Welcome to EJ2300 Power Electronics

Basics

DC/DC converters

DC-motor

Diode and thyristor converters

Power semiconductors (web-based)

Inverters

Switching DC power supplies

Power Electronic Systems

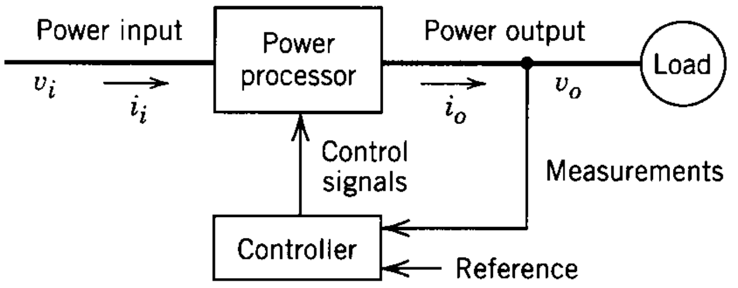
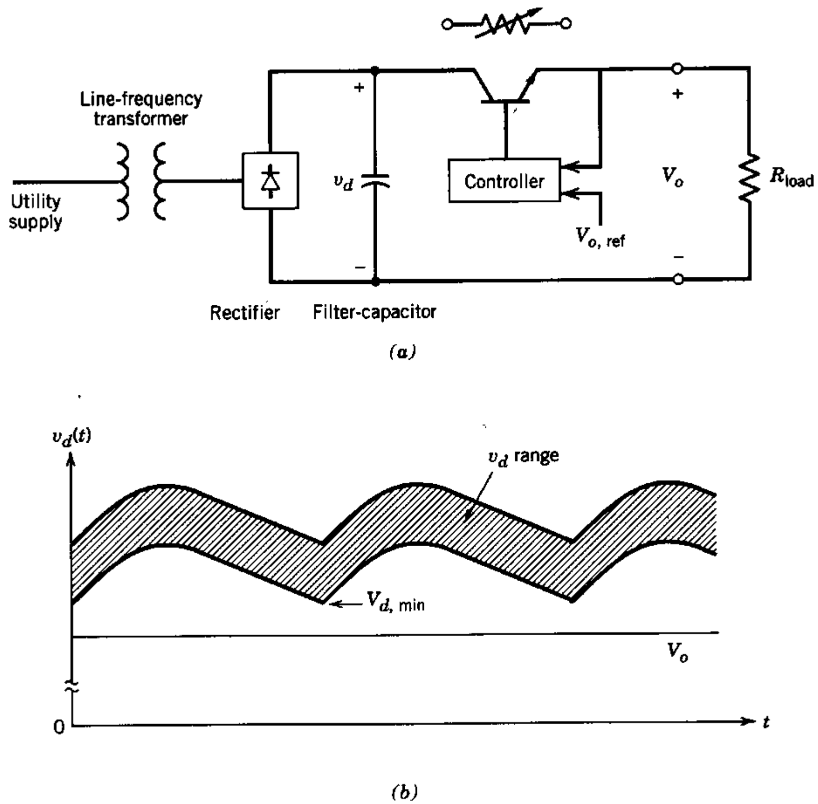


Figure 1-1 Block diagram of a power electronic system.

- Block diagram
- Role of Power Electronics
- Reasons for growth (power semiconductors, digital electronics, renewables, electric vehicles)

Linear Power Supply



- Series transistor as an adjustable resistor
- Low Efficiency
- Heavy and bulky

Basic Principle of Switch-Mode Synthesis

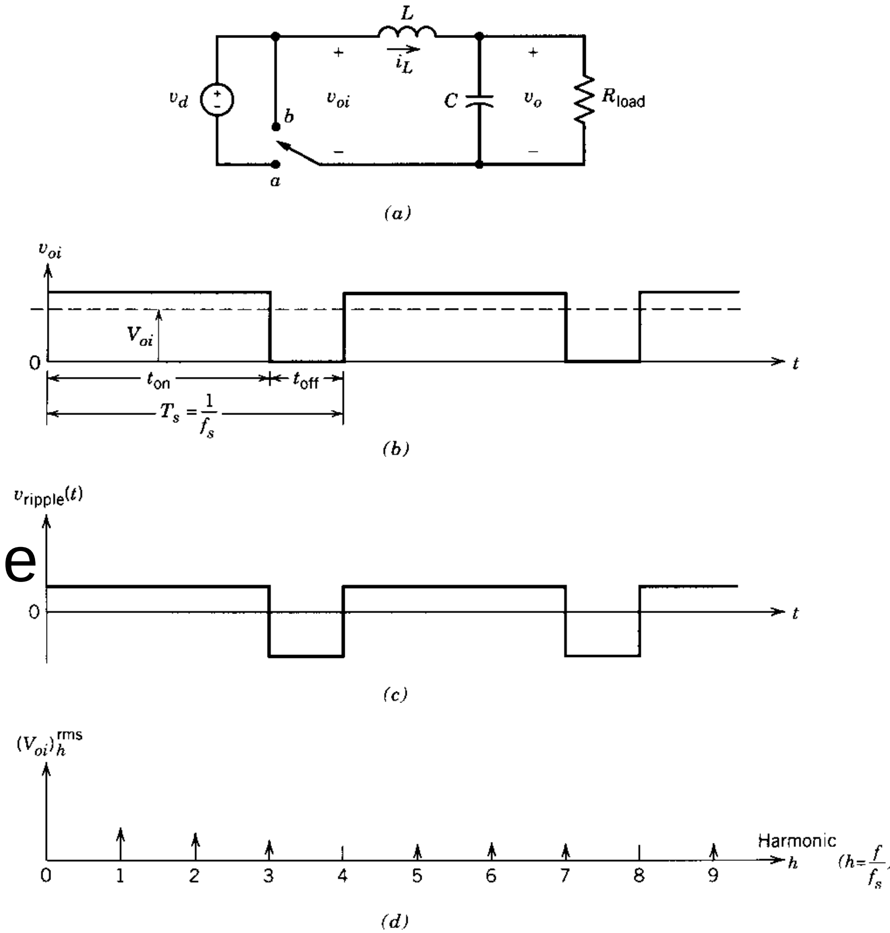


Figure 1-4 Equivalent circuit, waveforms, and frequency spectrum of the supply in Fig. 1-3.

- Constant switching frequency
- pulse width controls the average
- L-C filters the ripple

Switch-Mode Power Supply

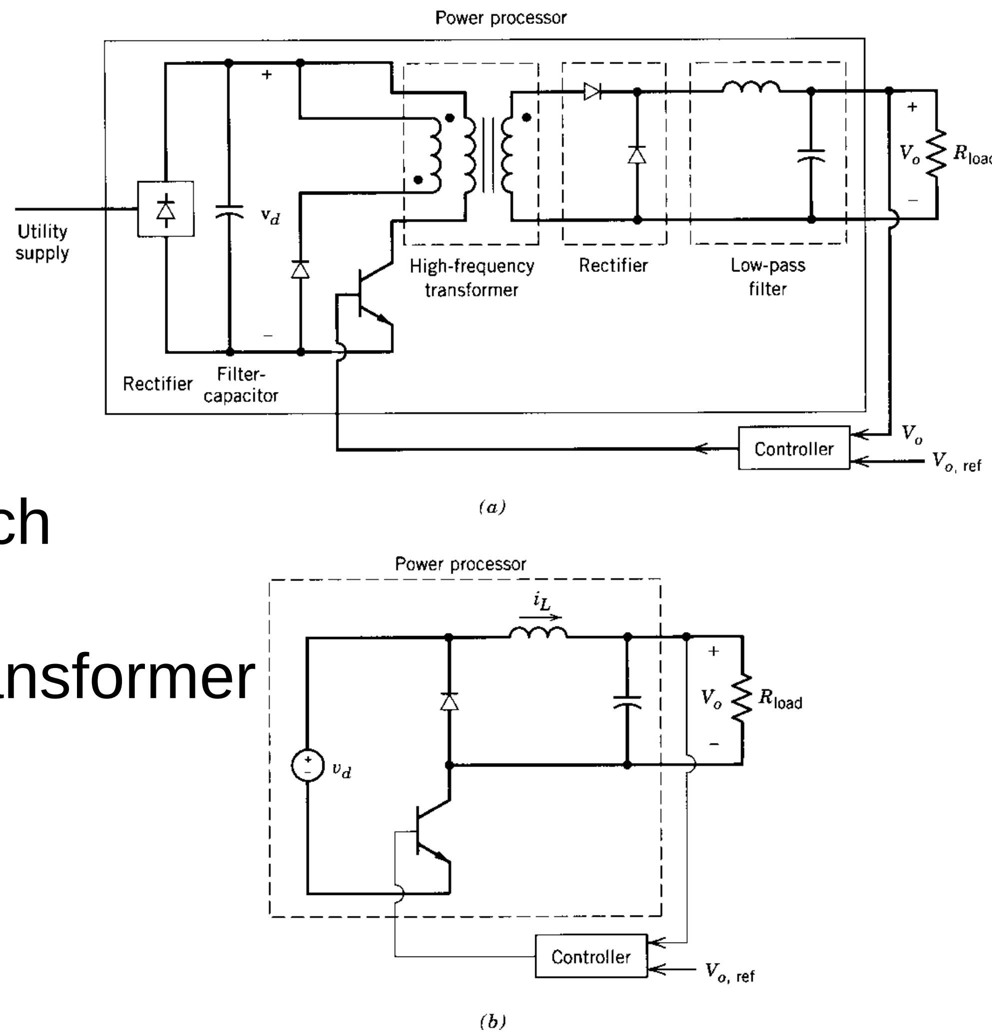


Figure 1-3 Switch-mode dc power supply.

- Transistor as a switch
- High Efficiency
- High-Frequency Transformer

AC Motor Drive

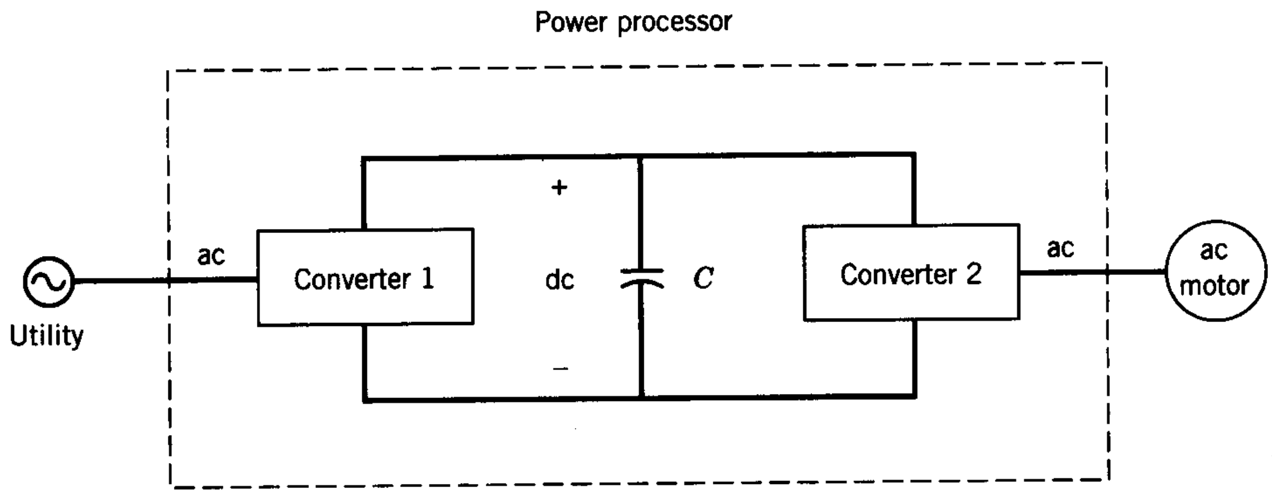


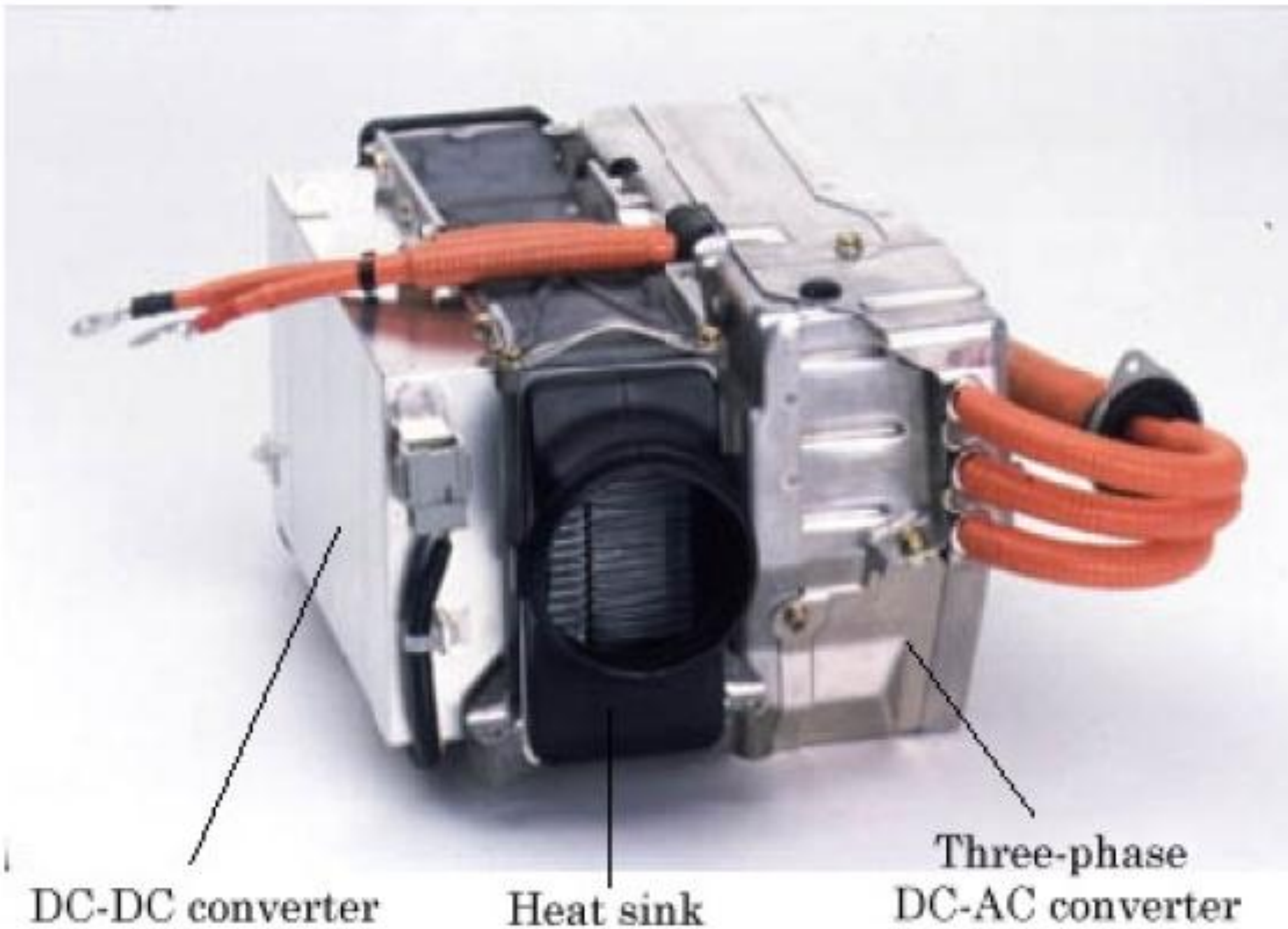
Figure 1-8 Block diagram of an ac motor drive.

- Converter 1 rectifies line-frequency ac into dc
- Capacitor acts as a filter; stores energy; decouples
- Converter 2 synthesizes low-frequency ac to motor
- Polarity of dc-bus voltage remains unchanged
  - ideally suited for transistors of converter 2

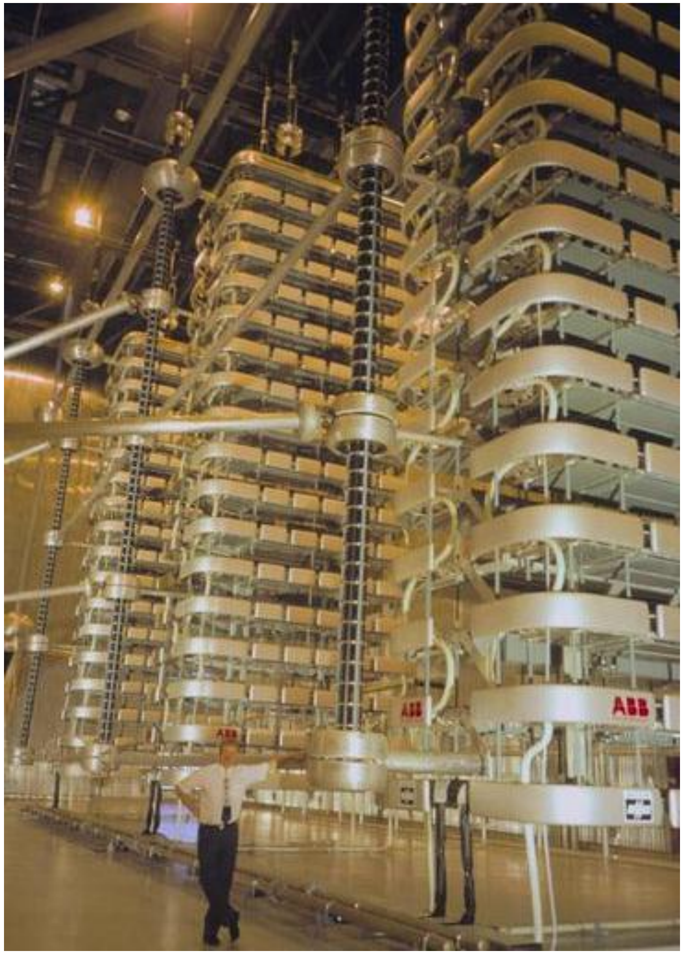
Applications

- Controlled DC power supplies
- Motor drives for various applications (industry, transport)
- Grid applications (HVDC, SVC, StatCom, TCSC)
- Windpower
- Photovoltaics

Honda Insight



Thyristor valve for HVDC
500 kV, 1500 MW

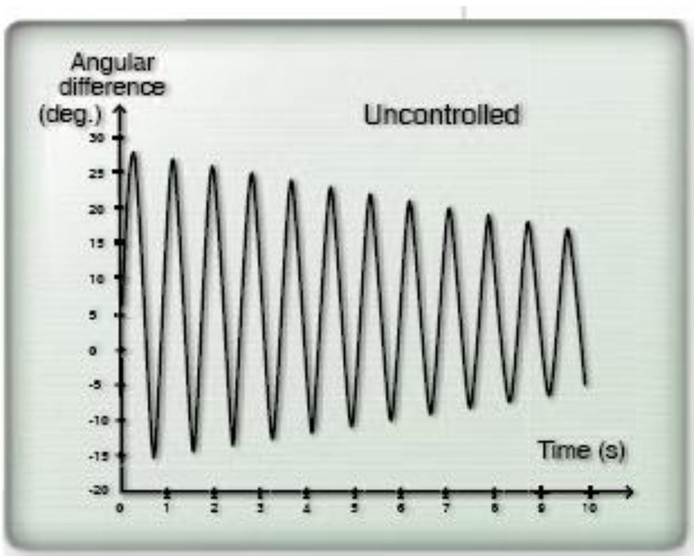


Source: ABB

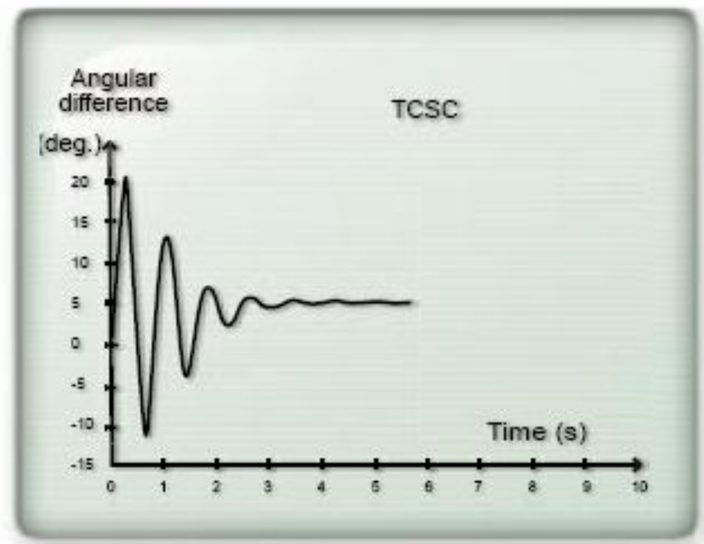
Thyristor Controlled Series Compensator
400 kV,
394 Mvar fixed, 71 Mvar controlled

Source: ABB

Power oscillation damping with TCSC
500 kV, 2000 MW line



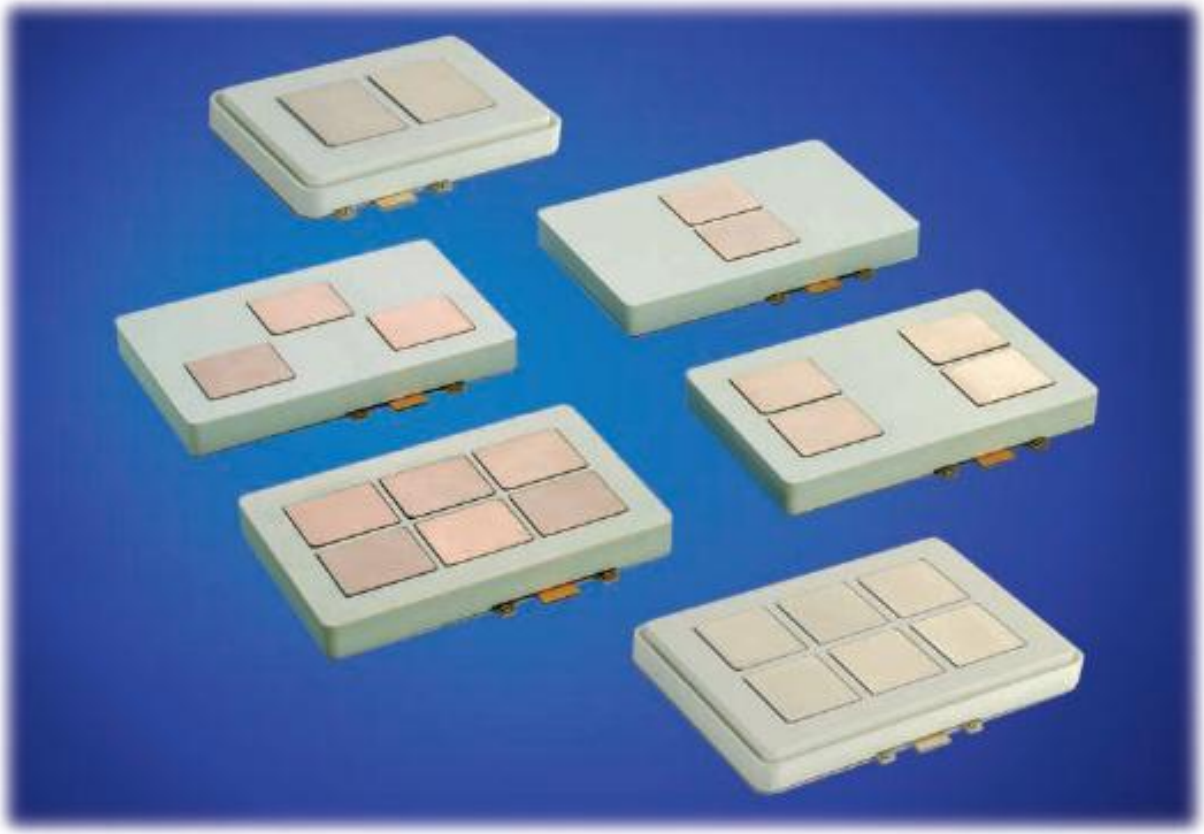
a)



b)

Source: ABB

IGBT press-pack modules



Source: ABB

IGBT stacks

Source: ABB

Valve assembly

Source: ABB

Cooling system

Source: ABB

High-voltage PEX cable

Source: ABB

Electrostatic precipitator

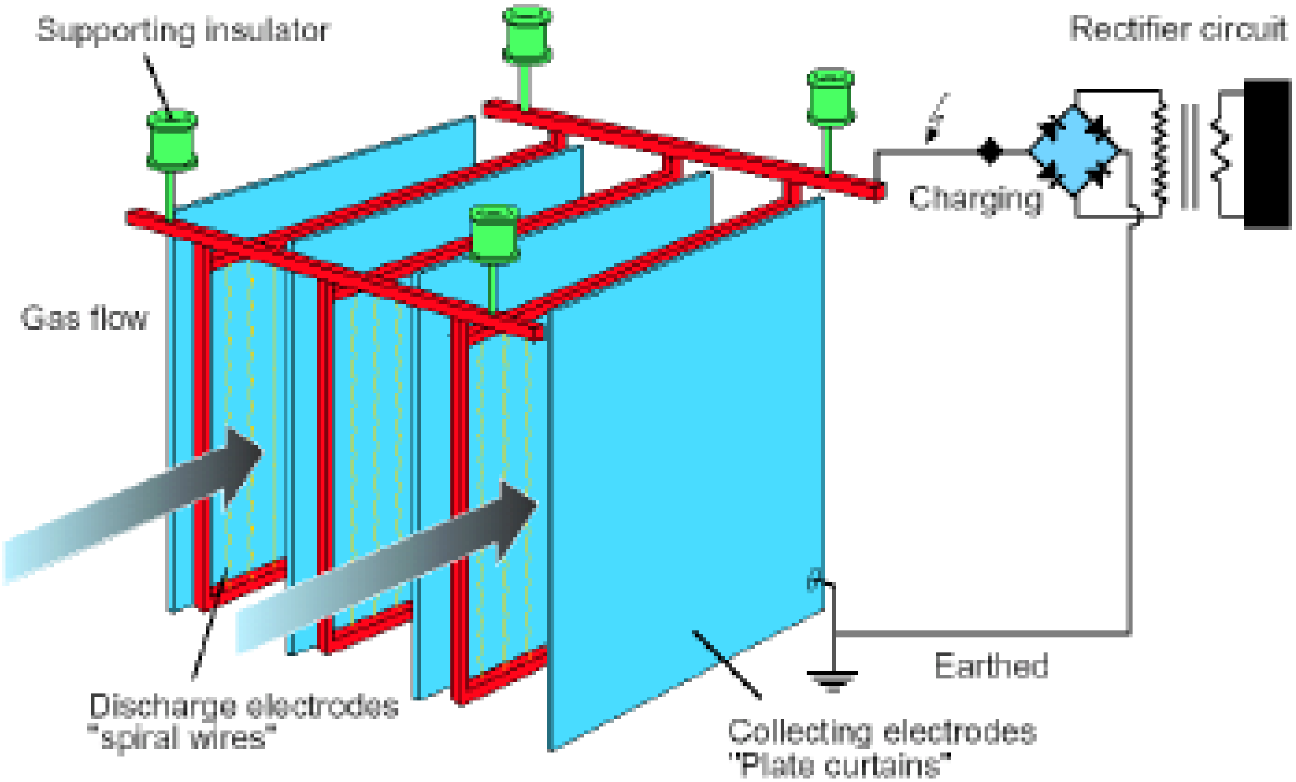


Figure 2.3 Typical design of bus-section of an ESP

Diodes

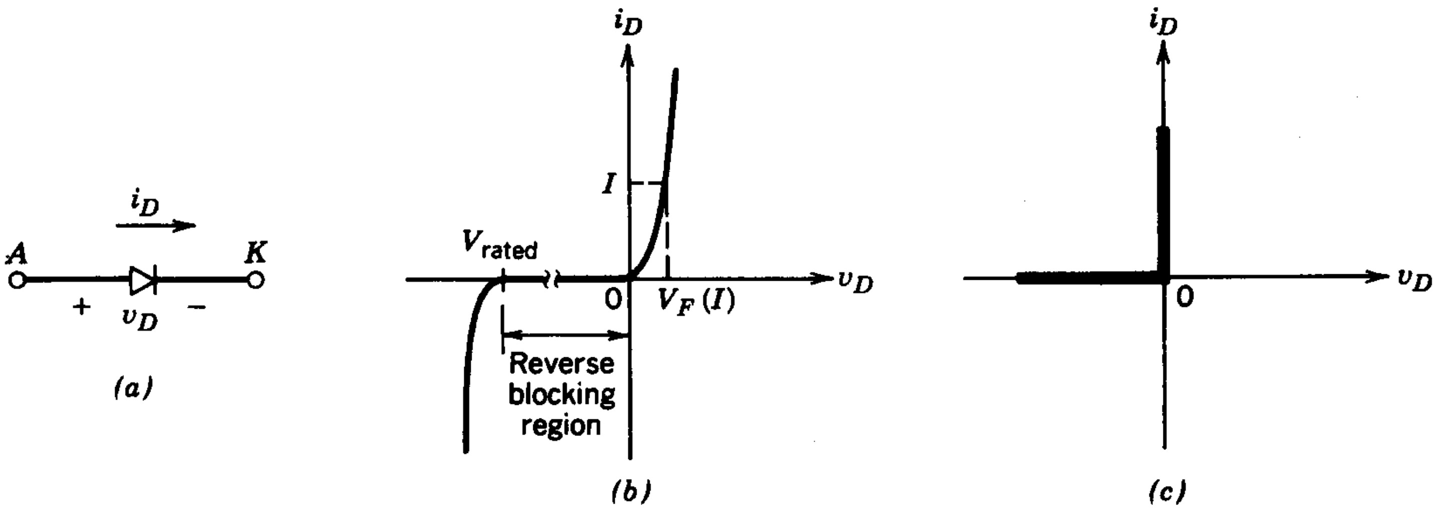
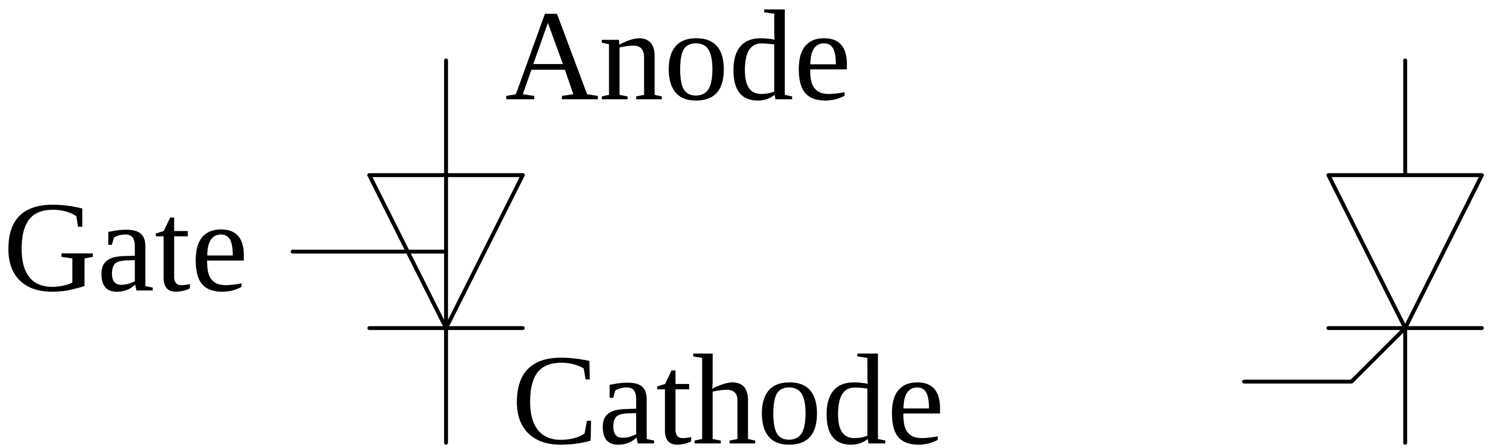


Figure 2-1 Diode: (*a*) symbol, (*b*) *i–v* characteristic, (*c*) idealized characteristic.

- On and off states controlled by the power circuit

Thyristor



Generic Switch Symbol

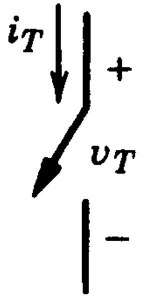


Figure 2-5 Generic controllable switch.

- Idealized switch symbol
- When on, current can flow only in the direction of the arrow
- Instantaneous switching from one state to the other
- Zero voltage drop in on-state
- Infinite voltage and current handling capabilities

Switching Characteristics (linearized)

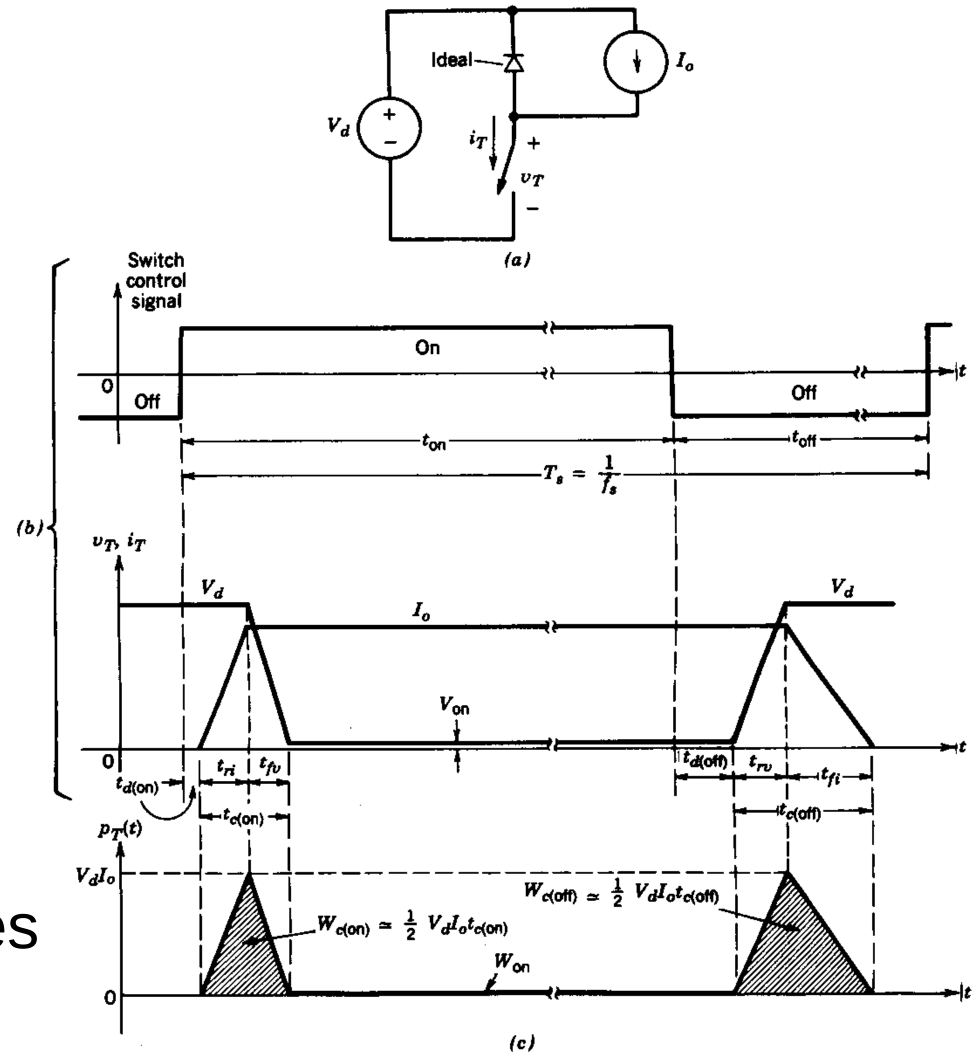


Figure 2-6 Generic-switch switching characteristics (linearized): (*a*) simplified clamped-inductive-switching circuit, (*b*) switch waveforms, (*c*) instantaneous switch power loss.

Switching Power Loss is proportional to:

- switching frequency
- turn-on and turn-off times

Switching speed

- Why do we want to switch fast?

  Low switching losses
  Well defined voltage waveform

- Why do we want to switch slowly?

  Voltage sharing
  EMI
  Electric stress on insulation systems

MOSFETs

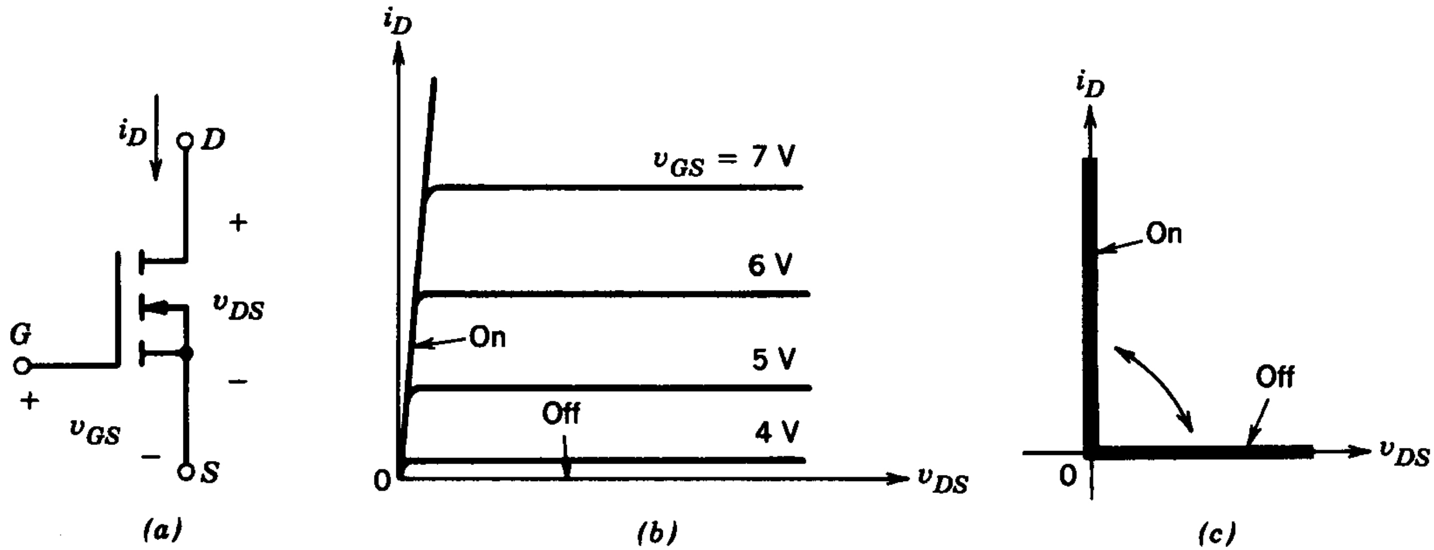


Figure 2-9 *N*-channel MOSFET: (*a*) symbol, (*b*) *i–v* characteristics, (*c*) idealized characteristics.

- Easy to control by the gate
- Optimal for low-voltage operation at high switching frequencies
- On-state resistance a concern at higher voltage ratings

IGBT

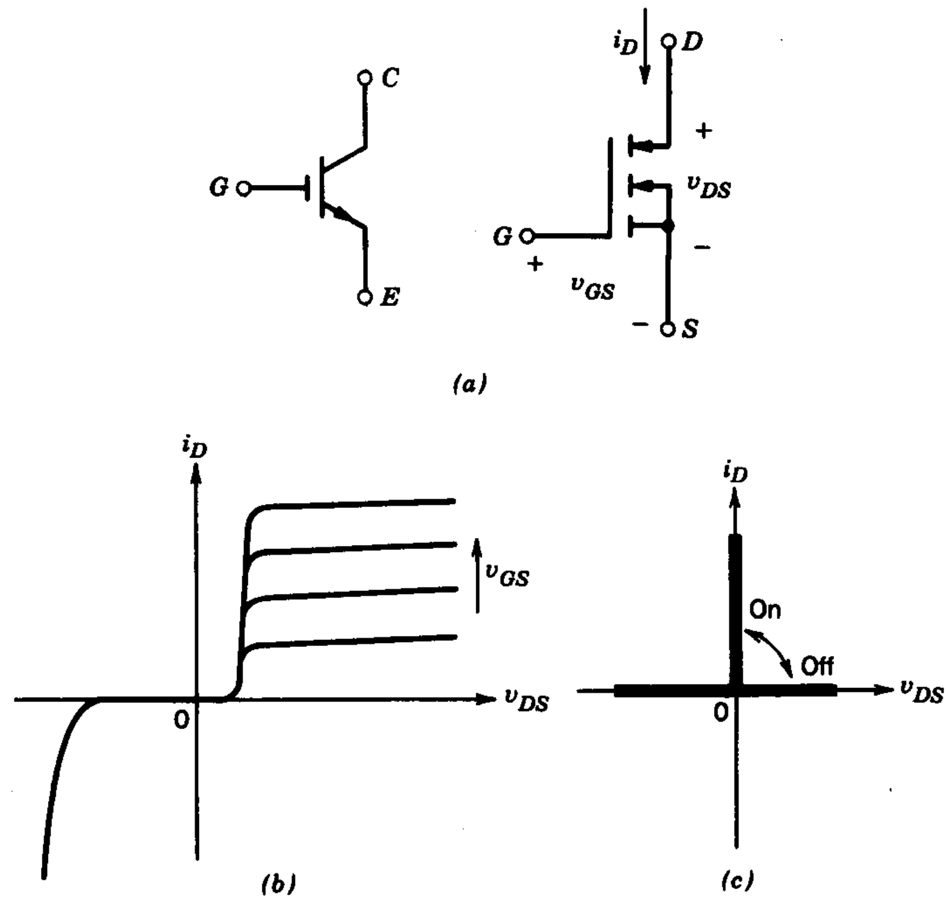
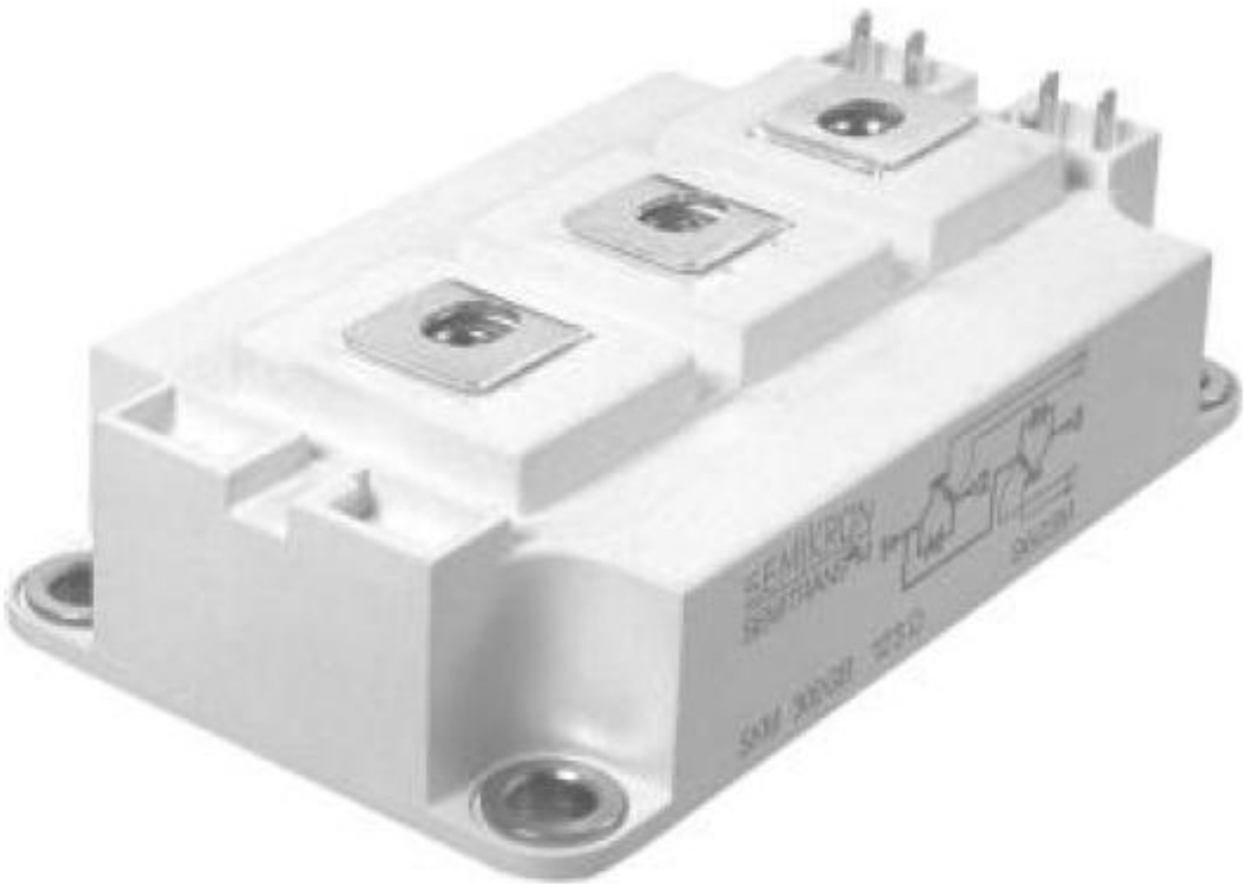


Figure 2-12 An IGBT: (*a*) symbol, (*b*) *i*–*v* characteristics, (*c*) idealized characteristics.

IGBT module



Source: Semikron

IGBT Datasheet

Characteristics			T_c = 25 °C, unless otherwise specified			
Symbol	**Conditions**		**min.**	**typ.**	**max.**	**Units**
IGBT						
$V_{GE(th)}$	$V_{GE} = V_{CE}$, I_C = 16 mA		5	5,8	6,5	V
I_{CES}	V_{GE} = 0 V, $V_{CE} = V_{CES}$	T_j = 25 °C		0,2	0,6	mA
		T_j = 125 °C				mA
V_{CE0}		T_j = 25 °C		1	1,2	V
		T_j = 125 °C		0,9	1,1	V
r_{CE}	V_{GE} = 15 V	T_j = 25°C		1,8	2,4	mΩ
		T_j = 125°C		2,8	3,4	mΩ
$V_{CE(sat)}$	I_{Cnom} = 400 A, V_{GE} = 15 V	T_j = 25°$C_{chiplev.}$		1,7	2,15	V
		T_j = 125°$C_{chiplev.}$		2	2,45	V
C_{ies}	V_{CE} = 25, V_{GE} = 0 V	f = 1 MHz		32		nF
C_{oes}				11		nF
C_{res}				2,2		nF
Q_G	V_{GE} = -8V - +20V			3600		nC
R_{Gint}	T_j = °C			1,88		Ω
$t_{d(on)}$	R_{Gon} = 2 Ω	V_{CC} = 600V		290		ns
t_r		I_C= 400A		60		ns
E_{on}		T_j = 125 °C		39		mJ
$t_{d(off)}$	R_{Goff} = 2 Ω	V_{GE} = ± 15V		670		ns
t_f				80		ns
E_{off}				64		mJ
$R_{th(j-c)}$	per IGBT				0,055	K/W

Source: Semikron

Bond wire lift-off

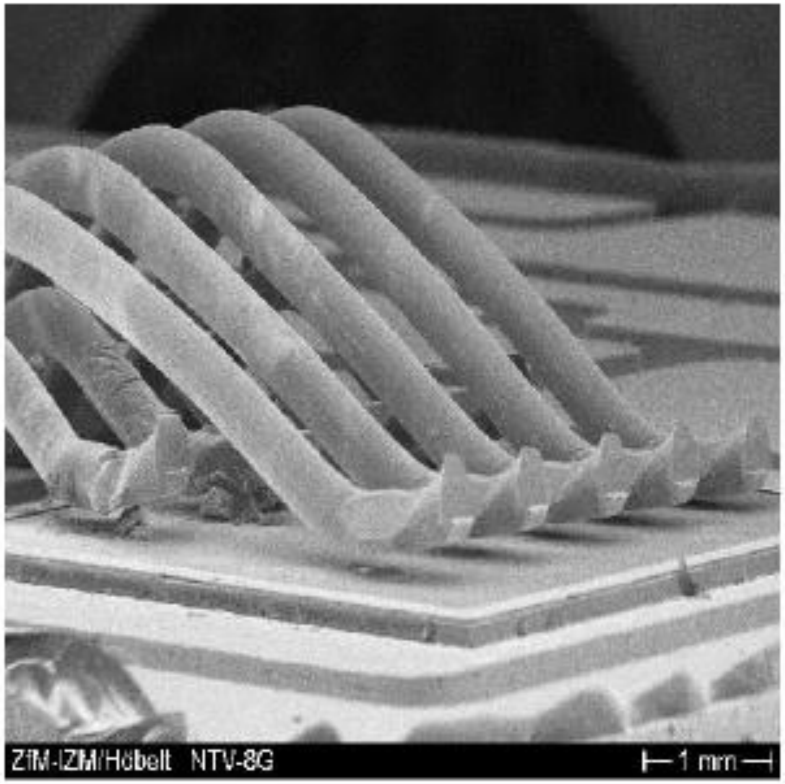


Fig .5: Bond wire lift-off of one-sided LT joined diode after 32000 power cycles

Soldering delamination

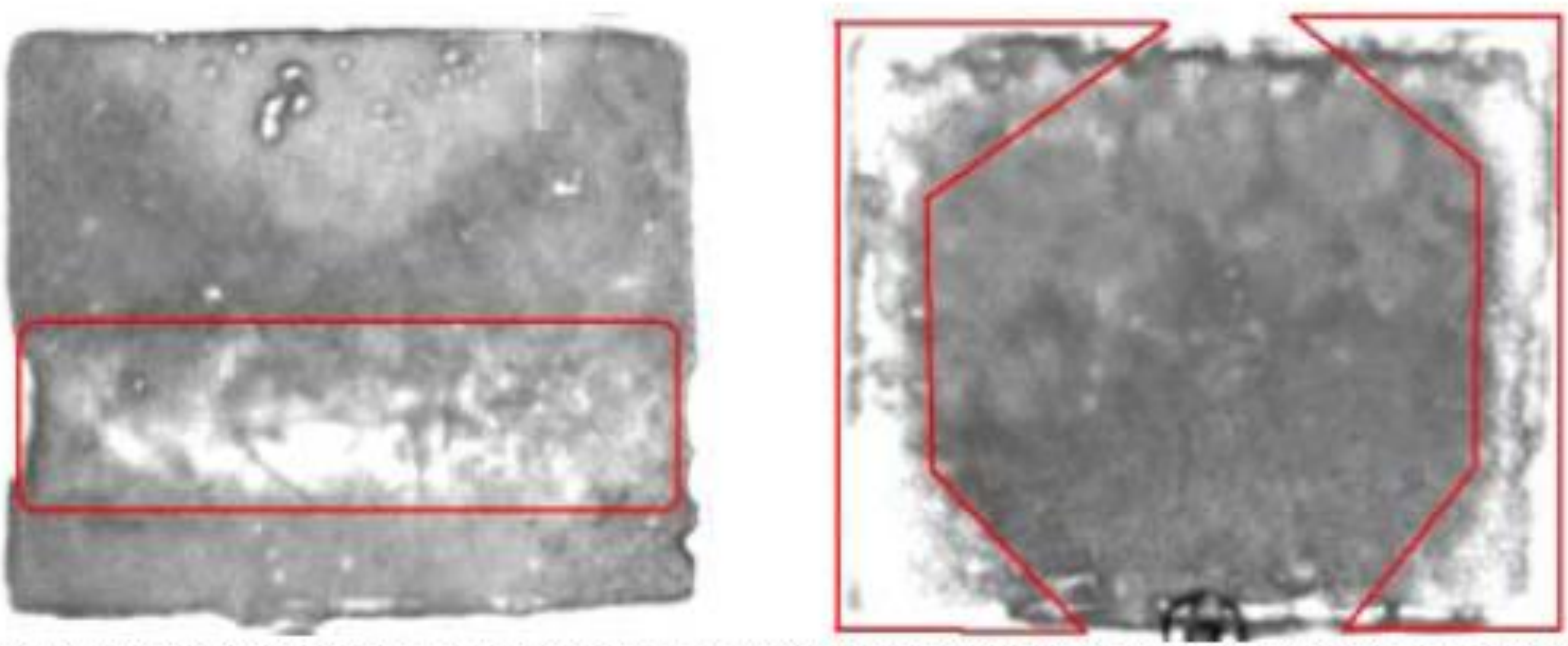


Figure 7: damage below active chips in a lead-free substrate solder joint after power cycling (left) and substrate soldering after 30 000 passive thermal cycles (right) in modules with AlSiC base plate.

V_{CE} = 2500 V
I_C = 2000 A

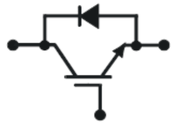


ABB StakPak™ H Series Press-pack IGBT

5SNR 20H2501

PRELIMINARY

Doc. No. 5SYA1582-03 May. 07

- **High SOA**
- **Fails into stable shorted state**
- **High tolerance to uneven mounting pressure**
- **Designed for series connection**
- **Explosion resistant package**
- **Modular design concept, available for a wide range of current ratings**
- **SPT chip set**

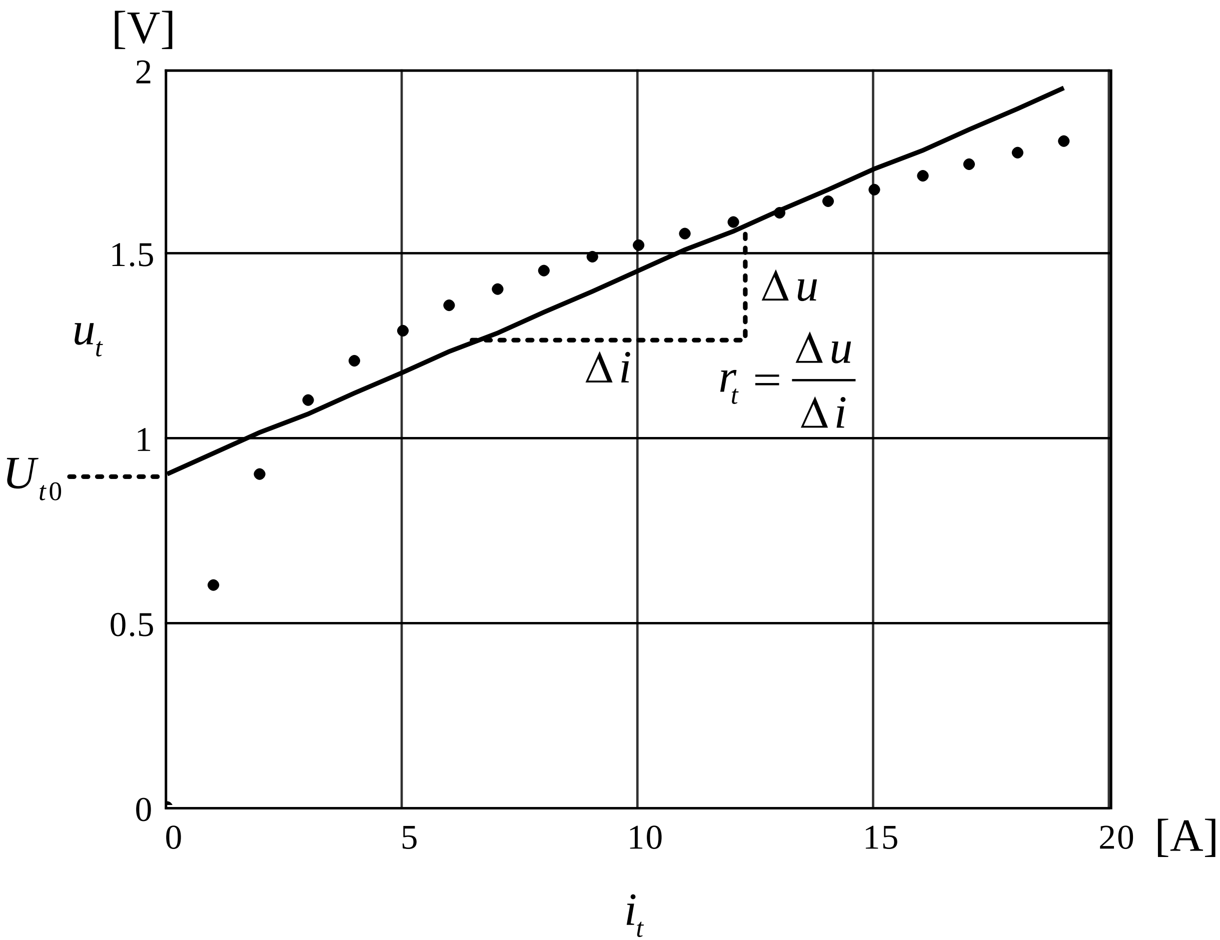
Maximum Rated Values[1)]

Parameter[2)]	Symbol	Conditions	min	max	Unit
Collector-emitter voltage	V_{CES}			2500	V
DC collector current	I_C	T_c = 75 °C		2000	A
Repetitive peak collector current	I_{CM}			4000	A
Gate-emitter voltage	V_{GES}			± 20	V
Total power dissipation	P_{tot}	T_c = 25 °C, (IGBT)		18000	W
DC forward current	I_F	T_c = 75 °C		2000	A
Repetitive peak forward current	I_{FM}			4000	A
Surge current	I_{FSM}	V_R = 0 V, t_p = 10 ms, T_{vj} = 125 °C, half-sinewave		23	kA
IGBT short circuit SOA	t_{psc}	V_{CC} = 1500 V, $V_{CEM} \leq$ 2500 V, $V_{GE} \leq$15V		10	µs
Junction temperature	T_{vj}		5	125	°C
Storage temperature	T_{stg}		-40	70	°C
Mounting force [2)]	F_M		65	95	kN

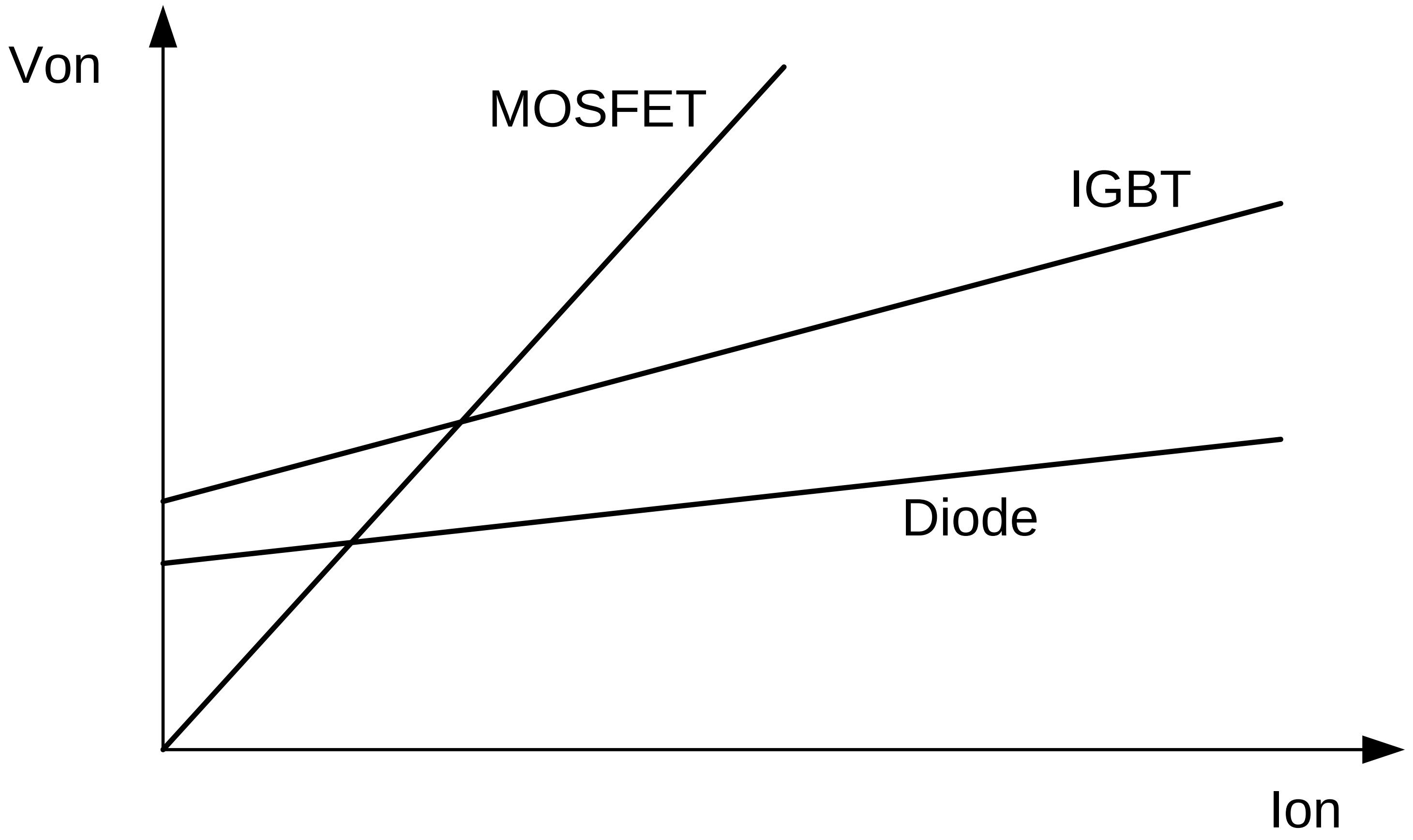
[1)]Maximum rated values indicate limits beyond which damage to the device may occur per IEC 60747-9
[2)]For detailed mounting instructions refer to ABB document no. 5SYA 2037-02

Source: ABB

Approximation of voltage drop



Voltage drop



Review of basics

- Steady state
- Mean value, RMS-value
- Phasor representation
- Active, reactive, and complex power
- Three-phase circuits
- Inductor
- Capacitor

Block Diagram of DC-DC Converters

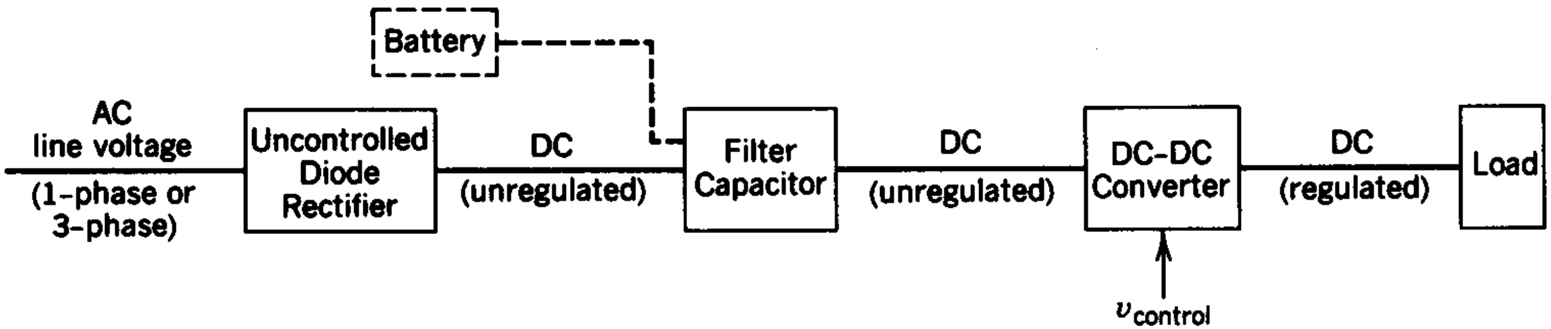
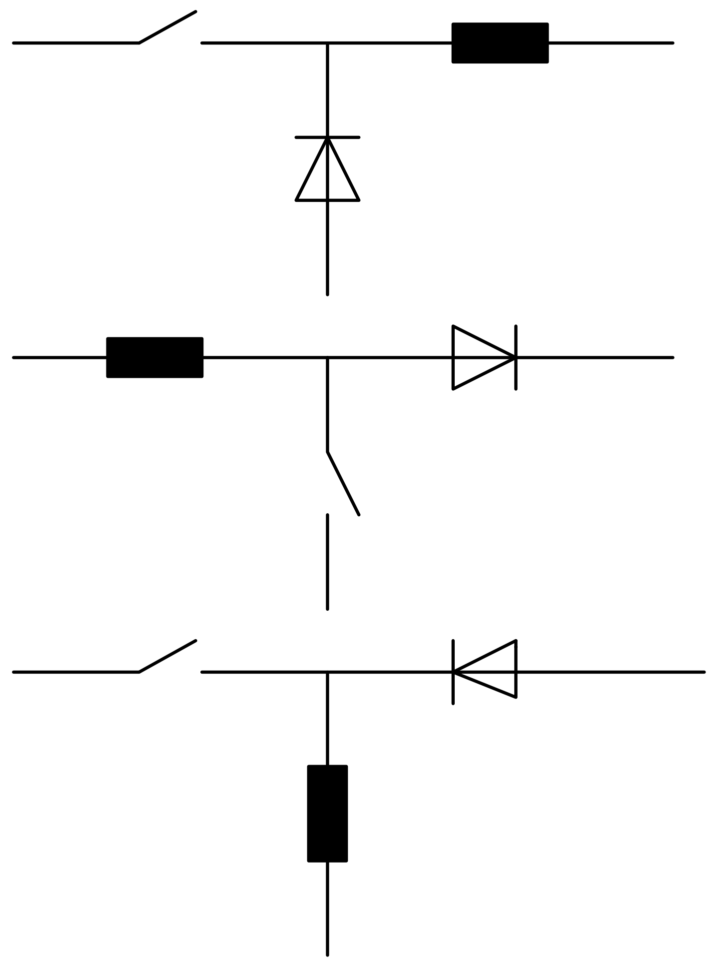


Figure 7-1 A dc–dc converter system.

- Functional block diagram

DC-DC converter types



Stepping Down a DC Voltage

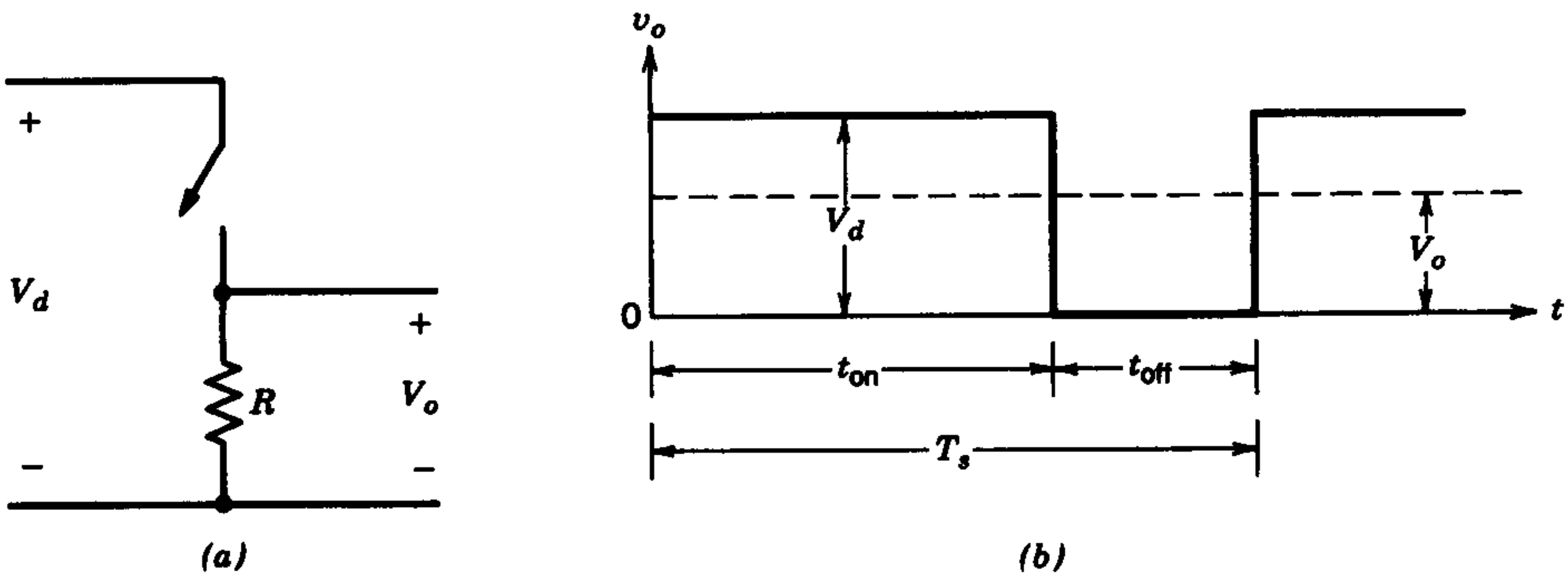


Figure 7-2 Switch-mode dc–dc conversion.

Step-Down DC-DC Converter

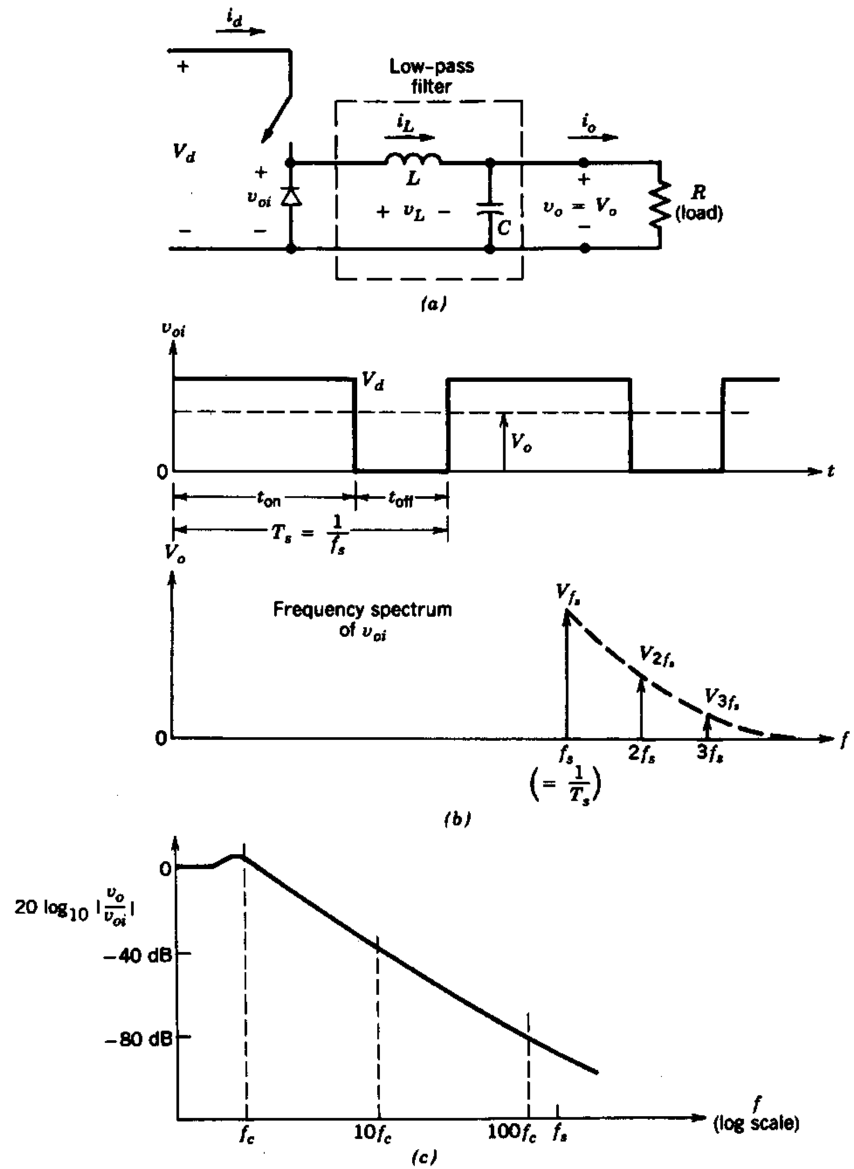


Figure 7-4 Step-down dc–dc converter.

- Pulsating input to the low-pass filter

Step-Down DC-DC Converter: Waveforms

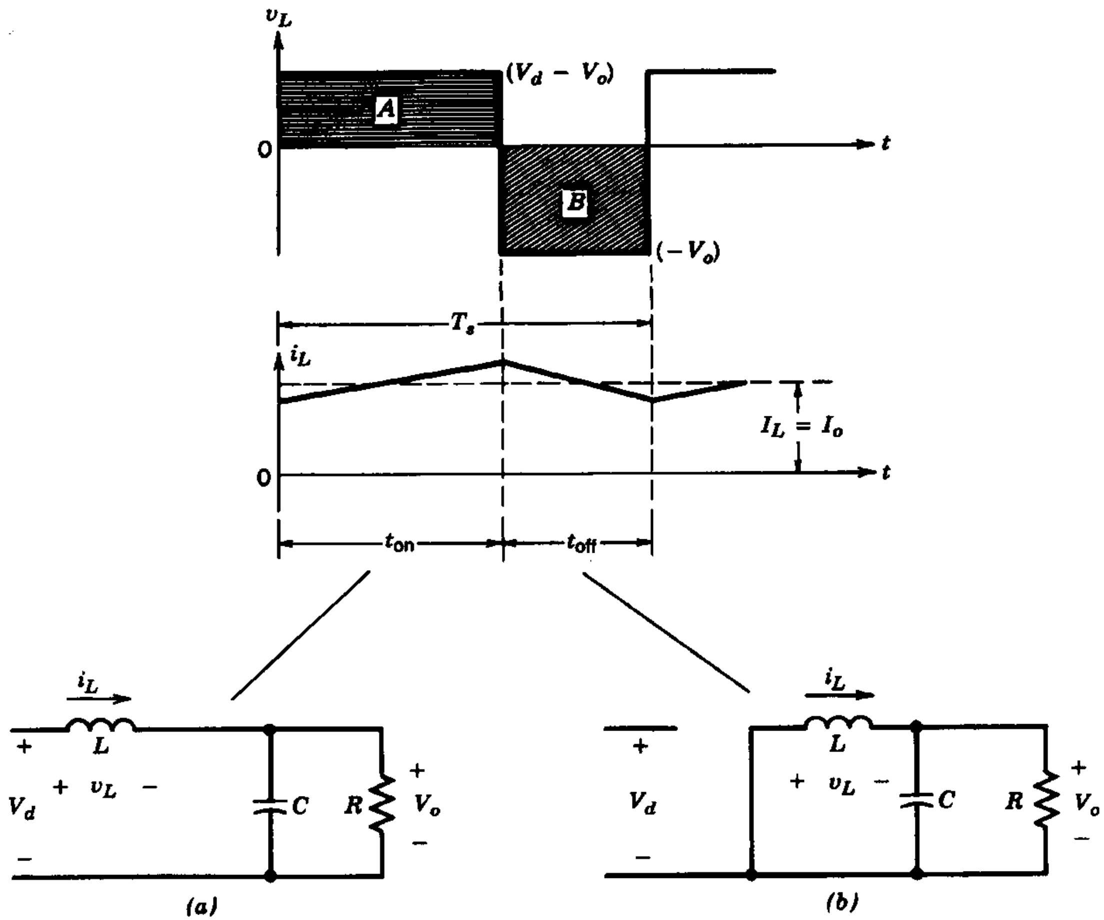


Figure 7-5 Step-down converter circuit states (assuming i_L flows continuously): (*a*) switch on; (*b*) switch off.

- Steady state; inductor current flows continuously