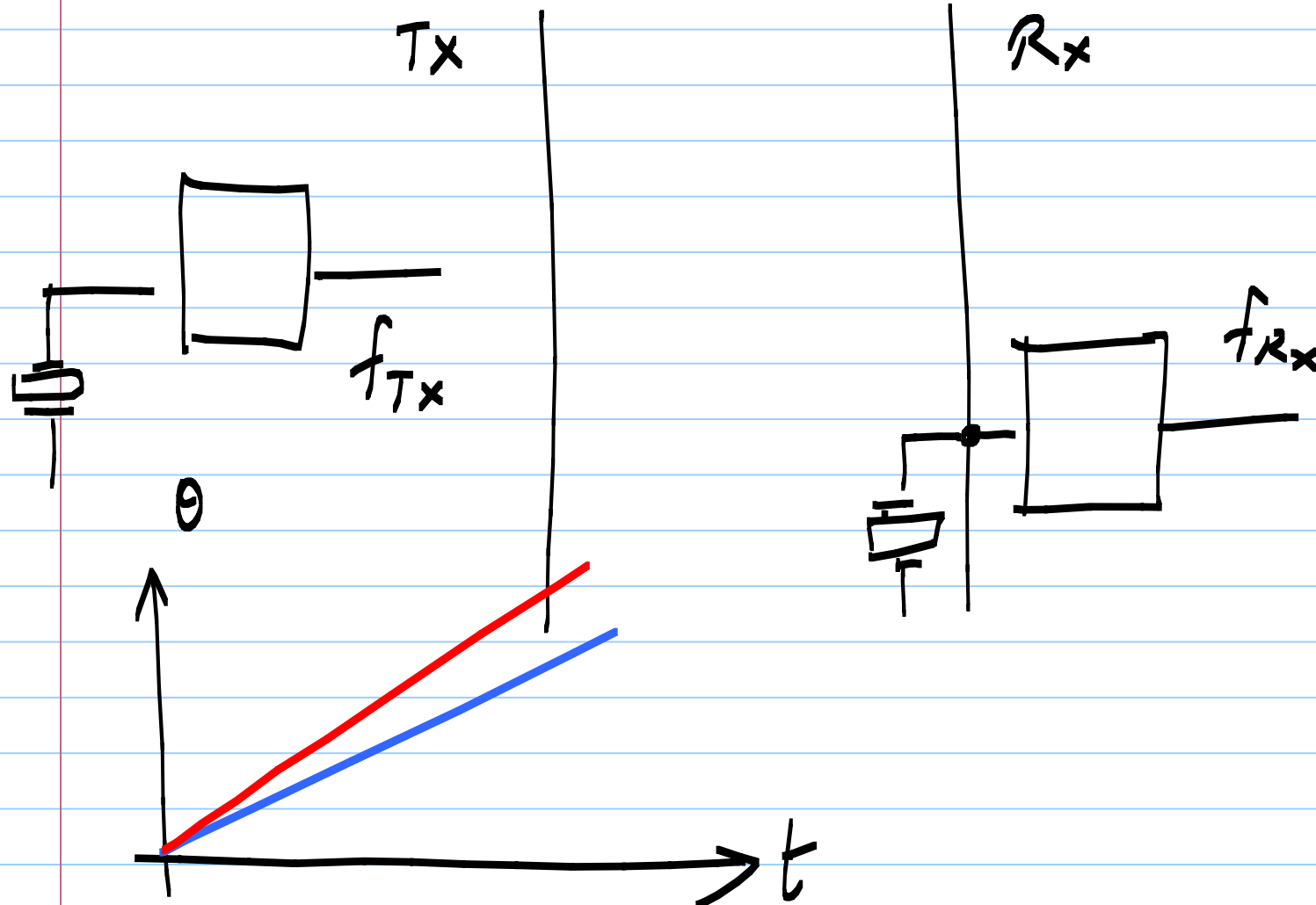


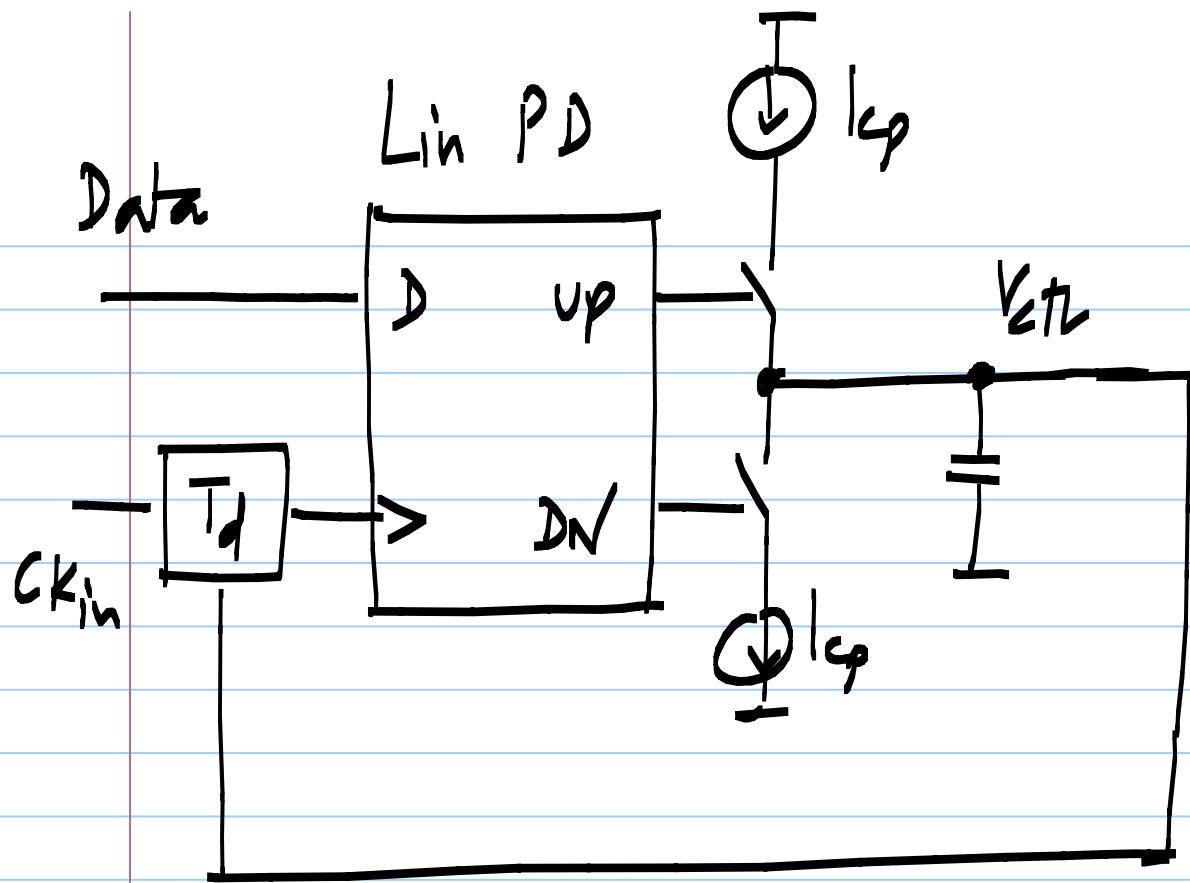
# Clock and data recovery w/o forwarded clock

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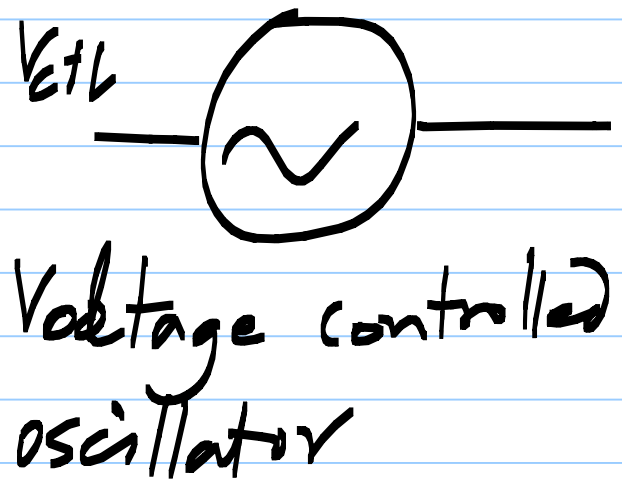


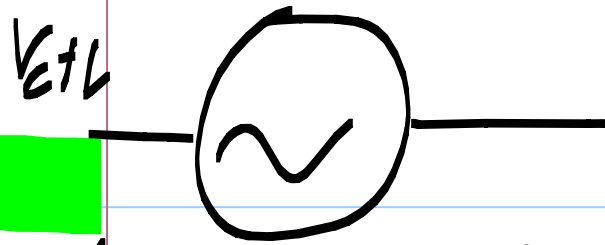
Need to  
recover the  
transmit  
frequency

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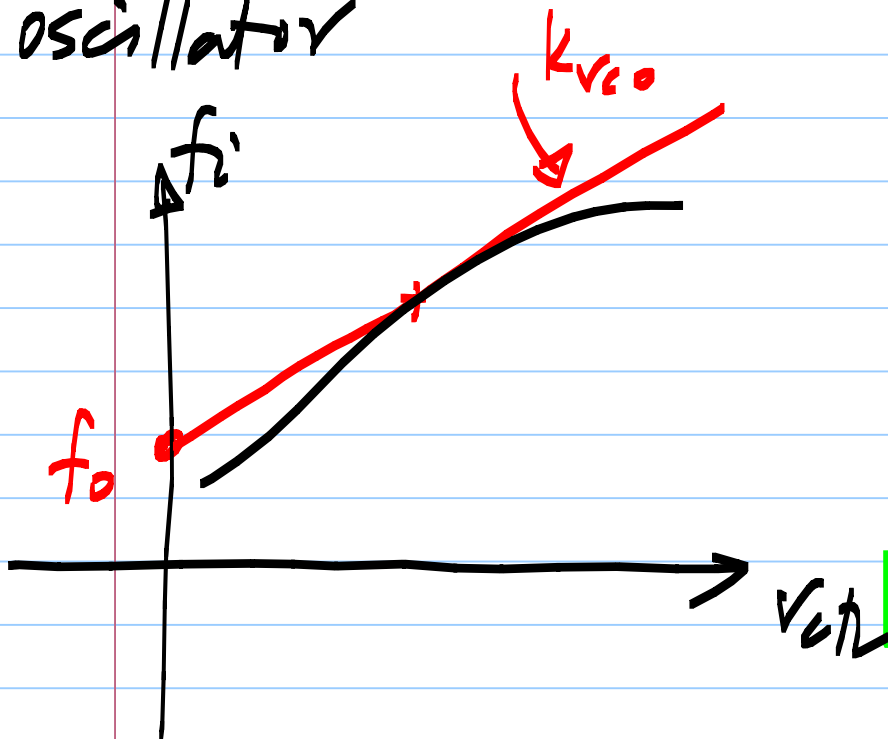
Without a forwarded clock, we need a clock generator in the receiver  
 - variable frequency





$$\cos(\theta(t))$$

Voltage controlled oscillator



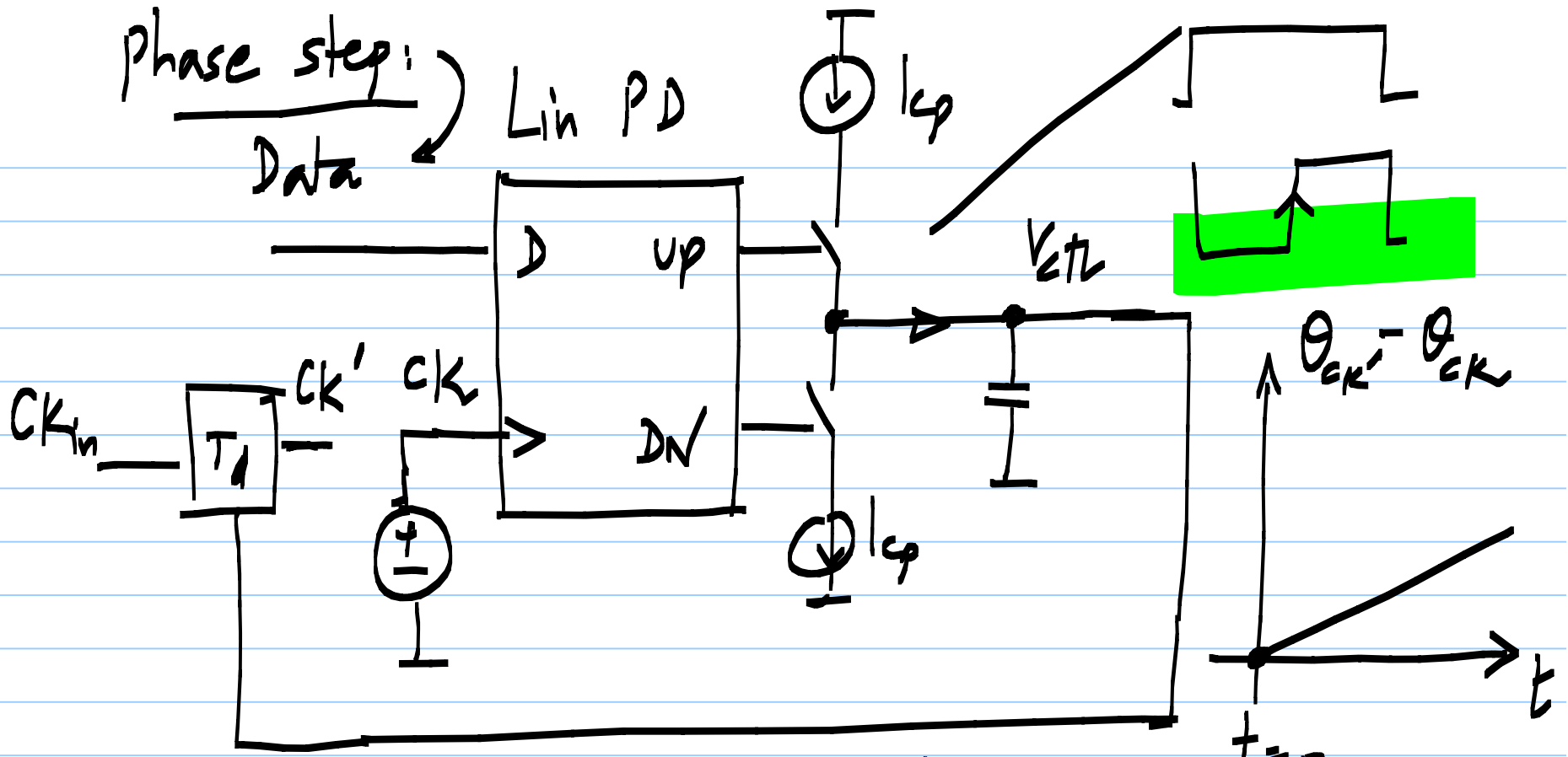
$$\theta(t) = \underbrace{2\pi f_0 t}_{\cancel{2\pi f_0 t}} + 2\pi \int K_{VCO} V_{ctrl} dt$$

$$\omega_i = \frac{d\theta}{dt} = 2\pi \left( f_0 + K_{VCO} V_{ctrl} \right)$$

Hz / V

$$f_i = \frac{1}{2\pi} \frac{d\theta}{dt} = f_0 + K_{VCO} V_{ctrl}$$

$f_0$ : free-running frequency



Phase step:  
Data

Lin PD

$I_{cp}$

$V_{ctrl}$

$CK_{in}$

$CK'$

$CK$

D

up

DN

$I_{cp}$

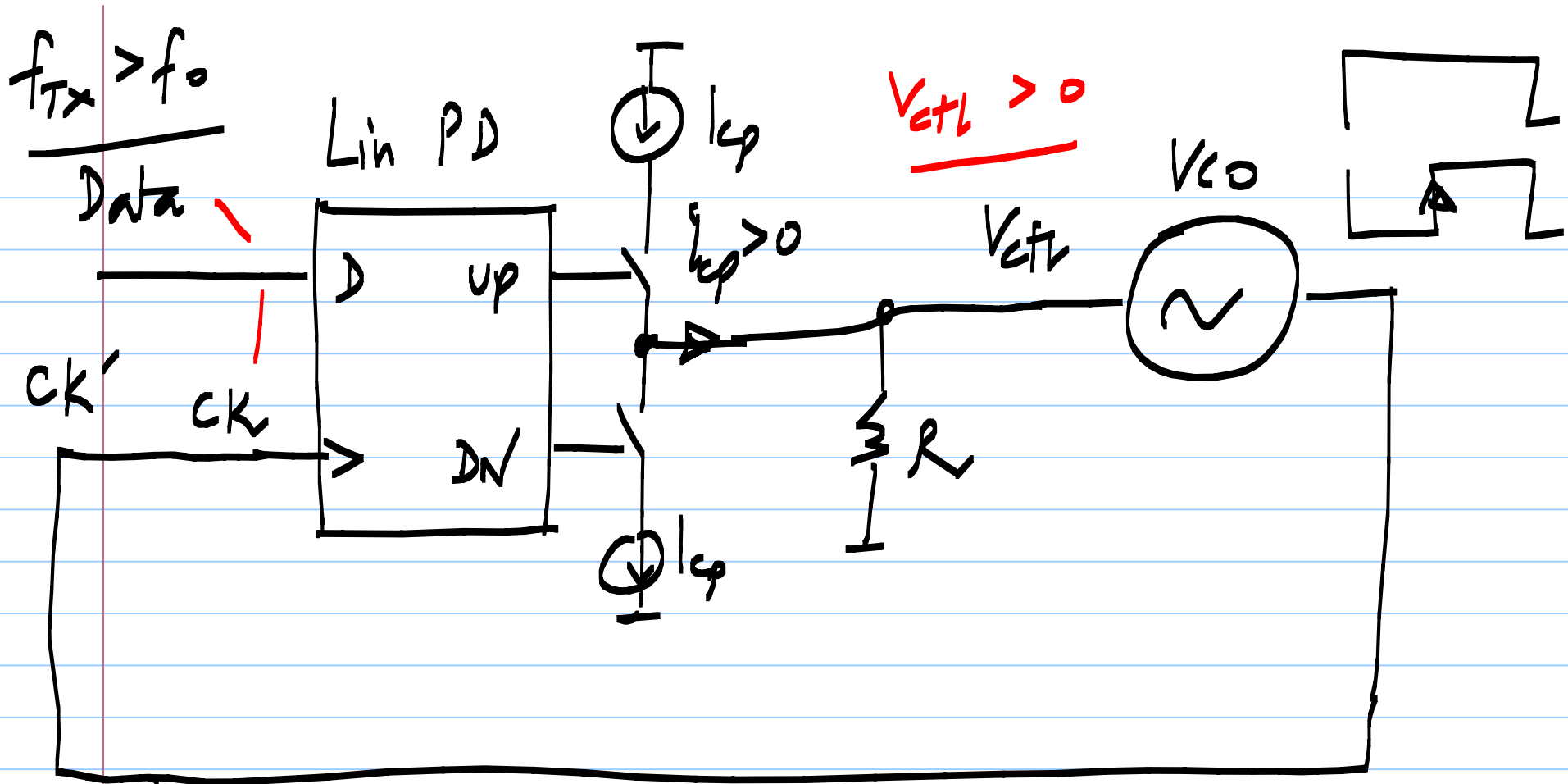
$\theta_{CK'} - \theta_{CK}$

$t=0$

$t$

\* Initially locked

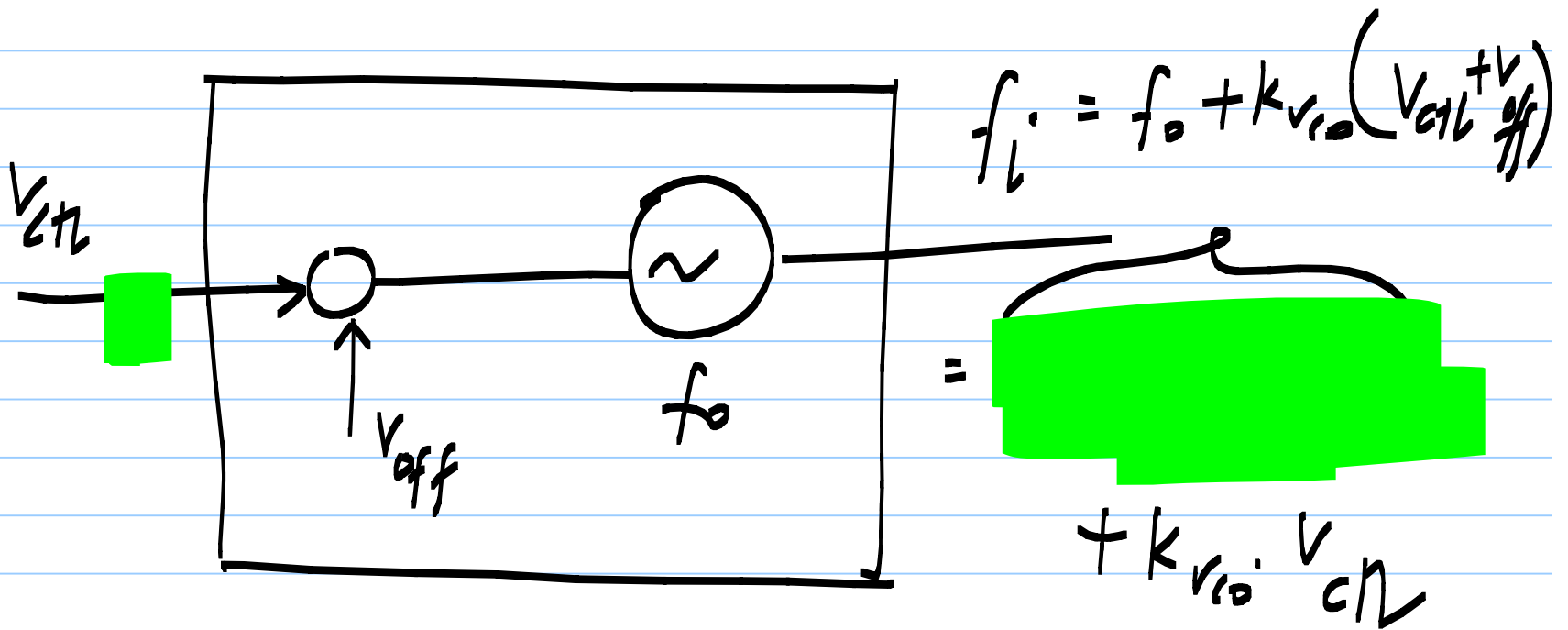
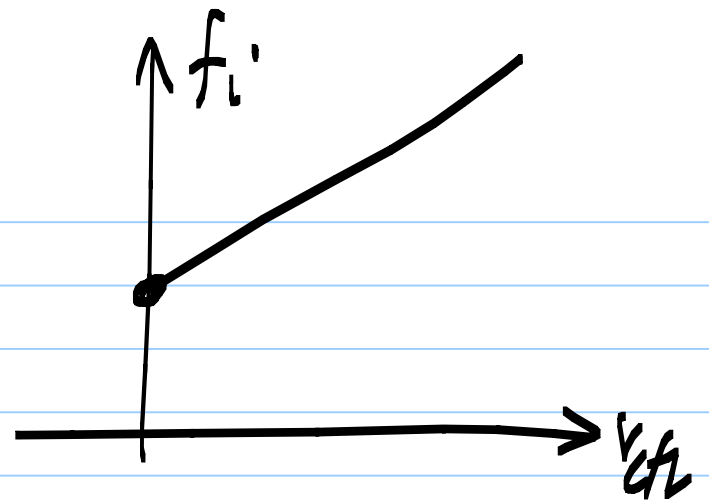
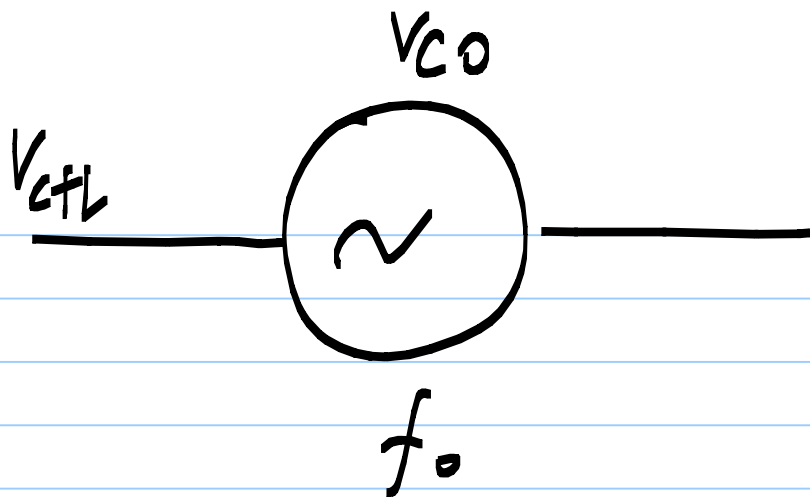
w/ forwarded clock

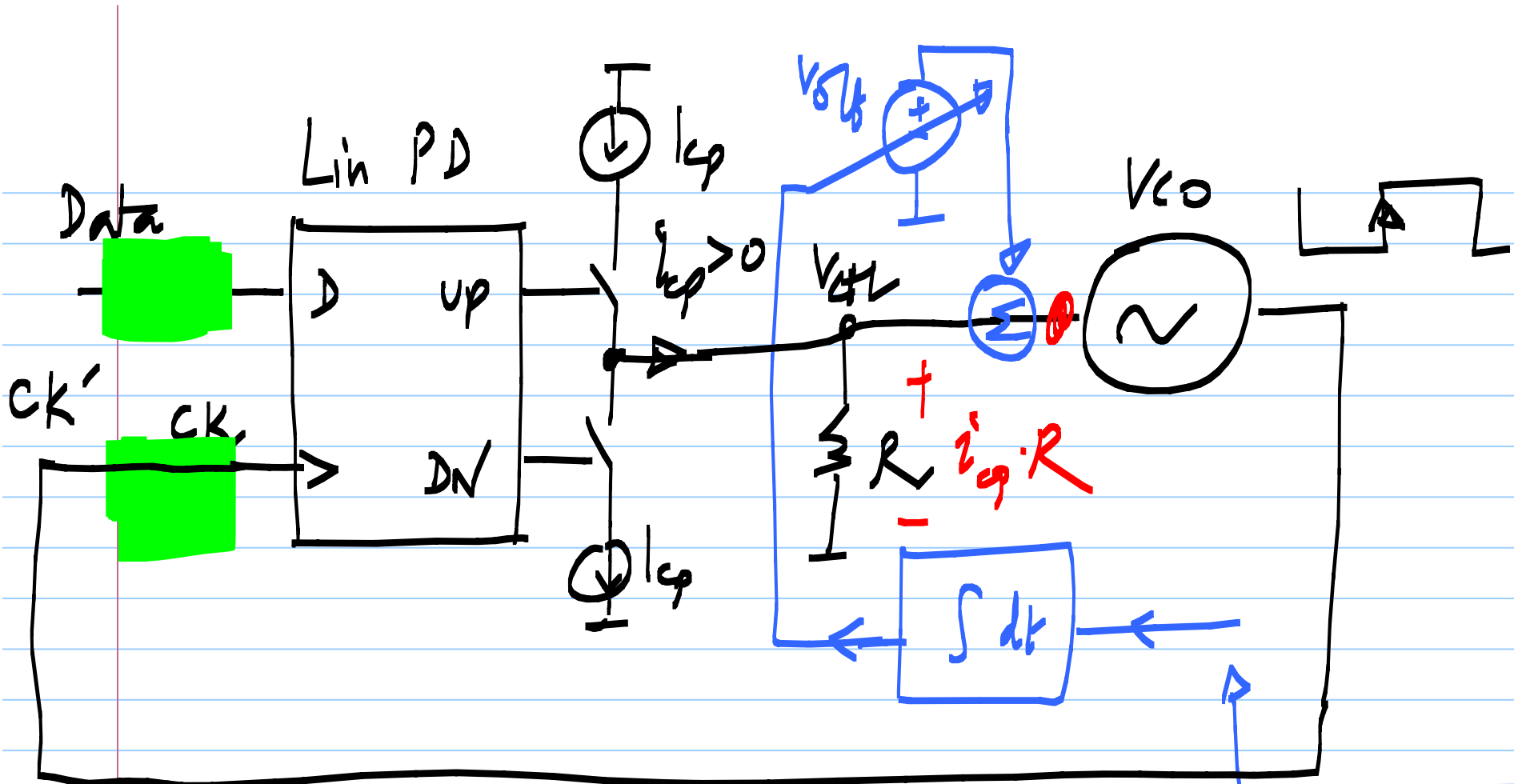


w/o forwarded clock

Assume:  $f_0 = f_{TX}$

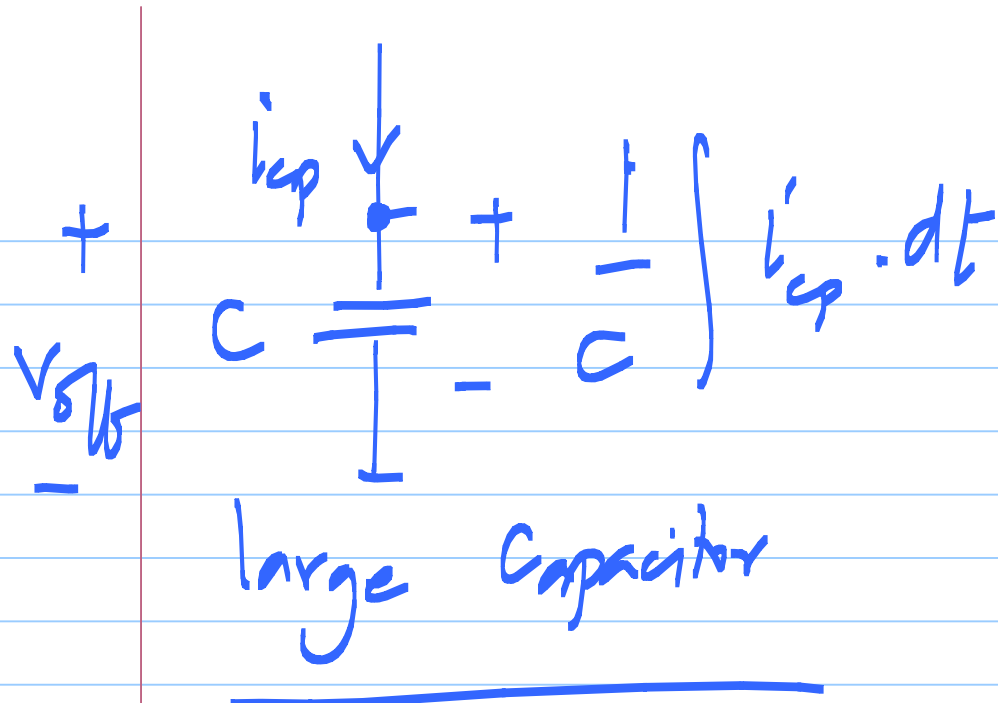






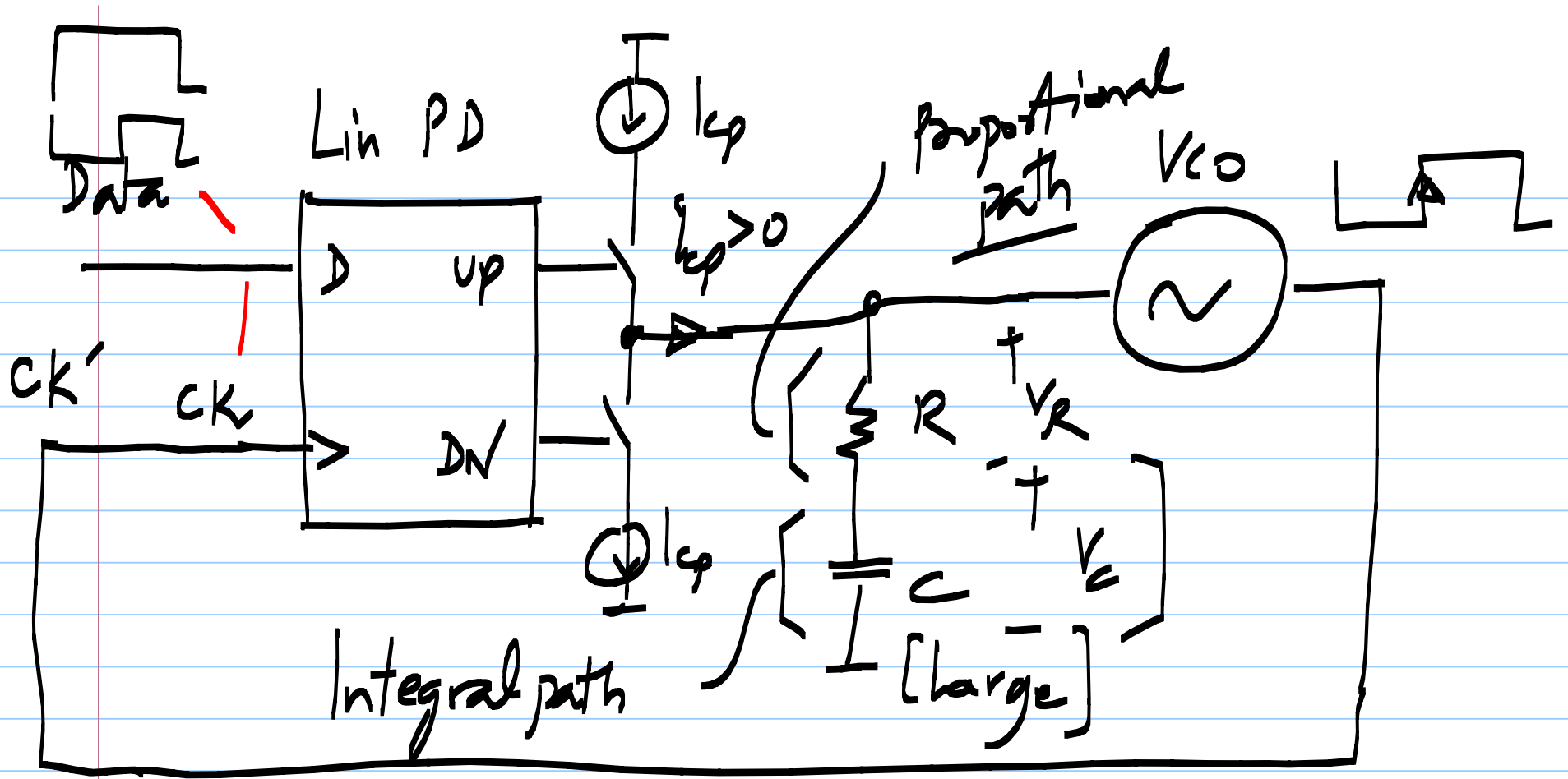
if  $f_0 \neq f_{ix}$ ;  $\phi_D - \phi_{ck} \neq 0$ ;  $i_{cp} \neq 0$ ;  $V_{ctrl} \neq 0$





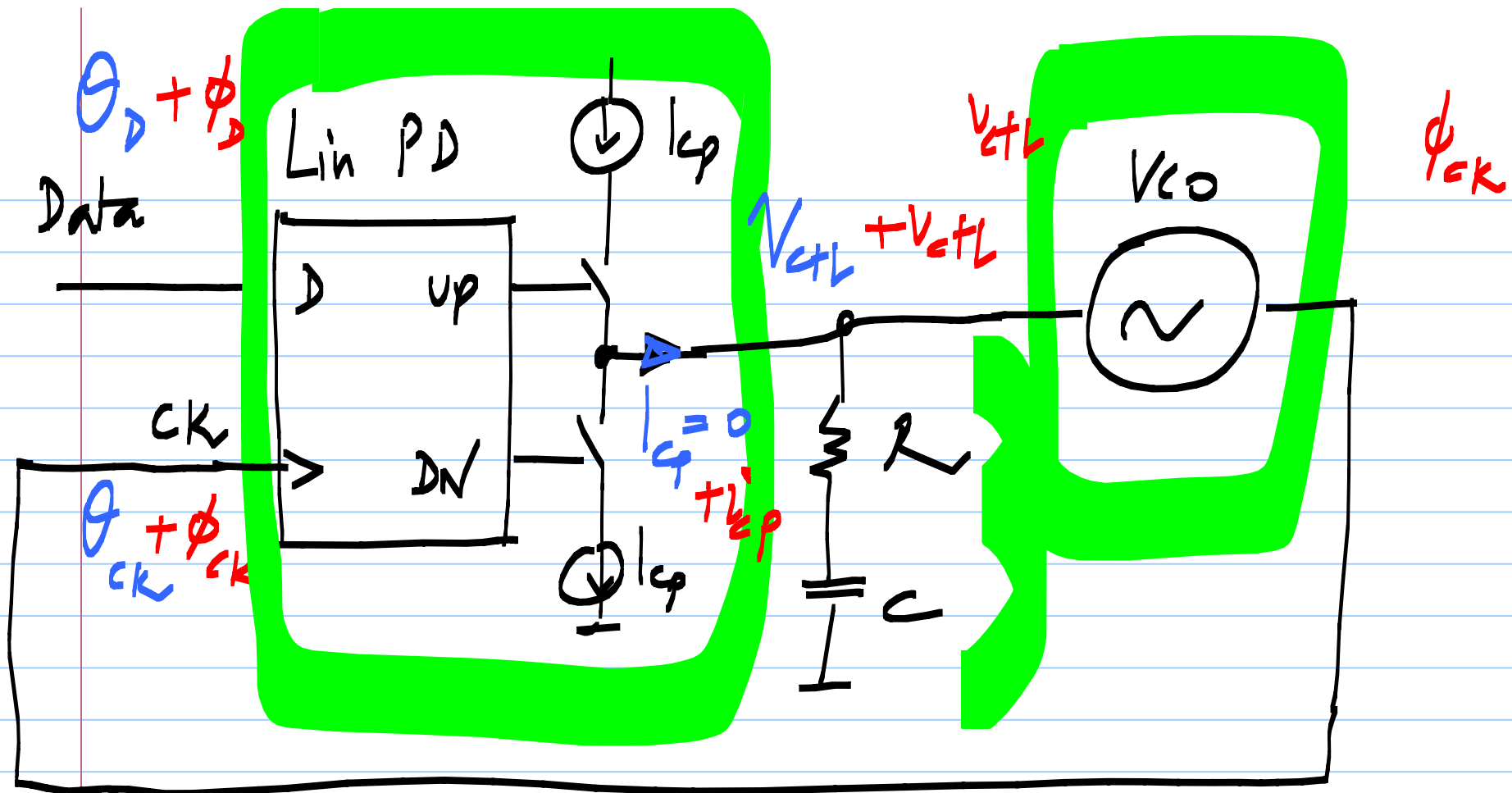
Add  $i_{cp} \cdot R$  to  $\frac{1}{C} \int i_{cp} dt$





CDR w/o forwarded clock:

In steady state,  $V_c$  moves  $V_{co}$  frequency to  $f_{Tx}$



Op. point