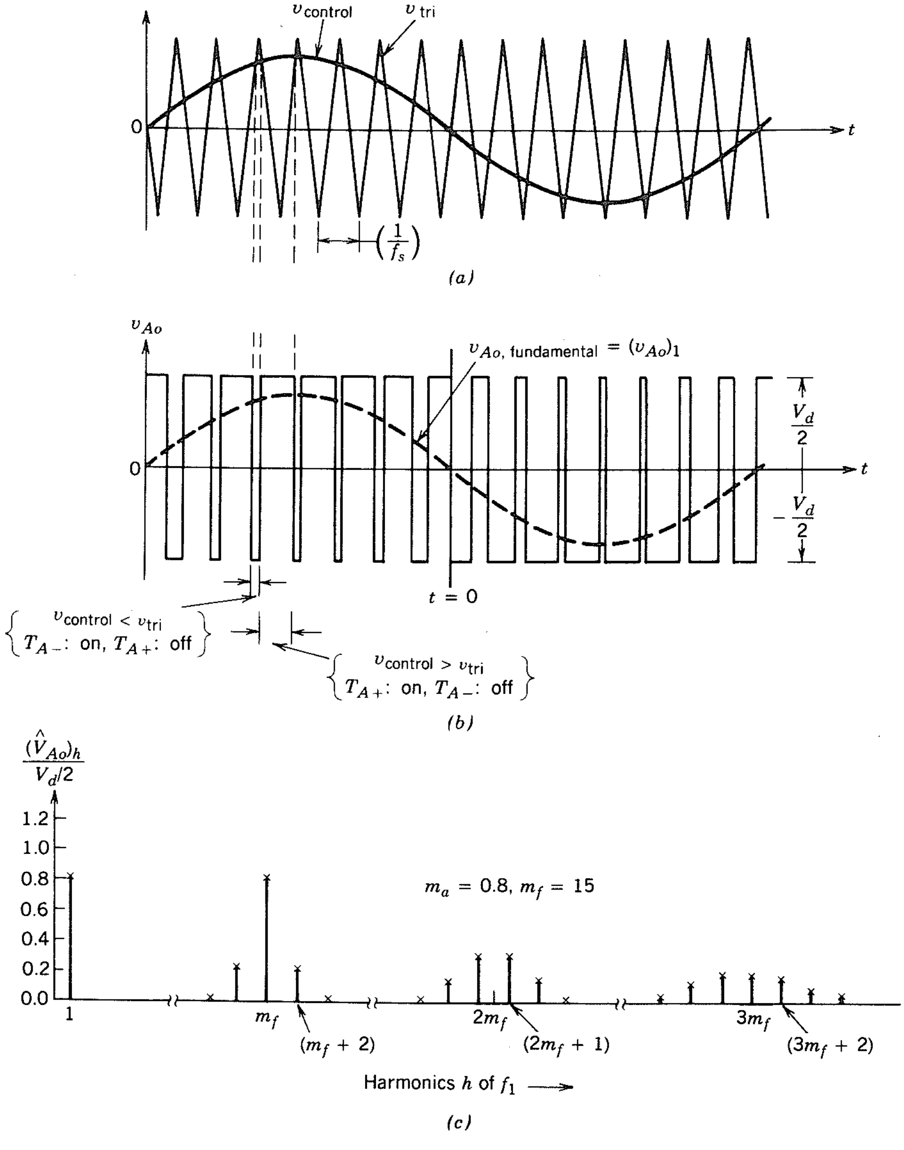

Figure 8-5 Pulse-width modulation.

The frequency modulation ratio m_f is defined as

$$m_f = \frac{f_s}{f_1}$$

In the inverter of Fig. 8-4*b*, the switches T_{A+} and T_{A-} are controlled based on comparison of v_{control} and v_{tri}, and the following output voltage results, independent of direction of i_o:

$$v_{\text{control}} > v_{\text{tri}}, \qquad T_{A+} \text{ is on}, \qquad v_{Ao} = \tfrac{1}{2}V_d$$

or

$$v_{\text{control}} < v_{\text{tri}}, \qquad T_{A-} \text{ is on}, \qquad v_{Ao} = -\tfrac{1}{2}V_d$$

Since the two switches are never off simultaneously, the output voltage v_{Ao} fluctuates between two values ($\frac{1}{2}V_d$ and $-\frac{1}{2}V_d$). Voltage v_{Ao} and its fundamental frequency component (dashed curve) are shown in Fig. 8-5*b*, which are drawn for $m_f = 15$ and $m_a = 0.8$.

The harmonic spectrum of v_{Ao} under the conditions indicated in Figs. 8-5*a* and 8-5*b* is shown in Fig. 8-5*c*, where the normalized harmonic voltages $(\hat{V}_{Ao})_h/\frac{1}{2}V_d$ having significant amplitudes are plotted. This plot (for $m_a \le 1.0$) shows three items of importance:

1. The peak amplitude of the fundamental-frequency component $(\hat{V}_{Ao})_1$ is m_a times $\frac{1}{2}V_d$. This can be explained by first considering a constant v_{control} as shown in Fig. 8-6*a*. This results in an output waveform v_{Ao}. From the discussion of Chapter 7 regarding the PWM in a full-bridge dc–dc converter, it can be noted that the average output voltage (or more specifically, the output voltage averaged over one switching time period $T_s = 1/f_s$) V_{Ao} depends on the ratio of v_{control} to $\hat{V}_{\text{tri}}$ for a given V_d:

$$V_{Ao} = \frac{v_{\text{control}}}{\hat{V}_{\text{tri}}} \frac{V_d}{2} \qquad v_{\text{control}} \le \hat{V}_{\text{tri}} \tag{8-4}$$

Let us assume (though this assumption is not necessary) that v_{control} varies very little during a switching time period, that is, m_f is large, as shown in Fig. 8-6*b*. Therefore, assuming v_{control} to be constant over a switching time period, Eq. 8-4 indicates how the "instantaneous average" value of v_{Ao} (averaged over one switching time period T_s) varies from one switching time period to the next. This "instantaneous average" is the same as the fundamental-frequency component of v_{Ao}.

The foregoing argument shows why v_{control} is chosen to be sinusoidal to provide a sinusoidal output voltage with fewer harmonics. Let the control voltage vary sinusoidally at the frequency $f_1 = \omega_1/2\pi$, which is the desired (or the fundamental) frequency of the inverter output:

$$v_{\text{control}} = \hat{V}_{\text{control}} \sin \omega_1 t$$

where

$$\hat{V}_{\text{control}} \le \hat{V}_{\text{tri}} \tag{8-5}$$

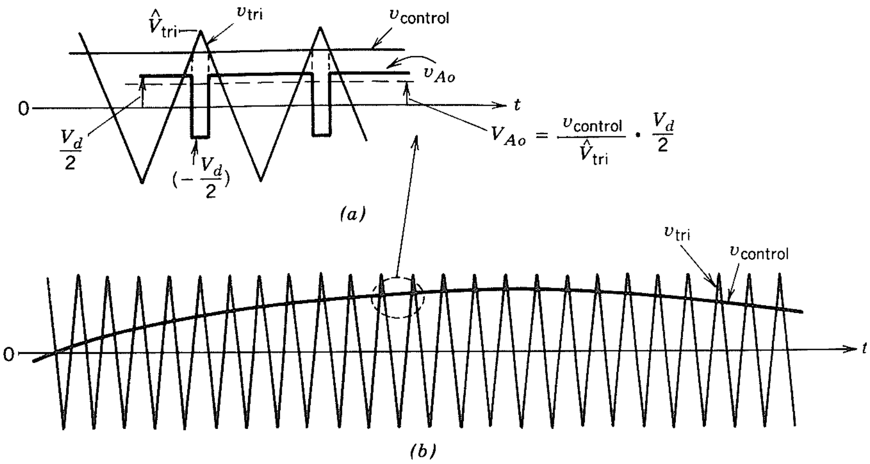

Figure 8-6 Sinusoidal PWM.