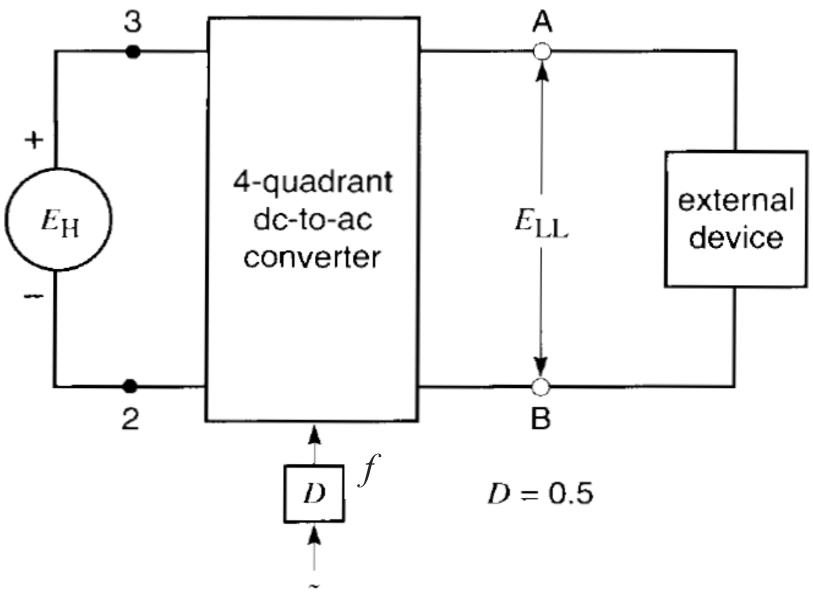
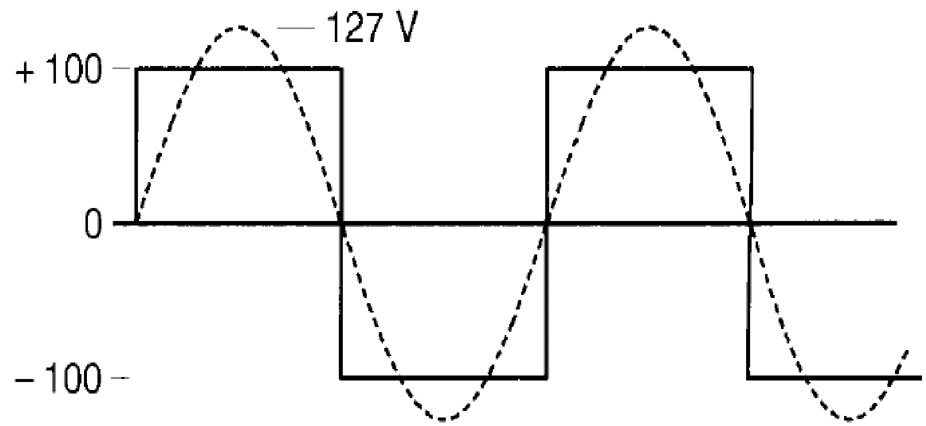
DC-to-AC rectangular wave converter



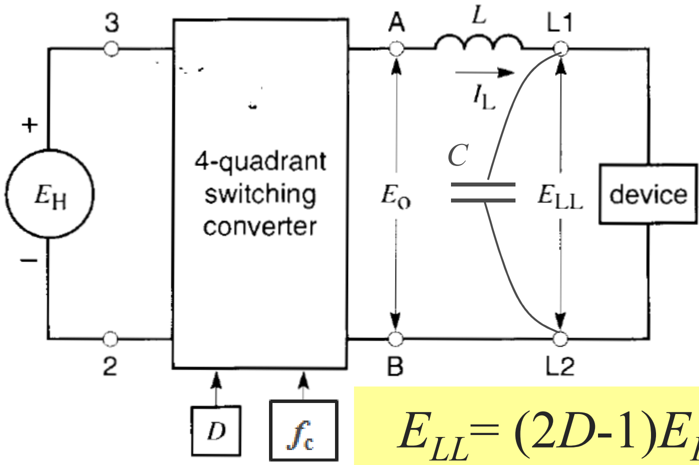
$$E_{LL} = \frac{400}{\pi}\left[\sin(2\pi ft) + \frac{1}{3}\sin(6\pi ft) + \frac{1}{5}\sin(10\pi ft) + \ldots\right]$$



- The 4-quadrant converter with D=0.5 is able to transform a DC voltage E_H into a rectangular AC voltage $\pm E_H$, which contains a fundamental sinusoidal component having an amplitude of $1.27E_H$ and an effective value of $1.27E_H/\sqrt{2}=0.90E_H$
- It is bidirectional (DC-to-AC and AC-to-DC) and frequency-variable
- The output has a fixed amplitude and large 3rd, 5th and 7th harmonics.

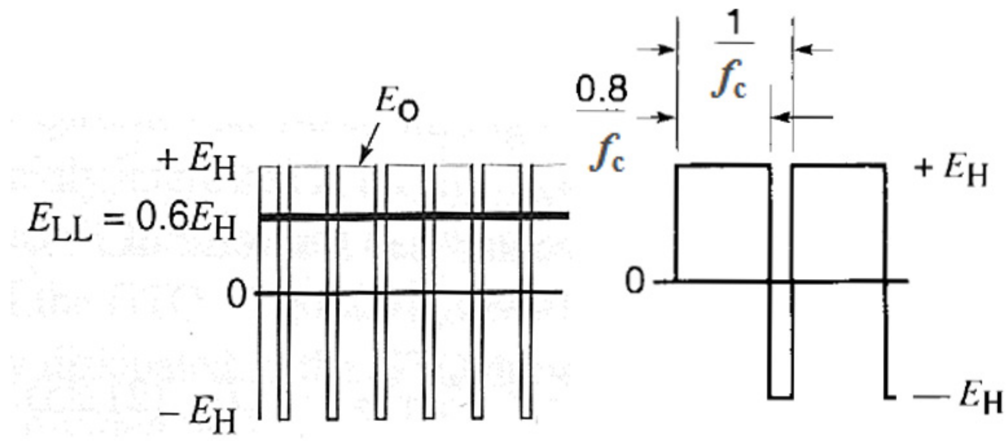
PWM (pulse width modulation)

- 4-quadrant DC-to-DC converter using a carrier frequency f_c and different values of D

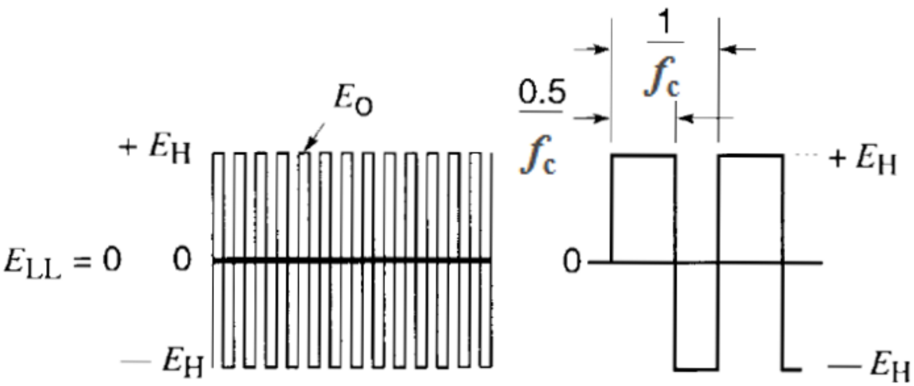


$E_{LL} = (2D-1)E_H$

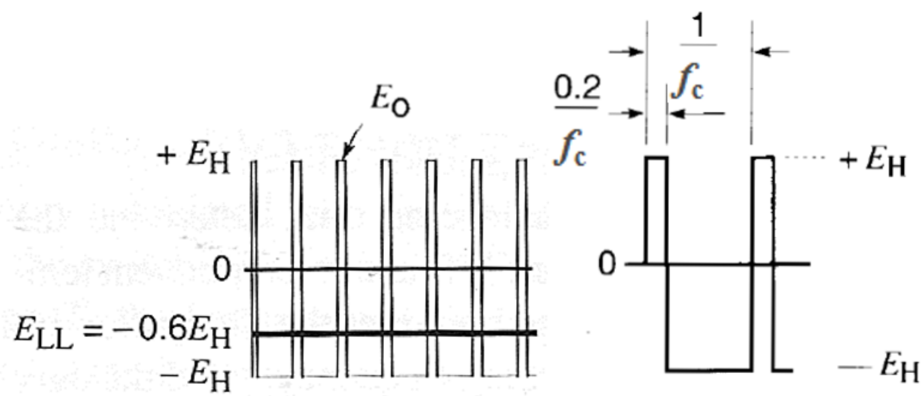
(a)



(b) $D = 0.8$ $E_{LL} = +0.6\,E_H$



(c) $D = 0.5$ $E_{LL} = 0$



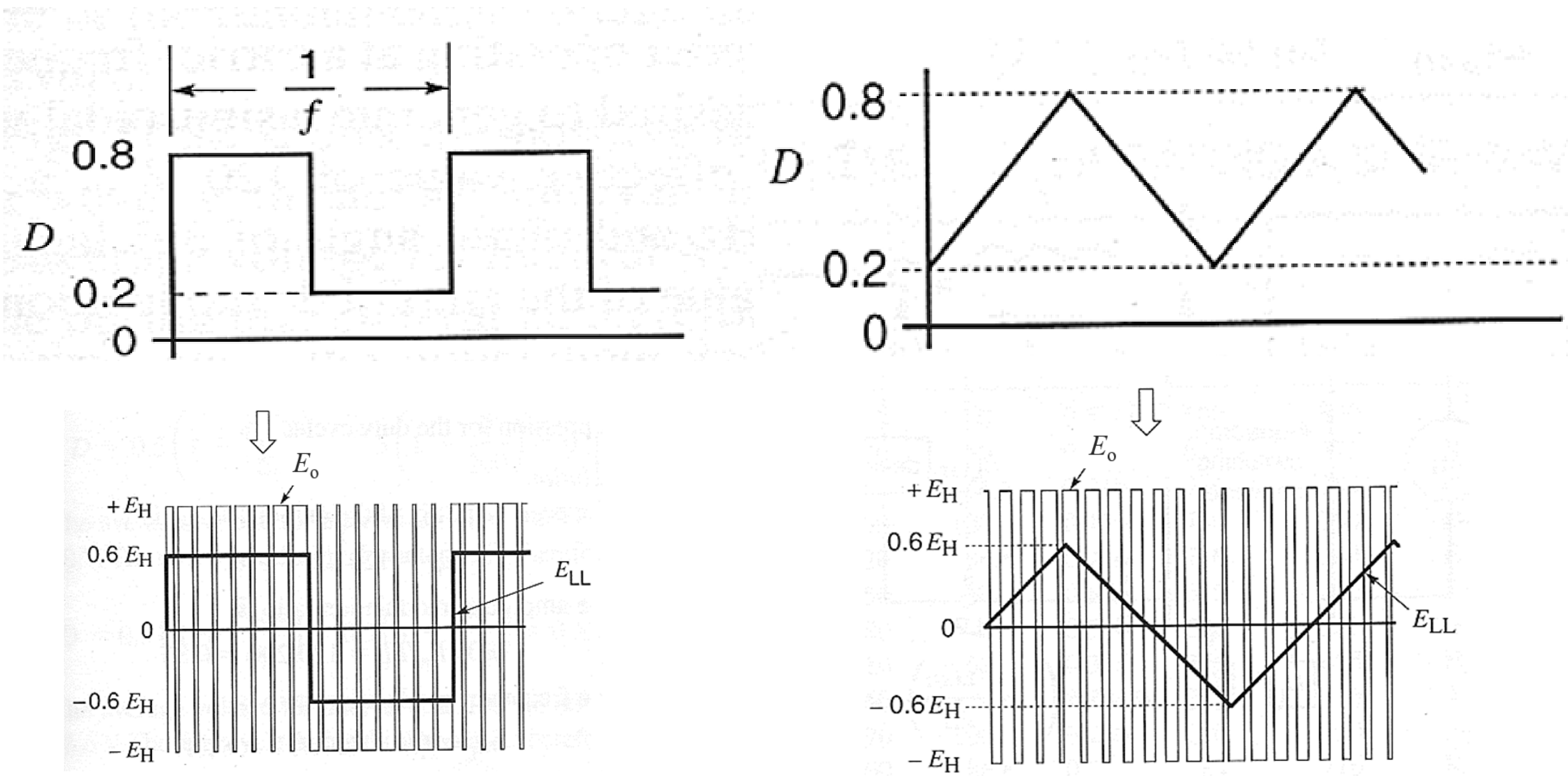
(d) $D = 0.2$ $E_{LL} = -0.6\,E_H$

- To obtain $E_{LL}(t) = E_m \sin(2\pi f t + \theta)$,

$$D(t) = \frac{E_m}{2E_H}\sin(2\pi f t + \theta) + \frac{1}{2}$$

DC-to-AC non-sine wave converters with PWM

- With D varying periodically between 0.8 and 0.2 at a frequency $f < 0.1 f_c$
- Although f_c is fixed, the ON/OFF pulse widths change continually with D.
- That is why this type of switching is called *pulse width modulation* or PWM



DC-to-AC sine wave converter with PMW

- To obtain $E_{LL}(t)=E_m \sin(2\pi ft+\theta)$

$$D(t) = \frac{E_m}{2E_H}\sin(2\pi ft+\theta)+\frac{1}{2}$$

  Amplitude modulation ratio $m=E_m/E_H$

  Frequency modulation ratio $m_f=f_c/f=T/T_c$

- Create a 83.33Hz sine voltage wave with peak value E_m=100V using a DC-to-AC converter with E_H=200V and f_c=1000Hz:

  T=1/83.33=0.012s=12000μs

  T_c=1/1000=1000μs

  $m_f=T/T_c=12$, so each T_c covers 360/12=30°

  Calculate D for $\phi(t)=2\pi ft+\theta$=0°, 30°, 60°, …, which correspond to $E_{LL}=100\sin\phi$ (V)

  In each carrier period T_c, Q1&Q4 are ON for first DT_c =1000D(μs) and then Q2&Q3 are ON for the remaining (1-D)T_c = 1000(1-D) (μs)

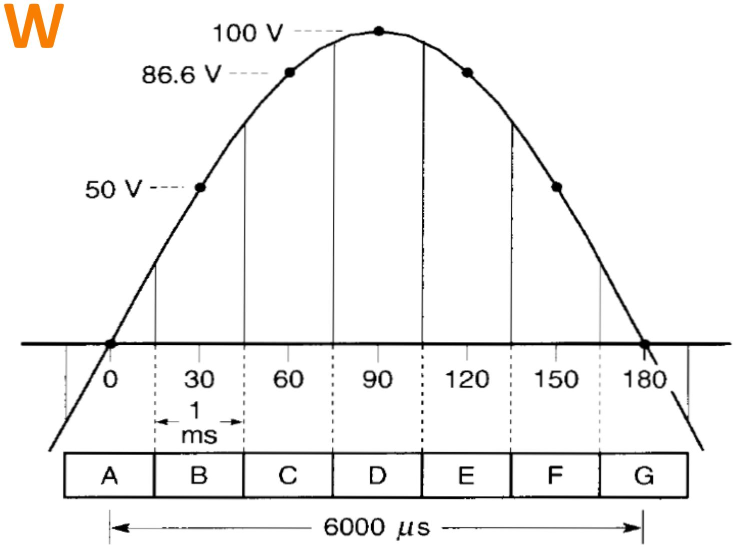


Figure 21.82
Positive half-cycle of the fundamental 83.33 Hz voltage comprises six carrier periods of 1 ms each.

TABLE 21E GENERATING A SINE WAVE

angle [deg]	E_{LL} [V]	D	Q1, Q4 on [μs]	Q2, Q3 on [μs]	interval
0	0	0.5	500	500	A
30	50	0.625	625	375	B
60	86.6	0.716	716	284	C
90	100	0.75	750	250	D
120	86.6	0.716	716	284	E
150	50	0.625	625	375	F
180	0	0.5	500	500	G
210	−50	0.375	375	625	H
240	−86.6	0.284	284	716	I
270	−100	0.250	250	750	J
300	−86.6	0.284	284	716	K
330	−50	0.375	375	625	L
360	0	0.5	500	500	M

Bipolar PWM and Unipolar PWM

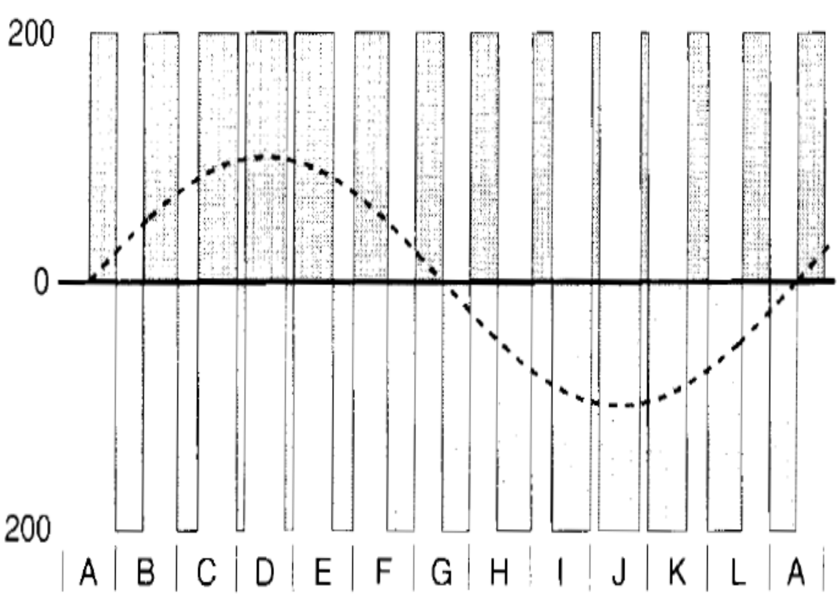


Figure 21.83
Alternative (+) and (−) pulses contain the sinusoidal component.

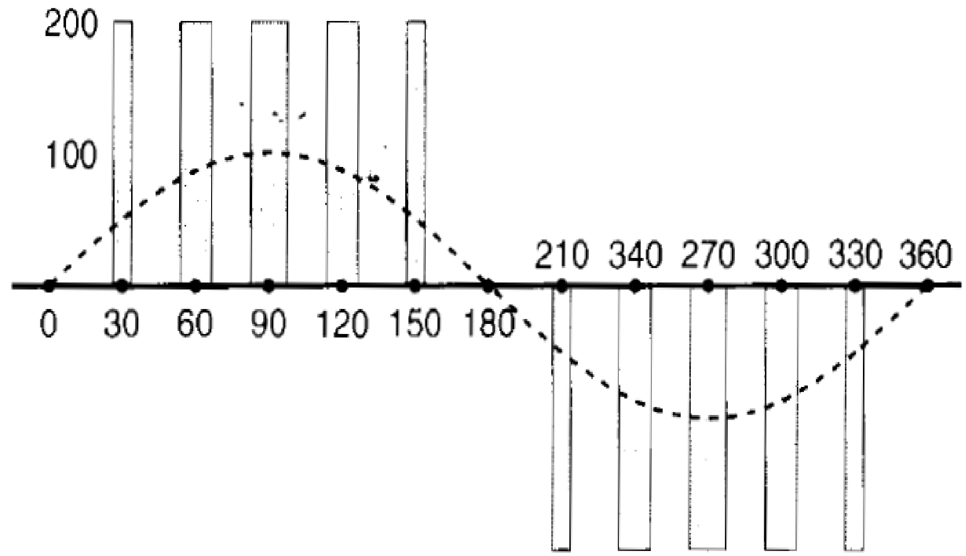


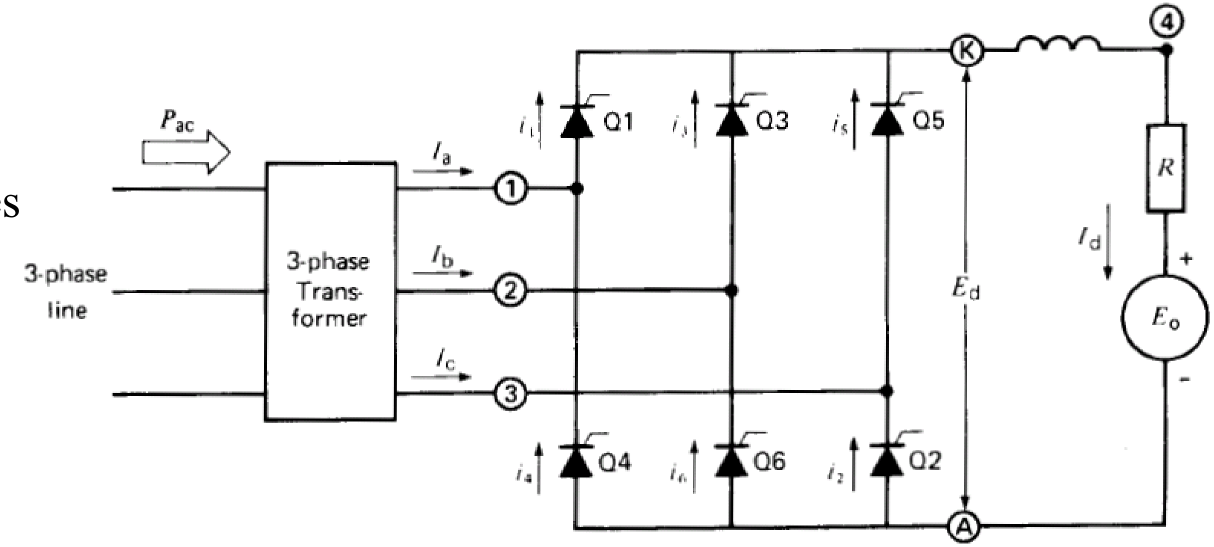
Figure 21.84
Sequential (+) and (−) pulses contain the sinusoidal components.

- Once the carrier frequency is filtered out, the resulting voltage will be sinusoidal
- A higher carrier frequency would yield a better sinusoidal waveform but would increase the power losses of the electronic switches, e.g. IGBTs

3-phase, 6-pulse thyristor rectifier (AC-to-DC converter)

- Control the DC output voltage E_d by the delay angle α of triggering pulses

$$E_d = 1.35 E \cos\alpha$$



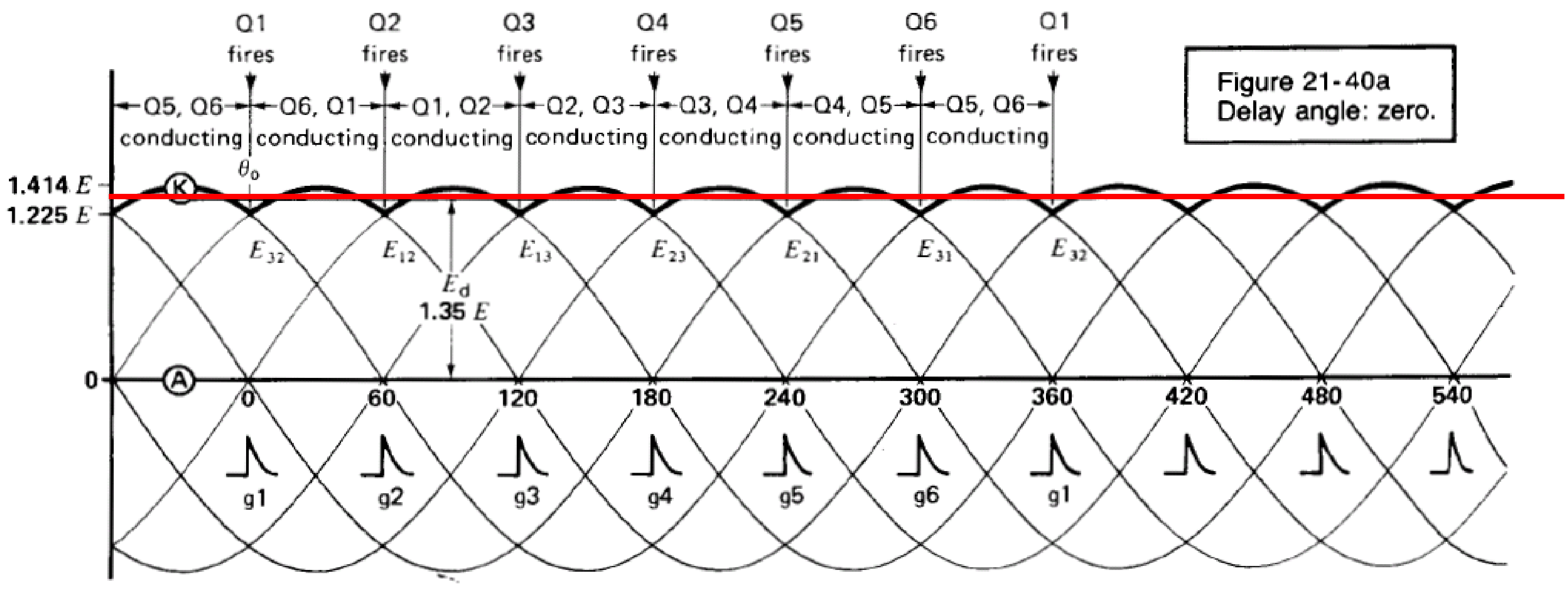


Figure 21-40a
Delay angle: zero.

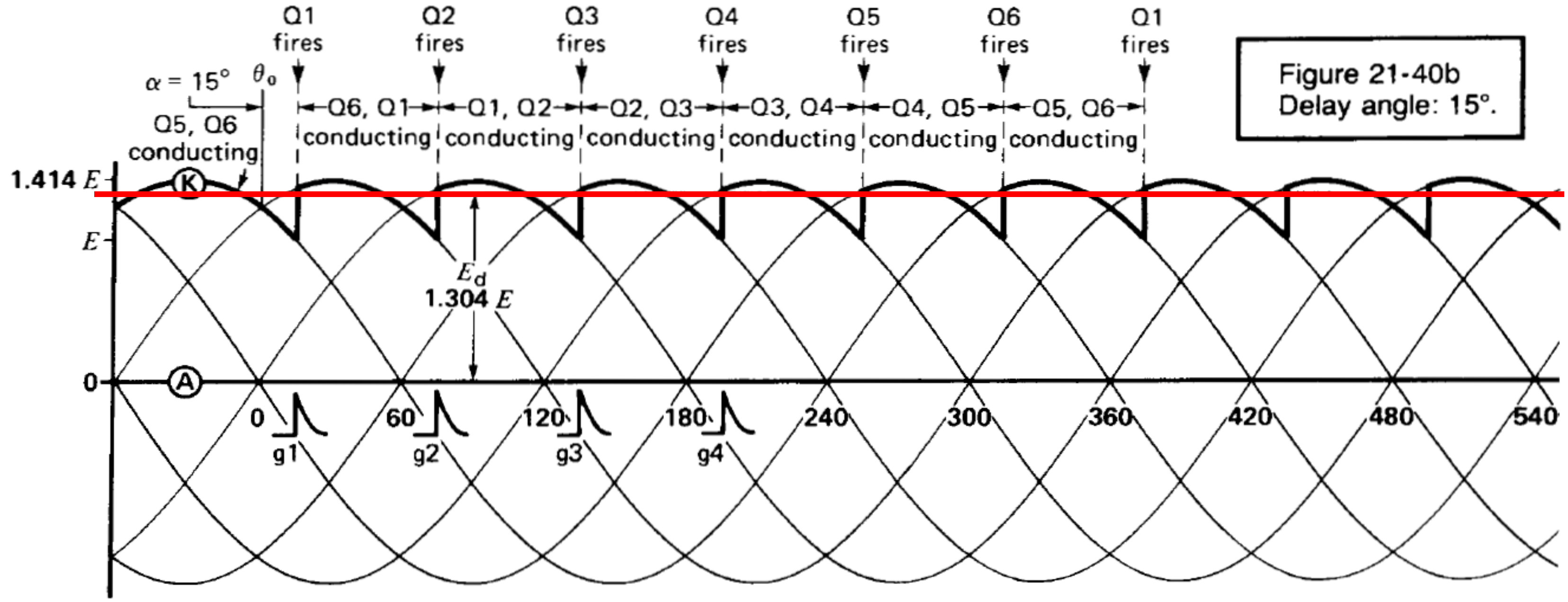


Figure 21-40b
Delay angle: 15°.

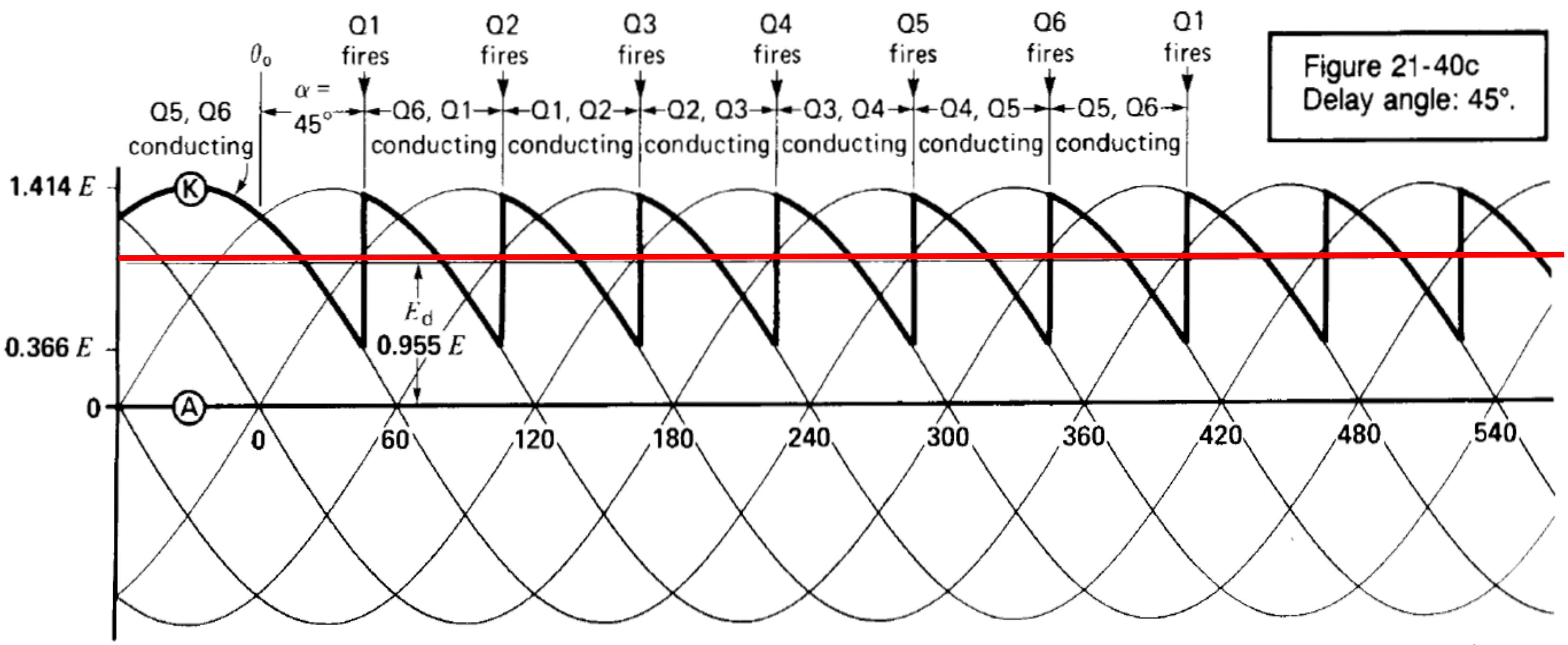


Figure 21-40c
Delay angle: 45°.

Homework Assignment #8

- Read Chapter 21
- Questions:
  - 21-25, 21-26, 21-33, 21-34, 21-35
- Due date:
  - hand in your solution to GTA Wenyun at MK 207 directly or by email before the end of 11/29 (Tuesday)