

PWM Inverter (DC-AC)

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개요

- 인버터 => DC - AC 컨버터
- 인버터 이득 = AC 출력 전압 / DC 입력 전압
 - 펄스폭 변조(PWM) 제어(가장 일반적인 방법)
- 출력 전압 가변 방법
 - 입력 DC 전압의 가변, 인버터 이득 일정
 - 입력 DC 전압 일정, 인버터 이득 가변
- 인버터 분류
 - 단상 인버터
 - 3상 인버터
- 인버터 분류
 - 전압형 인버터(VFI: voltage-fed-inverter): 입력 전압 일정
 - 전류형 인버터(CFI: current-fed inverter): 입력 전류 일정
 - 가변dc링크 인버터: 입력 전압 제어

Single-Phase Half-Bridge Inverter

- $0 < t < T_o/2$: Q1 On $\Rightarrow R, v_o = +V_s/2$
- $T_o/2 < t < T_o$: Q2 On $\Rightarrow R, v_o = -V_s/2$

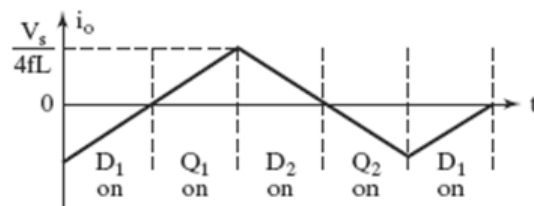
$$v_o(t) = \sum_{n=1,3,5,\dots}^{\infty} \frac{2V_s}{n\pi} \sin n\omega t$$

$$= 0 \quad \text{for } n = 2, 4, \dots$$

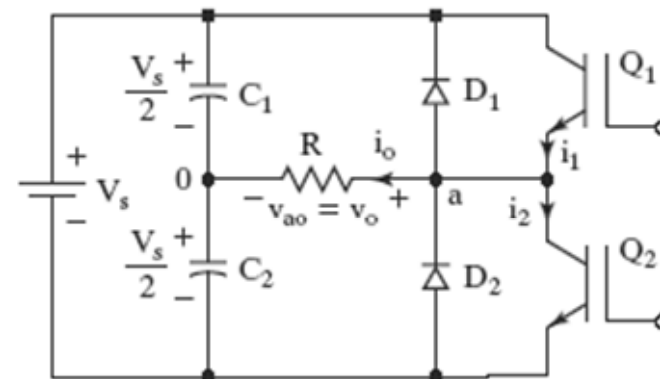
$$V_{o(rms)} = \sqrt{\frac{2}{\pi} \int_0^{\pi} \left(\frac{V_s}{2}\right)^2 d\theta} = \frac{V_s}{2}$$

$$V_{o1(rms)} = \frac{2V_s}{\sqrt{2}\pi} = 0.45 V_s$$

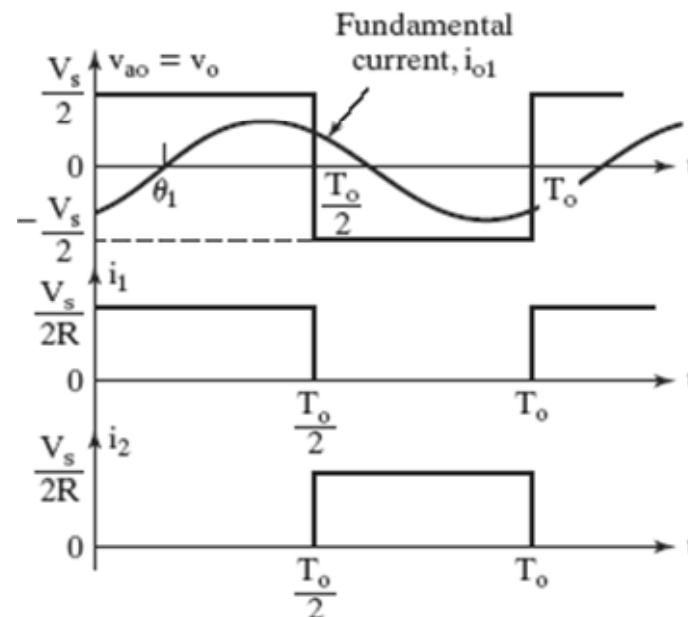
- 유도성 부하 \Rightarrow 전류 연속
 - Q1 OFF @ $T_o/2$: D2 $\Rightarrow R \Rightarrow C2$ 로 환원
 - Q2 OFF @ T_o : D1 $\Rightarrow R \Rightarrow C1$ 으로 환원



(c) Load current with highly inductive load



(a) Circuit



(b) Waveforms with resistive load

Performance Parameters

- n 차 고조파의 고조파율 HF_n
 - 개개 고조파 영향의 척도
 - n 차 고조파성분 실효치/기본파 고조파성분 실효치
- 전 고조파왜곡 THD
 - 기본파성분과 그외 파형간의 모양의 근접도
- 왜곡률 DF(distortion factor)
 - 고조파를 2차 감소(n^2)시킨후의 특별한 파형에 남아있는 고조파왜곡의 척도
 - 각각의(또는 n 차) 고조파성분의 왜곡률 DF_n
- 최저차 고조파(lowest-order harmonic) LOH
 - 기본파와 가장 가까운 고조파 성분
 - \geq 기본파성분의 3%

$$HF_n = \frac{V_{on}}{V_{o1}} \text{ for } n > 1$$

$$THD = \frac{1}{V_{o1}} \sqrt{\sum_{n=2,3,\dots}^{\infty} V_{on}^2}$$

$$DF = \frac{1}{V_{o1}} \sqrt{\sum_{n=2,3,\dots}^{\infty} \left(\frac{V_{on}}{n^2} \right)^2}$$

$$DF_n = \frac{V_{on}}{V_{o1} n^2} \text{ for } n > 1$$

$$LOH \geq 3\% \times V_{o1}$$

Single-Phase Bridge Inverter

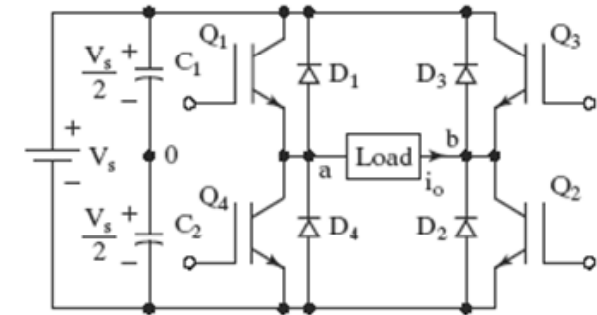
- $0 < t < T_o/2$: $Q1 \Rightarrow R \Rightarrow Q2$, $v_{ab}=V_s$
- $T_o/2 < t < T_o$: $Q3 \Rightarrow R \Rightarrow Q4$, $v_{ab}=-V_s$

$$v_o(t) = \sum_{n=1,3,5,\dots}^{\infty} \frac{4V_s}{n\pi} \sin n\omega t$$

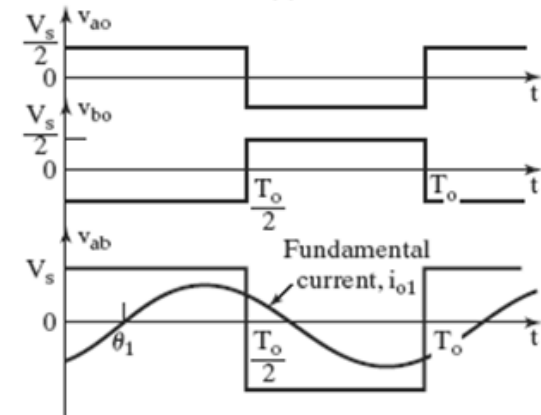
$$= 0 \quad \text{for } n = 2, 4, \dots$$

$$V_{o(rms)} = \sqrt{\frac{2}{\pi} \int_0^{\pi} V_s^2 d\theta} = V_s$$

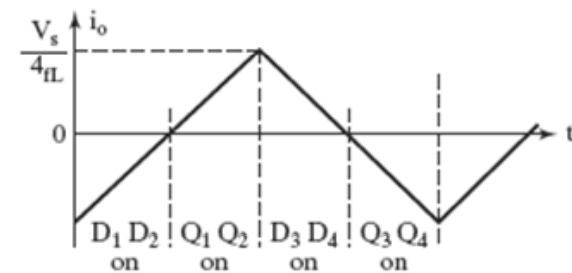
$$V_{o1(rms)} = \frac{4V_s}{\sqrt{2}\pi} = 0.90 V_s$$



(a) Circuit



(b) Waveforms



(c) Load current with highly inductive load

Example b.3

- 브리지 인버터 + RLC 부하 (a) 순시부하전류 (b) 부하전류의 THD

$$R = 10, L = 31.5mH, C = 112\mu F, f_o = 60Hz, V_s = 220V, \omega = 2\pi f = 377 \text{ rad / s}$$

$$X_L = jn\omega L = j11.87n \Omega, X_c = \frac{j}{n\omega C} = \frac{-j23.68}{n} \Omega$$

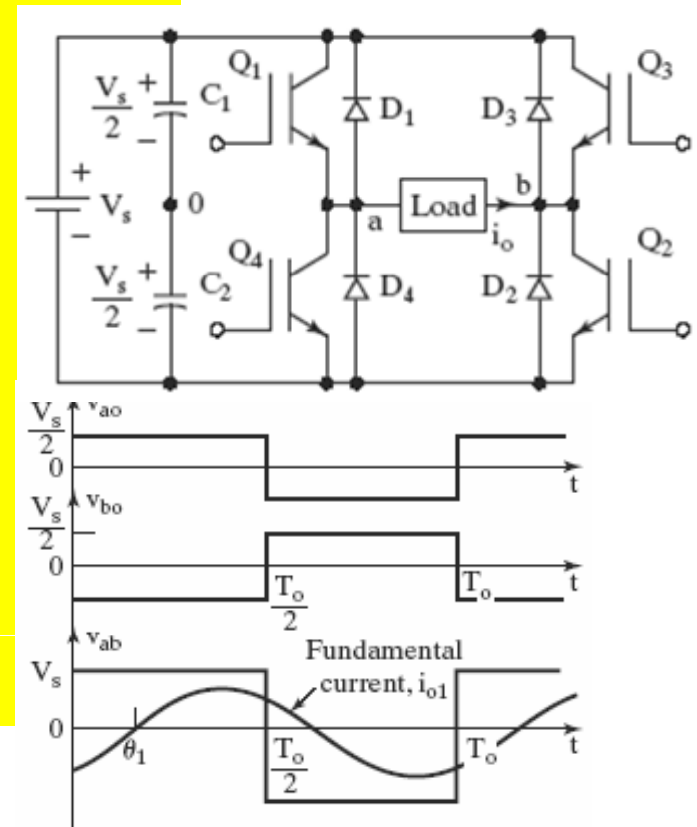
$$|Z_n| = \sqrt{R^2 + \left(n\omega L - \frac{1}{n\omega C}\right)^2} = \sqrt{10^2 + \left(11.87n - \frac{23.68}{n}\right)^2}$$

$$\theta_n = \tan^{-1} \left(\frac{11.87n}{10} - \frac{23.68}{10n} \right)$$

$$v_o(t) = \sum_{n=1,3,5,\dots}^{\infty} \frac{4V_s}{n\pi} \sin n\omega t$$

$$= 0 \quad \text{for } n = 2, 4, \dots$$

$$i_o(t) = \frac{v_o(t)}{|Z_n| \angle \theta_n} = \sum_{n=1,3,5,\dots}^{\infty} \frac{4V_s}{n\pi \sqrt{R^2 + \left(n\omega L - \frac{1}{n\omega C}\right)^2}} \sin(n\omega t - \theta_n)$$



(b) Waveforms

Example b.3

THD

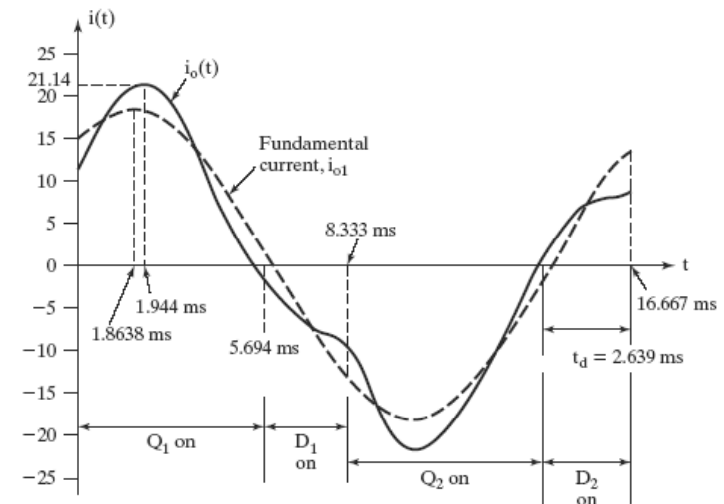
$$I_{m1} = \frac{4V_s}{n\pi \sqrt{R^2 + (n\omega L - \frac{1}{n\omega C})^2}} = 18.1A$$

9차 고조파까지 고려 :

$$I_m = (I_{m1}^2 + I_{m3}^2 + I_{m5}^2 + I_{m7}^2 + I_{m9}^2)^{1/2}$$

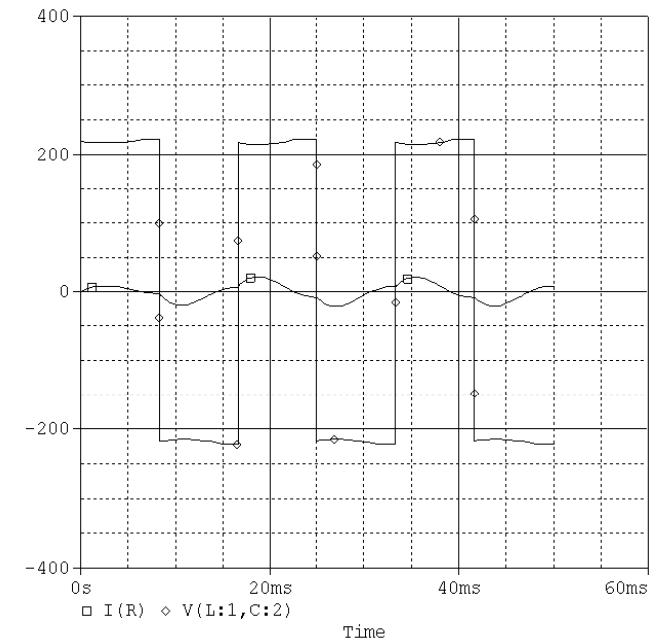
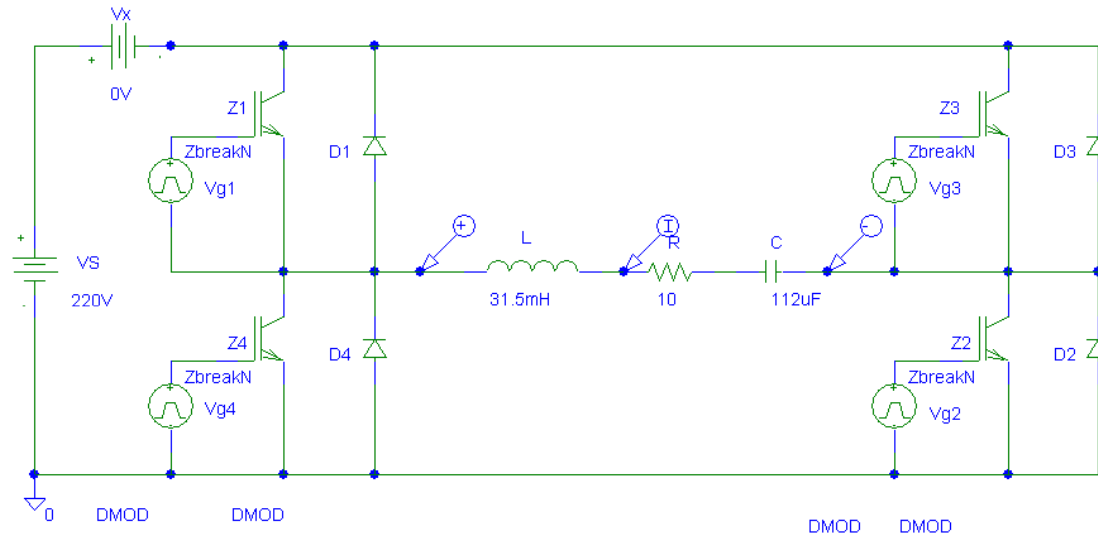
$$= (18.1^2 + 3.17^2 + 1.0^2 + 0.5^2 + 0.3^2)^{1/2} = 18.41A$$

$$THD = \frac{1}{I_{m1}} \sqrt{\sum_{n=2,3,..}^{\infty} I_{mn}^2} = \frac{1}{I_{m1}} (I_m^2 - I_{m1}^2)^{1/2} = 18.59\%$$



Example b.3

■ PSPICE Simulations



전압제어

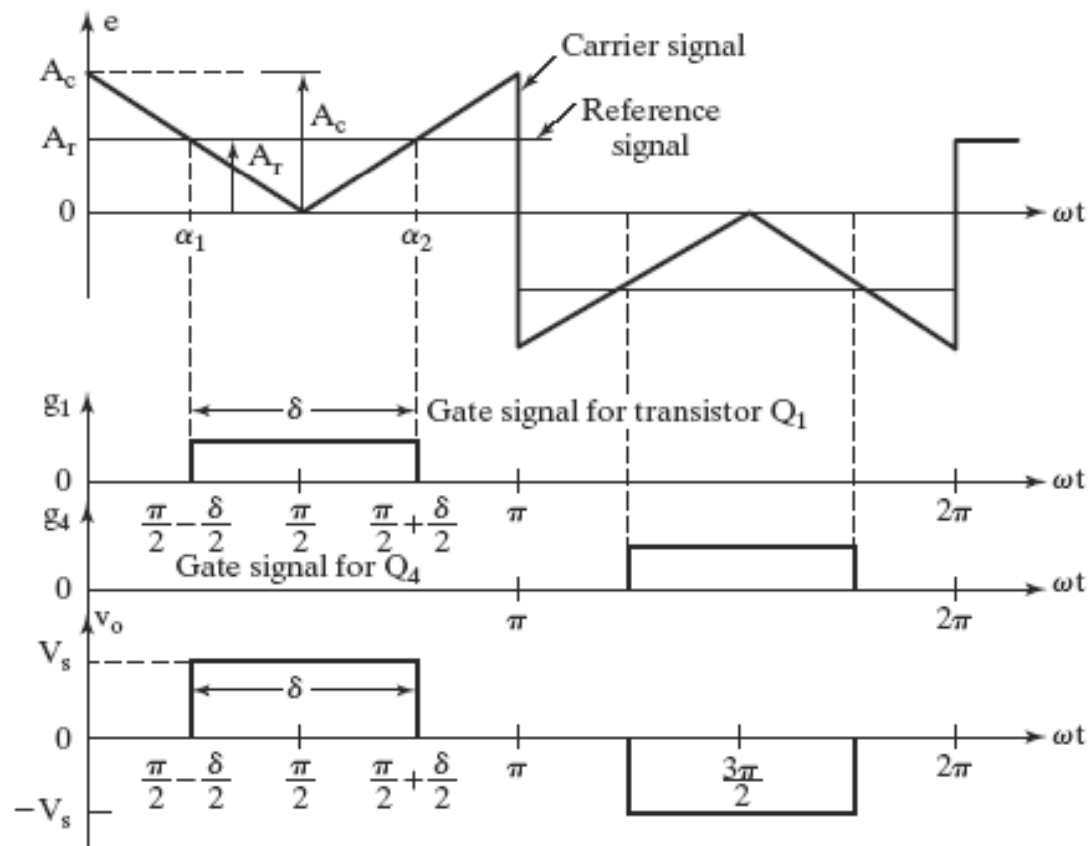
- 인버터의 전압제어 필요성
 - DC입력전압의 변동
 - 인버터의 전압조정
 - 일정 전압/주파수 제어
- 인버터 이득 변화(출력 전압 제어) 방법
 - 단펄스폭 변조
 - 다중펄스폭 변조
 - 정현파펄스폭 변조
 - 수정된 전현펄스폭 변조



Single-Pulse PWM

$$d = \frac{\delta}{\omega} = t_2 - t_1$$

$$= MT_s = M \frac{T}{2}$$



$$V_{o(rms)} = \sqrt{\frac{2}{2\pi} \int_{(\pi-\delta/2)}^{(\pi+\delta/2)} V_s^2 d\theta} = V_s \sqrt{\frac{\delta}{\pi}}$$

$$v_o(t) = \sum_{n=1,3,5,..}^{\infty} \frac{4V_s}{n\pi} \sin \frac{n\delta}{2} \sin n\omega t$$

Multiple-Pulse PWM

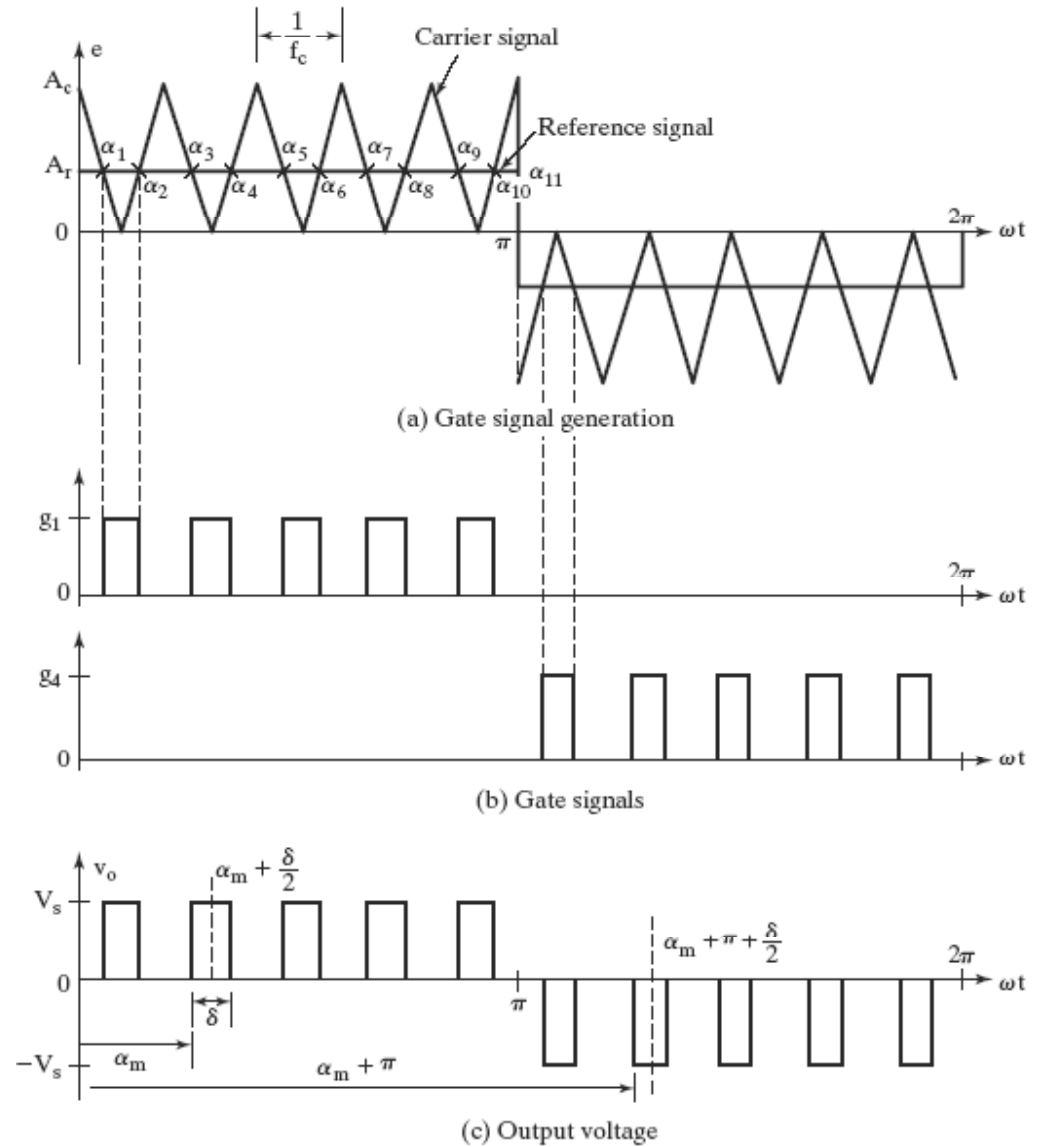
$$d = \frac{\delta}{\omega} = t_{m+1} - t_m$$

$$= MT_s = M \frac{T}{2p}$$

$$V_{o(rms)} = \sqrt{\frac{2p}{2\pi} \int_{(\pi/p-\delta)/2}^{(\pi/p+\delta)/2} V_s^2 d\theta}$$

$$= V_s \sqrt{\frac{p\delta}{\pi}}$$

$$v_o(t) = \sum_{n=1,3,5,\dots}^{\infty} B_n \sin n\omega t$$

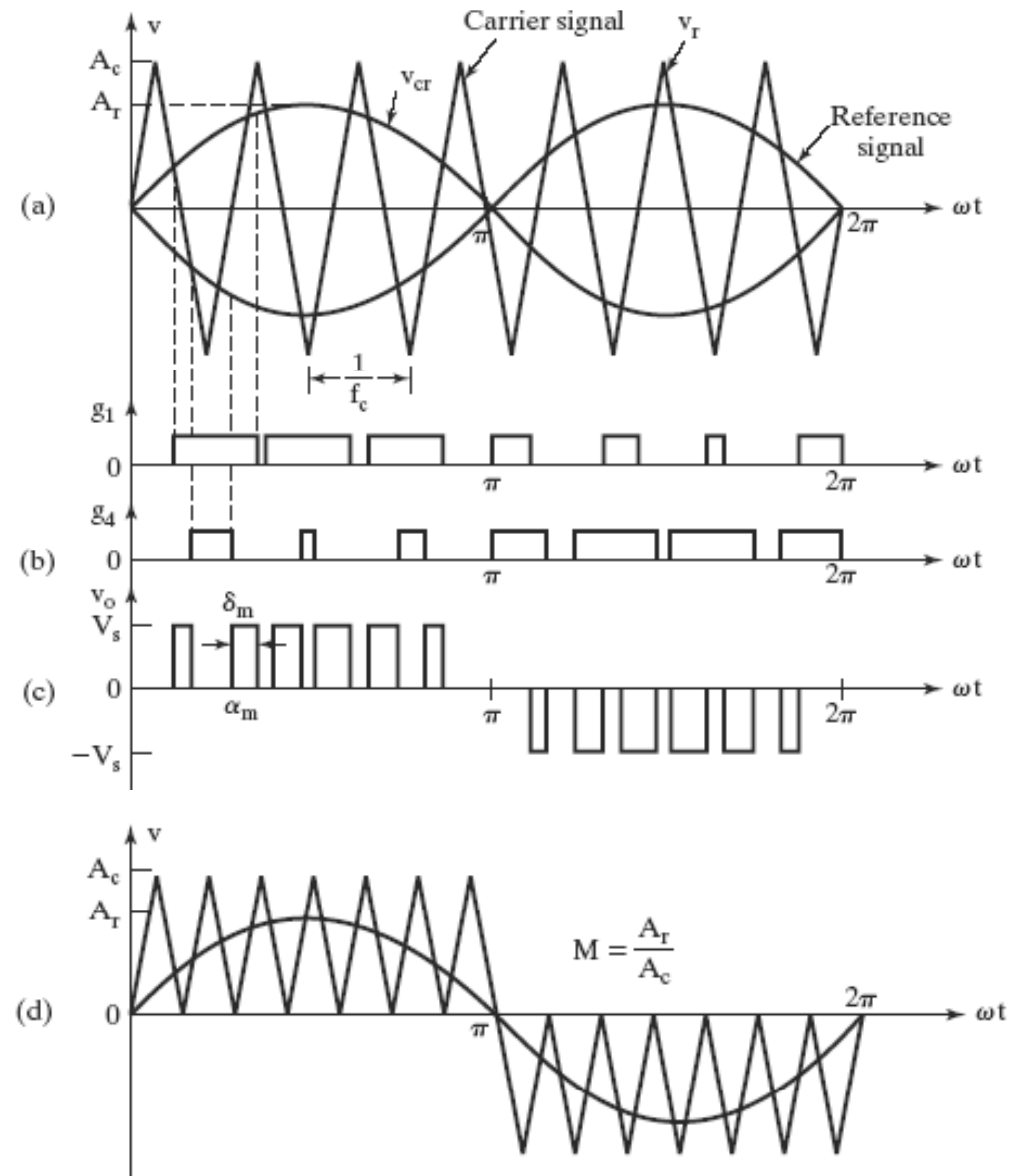


Sinusoidal PWM

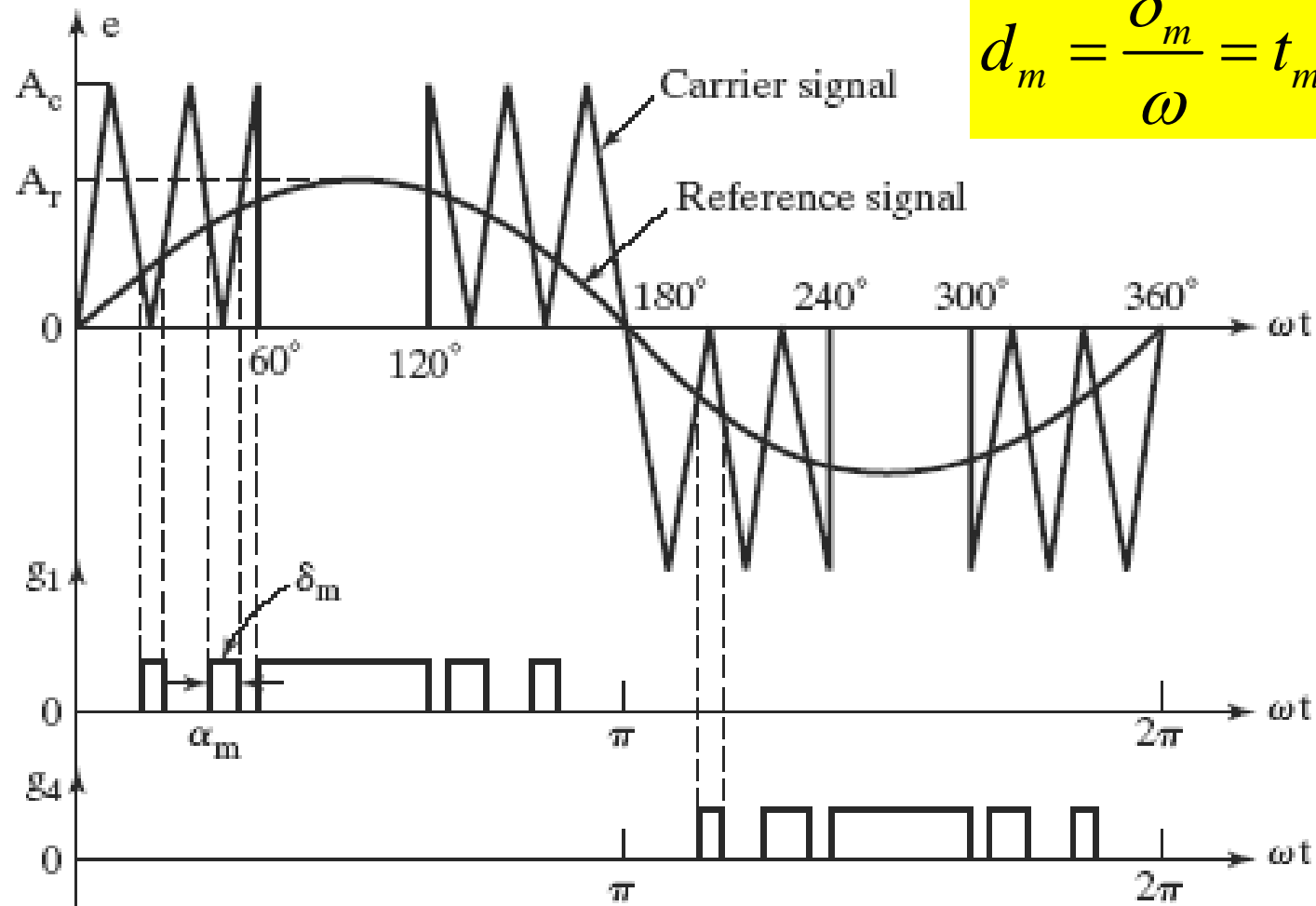
$$d_m = \frac{\delta_m}{\omega} = t_{m+1} - t_m$$

$$V_{o(rms)} = V_S \sqrt{\sum_{m=1}^{2p} \frac{\delta_m}{\pi}}$$

$$v_o(t) = \sum_{n=1,3,5,\dots}^{\infty} B_n \sin n\omega t$$

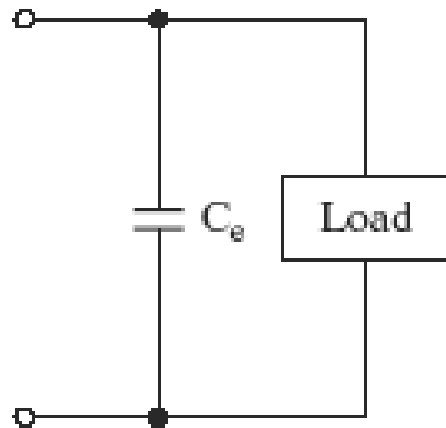


Modified Sinusoidal PWM

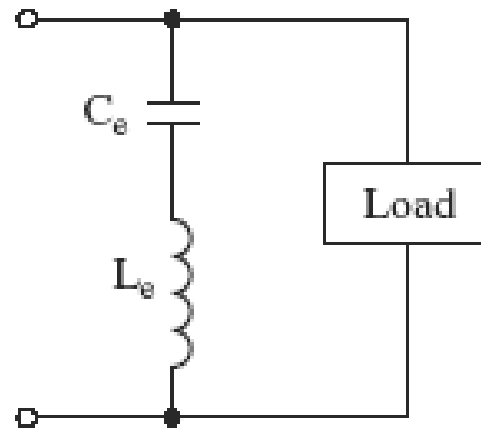


$$d_m = \frac{\delta_m}{\omega} = t_{m+1} - t_m$$

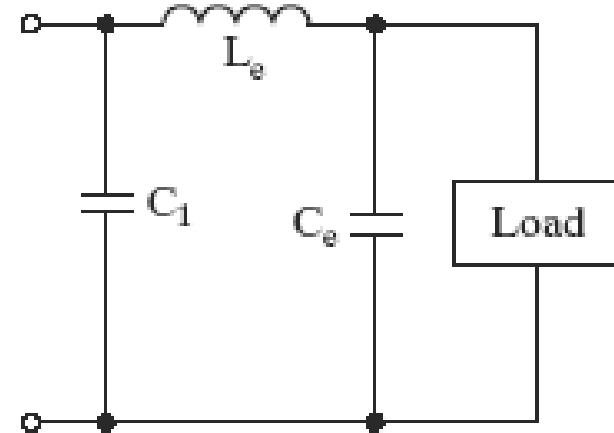
AC Filters



(a) C filter



(b) CL filter



(c) CLC filter

