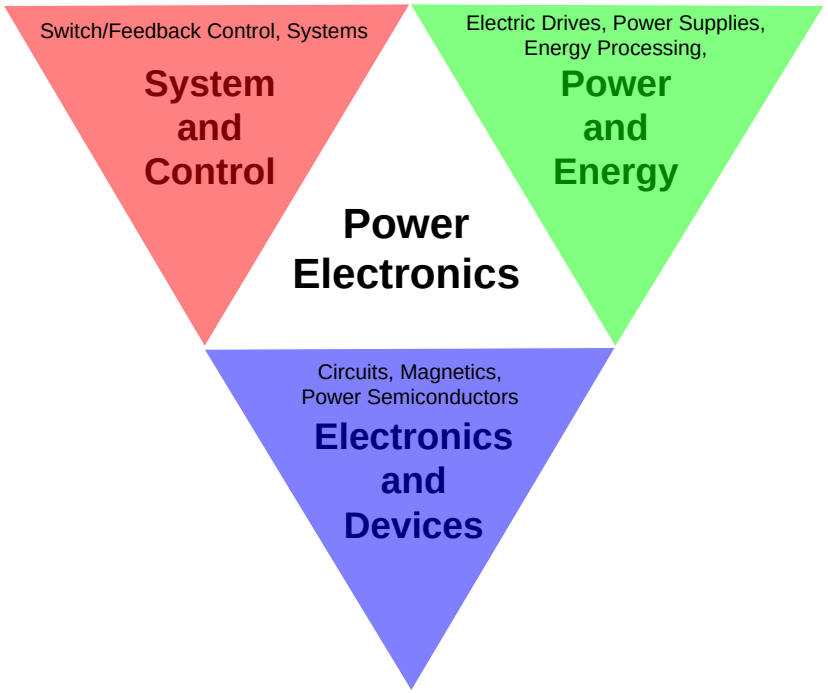
University of Glasgow

Power Electronics 电力电子

Lecture 1 Introduction



Lecturer

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http://www.gla.ac.uk/schools/engineering/staff/lianpinghou/

https://www.gla.ac.uk/schools/engineering/staff/shujaansari/

Course Information

- 2 Lectures per week:

  You should attend the lectures.

  4 Labs:
  - Measurement of circuit parameters, PWM Generator(TL494)
  - Rectifier Circuits
  - DC-DC Power Converter
  - Single-Phase PWM Inverters

  You will finish the first three labs in lab and use LTSPICE to finish lab 4

  You MUST submit all lab reports

- Courseware is available on **Moodle**
- Tutorials (Homework) and Solutions will be provided on **Moodle** AFTER the last lecture
- Sample Exam Papers will be in **Moodle**

You should check Moodle regularly and on time

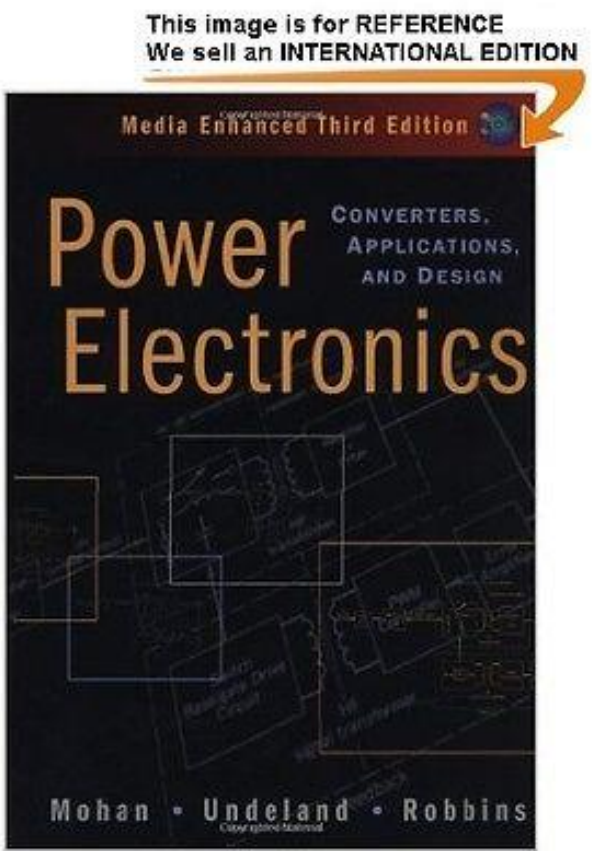
Course Assessment

The final examination counts 75% for this course. Labs will count for 25%.

Labs (25% of full final marks). Each lab is fairly full – you MUST submit the lab report on the Moodle on the date you are timetabled to do so. There will not be any opportunity to catch up if you miss your lab submission.

Final examination (75% of full final marks). This will be held at the end of the second semester and will be of 2 hours' duration. A re-sit will be available. A sample exam paper for 2020 will be available before the end of the semester. Previous exams will also be available on Blackboard. If the exam paper includes a formula sheet, you won't earn marks for remembering equations.

Recommended Textbook



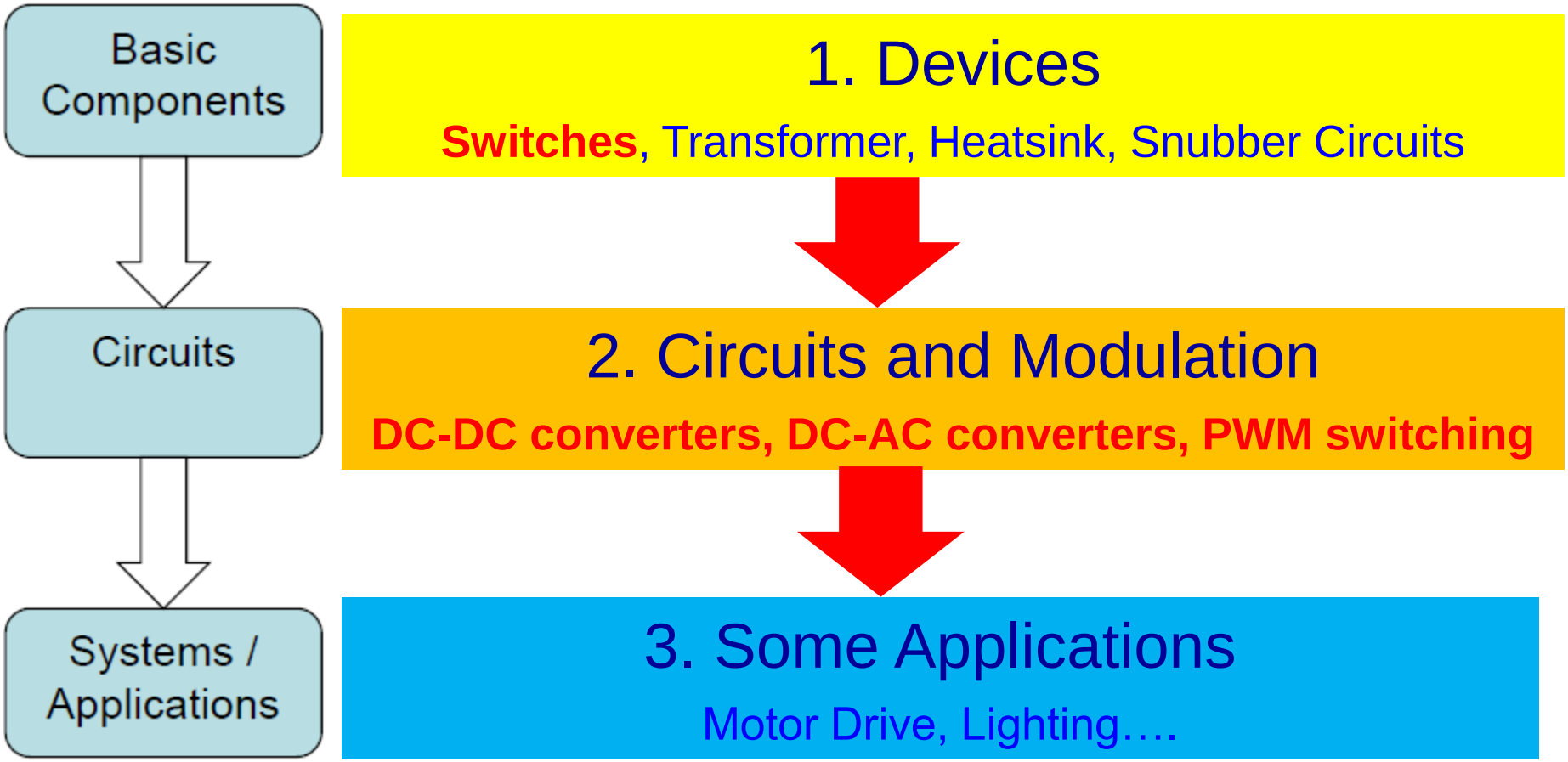
- Characteristics of power electronics
  - The ability to handle the electrical power, that is, its ability to withstand voltage and current, is its most important parameter and is generally much larger than the electronic device that processes the information.
  - In order to reduce its own loss and improve efficiency, it generally works in the switching state.
  - It is controlled by the information electronic circuit and requires a drive circuit.
  - Its own power loss is usually still much larger than that of information electronics, and it is generally necessary to install a heatsink during its operation

Mohan, Undeland and Robbins

Power Electronics: Converters, Applications and Design

Wiley 2003

Course Structure



Follow me

Prepare Lessons Before Class

预习功课

Practice Makes Perfect

熟能生巧

Any questions?

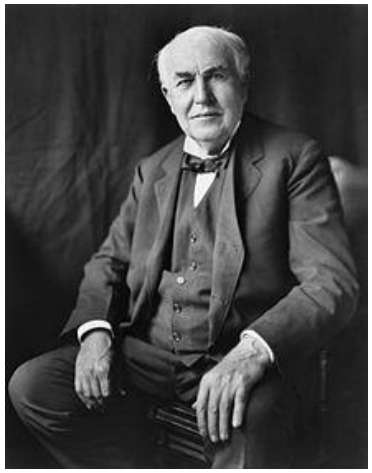
Let’s start with a story

Electrical Power

Being evolved from 1896, the electrical grid is the largest machine on the planet

We cannot imagine how miserable if our life without electricity

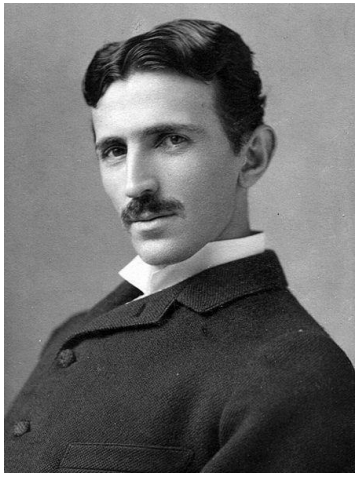
War of the Currents



Thomas Edison

Electricity

Direct current (DC)
Alterative current (AC)



Nikola Tesla

DC systems VS **AC systems**

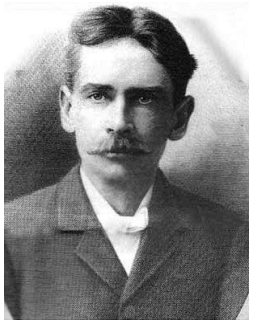
Westinghouse 西屋电气

Advantages of DC:

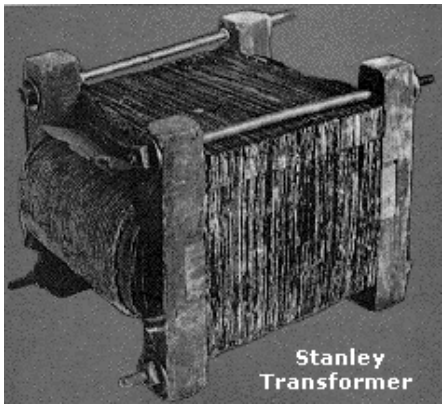
- Many applications require DC current for proper operation, e.g. computers, phones …
- HVDC is the most economic way to transmit electricity over long distance (> 1000km) without instability issues…

However, AC is compelling to people from 1890s

Keys to AC's Success



William Stanley, Jr.



Stanly Transformer

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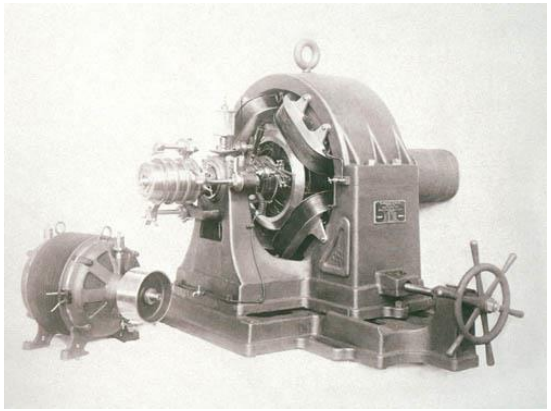
Low cost, reliable and easy-for use AC voltage level conversion



Tesla Poly-phase AC motor

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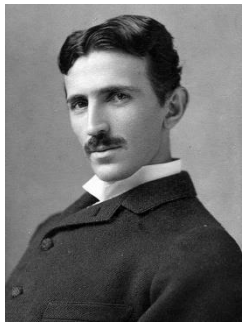
More reliable, cheaper, smaller and higher power rating, higher speed than DC motor

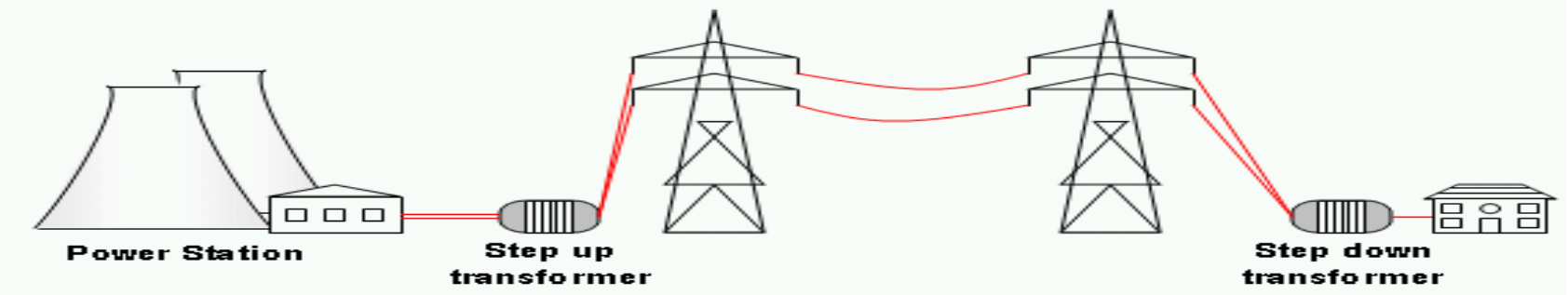


Nikola Tesla

AC systems

- **Transformer** – AC voltage level power converter, "the lethal weapon" with poly-phase AC motor determine the success of AC systems.

Role of Power Conversion



Electrical Power Chain

Generation	Transmission	Distribution	User Loads
Generators	voltage level conversion, long distance	voltage level conversion,	Conversion of voltage level , frequency, waveshape polyphase

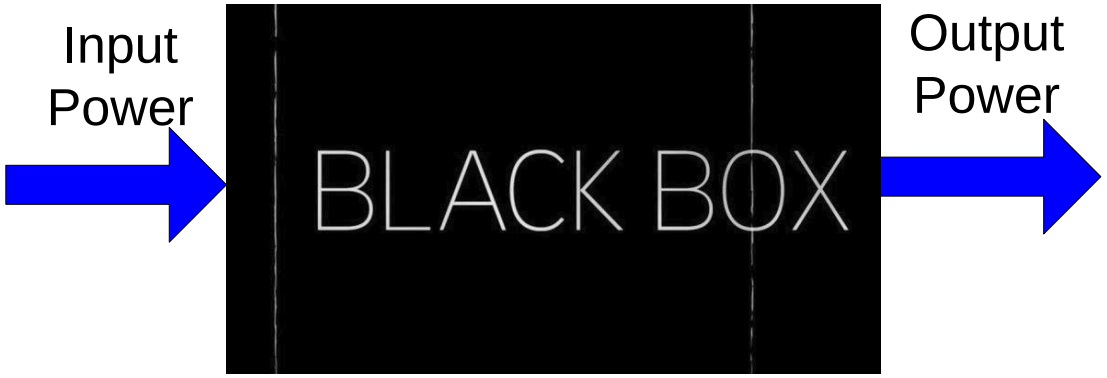
Power Conversion is very critical in the “electrical power chain”!!!

Country	Voltage	Frequency
China	220V	50Hz
United Kingdom	230/240V	50Hz
United States	120/240V	60Hz

Power Converter

Convert electrical power from one form to another to meet a specific need

Process Power rather than information.



Power Converter Circuit

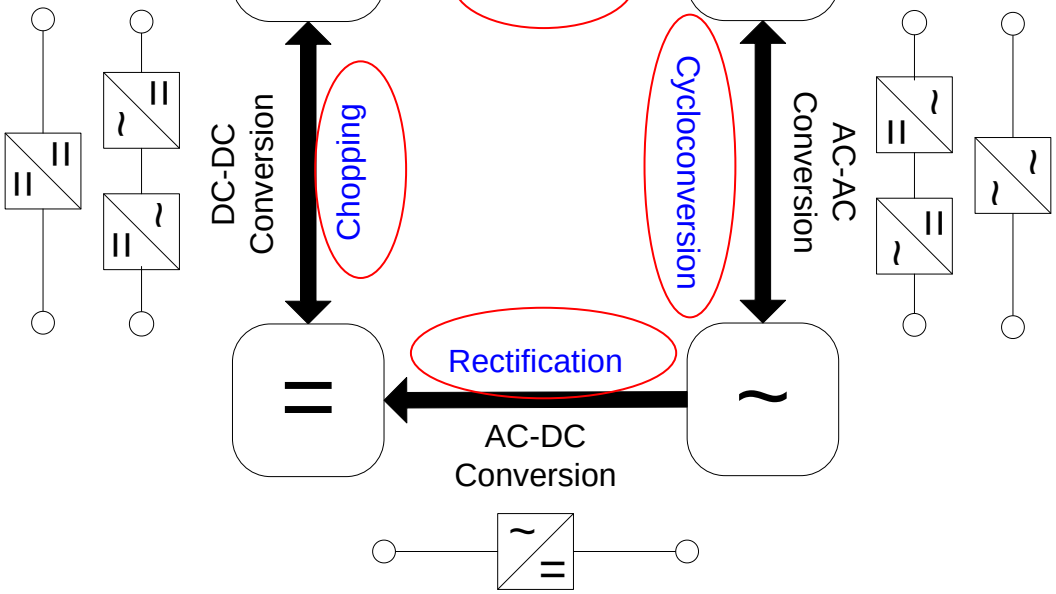
Types of Electrical Power

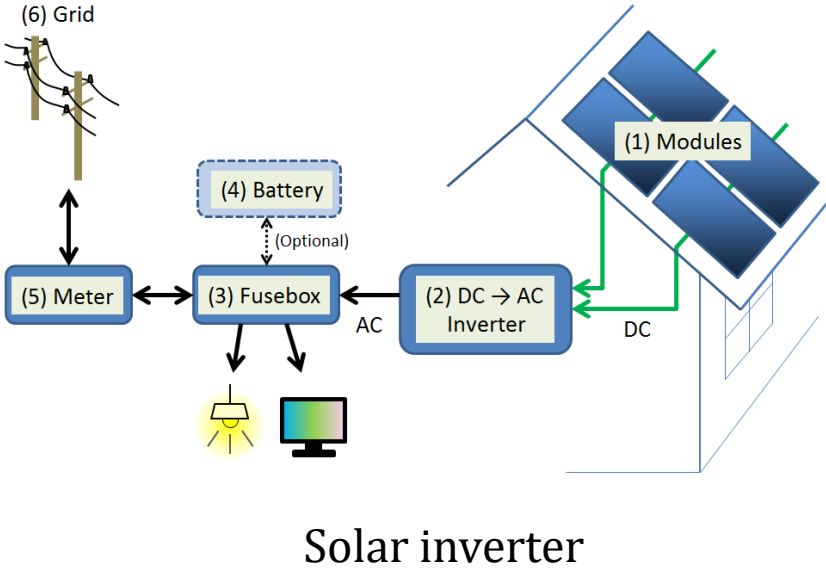
1. Direct Current (DC)
2. Alternating Current (AC)

Forms Conversion

1. Voltage level conversion
2. Frequency conversion
3. Waveshape conversion
4. Polyphase conversion

Four Types of Power Conversion



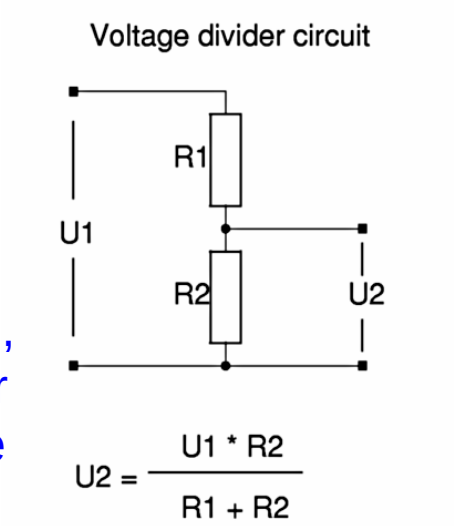


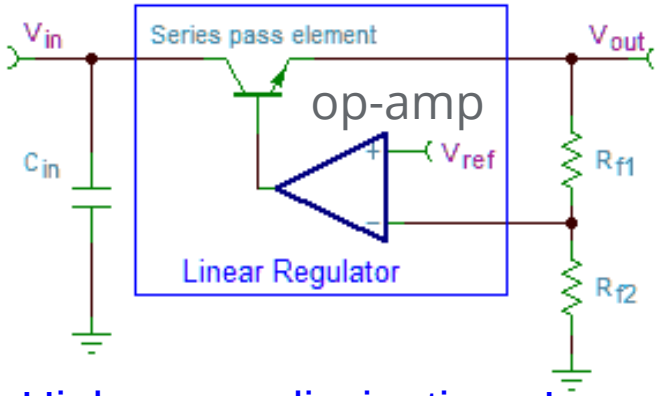
Solar inverter

Traditional Conversion Devices I

DC voltage
Step Down

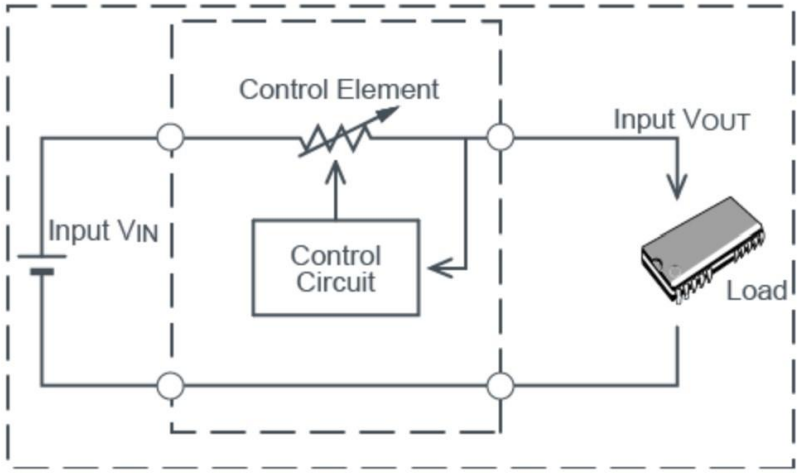
High power dissipation, Low efficiency, only for stepping down voltage





High power dissipation, Low efficiency, only for stepping down DC voltage

LM317

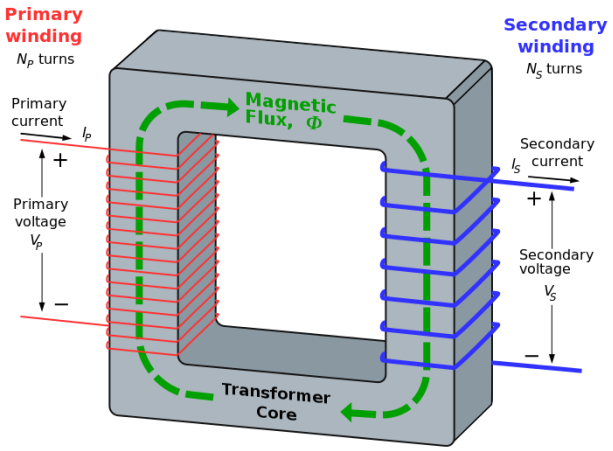


Advantages	Disadvantages
• Simple circuit configuration • Few external parts • Low noise	• Relatively poor efficiency • Considerable heat generation • Only step-down (buck) operation

Traditional Conversion Devices II

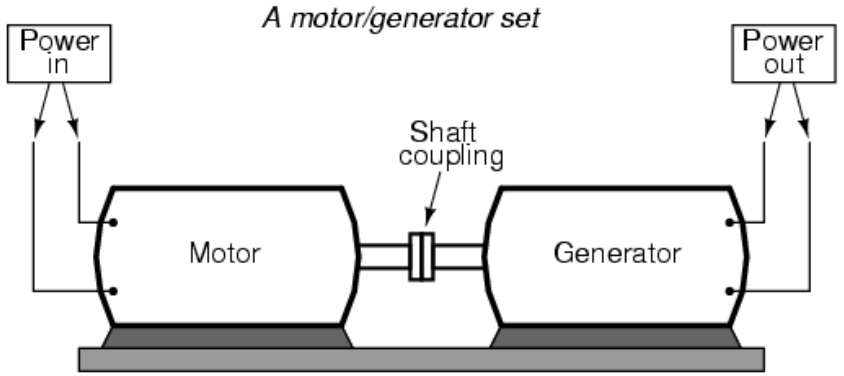
AC voltage
Step Up/Down

Static, Bulky, Heavy
Only for AC voltage level change



$$\frac{V_{sec}}{V_{pri}} = \frac{N_{sec}}{N_{pri}}$$

AC ↔ DC conversion



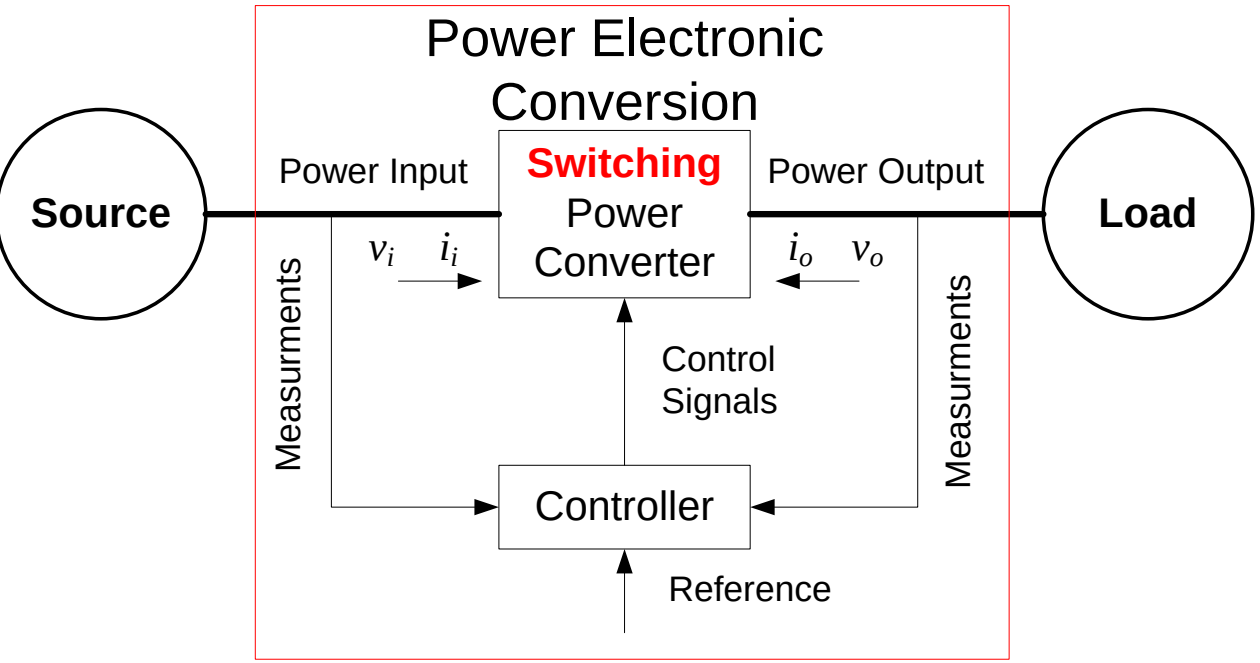
DC → AC

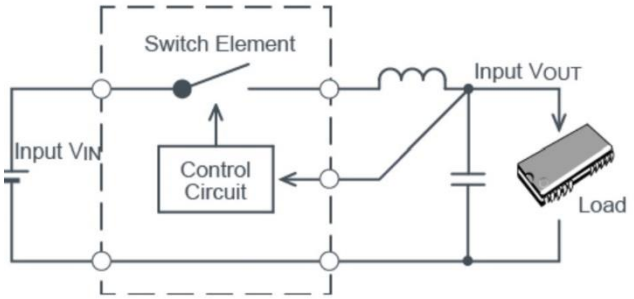
AC → DC

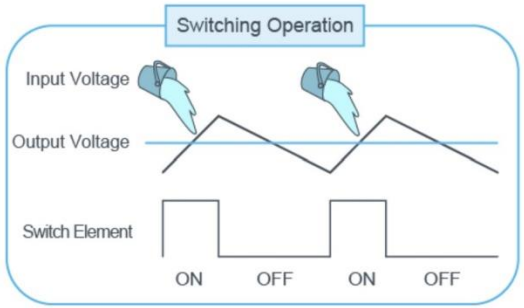
Rotational, Bulky, Heavy, Noisy, Slow Response, not very high efficiency and reliability

Power Electronic Conversion

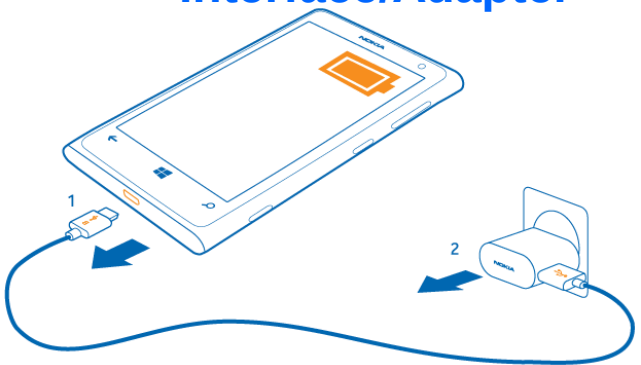
- Power Electronic Converters (Processors) use switching semiconductor devices to convert (process) power.





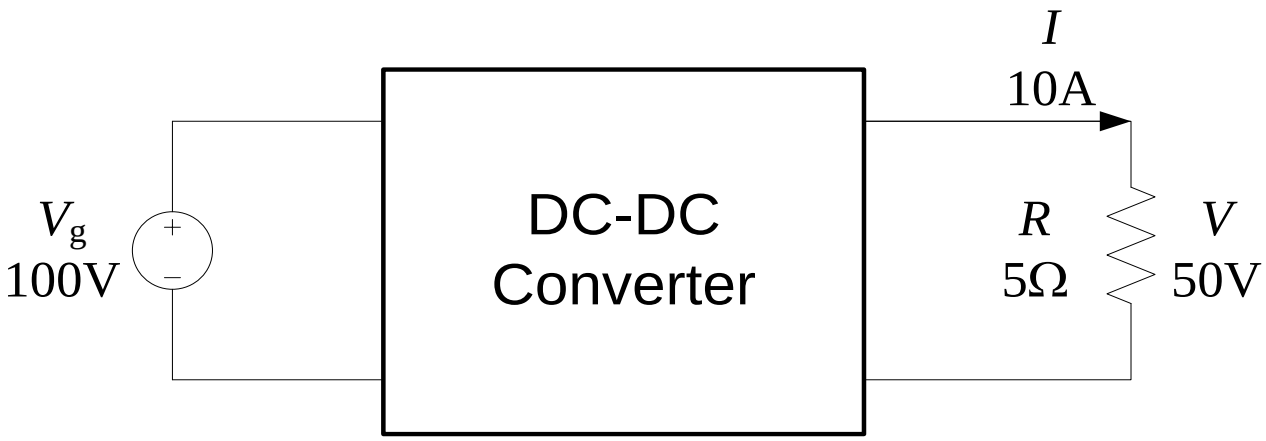


Interface/Adapter



Advantages	Disadvantages
• High efficiency • Low heat generation • Boost/buck/negative voltage operation possible	• More external parts required • Complicated design • Increased noise

An Example of Step-Down Conversion



DC-DC Buck (Step-Down) Converter

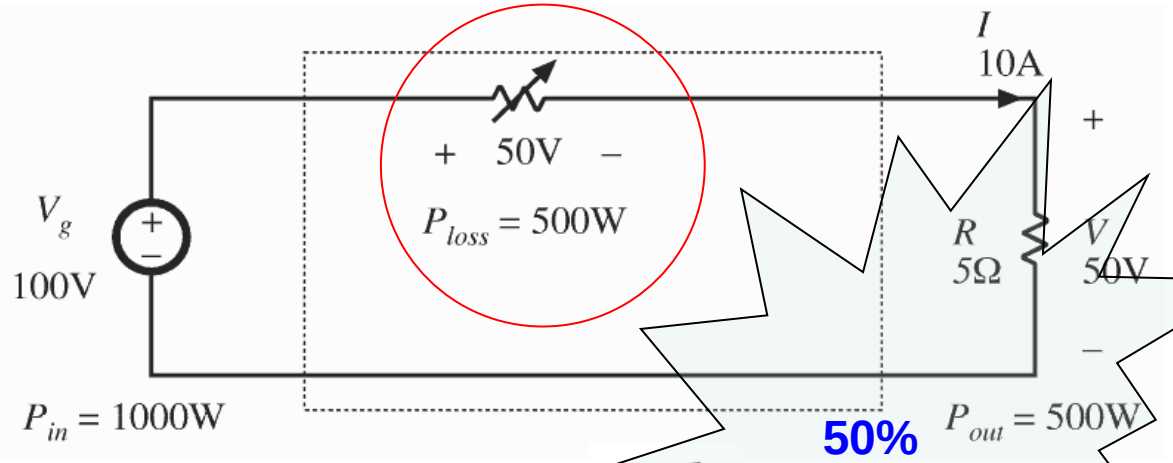
Input Source: 100V

Output Load: 50V, 10A, 500W

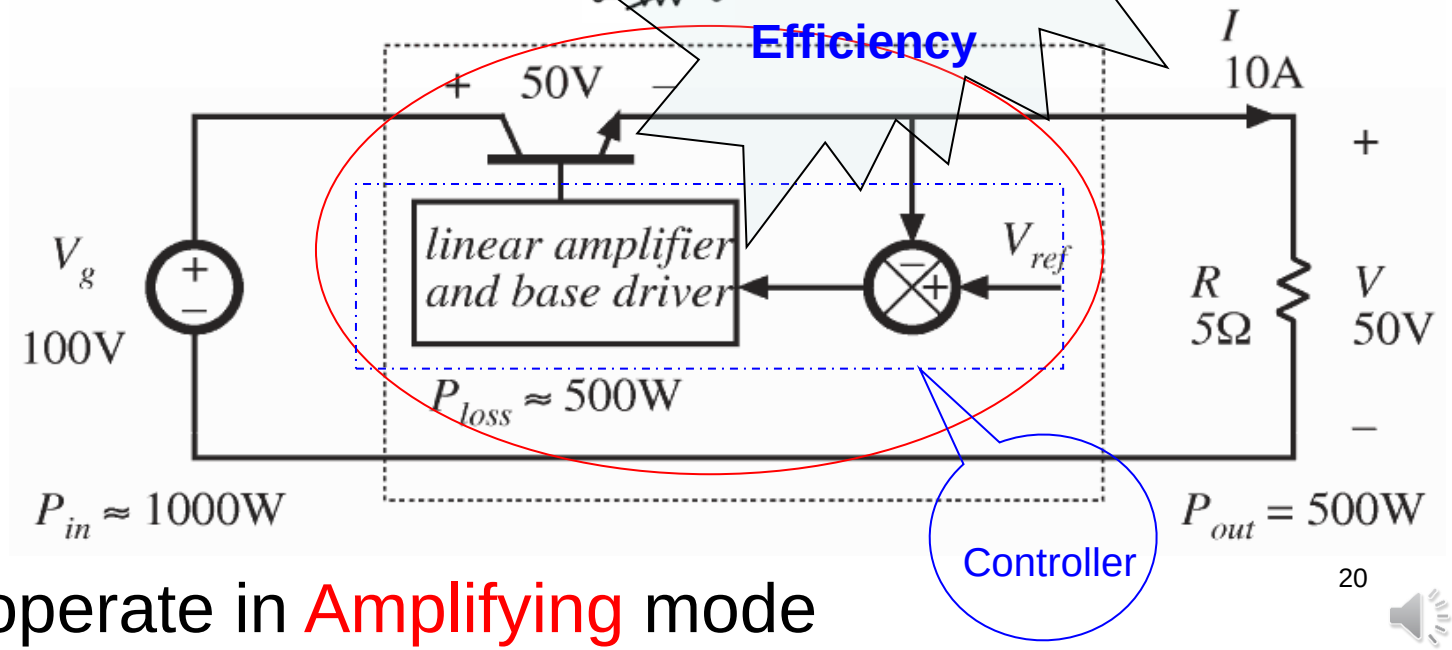
How to convert 100V dc voltage into a constant 50V dc voltage at the output ?

Dissipative Linear Power Conversion

1. Voltage Divider (open-loop)



2. Linear Regulator (close-loop)



Transistor operate in Amplifying mode

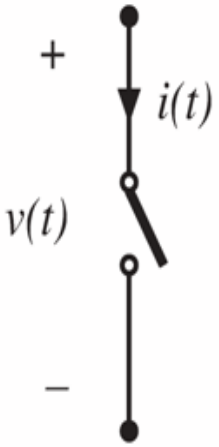
Switching Power Electronic Conversion

Switch closed: $v(t) = 0$

Switch open: $i(t) = 0$

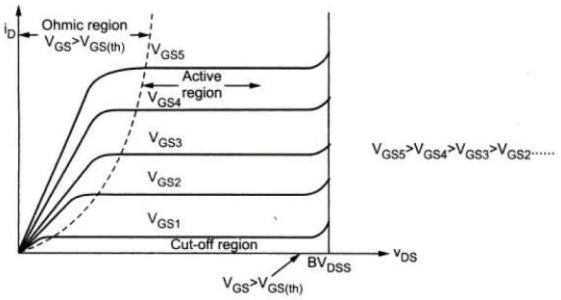
In either event: $p(t) = v(t)\, i(t) = 0$

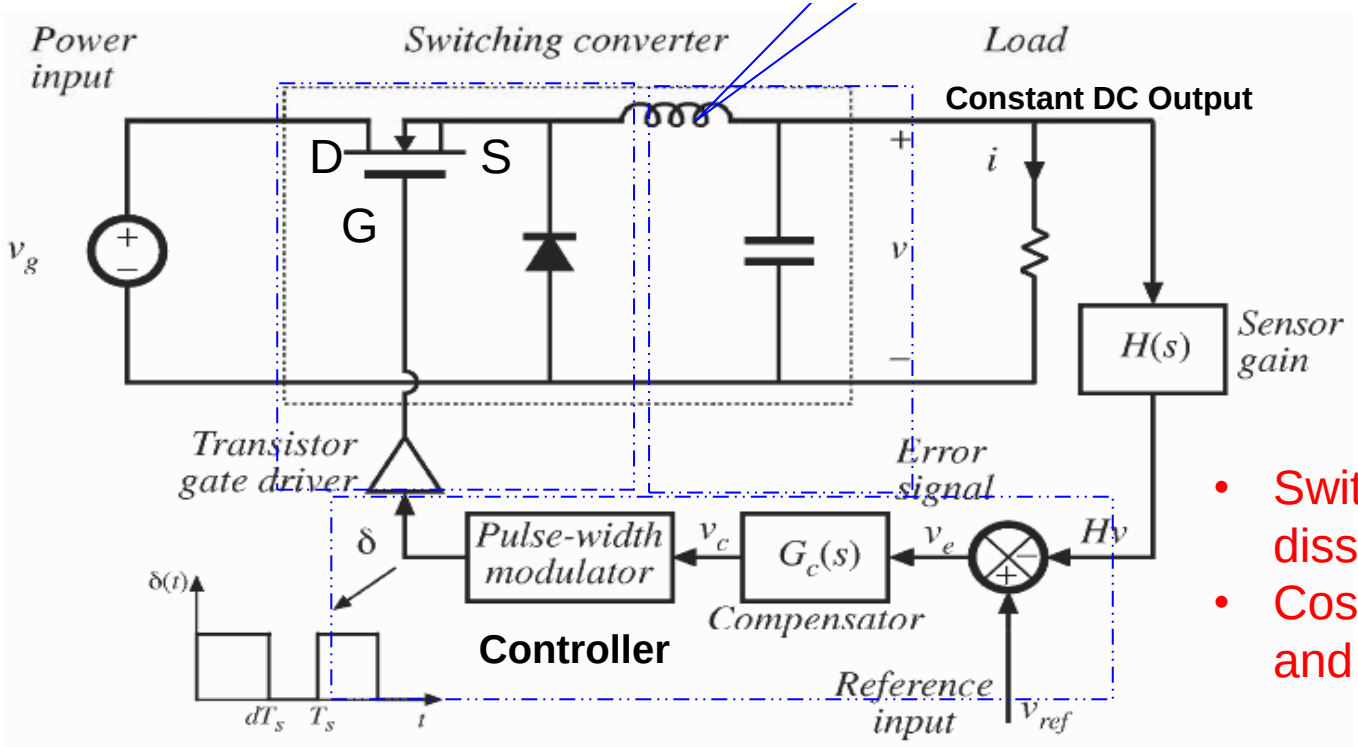
Ideal switch consumes zero power



Ideal L & C consumes zero power

LC low pass filter for removal of switching harmonics



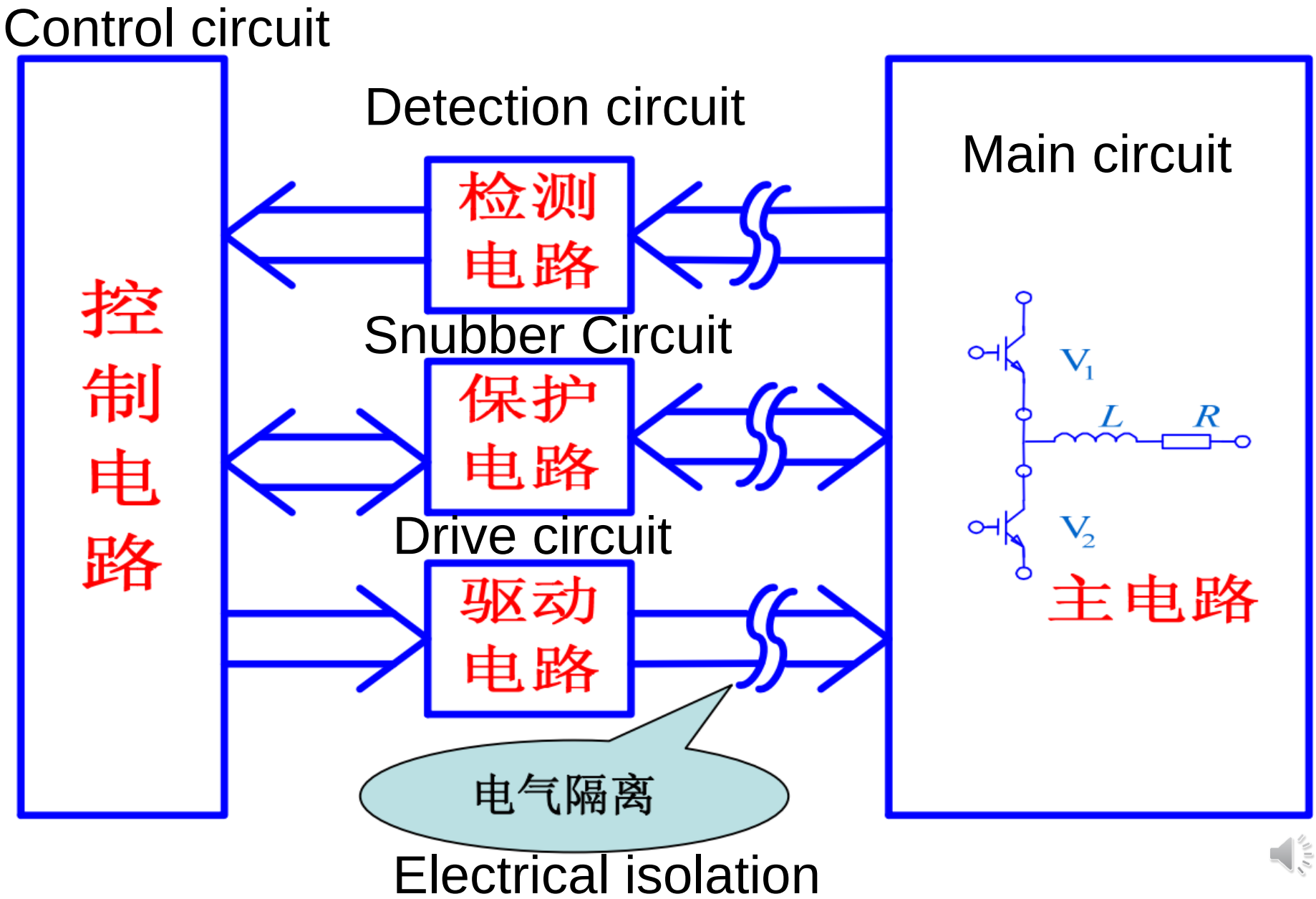


$$C: \frac{1}{\omega C} = Z_C \quad \left.\begin{matrix} \\ \end{matrix}\right\} \omega \uparrow \Rightarrow$$
$$L: \omega L = Z_L$$

smaller and lighter L & C are needed

- Switching power dissipation in transistor $\omega \uparrow\uparrow$
- Cost of the transformer and filter $\omega \uparrow\downarrow$

Power Electronics system



Why is Power Electronic Conversion needed?

- ✓ Efficient: typically in excess of 90% and up to 98% for large systems
- ✓ Flexible: DC-DC, DC-AC, AC-DC, AC-AC
- ✓ High power density, cost-effective: light and small, cheap
- ✓ High performance conditioning: fast, accurate, robust
- ✓ Static and quiet: no mechanical rotation
- ✓ Reliable: no failures over semiconductor device lifetime
- ✓ Switching Frequency: up to 1MHz
- ✓ Power Level: controlled power levels from milli-watts (e.g. portable appliances) through to giga-watts (e.g. high voltage dc transmission).

Success of Apple II and Switching Power Supply

Who is **Rod Holt** at Apple?

- Rod was brought in to design a new power supply for the Apple II computer so that it would not overheat, eliminating the need for an internal fan. He is responsible for creating the **revolutionary switching power supply**, which is significantly lighter due to the fact that it did not require a (line frequency) transformer.

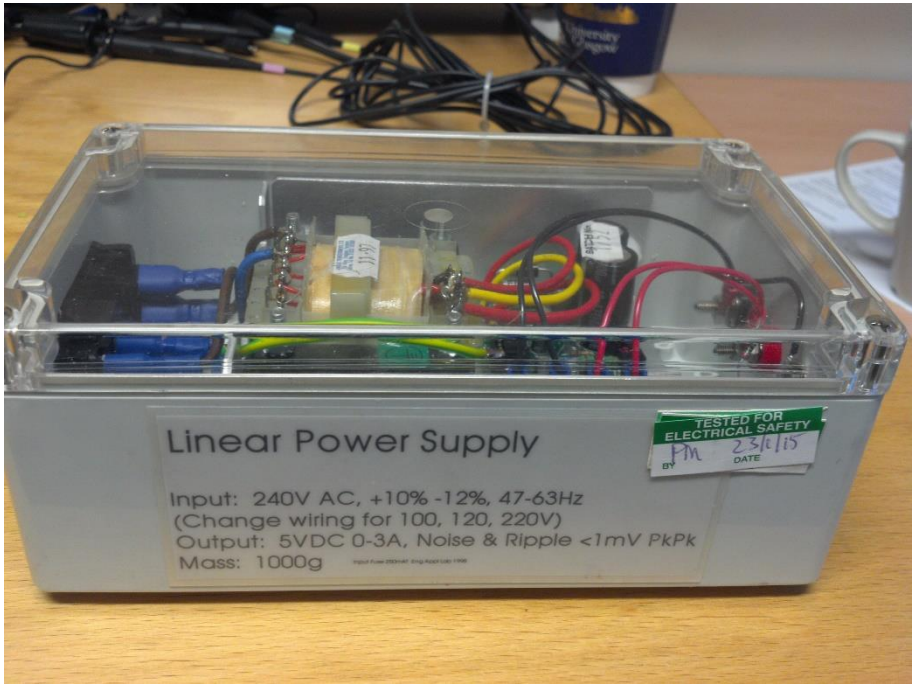
From Movie: *Jobs*

- Apple's original CEO - Michael Scott said, "One thing Holt has to his credit is that he created the **switching power supply** that allowed us to do a very lightweight computer compared to everybody else's that used transformers."

The First 10 Apple Employees: Where Are They Now?
Read more: http://www.businessinsider.com/apple-early-employees-2011-5?op=1&IR=T

Jobs (2013) QUESTIONING THE STORY
Read more: http://www.historyvshollywood.com/reelfaces/jobs.php

Example



Input:
240V AC, +10%-12% 47~63Hz

Output:
5V DC 0~3A

Linear Power Supply:

Output Noise&Ripple < 1mV pk-pk

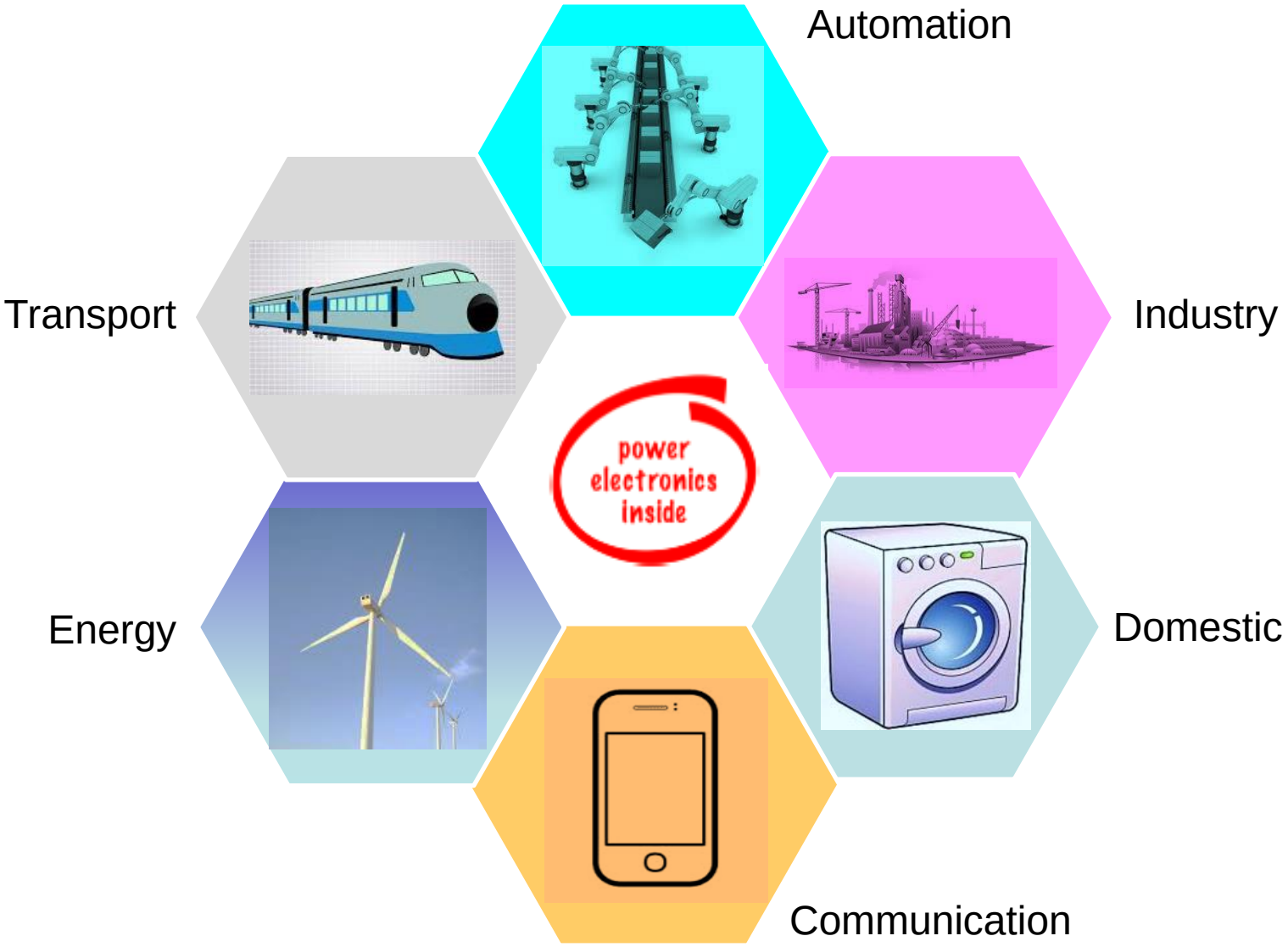
Mass: 1kg

Switch-Mode Power Supply:

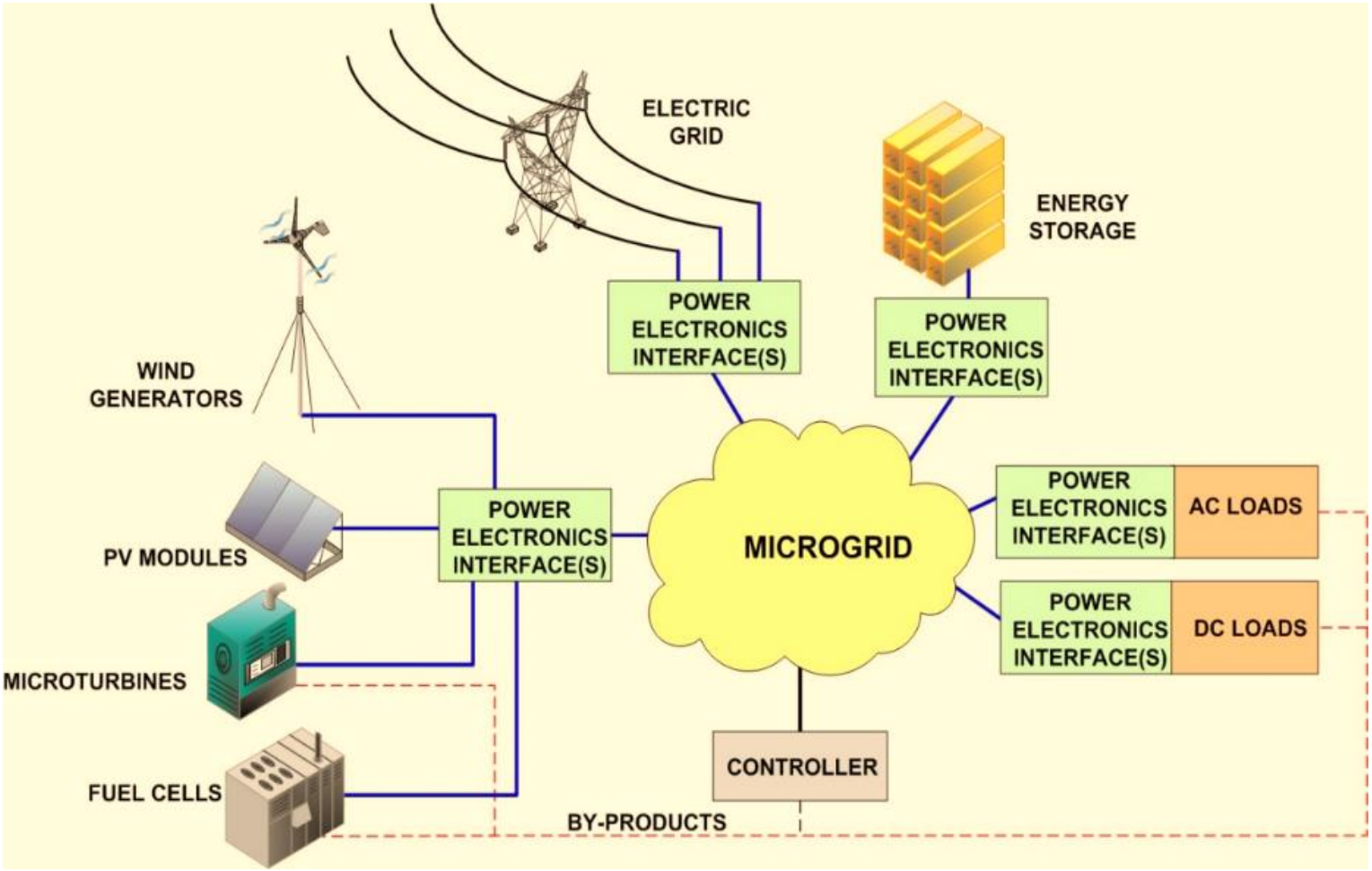
Output Noise&Ripple < 120mV pk-pk

Mass: 140g

Where is Power Electronics used?

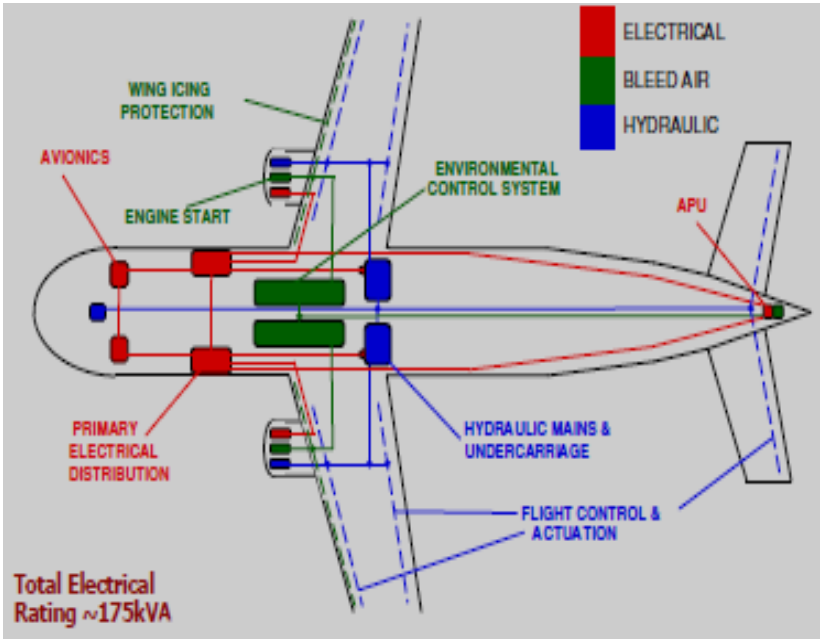


Reshaping Electrical Power Systems

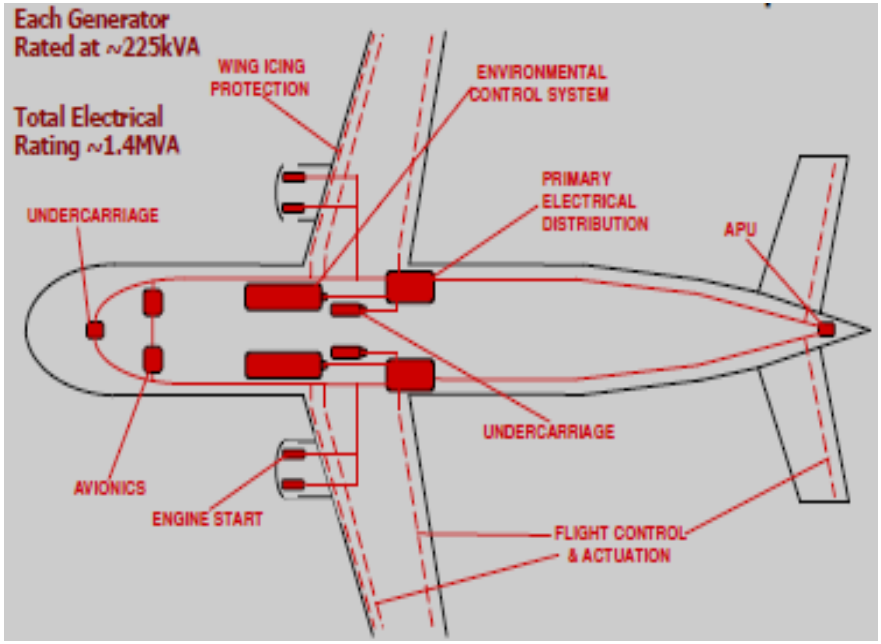


Power electronic provides the necessary adaptation functions to integrate different microgrid components into a common system

More Electric Aircraft



Conventional Aircraft:
About 175 kW electric power



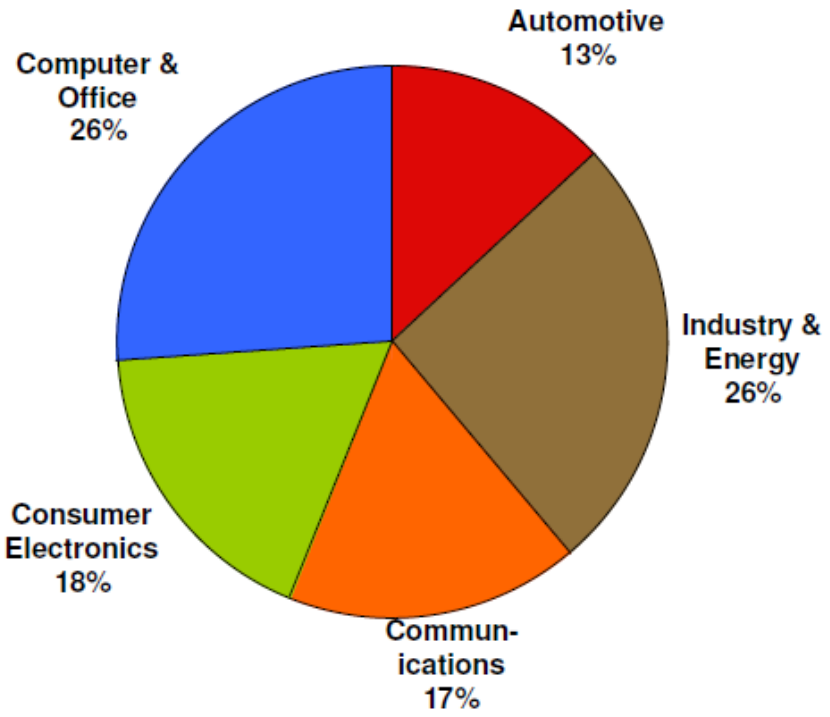
Boeing 787 Wide body Airliner
More Electric Aircraft Concept
About 1400 kW electric power

Power electronics on the Clyde: Type 45 destroyer（驱逐舰）

These ships are fitted with an integrated electric propulsion (IEP) system, where all propulsion systems and the ship's other electrical load are supplied with high voltage AC. The main propulsion motors are of 20 MW (27000 hp) power and are much smaller than you might expect. They rely on power electronics for their operation.

Image: BAE Systems

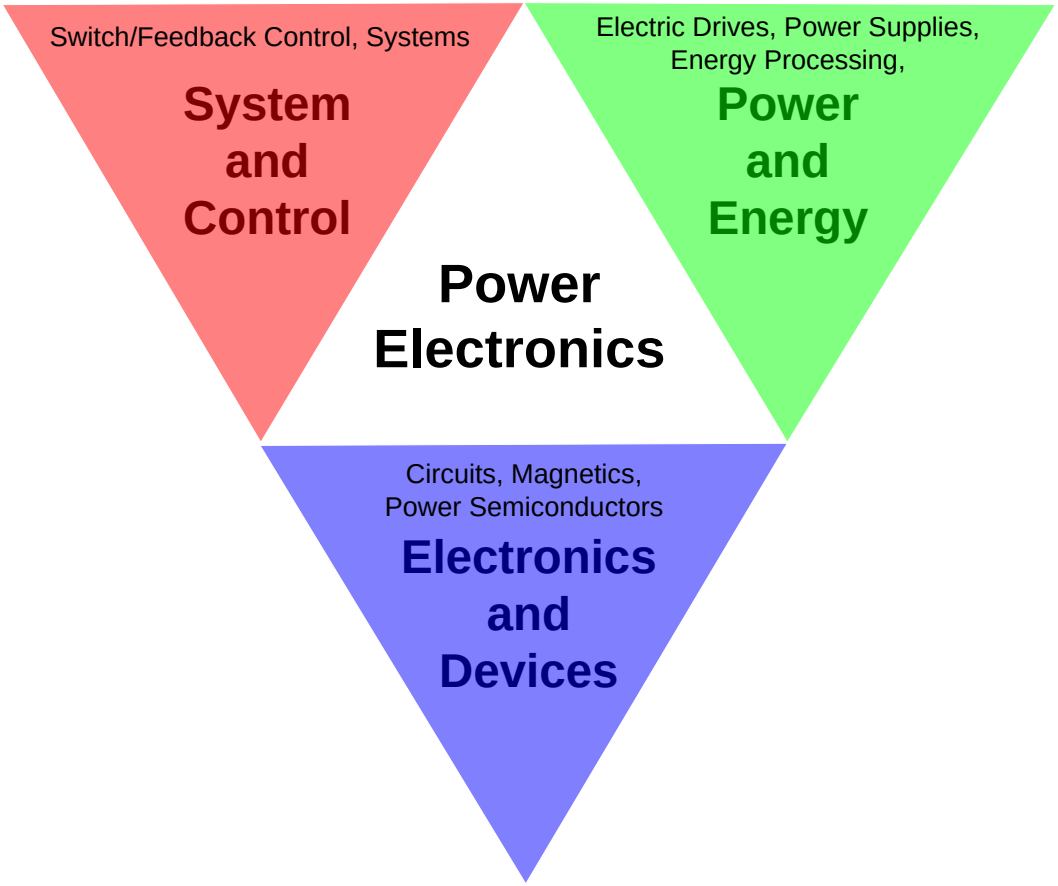
Global Power Electronics Market



A £70bn direct global market, growing at a rate of 11% per annum.

chart source: "electronics enabling efficient energy usage", e4u, 2009

Interdisciplinary Power Electronics



William E. Newell's Triangle