Part –1: Module Overview

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EEE Department, School of Advanced Technology

Course Works and Final Exam

- **Allocation of Time:**

In-class teaching	Tutorials	Lab/Practice	Private Study	Total
19.5	3	8	44.5	75

- **Assessment:**

Assignment	10%
Lab	10%
2-hour Final exam	80%

Office hours: Tuesday, 10:30 to 12:30

Laboratory : Week 8,9

Assignment: Week 11

Student Performance in 2020-21

SN	Assessment Component (eg. midterm; coursework; exam; project)	Weighting	Credit Weight	No. of Candidates(*)	No. of Absentees(*)	Average Mark	Median	Standard Deviation	Minimum Mark	Maximum Mark	No. of Failures(*)	% of Failure
1	Formal Exam (80%)	80%	2	56	3	56.19	57	21.19	0	92	9	16.07
2	Lab (10%)	10%	0.25	56	8	70.38	70	10.85	39	94	1	1.79
3	Assignment (10%)	10%	0.25	56	5	80.25	88	21.43	4	99	5	8.93
	Final Marks (100%)	100%	2.5	56(1)	2(0)	57.96	60	20.84	0	90	8(1)	14.29

Student Performance in 2021-22

SN	Assessment Component (eg. midterm; coursework; exam; project)	Weighting	Credit Weight	No. of Candidates(*)	No. of Absentees(*)	Average Mark	Median	Standard Deviation	Minimum Mark	Maximum Mark	No. of Failures(*)	% of Failure
1	Formal Exam (80%)	80%	2	51	1	59.14	67	23.66	2	94	8	15.69
2	Lab (10%)	10%	0.25	51	6	63.78	66	17.06	23	93	5	9.8
3	Assignment (10%)	10%	0.25	51	6	69.84	76	23.18	3	100	4	7.84
	Final Marks (100%)	100%	2.5	51(4)	0(0)	58.59	67	23.8	2	2	9(1)	17.65

Student Performance in 2022-23

SN	Assessment Component (eg. midterm; coursework; exam; project)	Weighting	Credit Weight	No. of Candidates(*)	No. of Absentees(*)	Average Mark	Median	Standard Deviation	Minimum Mark	Maximum Mark	No. of Failures(*)	% of Failure
1	Formal Exam (80%)	80%	2	80	12	40.41	40	23.19	0	96	33	41.25
2	Lab (10%)	10%	0.25	80	12	82.28	84	11.92	46	100	0	0
3	Assignment (10%)	10%	0.25	80	11	79.67	86	17.34	20	99	2	2.5
	Final Marks (100%)	100%	2.5	80(2)	7(2)	45.38	44	22.44	0	96	22(0)	27.5

Student Performance in 2023-24

SN	Assessment Component (eg. midterm; coursework; exam; project)	Weighting	Credit Weight	No. of Candidates(*)	No. of Absentees(*)	Average Mark	Median	Standard Deviation	Minimum Mark	Maximum Mark	No. of Failures(*)	% of Failure
1	Formal Exam (80%)	80%	2	98	13	47.34	50	26.12	0	93	25	25.51
2	Lab (10%)	10%	0.25	98	9	63.97	62	13.62	32	100	2	2.04
3	Assignment (10%)	10%	0.25	98	13	72.66	73	14.11	25	96	2	2.04
	Final Marks (100%)	100%	2.5	98(12)	7(3)	48.48	51	24.13	1	90	29(5)	29.59

Content

- Fundamental ON-OFF nature of power electronic switches;
- AC-DC uncontrolled and controlled rectifiers;
- DC-DC choppers design;
- AC-AC voltage control and cycloconverters;
- DC-AC inverter analyses;
- DC and AC Drives with variable speeds;
- Applications of power electronics.

Learning Outcomes

- *Intellectual Abilities*
  - To be able to recognise the ON-OFF nature of power electronics switches (circuits operate in a time series of transient modes, which is quite different from sinusoidal operation);
  - To be able to apply this understanding to the analysis and synthesis of circuits.
- *Practical Skills*
  - The design of simple AC - DC rectifiers;
  - The design of simple DC - DC converters;
  - The design of a AC-AC converter.
  - Simulate power electronic system by using LTSpice

References (Not compulsory)

- *Recommended Texts:*
  - Erickson, Robert W., and Dragan Maksimovic. ***"Fundamentals of power electronics"***. Springer Science & Business Media, 2007.
  - N. Mohan, T.M. Undeland and W.P. Robbins, "***Power Electronics: Converters, Applications and Design***", 3rd Edition, Higher Education Press, 2004.
  - 开关功率变换器:开关电源的原理、仿真和设计(原书第3版)

Appendix – Power Electronics related companies

- Texas Instruments
- IR HiReal
- Linear Technology Corporation

- ABB
- Siemens
- GE

- SMA
- Enphase
- Sungrow (阳光电源）

- Delta（台达） Huawei (华为） NARI（南瑞） SH Electric（上海电气）

Academic Journals and Conferences

- ***Important Journals and Conferences:***
  - IEEE
    - IEEE Transactions on Power Electronics
    - IEEE Journal of Emerging and Selected Topics in Power Electronics
    - IEEE Transactions on Industrial Electronics
    - IEEE Transactions on Industry Applications

    - APEC, ECCE, IECON, COMPEL

Appendix – Power Electronics related PG program

- ***USA and Canada:***
  - Univ. of Colorado at Boulder https://www.colorado.edu/ecee/
  - VT CPES https://cpes.vt.edu/
  - UT Knoxville http://power.eecs.utk.edu/index.htm
  - UIUC http://energy.ece.illinois.edu/
  - Queen's University, CA, http://my.ece.queensu.ca/Research/Groups/Power-Electronics/index.html
- ***EU:***
  - Aalborg CORPE DK http://www.corpe.et.aau.dk/
  - ETH Zurich https://www.pes.ee.ethz.ch/en/home.html
- ***Asia pacific:***
  - RMIT, UTS, Canterbury, HKPolyU, UNIST

Part –2: Module Introduction

Introduction - Outline

1. What is Power Electronics?
   - Definition
   - Relation with information electronics
   - The interdisciplinary nature
   - Significance in the human society

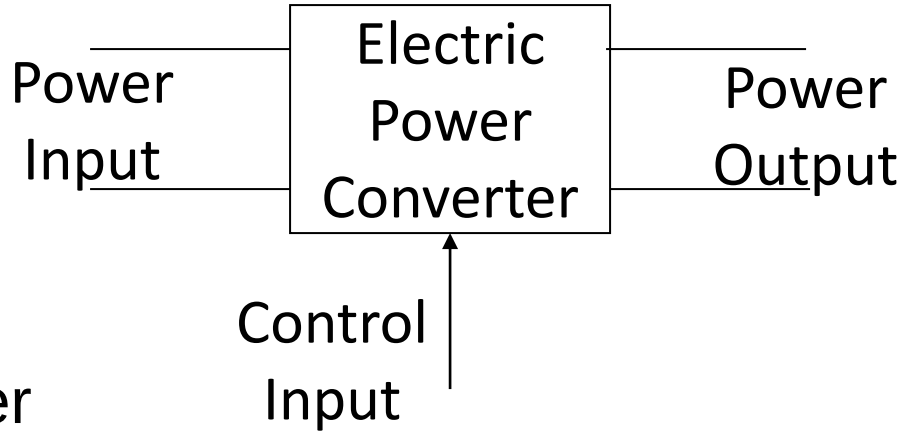
2. The brief history and Typical applications

3. Efficiency of power electronic system
   - Importance of the efficiency
   - Introduction to power processing

1.1 Definition

- Power Electronics:
  - *is the electronics applied to the conversion and control of electric power.*
  - Range of power scale:

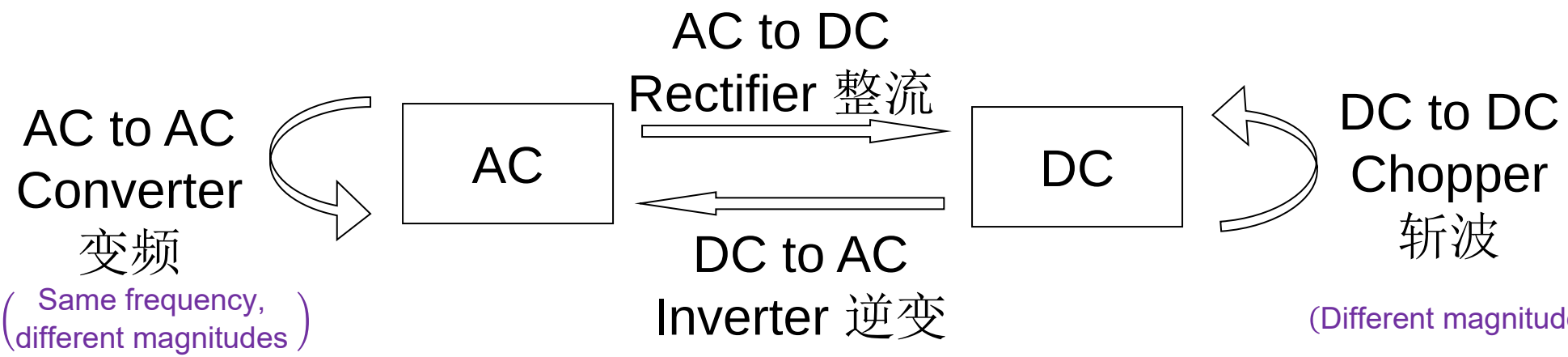
    milliwatts (mW) -> megawatts (MW) -> gigawatts (GW)
- Electric power converter is also called:
  - Power converter
  - Converter
  - Switching converter
  - Power electronic circuit
  - Power electronic converter



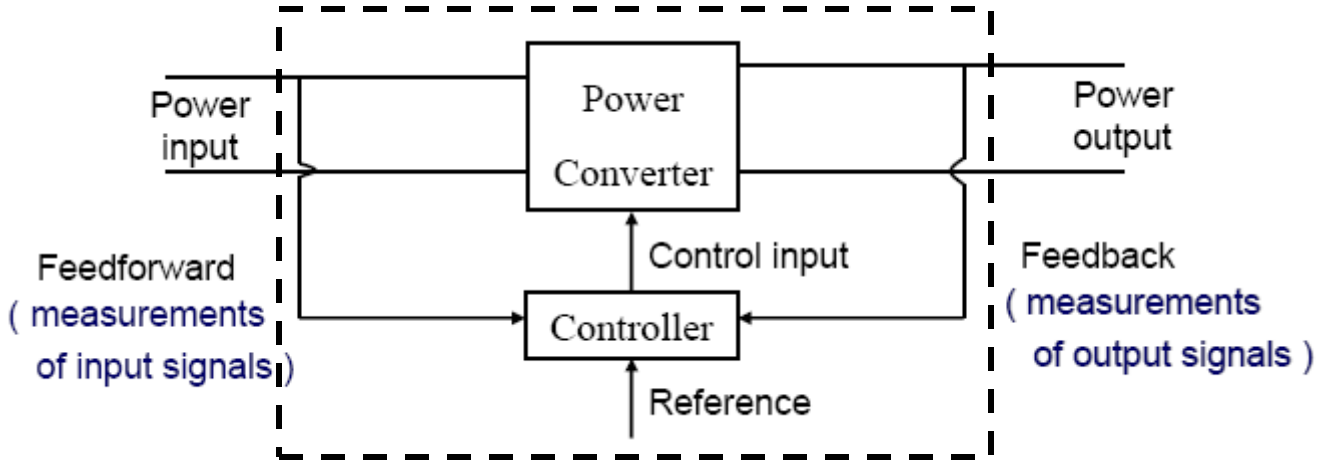
Conversion of electric power

Learnt in EEE103 and reviewed in EEE225

2 types of electric power	Changeable properties in conversion
DC (Direct Current)	Magnitude (*No change in direction*)
AC (Alternating Current)	Frequency, magnitude, phases



Generic structure of a power electronic system



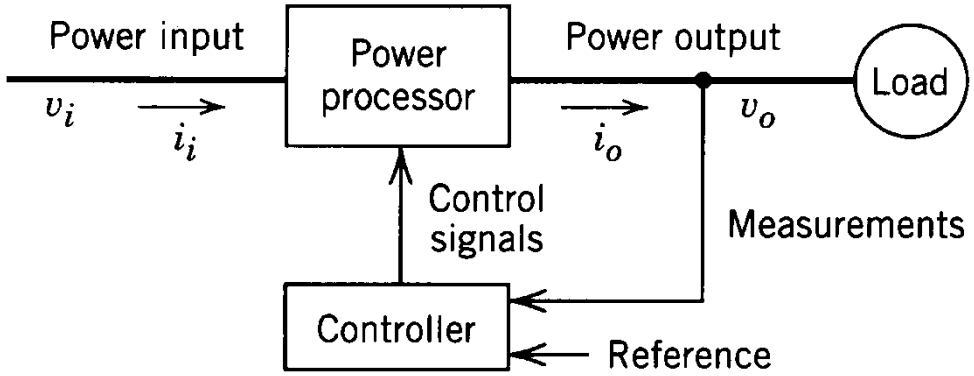
Power Electronic System

Power converter along with its controller including the corresponding measurement and interface circuits, is also called power electronic system.

- Control module;
- Feedforward or feedback control.

} Two crucial features

Typical power electronic system (feedback controlled)



The task of power electronics has been recently extended to also ensuring the currents and power consumed by power converters and loads to meet the requirement of electric energy sources.

- **Source:**

  Electric utility, battery, other electric energy source

- **Load:**

  Electric Motor, light, heating, other electric equipment

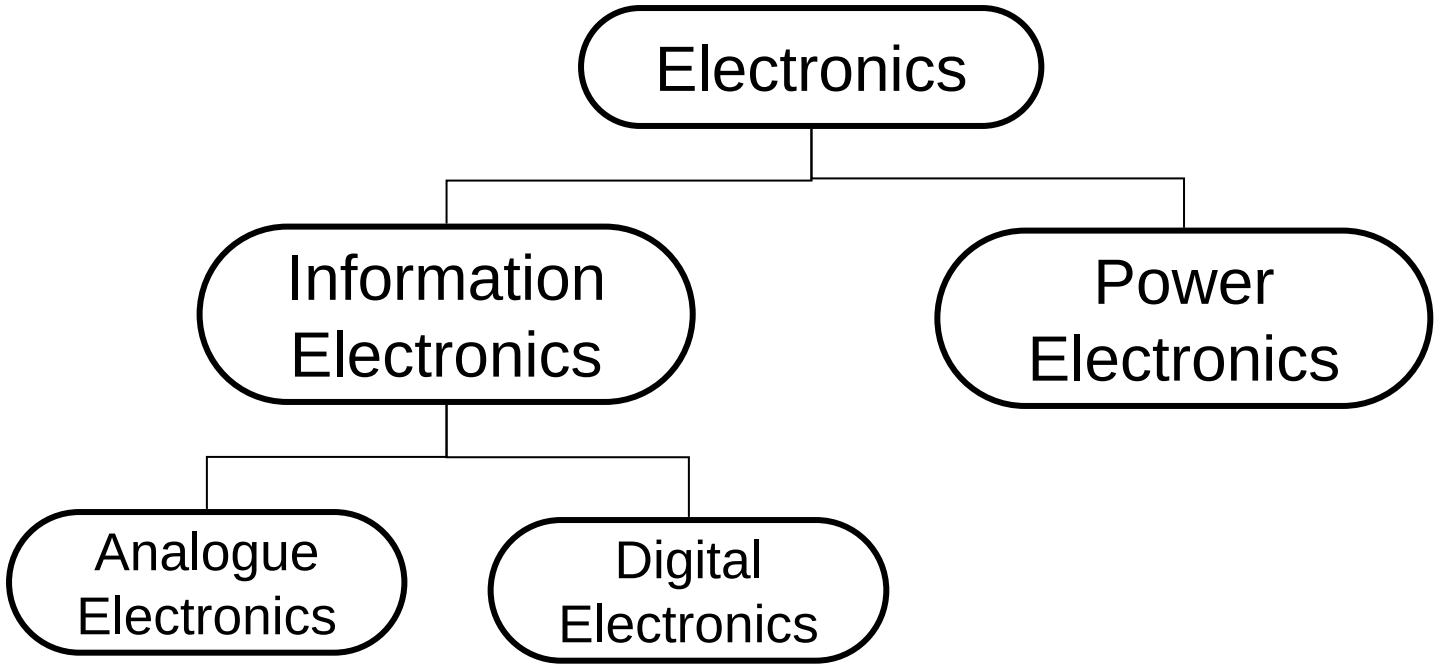
1.2 Classification of electronics

- A classification of electronics by processing ***object***:
  - Information electronics: to process information (Usually small signals)
  - Power electronics: to process electric power (Usually large signals)
- A classification of electronics by ***devices***:
  - Vacuum electronics: using vacuum devices

    e.g. vacuum tubes devices
  - Solid (solid state) electronics: using solid state devices

    e.g. semiconductor devices
- A classification of electronics by ***targets***:
  - Physical electronics: physics, material, fabrication, and manufacturing of electronic devices
  - Applied electronics: application of electronic devices to various areas

1.2 Relationship with information electronics



- A classification of electronics by processing object:
  - Information electronics: to process information
  - Power electronics: to process electric power

Relationship with Information Electronics

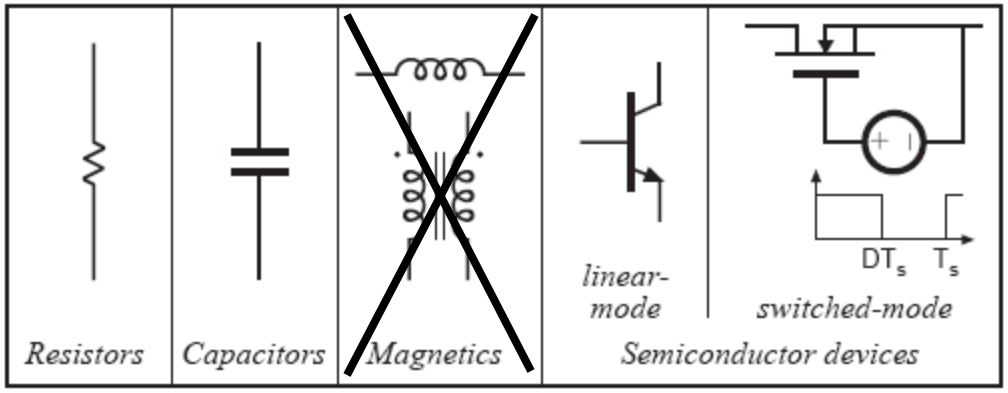
- Common:
  - Both of them have two branches, devices and applications;
  - Devices: material, fabrication and manufacture are similar, using microelectronics;
  - Application: fundamental theory, analysing methodology and software are similar;
- Differentia:
  - Devices for information electronics work both in switching status and amplifying status;
  - Devices for power electronics usually work in switching status only.

Devices available to the circuit designer

Information elec.

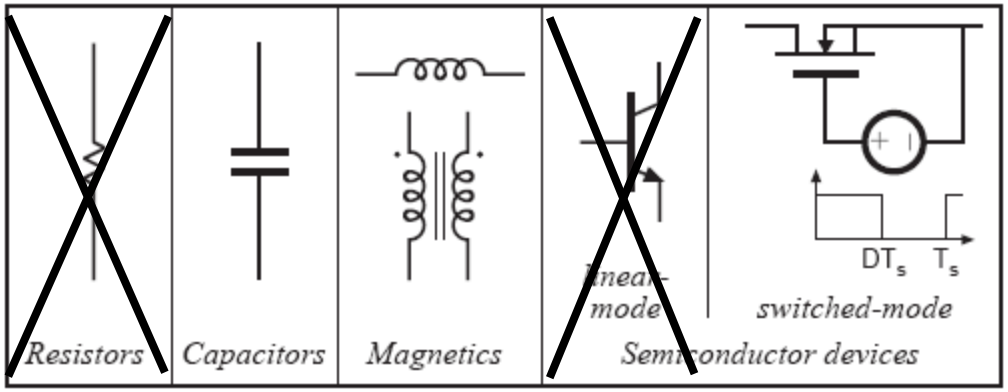
Signal processing

(avoid magnetics)



Power processing

(avoid lossy elements)

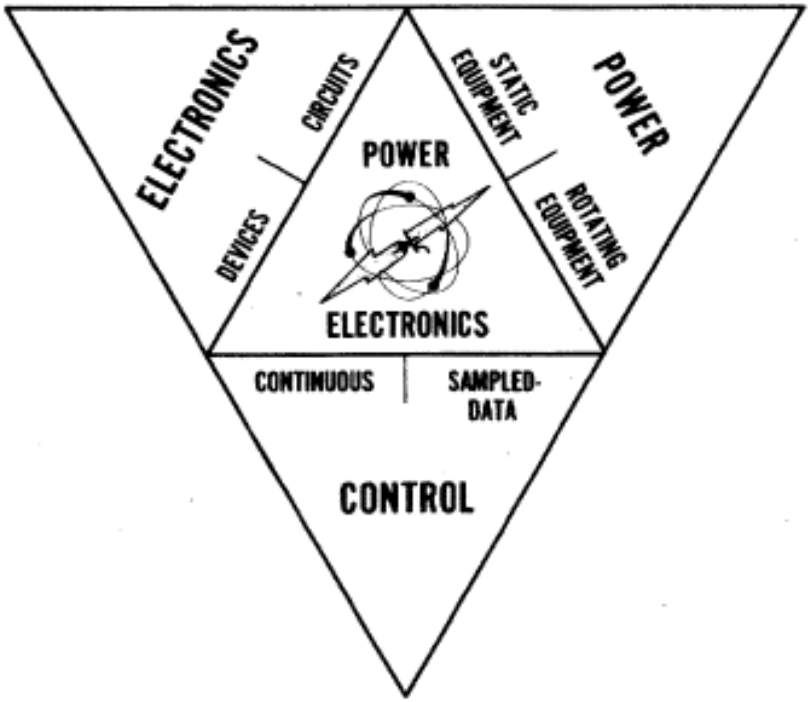


1.3 The interdisciplinary nature

Dr. William E. Newell

Research Laboratories

Westinghouse Electric Corporation



Power electronics: interstitial to all major disciplines of electrical engineering.

W. E. *NEWELL*, "Power Electronics—Emerging from Limbo," *IEEE Power Electronics Specialists Conference*, *1973*

Relationship with Power (Electrical Engineering)

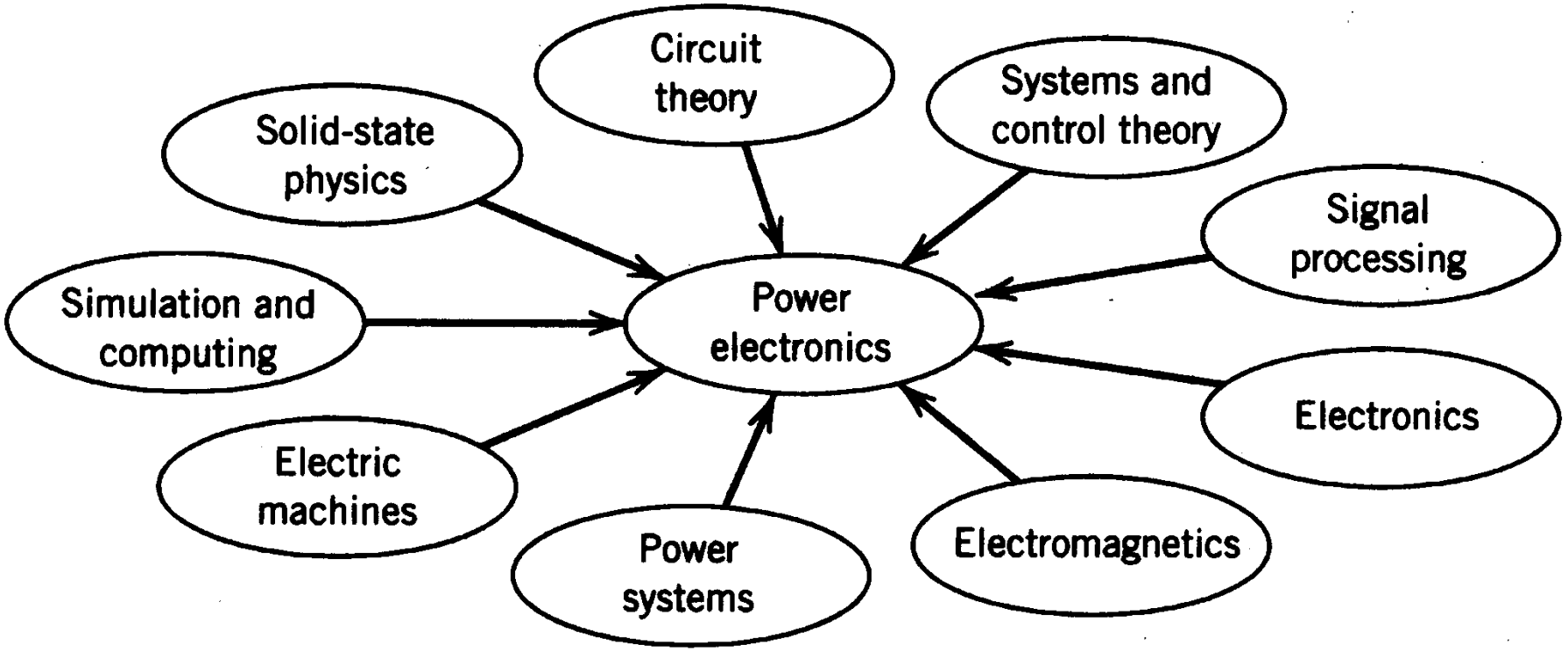
- Power electronics has been broadly applied in electrical engineering
  - High voltage DC power transmission
  - SVC (Static VAR [Volt-Amp Reactive] Compensator)
  - Electric locomotive traction
  - AC/DC drive
  - High performance AC/DC power supply

- Actually, power electronics is classified as one branch of electrical engineering

Relationship with Control (Automatisation)

- Control theory has been broadly applied in power electronics;
- Power electronics is to use light-current to control heavy-current;
  - The interface between the light-current system and heavy-current system;
- Power electronics is the important element and supporting technique in automatization;
- Power electronics is currently the most active discipline in electric power engineering.

Relationship with multiple disciplines



Interdisciplinary nature of power electronics

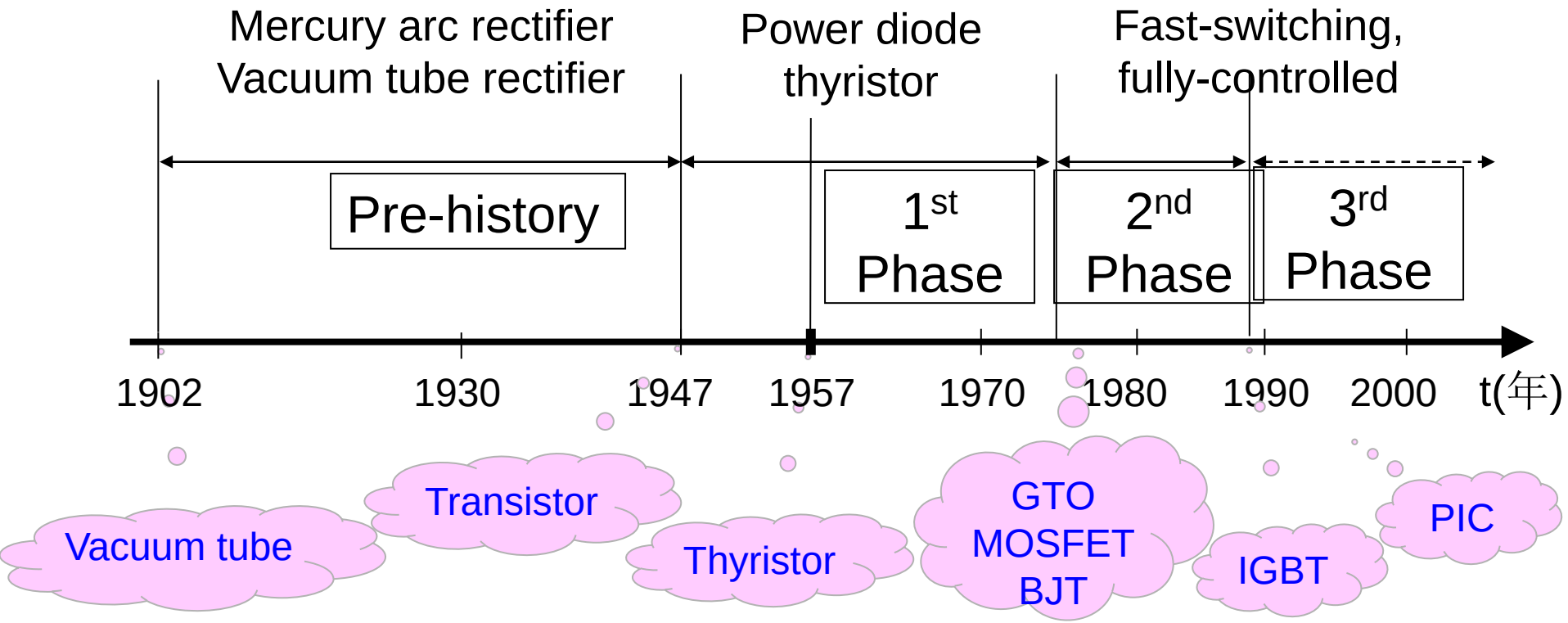
1.4 Significance in human society

- Electric power is used in almost every part and everywhere of modern human society. It is the major form of energy source used in modern human society.

- The objective of ***power electronics*** is right on how to use electric power, and how to use it effectively and efficiently, and how to improve the quality and utilization of electric power.

- Power electronics and information electronics make two poles of modern technology and human society: information electronics is the brain, and power electronics is the muscle.

2.1 The history



- The thread of the power electronics history is the break-through and evolution of power electronic devices

2.2 Applications

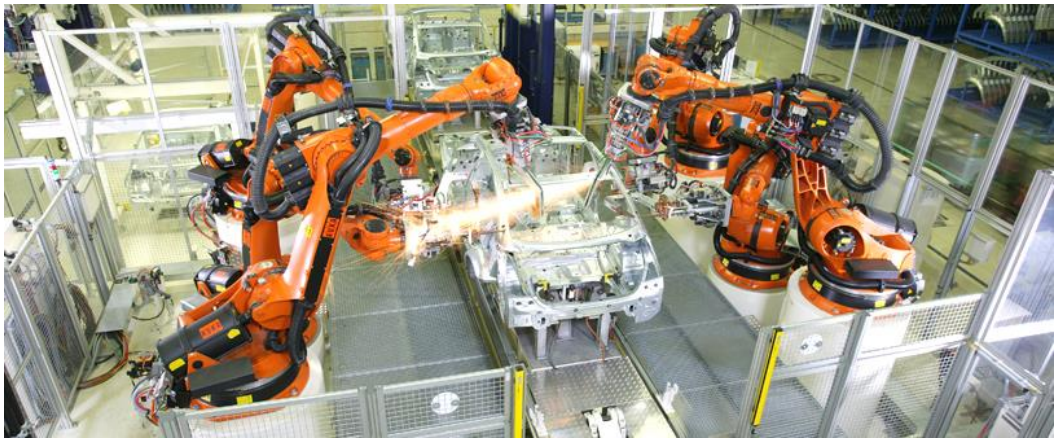
- Industrial
- Transportation
- Utility systems
- Renewable energy
- Residential and home appliances
- Other applications

2.2.1 Industrial Applications

- Motor drives
- Electrolysis
- Electroplating
- Induction heating
- Welding
- Arc furnaces and ovens
- Lighting

Port Machinery

Electrolytic aluminum



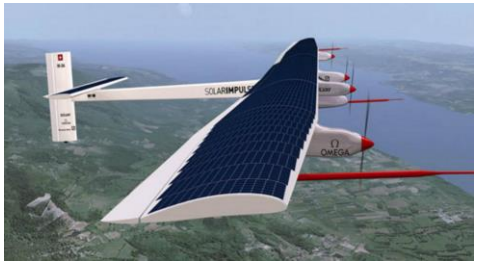
KUKA Robot

2.2.2 Transportation Applications

- Trains & locomotives
- Subways
- Trolley buses
- Magnetic levitation
- Electric vehicles
- Automotive electronics
- Ship power systems
- Aircraft power systems

CRH

Tesla Model s



Solar impulse 2

Zumwalt
All-Electric Destroyer

2.2.3 Utility systems Applications

- High-voltage dc transmission (HVDC)
- Flexible ac transmission (FACTS)
- Static var compensation (SVC)
- Solid State Transformer (SST)
- Custom power & power quality control

Solid State Transformer (SST)

▶ Classical Transformer - Basics

- Advantages

- Relatively Inexpensive
- Highly Robust / Reliable
- Highly Efficient (98.5%...99.5% Dep. on Power Rating)

- Weaknesses

- Voltage Drop Under Load
- Losses at No Load
- Sensitivity to Harmonics
- Sensitivity to DC Offset Load Imbalances
- Provides No Overload Protection
- Possible Fire Hazard
- Environmental Concerns

▶ SST Functionalities

- Protects Load from Power System Disturbance
  - Voltage Harmonics / Sag Compensation
  - Outage Compensation

- Protects Power System from Load Disturbance
  - Load Voltage Regulation (Load Transients, Harmonics)
  - Unity Inp. Power Factor Under Reactive Load
  - Sinus. Inp. Curr. for Distorted / Non-Lin. Load
  - Symmetrizes Load to the Mains
  - Protection against Overload & Output Short Circ.

- Further Characteristics
  - Operates on Distribution Voltage Level (MV-LV)
  - Integrates Energy Storage (Energy Buffer)
  - DC Port for DER Connection
  - Medium Frequency Isolation → Low Weight / Volume
  - Definable Output Frequency
  - High Efficiency
  - No Fire Hazard / Contamination

2.2.4 Renewable energy application

- Wind
- Photovoltaic
- Fuel cells
- Energy storage systems

2.2.5 Residential and home appliances

- Lighting
- Heating
- Air conditioning
- Refrigeration & freezers
- Cooking
- Cleaning
- Entertaining

FINsix (MIT Spin off company）

Smart home device

2.2.6 Other applications

- Power systems for particle accelerators
- Space technology
- Military application

Electromagnetic gun

Particle accelerator

Electromagnetic Aircraft Launch System (EMALS)

2.3 Trends

- It is estimated that in developed countries now 60% of the electric energy goes through power electronics converters before it is finally used.

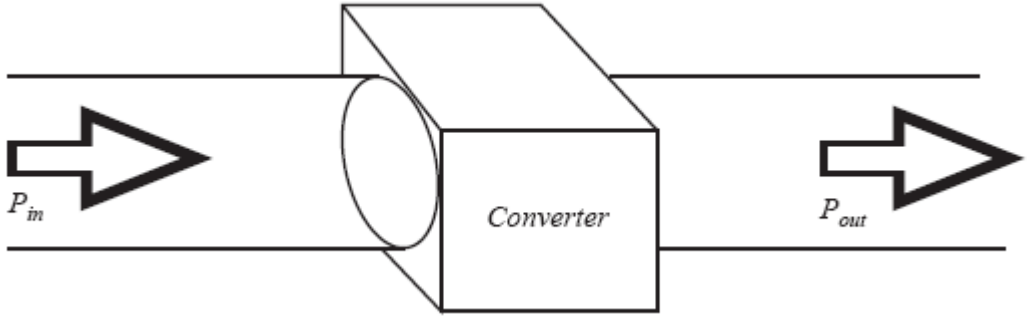
- Power electronics has been making major contributions to:
  - better performance of and better control of power supplies
  - electric equipment
  - energy saving
  - environment protection
    - reduction of energy consumption leads to less pollution
    - reduction of pollution produced by power converters
    - direct applications to environment protection technology

3. Efficiency of power electronic system

- In more general sense, ability to do things well without waste.
- In more mathematical or scientific terms, it is a measure of the extent to which input is well used for an intended task or function (output).

- 3.1 A high efficiency converter

Goal of current converter technology is to construct converters of small size & weight, which process substantial power at high efficiency

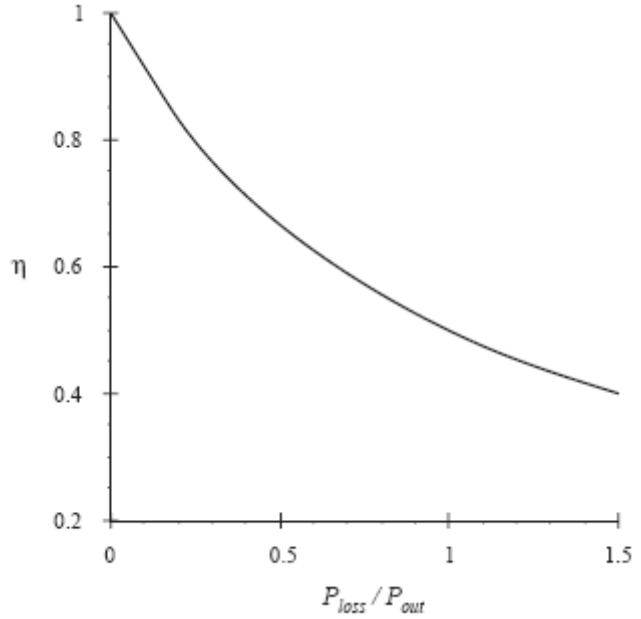


$$\eta = \frac{P_{out}}{P_{in}}$$

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

(Power wasted in the system, *called* P_{loss})

- $P_{loss} = P_{in} - P_{out}$ is the power dissipated by the converter elements, converted in to heat;
- It causes the electronic elements within the converter to operate at high temperature, and reduces the system reliability.
- It must be minimised in the converter.
- High efficiency is essential
  - High efficiency leads to low power loss within converter
  - Small size and reliable operation is then feasible
  - Efficiency is a good measure of converter performance



Major issues in power electronics

- How to meet the requirement of the load or gain better control of the load.
- How to improve the efficiency
  - for reliable operation of power semiconductor devices.
  - for energy saving.
- How to realize power conversion with less volume, less weight, and less cost.
- How to reduce negative influence to other equipment in the electric power system and to the electromagnetic environment.

Summary:-

- **Definition of power electronics:** the electronics applied to the conversion and control of electric power.
- **Typical power electronic system** consists of power processor, controller and load.
- **Types of converters:** Rectifier (AC-DC), Chopper (DC-DC), Inverter (DC-AC), Converter (AC-AC)
- **Applications:** Industrial, transportation, utility systems, renewable energy, residential etc.,
- **Types of electric power:** DC (direct current) and AC (alternating current)
- **Efficiency:** ratio between the output power and input power

See you in the next class (February 24th)

The End