



Aalto-yliopisto

Switched-Mode Power Supplies

School of Electrical Engineering

Department of Electrical Engineering and Automation

Spring 2023

Target of the course

- To understand the operation of switched-mode topologies used in modern power supplies
- Content:
 - DC-DC converters
 - Resonant converters
 - Galvanic isolation, converters with isolation
 - Control of SMPS
 - Diode rectification
 - Power factor correction
 - High-frequency inductive components
 - Snubbers

Requirements

- Exam
 - 75 % weight in the final grade of the course
 - One question can be replaced by voluntary design exercise
 - Topic must be accepted in advance
 - Studies on difference topologies, control circuits, components, simulations, building of converters etc....
- Simulation exercises with Plecs
 - 25 % weight in the final grade of the course
- One laboratory work with two themes
 - Buck and Voltage Mode Control
 - Forward Converter
 - Measurements about 3h reports about 6 h

Materials

- Textbook **Mohan, Undeland, Robbins: Power Electronics, Converters, Applications and Design, Wiley&Sons, 3. edition.**
 - Chapters 1, 7, 9, 10, 11, some parts of 5, 18 and 30.
 - Unfortunately, there is no electric version available, but Aalto library has quite many printed copies
 - Also, earlier editions of the book are fine but then the chapter numbers are a bit different
- Finnish students can also read pdf-version of the material of the previous version of this course
- Other material will be added to MyCourses

Staff in Spring 2023

- Lectures
 - Thursdays 12:15-14, starting on March 2nd
 - Maarintie 8, ELEC's main building, seminar hall TU 6
 - Prof. Jorma Kyyrä, jorma.kyyra@aalto.fi
- Exercises and simulations
 - Thursdays 14:15-16, starting on March 2nd
 - Konemiehentie 2, Computer Science building, room T5
 - MSc Yining Liu yining.1.liu@aalto.fi
 - MSc Hadi Tarzamni hadi.tarzamni@aalto.fi
- Labs in late April, early May

Tentative schedule for Spring 2023

- 2.3 Start, DC-DC converters
- 9.3 DC-DC
- 16.3 Resonant converters
- 23.3 Resonant converters and Isolated converters
- 30.3 Isolated converters
- 6.4 Control
- 13.4 Current control and digital control, AC-DC rectification
- 20.4 no teaching, exam week
- 27.4, Power Factor Correction PFC
- 4.5 Magnetics
- 11.5 Magnetics, Snubbers
- 18.5 Ascension Day, no teaching
- 25.5 and 1.6 Reserve
- 8.6 Exam 12-15, T2

Power Electronics

- Interface between power source (ac system) and user
 - Converter (suuntaaja, muuttaja)
 - Electric energy is converted efficiently and dynamically fast to the needs of the load
- Supplying power source can be
 - National power grid
 - Wind power, solar, diesel engine
 - Dc-network
 - Battery etc.

Applications of power electronics

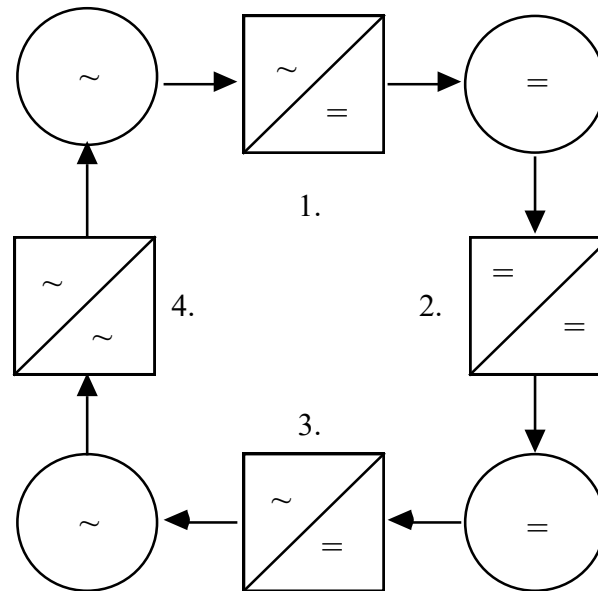
- Power supplies
- Motor drives
- UPS, unbreakable power supplies
- High voltage dc transmission, HVDC
 - Other applications in power systems, FACTS
- Lighting

Power electronics vs. electronics

- Electronics:
 - Operation is based on the linear region of transistors
 - Deals with signals, information
 - Power mW to W
 - Losses are small
 - Target is maximum output power, amplifier
- Power Electronics
 - Operation is based on switching (on-off) of devices
 - Deals with energy
 - Power level W to MW
 - Target is maximum efficiency and minimum size

Classification of converters

- Converter (Suuntaaja, muuttaja)
 - Power semiconductor devices, inductors and capacitors
- Direction of power
 - Rectification
 - Inversion



1. Rectification
2. Dc-dc conversion
3. Dc-ac conversion
4. Ac-ac conversion

Basic laws

- Do not open current source

$$u = L \frac{di}{dt} \Rightarrow di = \frac{u}{L} dt$$

- So not short circuit voltage source

$$i = C \frac{du}{dt} \Rightarrow du = \frac{i}{C} dt$$

- From the input and output sides of the converter the other one is current source and the other one voltage source, reciprocity

Switched-Mode Power Supplies

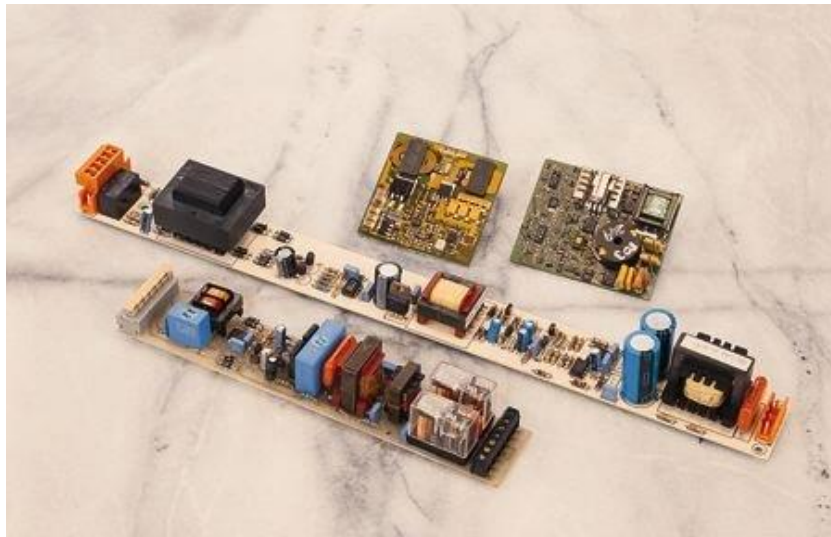
- Computers, chargers, base stations
 - Always when good quality DC or AC (UPS) power is needed
- Switched-mode reduces size and weight and efficiency increases



48Vin / 2Vout / 160Watts
DC-DC Converter Module
Model Number V48A2C160A*



Shown actual size:
4.6 x 2.2 x 0.5 in
117 x 56 x 12.7 mm



Switching DC Power Supply: Block Diagram

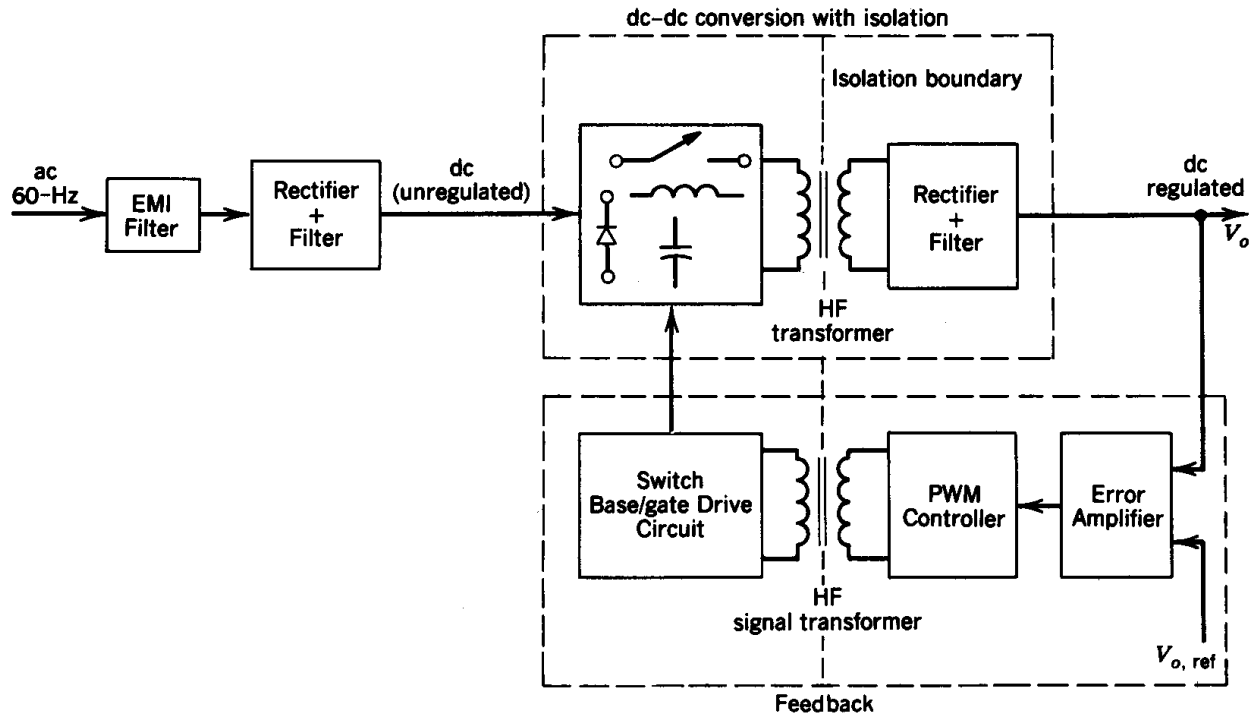


Figure 10-2 Schematic of a switch-mode dc power supply.

Requirements for SMPS

- Controlled output voltage although supply voltage or load (current) change
 - Galvanic isolation (not always, depends on application)
 - Many outputs, with different voltage and current ratings
- Other targets:
 - Reduction of size and weight
 - Increase of efficiency

Multiple outputs

- Only one controlled output
- Others can be controlled with additional dc-dc converters or linear regulators (losses)

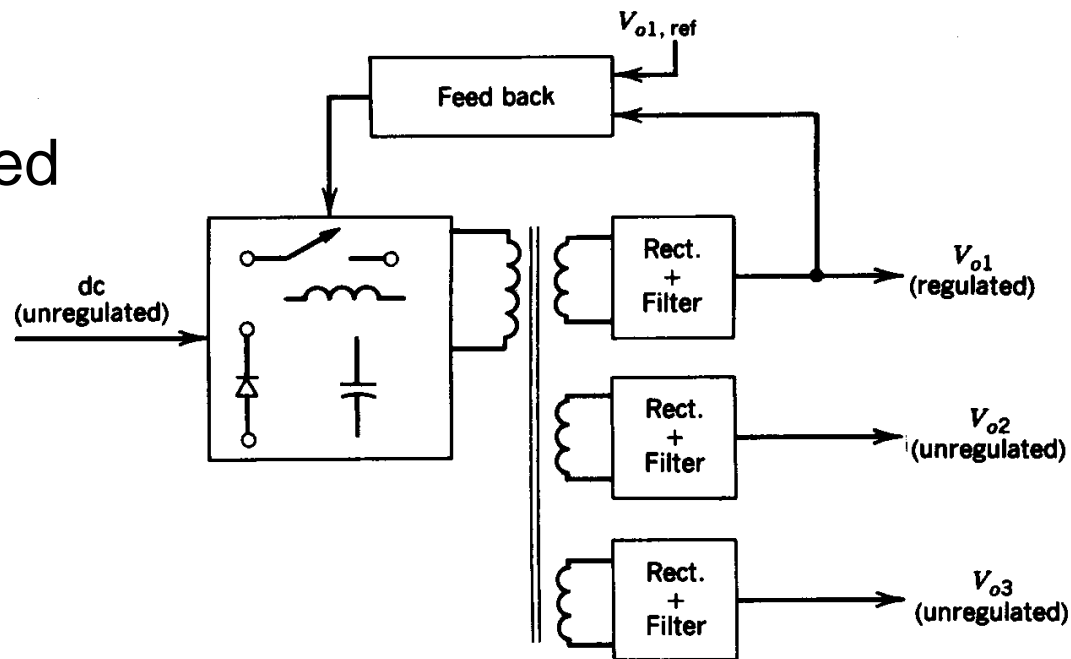


Figure 10-3 Multiple outputs.

Advantages and disadvantages of SMPS

Advantages

- Semiconductors are used as switches
 - High efficiency, 85-98 %
 - Same component can treat higher powers as in linear mode
- High switching frequency reduces size of inductive (inductors and transformers) and capacitive components
- Typical power density in 30 W/in³.
/Chrysis, s.3/
- 100 W dc-dc-converter 70 W/in³
EDN 19.3.1992, already more than 25 year ago!

Disadvantages

- More complicated
- More EMI and filtering is needed

Linear Power Supplies

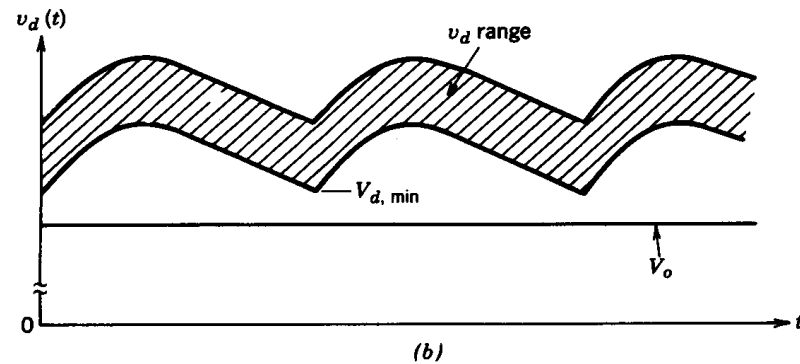
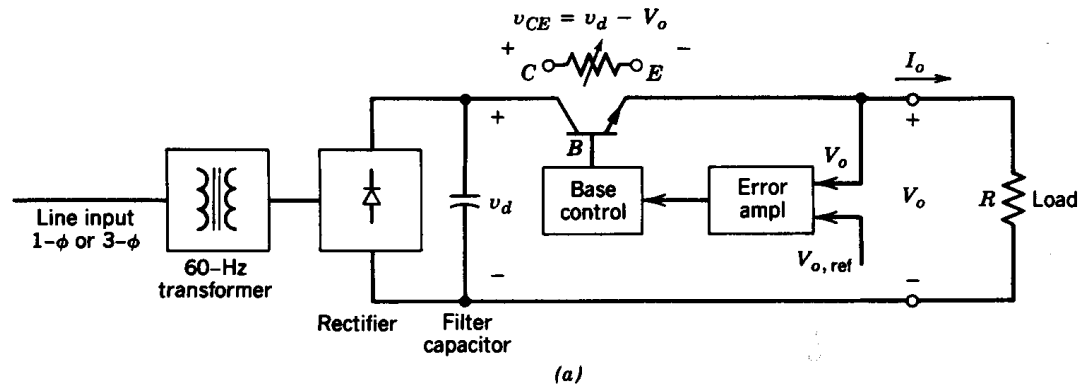


Figure 10-1 Linear power supply: (a) schematic; (b) selection of transformer turns ratio so that $V_{d, min} > V_o$ by a small margin.

Principle

- Control of base current adjusted and voltage drop over the transistor changes, output voltage is controlled
- Voltage over transistor $u_d - U_o$
 - Voltage drop and power losses increase as output voltage gets lower
- Turns ratio of the line side transformers needs to be selected properly
 - Voltage drop is not too high
 - The wanted output voltage can be obtained

Linear Power Supply

- Disadvantages
 - Large line-frequency transformer
 - Typical power density 0,3 W/in³
 - Transistor in linear area
 - High losses, efficiency typically less than 50 %
- Advantages
 - Simple construction, cheap at low powers
 - Not noisy, only small amount of EMI