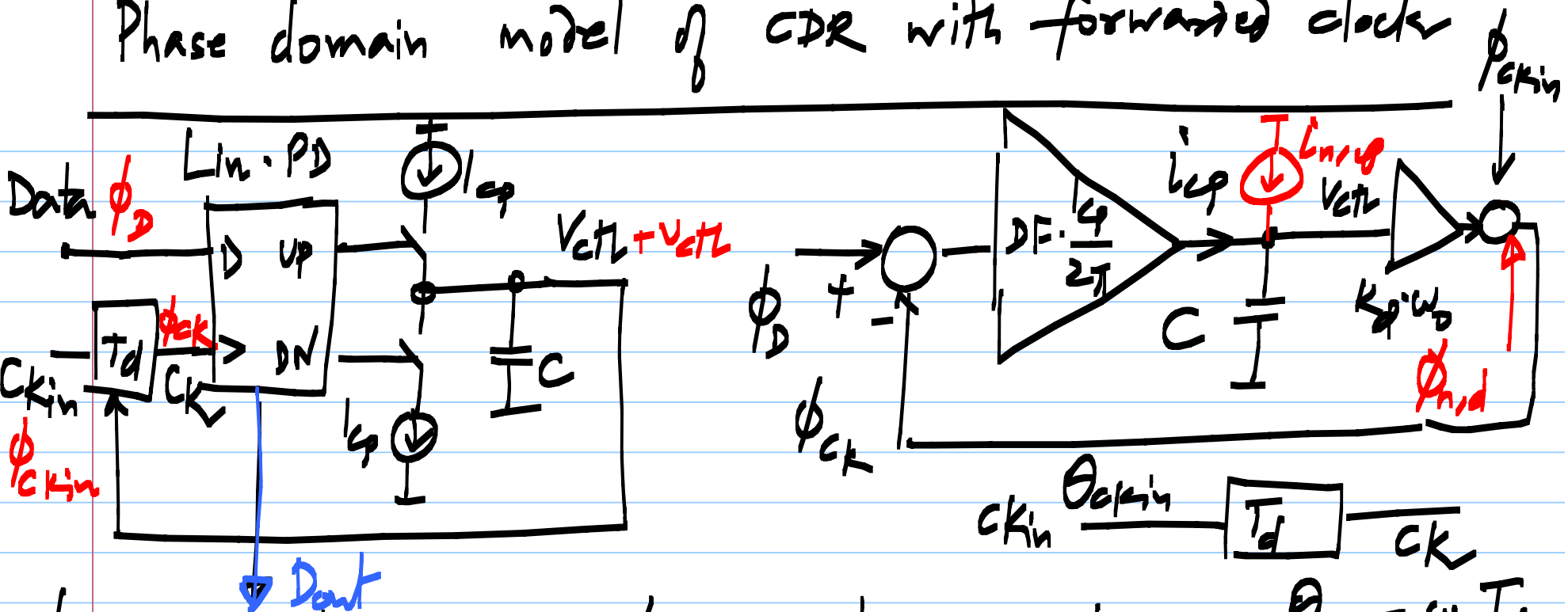
Phase domain model of CDR with forwarded clock



$$\frac{\phi_{CK}}{\phi_D} = \frac{1}{1 + s/\omega_{BW}}\,; \qquad \frac{\phi_{CK}}{i_{n,cp}} = \frac{1}{DF\cdot\frac{I_{cp}}{2\pi}} \cdot \frac{1}{1 + s/\omega_{BW}}\,;$$

$$\frac{\phi_{CK}}{\phi_{CKin}} = \frac{s/\omega_{BW}}{1 + s/\omega_{BW}}\,;$$

JTOL

Jitter tolerance: Amount of jitter in input data that can be tolerated [maintain BER < required value]

[Assume $\phi_{CKin} = 0$] → ϕ_{CKin} is correlated with ϕ_D

$$|\phi_D - \phi_{CK}| < \Delta\phi_{max} \Rightarrow \left|\phi_D \cdot \frac{s/\omega_{BW}}{1+s/\omega_{BW}}\right| < \Delta\phi_{max}$$

To maintain BER < required value

$$\frac{\phi_{CK}}{\phi_D} = \frac{1}{1+s/\omega_{BW}}; \quad \frac{\phi_D - \phi_{CK}}{\phi_D} = \frac{s/\omega_{BW}}{1+s/\omega_{BW}}$$

ω: jitter frequency

$$|\phi_D| < \Delta\phi_{max} \left| \frac{1 + s/\omega_{BW}}{s/\omega_{BW}} \right|_{s=j\omega}$$

[UI] JTOL (jitter tolerance)

Jitter:

Time (jitter)

Phase (radian)

UI (unit interval)

$= \frac{\text{Phase}}{2\pi}$

JAEN (Jitter generation) ouput jitter with

- Charge pump noise $i_{n,cp}$
- Delay line noise $\phi_{n,d}$
- Input ref. noise of the phase detector

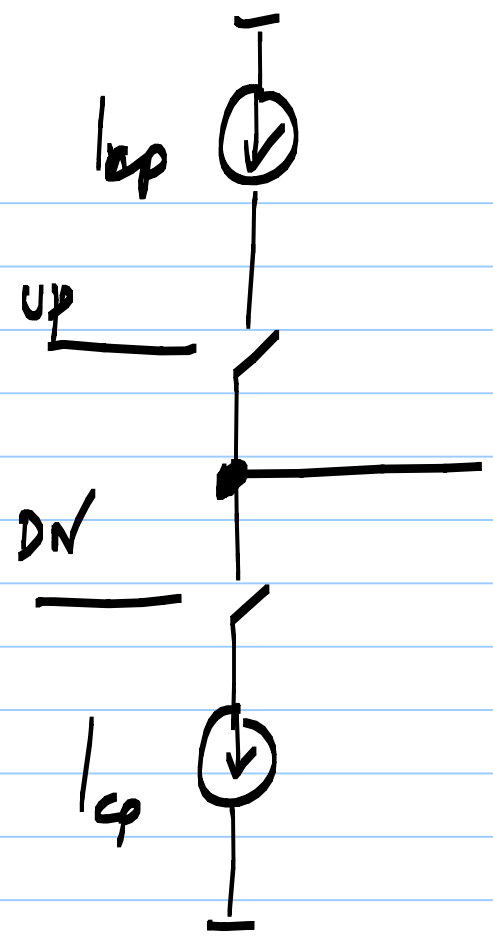
$\phi_D = 0$, $\phi_{clk,in} = 0$

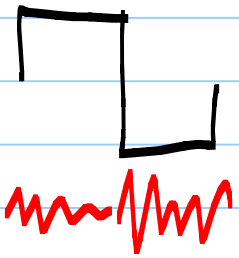
(clean data & input clock)

$$\frac{\phi_{clk}}{i_{n,cp}} = \frac{1}{DF \cdot \frac{I_{cp}}{2\pi}} \cdot \frac{1}{(1 + s/\omega_{BW})}$$

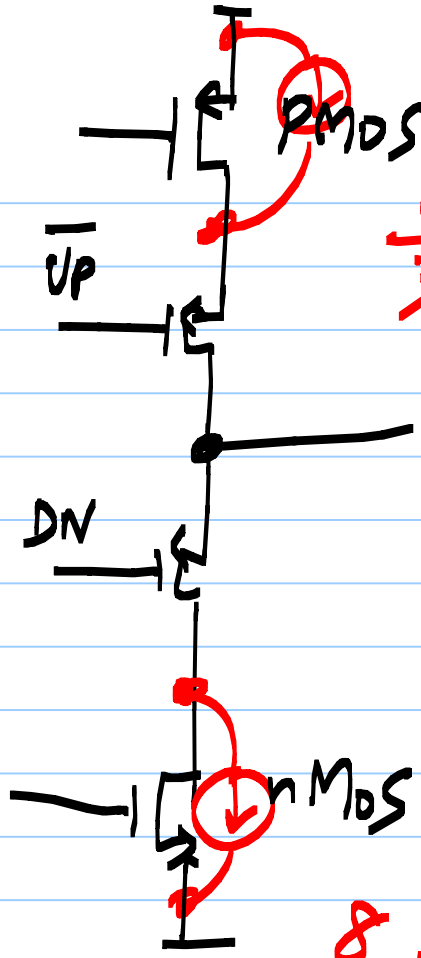
$$f_0 = \omega_0 / 2\pi$$

$$S_{\phi_{clk}} = S_{i_{n,cp}} \cdot \frac{1}{(DF \cdot I_{cp}/2\pi)^2} \cdot \left[\frac{1}{1 + (f/f_{BW})^2} \right] \xrightarrow{\int} \sigma^2_{\phi_{clk}}$$





$\frac{8}{3}kT\overline{g_m}$.



pMOS current source I_{cp}

$\frac{8}{3}kT \cdot g_{m_p} = \frac{8}{3}kT \cdot \frac{2I_{cp}}{V_{GS} - V_{Tp}}$

nMOS current source I_{cp}

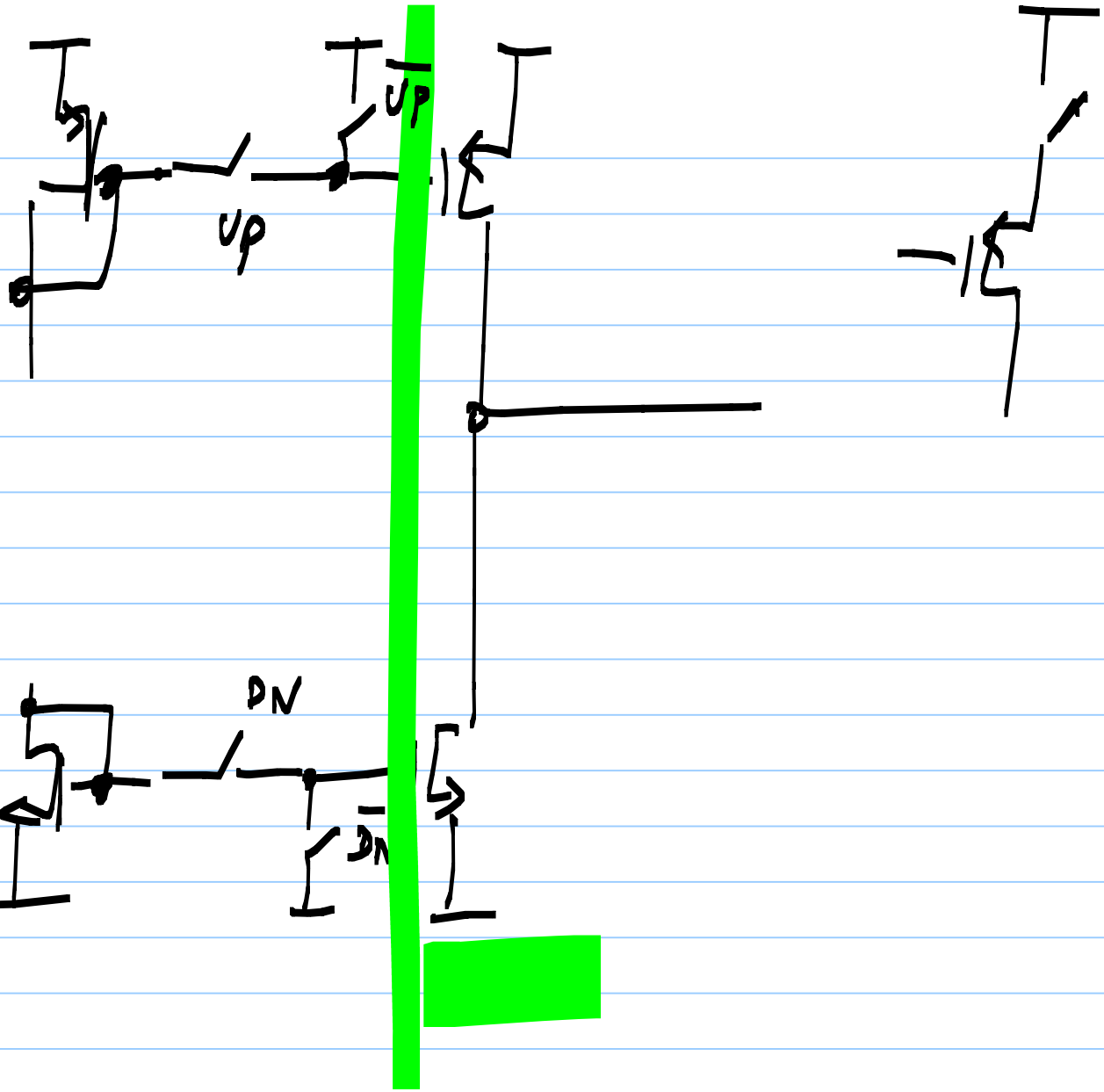
$\frac{8}{3}kT g_{m_n} = \frac{8}{3}kT \cdot \frac{2I_{cp}}{V_{GS} - V_{Tn}}$

$$\frac{8}{3}kT\,g_m$$

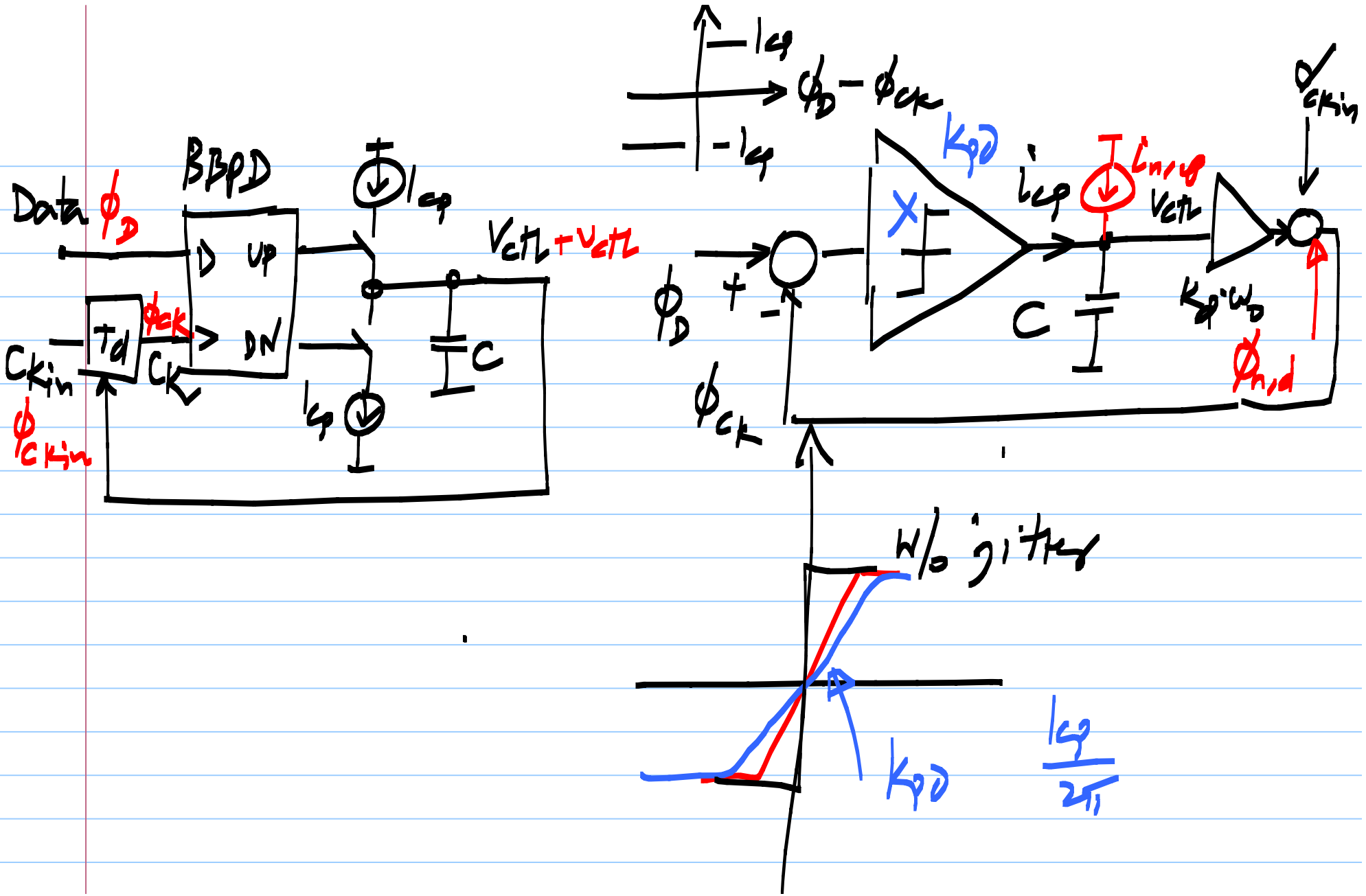
$$\sigma^2_{\phi_{CK}} = \frac{8}{3}kT\,\frac{2I_{CP}}{(V_{GS}-V_T)}\cdot\frac{1}{\left(\Delta F\cdot\frac{I_{CP}}{2\pi}\right)^2}\cdot\frac{\pi}{2}f_{BW}$$

$$S_{\phi_{CK}} = \frac{8}{3}kT\cdot\frac{2I_{CP}}{(V_{GS}-V_T)}\cdot\frac{1}{\left(\Delta F\,\frac{I_{CP}}{2\pi}\right)^2}\cdot\frac{1}{1+\left(f/f_{BW}\right)^2}$$

$$\mathcal{L}(f) = \frac{4}{3}kT\cdot\left[\ \ldots\ \right]$$


UP
UP
DN
DN

$$\frac{\phi_{ck}}{\phi_{in,d}} = \frac{s/\omega_{BW}}{1 + s/\omega_{BW}}$$


Data
ϕ_D
BBPD
D
UP
DN
Td
ϕ_{CK}
CK
CK_{in}
ϕ_{CKin}
I_{cp}
V_{ctl}
$+v_{ctl}$
C
$-I_{cp}$
$\phi_D - \phi_{CK}$
K_{pd}
X
i_{cp}
$i_{n,cp}$
V_{ctl}
C
$K_{vco} \cdot v_{ctl}$
ϕ_{CKin}
$\phi_{n,d}$
ϕ_D
+
−
ϕ_{CK}
W/o jitter
K_{pd}
$\frac{I_{cp}}{2\pi}$