EE 238

Power Engineering - II

Power Electronics

Lecture 4

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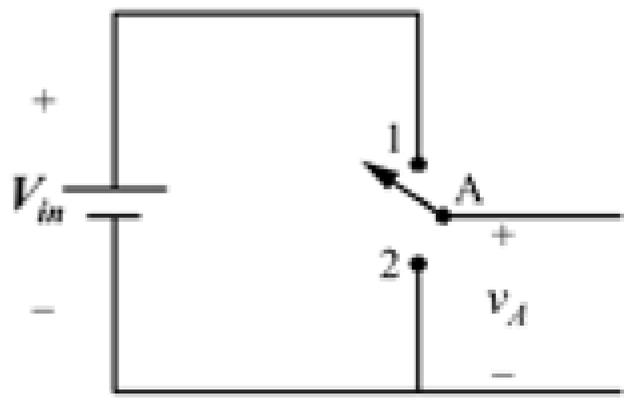
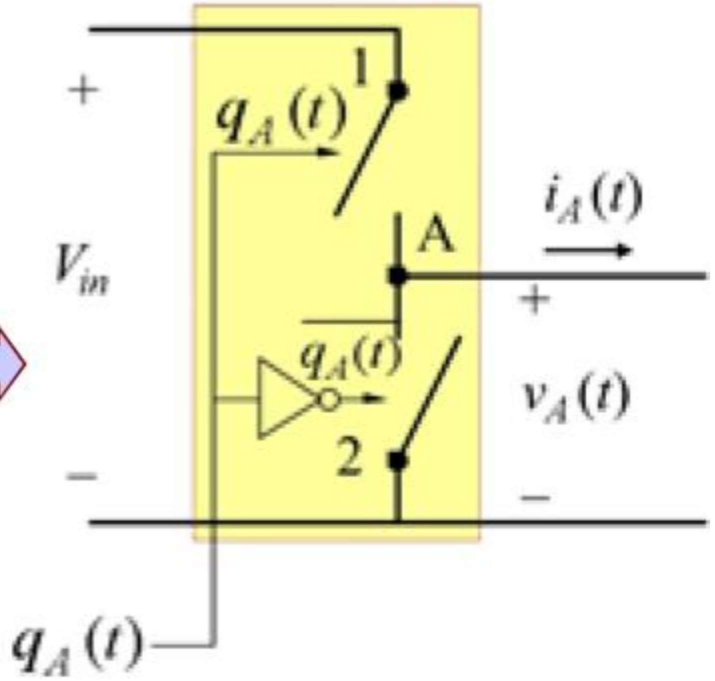
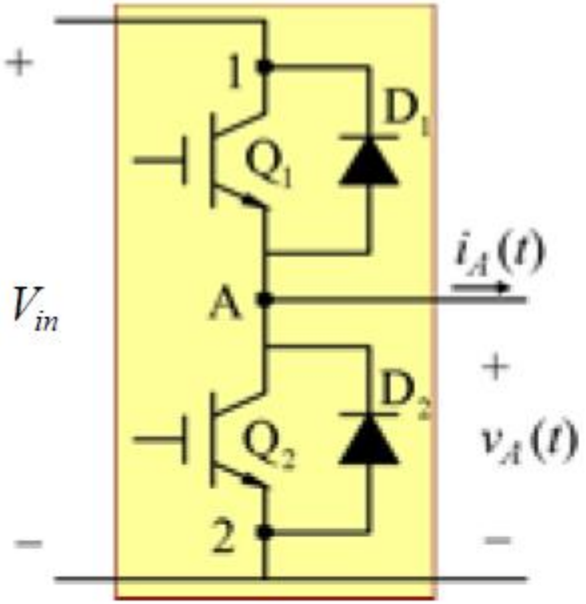
Bi-positional switch: electronic implementation

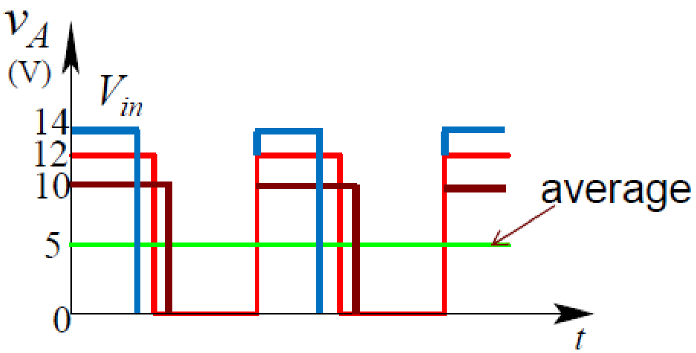






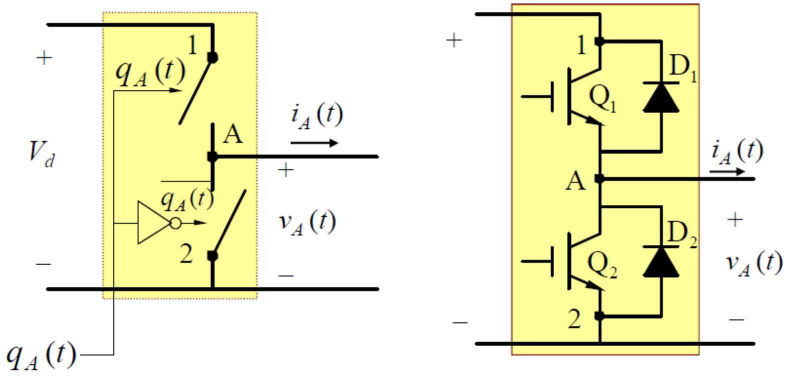
Switch in position 1 $\Rightarrow$ $v_A = V_{in}$

Switch in position 2 $\Rightarrow$ $v_A = 0$



- ✓ **SPDT switch realized with two SPST switches**
- ✓ **SPST implemented with MOSFETs and IGBTs or other power semiconductor devices**
- ✓ **Bi-positional switch is a main building-block of power converters**

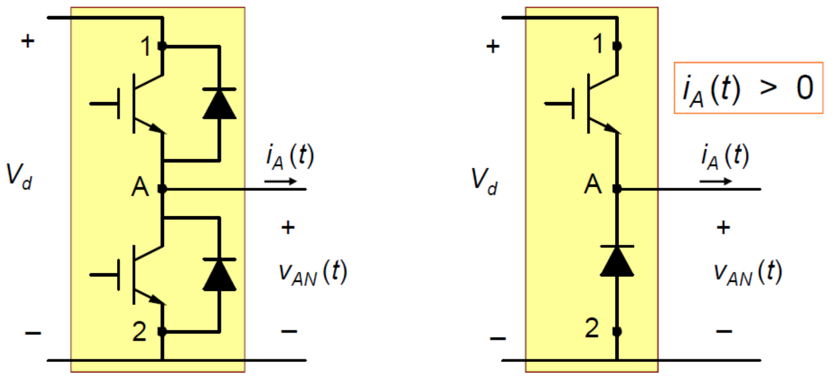
Bi-positional switch: electronic implementation



$q_A = 1$ ⇨ Top switch Q_1 ON, bottom switch Q_2 OFF ⇨ $v_A = V_d$

$q_A = 0$ ⇨ Top switch Q_1 OFF, bottom switch Q_2 ON ⇨ $v_A = 0$

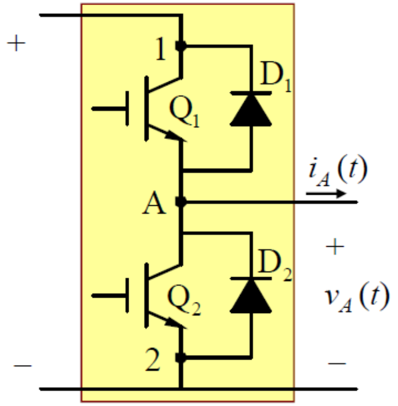
Bi-directional and uni-directional Power Flow



For bi-directional i_A

For uni-directional i_A
uni-directional power flow

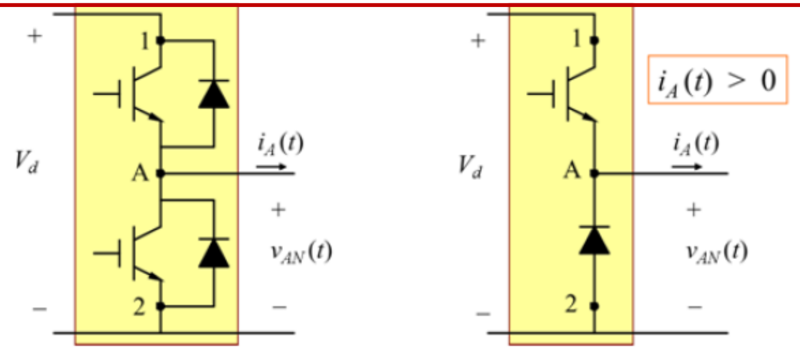
- Numerous applications of dc-dc converters require only uni-directional power flow; e.g., power supplies for electronics



Which devices conduct?

	$q_A = 1$	$q_A = 0$
$i_A > 0$		
$i_A < 0$		

- Combination of a controllable switch (MOSFET or IGBT) and diode for **each** SPST can support current in both directions
  - $i_A(t)$ can be bi-directional
  - $v_A(t)$ is unipolar (positive or zero only)
  - Power flow is bi-directional

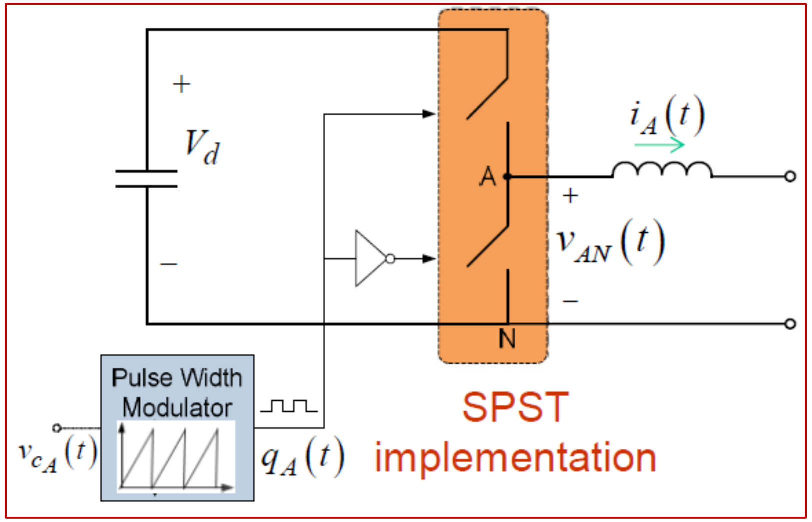


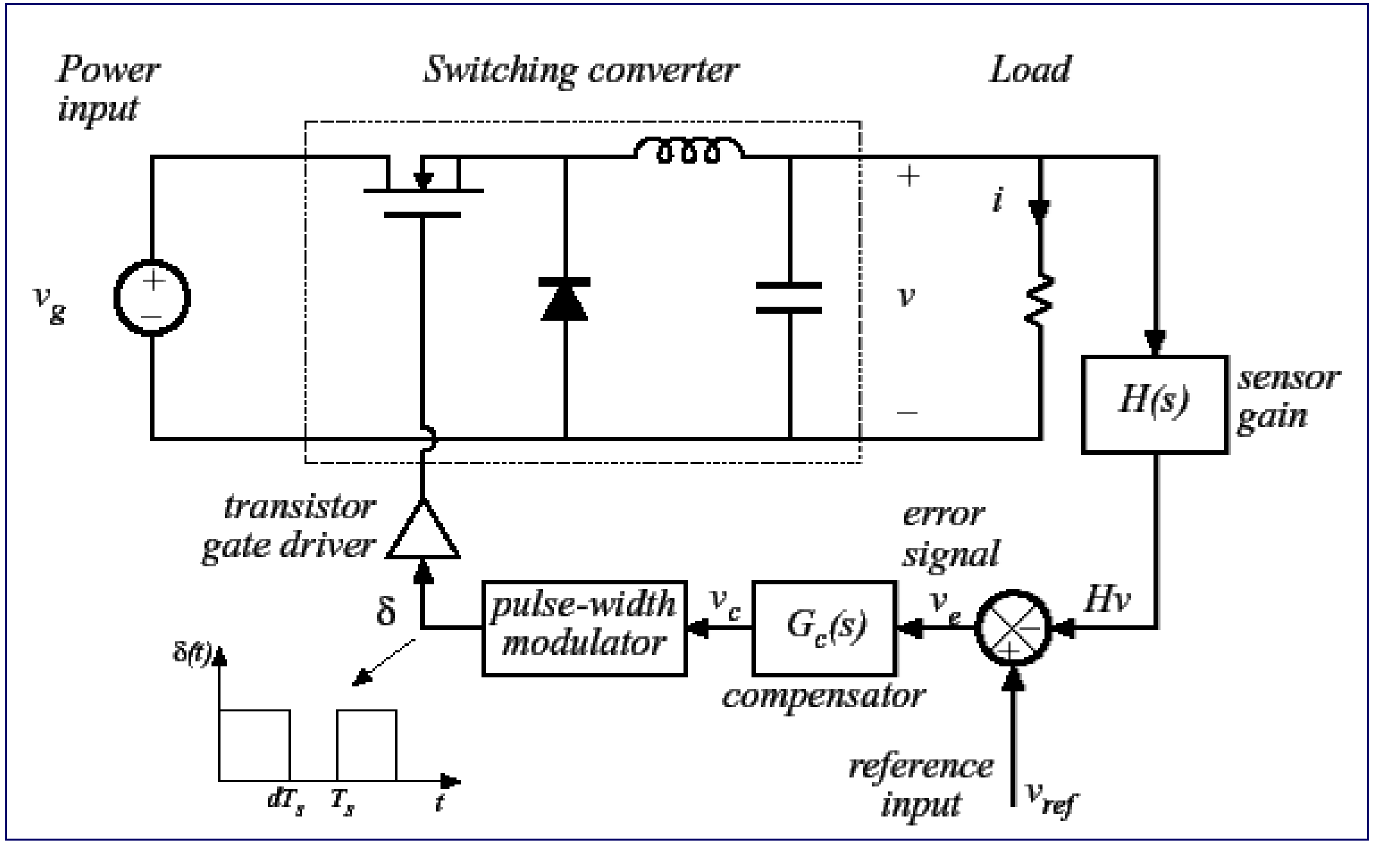
For bi-directional i_A

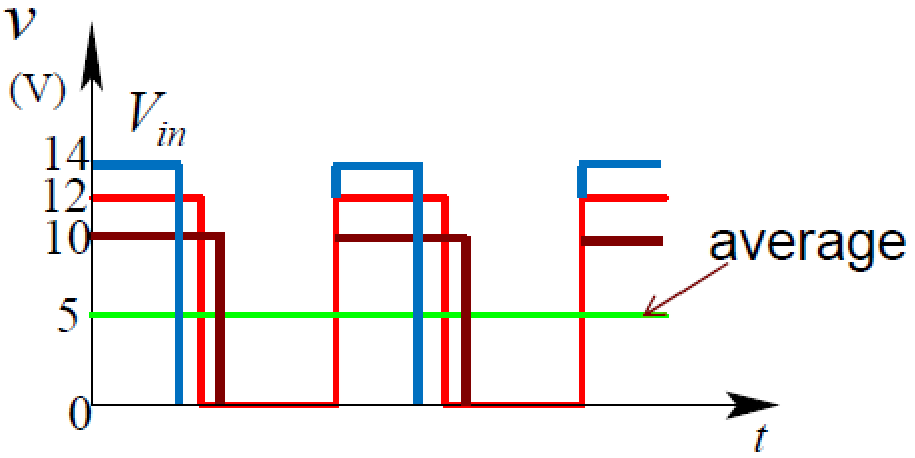
For uni-directional i_A

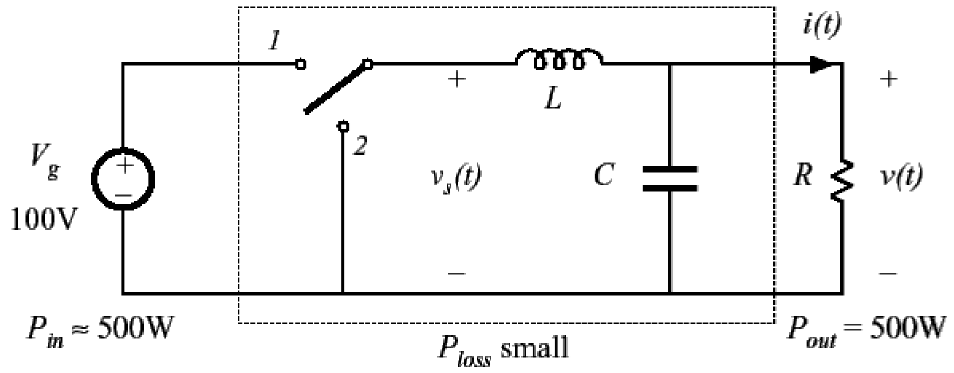
- Controllable switch - Power MOSFETs or IGBTs
  - turn-on and turn-off by controlling the gate drive signal
- Power diode – ultrafast diodes
  - turn-on (forward bias) and turn-off (reverse bias) by circuit operating conditions

Addition of control system for regulation of output voltage

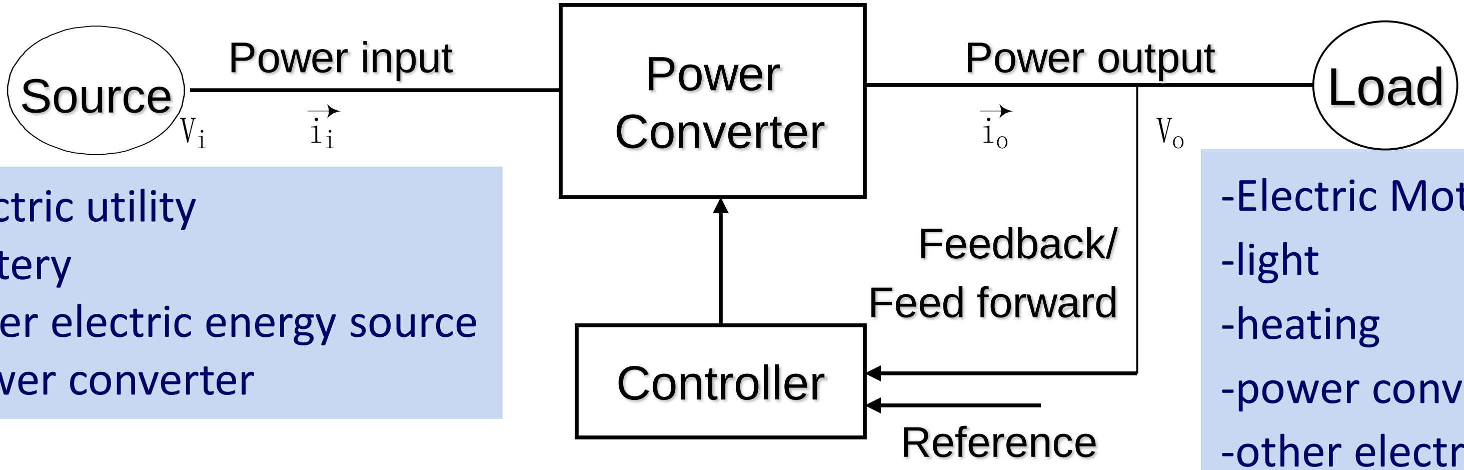








Typical power sources and loads for a power electronic system



-Electric utility
-battery
-other electric energy source
-power converter

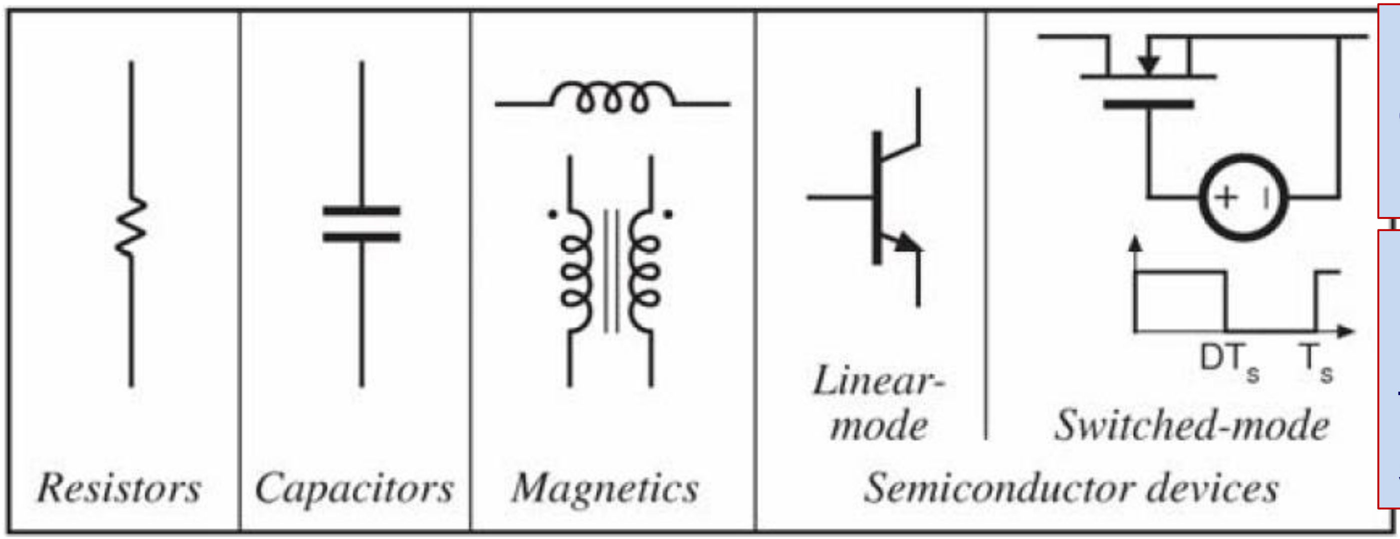
-Electric Motor
-light
-heating
-power converter
-other electric or electronic equipment

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.

The main aims in modern PE systems are to convert electrical energy from one form to another, i.e. from the source to load with:

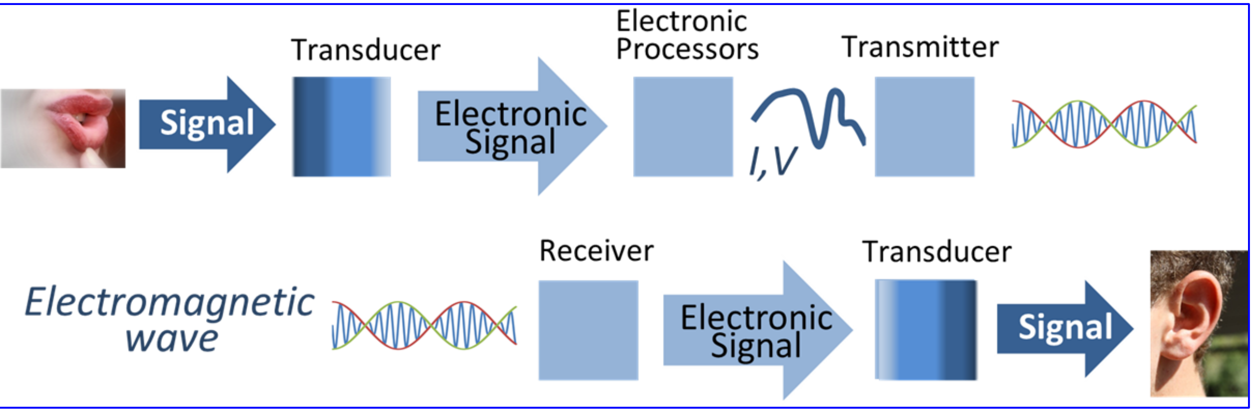
– highest efficiency,
– highest availability
– highest reliability
– lowest cost,
– smallest size
– least weight.

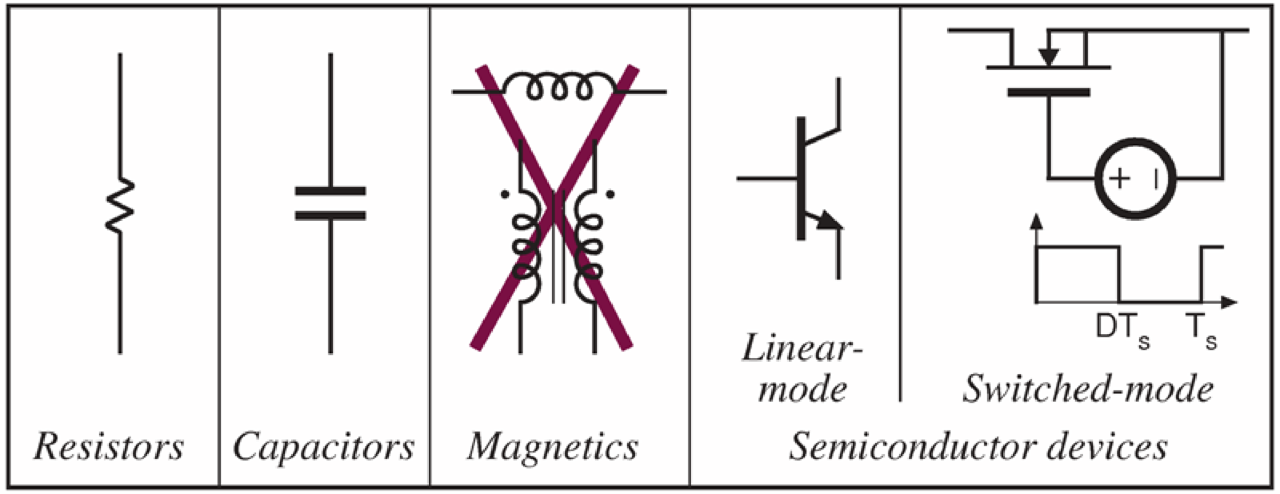
Devices available to the circuit designer



In linear region, the transistor operates as an adjustable resistor, resulting in a low energy efficiency.

In ***signal processing***, magnetics is avoided. It is difficult to include magnetic elements in to the integrated circuits as they are large in size compared to capacitors and inductors.





Signal processing: avoid magnetics

In most electronic circuits for signal processing, efficiency is not the main concern.

Power Processing

High efficiency is essential

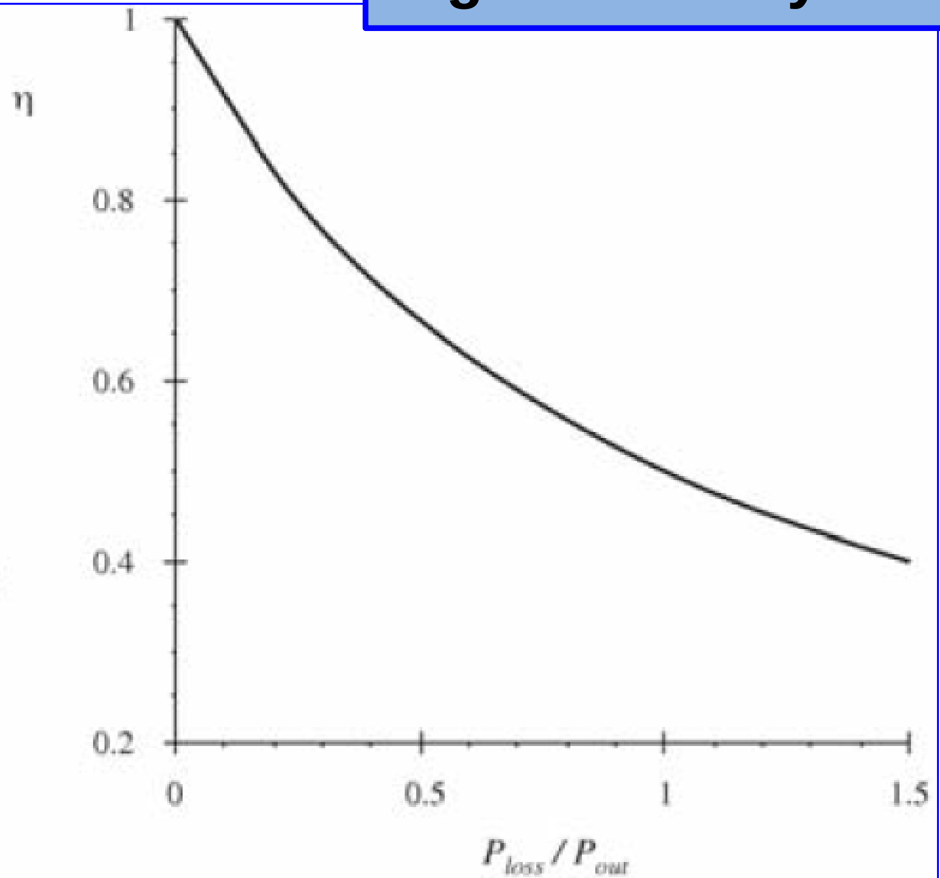
$$\eta = \frac{P_{out}}{P_{in}}$$

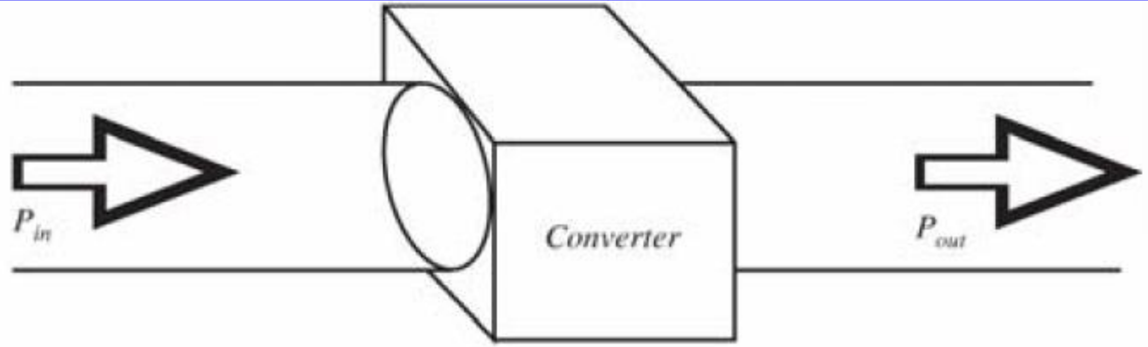
$$P_{loss} = P_{in} - P_{out} = P_{out}\left(\frac{1}{\eta} - 1\right)$$

High efficiency leads to low power loss within converter

Small size and reliable operation is then feasible

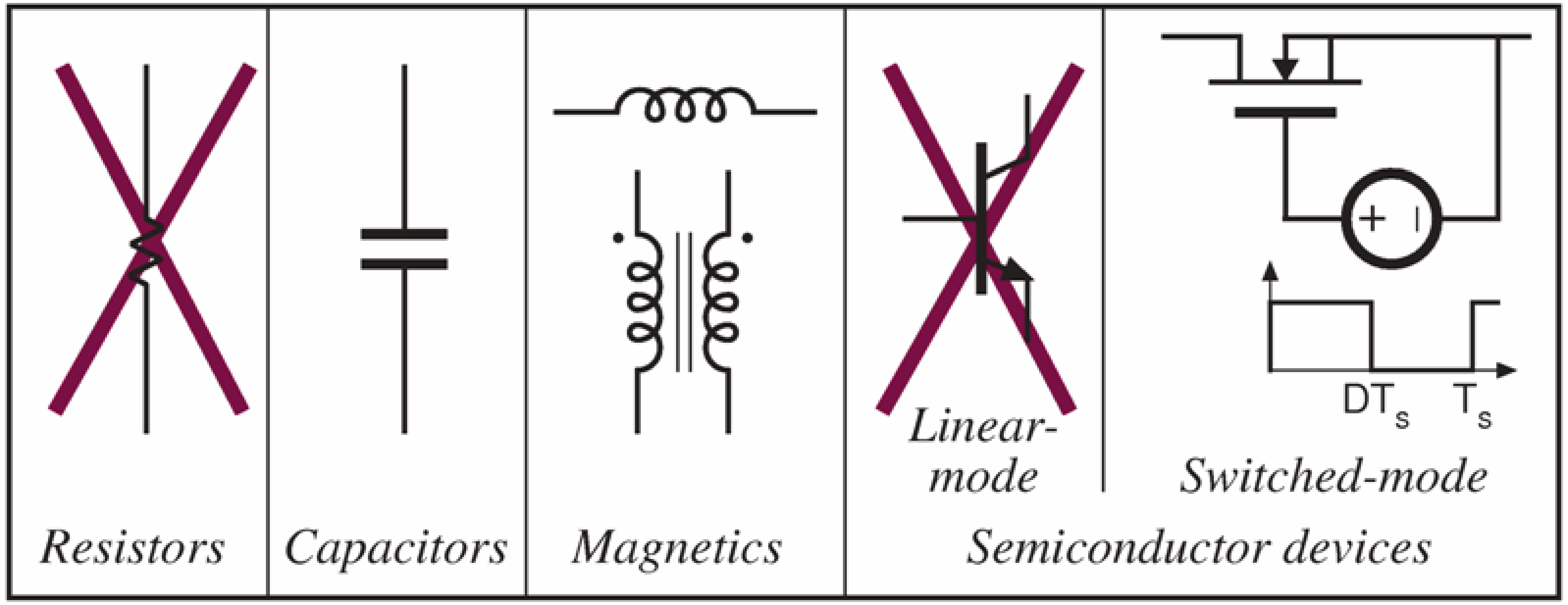
Efficiency is a good measure of converter performance





A goal of current converter technology is to construct converters of small size and weight, which process substantial power at high efficiency

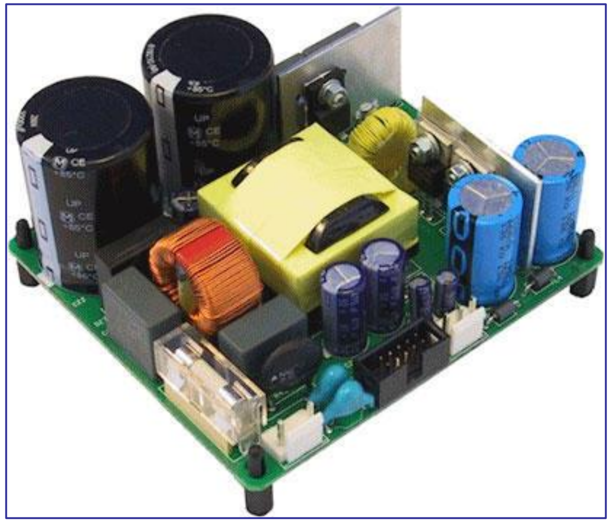
Power Processing



Power processing: avoid lossy elements

In power converters, efficiency is the main concern. Power circuits consist of capacitors, magnetic elements and transistors in switched mode. Resistors and power switches in linear mode are not used in power circuits due to significant losses generated by current through these components which decreases the efficiency and causes thermal problems.

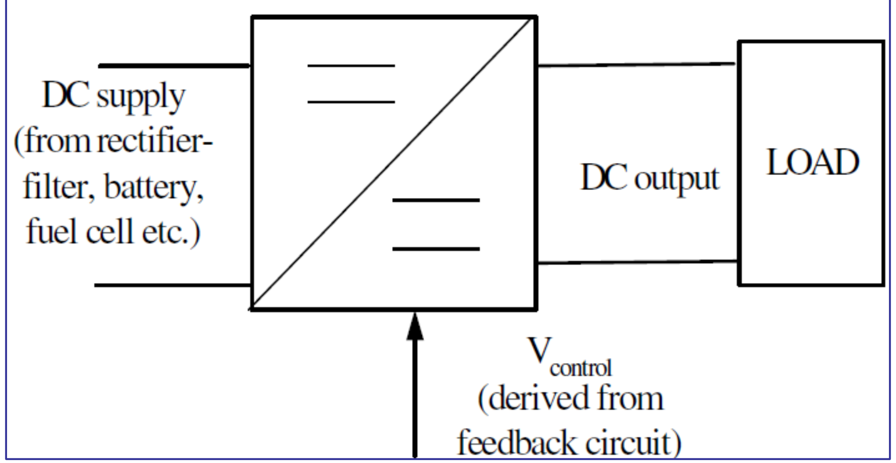
DC to DC CONVERTER (CHOPPER)



DEFINITION:
Converting the unregulated DC input to a controlled DC output with a desired voltage level.

DC equivalent to an ac transformer without a continuously variable turns-ratio.

General block diagram:



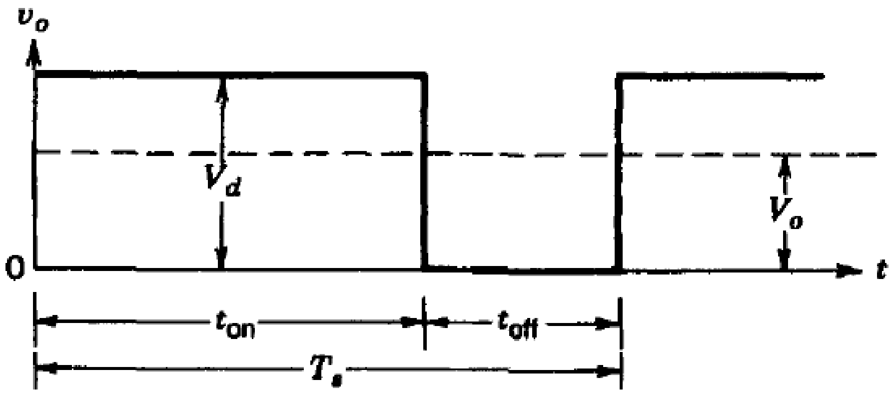
Like a transformer, it can be used to step down or step-up a dc voltage source.

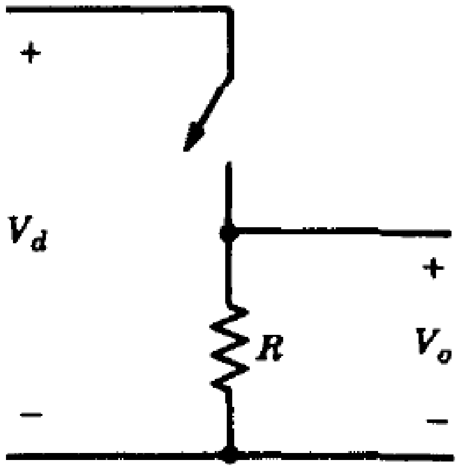
These can be realized using MOSFETs, IGBTs, etc.

- **APPLICATIONS:**

– Switched-mode power supply (SMPS), DC motor control, battery chargers

CONTROL OF dc-dc CONVERTERS





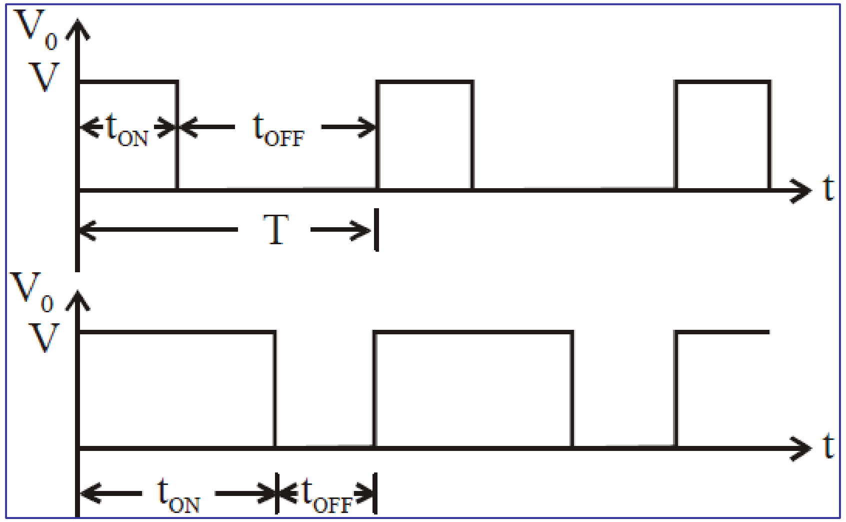
METHODS OF OUTPUT VOLTAGE CONTROL

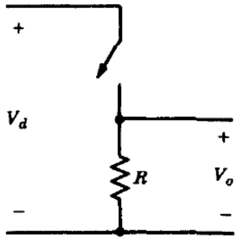
- **Pulse width modulation control or constant frequency operation.**
- **Variable frequency control.**

CONTROL OF dc-dc CONVERTERS

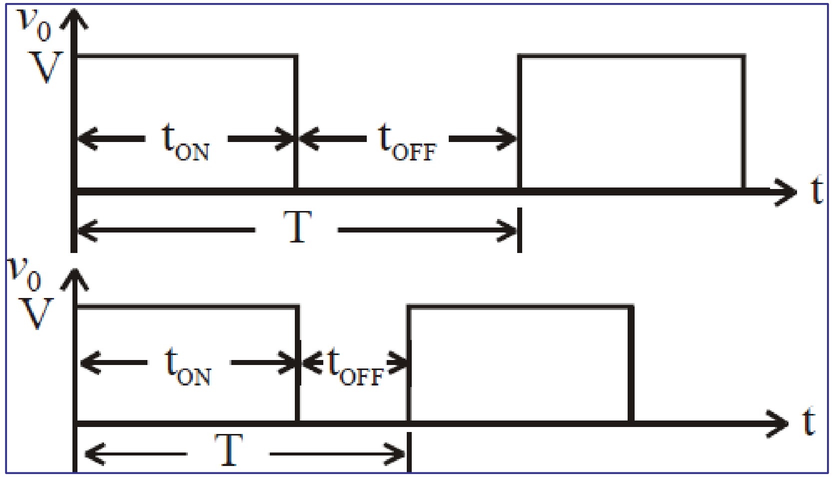
PULSE WIDTH MODULATION (PWM):

- Pulse width (t_{on}) of the output waveform is varied keeping chopping frequency '*f*' and hence chopping period 'T' constant.
- Therefore output voltage is varied by varying t_{on}.





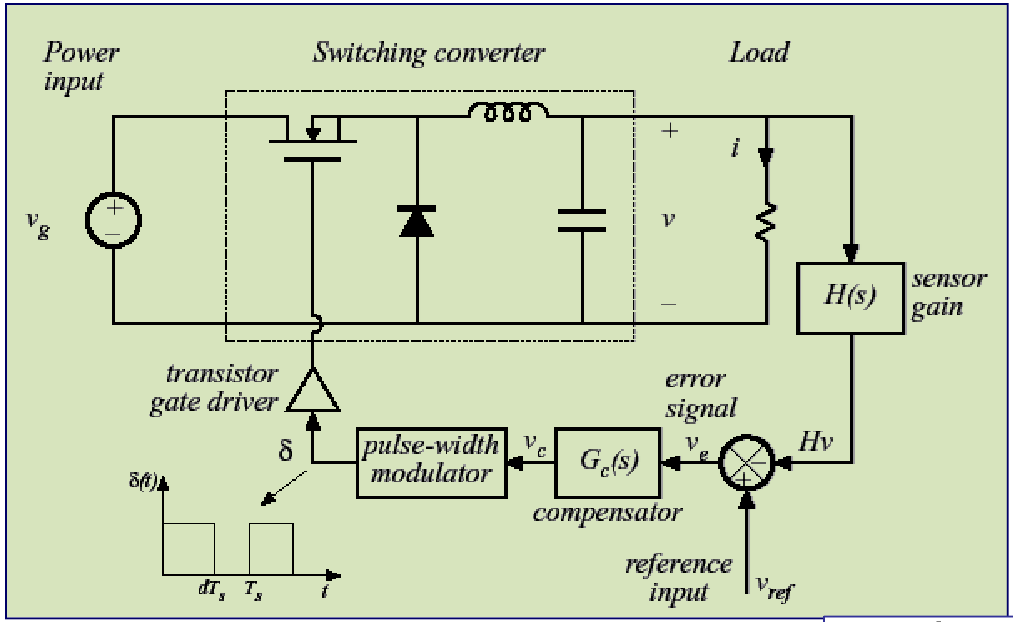
- **VARIABLE FREQUENCY CONTROL**
- f is varied keeping either t_{on} or t_{off} constant.
- Also known as frequency modulation.
- To obtain full output voltage range frequency has to be varied over a wide range.
- This method produces harmonics in the output and for large t_{off} load current may become discontinuous.

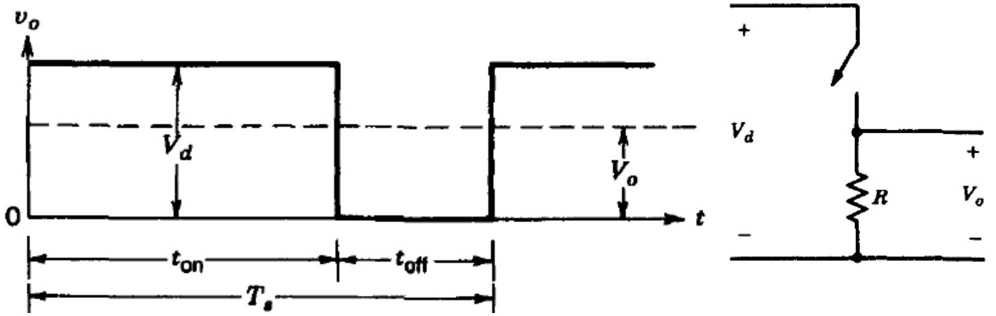


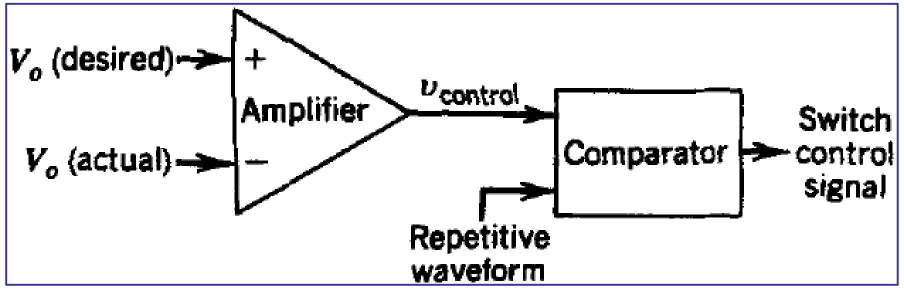
In another control method, both f and t_{on} are varied.

Variation in the switching frequency makes it difficult to filter the ripple components in the input and the output waveforms of the converter.

CONTROL OF dc-dc CONVERTERS







PWM switching:

- the switch control signal is generated by comparing a signal-level control voltage *vcontrol*, with a repetitive waveform.
- *vcontrol* is obtained by amplifying the error.
- The frequency of the repetitive waveform with a constant peak establishes *f*.
- *f* is chosen to be in a few kilohertz to a few hundred kilohertz range.

$$D = \frac{t_{on}}{T_s} = \frac{v_{control}}{\hat{V}_{st}}$$