Chapter 1

POWER ELECTRONICS AND DRIVES: ENABLING TECHNOLOGIES

Role of Power Electronics

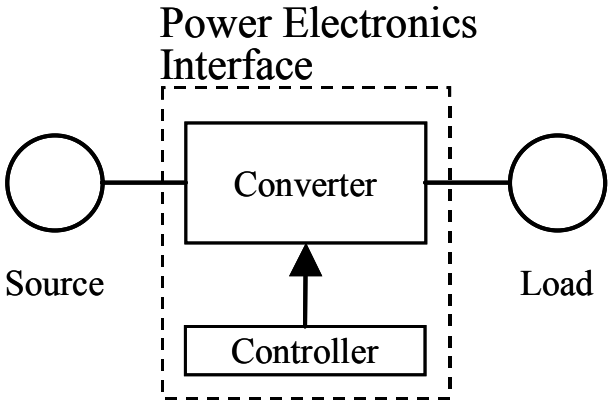


Figure 1-1 Power electronics interface between the source and the load.

The power electronics interface facilitates the transfer of power from the source to the load by converting voltages and currents from one form to another, in which it is possible for the source and load to reverse roles. The controller shown in Fig. 1-1 allows management of the power transfer process in which the conversion of voltages and currents should be achieved with as high energy-efficiency and high power density as possible.

Powering the Information Technology

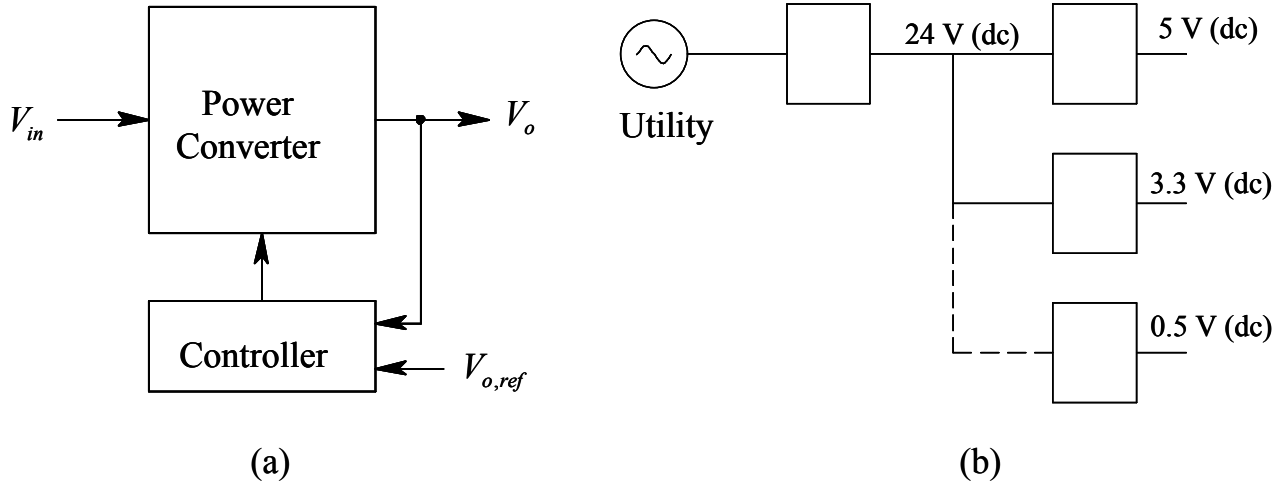


Figure 1-2 Regulated low-voltage dc power supplies.

Boost Converter

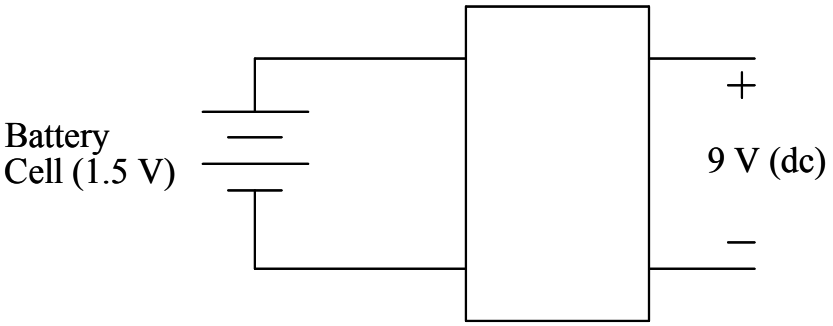


Figure 1-3 Boost dc-dc converter needed in cell operated equipment.

Adjustable Speed Drives

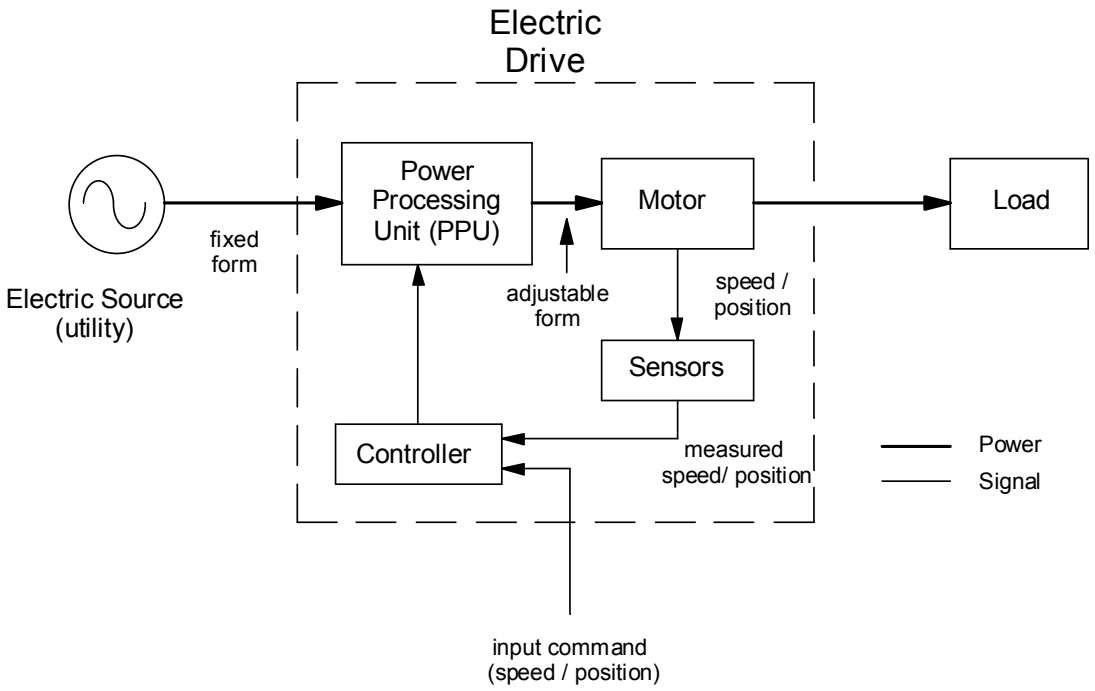


Figure 1-4 Block diagram of adjustable speed drives.

Induction Heating

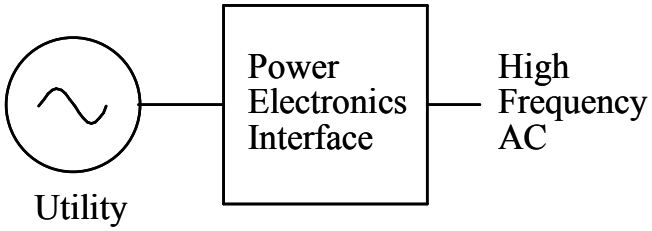


Figure 1-5 Power electronics interface required for induction heating.

Electric Welding

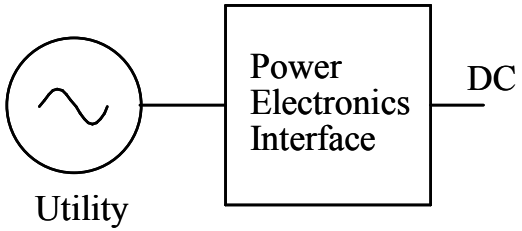


Figure 1-6 Power electronics interface required for electric welding.

Energy and the Environment: The Percentage Energy Consumption

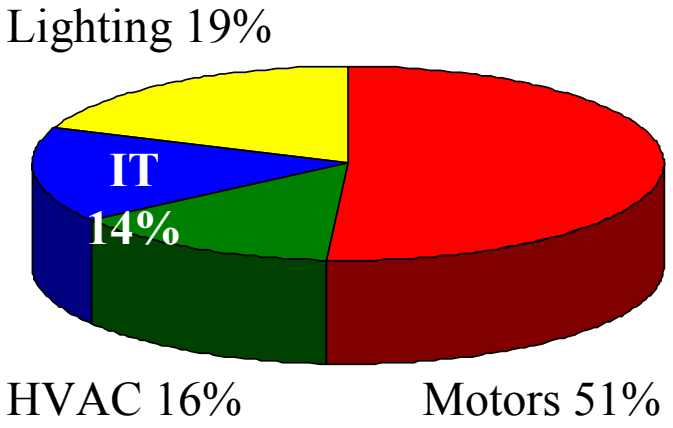


Figure 1-7 Percentage use of electricity in various sectors in the U.S.

Role of adjustable speed drives in pump-driven systems

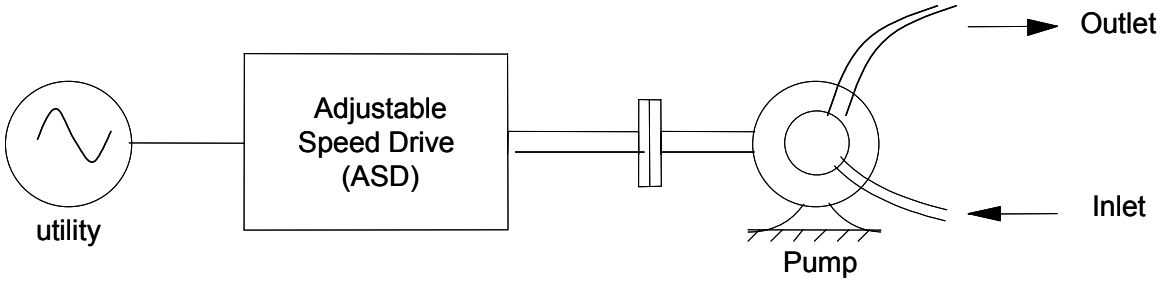


Figure 1-8 Role of adjustable speed drives in pump-driven systems.

Compact Fluorescent Lamps

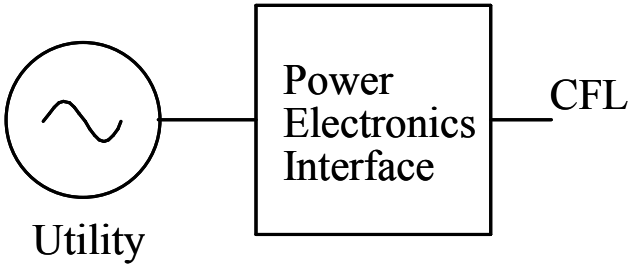


Figure 1-9 Power electronics interface required for CFL.

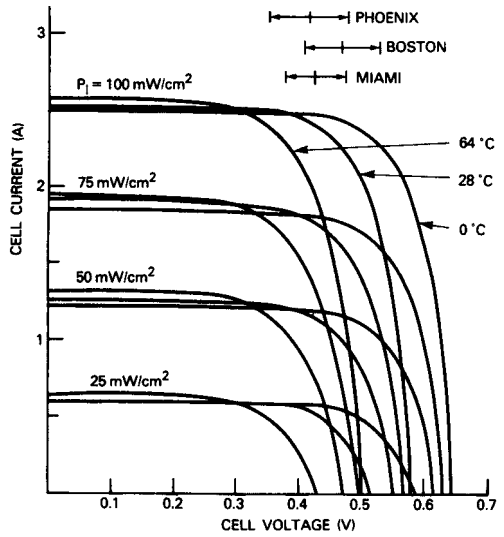
Transportation

Figure 1-10 Hybrid electric vehicles with much higher gas mileage.

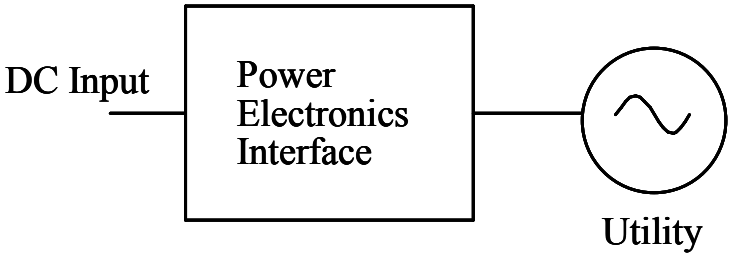
- Hybrid electric vehicles with much higher gas mileage
- light rail, fly-by-wire planes
- all-electric ships
- drive-by-wire automobiles.

Renewable Energy

Photovoltaic Systems



(a)



(b)

Figure 1-11 Photovoltaic Systems.

Wind-Electric Systems

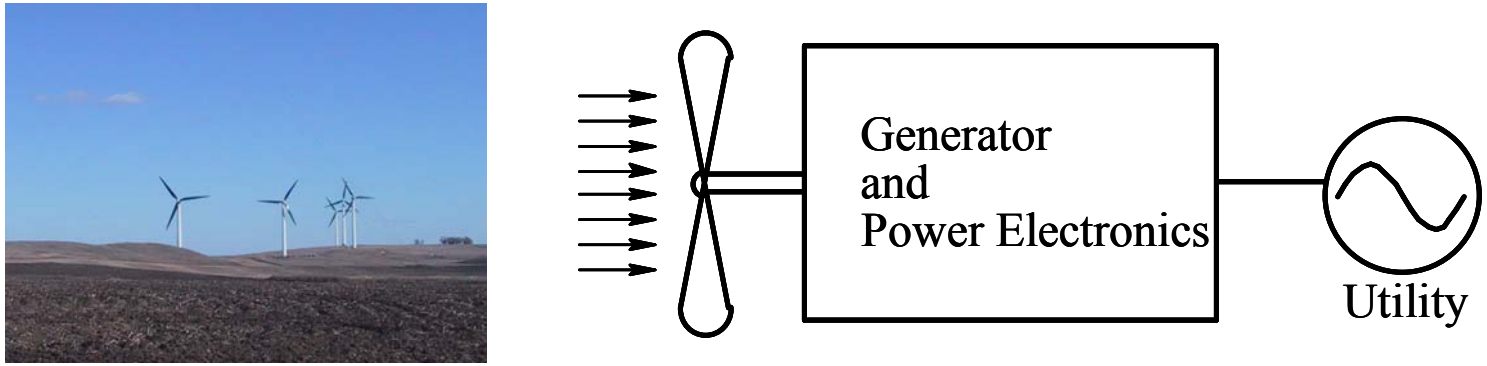


Figure 1-12 Wind-electric systems.

Uninterruptible Power Supplies

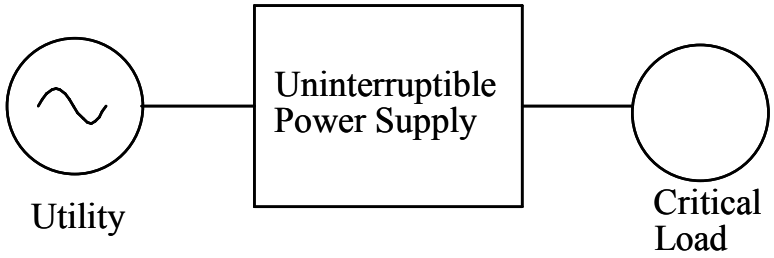
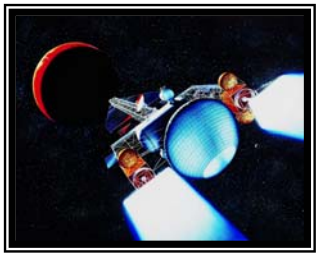
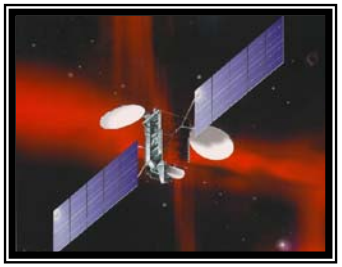


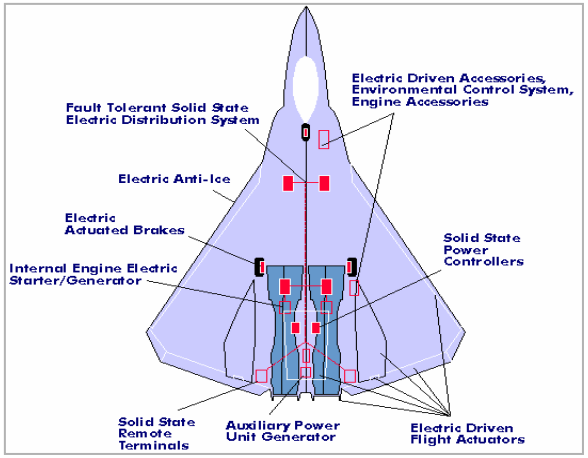
Figure 1-13 Uninterruptible power supply (UPS) system.

Strategic Space and Defense Applications

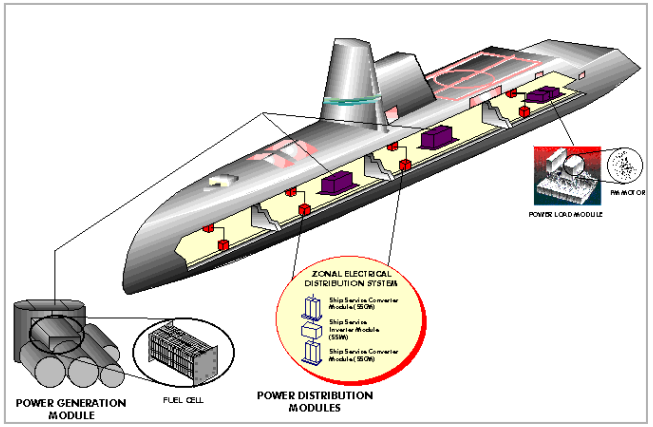




More Electric Aircraft



Electric Warship



Source: James Soeder, NASA and Terry Ericsen, ONR.

NEED FOR HIGH EFFICIENCY AND HIGH POWER DENSITY

$$\eta = \frac{P_o}{P_o + P_{loss}} \qquad P_o = \frac{\eta}{1-\eta} P_{loss}$$

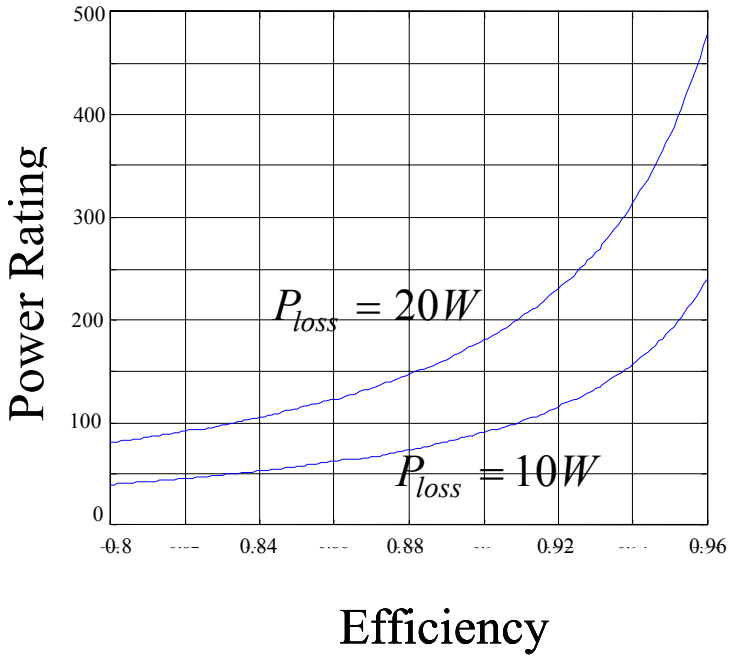


Figure 1-14 Power output capability as a function of efficiency.

Summarizing the Role of Power Electronics

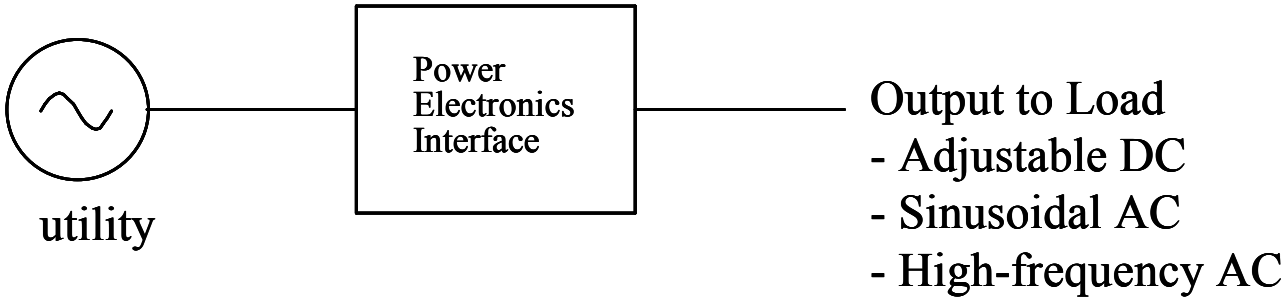


Figure 1-15 Block diagram of power electronic interface.

STRUCTURE OF POWER ELECTRONICS INTERFACE

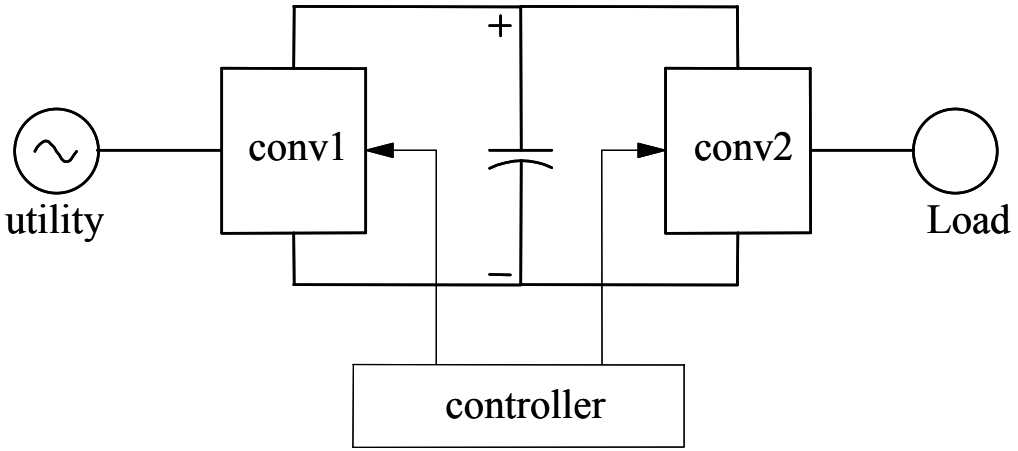


Figure 1-16 Voltage-link structure of power electronics interface.

Voltage-link structure of power electronics interface

- Unipolar voltage handling transistors used
- Decoupling of two converters
- Immunity from momentary power interruptions

- Current-Link Systems
- Matrix Converters

SWITCH-MODE LOAD-SIDE CONVERTER

- Group 1 Adjustable dc or a low-frequency sinusoidal ac output in
  - dc and ac motor drives
  - uninterruptible power supplies
  - regulated dc power supplies without electrical isolation
- Group 2 High-frequency ac in
  - compact fluorescent lamps
  - induction heating
  - regulated dc power supplies where the dc output voltage needs to be electrically isolated from the input, and the load-side converter internally produces high-frequency ac, which is passed through a high-frequency transformer and then rectified into dc.

Switch-Mode Conversion: Switching Power-Pole as the Building Block

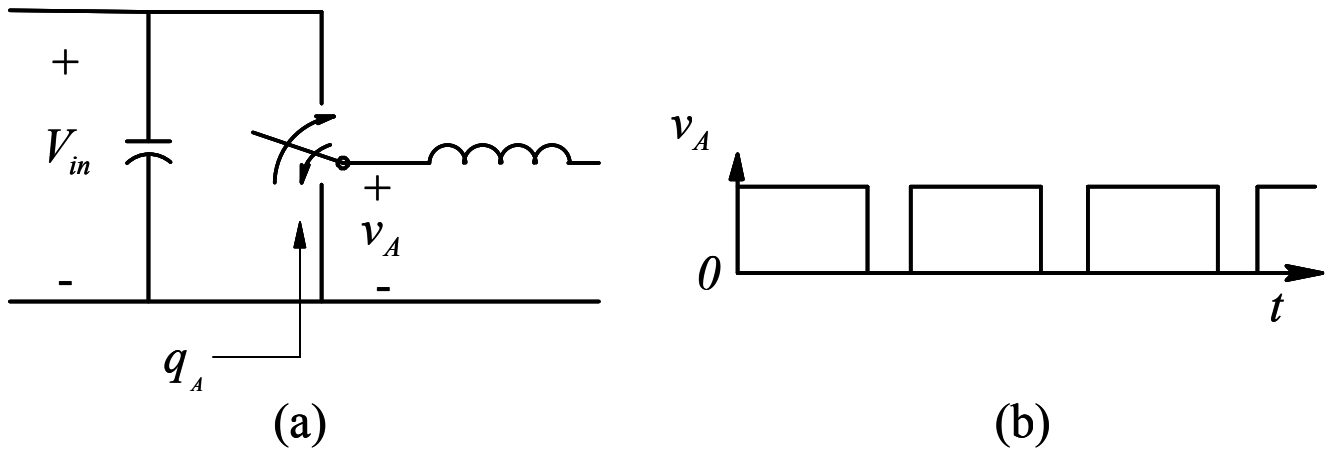


Figure 1-17 Switching power-pole as the building block in converters.

Pulse-Width Modulation (PWM) of the Switching Power-Pole

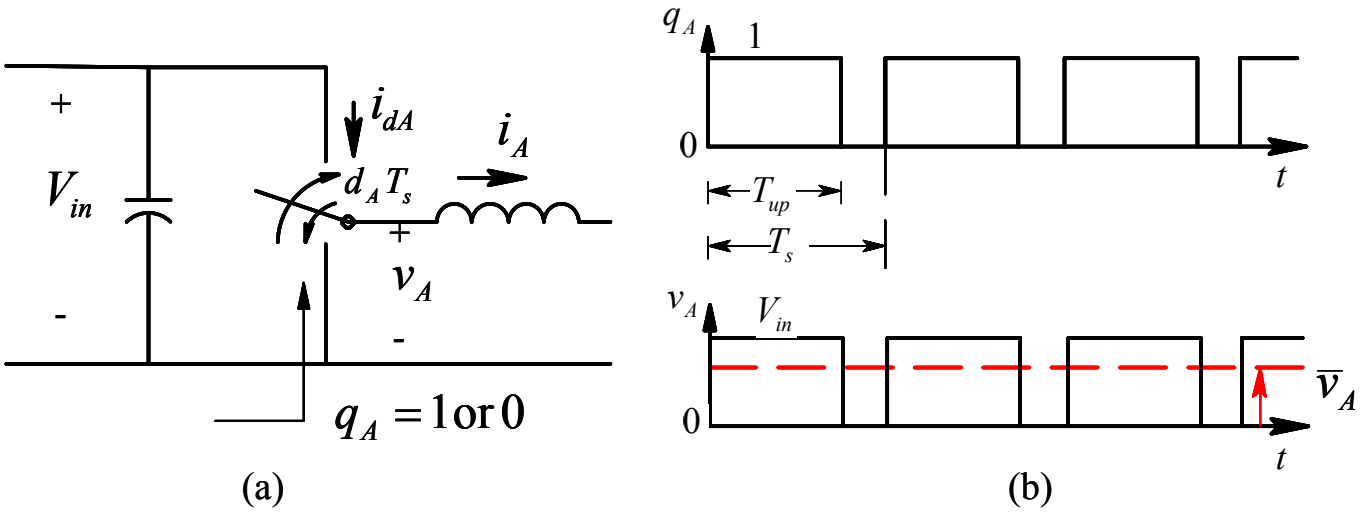


Figure 1-18 PWM of the switching power-pole.

$$d_A (= T_{up} / T_s)$$

$$\overline{v}_A = \frac{T_{up}}{T_s} V_{in} = d_A V_{in} \qquad 0 \le d_A \le 1$$

Switching Power-Pole in a Buck DC-DC Converter: An Example

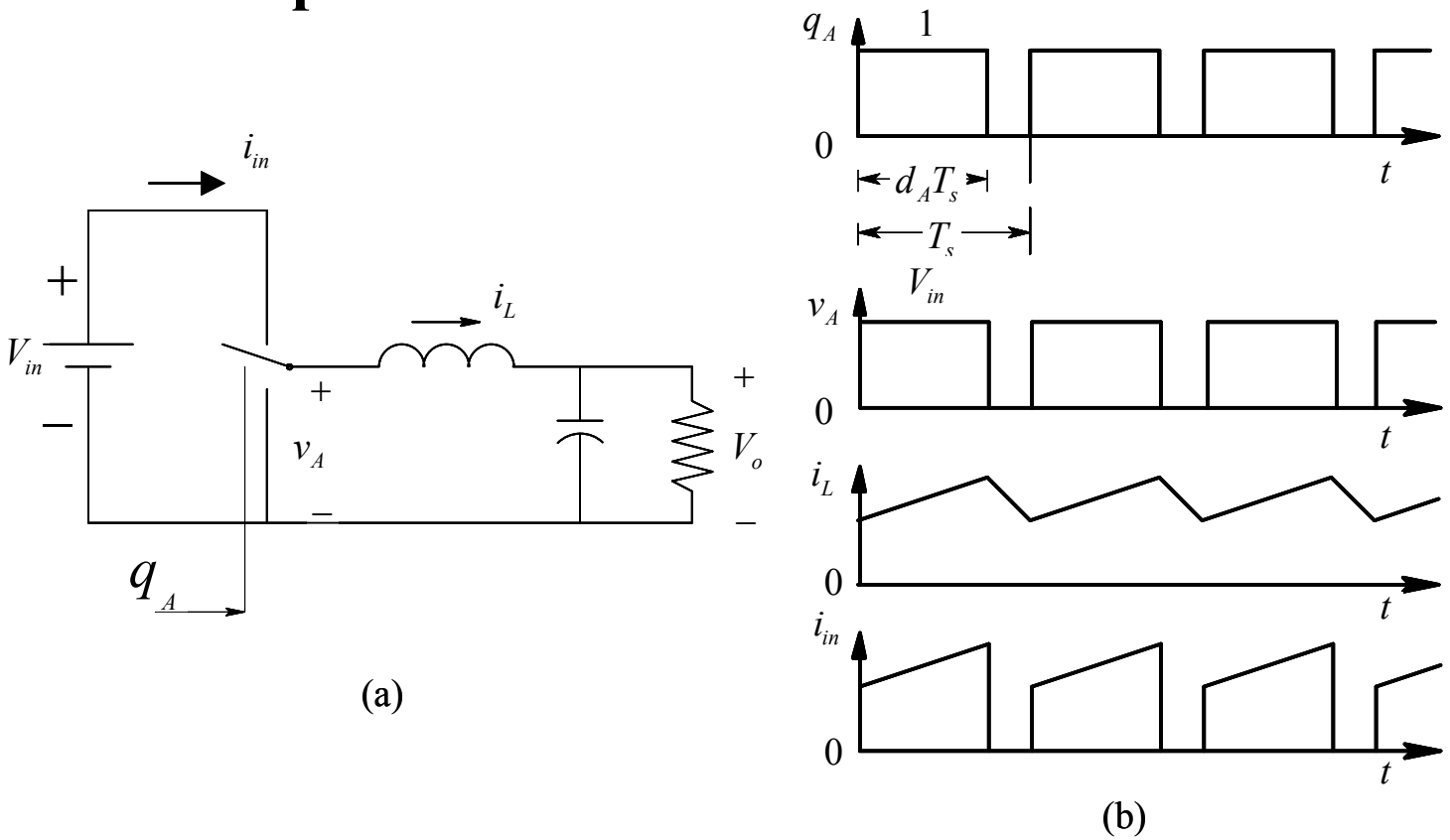


Figure 1-19 Switching power-pole in a Buck converter.

$$V_o = \overline{v}_A = d_A V_{in} \qquad 0 \le V_o \le V_{in}$$

Transistor and diode forming a switching power-pole in a Buck converter

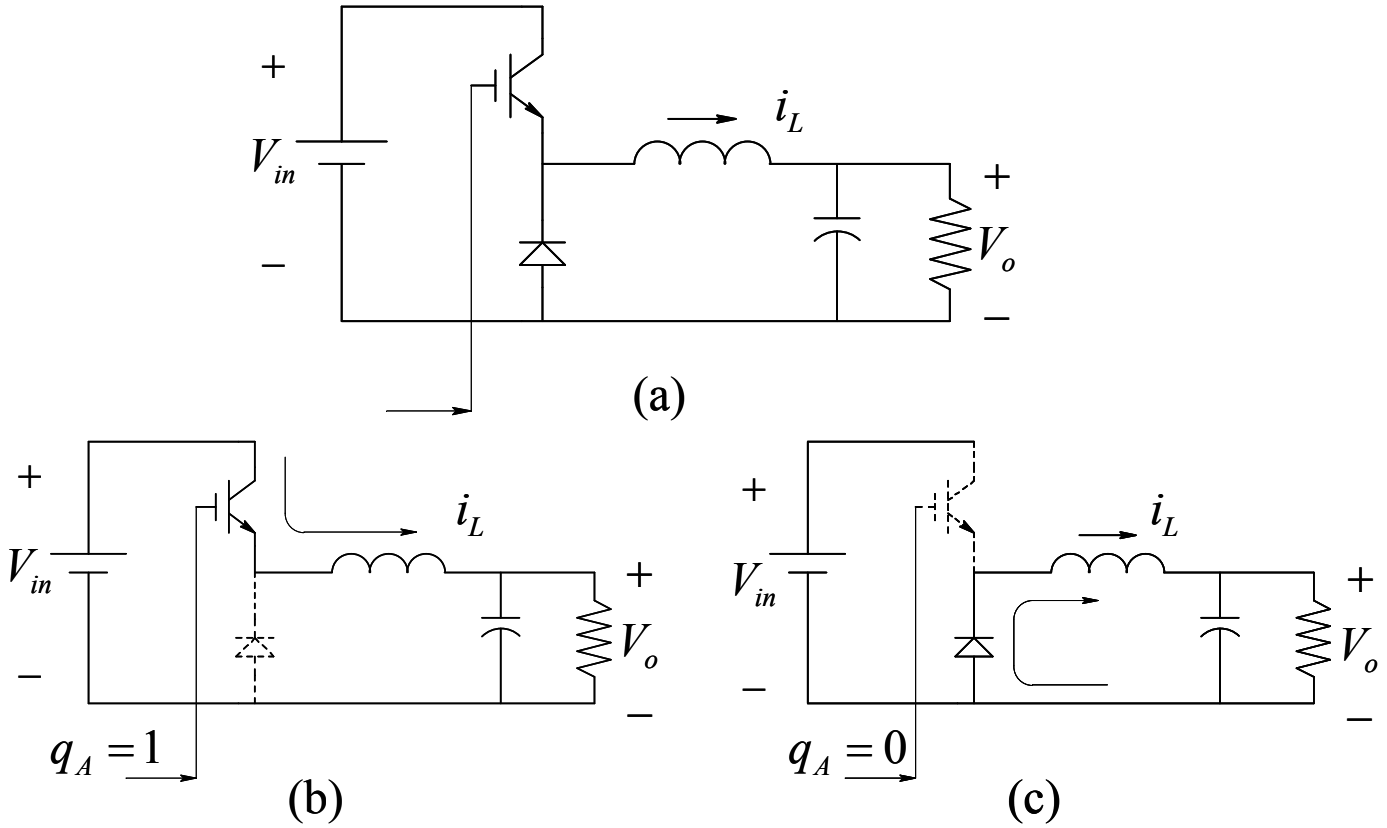


Figure 1-20 Transistor and diode forming a switching power-pole in a Buck converter.

RECENT AND POTENTIAL ADVANCEMENTS

- Devices that can handle voltages in kVs and currents in kAs
- ASICs
- DSPs
- Micro-controllers
- FPGA
- Integrated and intelligent power modules
- Packaging
- SiC-based solid-state devices
- High energy density capacitors