1.1 Introduction to Power Processing
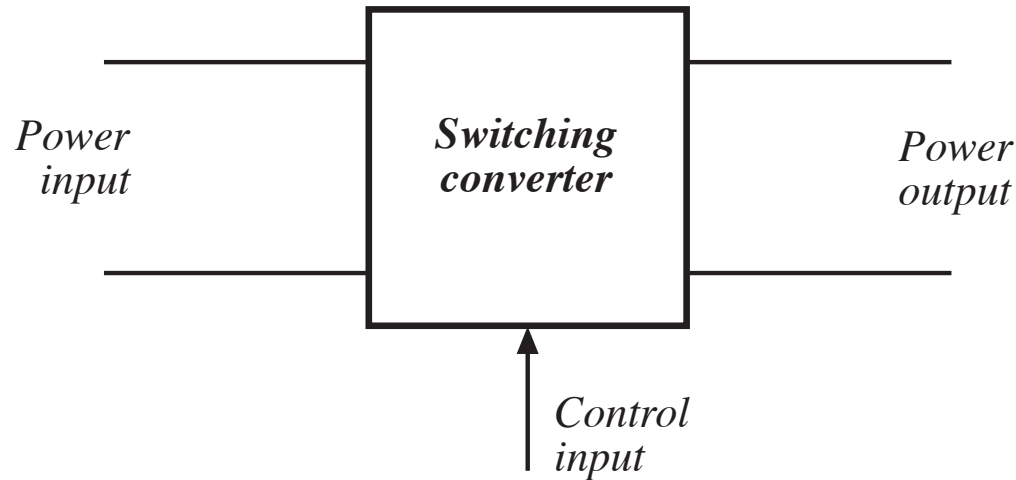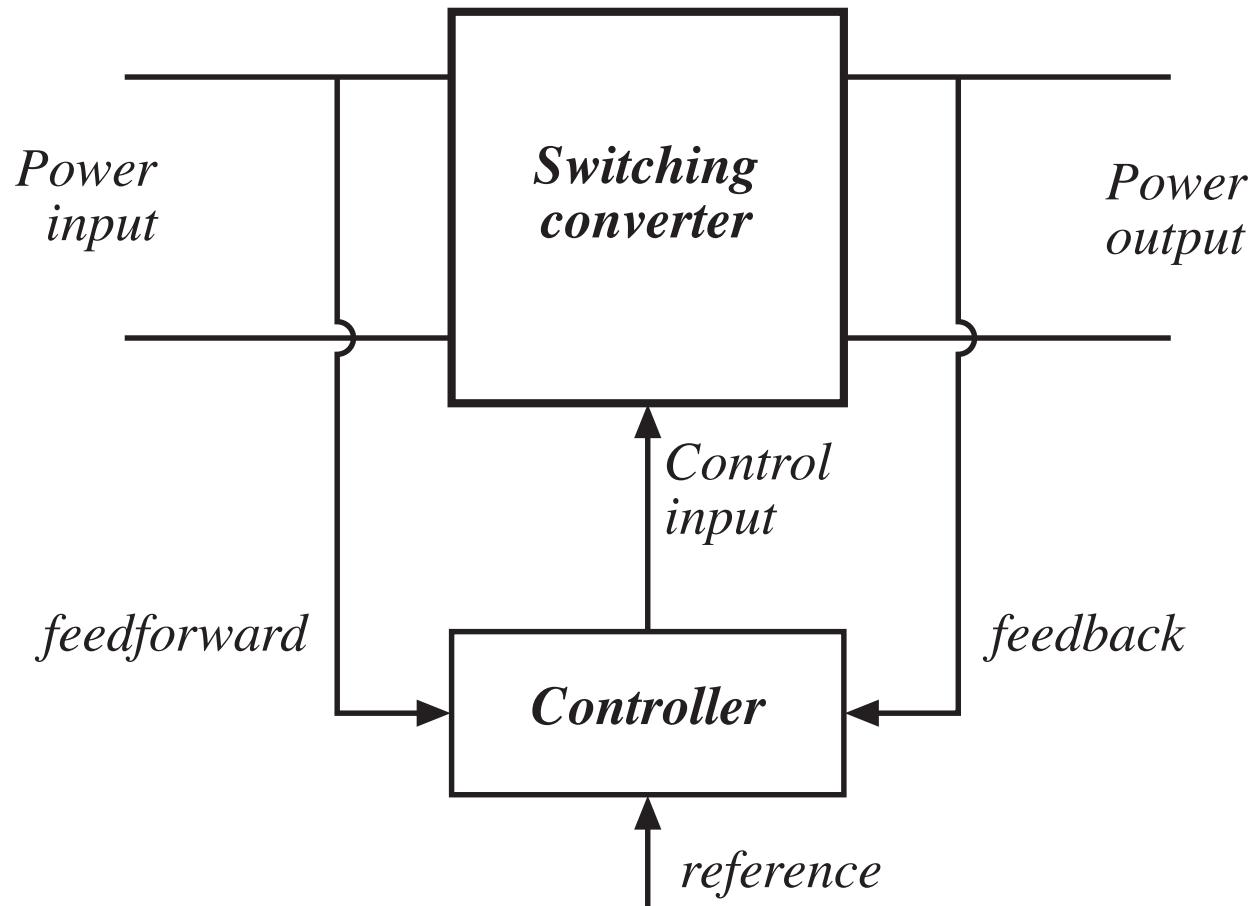

Dc-dc conversion: Change and control voltage magnitude

Ac-dc rectification: Possibly control dc voltage, ac current

Dc-ac inversion: Produce sinusoid of controllable
                         magnitude and frequency

Ac-ac cycloconversion: Change and control voltage magnitude
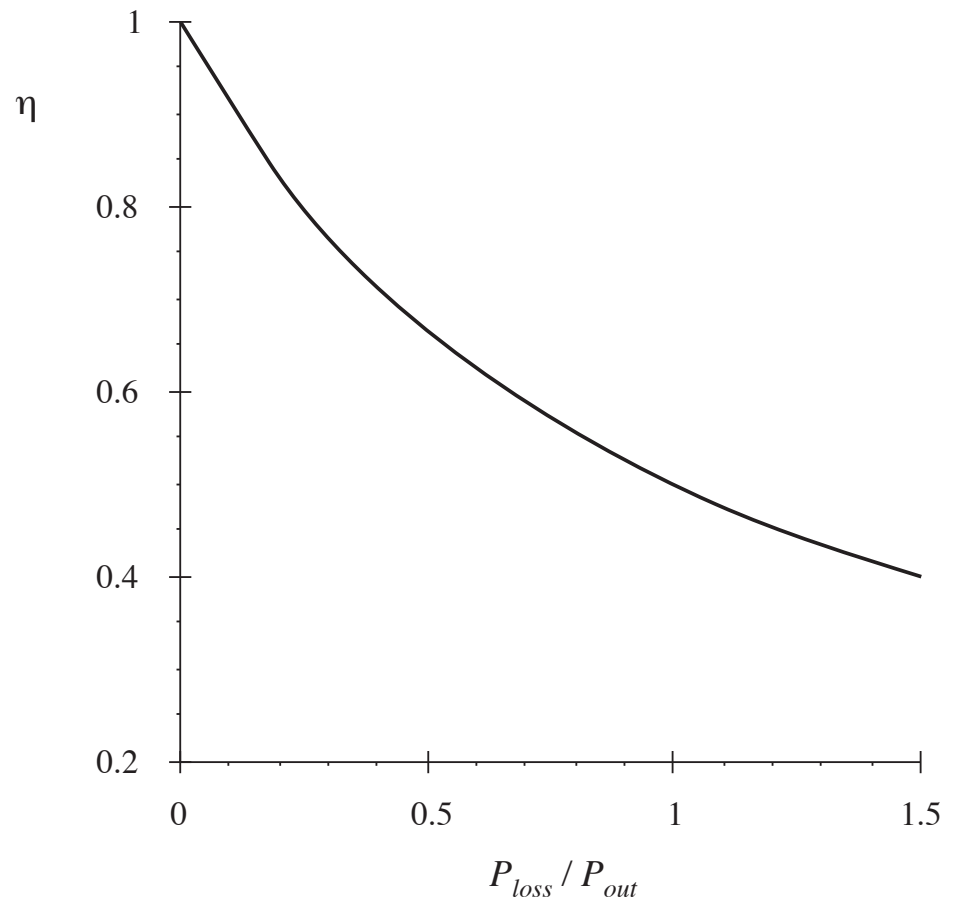   and frequency

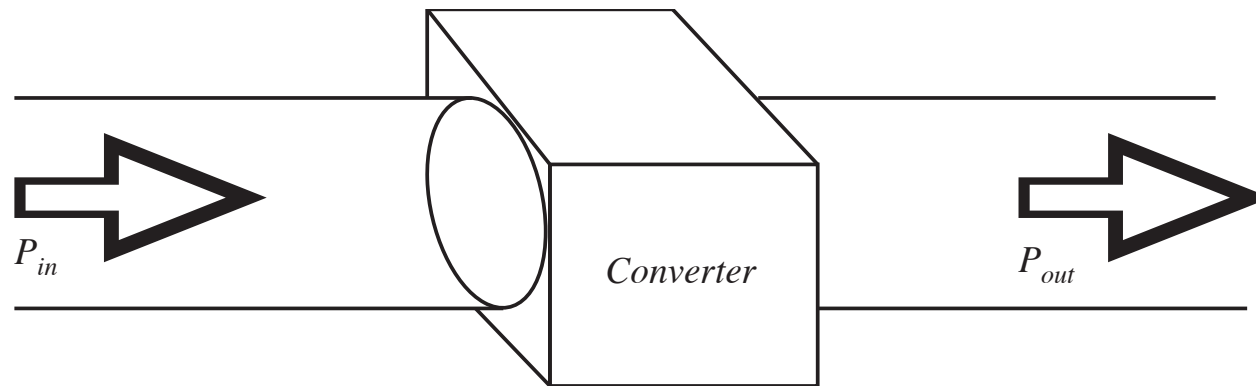# Control is invariably required

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

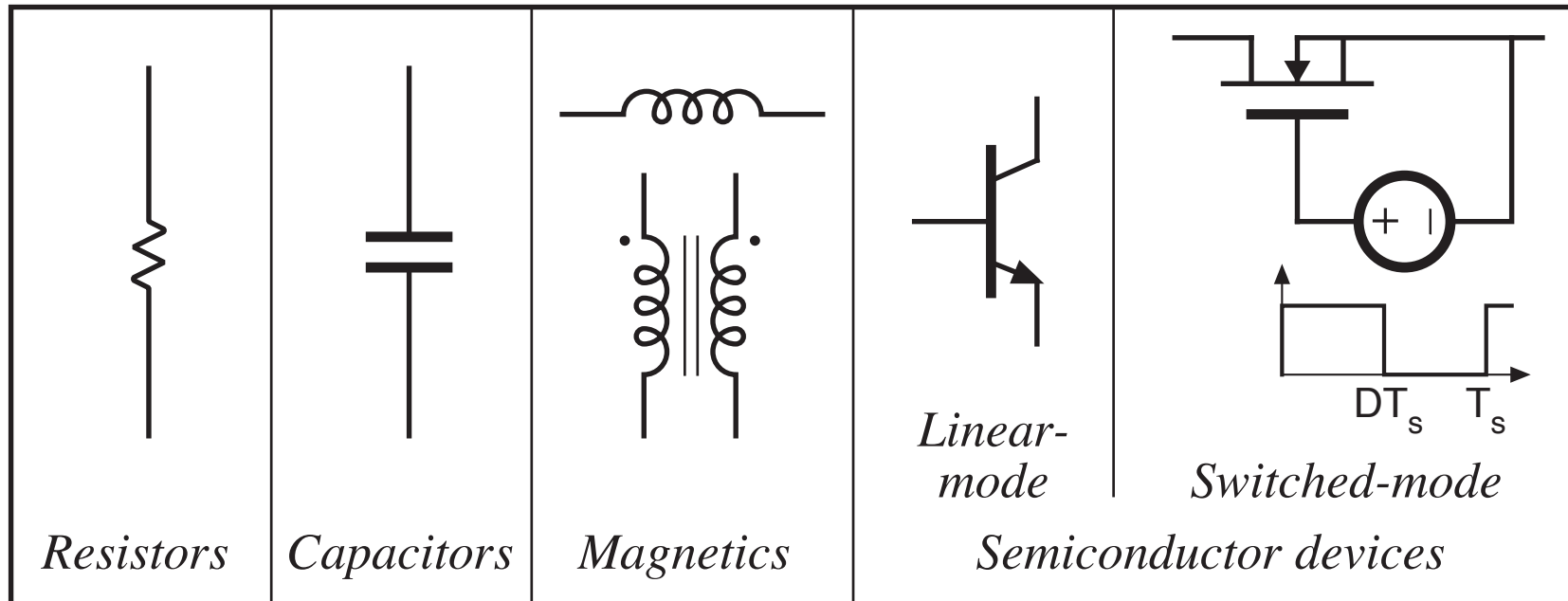Efficiency is a good measure of converter performance
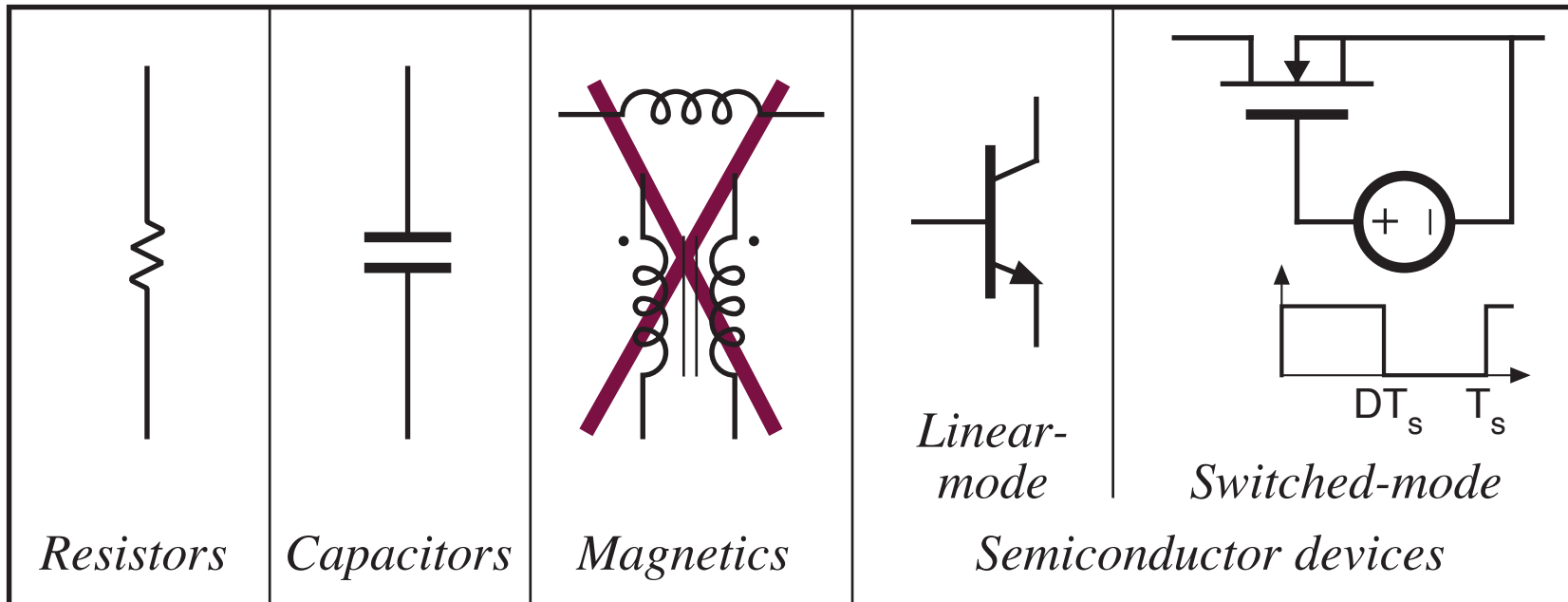
A high-efficiency converter

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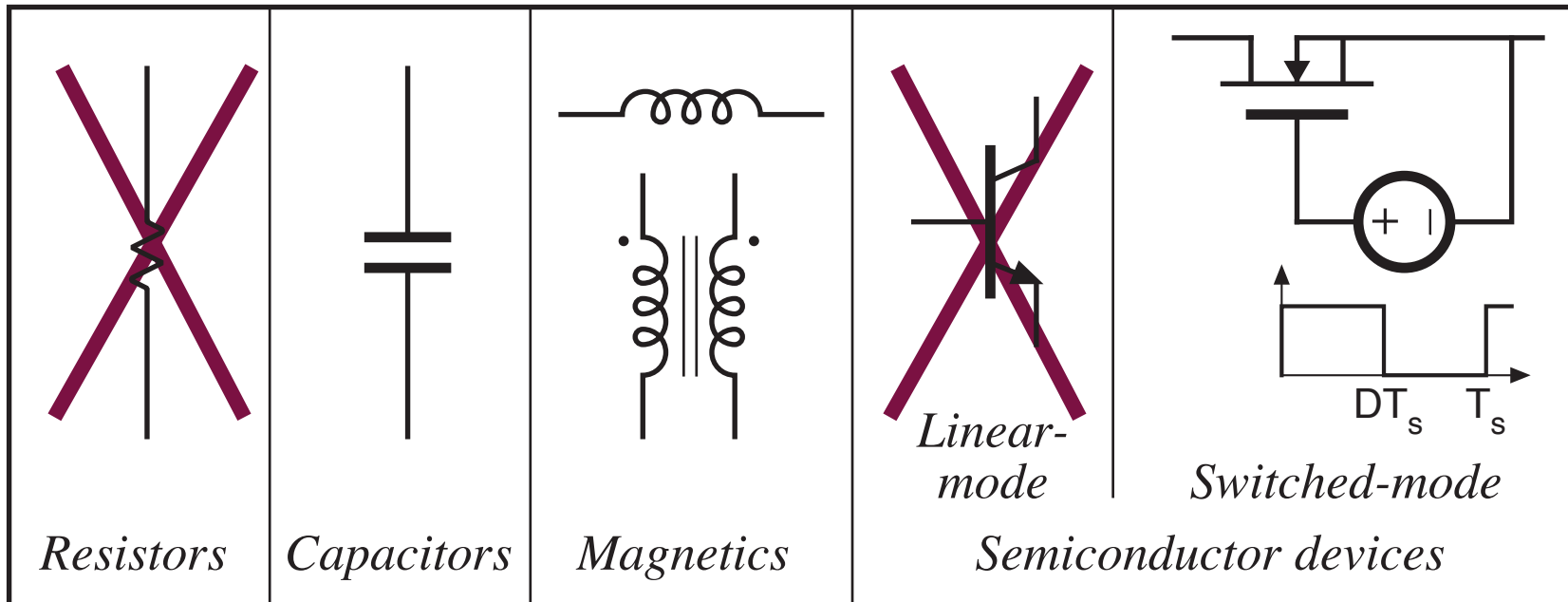
Devices available to the circuit designer

Linear-mode   *Switched-mode*

DT_s T_s

Resistors | *Capacitors* | *Magnetics* | *Semiconductor devices*

Devices available to the circuit designer

Resistors	Capacitors	Magnetics	Linear-mode	Switched-mode
			Semiconductor devices	

Signal processing: avoid magnetics

Devices available to the circuit designer

Resistors	Capacitors	Magnetics	Semiconductor devices
			Linear-mode · *Switched-mode*

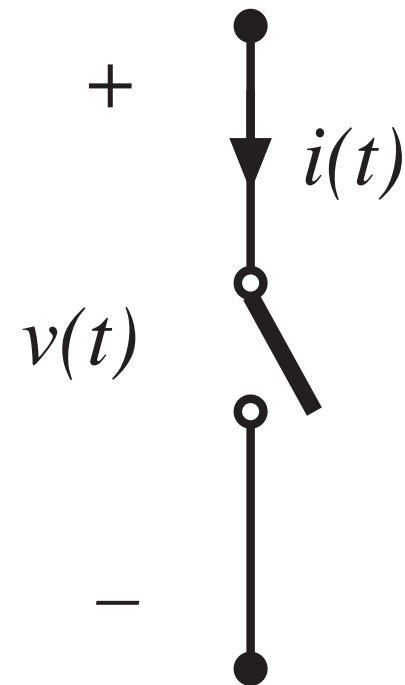**Power processing: avoid lossy elements**

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

$+$

$i(t)$
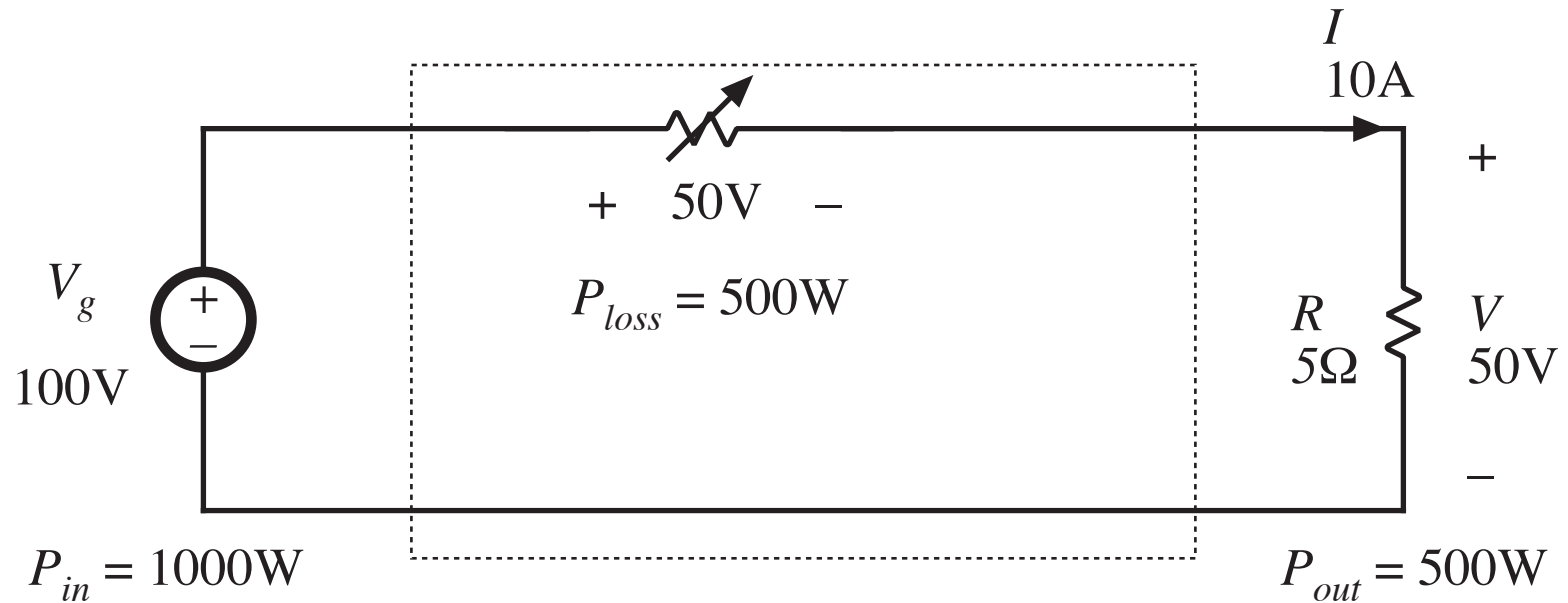
$v(t)$

$-$

A simple dc-dc converter example
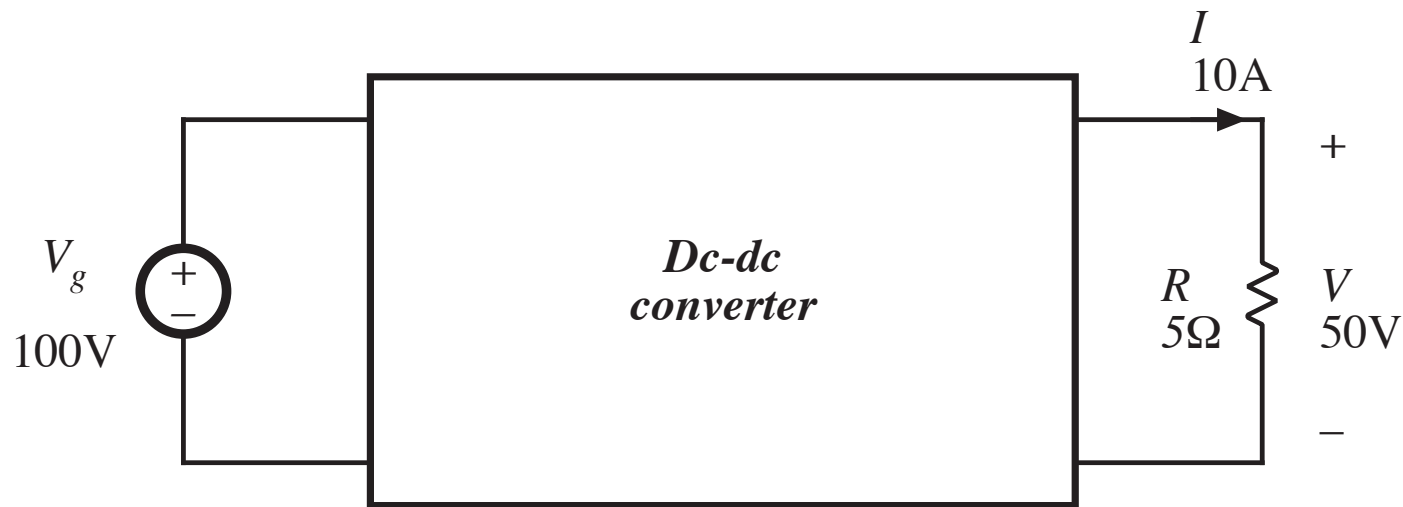
Input source: 100V

Output load: 50V, 10A, 500W

How can this converter be realized?

Dissipative realization
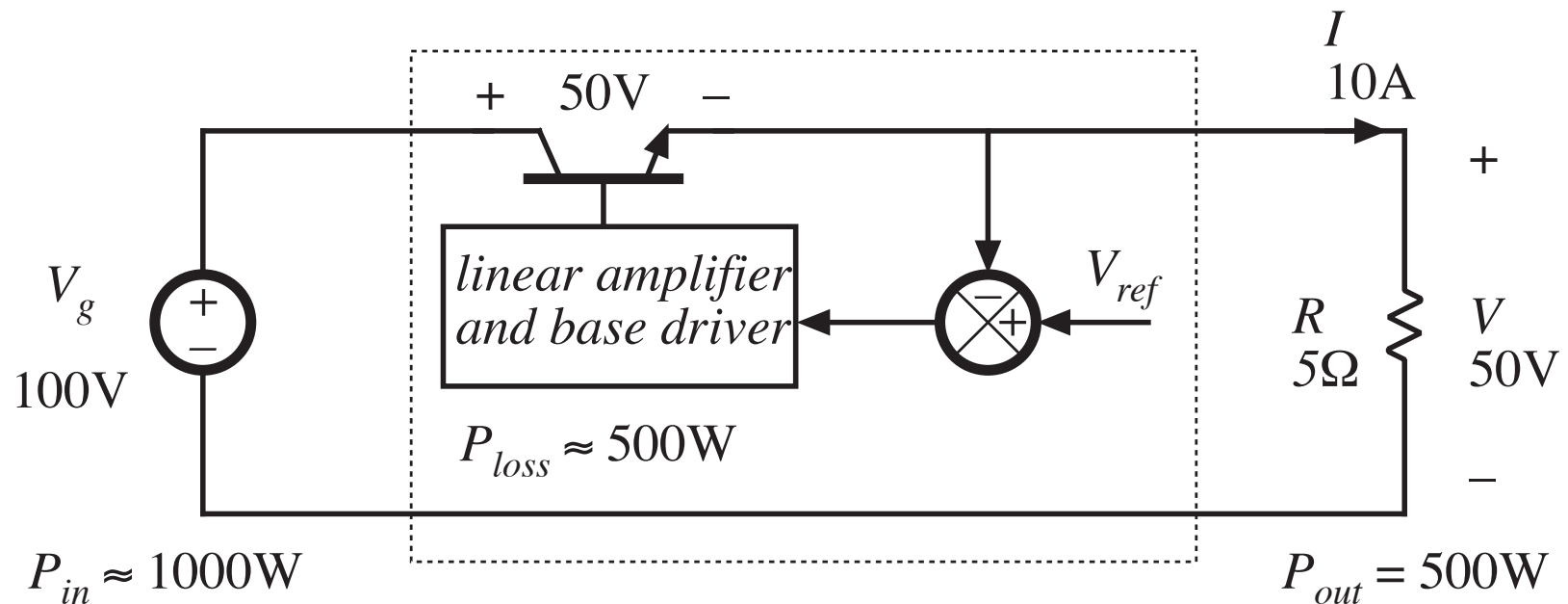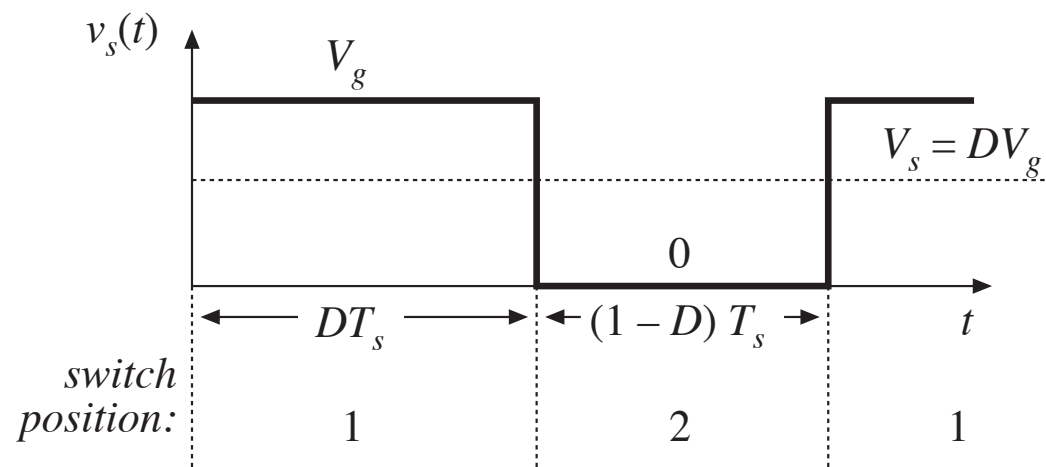
Resistive voltage divider

I
10A

$+$

$+$ 50V $-$

V_g

$P_{loss} = 500$W

R
5Ω

V
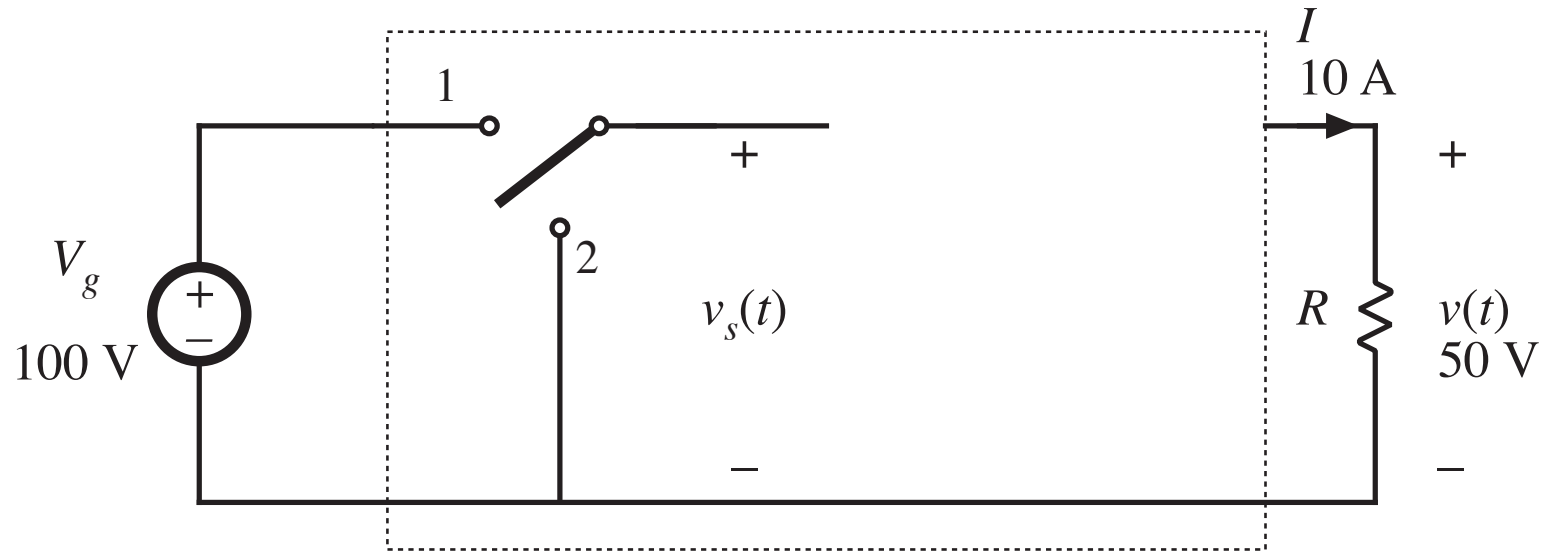50V

100V

$-$

$P_{in} = 1000$W

$P_{out} = 500$W
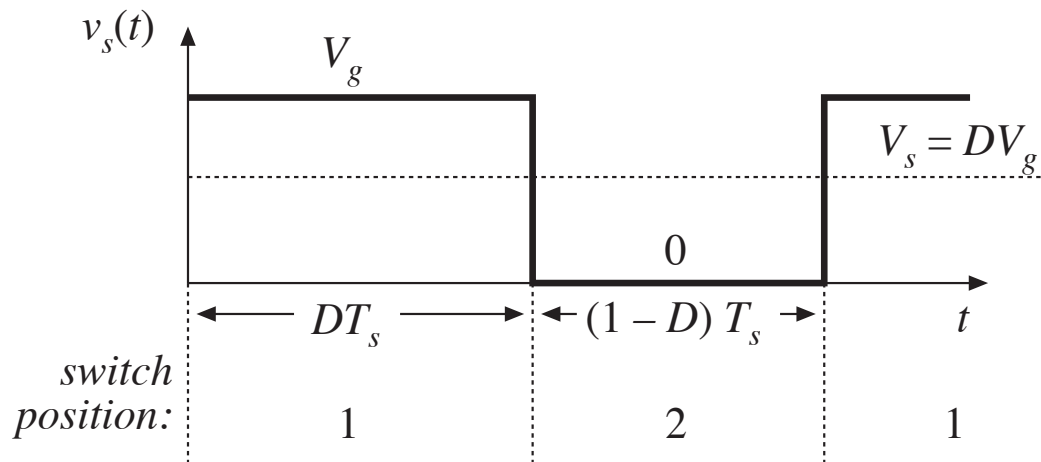
Dissipative realization

Series pass regulator: transistor operates in
active region

Use of a SPDT switch

The switch changes the dc voltage level

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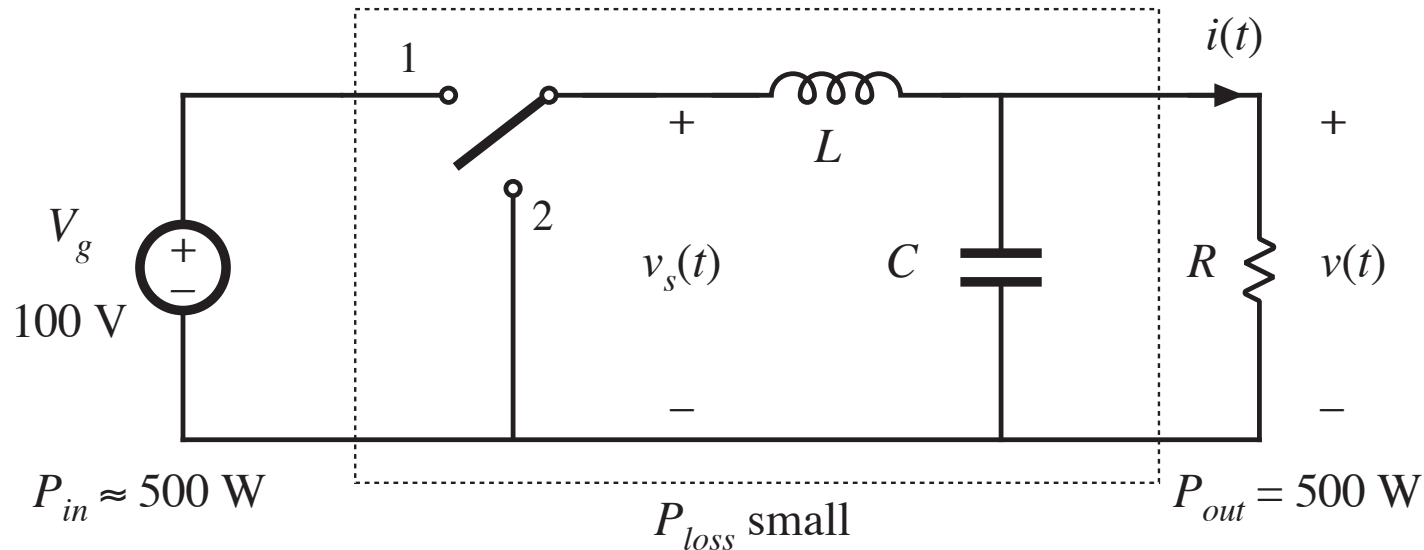
$$0 \leq D \leq 1$$

T_s = switching period

f_s = switching frequency
$$= 1 / T_s$$

DC component of $v_s(t)$ = average value:
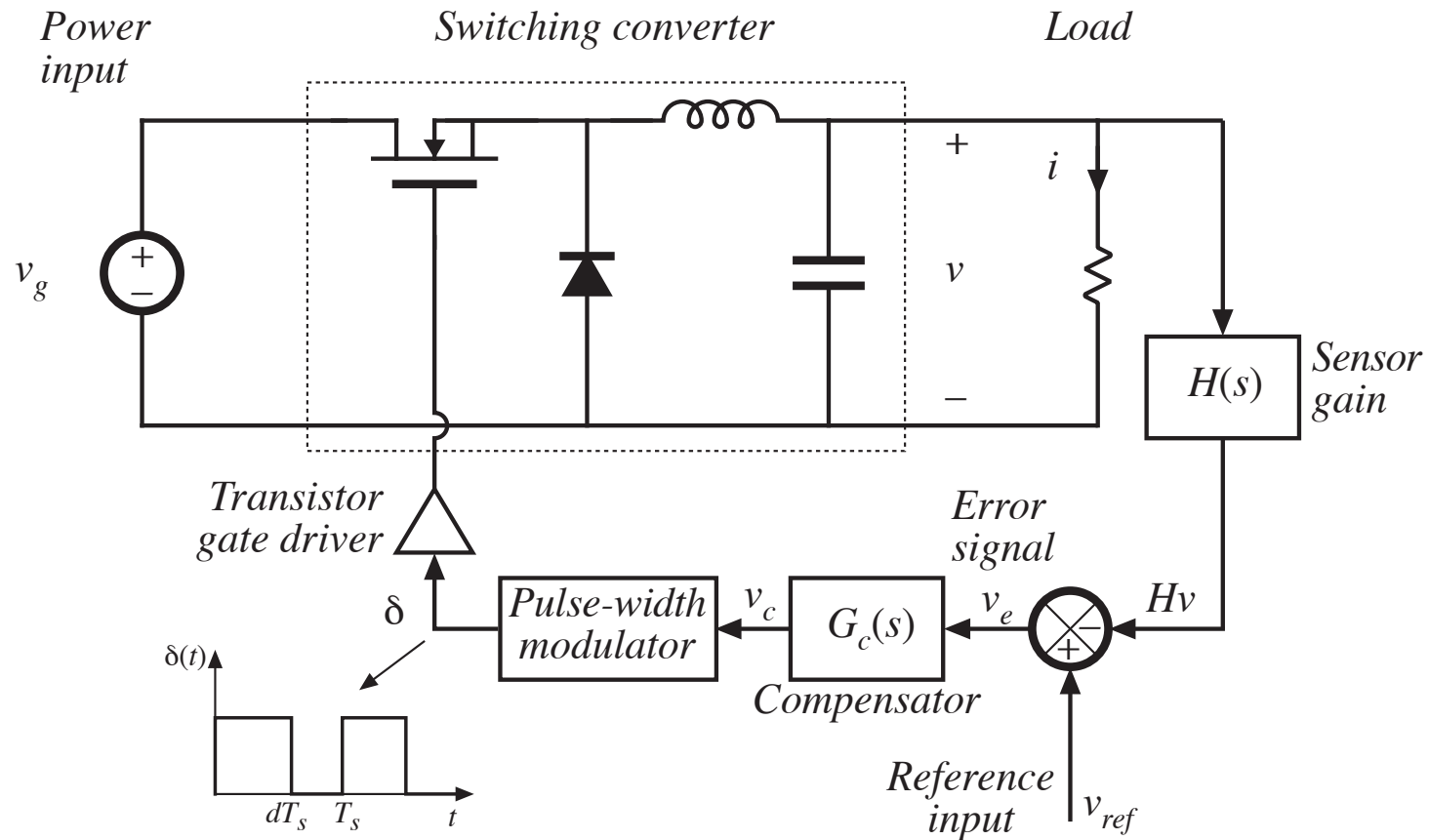
$$V_s = \frac{1}{T_s} \int_0^{T_s} v_s(t)\, dt = DV_g$$

Addition of low pass filter

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

$P_{in} \approx 500 \text{ W}$
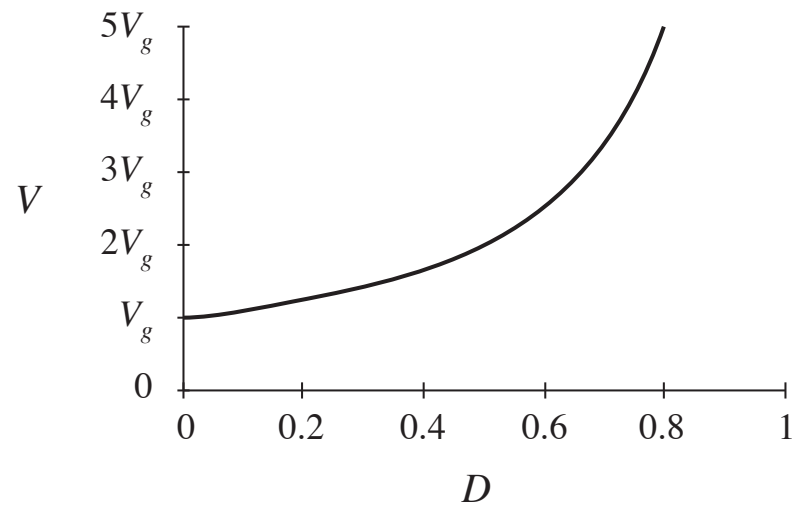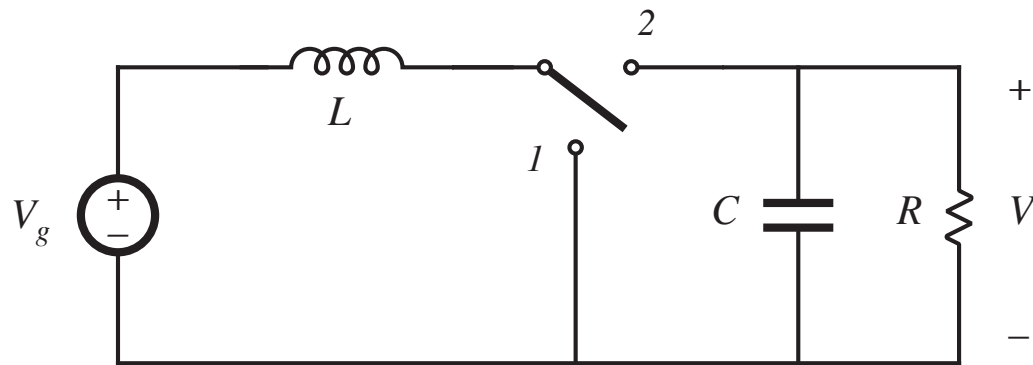
P_{loss} small

$P_{out} = 500 \text{ W}$

- Choose filter cutoff frequency f_0 much smaller than switching frequency f_s

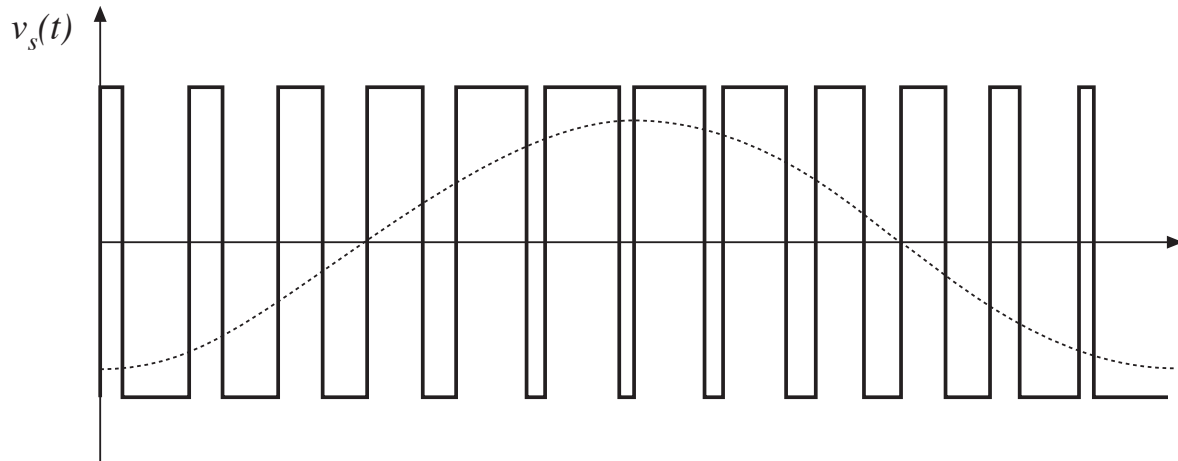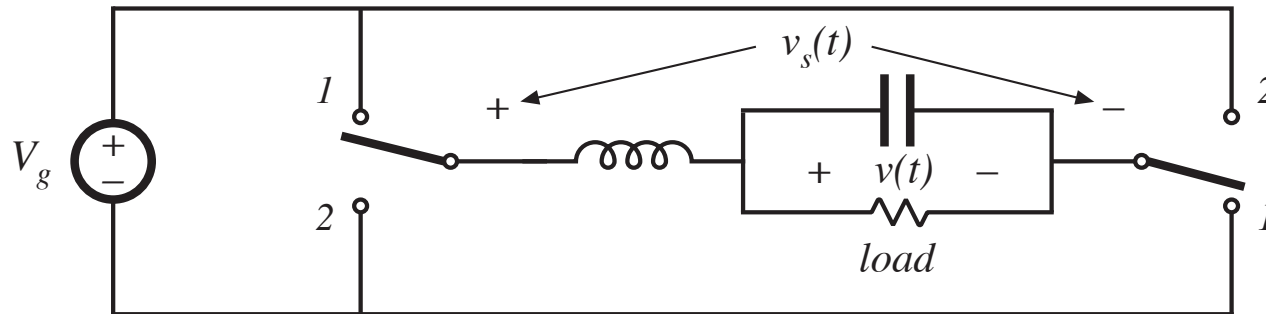- This circuit is known as the "buck converter"

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

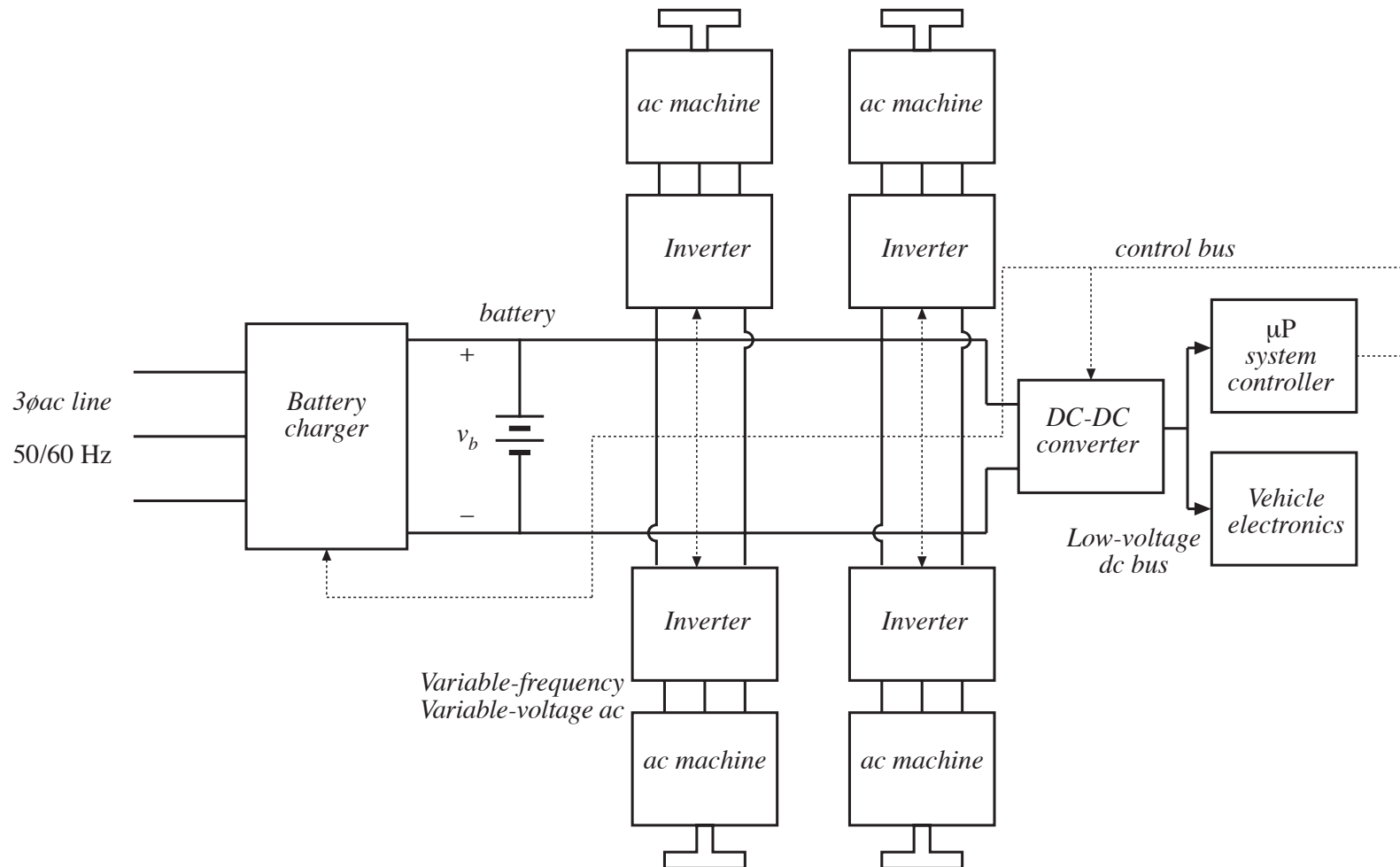- 1000 MW in rectifiers and inverters for utility dc transmission lines
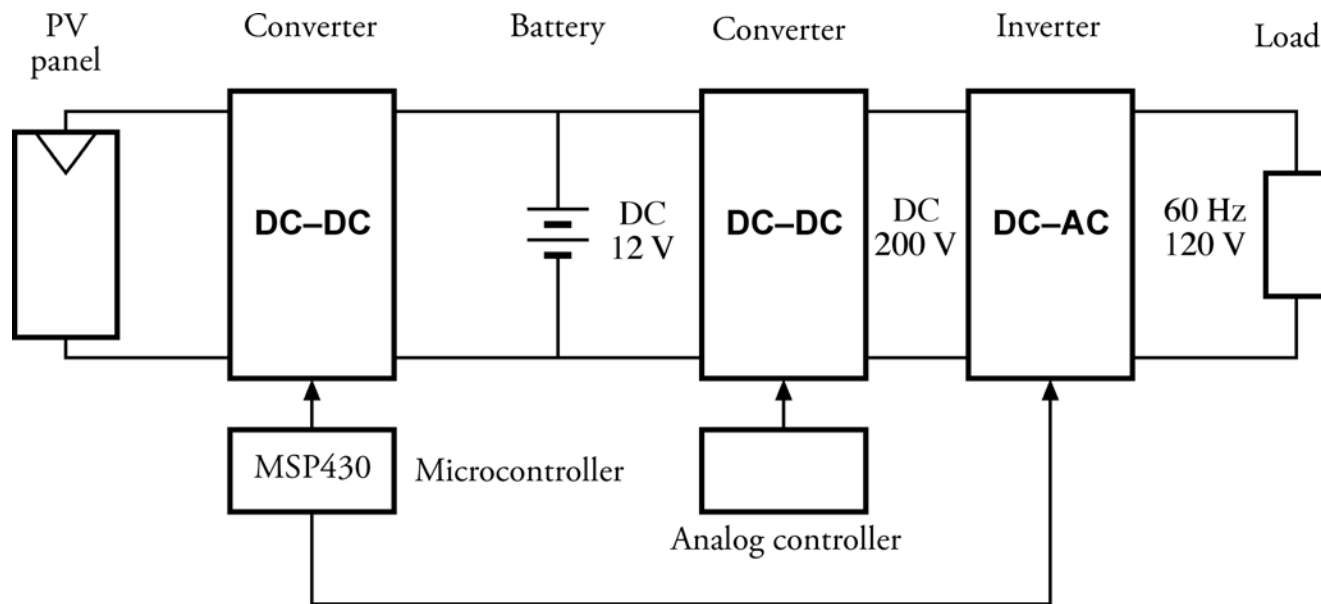
A laptop computer power supply system
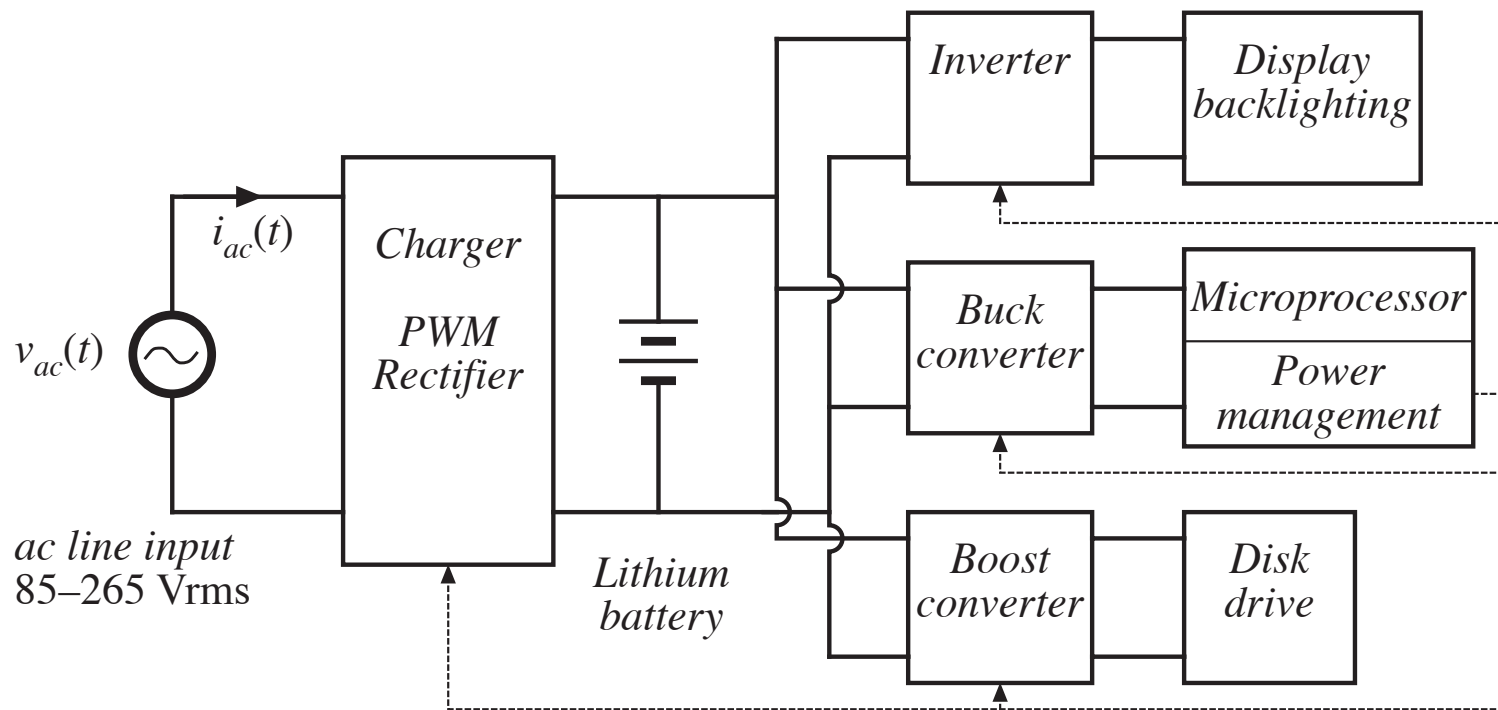
Power system of an earth-orbiting spacecraft
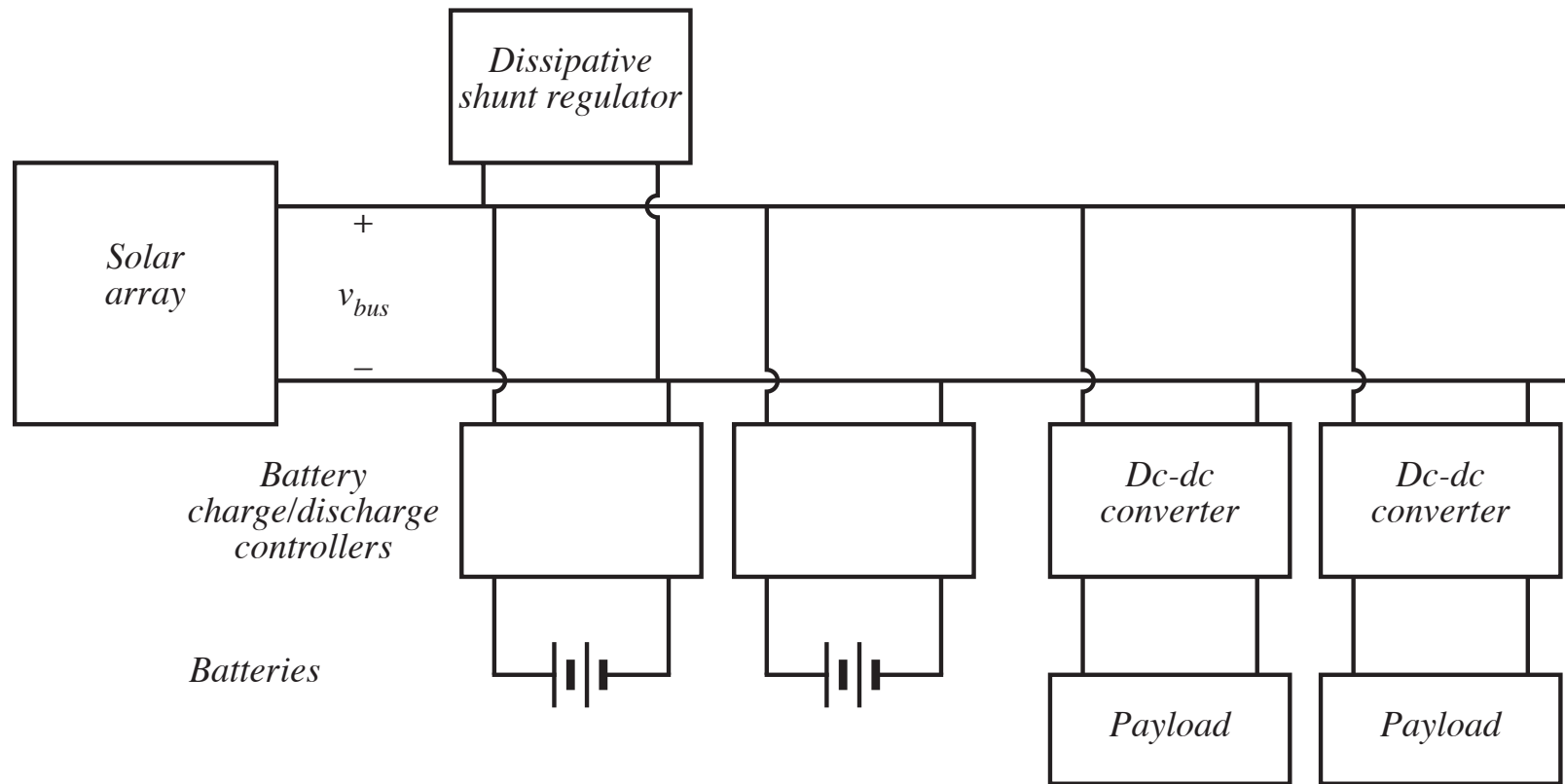
An electric vehicle power and drive system

A standalone photovoltaic power system

The system constructed in ECEN 4517/5517 Power
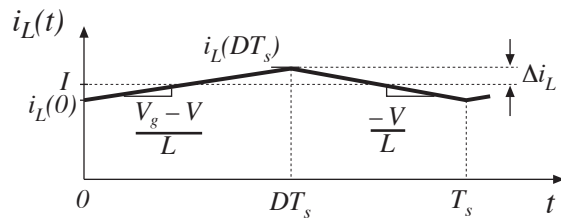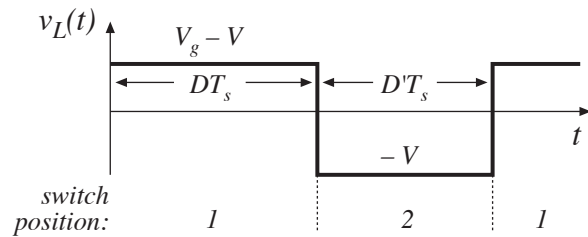Electronics and Photovoltaic Systems Laboratory

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

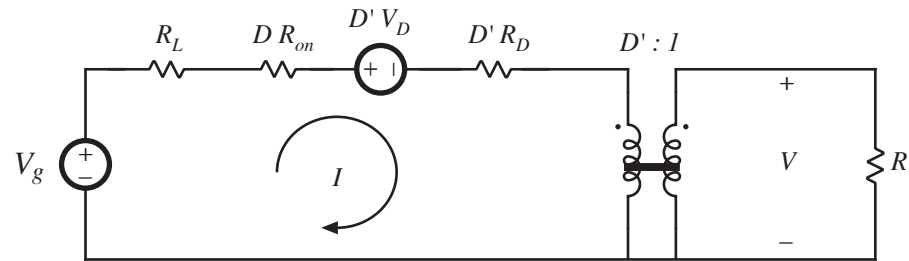   numerical simulation
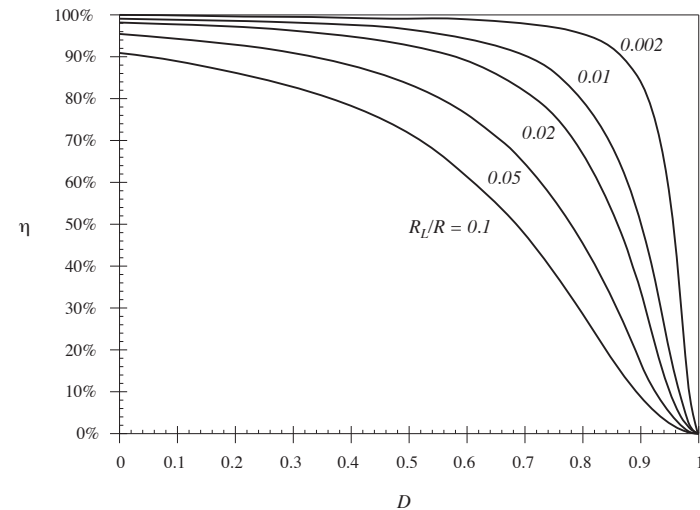
Part I. Converters in equilibrium

Inductor waveforms

switch position: *1*   *2*   *1*

Discontinuous conduction mode

Transformer isolation

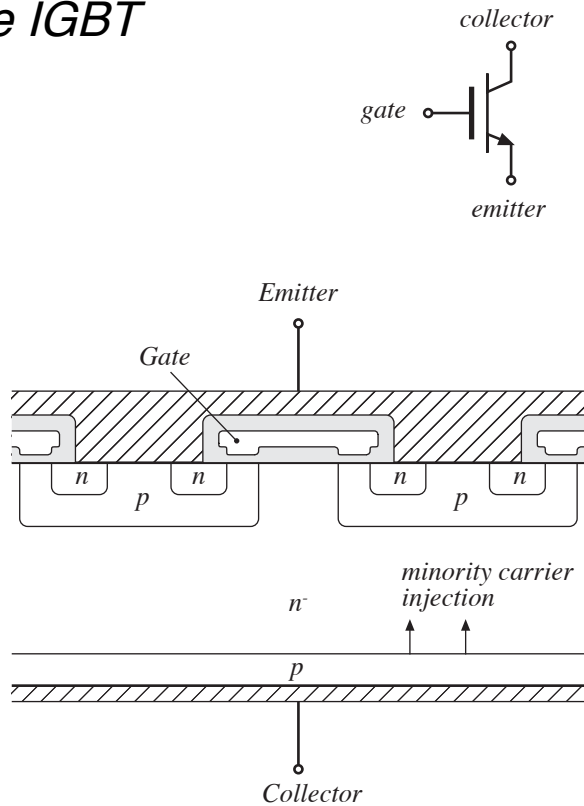## Averaged equivalent circuit
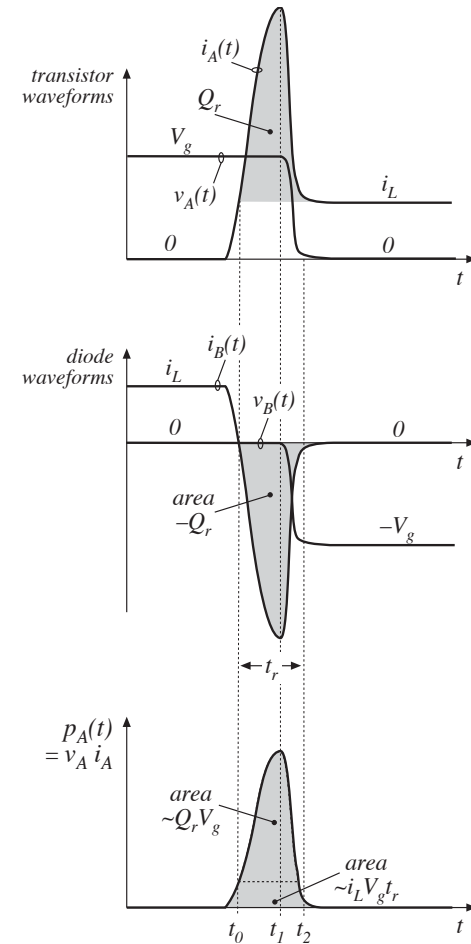

Predicted efficiency

Switch realization: semiconductor devices

The IGBT

Switching loss

Part I. Converters in equilibrium

2. Principles of steady state converter analysis

3. Steady-state equivalent circuit modeling, losses, and efficiency

4. Switch realization

5. The discontinuous conduction mode

6. Converter circuits