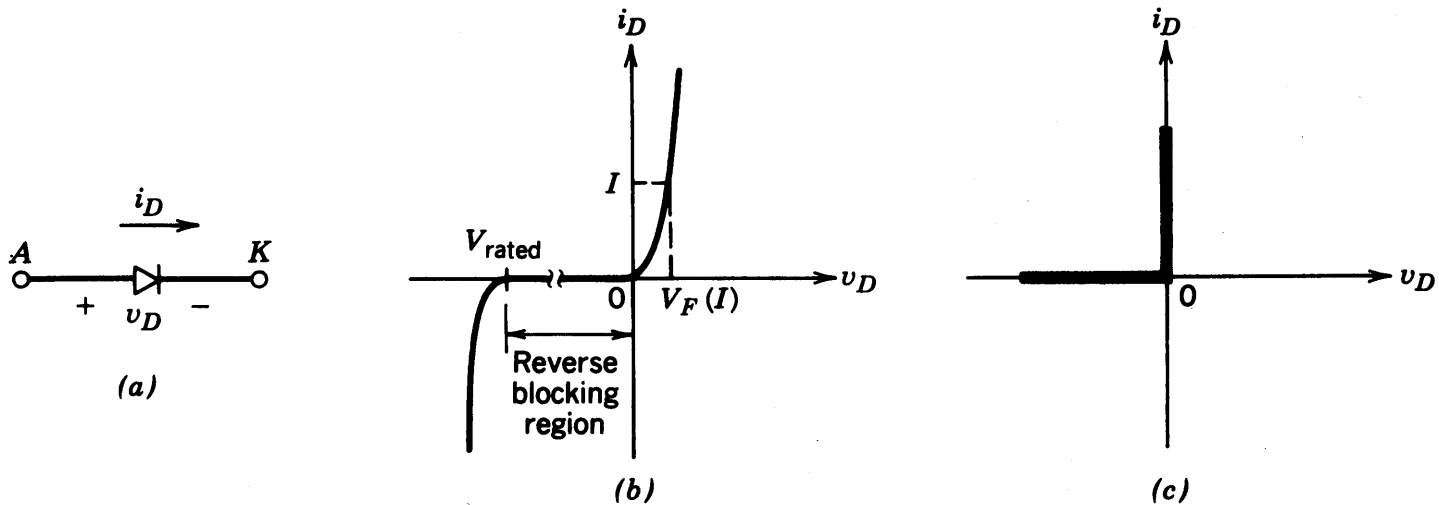


# Chapter 2 Overview of Power Semiconductor Devices

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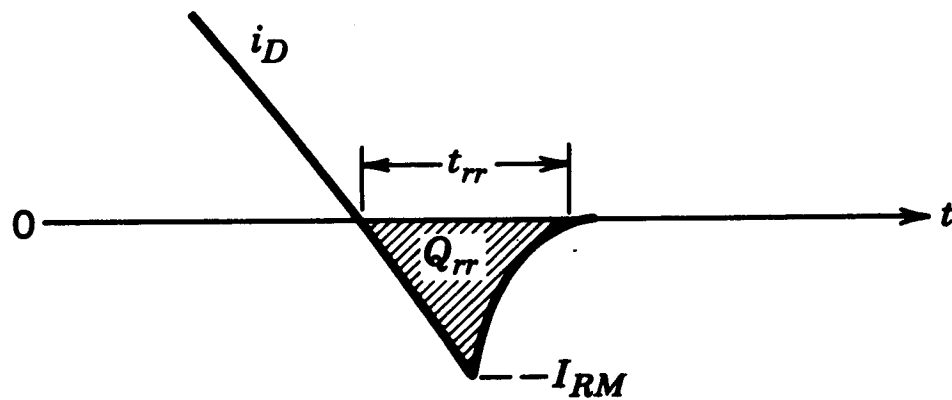
# Diodes



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

- On and off states controlled by the power circuit

# Diode Turn-Off



**Figure 2-2** Diode turn-off.

- Fast-recovery diodes have a small reverse-recovery time

# Thyristors

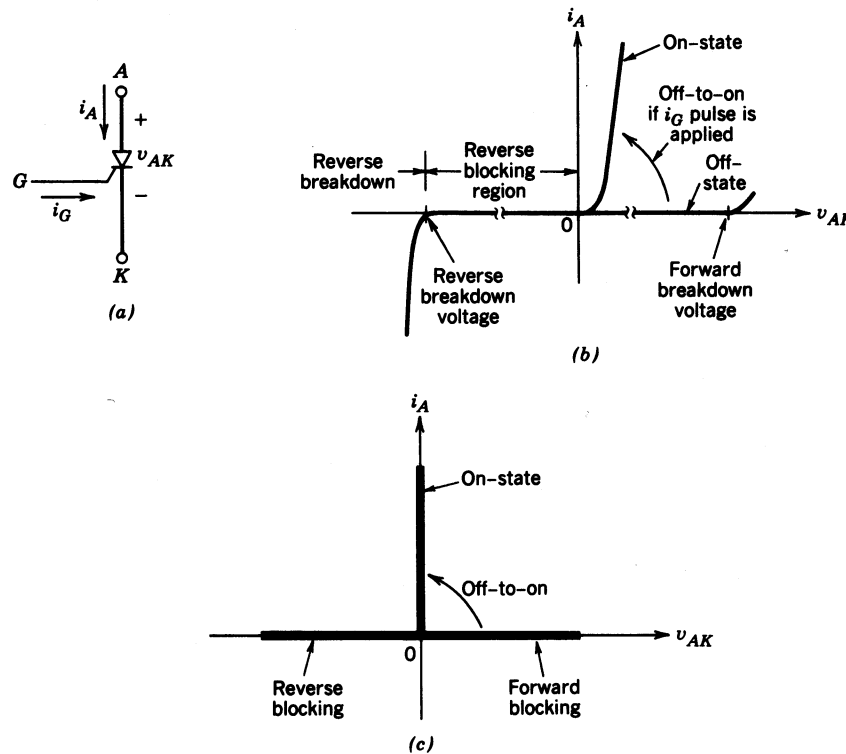


Figure 2-3 Thyristor: (a) symbol, (b)  $i$ - $v$  characteristics, (c) idealized characteristics.

- Semi-controlled device
- Latches ON by a gate-current pulse if forward biased
- Turns-off if current tries to reverse

# Thyristor in a Simple Circuit

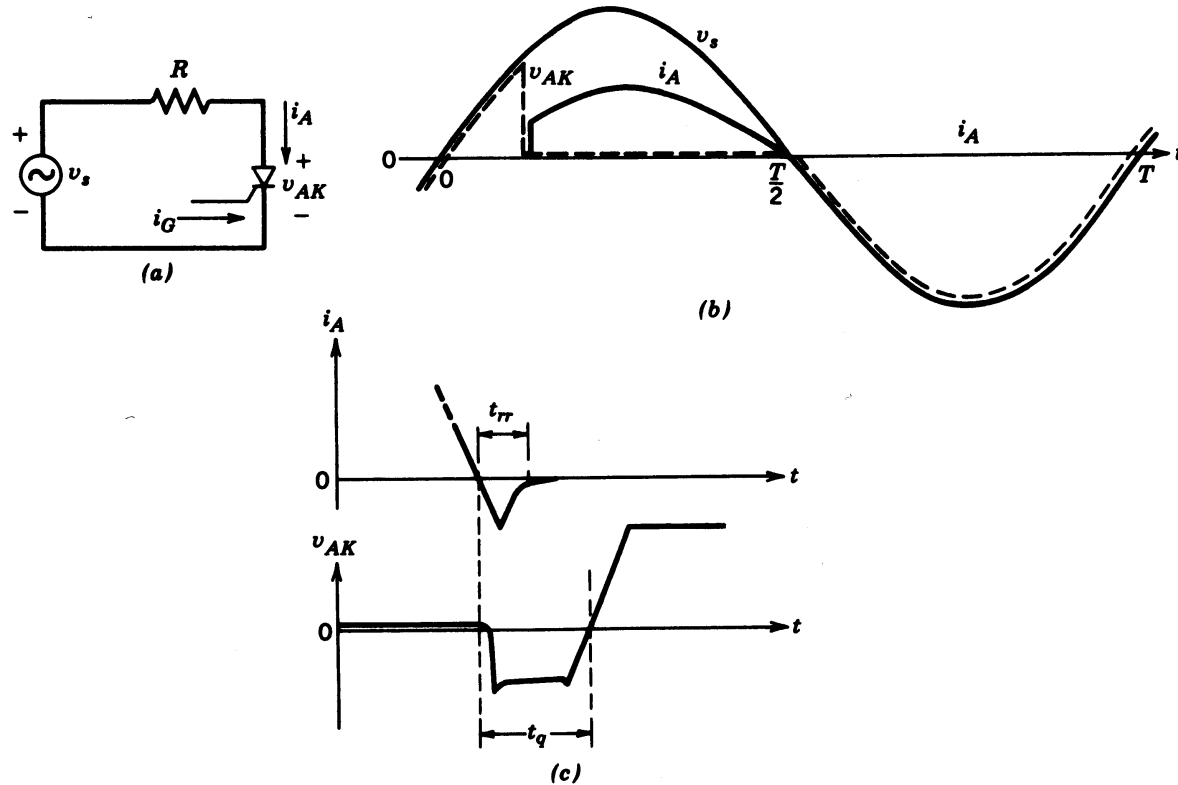
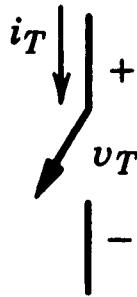


Figure 2-4 Thyristor: (a) circuit, (b) waveforms, (c) turn-off time interval  $t_q$ .

- For successful turn-off, reverse voltage required for an interval greater than the turn-off interval

# 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)

- Switching Power Loss is proportional to:
- switching frequency
  - turn-on and turn-off times

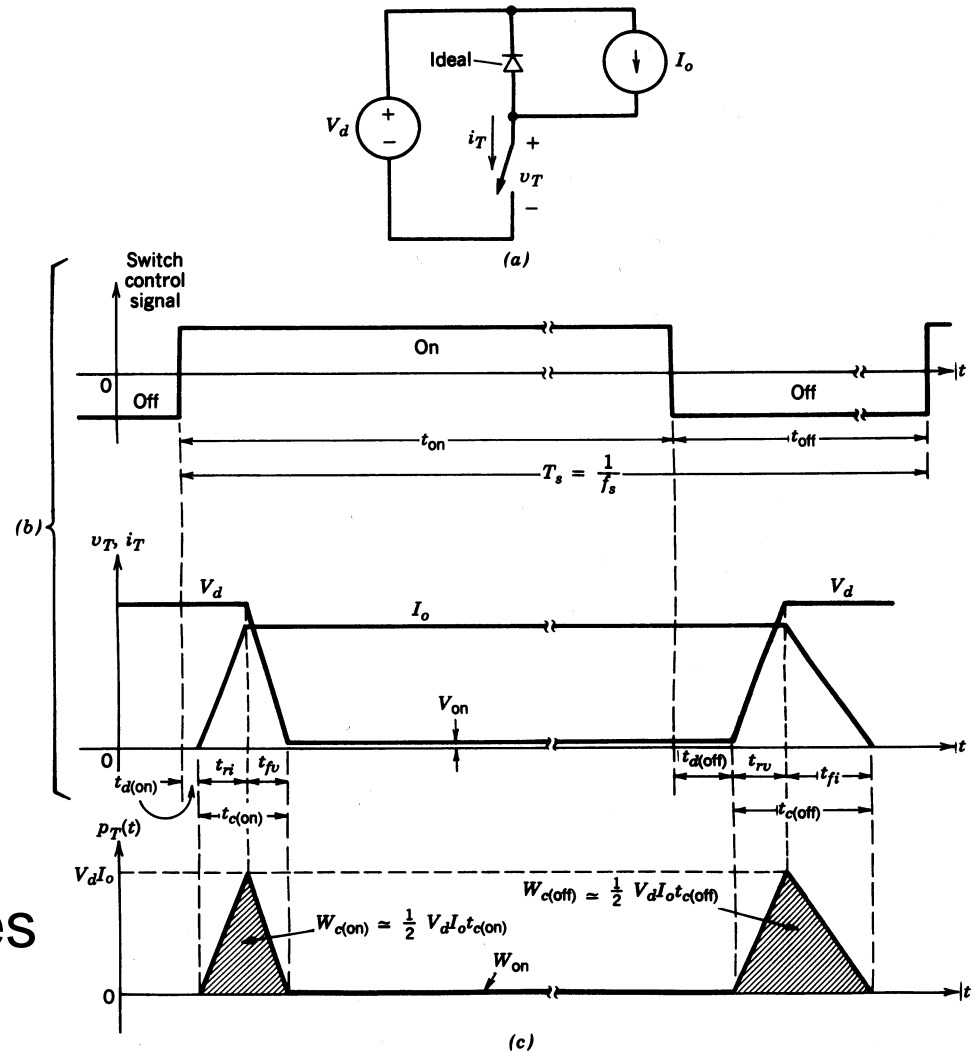
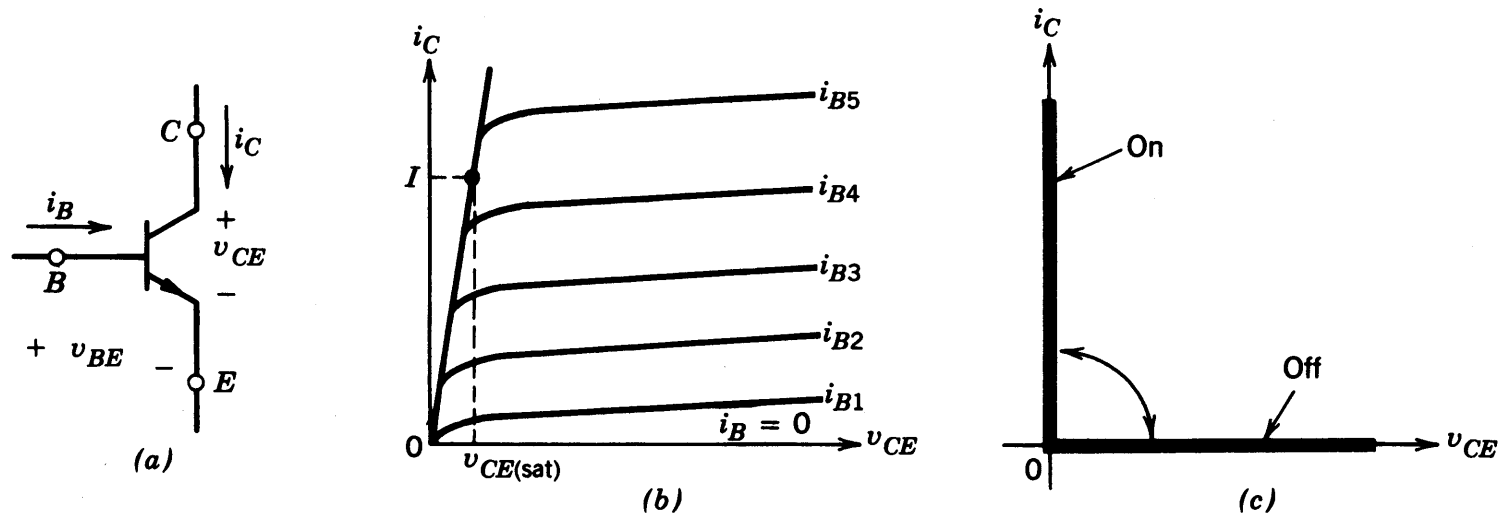


Figure 2-6 Generic-switch switching characteristics (linearized): (a) simplified clamped-inductive-switching circuit, (b) switch waveforms, (c) instantaneous switch power loss.

# Bipolar Junction Transistors (BJT)

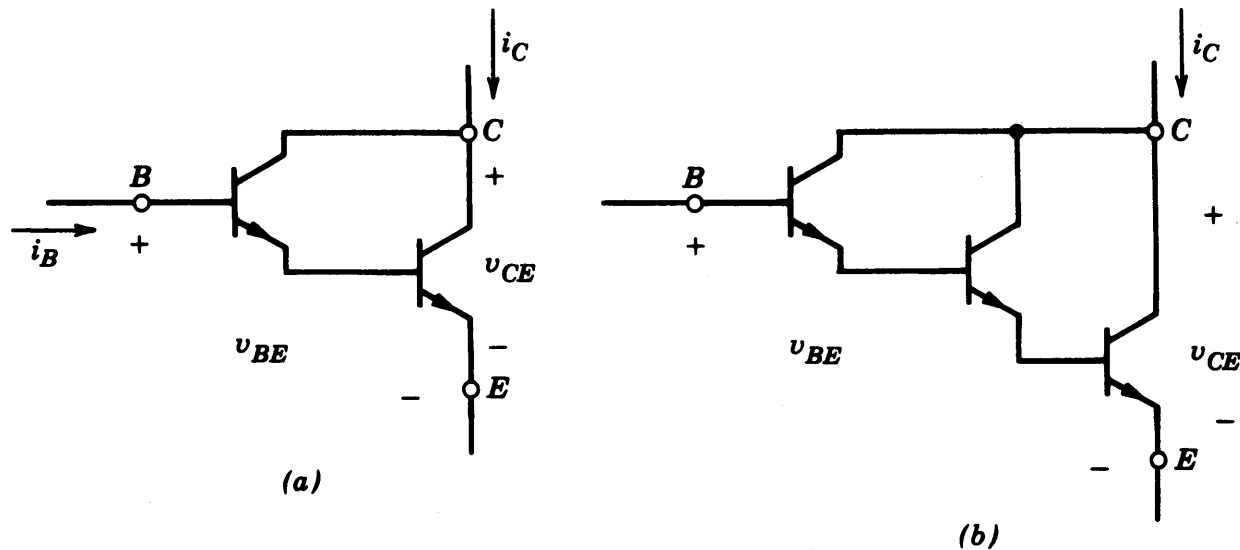


**Figure 2-7** A BJT: (a) symbol, (b)  $i$ - $v$  characteristics, (c) idealized characteristics.

- Used commonly in the past
- Now used in specific applications
- Replaced by MOSFETs and IGBTs

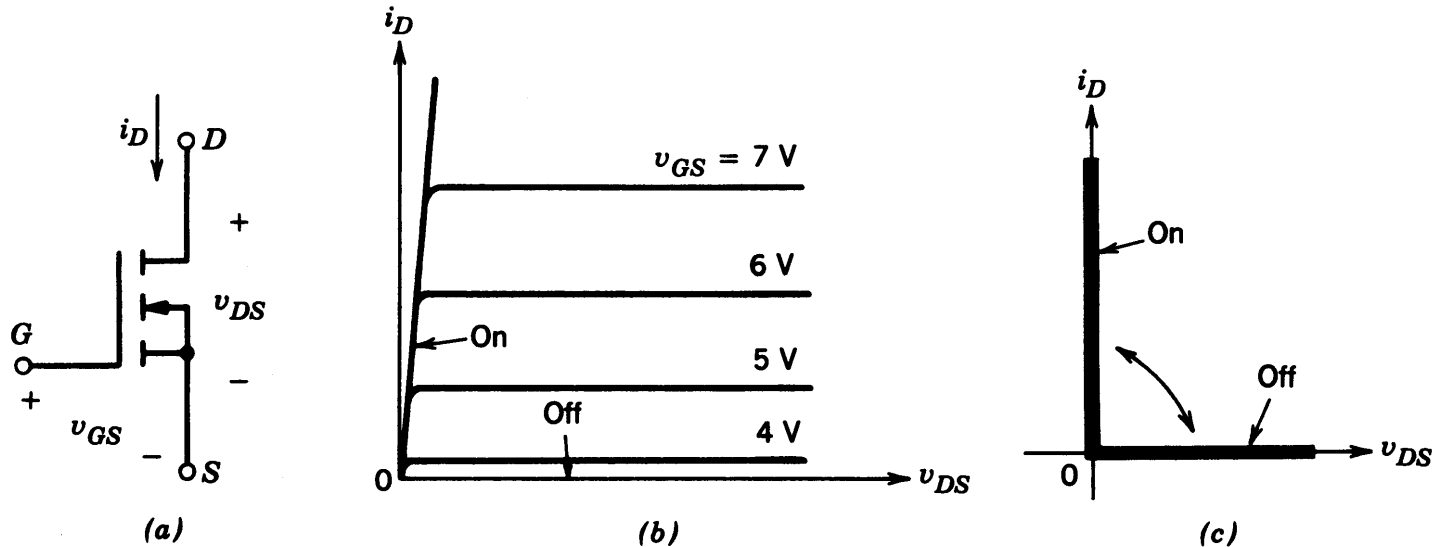


# Various Configurations of BJTs



**Figure 2-8** Darlington configurations: (a) Darlington, (b) triple Darlington.

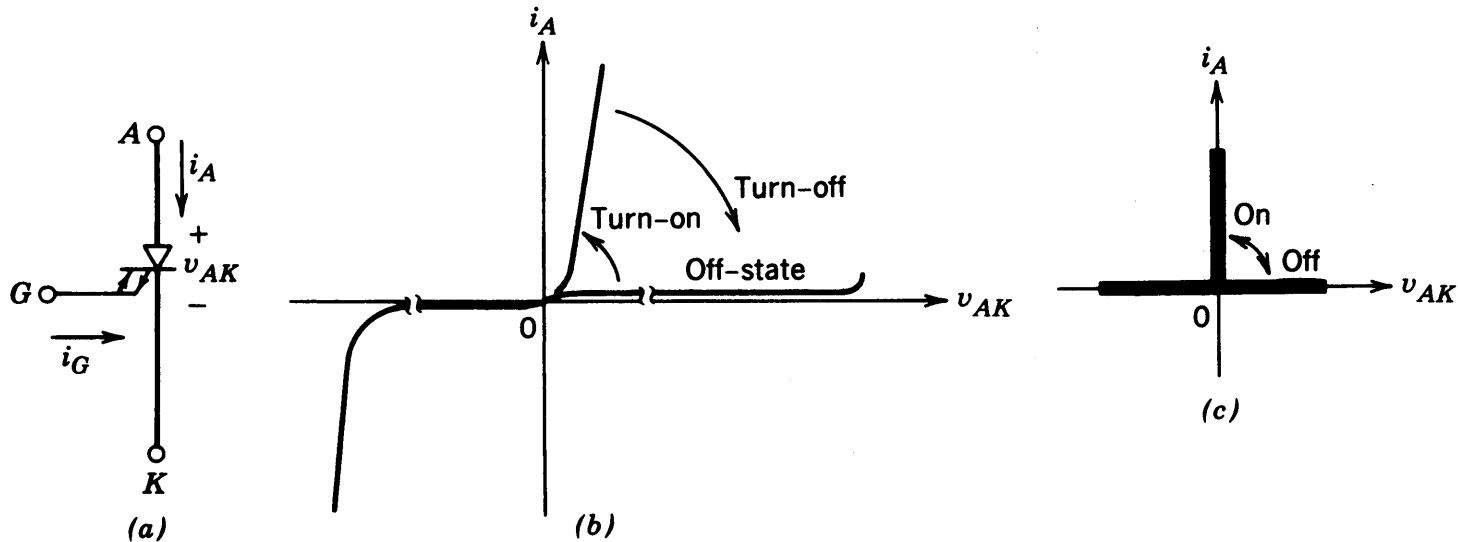
# MOSFETs



**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

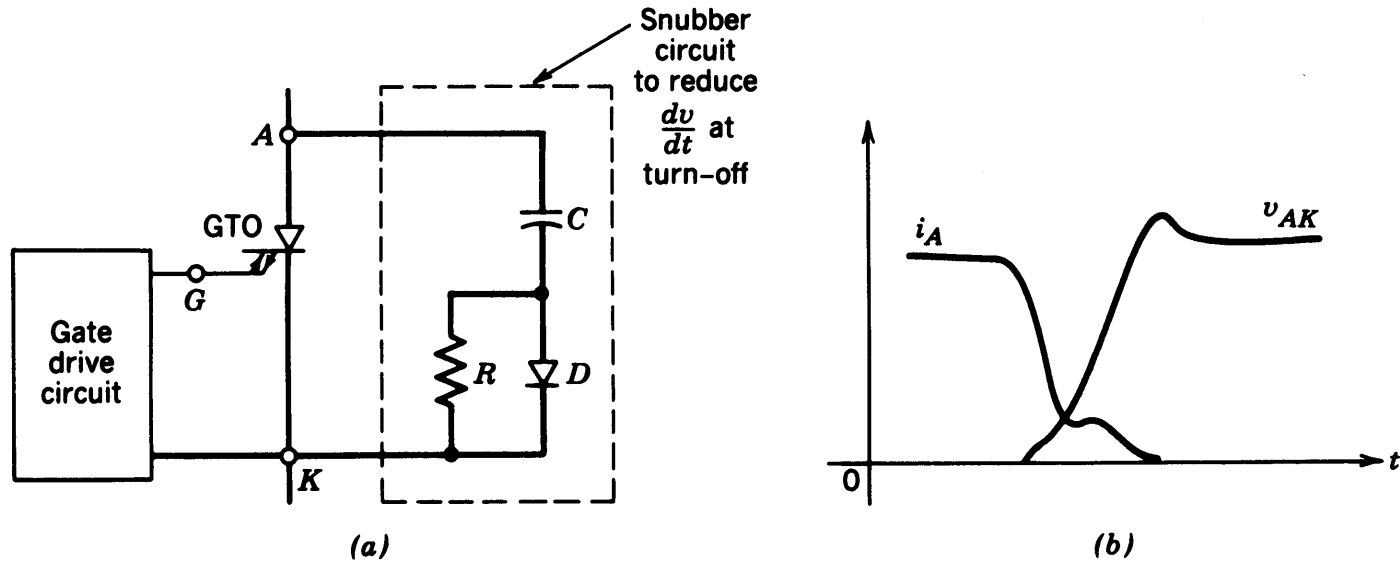
# Gate-Turn-Off Thyristors (GTO)



**Figure 2-10** A GTO: (a) symbol, (b)  $i$ - $v$  characteristics, (c) idealized characteristics.

- Slow switching speeds
- Used at very high power levels
- Require elaborate gate control circuitry

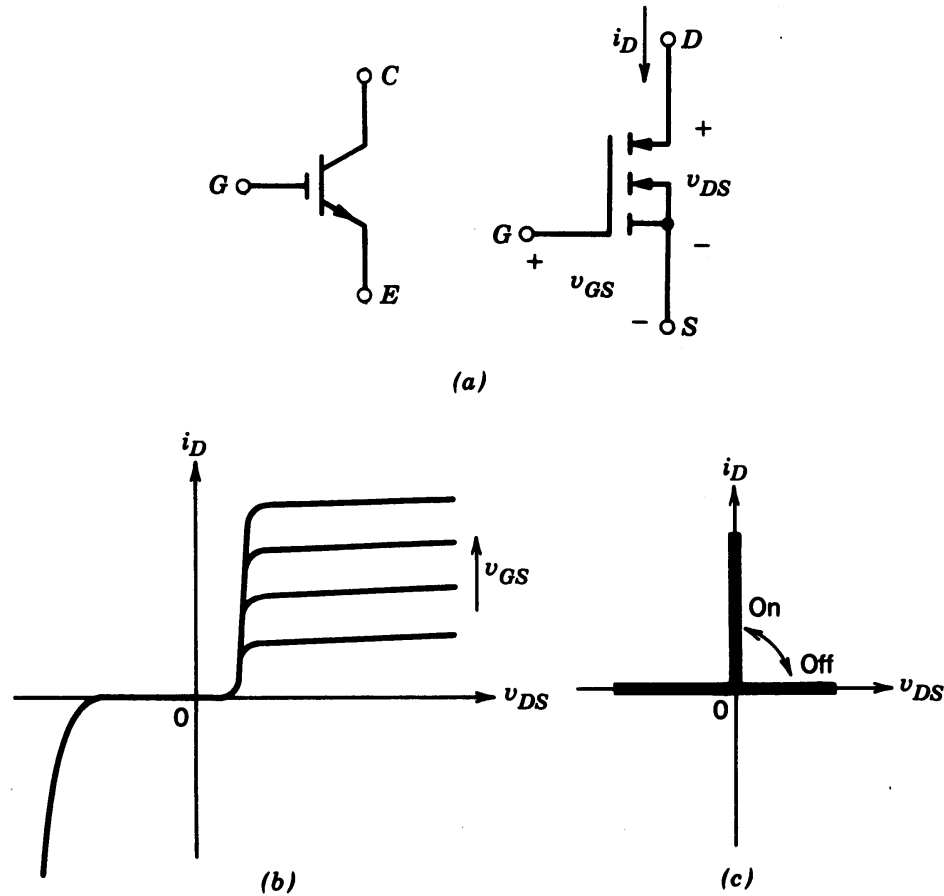
# GTO Turn-Off



**Figure 2-11** Gate turn-off transient characteristics: (a) snubber circuit, (b) GTO turn-off characteristic.

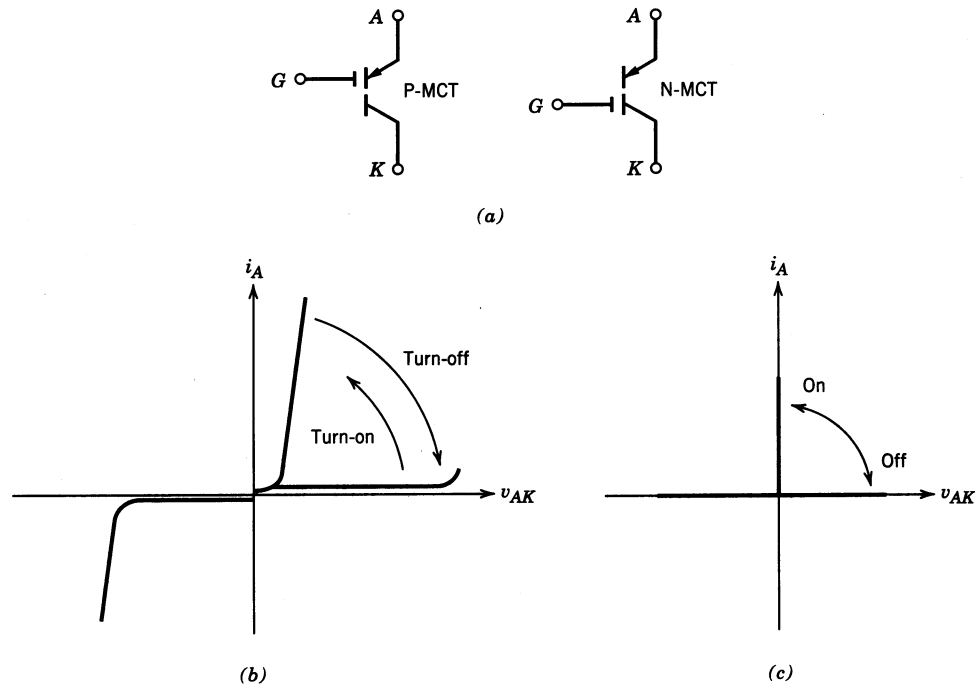
- Need a turn-off snubber

# IGBT



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

# MCT



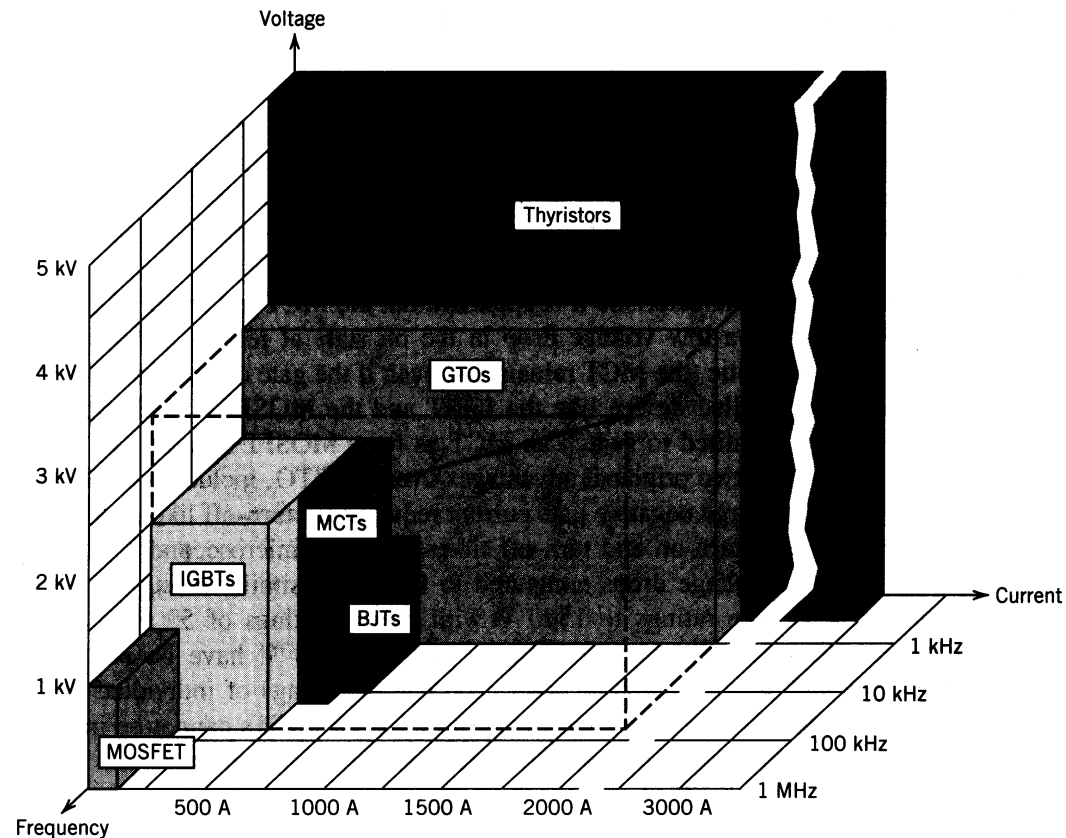
**Figure 2-13** An MCT: (a) circuit symbols, (b)  $i$ - $v$  characteristic, (c) idealized characteristics.

# Comparison of Controllable Switches

**Table 2-1** Relative Properties of Controllable Switches

<i>Device</i>	<i>Power Capability</i>	<i>Switching Speed</i>
<b>BJT/MD</b>	<b>Medium</b>	<b>Medium</b>
<b>MOSFET</b>	<b>Low</b>	<b>Fast</b>
<b>GTO</b>	<b>High</b>	<b>Slow</b>
<b>IGBT</b>	<b>Medium</b>	<b>Medium</b>
<b>MCT</b>	<b>Medium</b>	<b>Medium</b>

# Summary of Device Capabilities



**Figure 2-14** Summary of power semiconductor device capabilities. All devices except the MCT have a relatively mature technology, and only evolutionary improvements in the device capabilities are anticipated in the next few years. However, MCT technology is in a state of rapid expansion, and significant improvements in the device capabilities are possible, as indicated by the expansion arrow in the diagram.