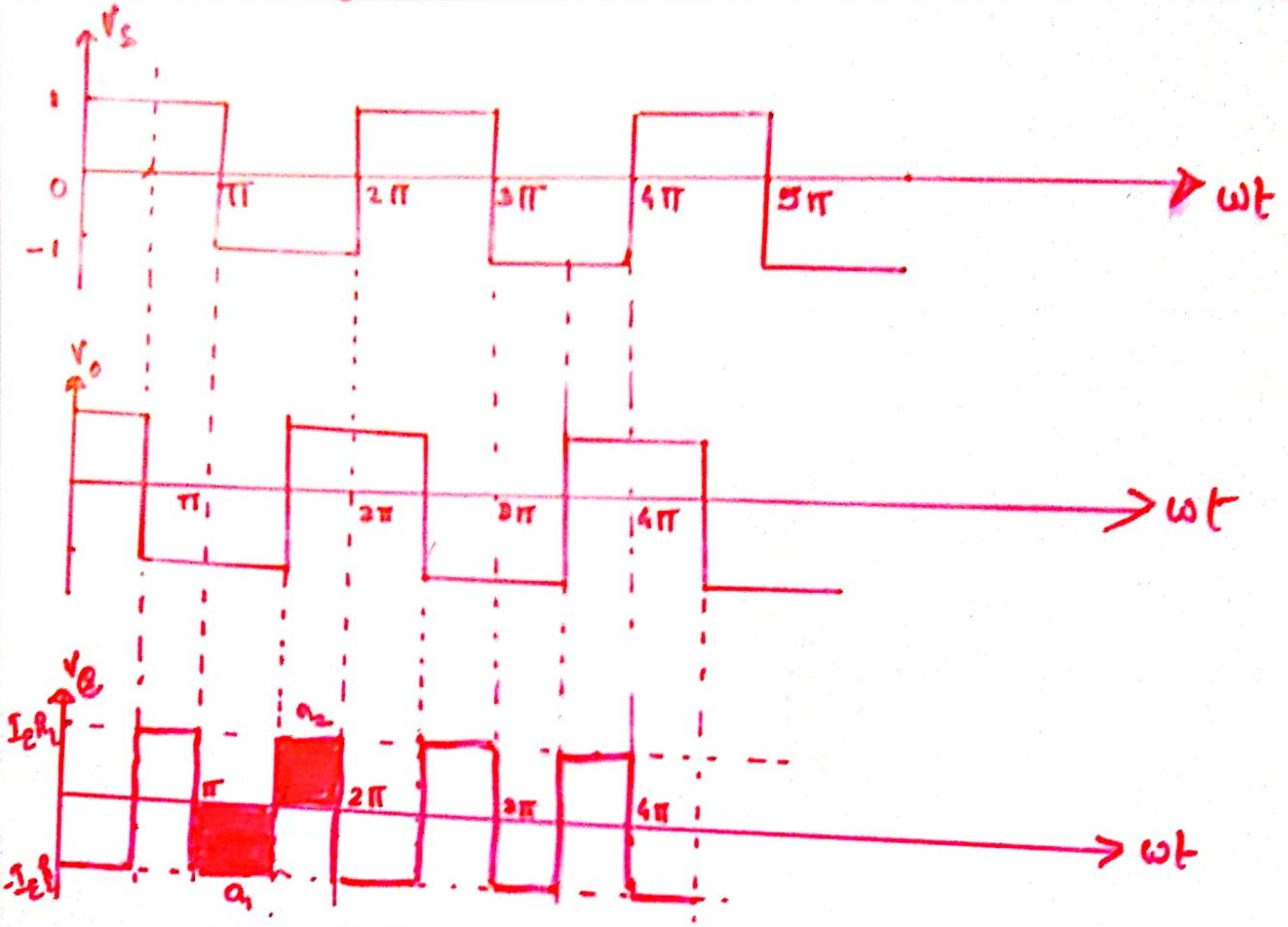
Waveforms of balanced modulator phase detector ⇒



$$V_e = I_E R_L$$

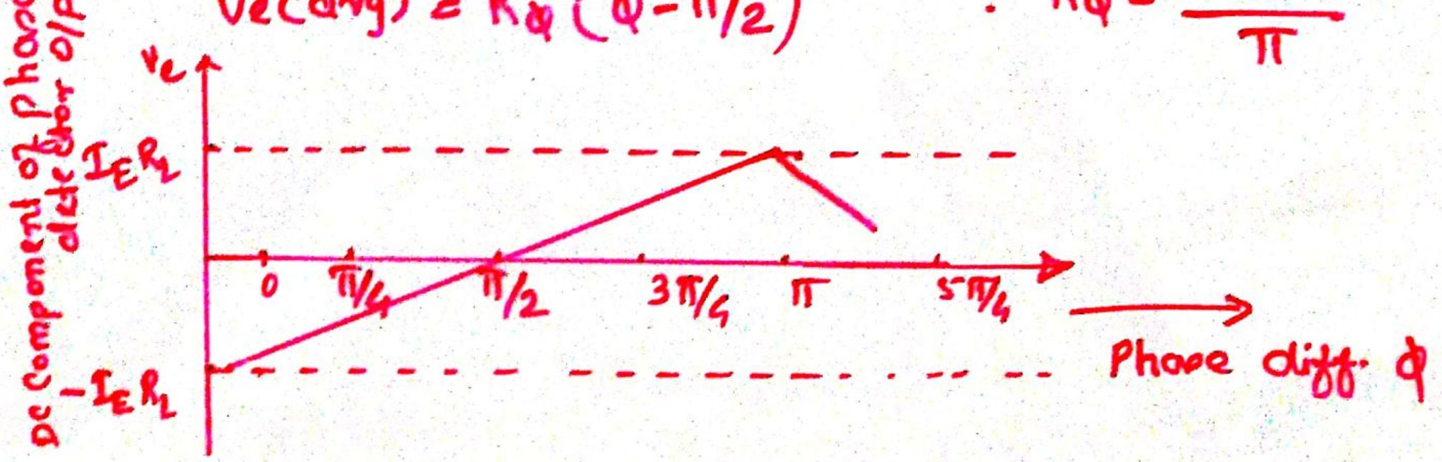
$$V_e(avg) = \frac{1}{\pi}(a_1 + a_2)$$

$$V_e(av) = \frac{1}{\pi}\left[(-I_E R_L)(\pi - \phi) + (I_E R_L)(\phi)\right] = \frac{I_E R_L}{\pi}\left[-\pi + \phi + \phi\right]$$

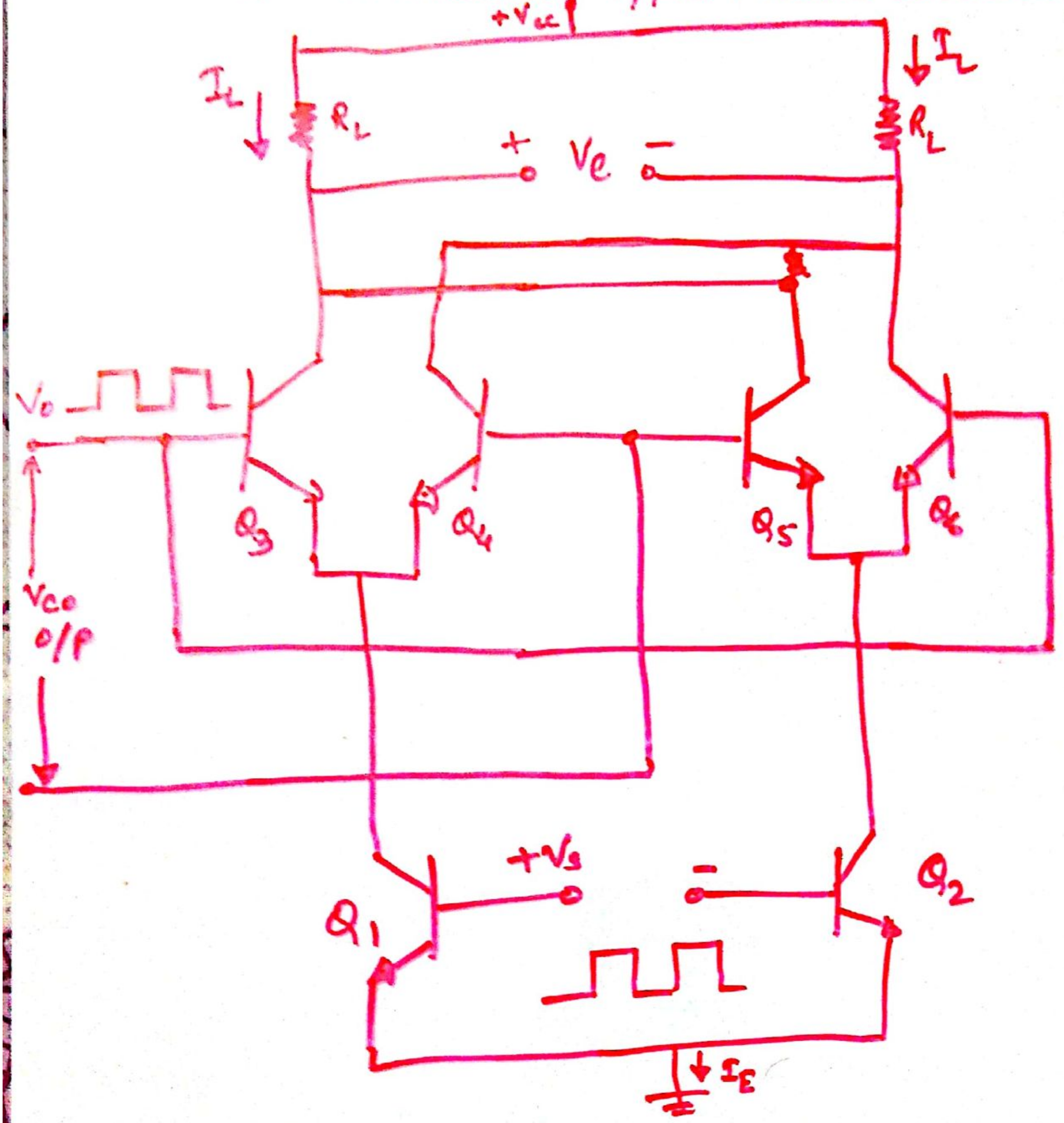
$$= \frac{2 I_E R_L}{\pi}\left[\phi - \pi/2\right]$$

$$V_e(avg) = \frac{4 I_L R_L}{\pi}\left[\phi - \pi/2\right] \qquad \because I_E = 2 I_L$$

$$V_e(avg) = K_\phi(\phi - \pi/2) \qquad \because K_\phi = \frac{4 I_L R_L}{\pi}$$

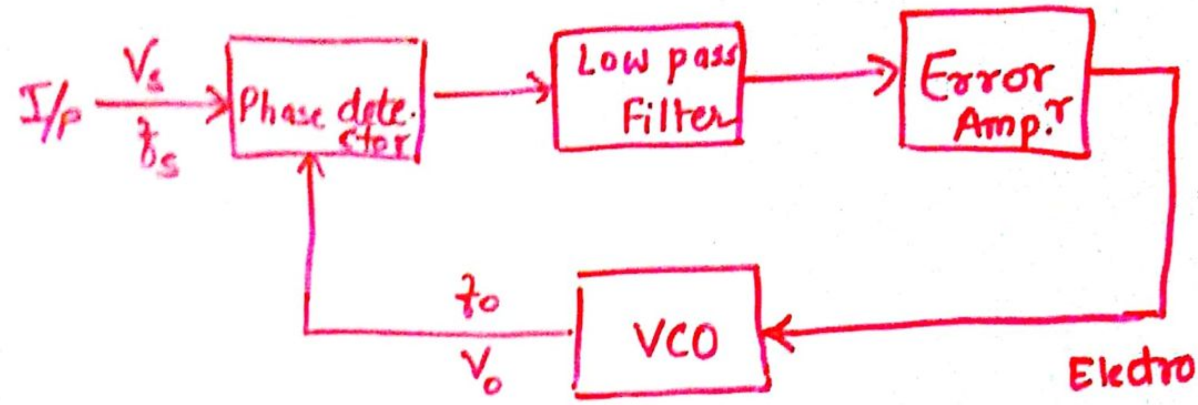


Balanced Modulator Type Phase Detector :-

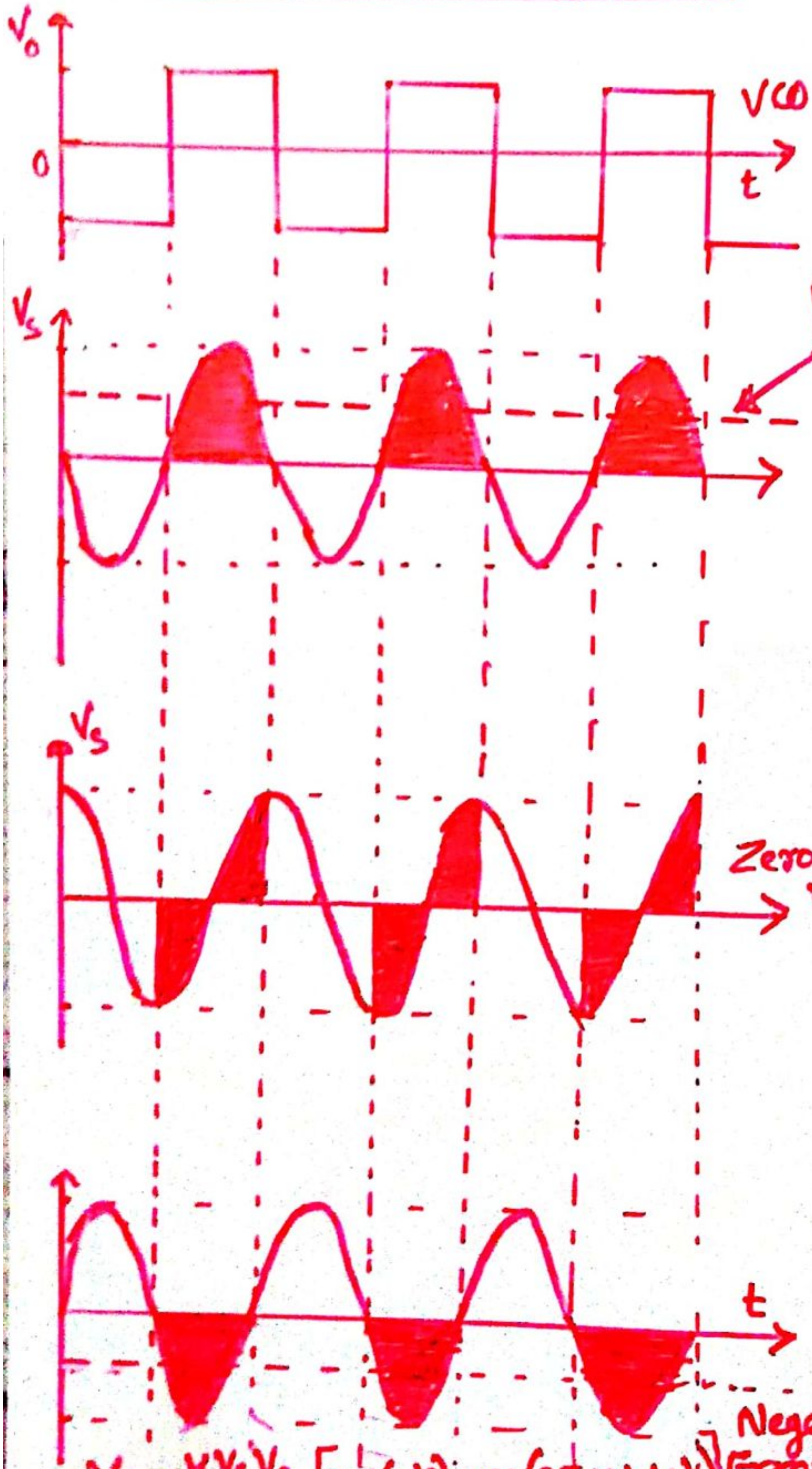


Vs	Vo	Q1	Q2	Q3-Q6	Q4-Q5	Ve
Positive	Positive	ON	OFF	ON	OFF	Negative
Positive	Negative	ON	OFF	OFF	ON	Positive
Negative	Positive	OFF	ON	ON	OFF	Positive
Negative	Negative	OFF	ON	OFF	ON	Negative

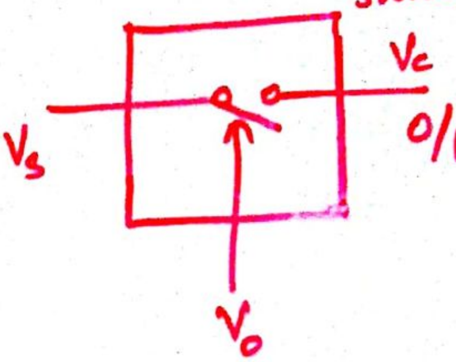
BLOCK DIAGRAM OF PLL :-



Phase detector Waveforms ⇒



Electronic switch



$V_s = V_s \sin(2\pi f_s t)$

$V_o = V_o \sin(2\pi f_o t + \phi)$

$V_e = K V_s V_o \sin(2\pi f_s t) \sin(2\pi f_o t + \phi)$

K → Phase detector gain or attenuation const.

The eq.n for V_e can be simplified as

$$V_e = \frac{K V_s V_o}{2}\left[\cos(2\pi f_s t - 2\pi f_o t - \phi) - \cos(2\pi f_s t + 2\pi f_o t + \phi)\right]$$

At lock condition $f_s = f_o$

$$V_e = \frac{K V_s V_o}{2}\left[\cos(-\phi) - \cos(2\pi \times 2 f_o t + \phi)\right]$$