**Instituto Superior Técnico**

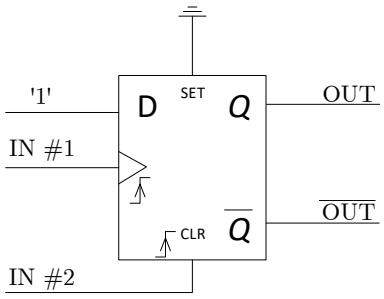
## Sistemas de Processamento Digital de Sinais (SPDSina)

# XOR phase detector

Consider two square-wave signals with period $T$. Determine and sketch the static phase detector characteristic of a XOR circuit operating with these signals with amplitude 0 V and 1 V. Generalize for amplitudes $V_N$ e $V_P$.

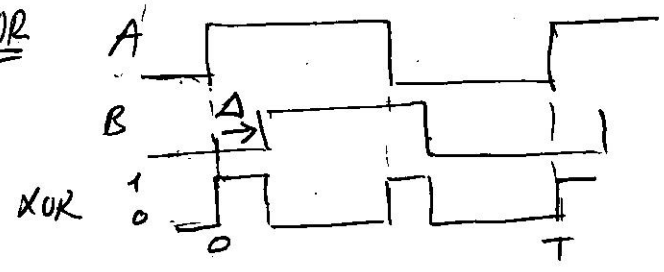
# Phase detector with a D-type flip-flop

Consider the phase detector in the figure which operates with rectangular signals with duty cycles $\delta_1$ and $\delta_2 < \delta_1$, period $T$ and amplitude 0 V and 1 V. Show that its operation is independent of the signals' duty-cycle. Determine and sketch the phase detector static characteristic. What happens when the input signals are switched?

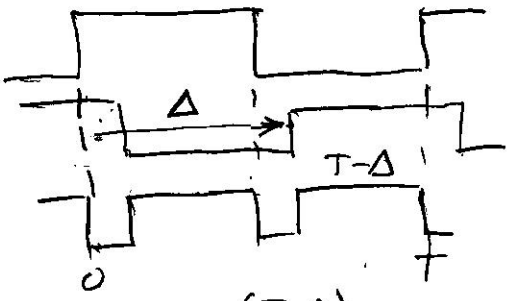


# Phase Detectors

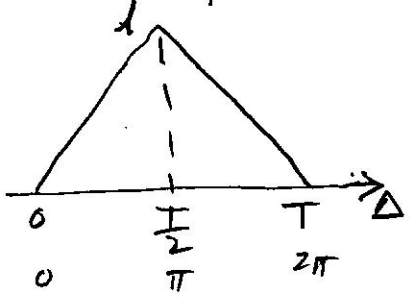
## XOR




$\langle XOR \rangle = \frac{2\Delta}{T}$ , $0 \le \Delta \le \frac{T}{2}$



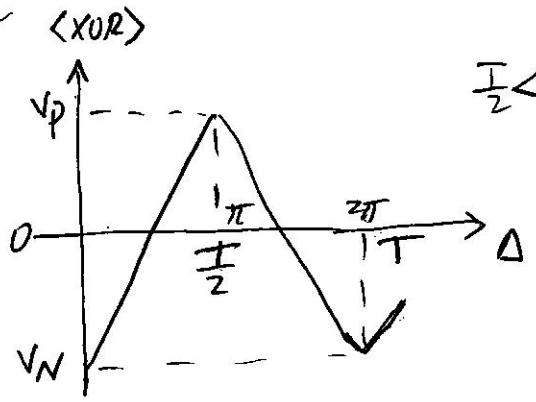

$\langle XOR \rangle = \frac{2(T-\Delta)}{T}$ , $\frac{T}{2} < \Delta \le T$




For $V_P$, $V_N$:

$0 \le \Delta \le \frac{T}{2}$ $\quad \langle XOR \rangle = V_P \frac{2\Delta}{T} + V_N \left(\frac{T-2\Delta}{T}\right)$ (time @ $V_P$, time @ $V_N$)

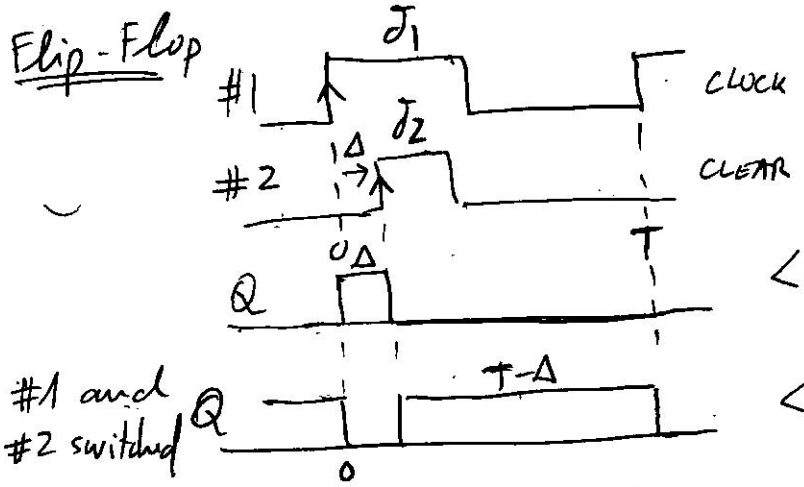
$= V_P \frac{2\Delta}{T} + V_N \left(1 - \frac{2\Delta}{T}\right)$




$\frac{T}{2} < \Delta \le T$ $\quad \langle XOR \rangle = V_P \frac{2(T-\Delta)}{T} + V_N \frac{T-2(T-\Delta)}{T}$

$= V_P 2\left(1 - \frac{\Delta}{T}\right) + V_N \left(\frac{2\Delta}{T} - 1\right)$

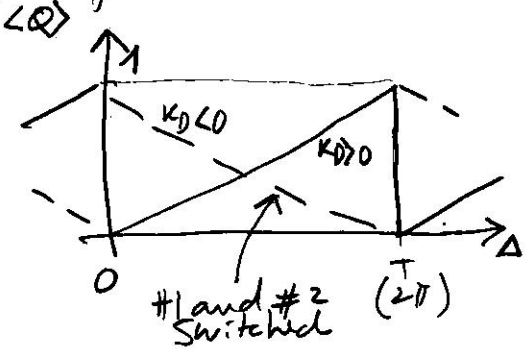
## Flip-Flop




$\langle Q \rangle = \frac{\Delta}{T}$ , $0 \le \Delta \le T$

$\langle Q \rangle = \frac{T-\Delta}{T} = 1 - \frac{\Delta}{T}$ , $0 \le \Delta \le T$

Because both CLOCK and CLEAR inputs are edge-triggered, the operation is only sensitive to positive-going transitions. Therefore it does not depend on either $\sigma_1$ or $\sigma_2$ (duty-cycle)




- The available phase is $2\pi$ because the detector only has one slope, either positive ($K_D > 0$) or negative ($K_D < 0$) when the inputs are switched.
- The characteristic $\langle Q \rangle$ is periodic with the period equal to $2\pi$.
- Need to be careful about PLL return gain, $\lambda > 0$!