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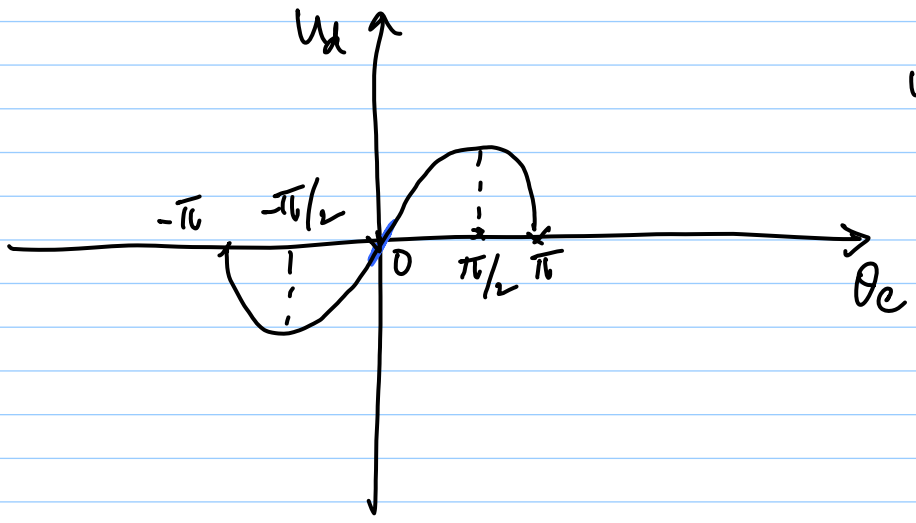
In PLL steady state, $\omega_1 = \omega_2$

$$u_d(t) = \frac{2}{\pi} u_{10} u_{20} \sin\theta_e$$ (Desired term)

$\theta_e = \theta_1 - \theta_2$ = phase error



$$u_d(t) = K_d \sin\theta_e$$

$$K_d = \frac{2}{\pi} u_{10} u_{20}$$

$\omega_1 \neq \omega_2$ (unlocked state)

$$u_d(t) = \frac{2}{\pi} u_{1o} u_{2o} \sin\left[(\omega_1 - \omega_2)t + \theta_e\right]$$

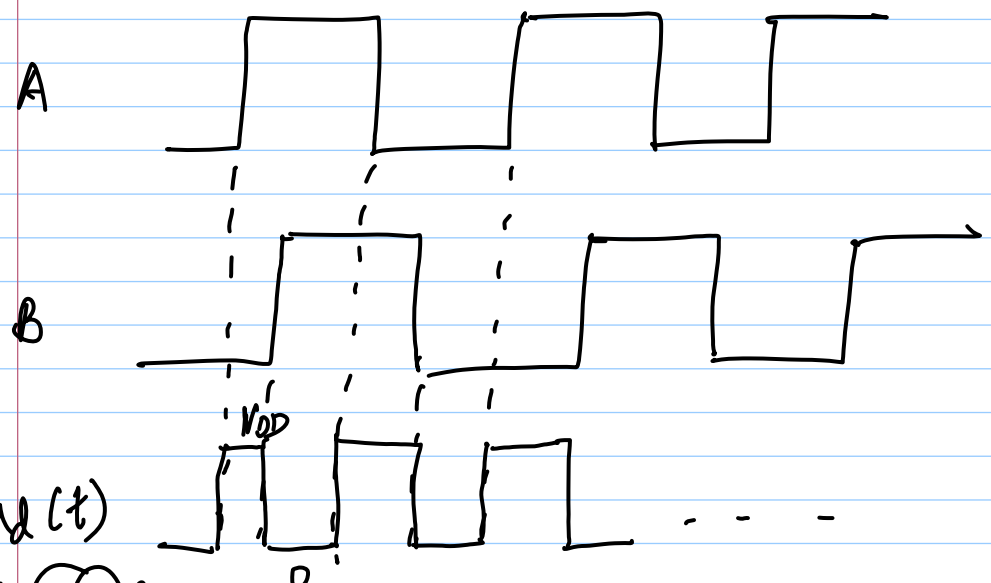
+ higher order terms

* If $u_d(t)$ were fully sinusoidal

average value of sine $= 0$

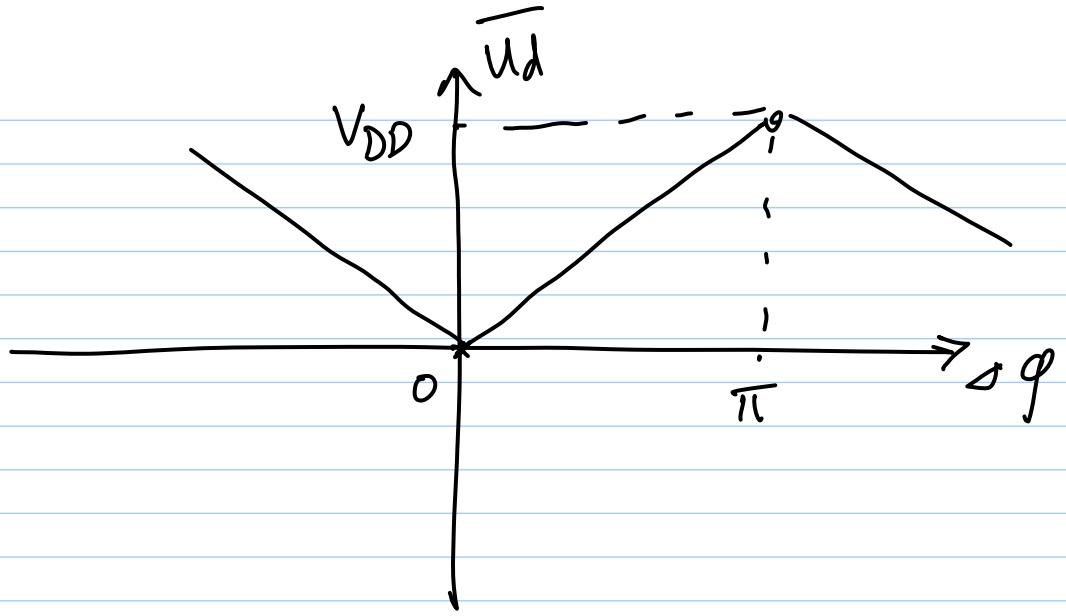
→ $u_d(t)$ has to have some distortion (dc term)

XOR P.D.



$= A \oplus B$

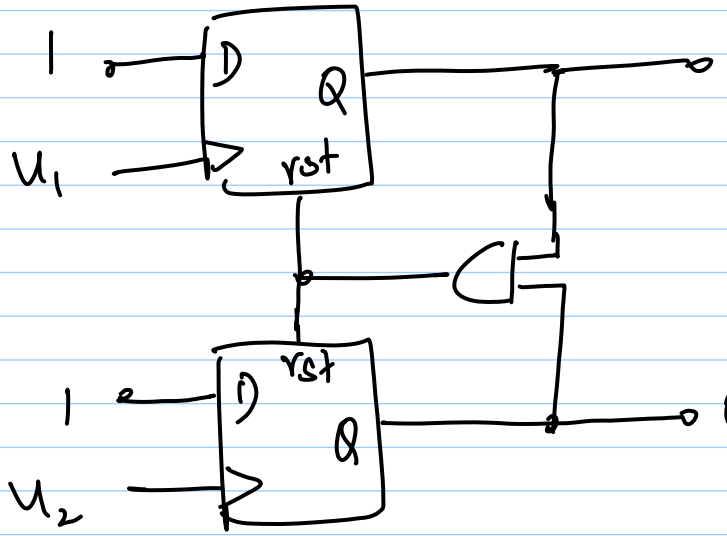
$\overline{u_d(t)} = 0$ if $\Delta\varphi = 0/2\pi$



3) PFD ≡ phase-frequency detector

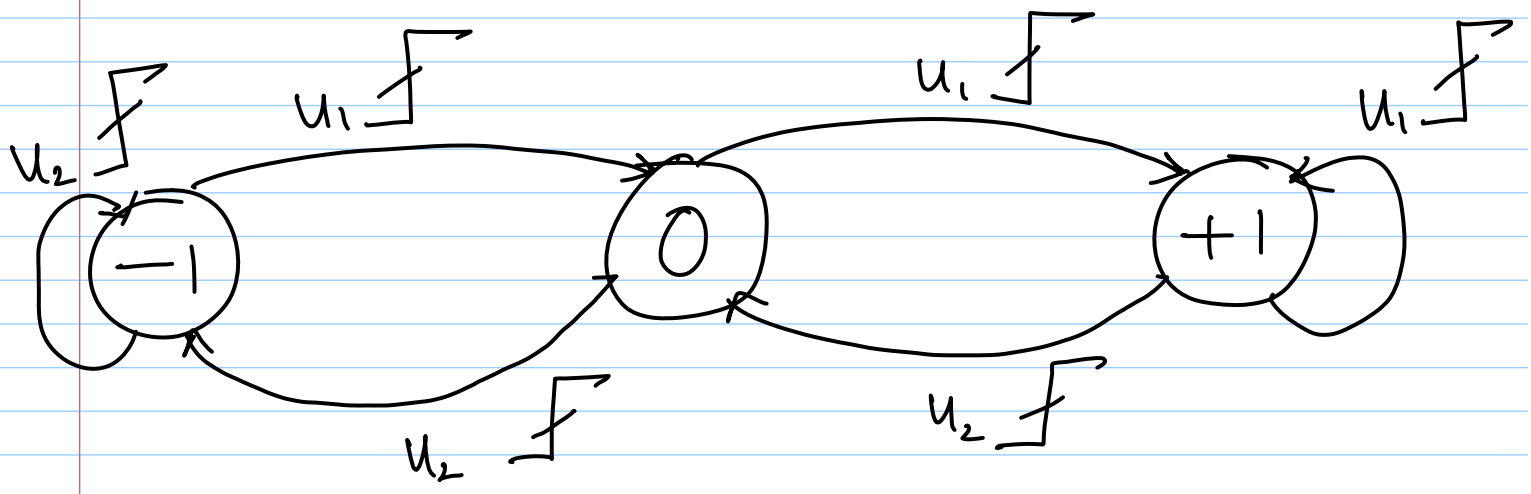
$W_1 = W_2$ no DC term

only DC term comes from distortion



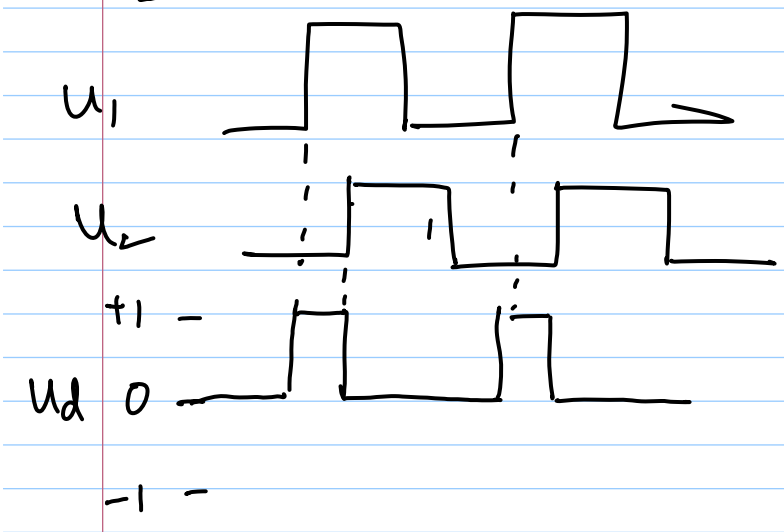
Tristate PFD

Q_A	Q_B	states
0	0	0
0	1	−1
1	0	+1
1	1	Prohibited (PFD is reset)

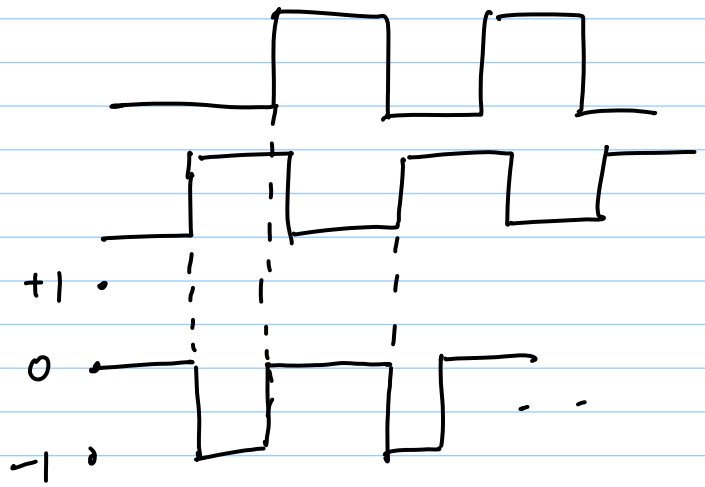


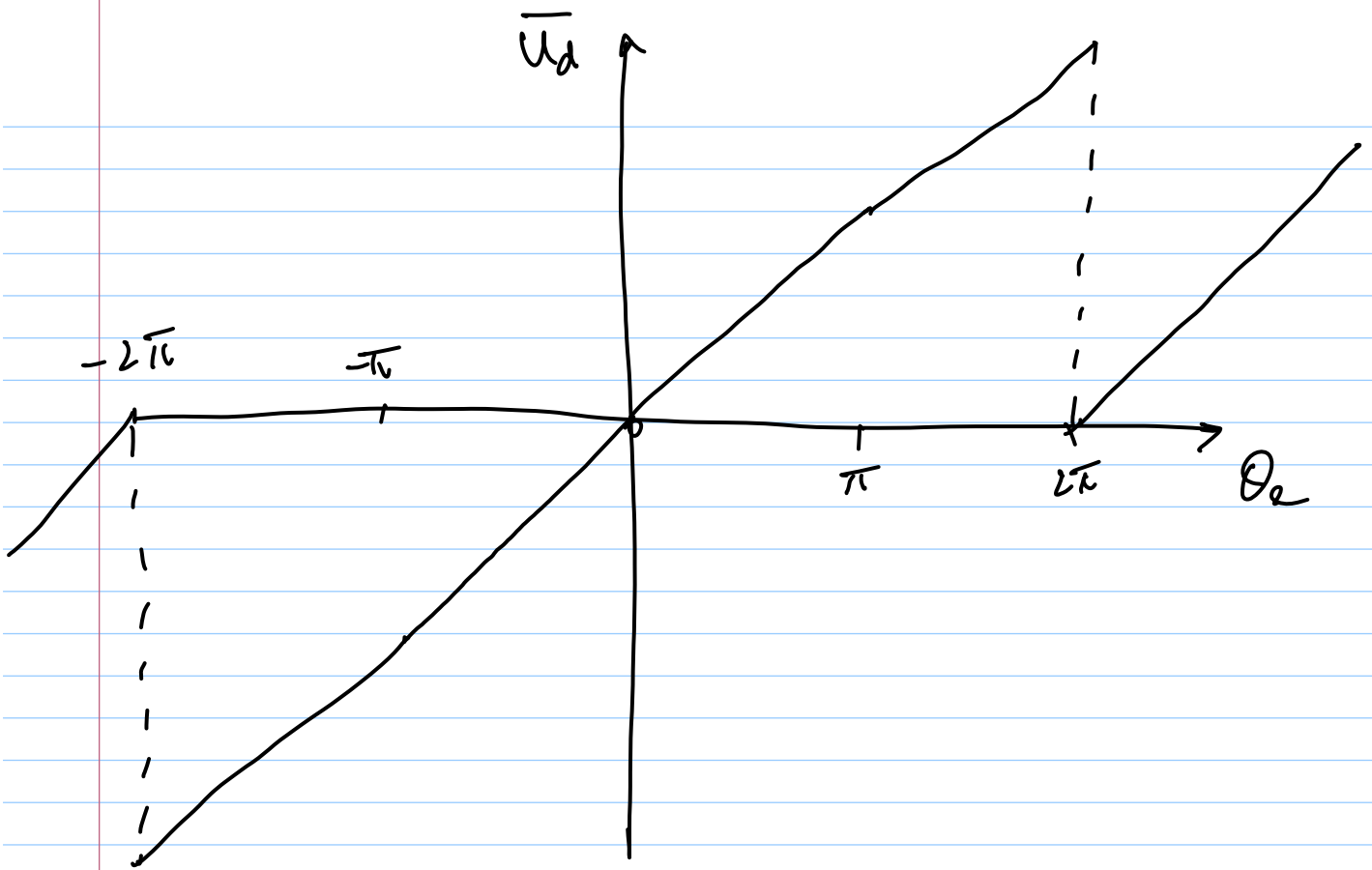
$$Q_e = 0 \Rightarrow \text{avg.}(Q_A - Q_B) = 0$$

$Q_e > 0$



$Q_e < 0$




$\overline{u_d}$
-2π
$-\pi$
0
π
2π
θ_e