Electronic Power Conversion

Introduction

Electronic Power Conversion (ET4119)

- Lecturers: Dr. Jelena Popović-Gerber (LB 3.630) j.popovic@tudelft.nl

- Material:
  - Study guide (see Blackboard)
  - Book:
  "Power Electronics: Converters, Applications, and Design"
  Authors: Mohan, Undeland, Robins
  Publisher: Wiley, 2nd or 3rd ed.
  available at the ETV for about € 50,-
  Book is used for ET3165, ET4119, ET4116 & ET4145

- Additional material:
  "Fundamentals of Power Electronics"
  Authors: R.W. Erickson, D. Maksimovic
  Publisher: Springer; 2nd ed.

Electronic Power Conversion (ET4119)

- Practicals: 3 half days; subscribe in pairs
  H.J.M. Olsthoorn, H.J.M.Olsthoorn@tudelft.nl
- Exam: Written, closed book, January/June (April)
- Homeworks: 3 homeworks, each worth 2 points towards final mark
- Examination requirements: see study guide
- Blackboard: - study guide; course objectives
  - sheets
  - answers to problems
  - exams

Additional Info

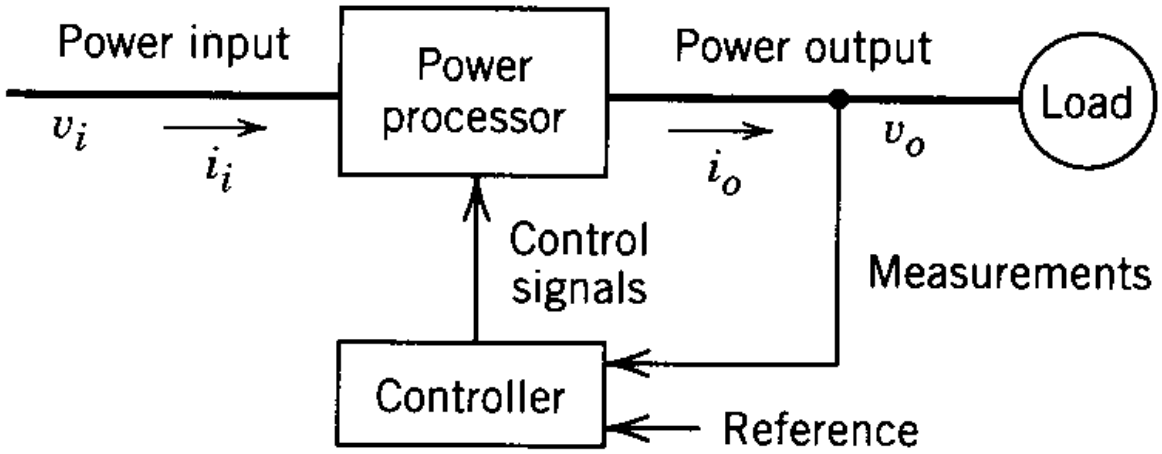
- http://www.ipes.ethz.ch/ educational module basic power electronic circuits – Java applets

Electronic Power Conversion (ET4119)

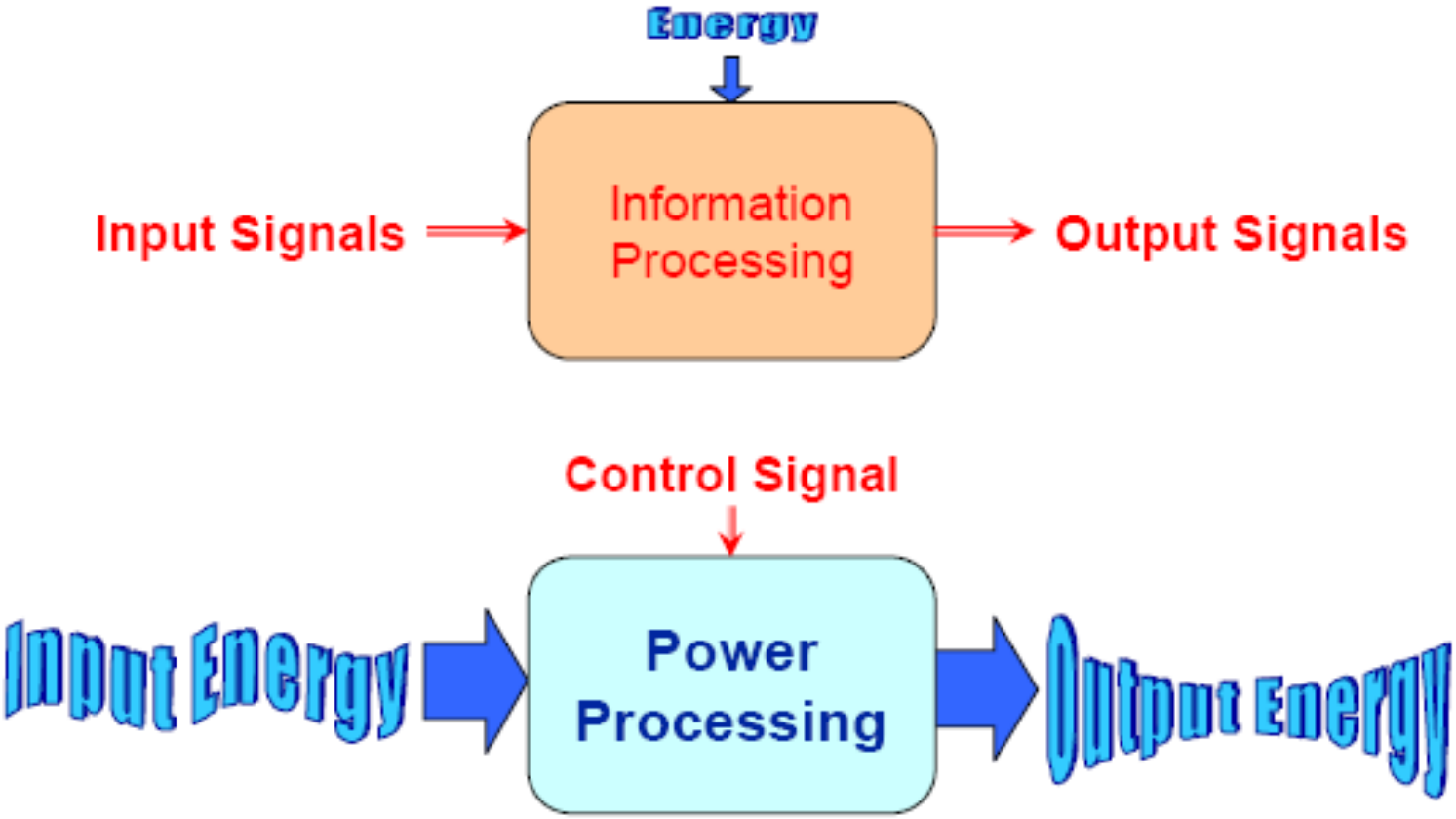
- Intro (Ch1)
- Overview power semiconductors (Ch2)
- Review of basics (Ch3)
- Diode rectifiers (Ch5)
- DC-DC converters (Ch7)
- DC-AC converters (Ch8)
- Isolated power supplies (Ch10)
- Power electronics applications

What is Power Electronics?

- Power electronics is a technology
  for **converting, controlling and conditioning** the flow of **electrical energy**
  from the source to the load according to the requirements of the load.



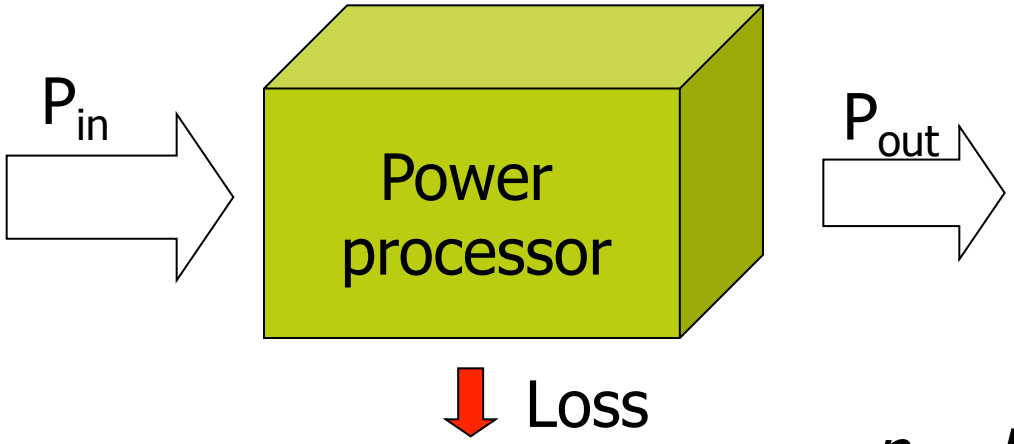
Microelectronics *vs.* Power Electronics



Source: CPES, ECPE seminar

Conversion Efficiency

- High conversion efficiency:
  - Efficient energy usage (cost);
  - Loss → heat→ additional components for heat removal→ negatively influences size and cost.



$$\eta = P_{out}/P_{in} = (P_{in}-P_{loss})/P_{in}$$

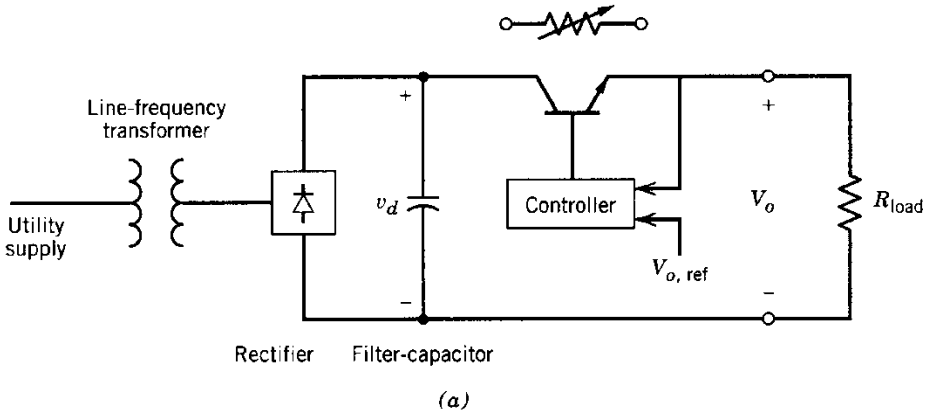
Example

- Comparison of 2 desktop computer power supplies
  - η_1=75%
  - η_2=95%
  - P_{out}=500W
  - P_{loss1}=167W
  - P_{loss2}=26W
  - ΔP_{loss}=141W
  - Annual energy consumption saving
    - 141W*24h*365→1235kWh*0.2€/kWh=247€
    - *per computer!*
    - NL: 0.8 computers per person – 12million computers 3 billion euros

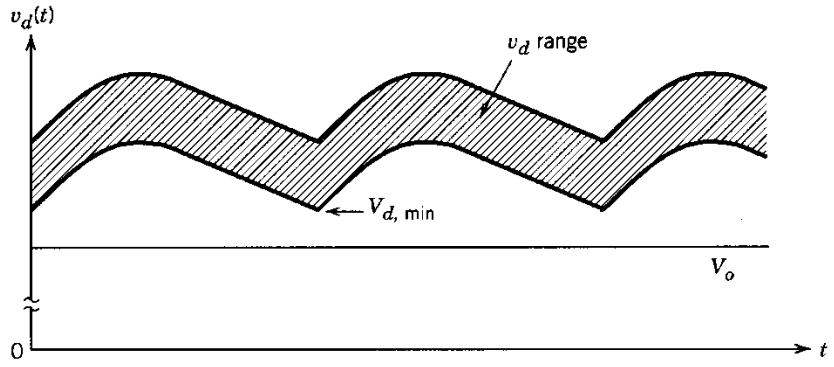
$$P_{loss} = P_{in}(1-\eta) = \frac{P_{out}}{\eta}(1-\eta)$$

Linear vs. Switching Power Conversion

- **Linear** dc power supply
- Example: 230V ac to 5V dc



(a)



- Transistor operates in active region

Cons:

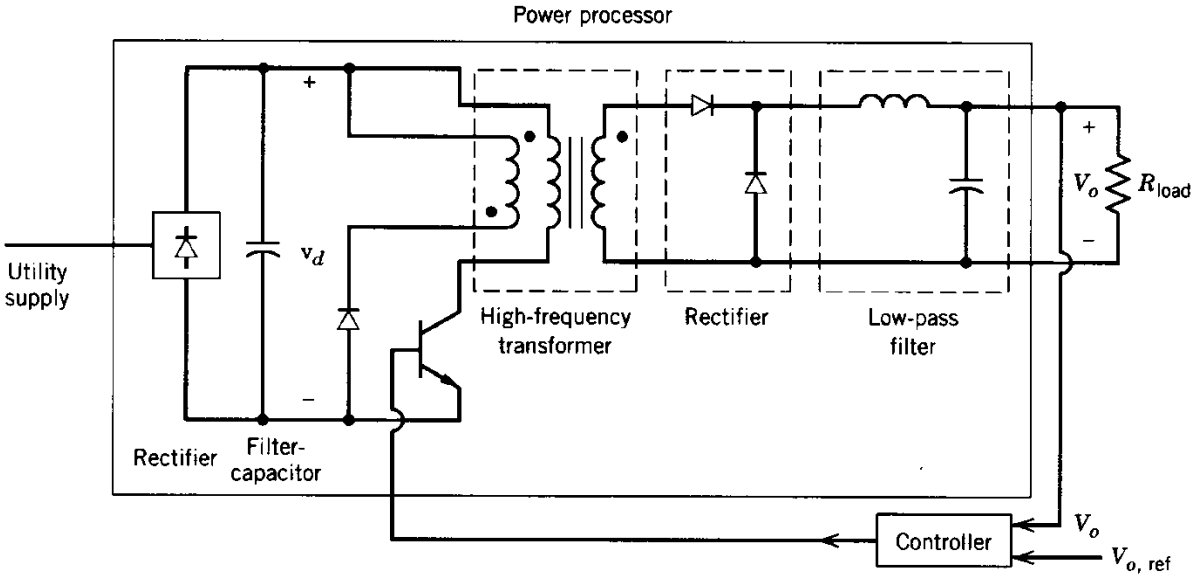
- Dissipation in transistor;
- $V_{dmin} > V_o$;
- Heavy & bulky line transformer;

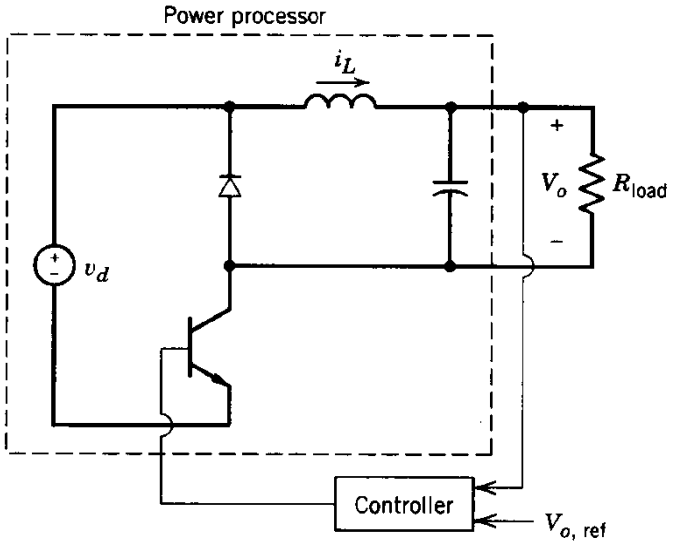
Pros:

- Less electromagnetic noise;

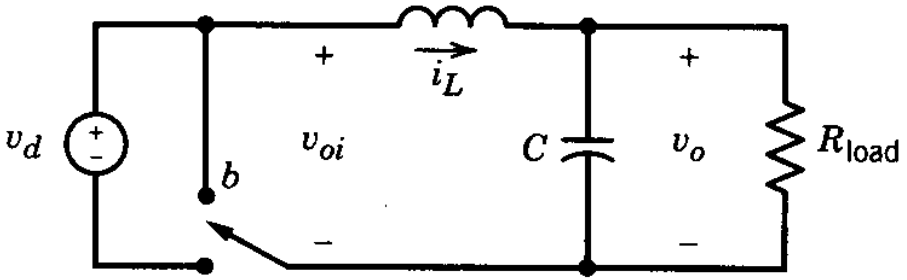
Linear vs. Switching Power Conversion

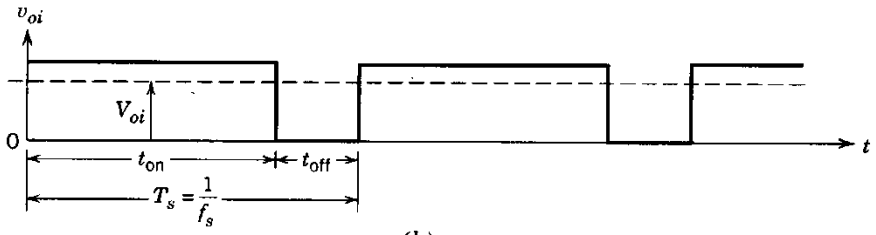
- **Switch-mode** dc power supply
- Example: 230V ac to 5V dc





Linear vs. Switching Power Conversion





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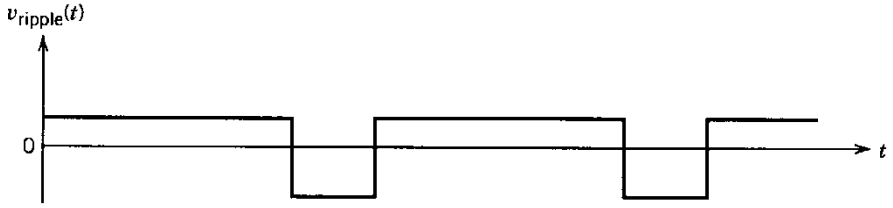

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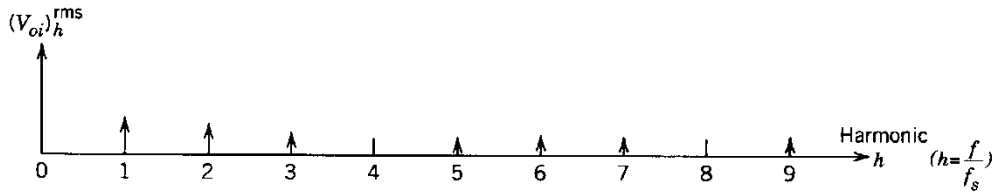


Output voltage control through duty ratio

$$v_0 = \frac{1}{T_s}\int_0^{T_s} v_{oi}\ dt$$

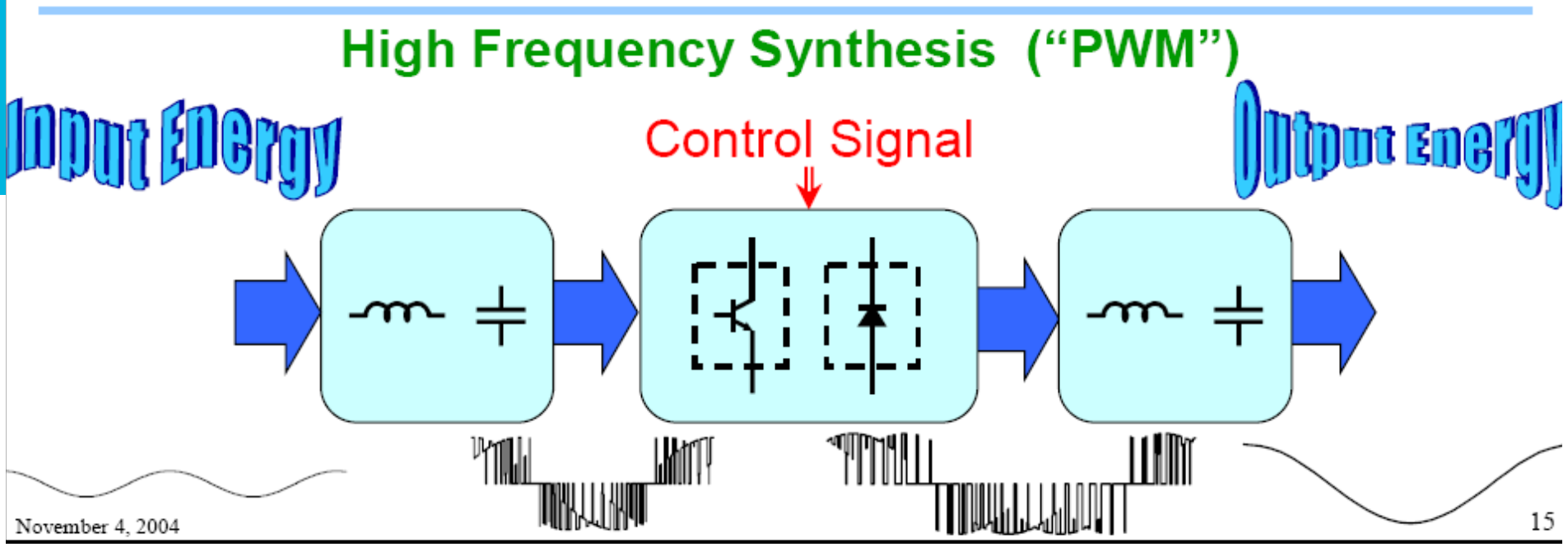
$$= \frac{t_{on}}{T_s}\ V_d = D\,V_d$$

Pros:

- High effciency
- Small hf transformer, L and C

Cons:

- Noisy;

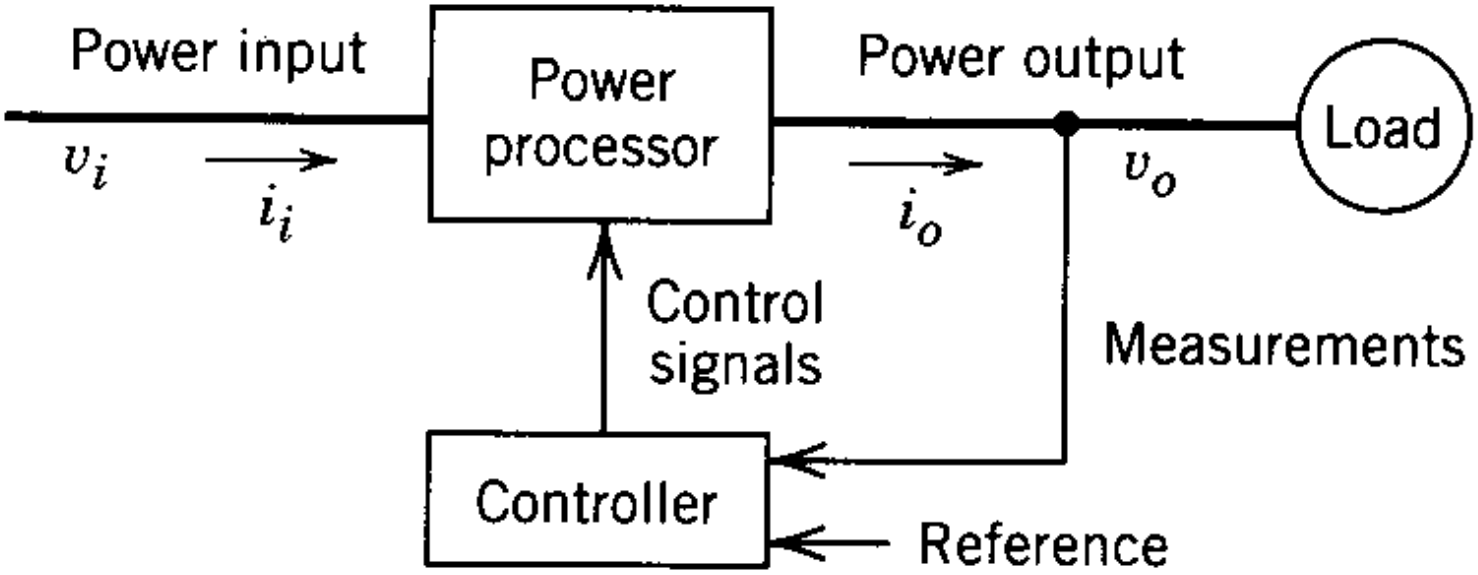


Source:CPES@ECPE seminar

How?

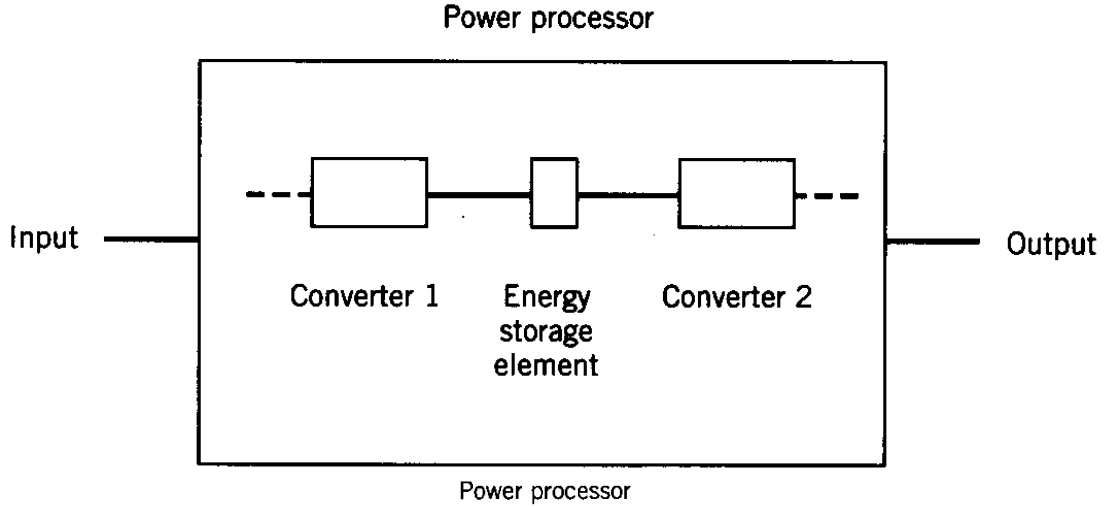
"Processing of electrical energy with semiconductors by means of a non-dissipative switching process."

Power Electronic System

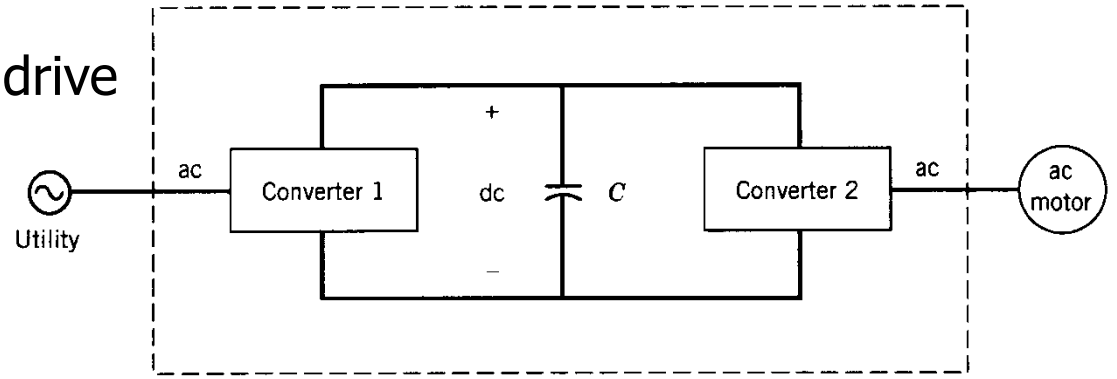


Power Electronic Processor

- PE processor (converter): basic block of PE systems



Example: motor drive



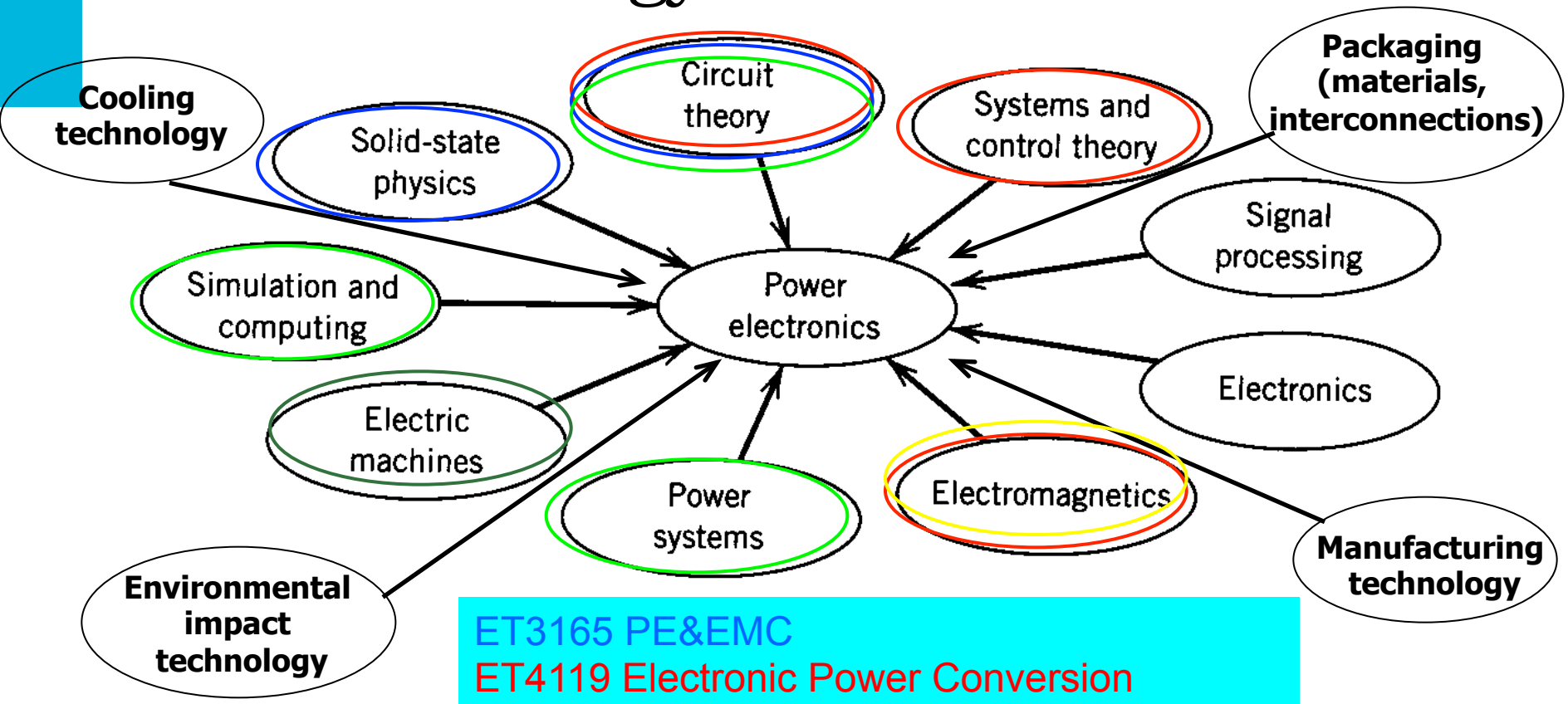
Power Electronic Processor

- Generic term: **converter** (*omzetter*)
- On the basis of the form of input and output
  - ac to dc (rectification, *gelijkrichten*)
  - dc to ac (inversion, *wisselrichten*)
  - dc to dc
  - ac to ac
- On the basis of the type of switching
  - line-frequency (naturally) commutated
  - forced commutated
  - (quasi) resonant

Power Electronic Converter – Fundamental Functions

- Switching function
  - Controls energy flow
- Electromagnetic energy storage function components
  - Enables energy continuity when interrupted by switching function
- Conduction function
  - Guides energy flow through the converter
- Control/information function
  - Enables relationship between the three functions above

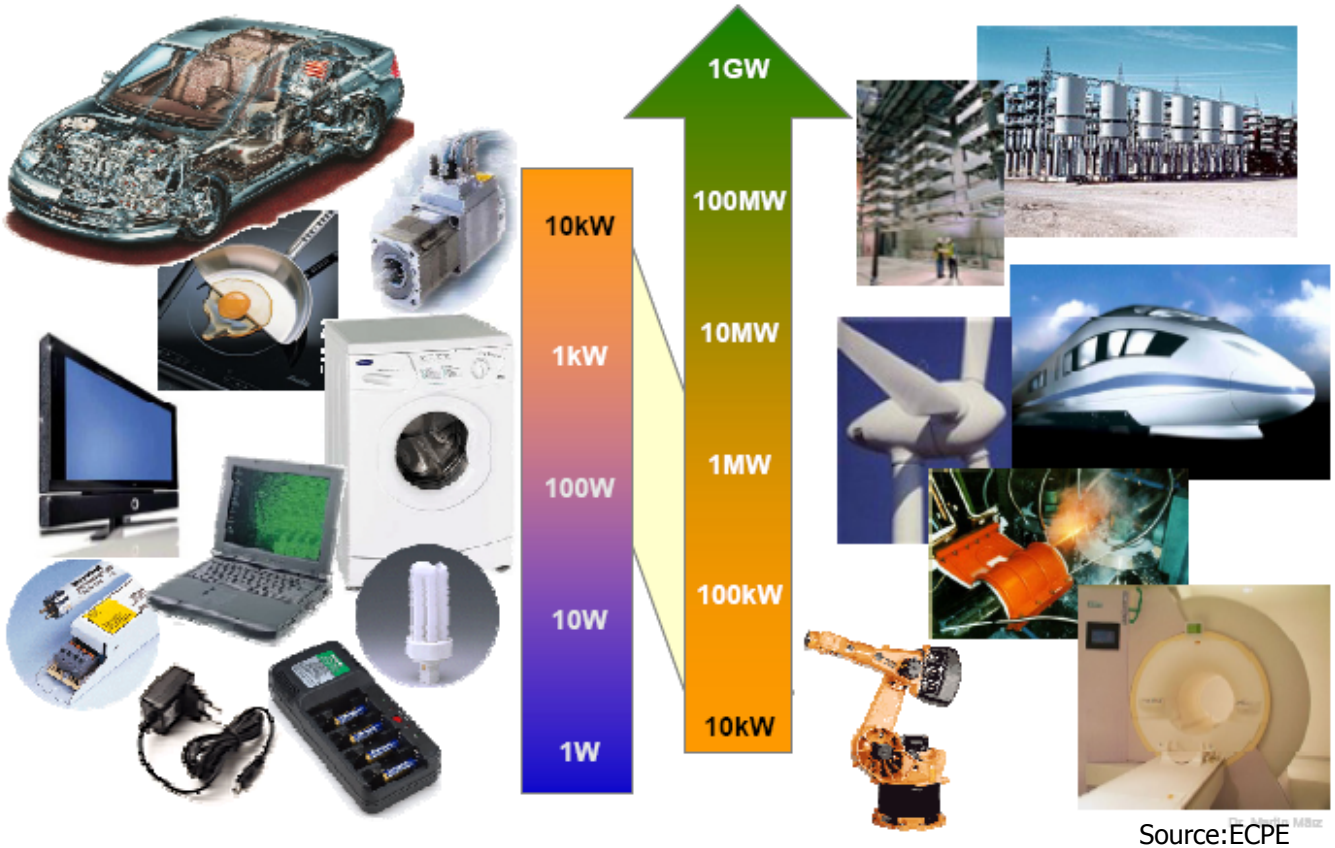
Power Electronics – Interdisciplinary Technology



ET3165 PE&EMC
ET4119 Electronic Power Conversion
ET4116 PE Components
ET4003 Power Electromagnetics
ET4117 Electrical Machines and Drives

Power Electronics Applications

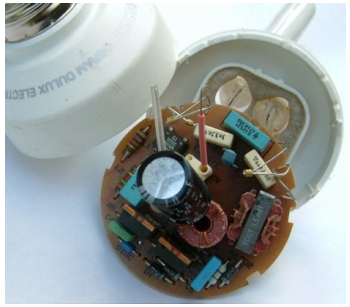
- Wide power range applications
  - mW – portable electronics → GW – energy transmission lines



Source:ECPE

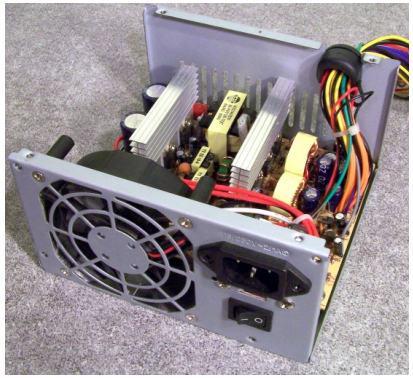
Applications - Residential

Lighting



Home appliances

Personal computers



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Applications - Commercial

Air conditioning

Elevators

UPS

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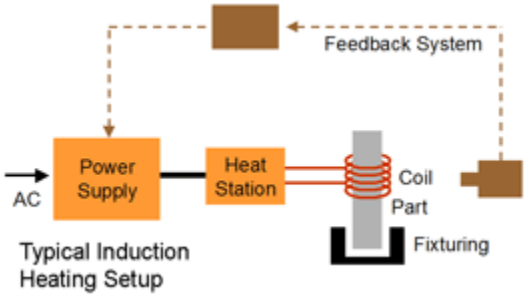
Applications - Industrial

Variable Speed Drives
(fans, pumps, compressors)

Induction heating

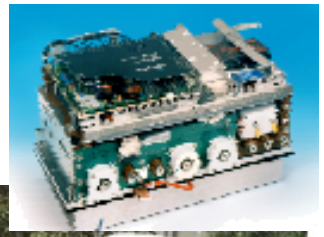


Application - Transportation

Hybrid car

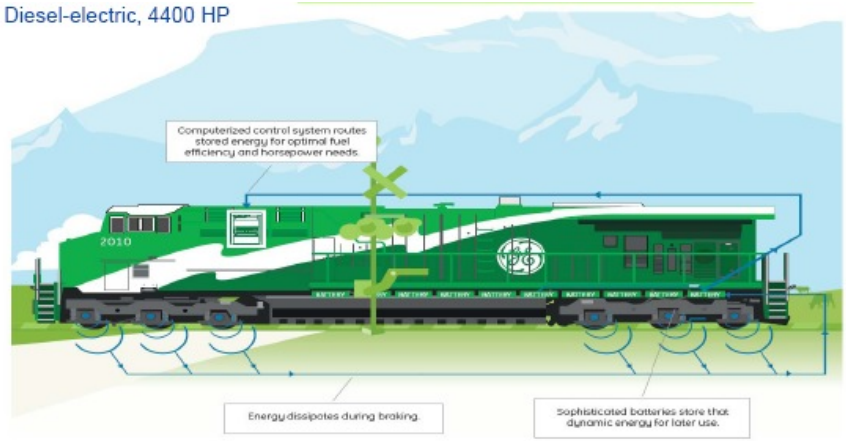
Source: Toyota

Tram



Source: Bombardier

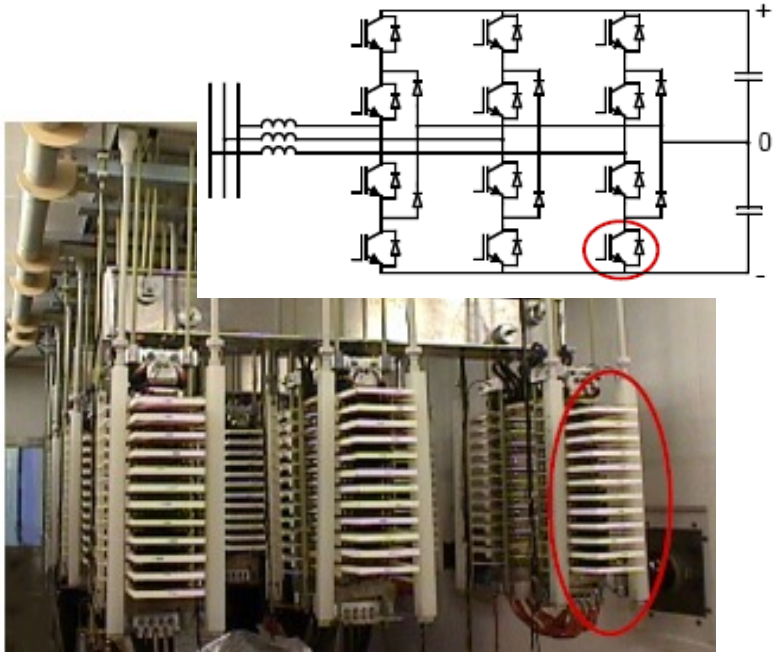
Hybrid locomotive



Source: GE

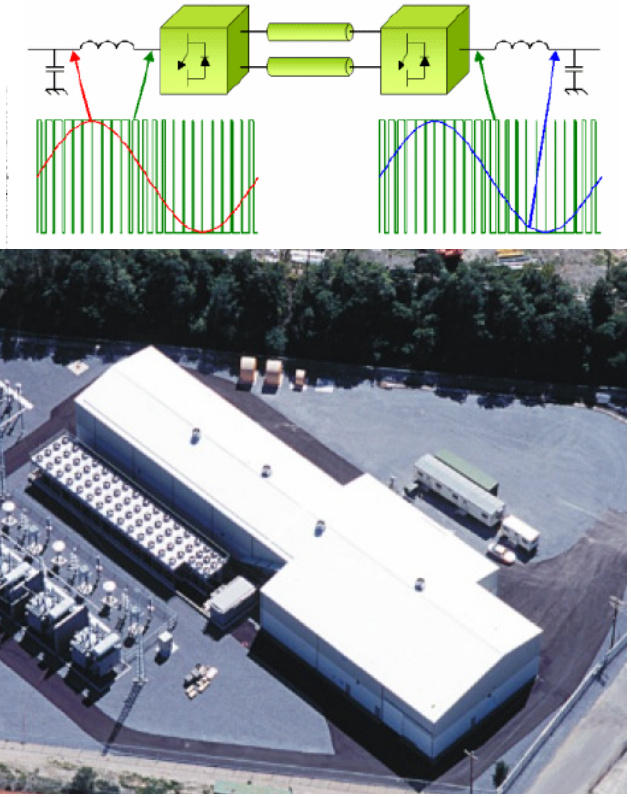
Application – Utility Systems

FACTS
(Flexible AC Transmission Systems)



Source: ABB

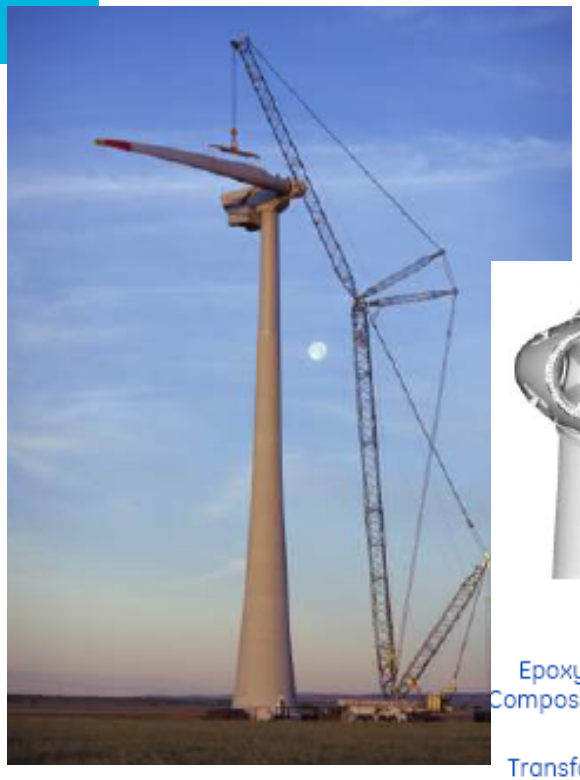
HVDC
(High Voltage DC Transmission)

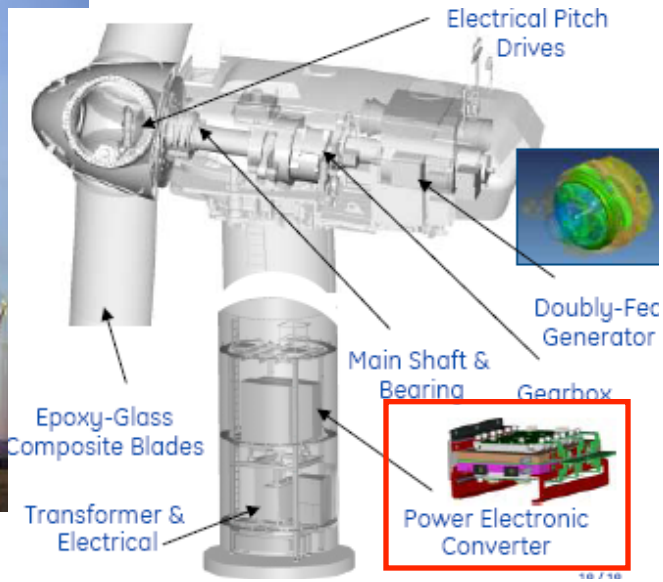


Source: ABB

Applications – Renewable Energy Sources

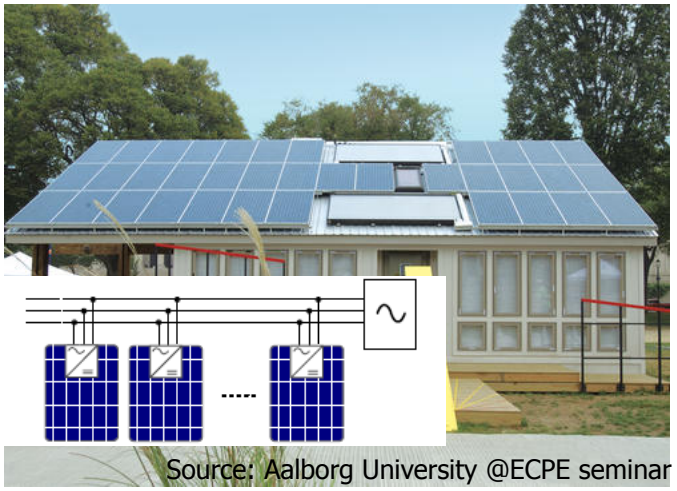
Wind turbine





Source: GE@ECPE seminar

Photovoltaic systems



Source: Aalborg University @ECPE seminar

Power Electronics Growth

- Societal, Economic and Environmental Megatrends

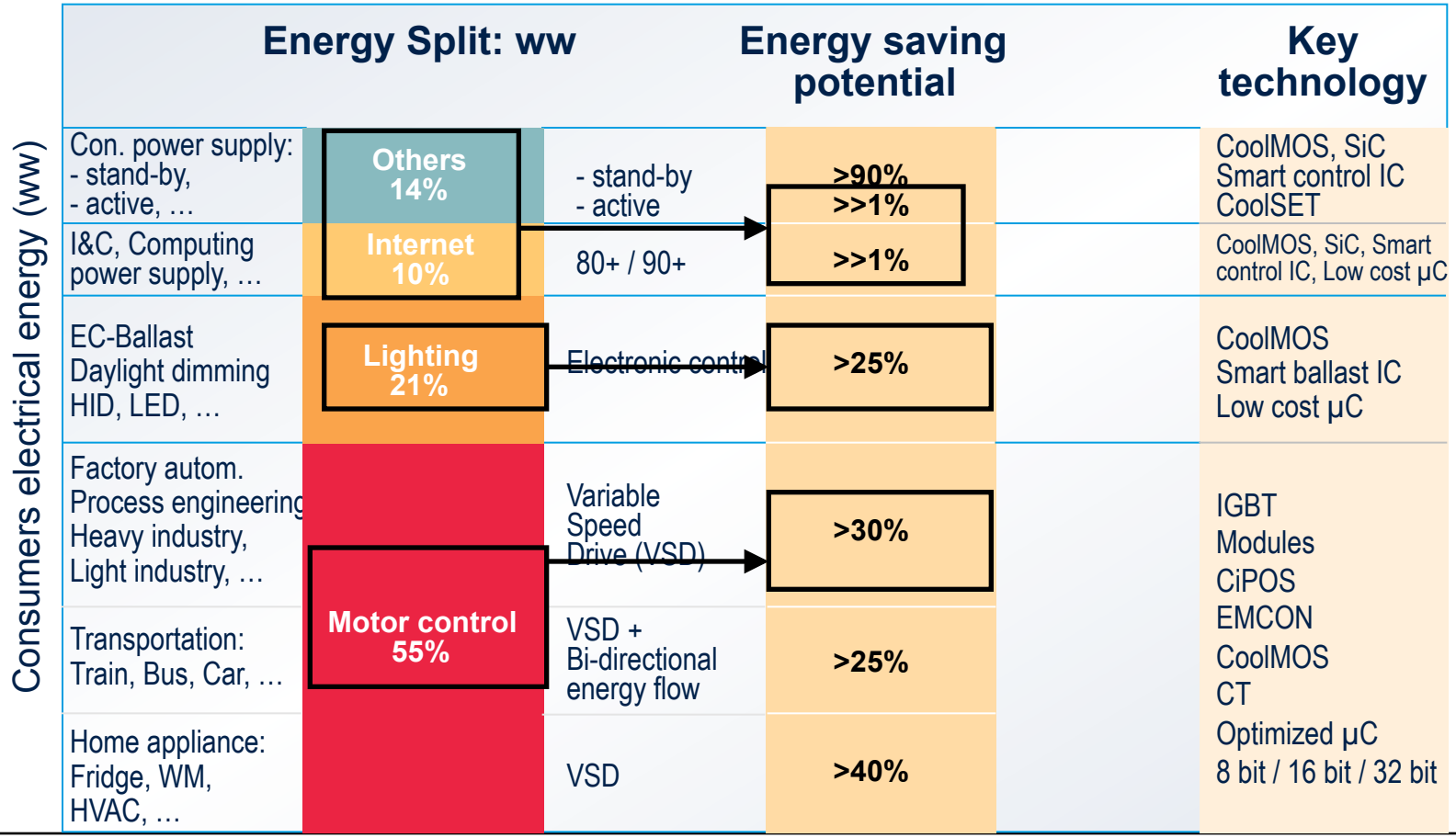
Mobility	Hybrid and electric vehicles More electric aircraft/ship Trains	**Energy savings**	Utility systems -*Smart Grid* Intelligent power management Energy efficiency
Information & Communication	Portable electronics Internet PC Wireless sensor networks	**Comfort & Health**	Electrification Body implants

Energy Efficiency – the Role of Power Electronics

- Energy saving ubiquitous topic globally;
  - Various EU and international programmes and policies: Intelligent Energy Programme, Energy Star
- EC plan: reduce total energy consumption by 20% by 2020;
- Power electronics savings potential: 1150TWh or 30% of the predicted EU-25 electricity consumption;
- 40% of total energy consumption is electrical energy → power electronics can achieve half of the target!

Major Consumers of Electrical Energy – Savings Potential

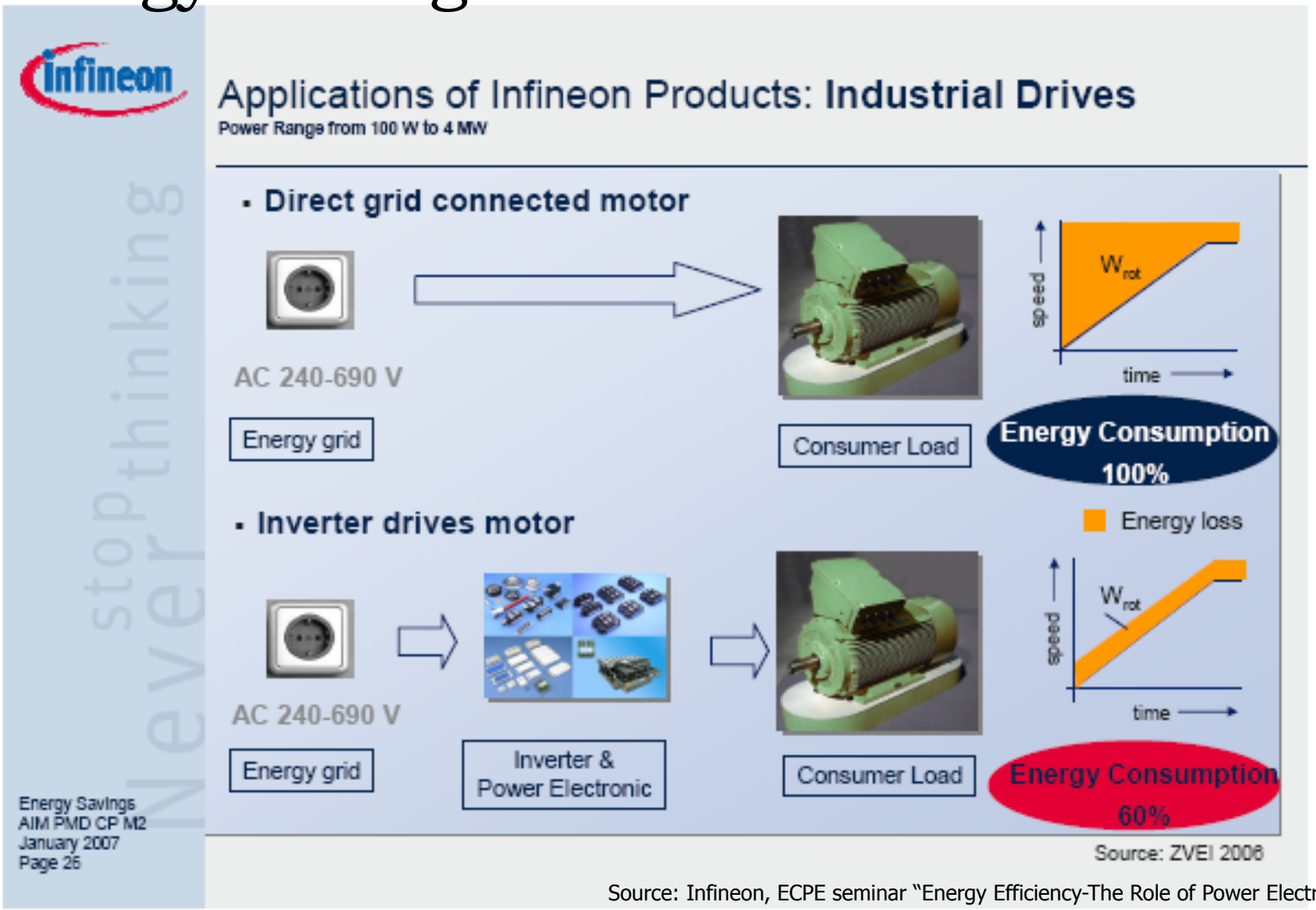
Today: 40% out of the overall energy consumption is electrical energy



Source: ZVEI, Siemens, CEMEP, CPES, EPA, NRDC

Source: Infineon, ECPE seminar "Energy Efficiency-The Role of Power Electronics"

Energy Savings Potential – Motor Drives



Source: Infineon, ECPE seminar "Energy Efficiency-The Role of Power Electronics"

Energy Savings Potential – Home

Electricity Use in Homes: Examples

Data: EU Greenbook and ECPE calculations

Lighting

- Energy consumption EU-15: ~240'000 GWh
- Energy efficiency potential: 30%
- Example: High efficiency electronic ballast

Circulator Pumps

- Energy consumption EU-15: ~41'000 GWh
- Energy efficiency potential: 30%-40%
- Example: Variable speed control

Washing

- Energy consumption EU-15: ~26'000 GWh (2003)
- Energy efficiency potential: 35%
- Examples: Variable speed control, direct drive/mechatronic integration

Source: ABB, ECPE seminar "Energy Efficiency-The Role of Power Electronics"

Image credits

- All uncredited diagrams are from the book "Power Electronics: Converters, Applications, and Design" by N. Mohan, T.M. Undeland and W.P. Robbins.
- All other uncredited images are from research done at the EWI faculty.