Structures of the Energy flow system

Mechatronics 2007

Mekatronics - energiflow

Structures of the energy conversion system (< 1 h)

    Primary energy to output

    Electrical as intermediate

Power electronic converters as components (< 3 h)

    AC/DC/AC

    Modulation

    Power Units (50 Hz / SMPS / Integration)

    Passive components / Integration of passives

Electromechanical converters as components (< 3 h)

    Conv. machine types

    Elektrostrictive/magnetostrictive converters

    Cooling

    Power and Energy density

Energyconverters as construction elements (< 1 h)

    Laminated steel / powder pressing / injection moulding

Powerelectronic measurements (< 2 h)

    Current / voltage / flux

    Torque /speed / position

    Preassure / flow (in pumps)

Energy processed in several steps

| Energy | Process | Output energy |

Signal

- **Primary energy source**
  - (chemical, mechanical, electrical)

- **Intermediate electrical energy storage**
  - (capacitive, inductive, ...)

- **Output energy**
  - (mechanical, heat, light, sound,...)

Primary energy sources

- **Chemical**
  - Batteries
  - fuel cell with hydrogen
  - Combustion
  - Capacitors
- **Electrical**
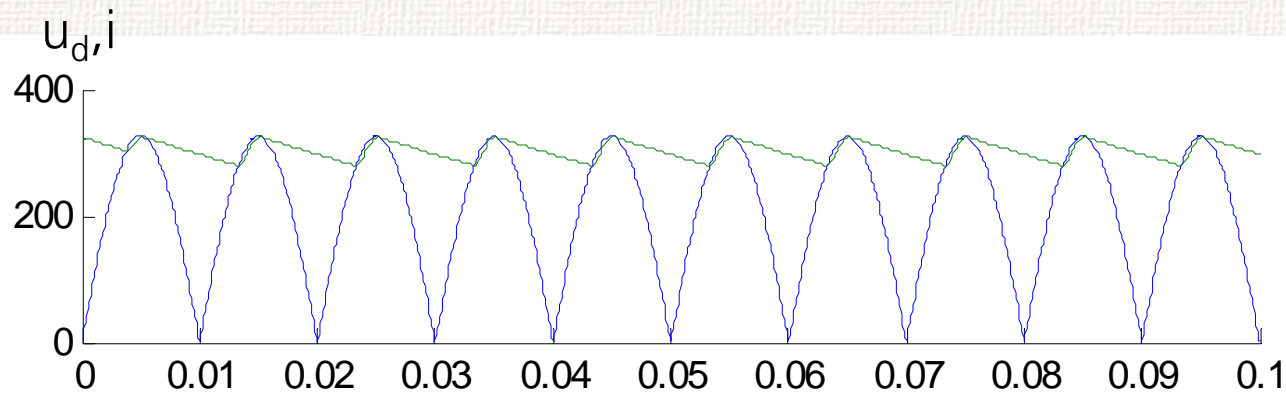 - Power grid
- **Mechanical**
  - Flywheel
- **Solar power**
  - Max 10…15% 1000 W/m2
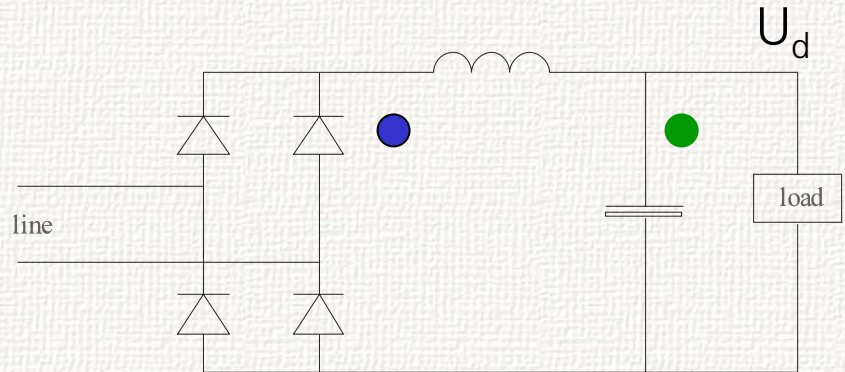
Electrical Power & Energy Storage Comparison
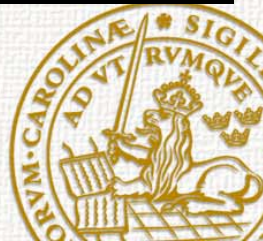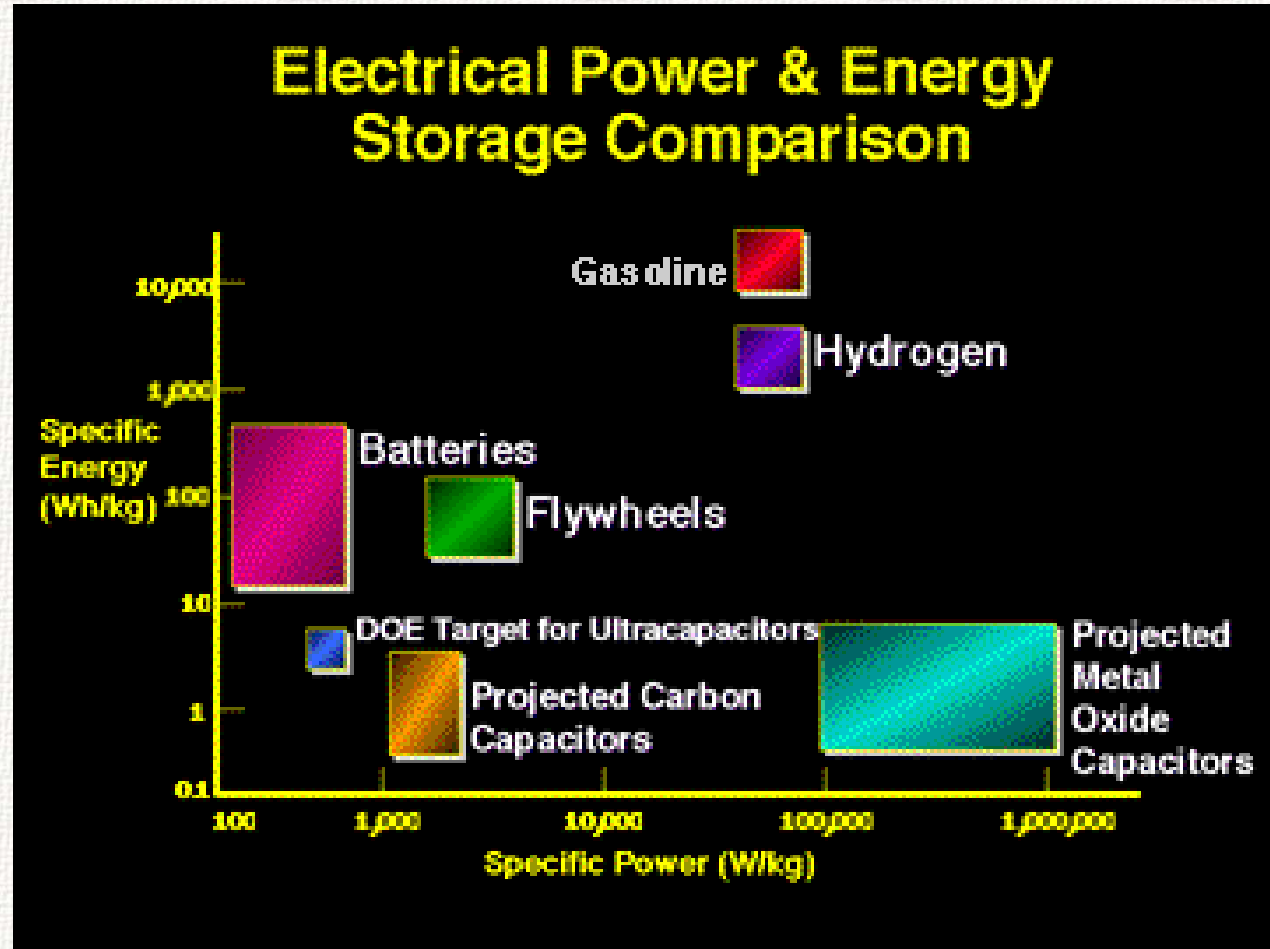
Primary to intermediate energy conversion

- ## AC to rectified DC
  - **230 V / 50 Hz to almost 325 V (singel phase rectifier)**
  - **400 V / 50 Hz to almost 540 V (three phase rectifier)**

- ## AC to low voltage DC
  - **Transformer + rectifier**
  - **Switched Mode Power Supply (SMPS)**

- ## DC to DC
  - **Non-isolated, step down**
  - **Non-isolated, step up**
  - **Isolated**

AC to rectified DC – 1 phase

U_d

line

load

- **High harmonic content in the line current**

u_d, i

400

200

0

0   0.01   0.02   0.03   0.04   0.05   0.06   0.07   0.08   0.09   0.1

$$U_d = \frac{2}{\pi} * \hat{U} \approx 0.9 * U_{rms}$$

Industrial Electrical Engineering and Automation

AC to rectified DC – 3 phase

- **High harmonic content in the line current**
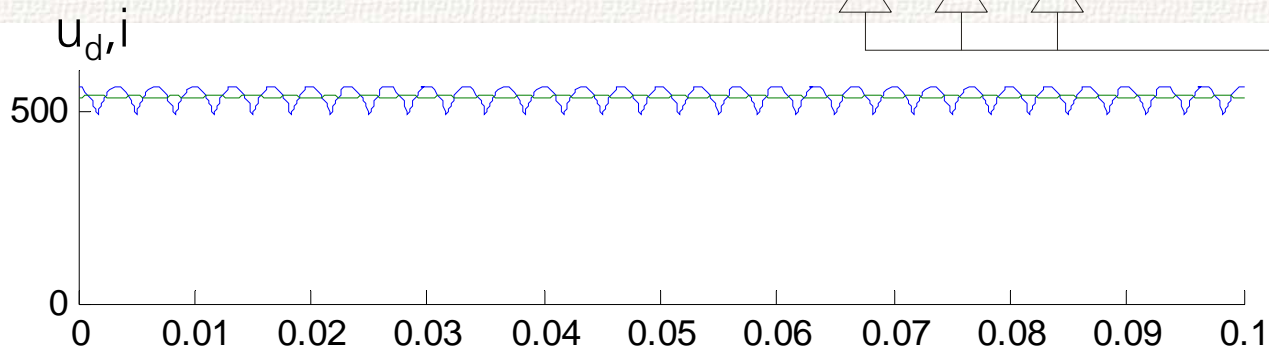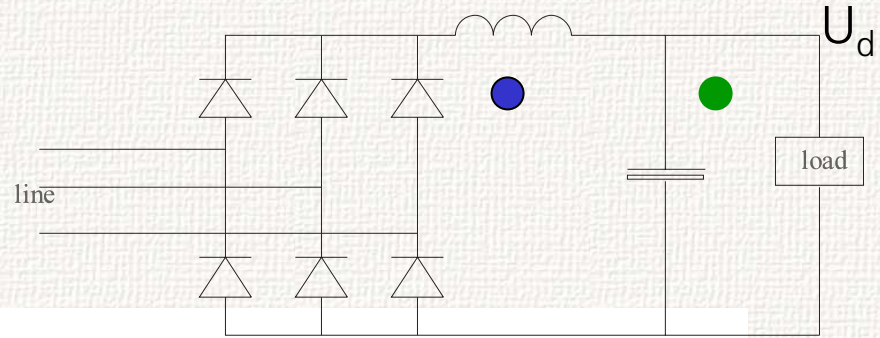
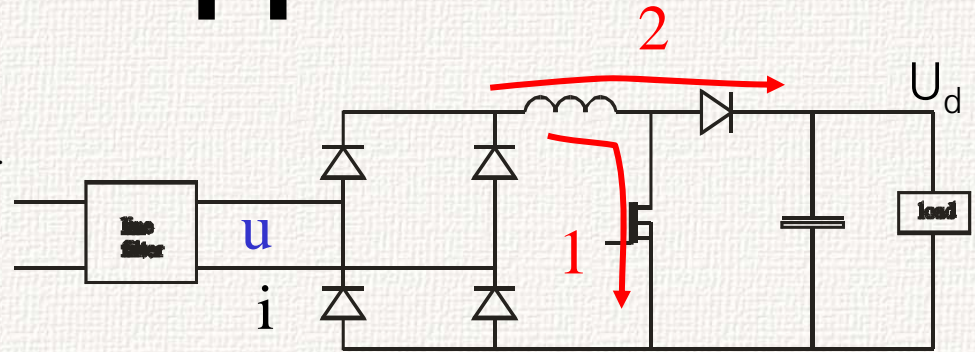$$U_d = \frac{3}{\pi} * \hat{U}_h \approx 1.35 * U_{h,rms}$$

AC to low voltage DC

- **Step down transformer + rectifier. Still the same problem with high harmonics in the line current.**
- **Galvanic isolation**
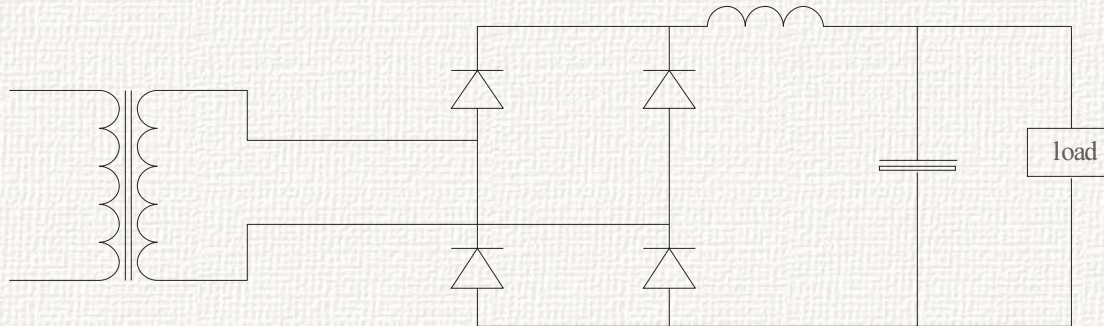
SMPS – Switched Mode Power Supplies

- Function
  - Transistor "on" -> increasing inductor current through transistor
 - Transistor off -> decreasing inductor current through diode

- Advantages:
  - Output voltage greater than input voltage (universal input);
  - Simple control;
  - Input inductance acts like a filter toward AC line;
  - Many control ICs available on the market.
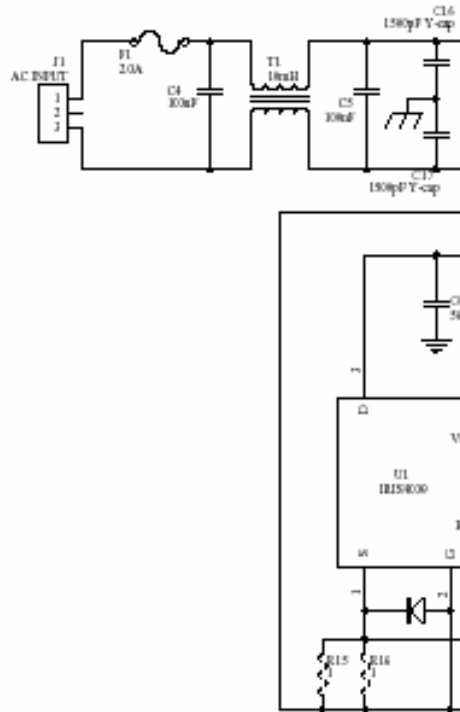 - PFC of 0.95 or better over line and load variations.
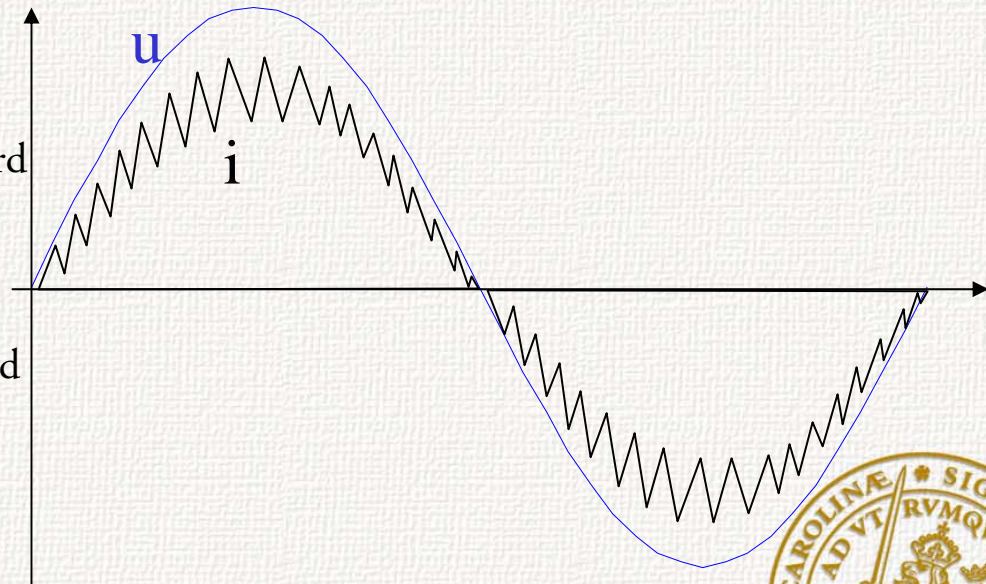
Switched mode power supplies for low voltage DC with flyback
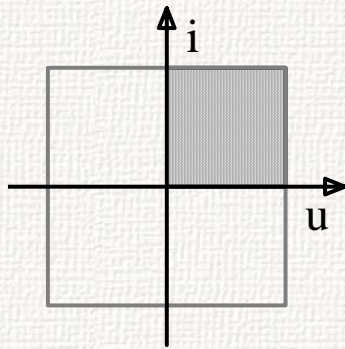
- **Features:**
  - Galvanic isolation to the feeding grid
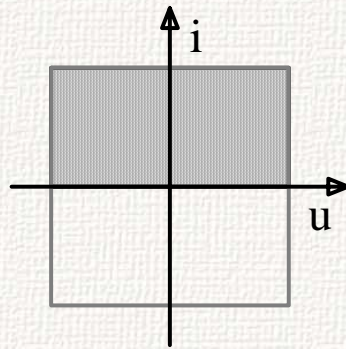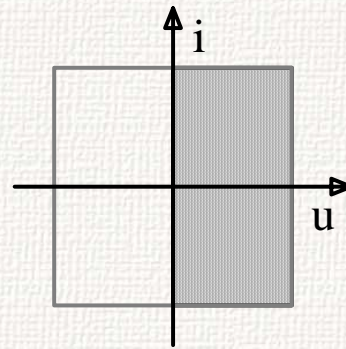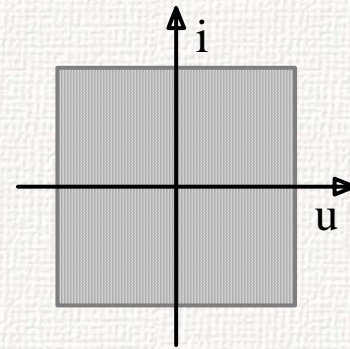 - Output voltage range adjusted with the transformer ratio

Example from http://www.irf.com/technical-info/refdesigns/irismps4.pdf
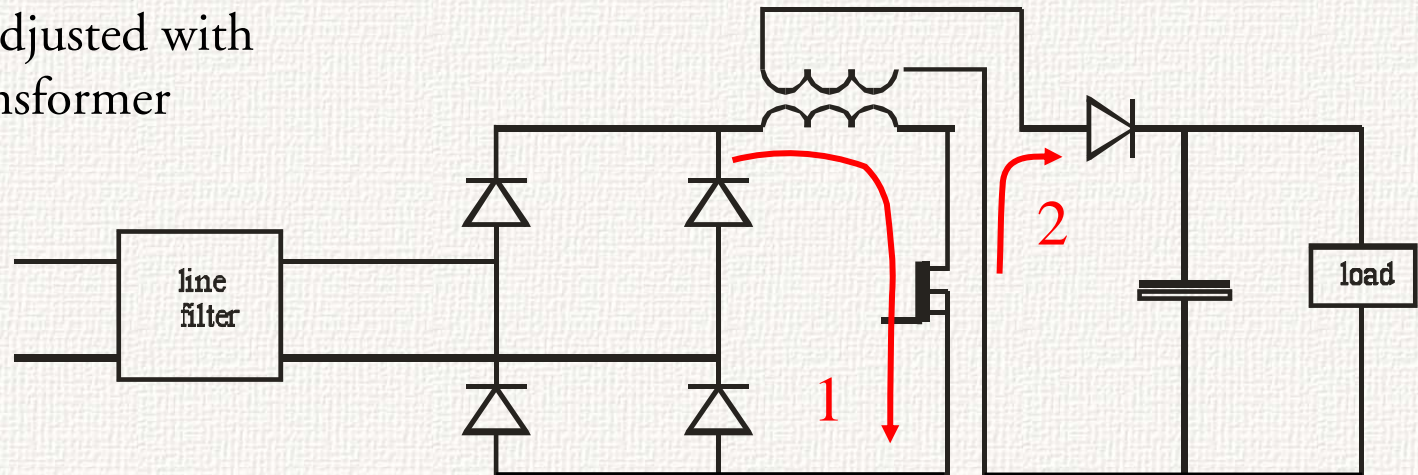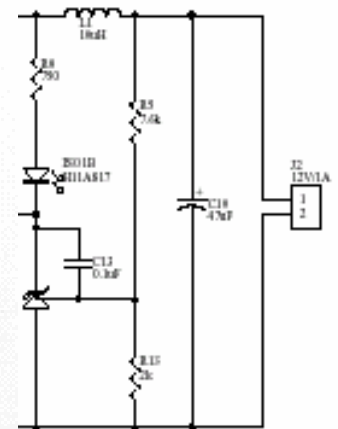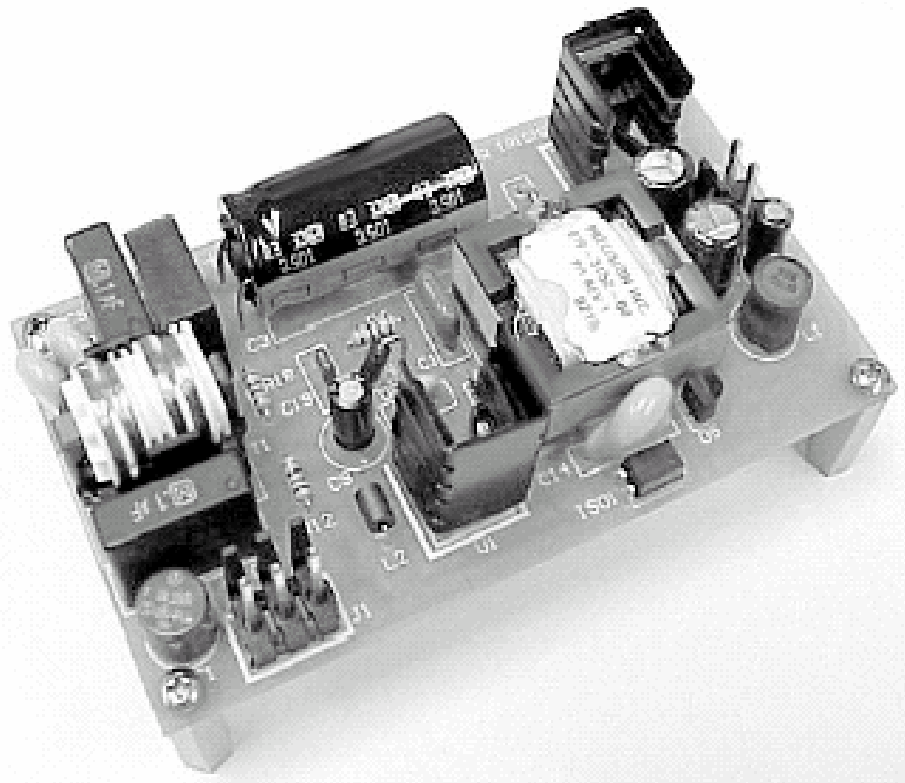
Kvadranter

1-kvadrant   2-kvadrant   2-kvadrant   4-kvadrant

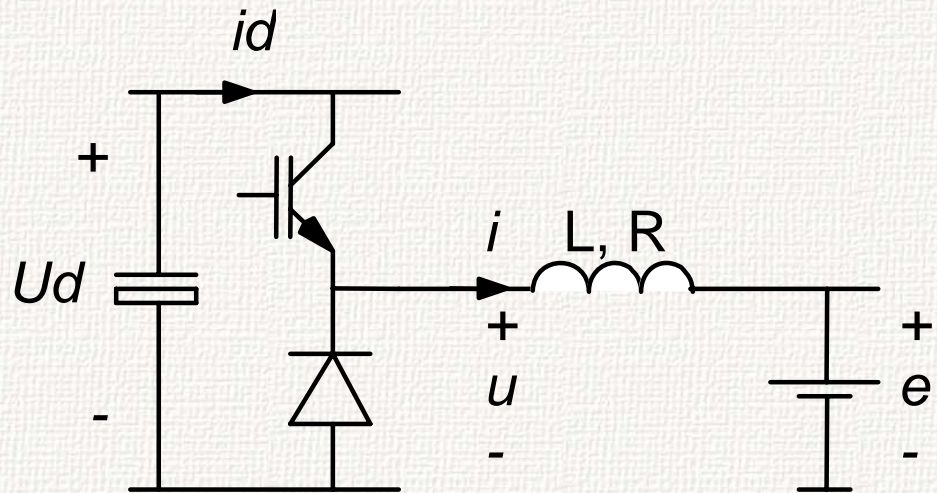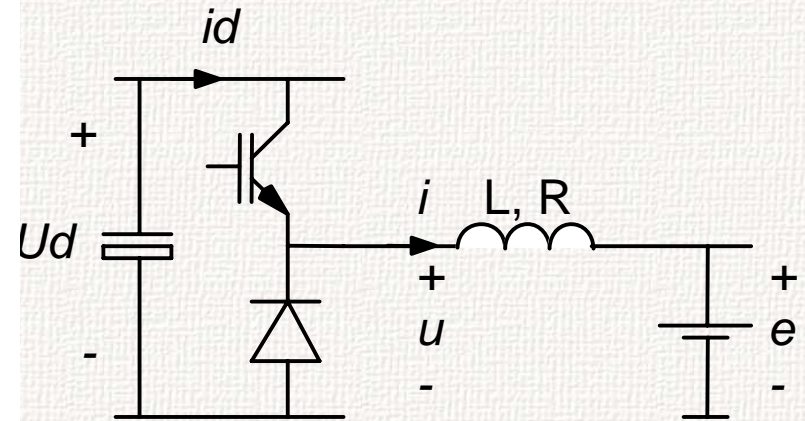**Kraft-
elektronisk
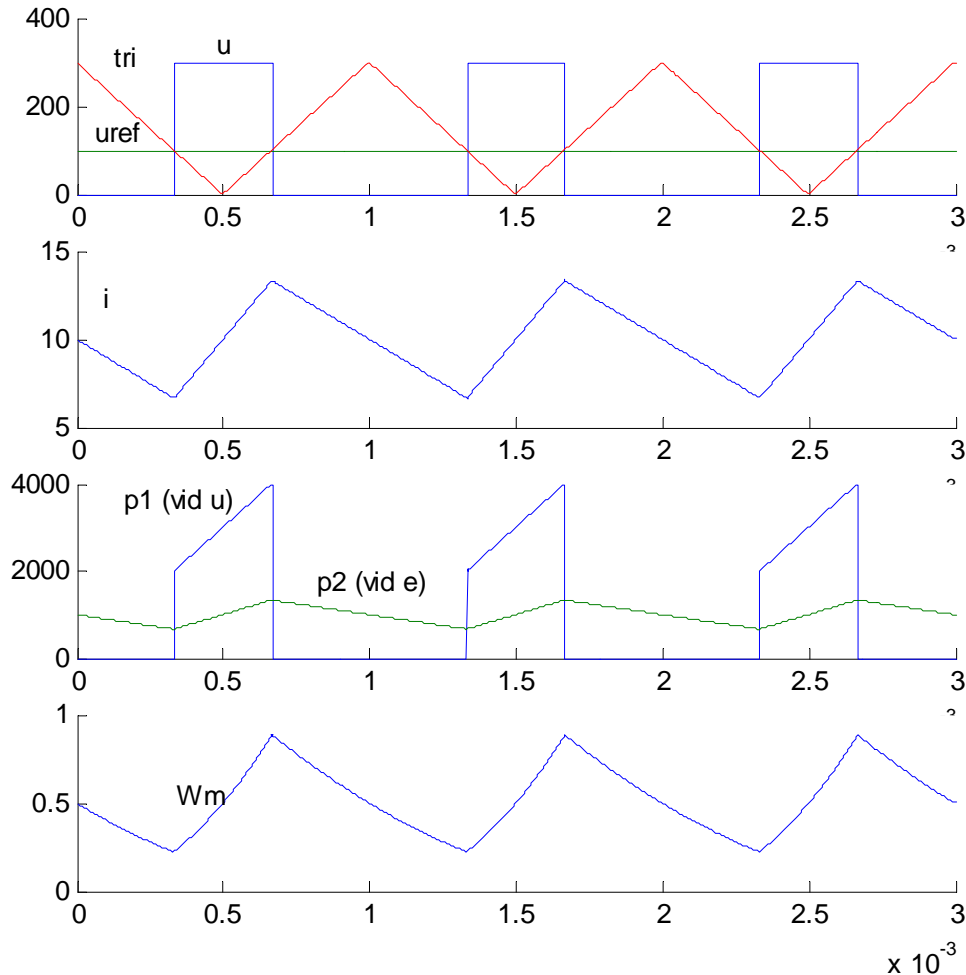omvandlare**

i   **+**

u

-

1-quadrant step down converter (buck-converter)

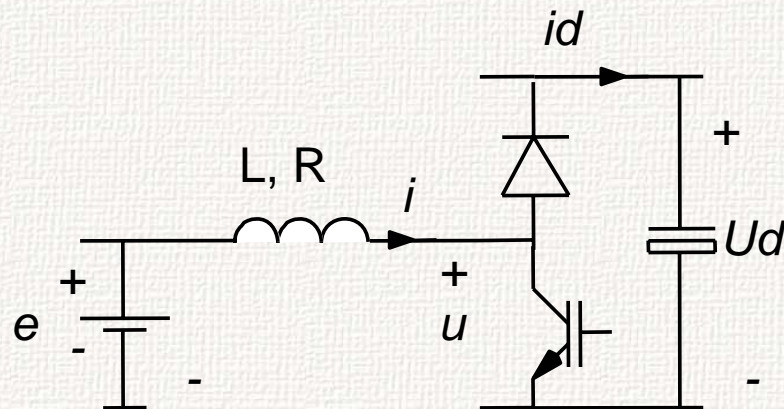- **Output voltage lower than input voltage**
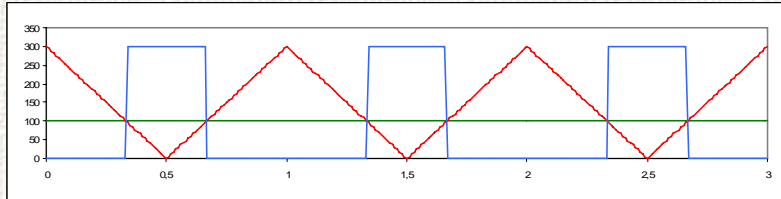- **Output current positive**

Control of 1-q. buck converter.

1-quadrant step up converter (boost-converter)

- **Output voltage higher than input voltage**
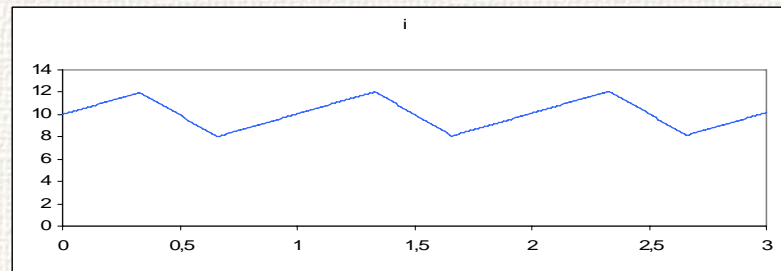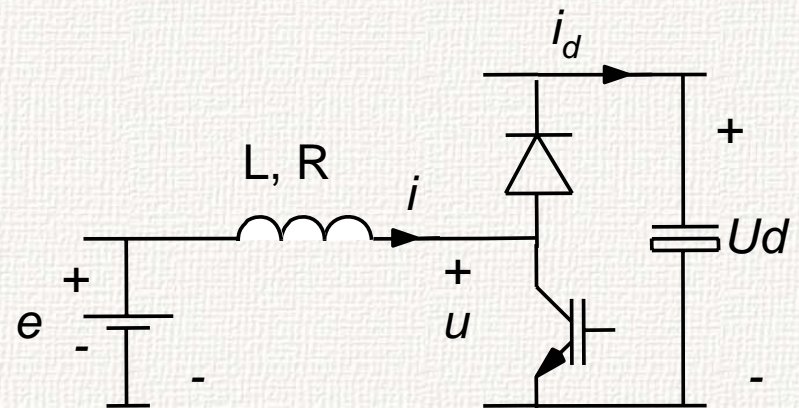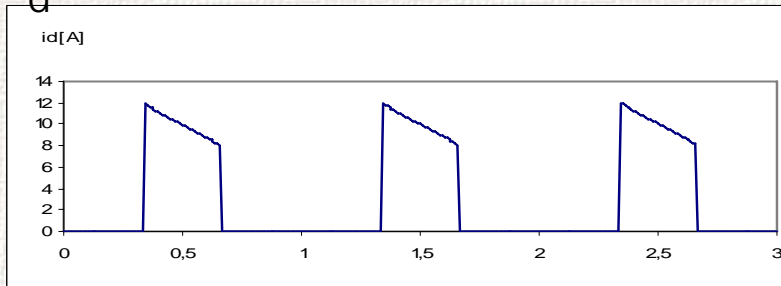- **Output current positive**

$$e \quad L, R \quad i \quad id \quad u \quad Ud$$

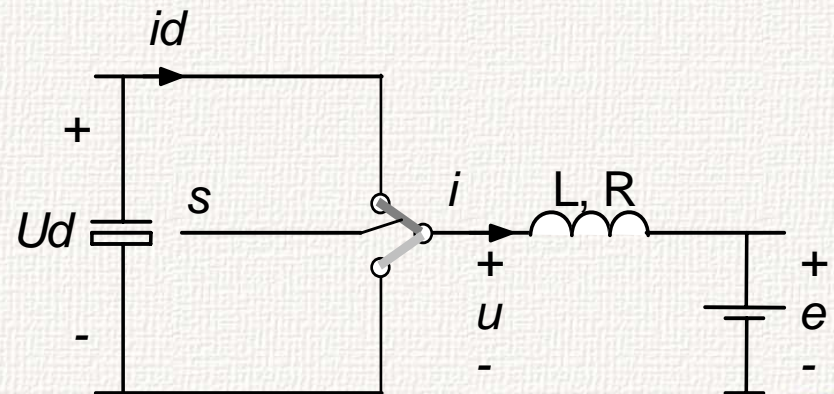# Styrning av 1-kv. Uppsp.omv
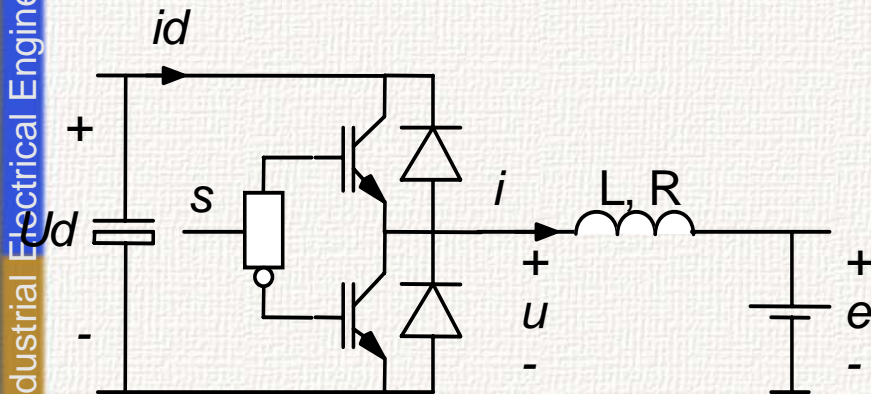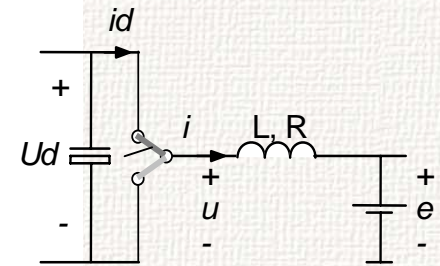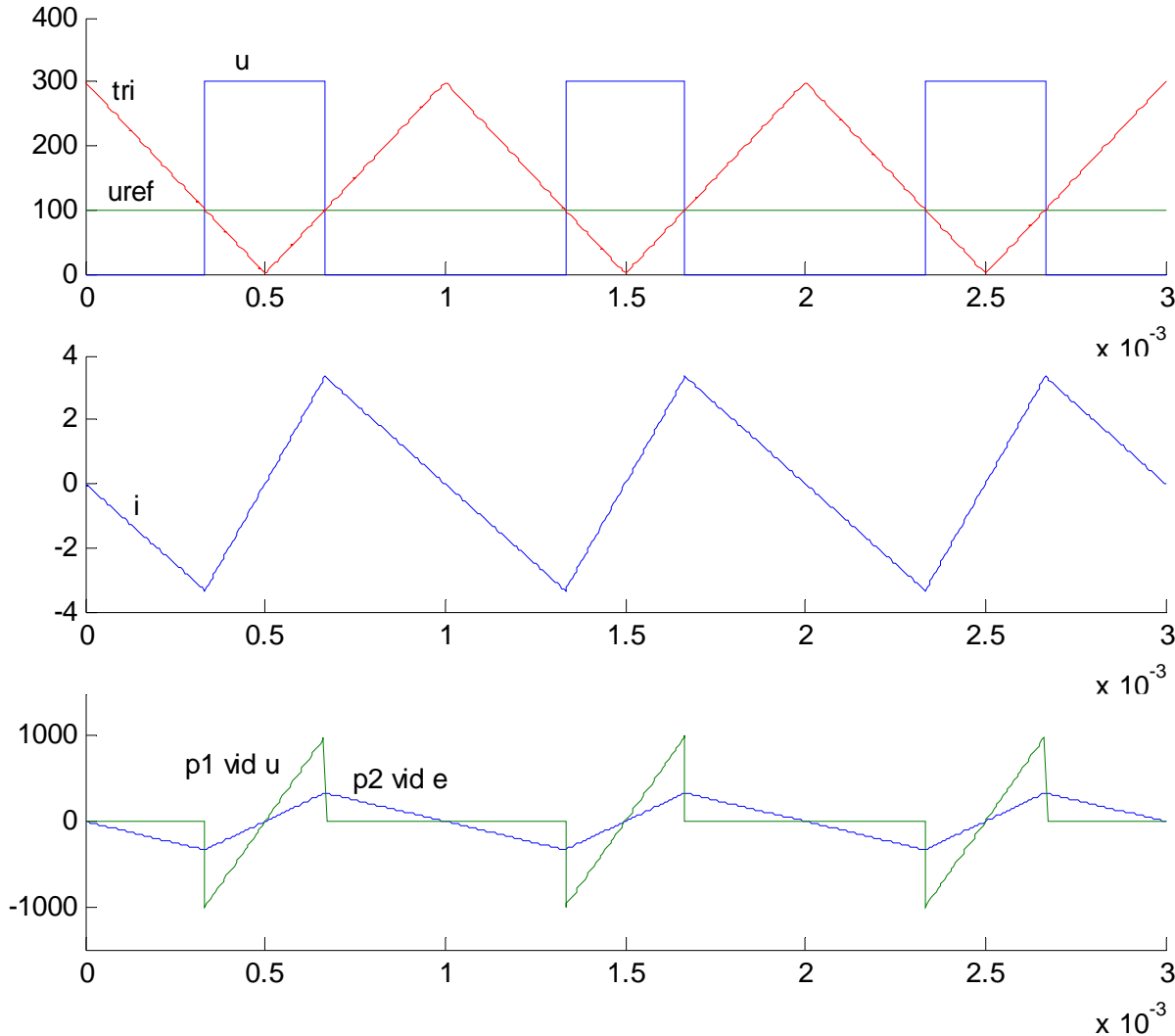
u

i

i$_d$

2-quadrant DC converter

- **Current can be negative**
- **Both directions for energy flow**
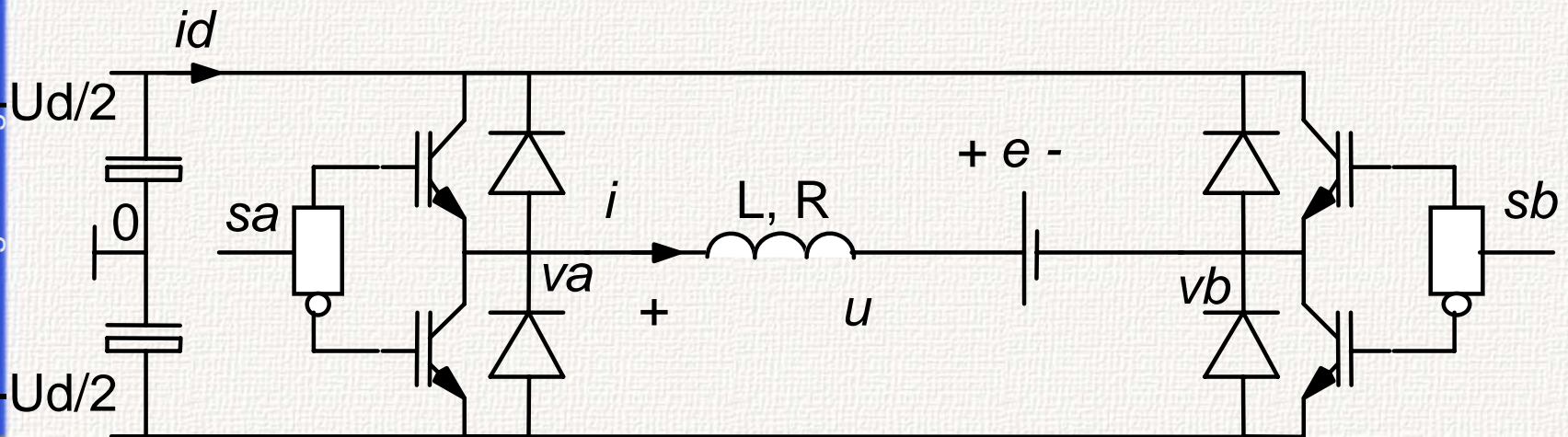 - Voltage unipolar, current bipolar
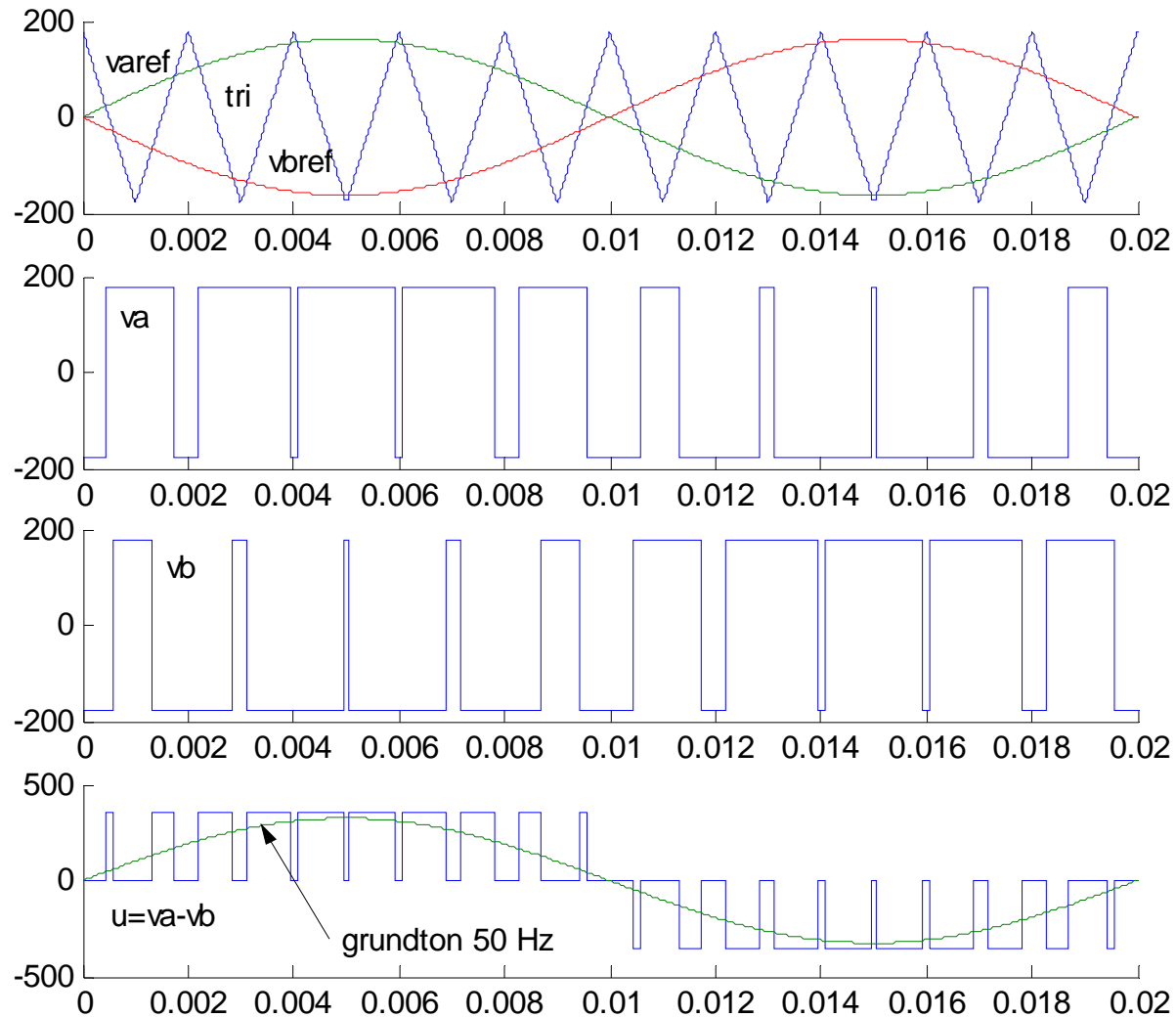- **Equivalent switch:**
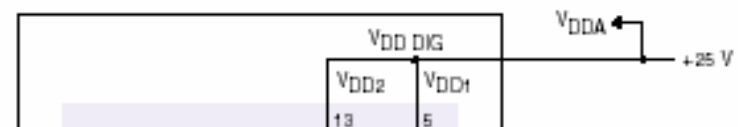
Control of 2-Q. converter.

4-Quadrant DC converter

- **All combinations of voltage and current**
- **AC-voltage**
- **Both directions for energy flow**

# Control of 4-Q converter

Class D Audio Amplifiers

Features

- Power ranges from 20 to 150 W
  (up to 400 W with application support)
- Excellent power efficiency ($\leq$ 95%)
- Good EMC performance
- Excellent THD (0.01%)
- Symmetrical supply between 15 - 30 V
- Internal oscillator:
  - frequency adjustable between 200 and 600 kHz
  - can be overridden by an external clock (tracking option)
- Output stage protected against short circuit and overheating
- Simple SE and BTL applications
- Few external components
- Asymmetrical supply possible for BTL configurations
  (with application support)
- Powerpath ICs in Sil17P and HSOP24 Power SMD package
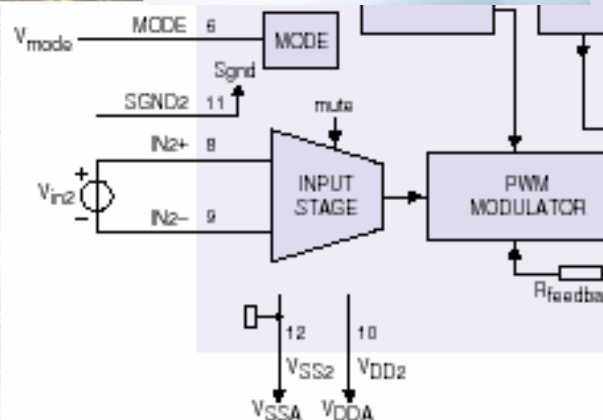
3-phase converter
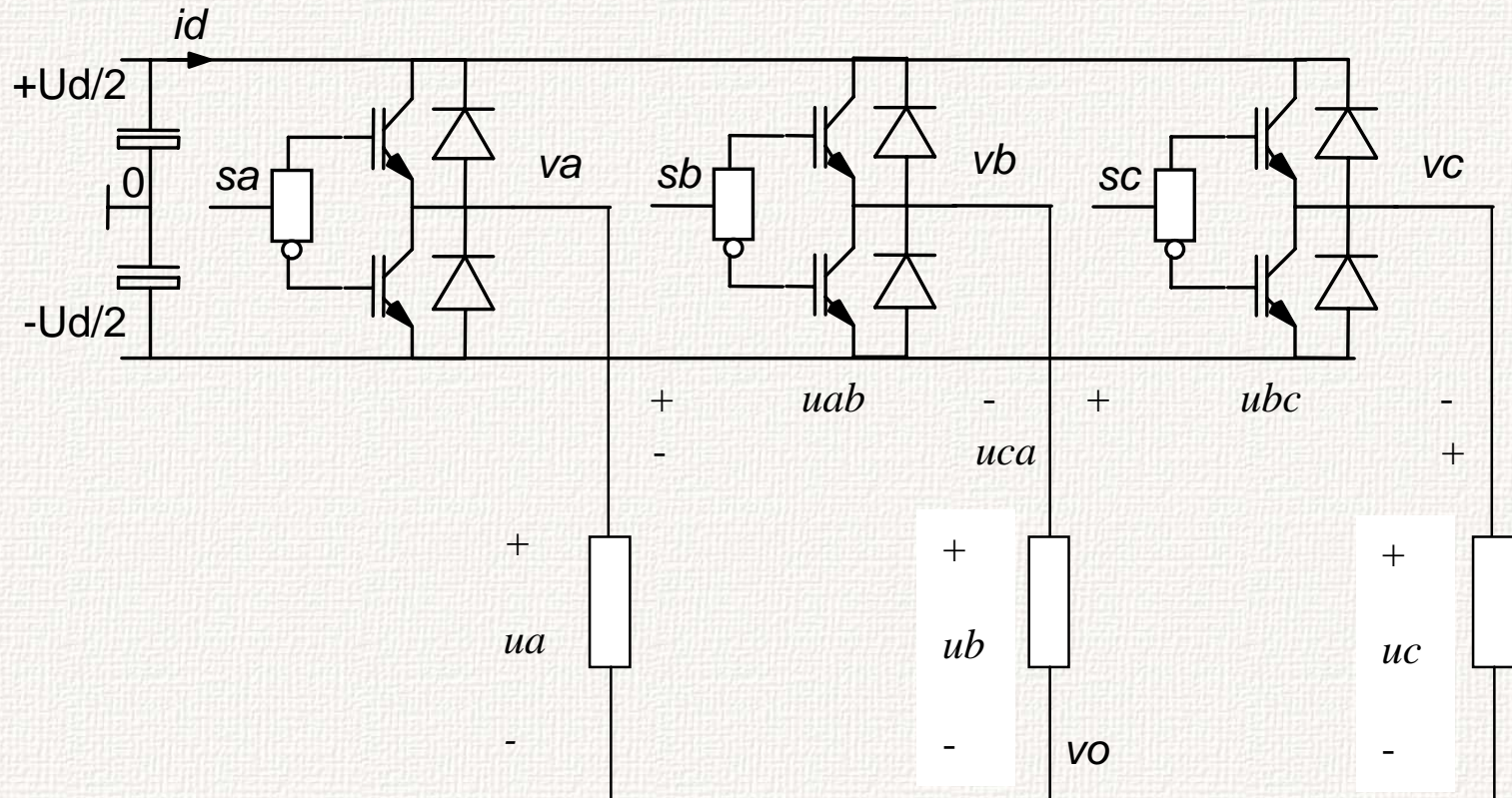
Drive circuits

- **All power transistors need a gate/base-driver to**
  - Switch between on- and off-state
  - Turn off at over current
  - Provide galvanic isolation to the control circuitry

- **Example of separate driver**
  - 600V and 1200V gate driver in a single IC for MOSFET and IGBTs
  - Multiple Configurations
  - Single high side
  - Half-bridge
  - 3 phase inverter driver
  - Up to +2.0/-2.0A output source/sink current enables fast switching
  - Integrated protection and feedback functions
  - Optional deadtime control
  - Tolerant to negative voltage transient
  - Up to 50V/ns dV/dt immunity
  - Optional soft turn-on
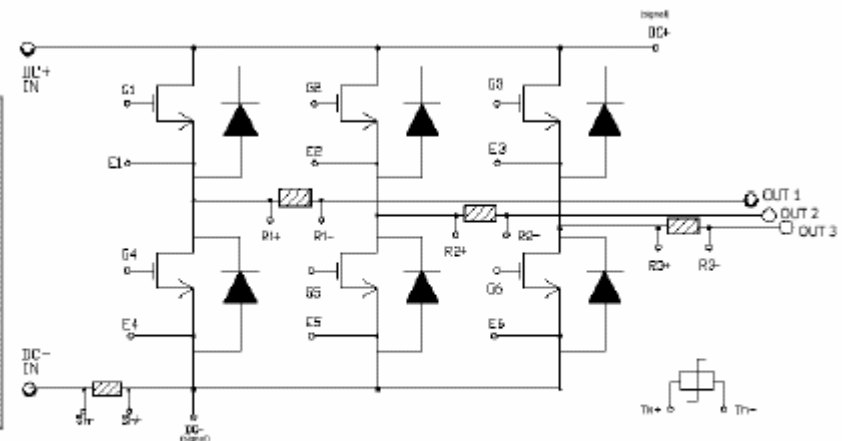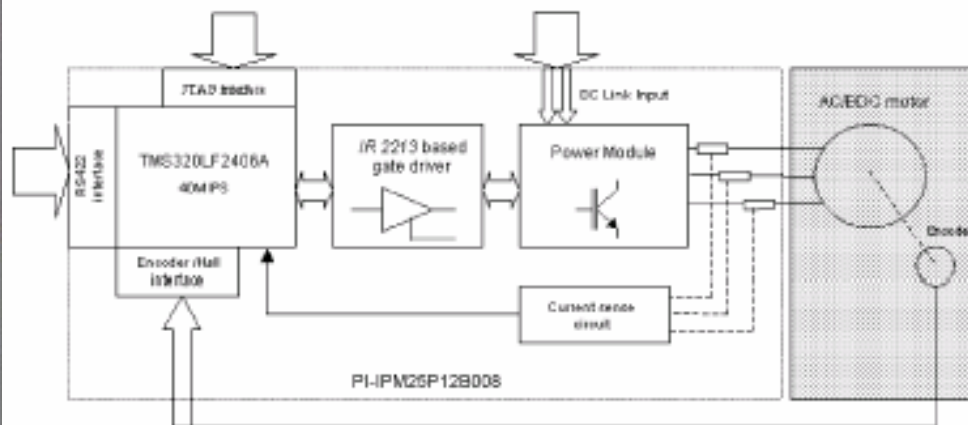 - Uses low cost bootstrap power supply
  - CMOS and LSTTL input compatible

IR2184
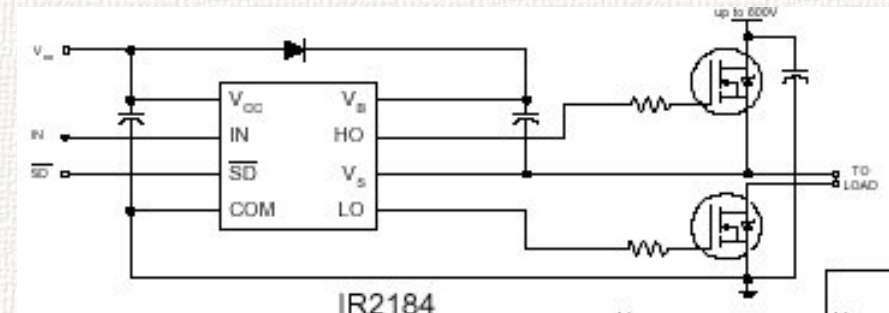
Fully integrated power semiconductors

- **Self-containing with built in:**
    - Drive circuit
    - Protection circuit
    - Galvanic isolation
    - Power transistor

Three phase inverter with current sensing resistors on all output phases and thermistor

Passive components

- **Inductors**
- **Capacitors**
- **Heat sinks**

Inductors

- Many types:
  - Ferrite type components
    - For SMPS transformers @ 100 kHz
  - Chokes & Coils & Inductors
    - For EMC supression
  - Toroidal transformers
  - Laminated core transformers
  - Current transformers
  - Noise protection transformers
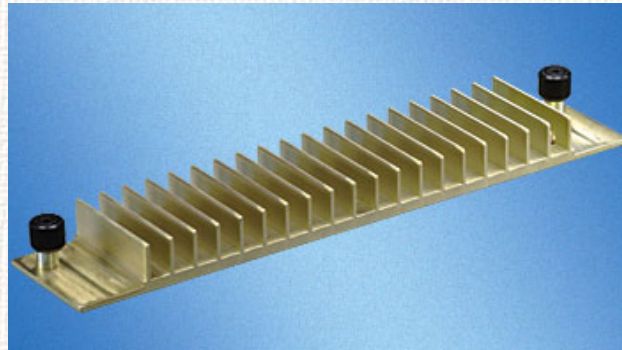 - AC voltage stabilizers

Capacitors

- **Electrolytic**
  - For energy storage and filtering
- **Film**
  - For filtering
- **Must be selected with care, can be destroyed by:**
  - Harmonic currents
  - Over voltages
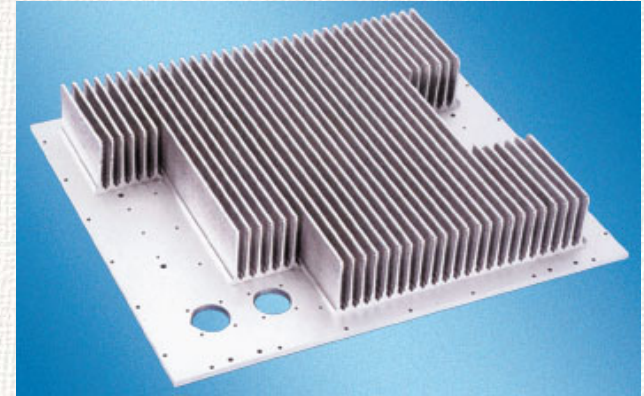- **Most producers have software design tools available on their home page.**
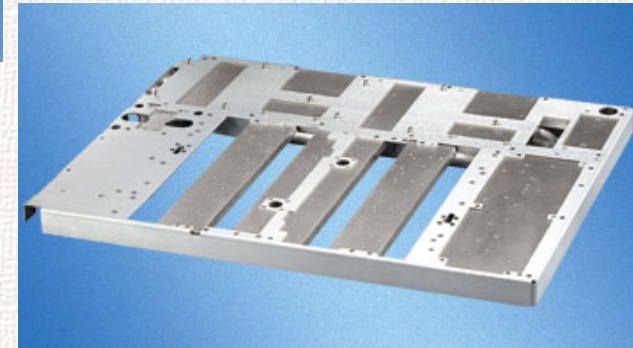
Heat sinks

- **Extruded**
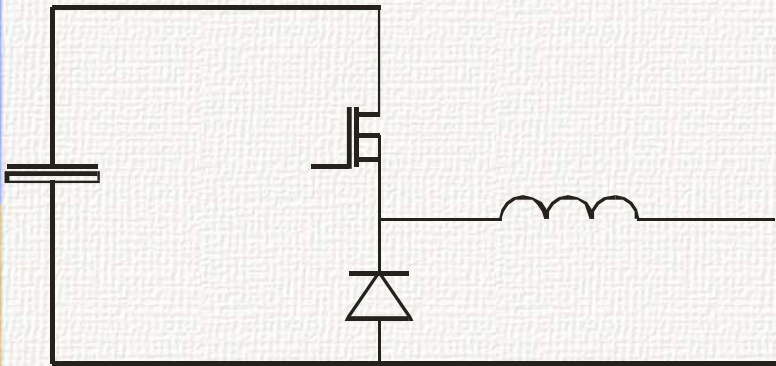
- **Stacked fin**

- **Water cooled**
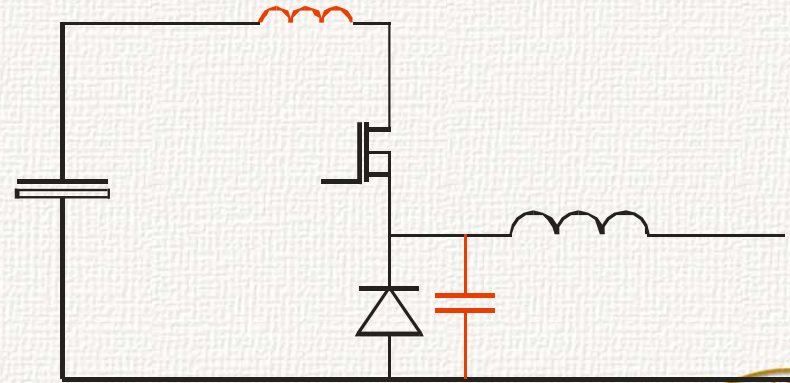
- **Integrated in housing**

Power Electronic Design

- **All circuits contain capacitive and inductive elements with switches in between.**
- **Non ideal components contribute to short circuit currents and over voltages that may harm/destroy the circuit.**
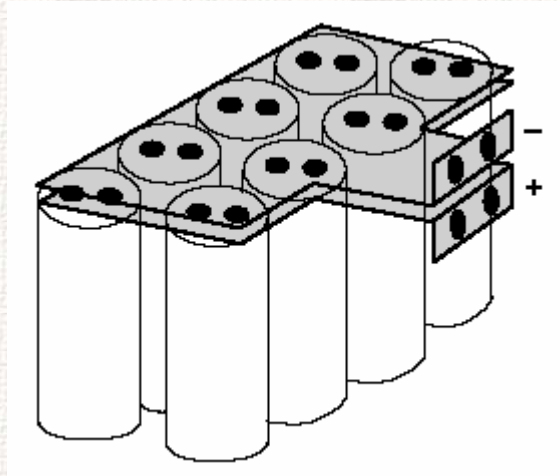- **Example:**

What should look like this:

do instead look like this:

- **Solution: - Minimize non ideal components and distances**

How to improve a circuit

- **Minimize length of capacitive cables**
- **Example:**

- **Avoid capacitance in inductive circuits**
  - Eg. keep primary and secondary winding of a transformer apart.

Integration of passive components