current to rise to the holding current value I_H. In practice, the pulse width t_G is normally made more than the turn-on time t_{on} of the thyristor.

Example 7.1 Finding the Critical Value of *dv/dt* for a Thyristor

The capacitance of reverse-biased junction J_2 in a thyristor is $C_{J2} = 20$ pF and can be assumed to be independent of the off-state voltage. The limiting value of the charging current to turn on the thyristor is 16 mA. Determine the critical value of dv/dt.

Solution

$C_{J2} = 20$ pF and $i_{J2} = 16$ mA. Because $d(C_{J2})/dt = 0$, we can find the critical value of dv/dt from Eq. (7.6):

$$\frac{dv}{dt} = \frac{i_{J2}}{C_{J2}} = \frac{16 \times 10^{-3}}{20 \times 10^{-12}} = 800\ \text{V}/\mu\text{s}$$

THYRISTOR TYPES

Thyristors are manufactured almost exclusively by diffusion. The anode current requires a finite time to propagate to the whole area of the junction, from the point near the gate when the gate signal is initiated for turning on the thyristor. The manufacturers use various gate structures to control the *di/dt*, turn-on time, and turn-off time. Thyristors can easily be turned on with a short pulse. For turning off, they require special drive circuitry or special internal structures to aid in the turning-off process. There are several versions of thyristors with turn-off capability and the goal of any new device is to improve on the turn-off capability. With the emergence of new devices with both turn-on and turn-off capability, the device with just the turn-on capability is referred to as "conventional thyristor," or just "thyristor." Other members of the thyristor or silicon-controlled rectifier (SCR) family have acquired other names based on acronyms. The use of the term *thyristor* is generally meant to be the conventional thyristor. Depending on the physical construction, and turn-on and turn-off behavior ers use various gate structures to control the *di/dt*, turn-on time, and turn-off time. Thyristors can easily be turned on with a short pulse. For turning off, they require special drive circuitry or special internal structures to aid in the turning-off process. There are several versions of thyristors with turn-off capability and the goal of any new device is to improve on the turn-off capability. With the emergence of new devices with both turn-on and turn-off capability, the device with just the turn-on capability is referred to as "conventional thyristor," or just "thyristor." Other members of the thyristor or silicon-controlled rectifier (SCR) family have acquired other names based on acronyms. The use of the term *thyristor* is generally meant to be the conventional thyristor. Depending on the physical construction, and turn-on and turn-off behavior, thyristors can be broadly classified into 13 categories:

1. Phase-controlled thyristors (or SCRs)
2. Bidirectional phase-controlled thyristors (BCTs)
3. Fast switching thyristors (or SCRs)
4. Light-activated silicon-controlled rectifiers (LASCRs)

Controlled Rectifiers

learning objectives of this chapter are as follows:

- To understand the operation and characteristics of controlled rectifiers
- To learn the types of controlled rectifiers
- To understand the performance parameters of controlled rectifiers
- To learn the techniques for analysis and design of controlled rectifier circuits
- To learn the techniques for simulating controlled rectifiers by using SPICE
- To study effects of load inductance on the load current

INTRODUCTION

We have seen in Chapter 3 that diode rectifiers provide a fixed output voltage only. To obtain controlled output voltages, phase-control thyristors are used instead of diodes. … r rectifiers is varied by controlling the delay or firing

These phase-controlled rectifiers are simple and less expensive; and the efficiency of these rectifiers is, in general, above 95%. Because these rectifiers convert from ac to dc, these controlled rectifiers are also called *ac–dc converters* and are used extensively in industrial applications, especially in variable-speed drives, ranging from fractional horsepower to megawatt power level.

The phase-control converters can be classified into two types, depending on the input supply: (1) single-phase converters, and (2) three-phase converters. Each type can be subdivided into (a) semiconverter, (b) full converter, and (c) dual converter. A *semiconverter* is a one-quadrant converter and it has one polarity of output voltage and current. A *full converter* is a two-quadrant converter and the polarity of its output voltage can be either positive or negative. However, the output current of full converter has one polarity only. A *dual converter* can operate in four quadrants; and both the output voltage and current can be either positive or negative. In some applications, converters are connected in series to operate at higher voltages and to improve the input power factor (PF).

The method of Fourier series similar to that of diode rectifiers can be applied to analyze the performances of phase-controlled converters with RL loads. However, to simplify the analysis, the load inductance can be assumed sufficiently high so that the load current is continuous and has negligible ripple.

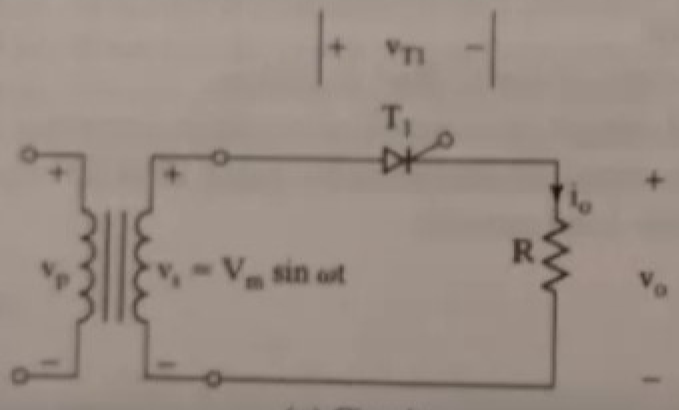
PRINCIPLE OF PHASE-CONTROLLED CONVERTER OPERATION

Let us consider the circuit in Figure 10.1a with a resistive load. During the positive half-cycle of input voltage, the thyristor anode is positive with respect to its cathode and the thyristor is said to be *forward biased*. When thyristor T_1 is fired at $\omega t = \alpha$

load current is continuous and has negligible ripple

10.2 PRINCIPLE OF PHASE-CONTROLLED CONVERTER OPERATION

Let us consider the circuit in Figure 10.1a with a resistive load. During the positive half-cycle of input voltage, the thyristor anode is positive with respect to its cathode and the thyristor is said to be *forward biased*. When thyristor T_1 is fired at $\omega t = \alpha$, thyristor T_1 conducts and the input voltage appears across the load. When the input voltage starts to be negative at $\omega t = \pi$, the thyristor anode is negative with respect to its cathode and thyristor T_1 is said to be *reverse biased*; and it is turned off. The time



(a) Circuit