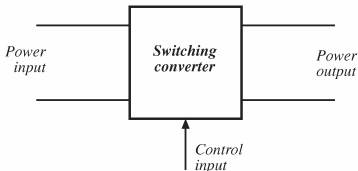

Fundamentals of Power Electronics

Second edition

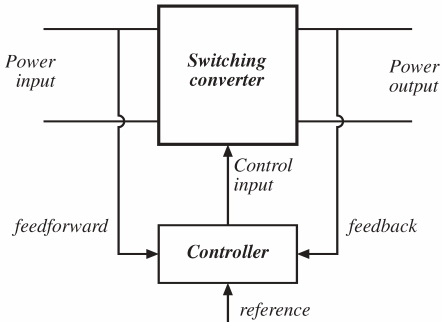
Robert W. Erickson
Dragan Maksimovic
University of Colorado, Boulder

1.1 Introduction to Power Processing



- | | |
|-------------------------------|--|
| <i>Dc-dc conversion:</i> | Change and control voltage magnitude |
| <i>Ac-dc rectification:</i> | Possibly control dc voltage, ac current |
| <i>Dc-ac inversion:</i> | Produce sinusoid of controllable magnitude and frequency |
| <i>Ac-ac cycloconversion:</i> | Change and control voltage magnitude and frequency |

Control is invariably required

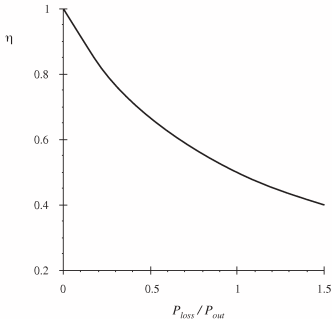


High efficiency is essential

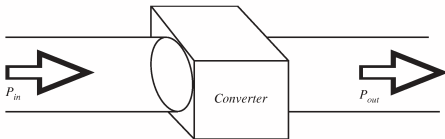
$$\eta = \frac{P_{out}}{P_{in}}$$

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

- 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

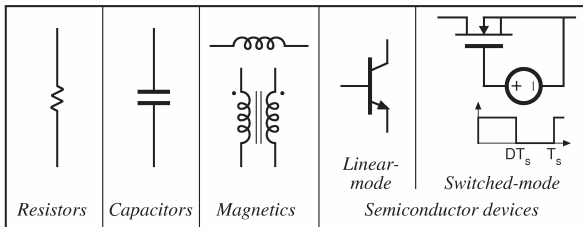


A high-efficiency converter

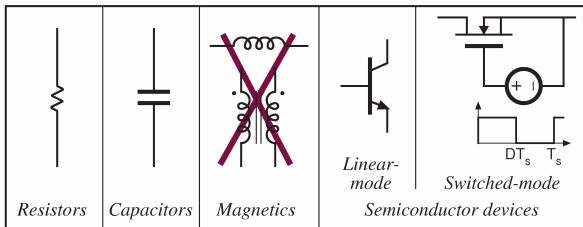


A goal of current converter technology is to construct converters of small size and weight, which process substantial power at high efficiency

Devices available to the circuit designer

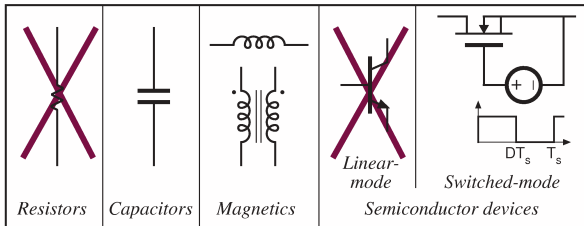


Devices available to the circuit designer



Signal processing: avoid magnetics

Devices available to the circuit designer



Power processing: avoid lossy elements

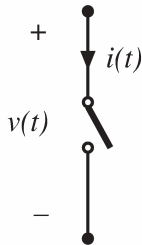
Power loss in an ideal switch

Switch closed: $v(t) = 0$

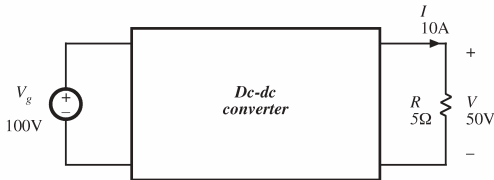
Switch open: $i(t) = 0$

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

Ideal switch consumes zero power



A simple dc-dc converter example



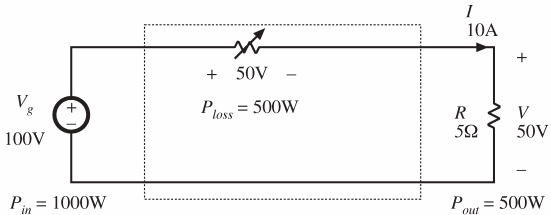
Input source: 100V

Output load: 50V, 10A, 500W

How can this converter be realized?

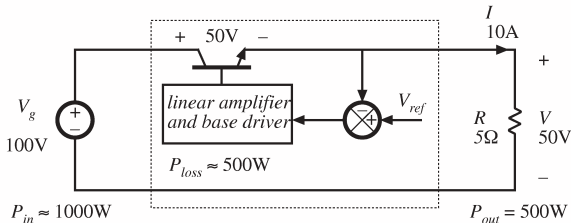
Dissipative realization

Resistive voltage divider

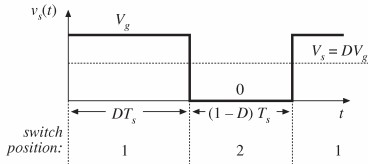
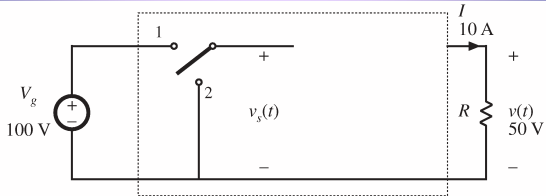


Dissipative realization

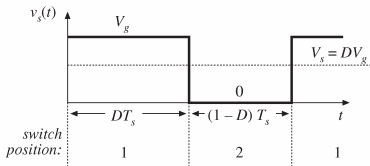
Series pass regulator: transistor operates in active region



Use of a SPDT switch



The switch changes the dc voltage level



D = switch duty cycle
 $0 \leq D \leq 1$

T_s = switching period

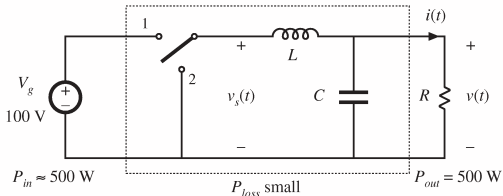
f_s = switching frequency
 $= 1 / T_s$

DC component of $v_s(t)$ = average value:

$$V_s = \frac{1}{T_s} \int_0^{T_s} v_s(t) dt = DV_g$$

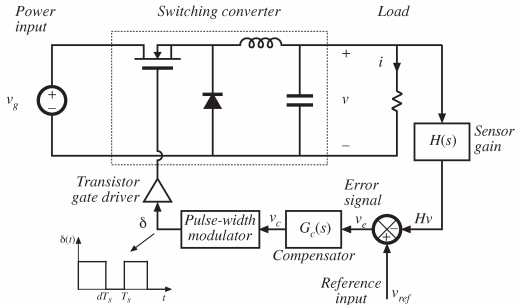
Addition of low pass filter

Addition of (ideally lossless) L - C low-pass filter, for removal of switching harmonics:

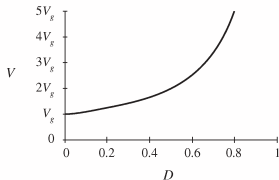
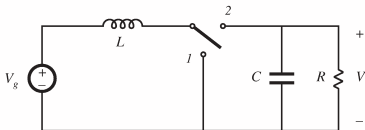


- Choose filter cutoff frequency f_0 much smaller than switching frequency f_s
- This circuit is known as the “buck converter”

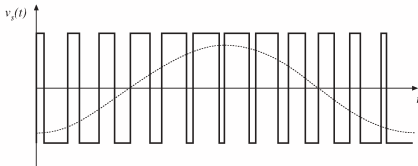
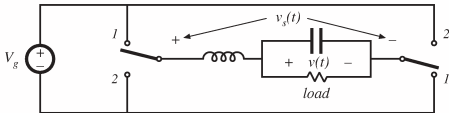
Addition of control system for regulation of output voltage



The boost converter



A single-phase inverter



“H-bridge”

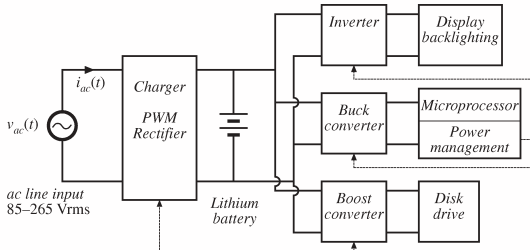
Modulate switch duty cycles to obtain sinusoidal low-frequency component

1.2 Several applications of power electronics

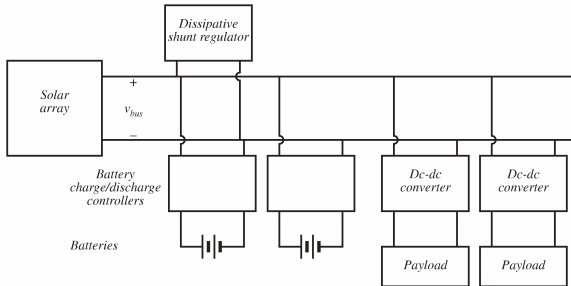
Power levels encountered in high-efficiency converters

- less than 1 W in battery-operated portable equipment
- tens, hundreds, or thousands of watts in power supplies for computers or office equipment
- kW to MW in variable-speed motor drives
- 1000 MW in rectifiers and inverters for utility dc transmission lines

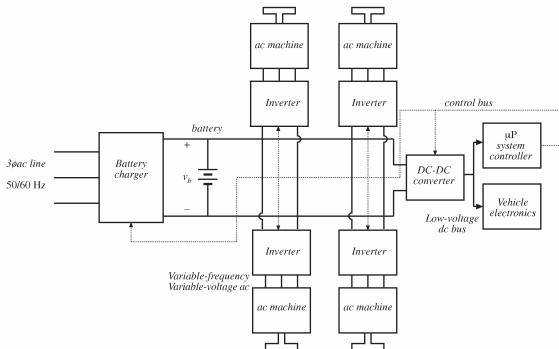
A laptop computer power supply system



Power system of an earth-orbiting spacecraft



An electric vehicle power and drive system



1.3 Elements of power electronics

Power electronics incorporates concepts from the fields of

- analog circuits
- electronic devices
- control systems
- power systems
- magnetics
- electric machines
- numerical simulation