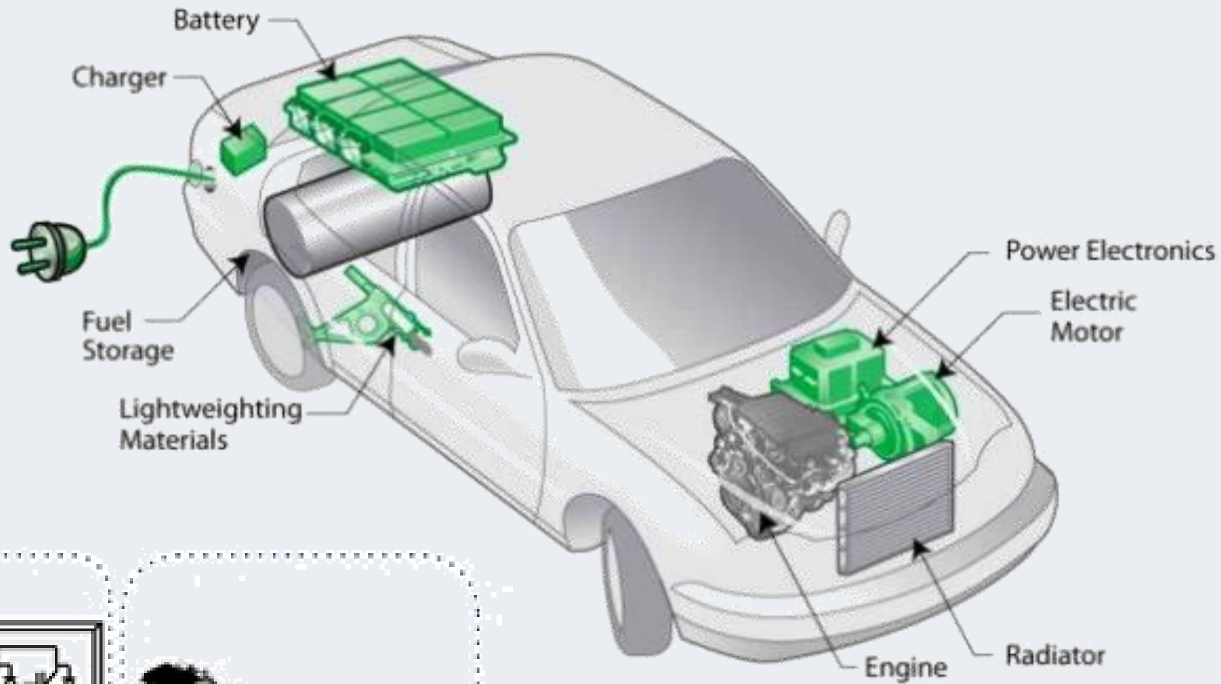


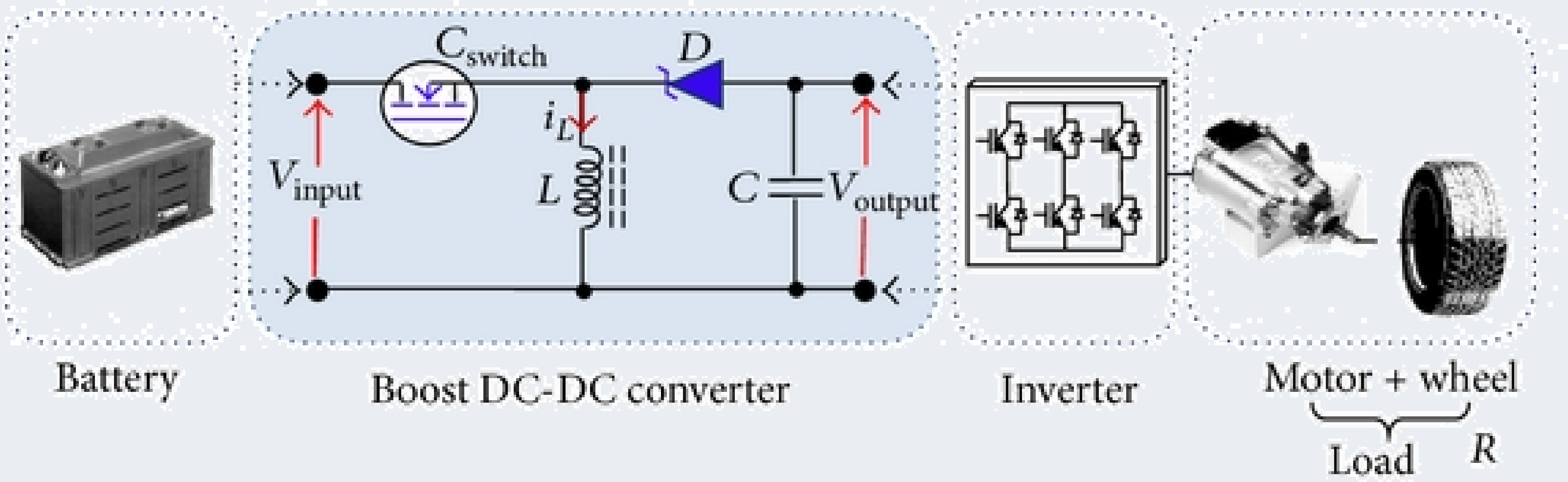




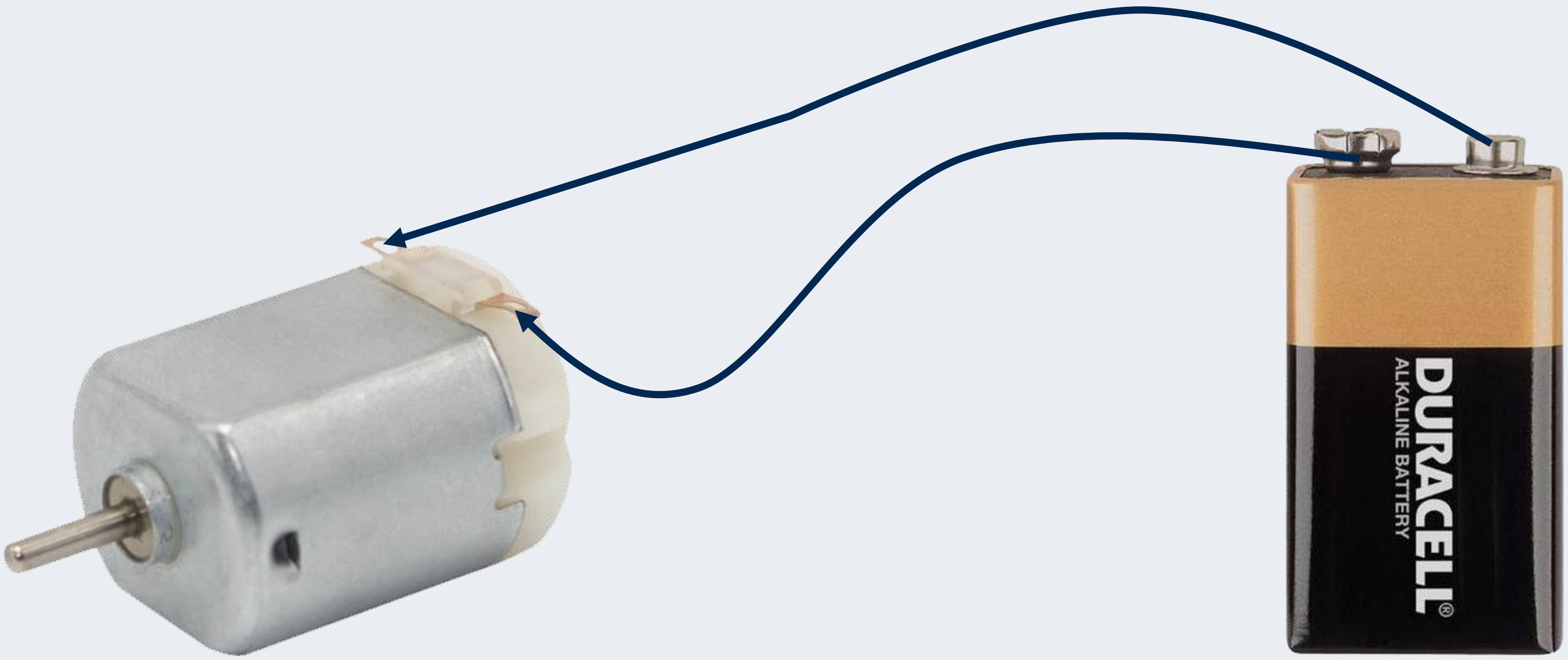


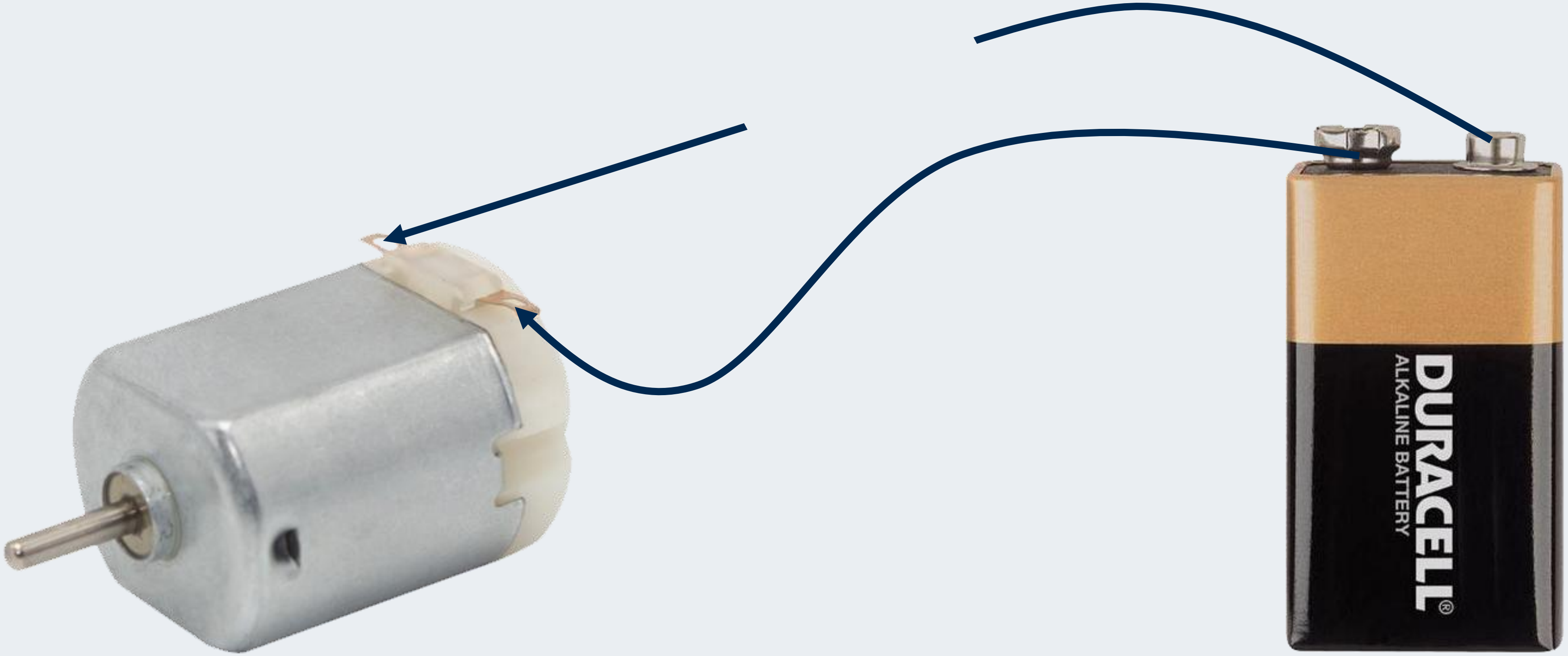
Power Semiconductor Devices

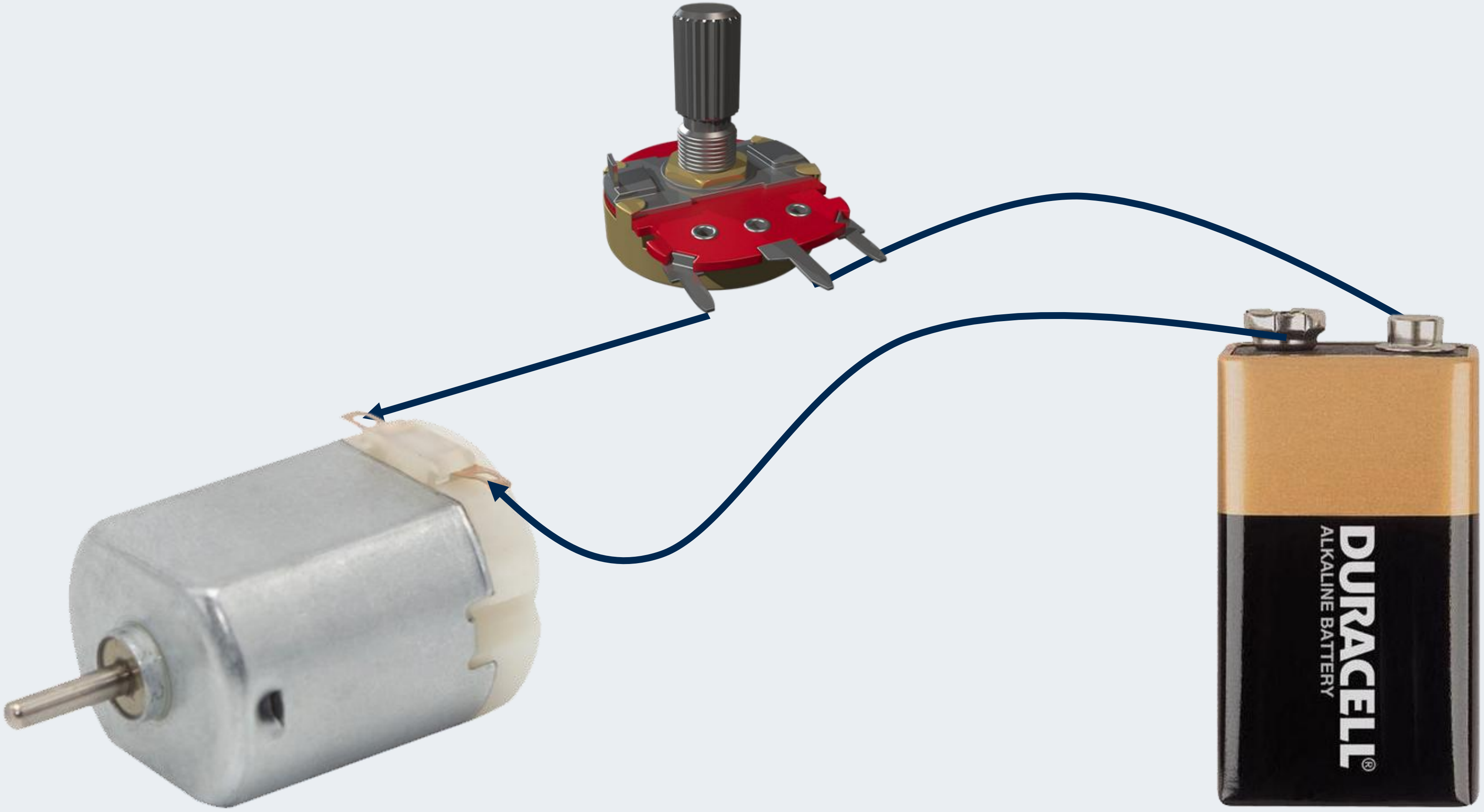




Why Pulse Width Modulation (PWM)




DURACELL
ALKALINE BATTERY


DURACELL
ALKALINE BATTERY

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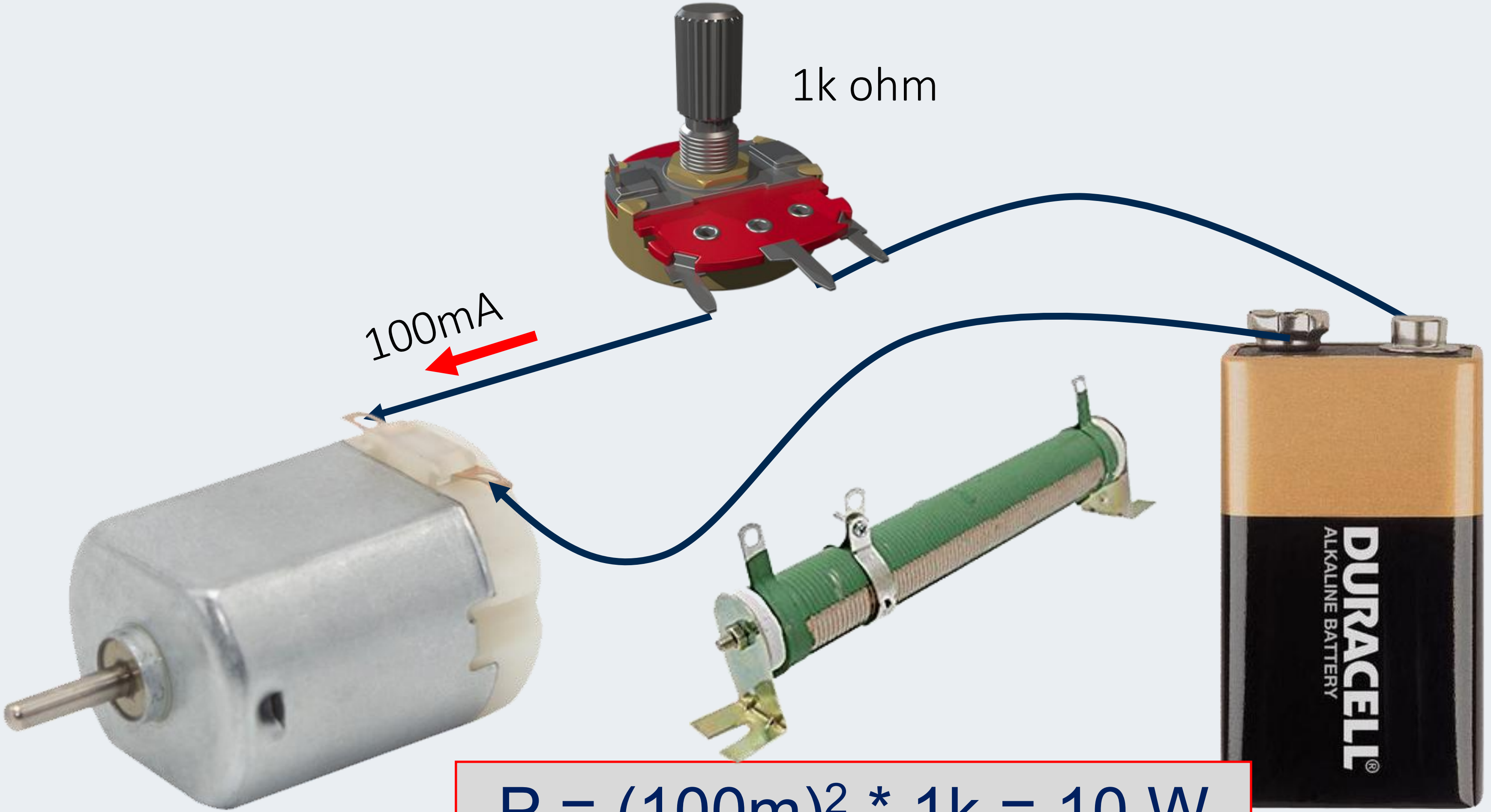
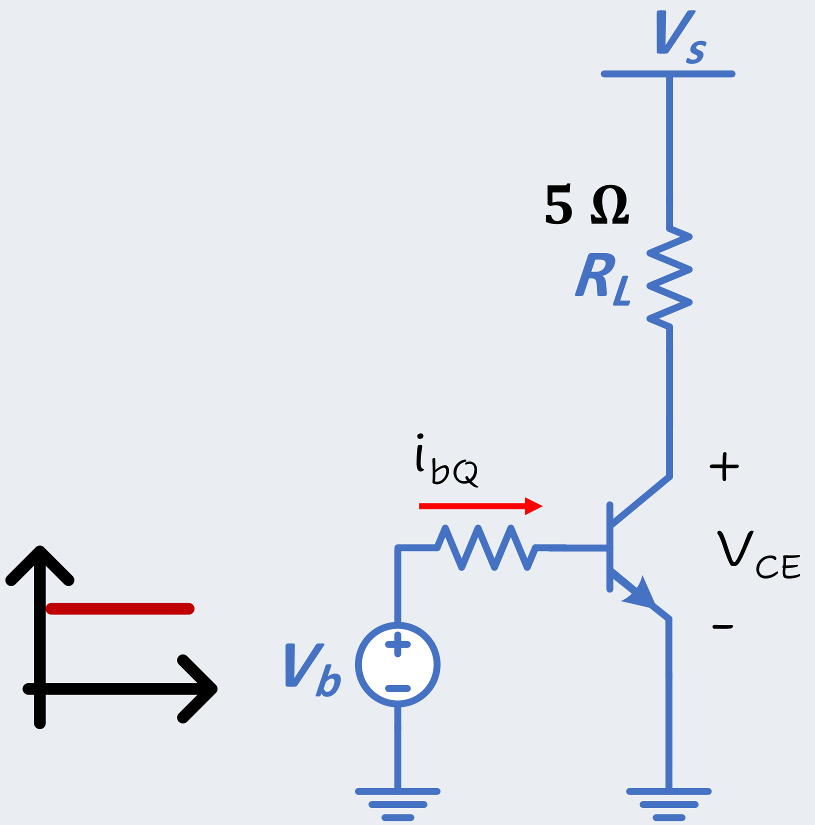
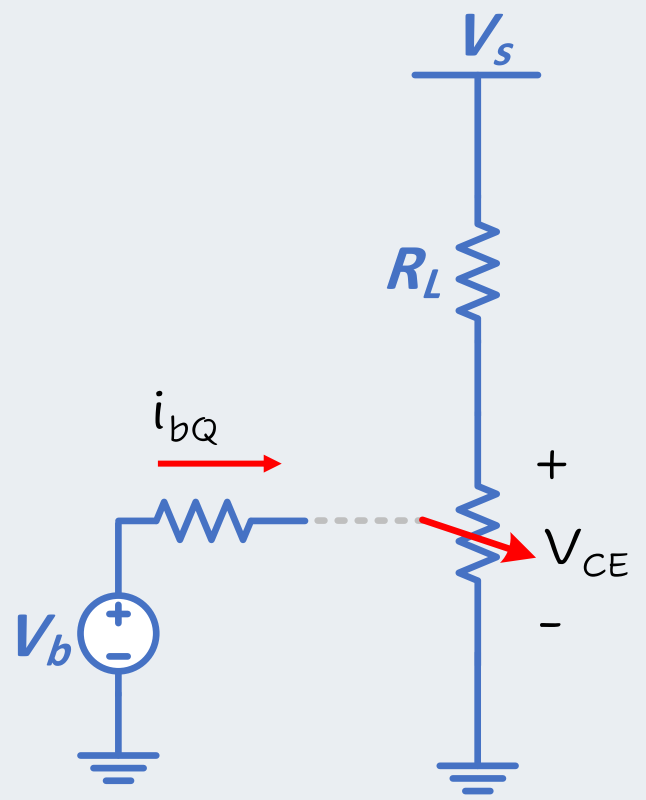


$$P = (100m)^2 * 1k = 10\ W$$

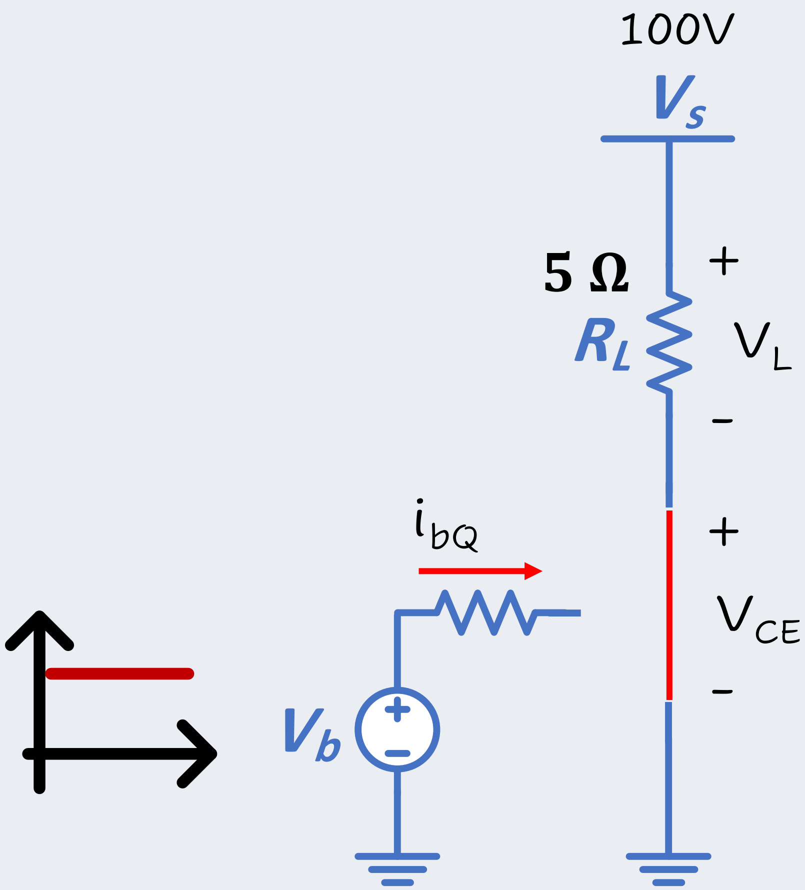
$$P = (1)^2 * 100 = 100\ W$$

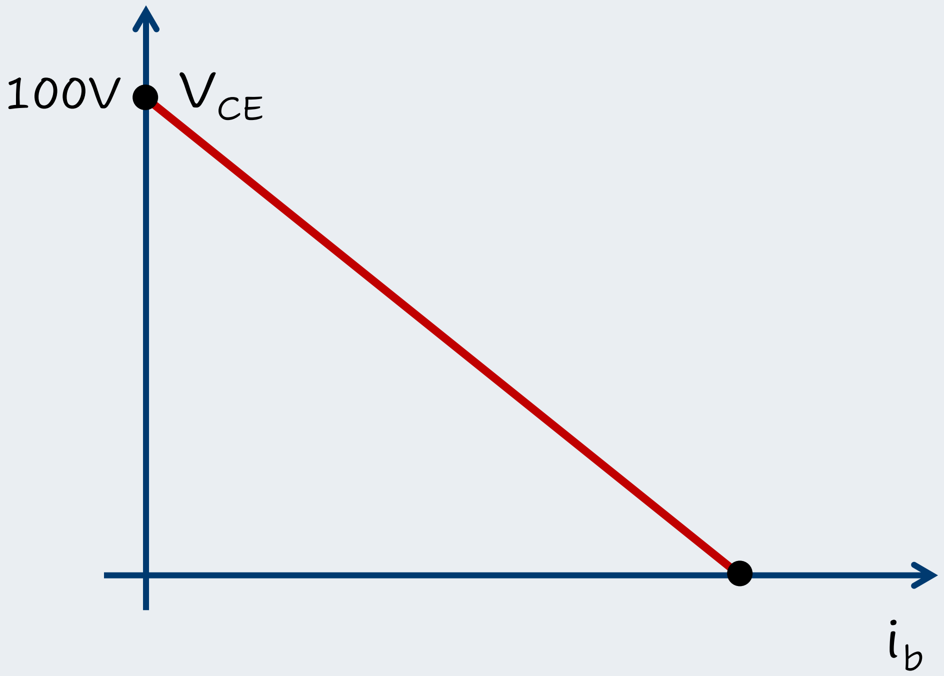
Linear operation



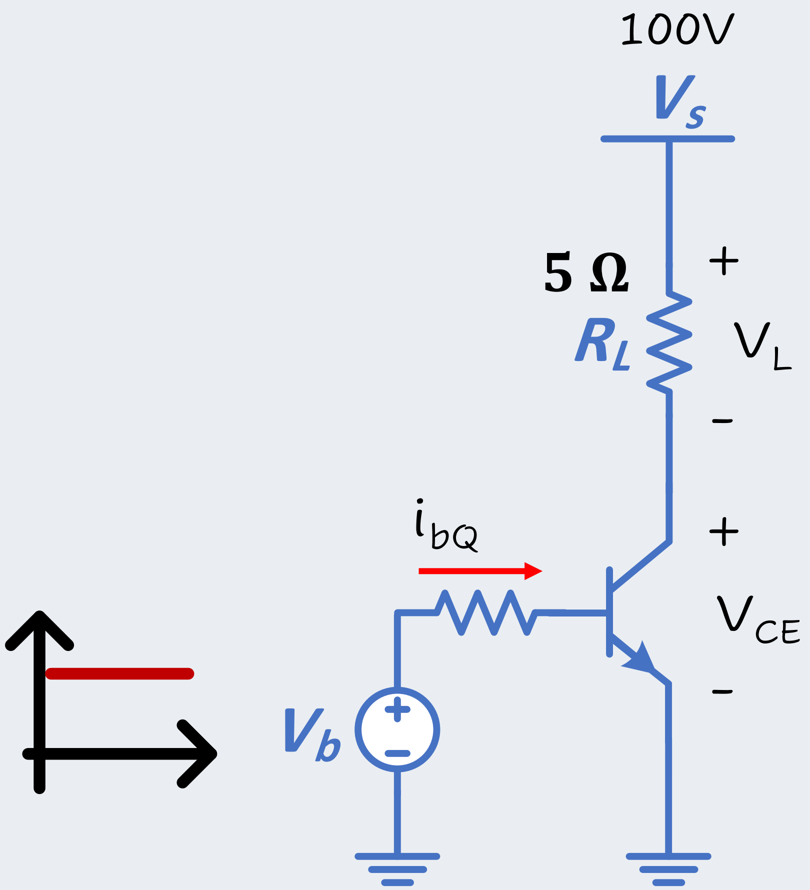


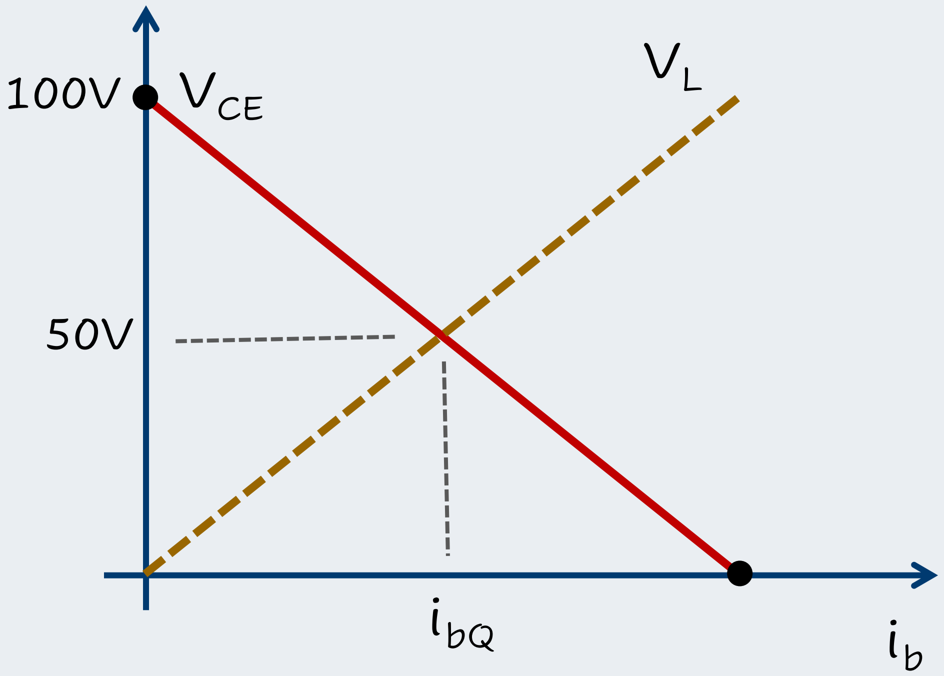
Linear operation





Linear operation

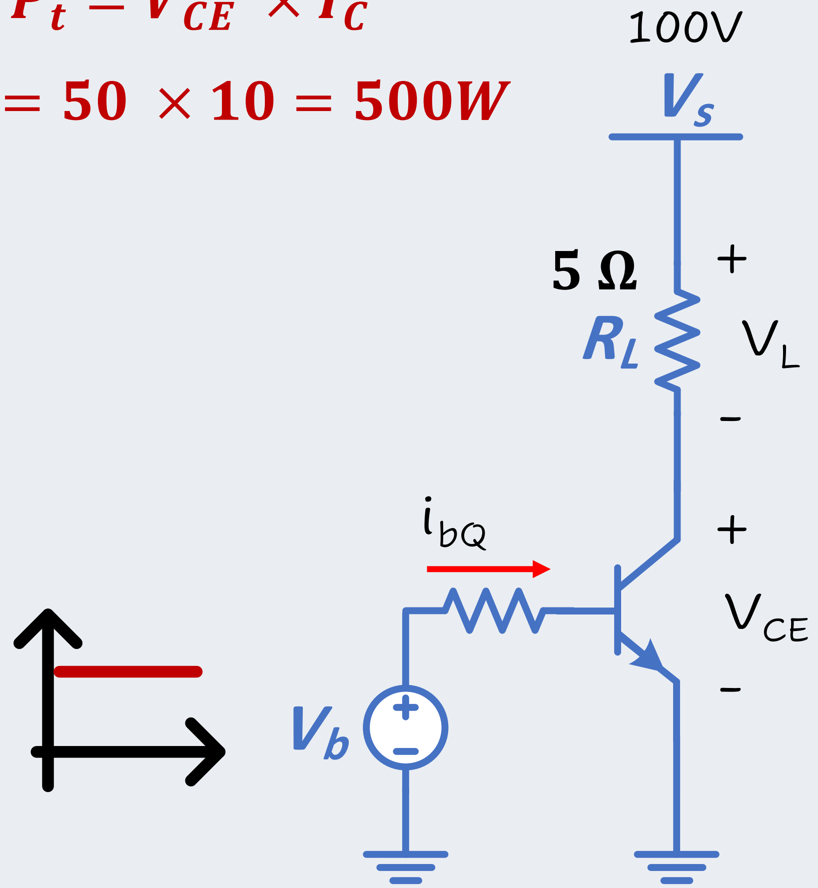


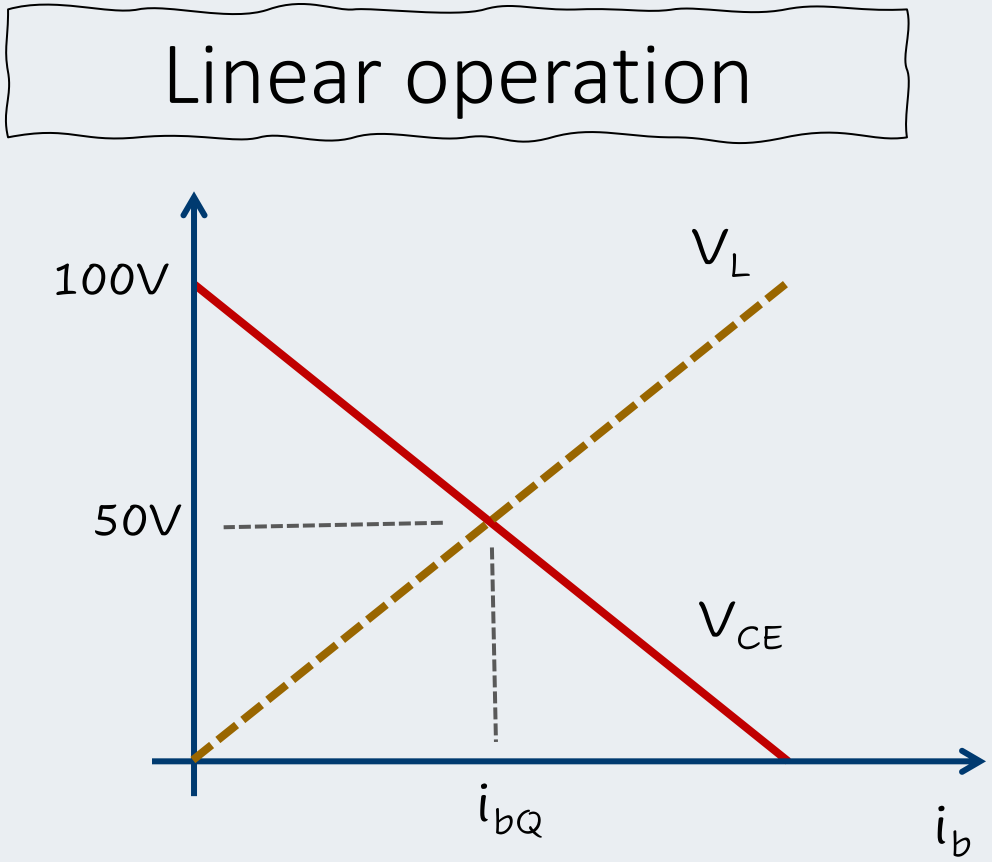


$$I_C = \frac{50}{5} = 10A$$

$$P_t = V_{CE} \times I_C$$

$$P_t = 50 \times 10 = 500W$$





What is the PWM ?

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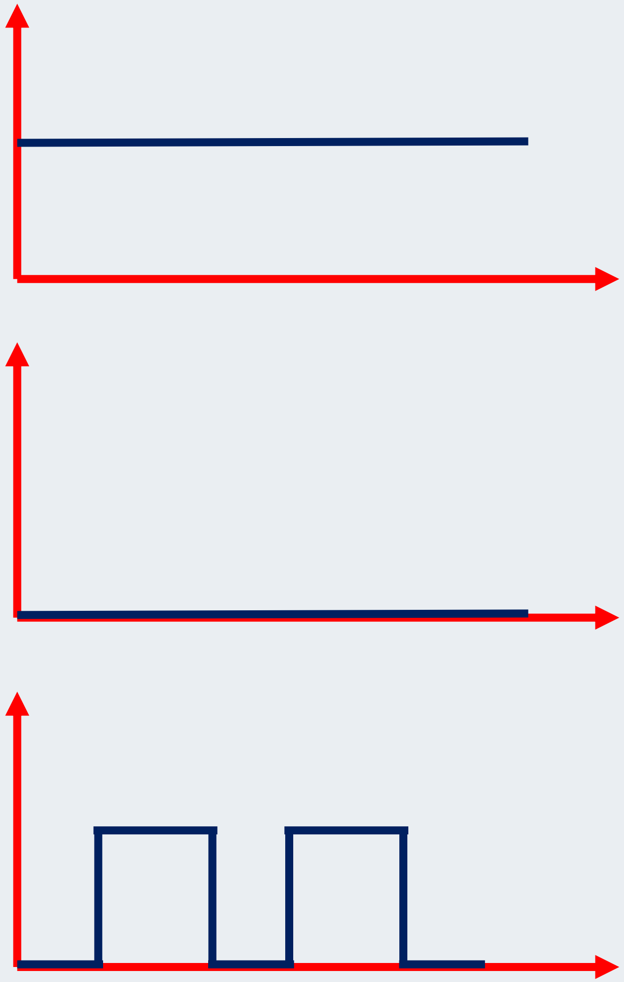
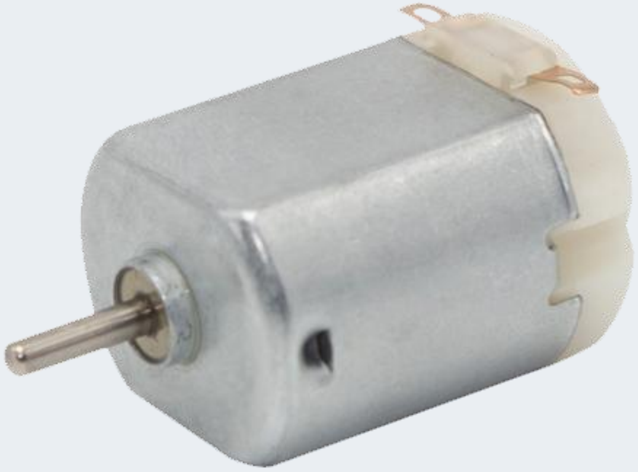
Voltage

Pulse Width Modulation ?

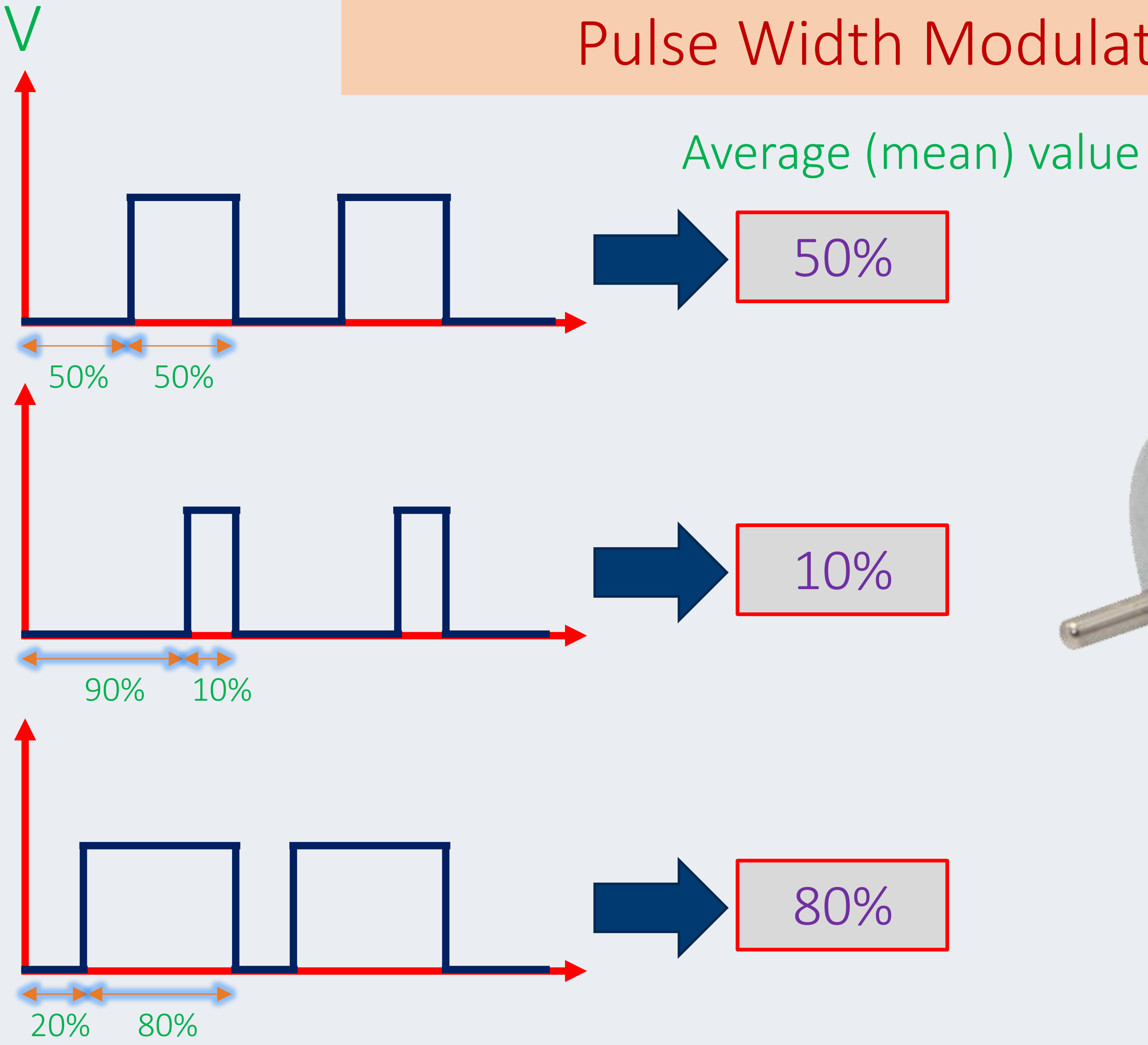


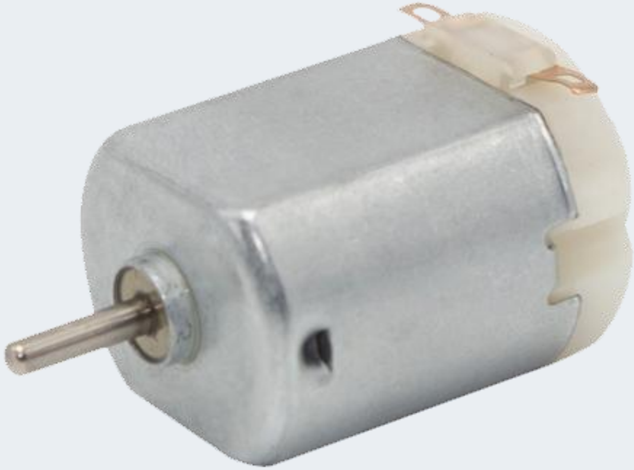


Average (mean) value

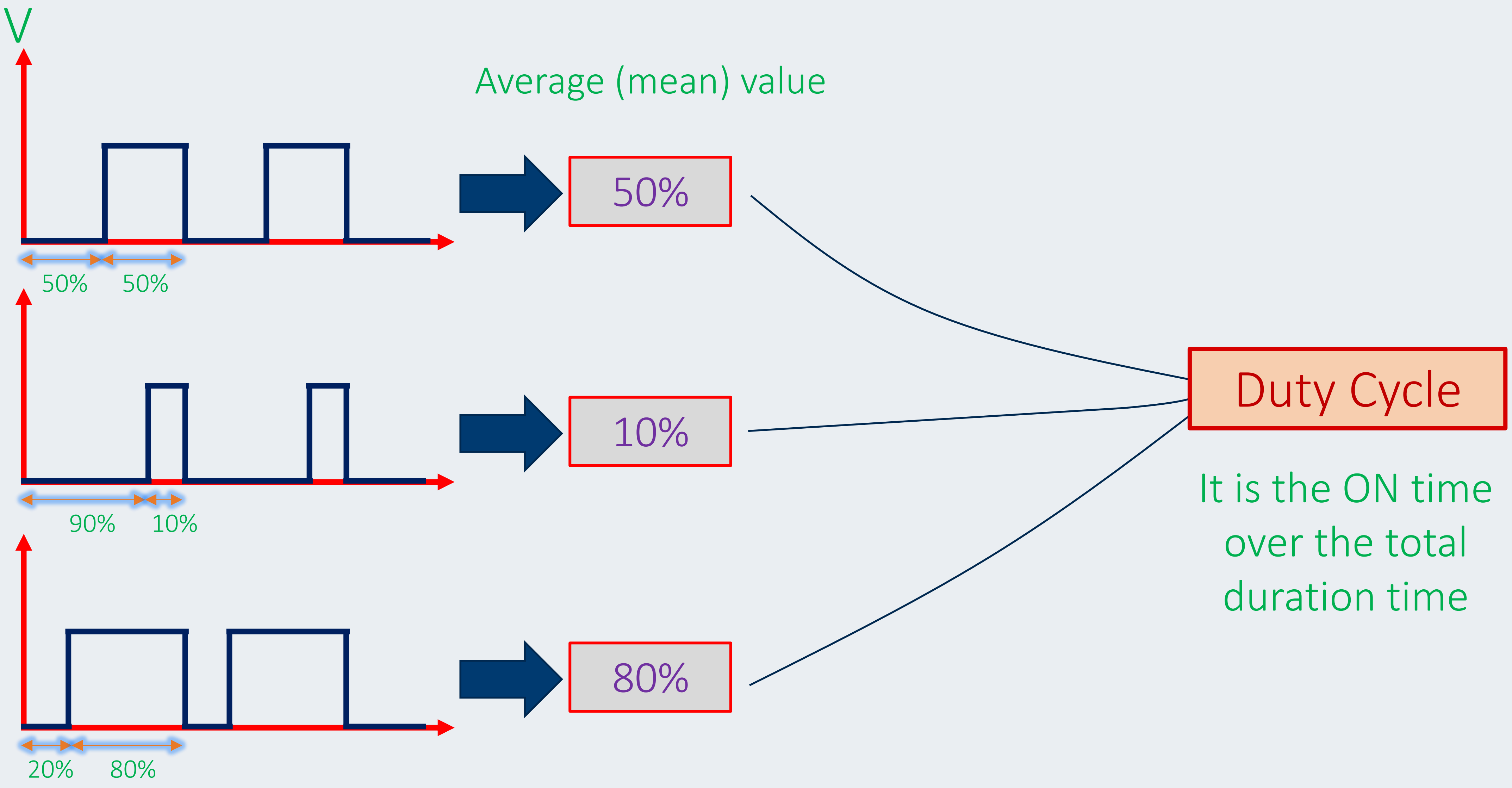
What is the PWM ?

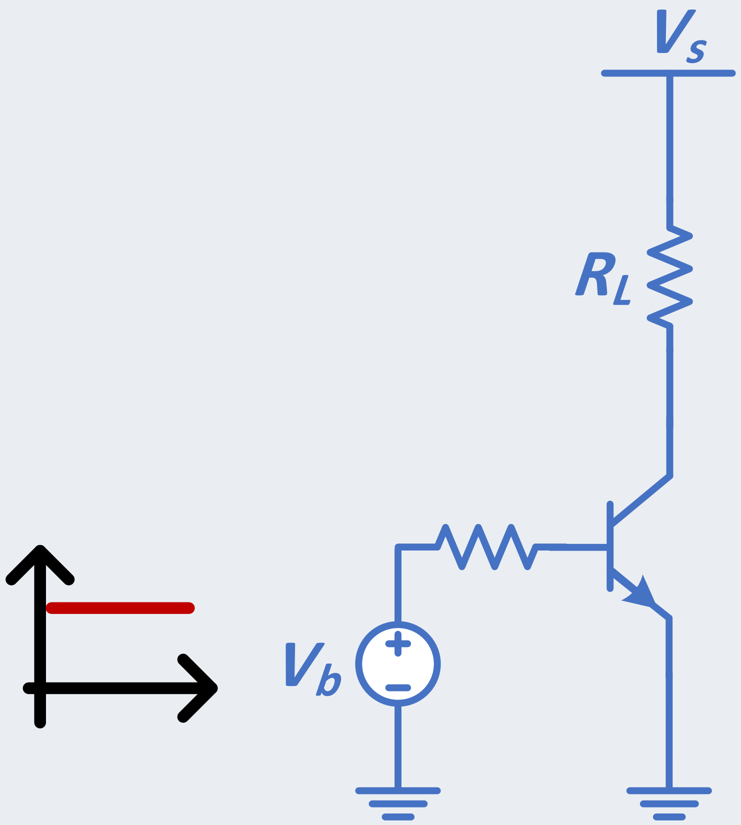
Pulse Width Modulation

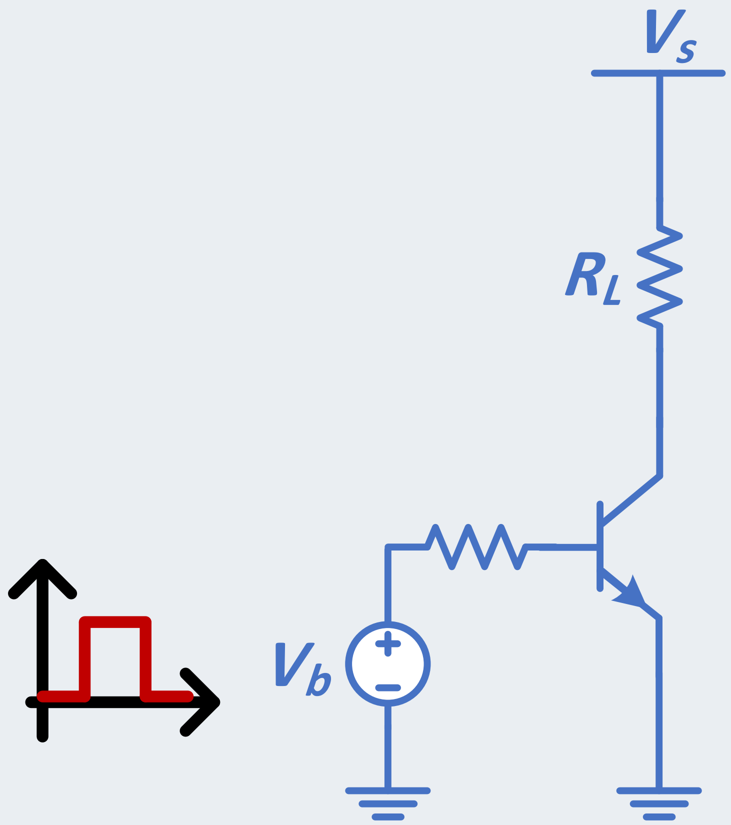




What is the PWM ?



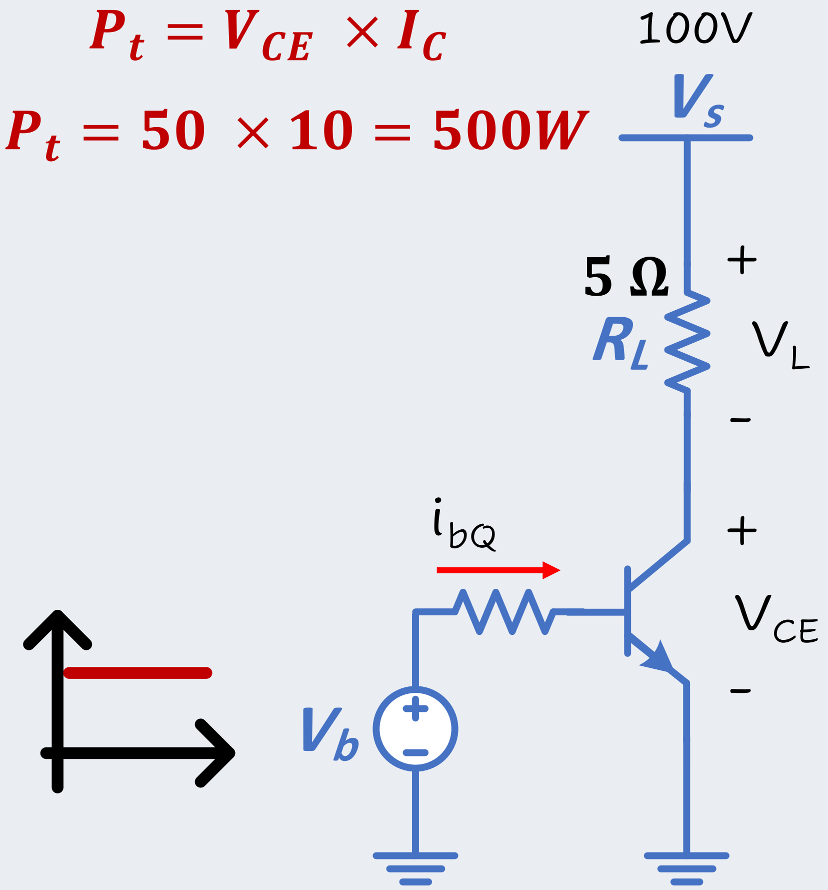

V_s
R_L
V_b


V_s
R_L
V_b

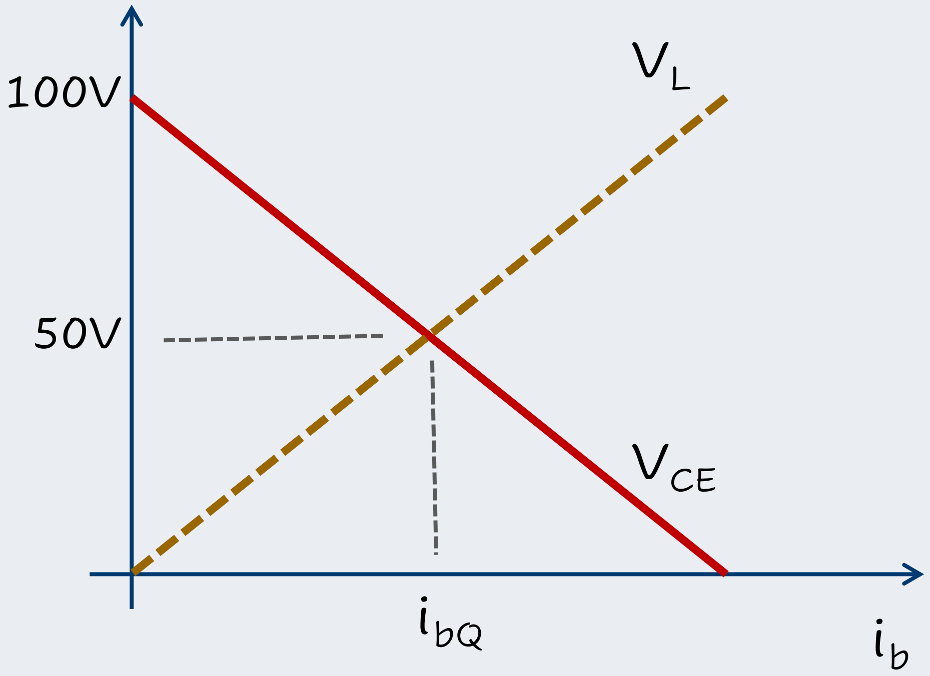
$$I_C = \frac{50}{5} = 10A$$

$$P_t = V_{CE} \times I_C$$

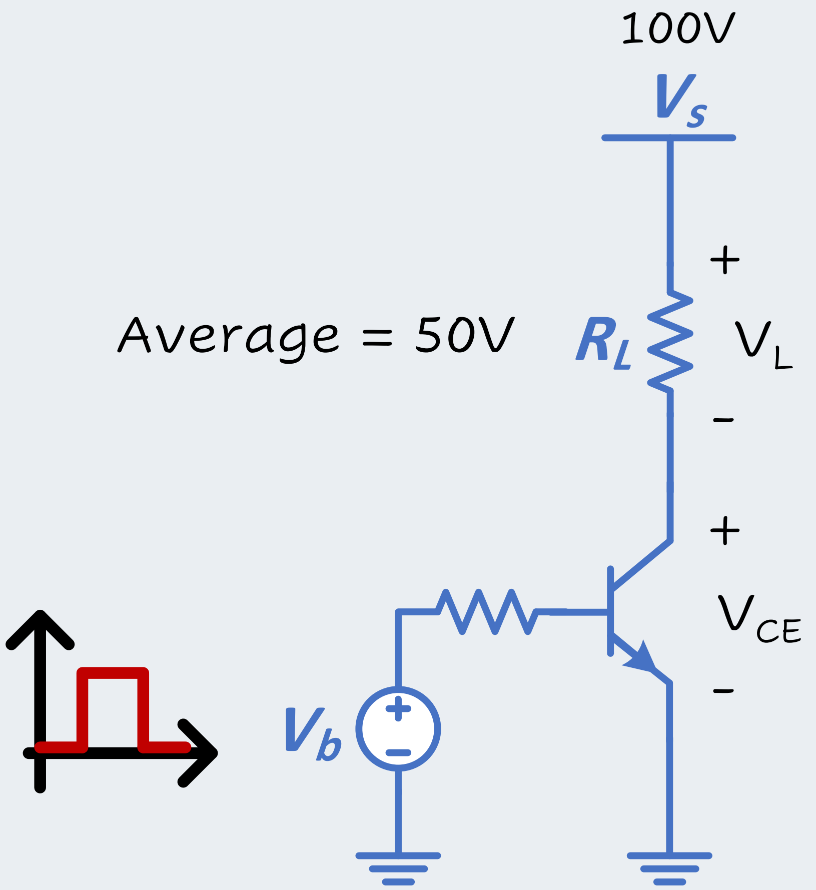
$$P_t = 50 \times 10 = 500W$$

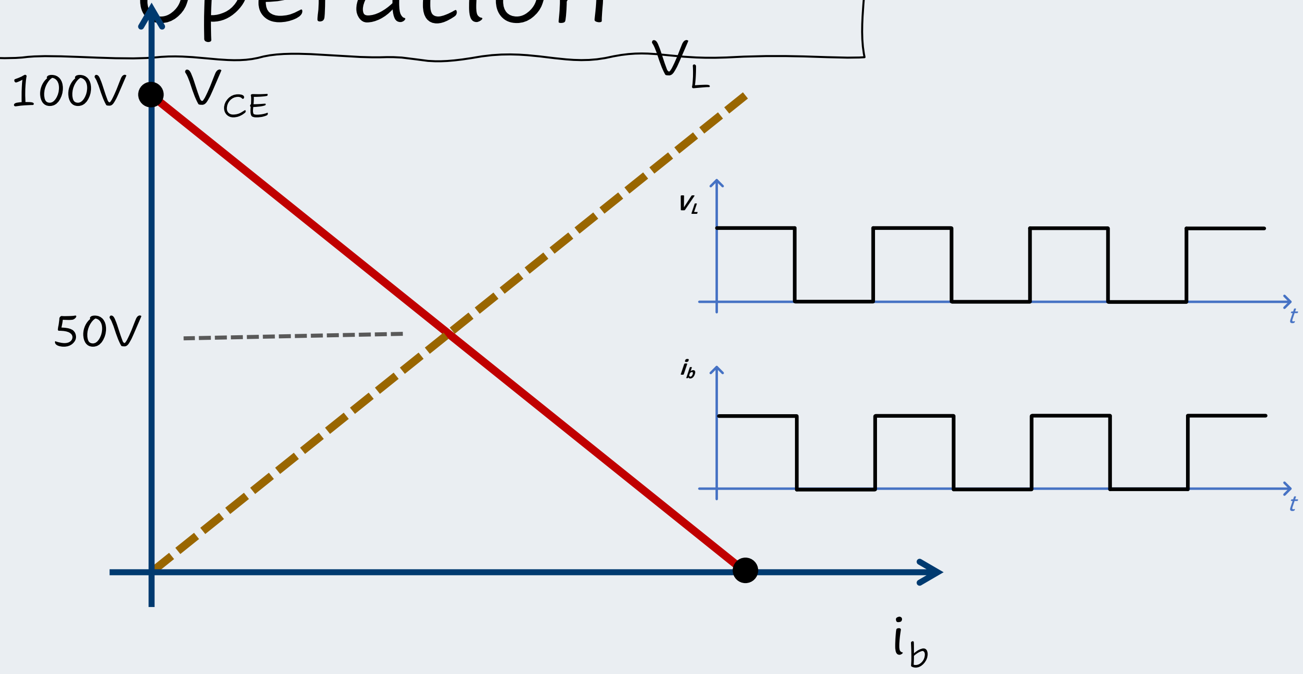


Linear operation



Switched operation





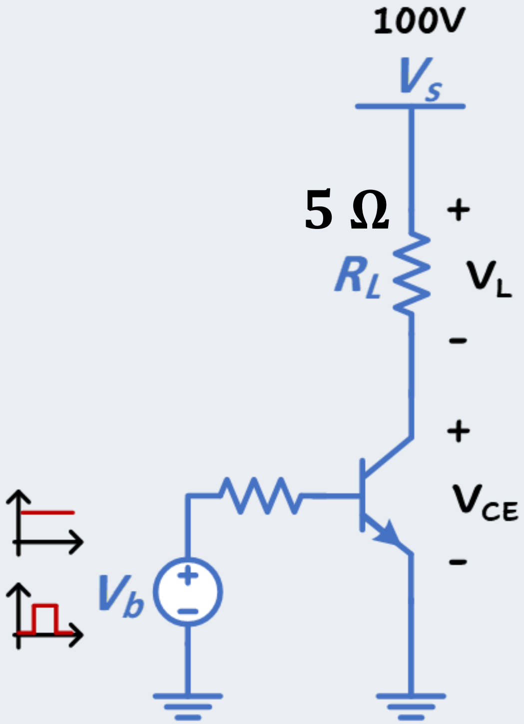
Dissipated power in transistor

Linear operation

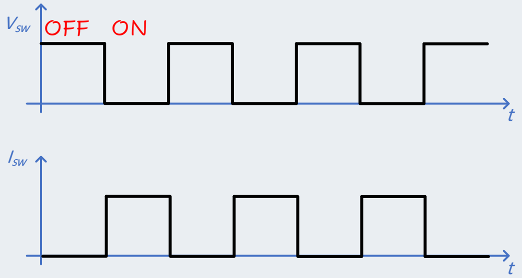
$$I_C = \frac{50}{5} = 10A$$

$$P_t = V_{CE} \times I_C$$

$$P_t = 50 \times 10 = 500W$$



Switched operation



$$P_t = V_{CE} \times I_C$$

ON state $p_t = 0 \times 20 = 0W$

OFF state $p_t = 100 \times 0 = 0W$

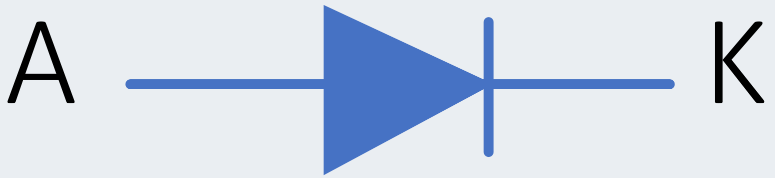
$$Average\ P_t = 0W$$

$$P_t = \int_0^T V_{CE} \times I_C \, dt = 0W$$

Power Switches

The switches can be controlled by either

Passive The switch state depends on the polarity of the voltage across its terminals, or the current flowing thought it



Uncontrolled

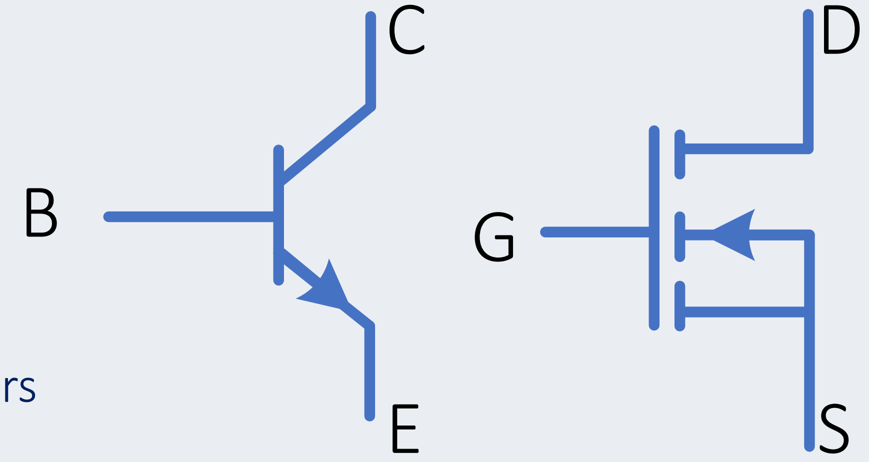
Diodes

$$V_A > V_K$$

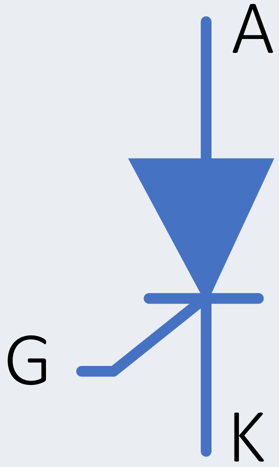
Power Switches

The switches can be controlled by either

Active The switch state depends on some control signal applied on its terminal to control the conduction through it.



Transistors

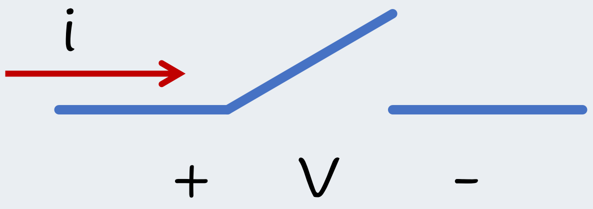


Thyristors

Fully-Controlled

Semi-Controlled

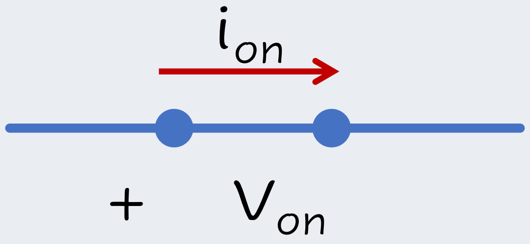
Ideal Switches



ON

$V_{on} = 0$

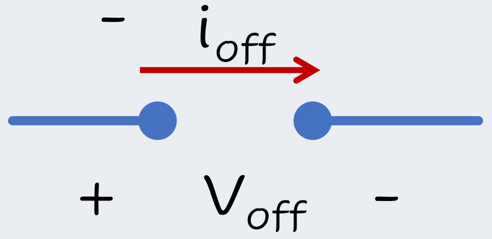
$-\infty < i_{on} < \infty$



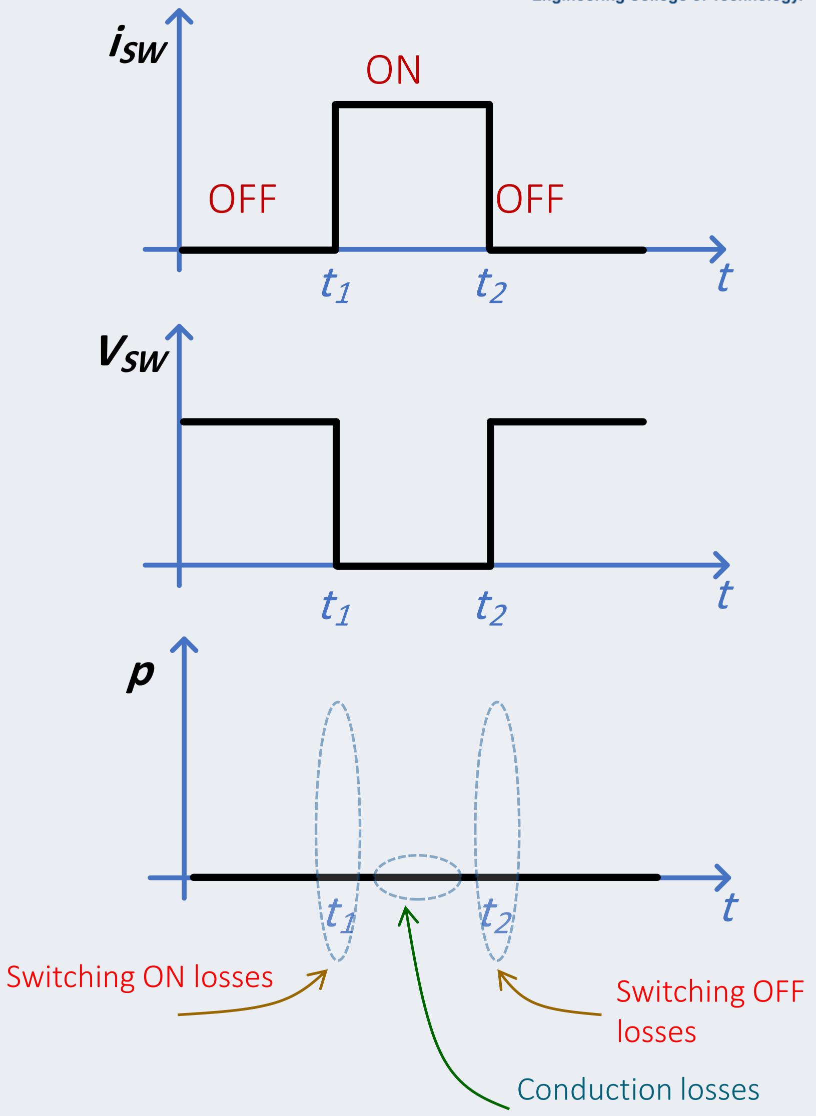
OFF

$-\infty < V_{off} < \infty$

$i_{off} = 0$



Power Loss = Switching losses + Conduction Losses



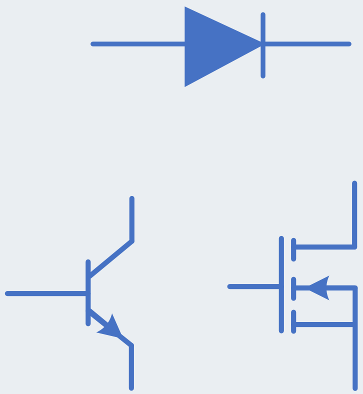
Practical Switches

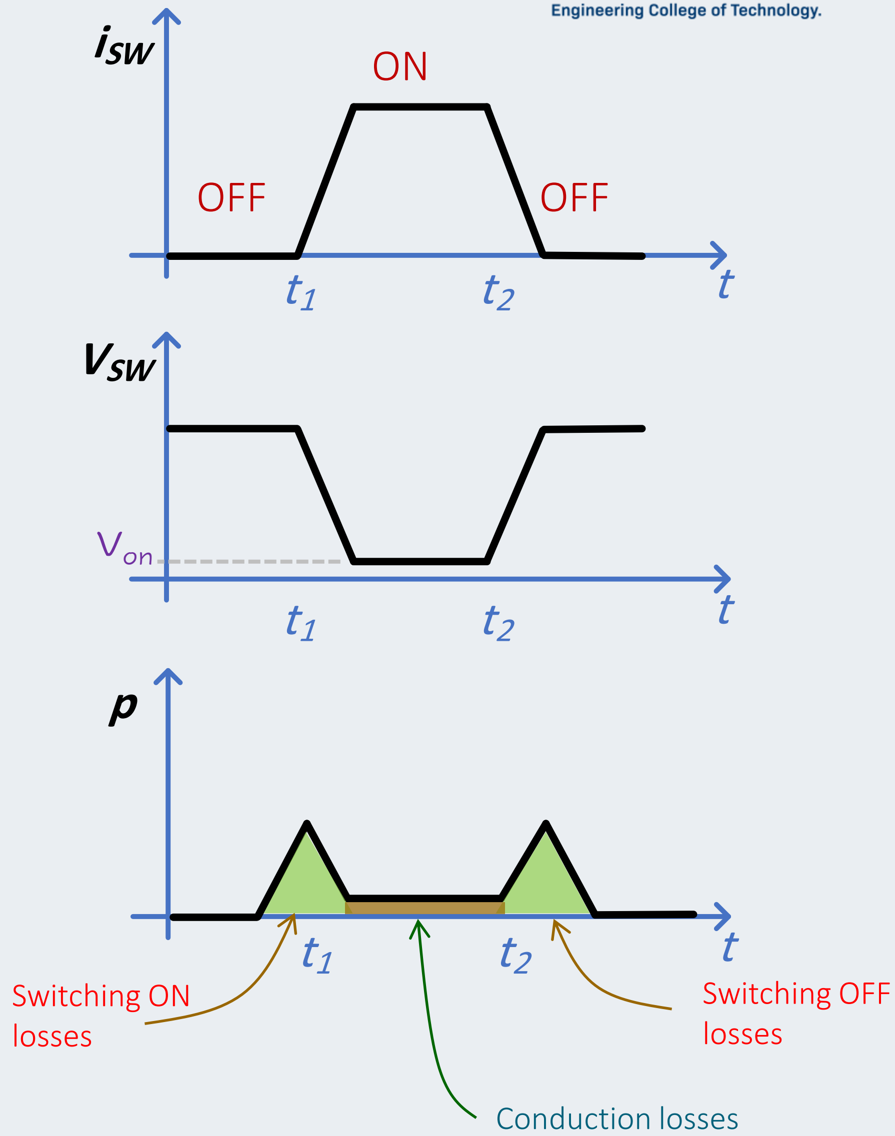
ON $V_{on} \neq 0$

$i_{on} < I_{max}$

OFF $V_{off} < V_{max}$

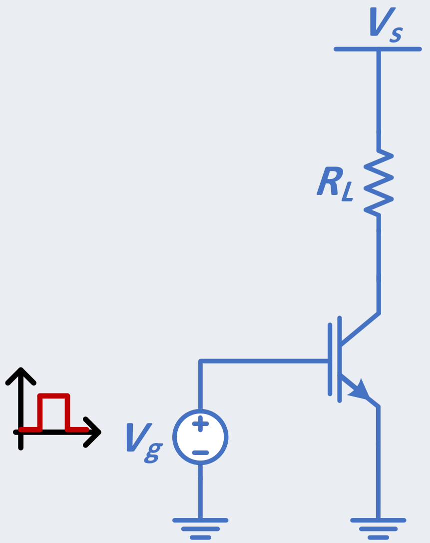
$i_{off} \neq 0$

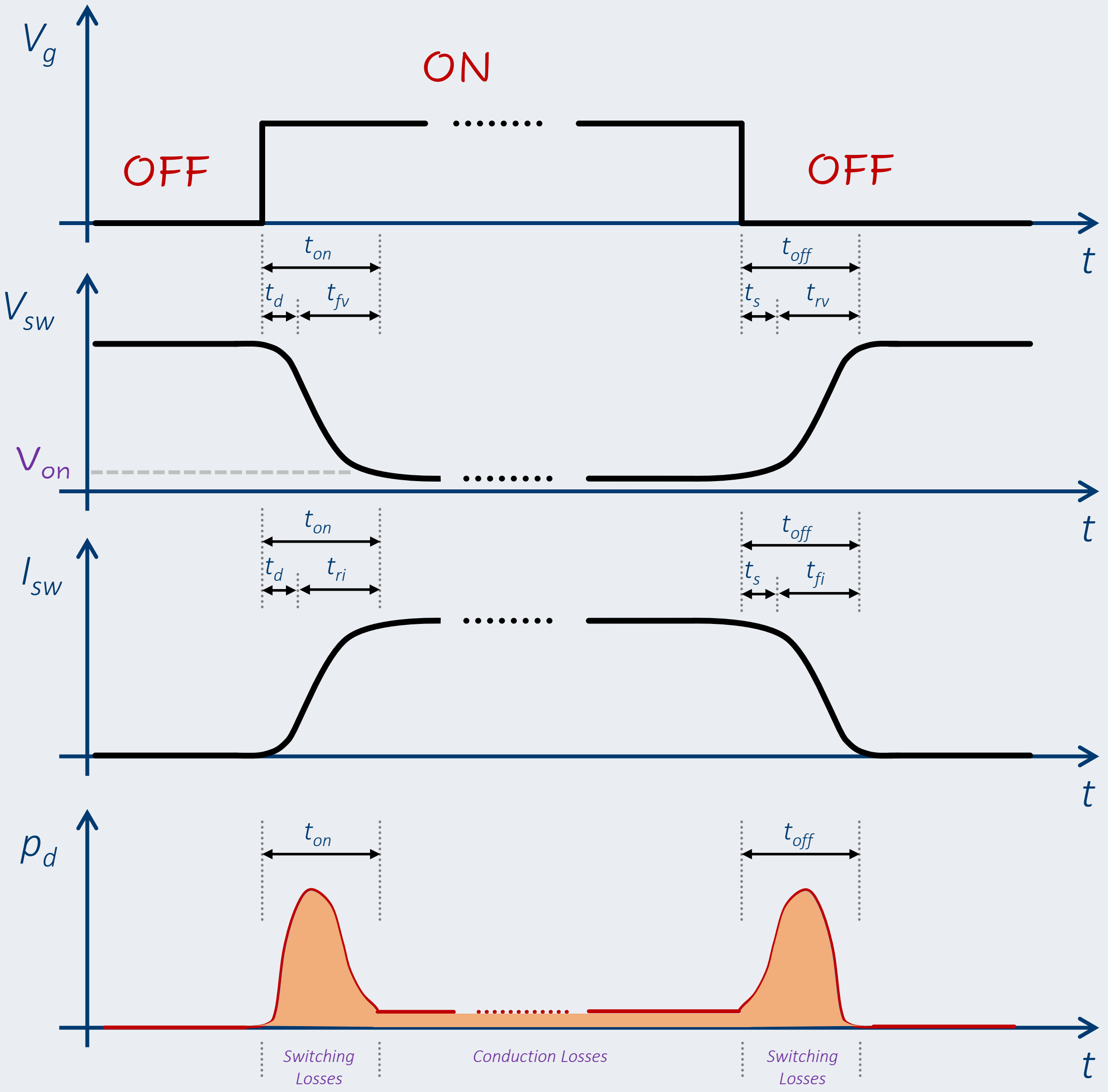




Power Loss = Switching losses + Conduction Losses

Practical Switches



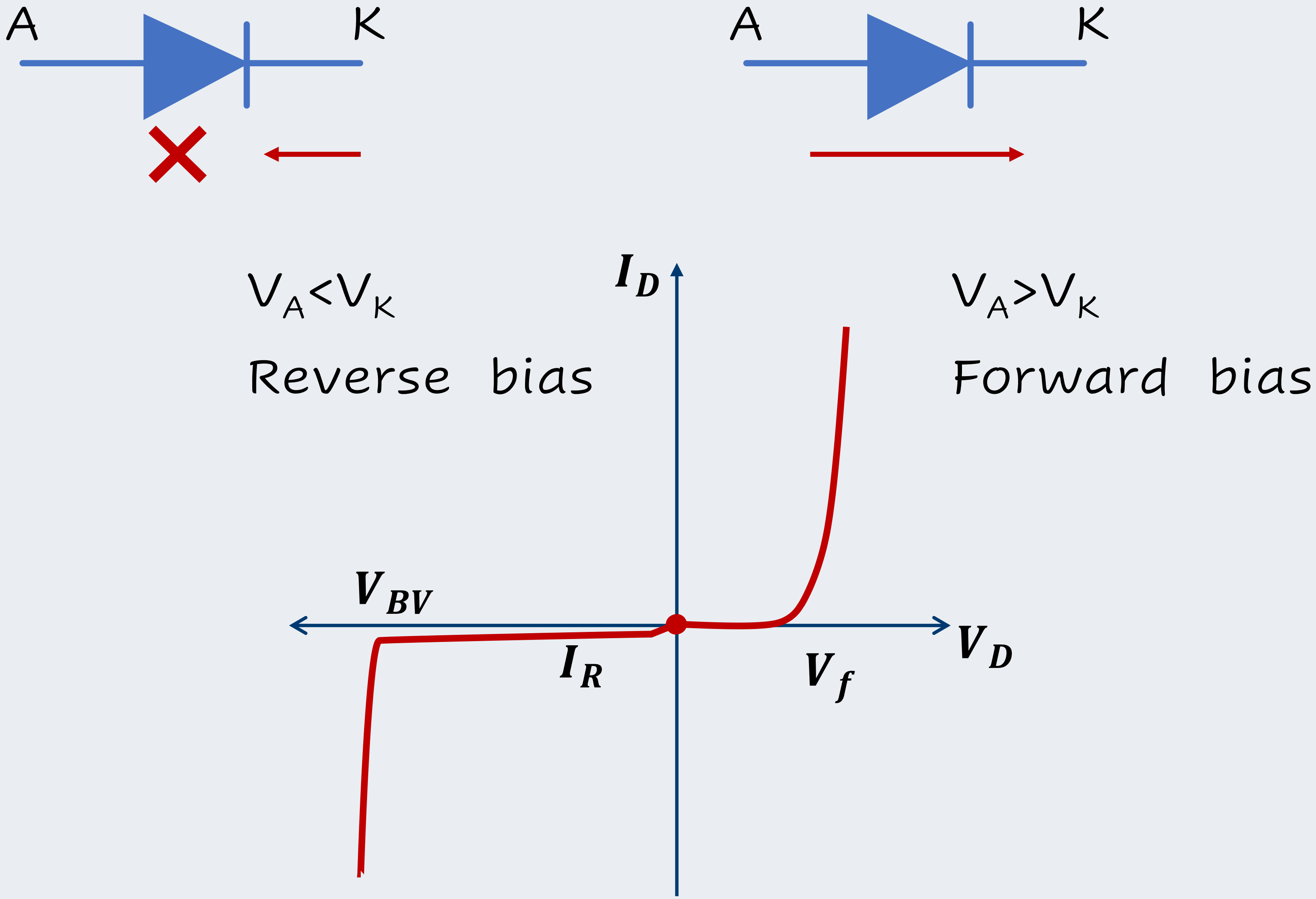


The delay time (t_d) corresponds mainly to the charging of the base-emitter junction diffusion capacitance or Vth and gain for the Mosfet

The current rise/fall time (t_r, t_f) is related to the effective base zone width and, as the base charge increases because of the base current, the collector current increases

t_s: The period after the cessation of positive base current until the transistor enters the linear region is termed storage or saturation time, because of overdriving.

Power Diodes



Diode-specific Electrical Characteristics

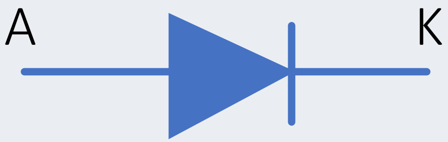
*VF : Forward voltage

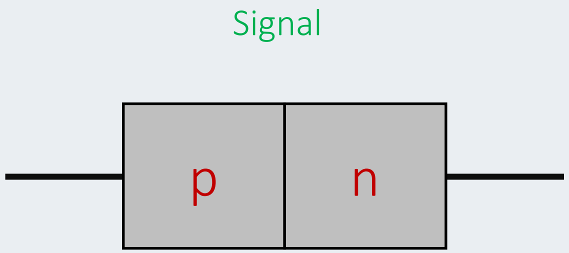
*IR : Reverse current (leak current)

*Ct : Capacitance

*Trr : Reverse recovery time

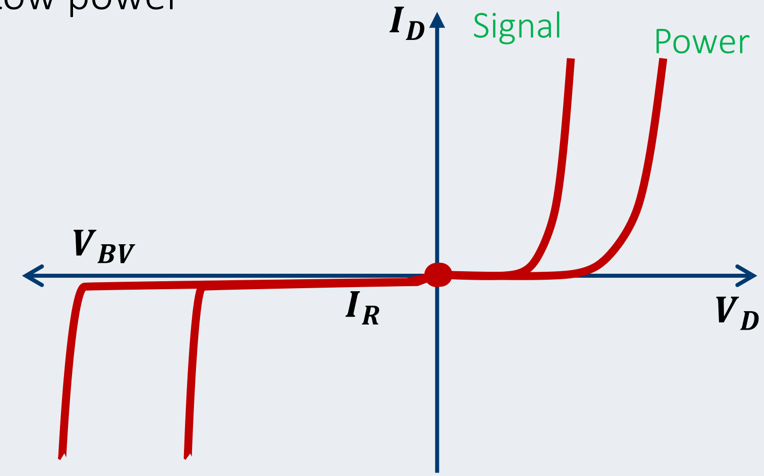
Power Diodes





n- : Lightly dopped
n+ : Heavily dopped

Low currents
Low Blocking voltages
Low power

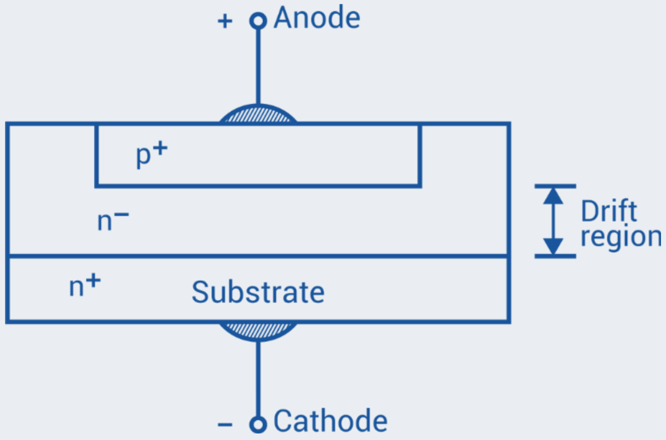


Higher currents
Higher Blocking voltages
Higher power

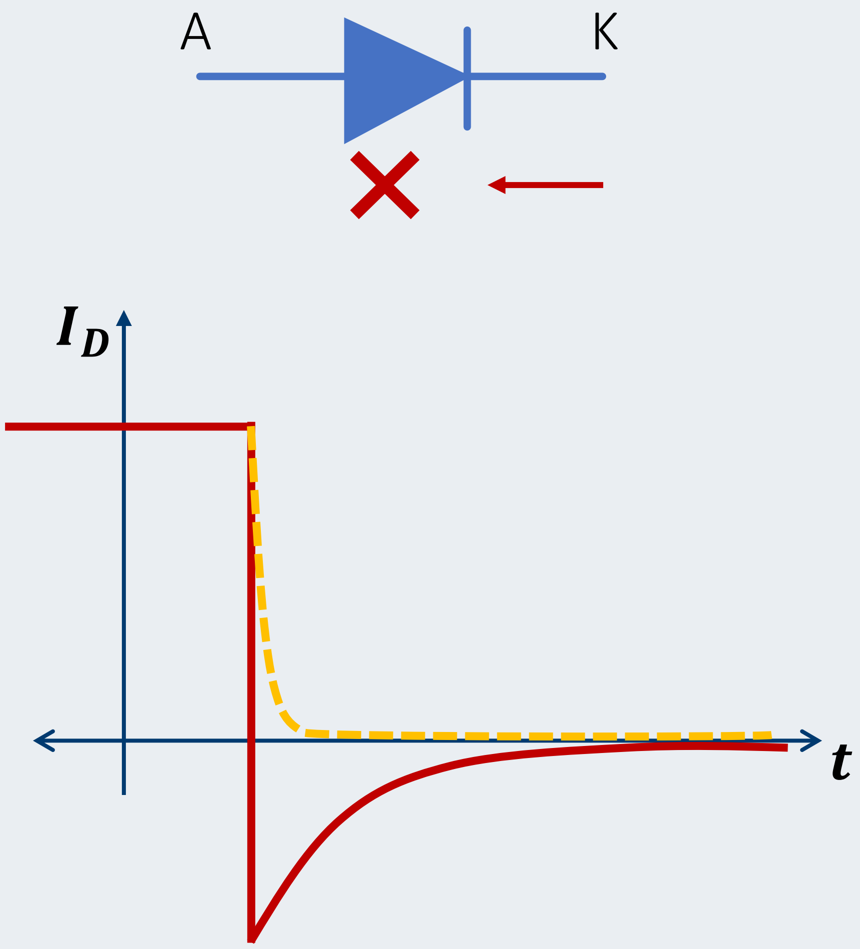
Higher forward voltage drop
Higher resistance in forward bias

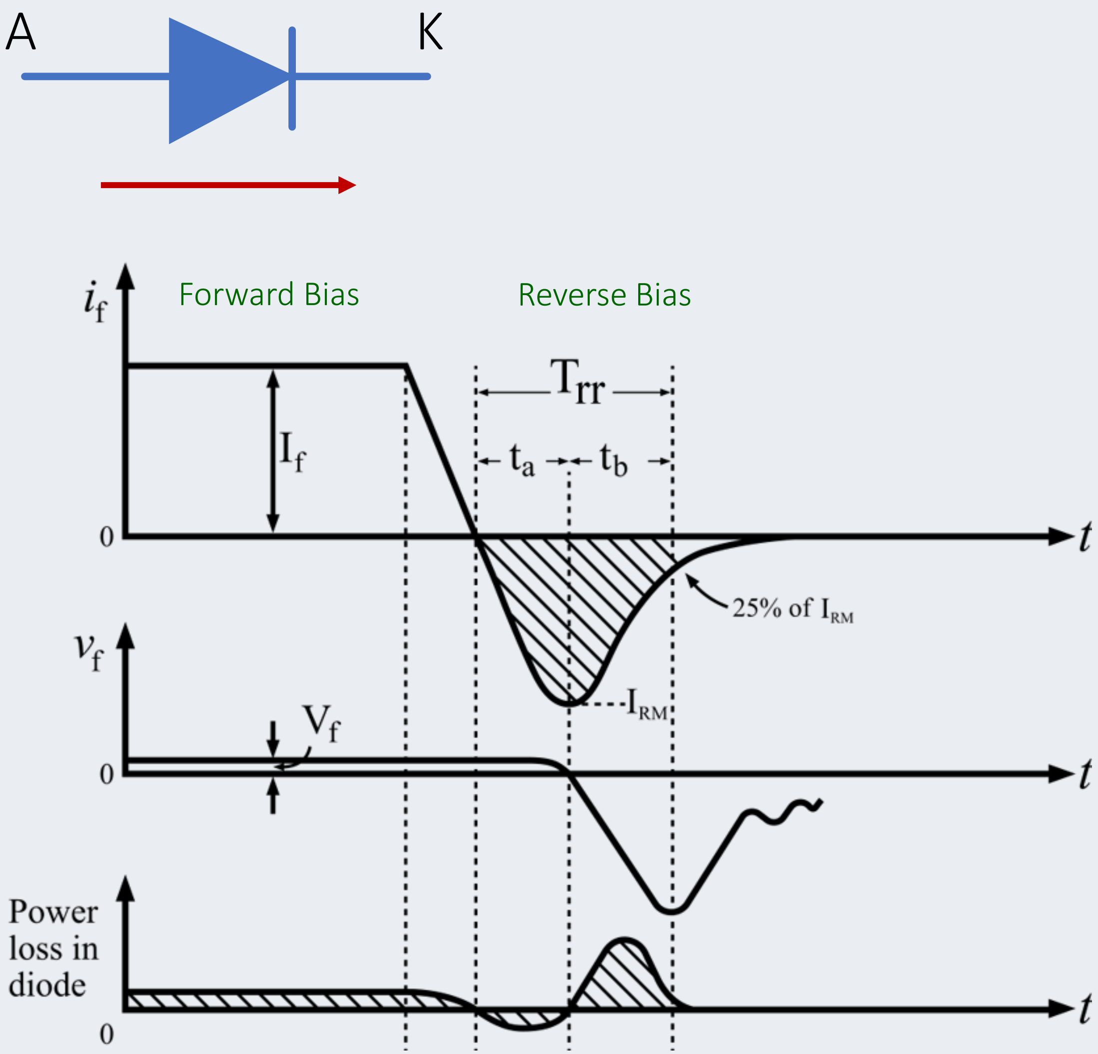
PIN

where i stands for intrinsic



Power Diodes

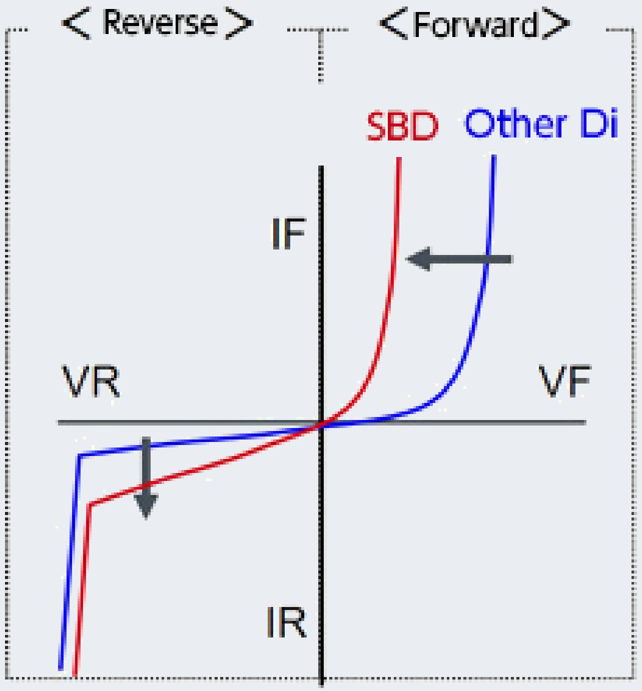


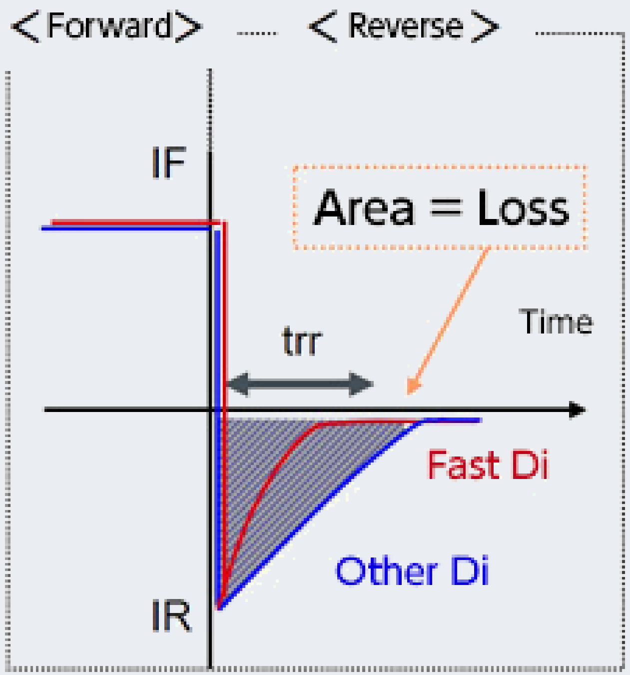


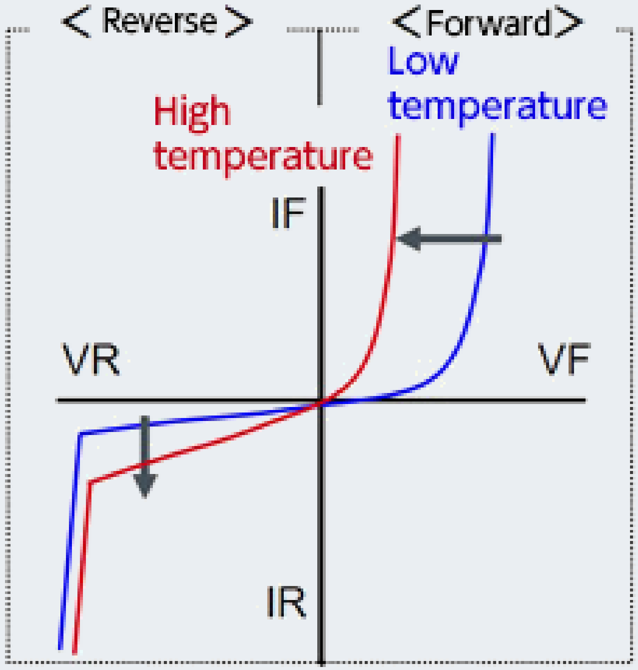
Left Figure indicates that SBDs have a lower V_F and higher I_R than the other three types.

Middle Figure indicates that t_{rr} is much shorter for SBDs and FRDs than for the other two diode types, and that if the I_R flowing during the time t_{rr} is large, losses are large.

Right Figure is the basic temperature characteristic for Si diodes. At higher temperatures, the V_F falls and the I_R increases.





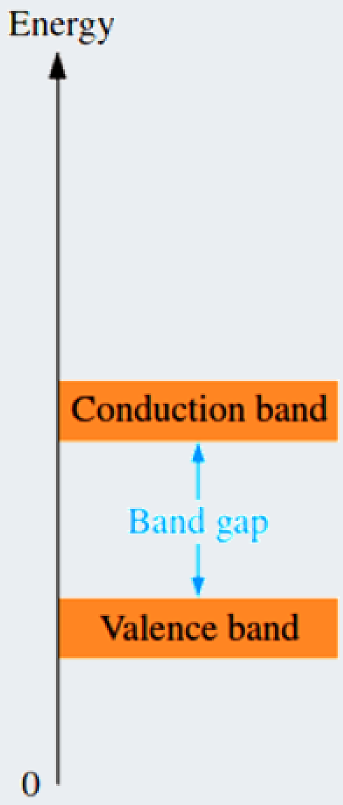


General Purpose Diodes	Fast Recovery Diodes	Schottky Diodes
Upto 5000V & 3500A	Upto 3000V and 1000A	Upto 100V and 300A
Reverse recovery time – High	Reverse recovery time – Low	Reverse recovery time – Extremely low.
$t_{rr} \approx 25\mu s$	$t_{rr} = 0.1\mu$s to 5μs	t_{rr} = a few nanoseconds
Turn off time - High	Turn off time - Low	Turn off time – Extremely low
Switching frequency – Low	Switching frequency – High	Switching frequency – Very high.
$V_F = 0.7$V to 1.2V	$V_F = 0.8$V to 1.5V	$V_F \approx 0.4$V to 0.6V

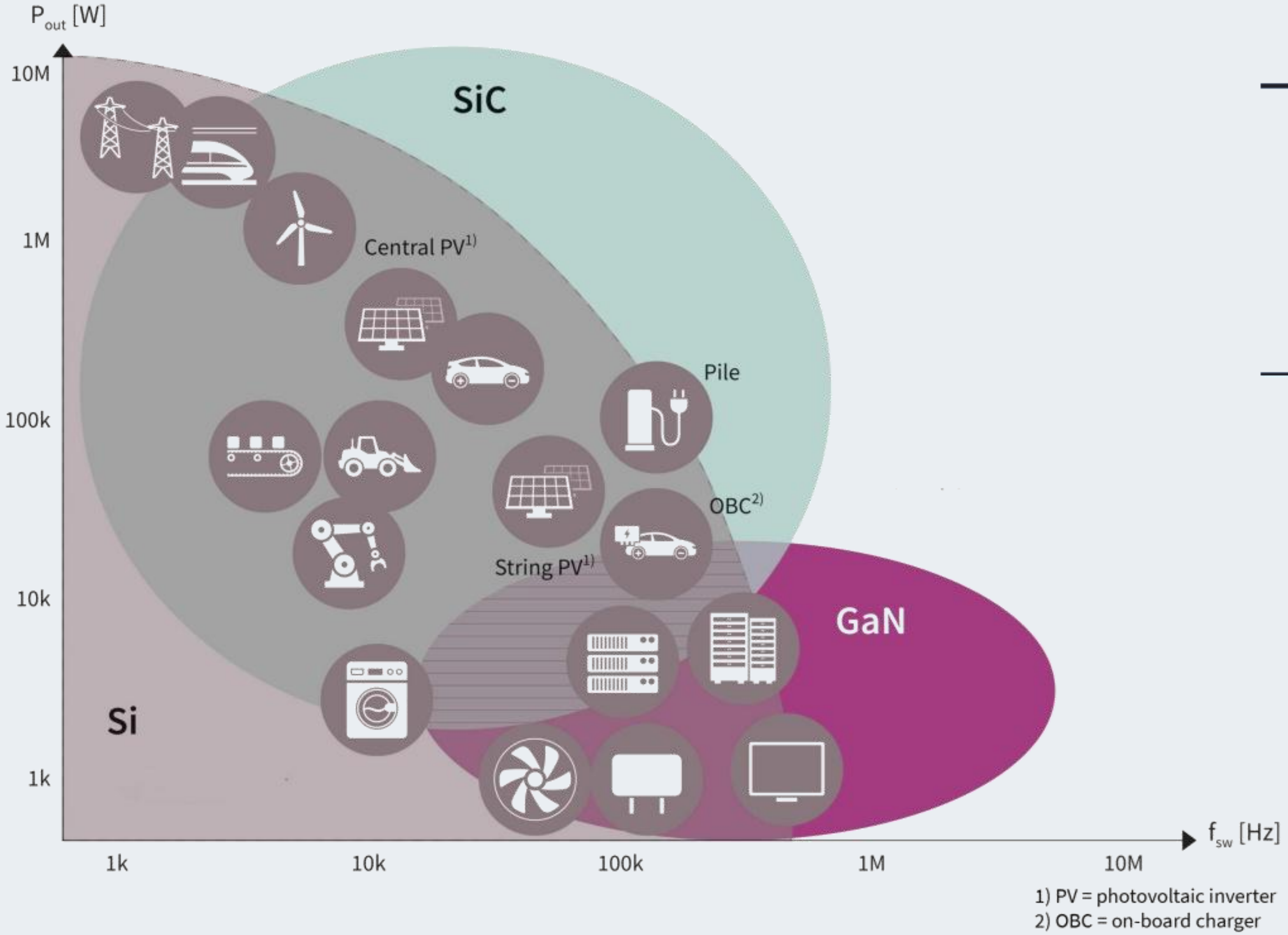
Wide Bandgap Semiconductors

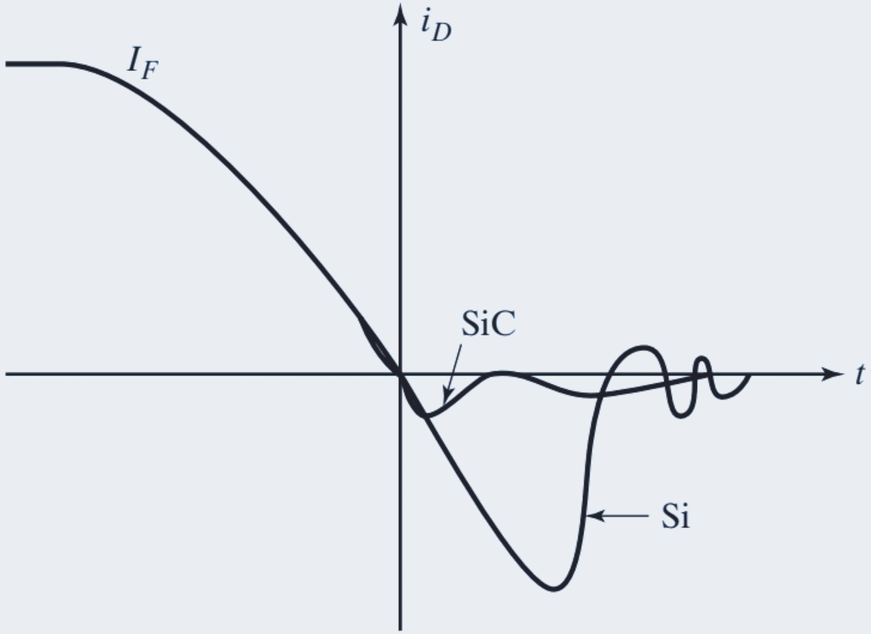
Silicon Carbide (SiC) and Gallium Nitride (GaN)

Properties	Si	4H-SiC	GaN	Application
Crystal structure	Diamond	Hexagonal	Hexagonal	
Energy gap : E_G (eV)	1.12	3.26	3.5	high temp. operation,emission wavelength
Electrical mobility : μ_n (cm^2/Vs)	1400	900	1250	High frequency devices
Hole mobility : μ_p (cm^2/Vs)	600	100	200	
Breakdown field : E_B (V/cm) $\times 10^6$	0.3	3	3	Power devices
Thermal conductivity (W/cmK)	1.5	4.9	1.3	High heat dissipation
Saturated drift velocity : v_S (cm/s) $\times 10^7$	1	2.7	2.7	High frequency devices



Wide Bandgap Semiconductors





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Bachelor of Engineering (Honours) in Electrical Engineering	16 February 2026
Master of Science (Power System Analysis and Renewable Integration)	9 February 2026
Master of Science (Industrial Automation and Instrumentation Control)	9 February 2026

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