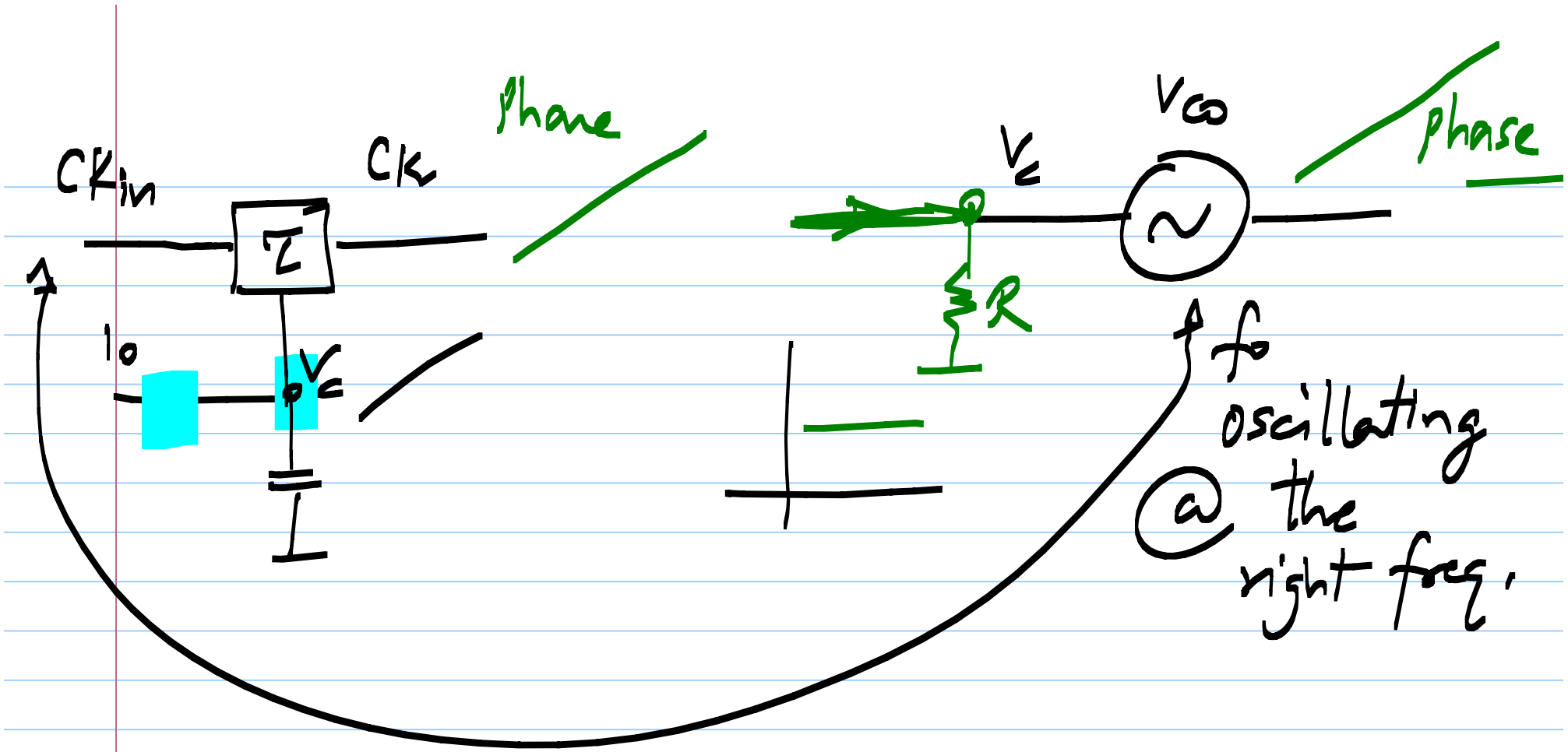
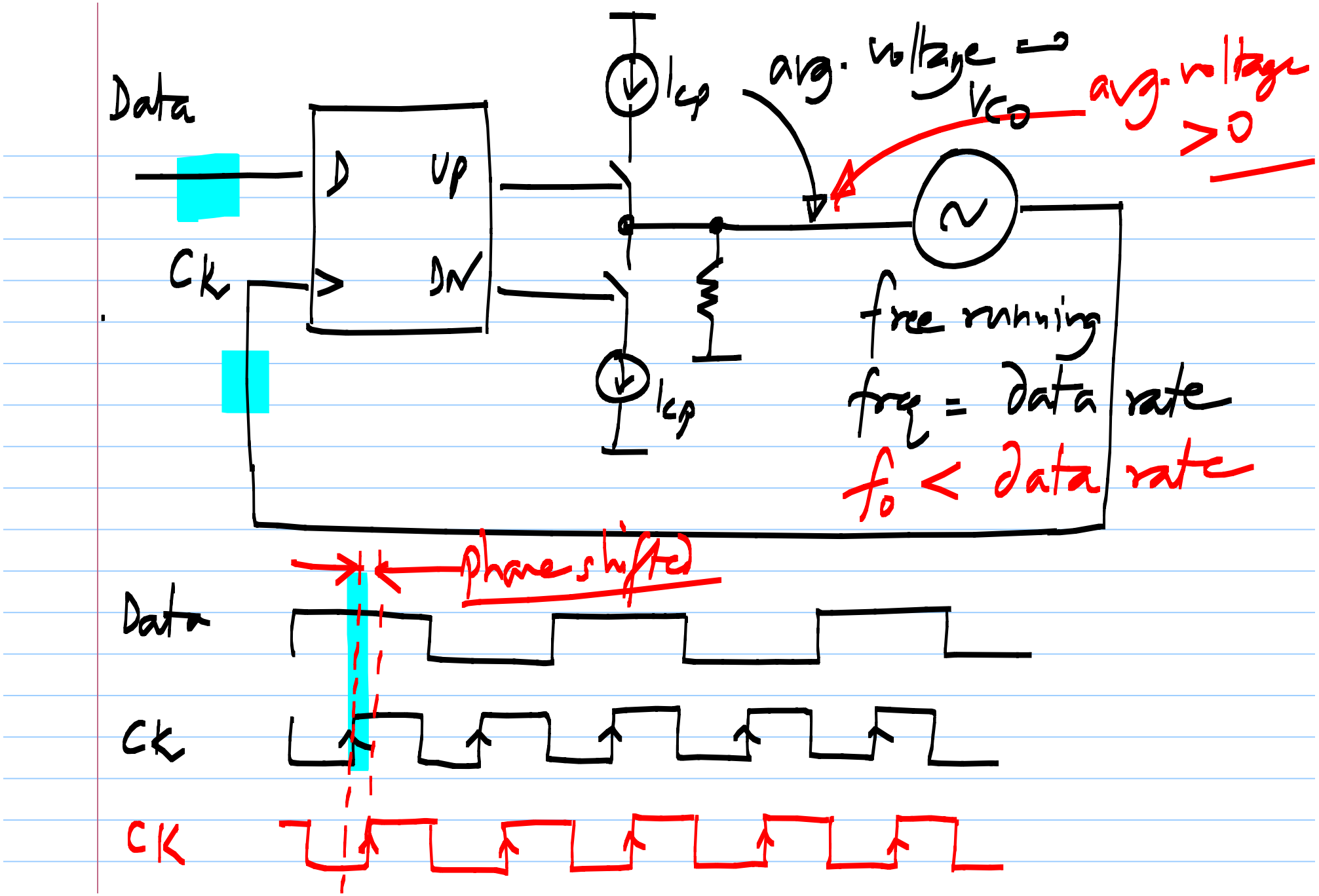
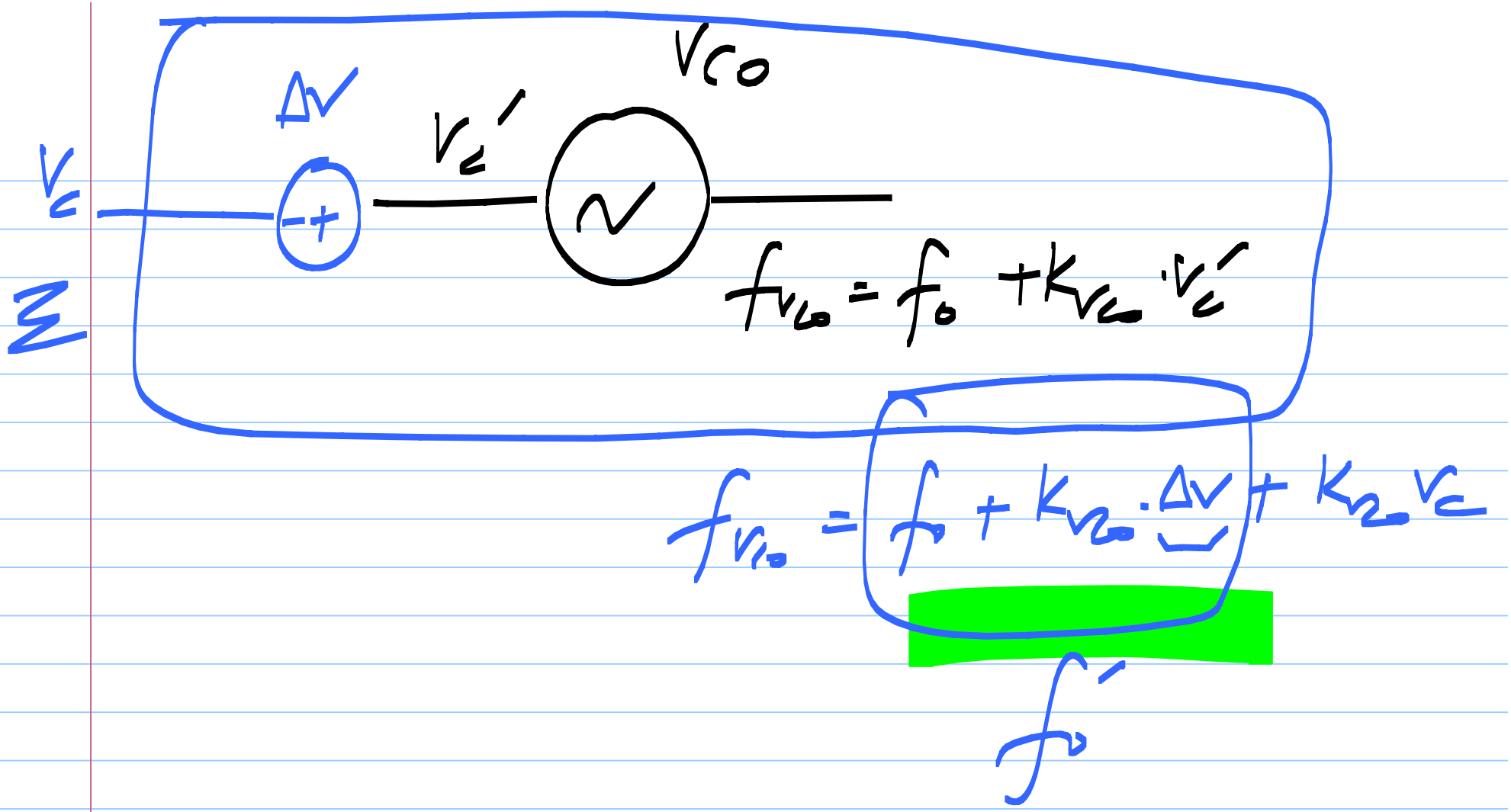
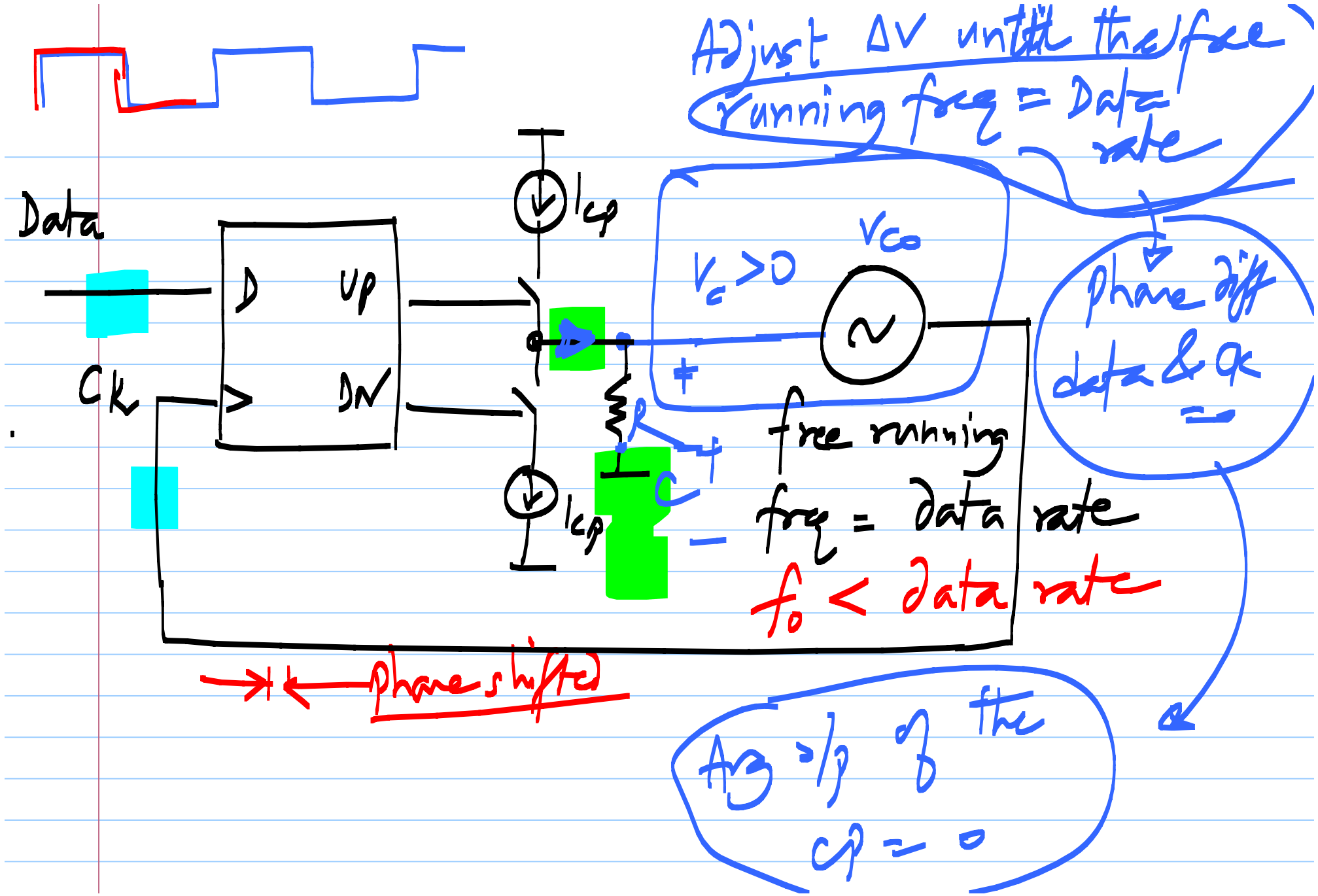
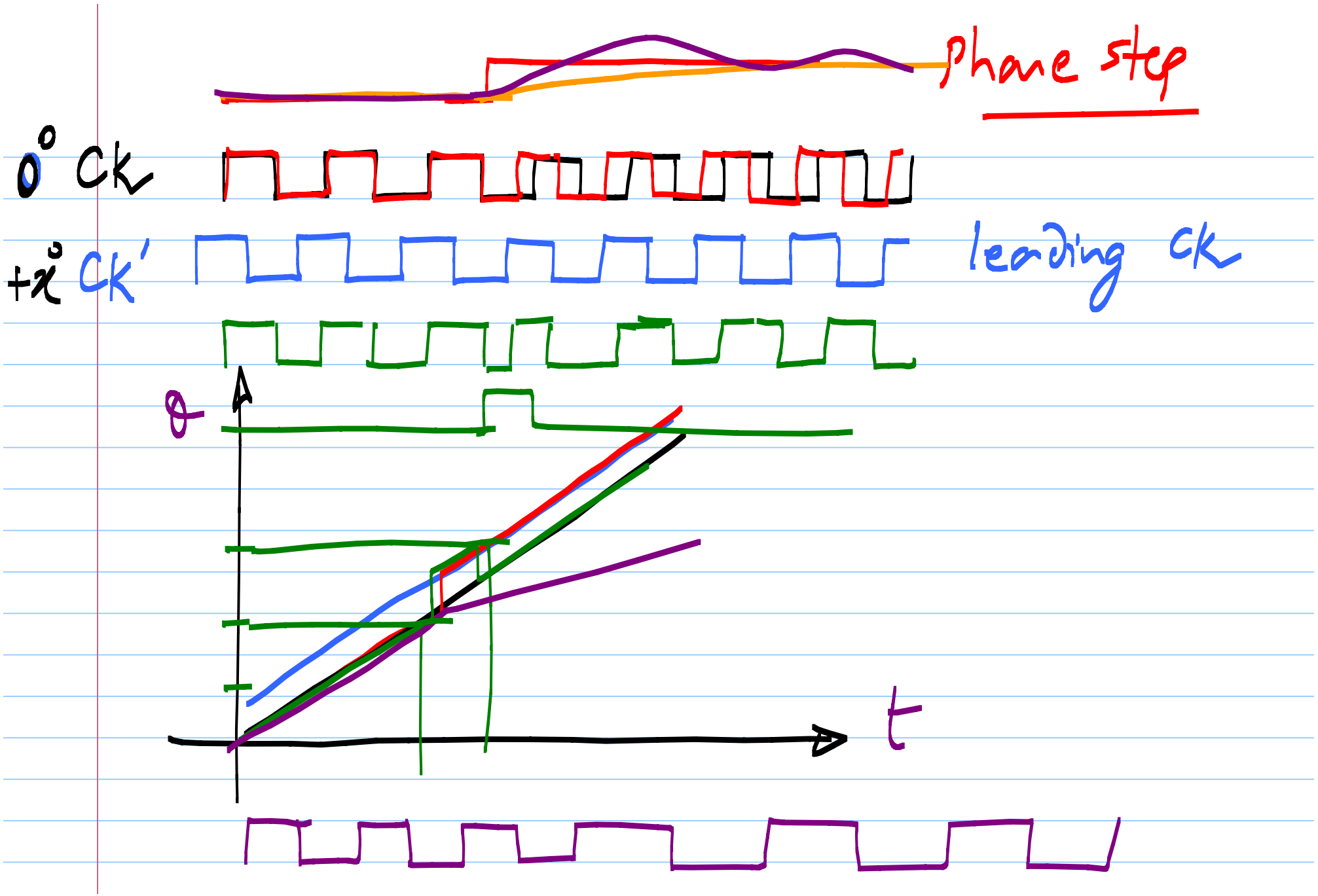
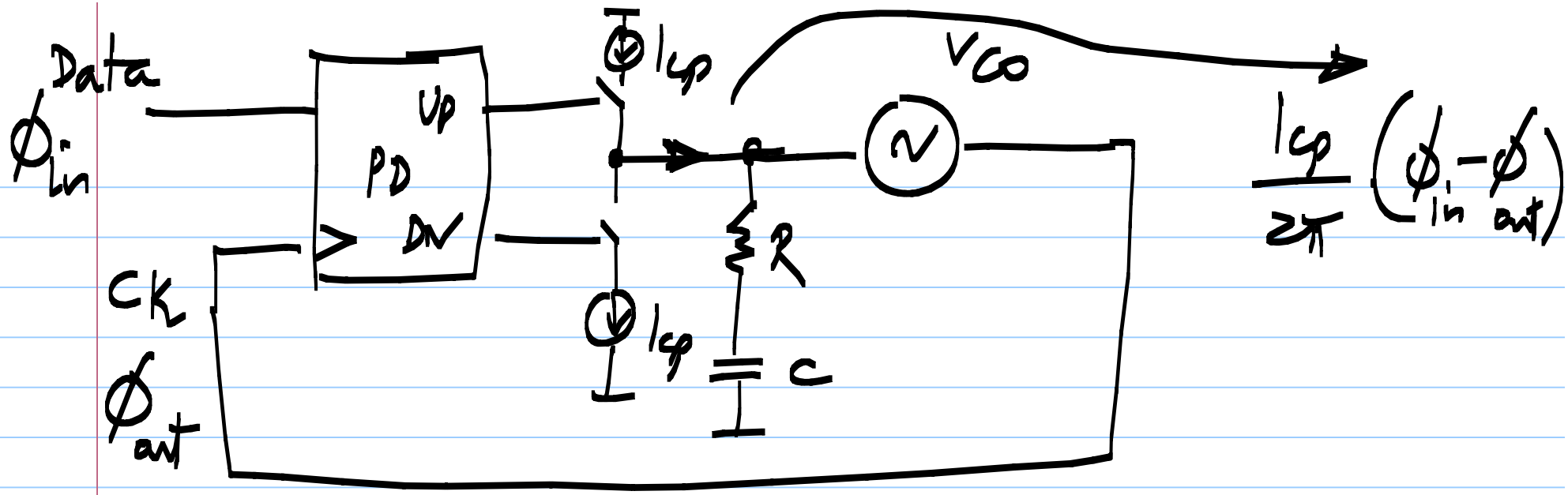

CKin
CK
Phase
Io
Vc
Vc
Vco
Phase
R
f
oscillating
@ the
right freq.

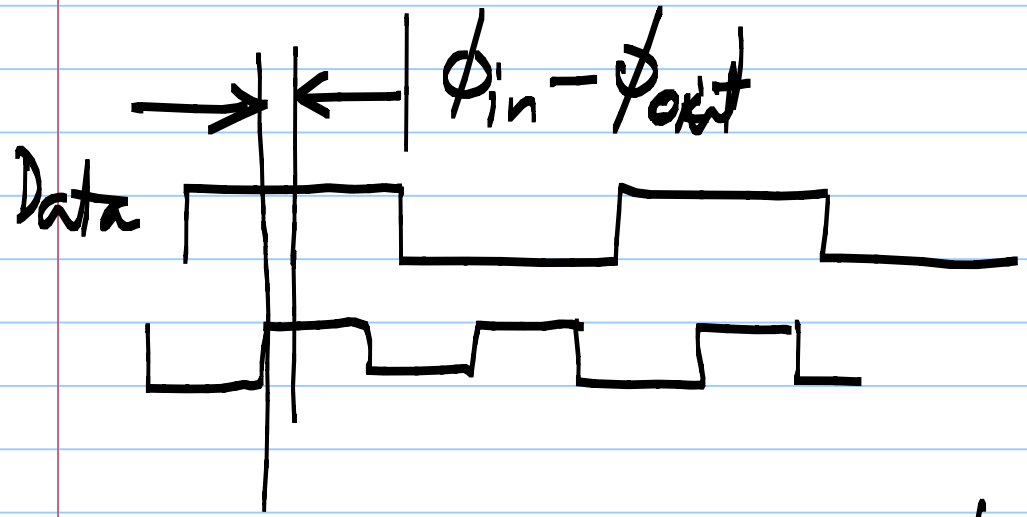

Data
D
Up
Ck
>
Dn
Icp
Icp
avg. voltage →
Vc
avg. voltage
>0
free running
freq = data rate
f0 < data rate
phase shifted
Data
Ck
CK


VCO
Δv
v_c'
v_c
$f_{vco} = f_0 + k_{vco} \cdot v_c'$
$f_{vco} = f_0 + k_{vco} \cdot \Delta v + k_{vco} v_c$
f_0'

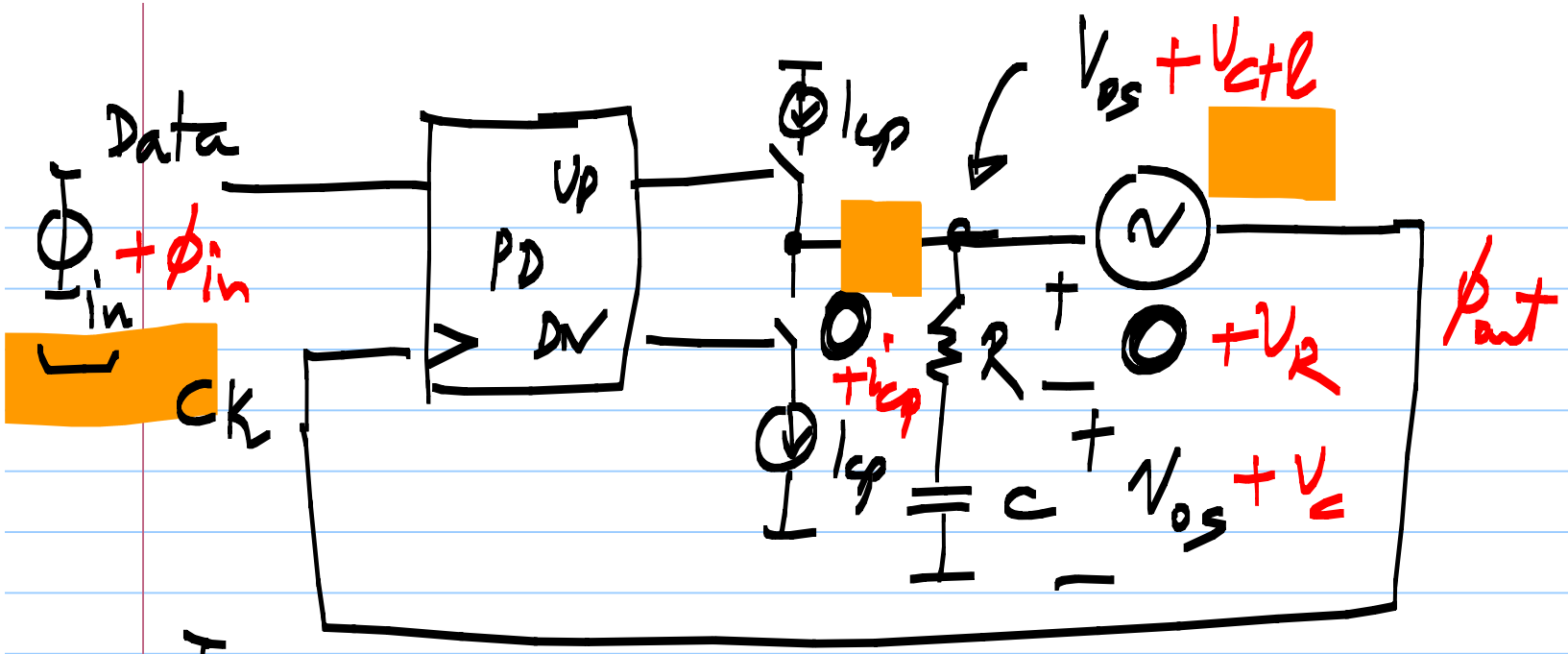

Adjust ΔV until the free running freq = Data rate
Data
D
Up
Ck
Dn
Icp
Icp
C
Vco
Vc > 0
+
free running freq = data rate
f0 < data rate
phase diff data & ck
phase shifted
Adj Vc of the cp = 0


phase step
0° ck
+x° ck'
leading ck
θ
t

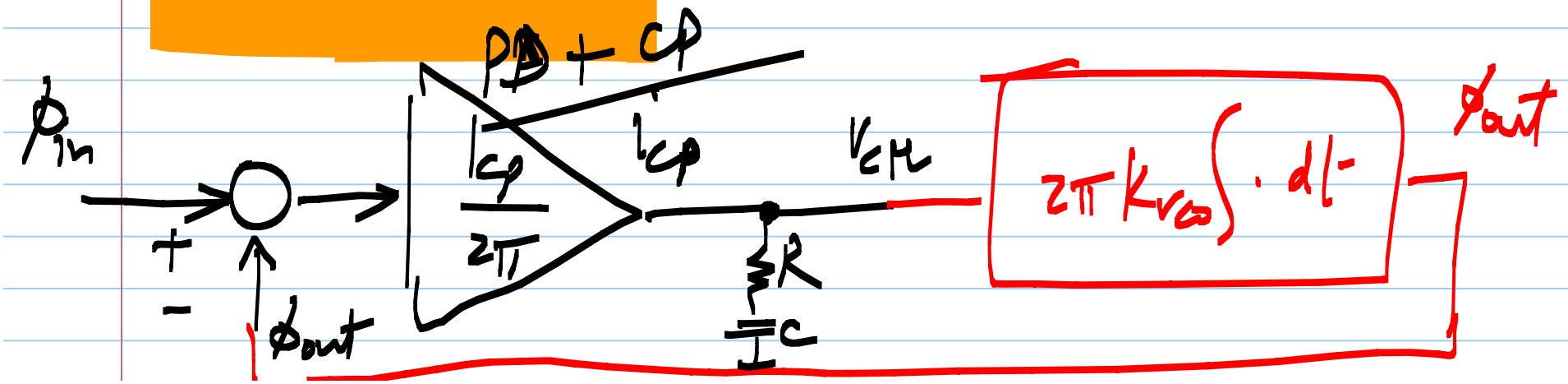


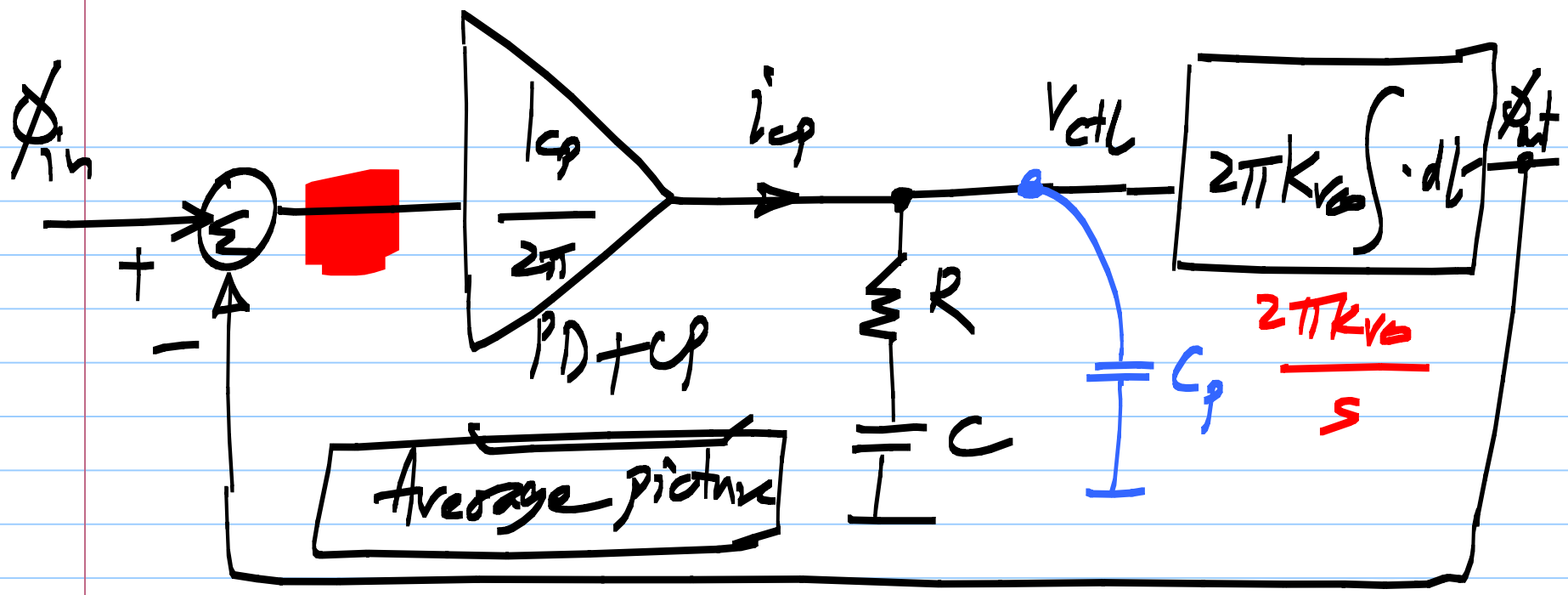


CK is leading Data by $\phi_{out} - \phi_{in}$



$$\Phi_{CK} = \Phi_{in} + \phi_{out}$$





$$\frac{\phi_{out}(s)}{\phi_{in}(s)} = \frac{L}{1+L} = \frac{1}{1+\frac{1}{L}}$$

dc gain = 1

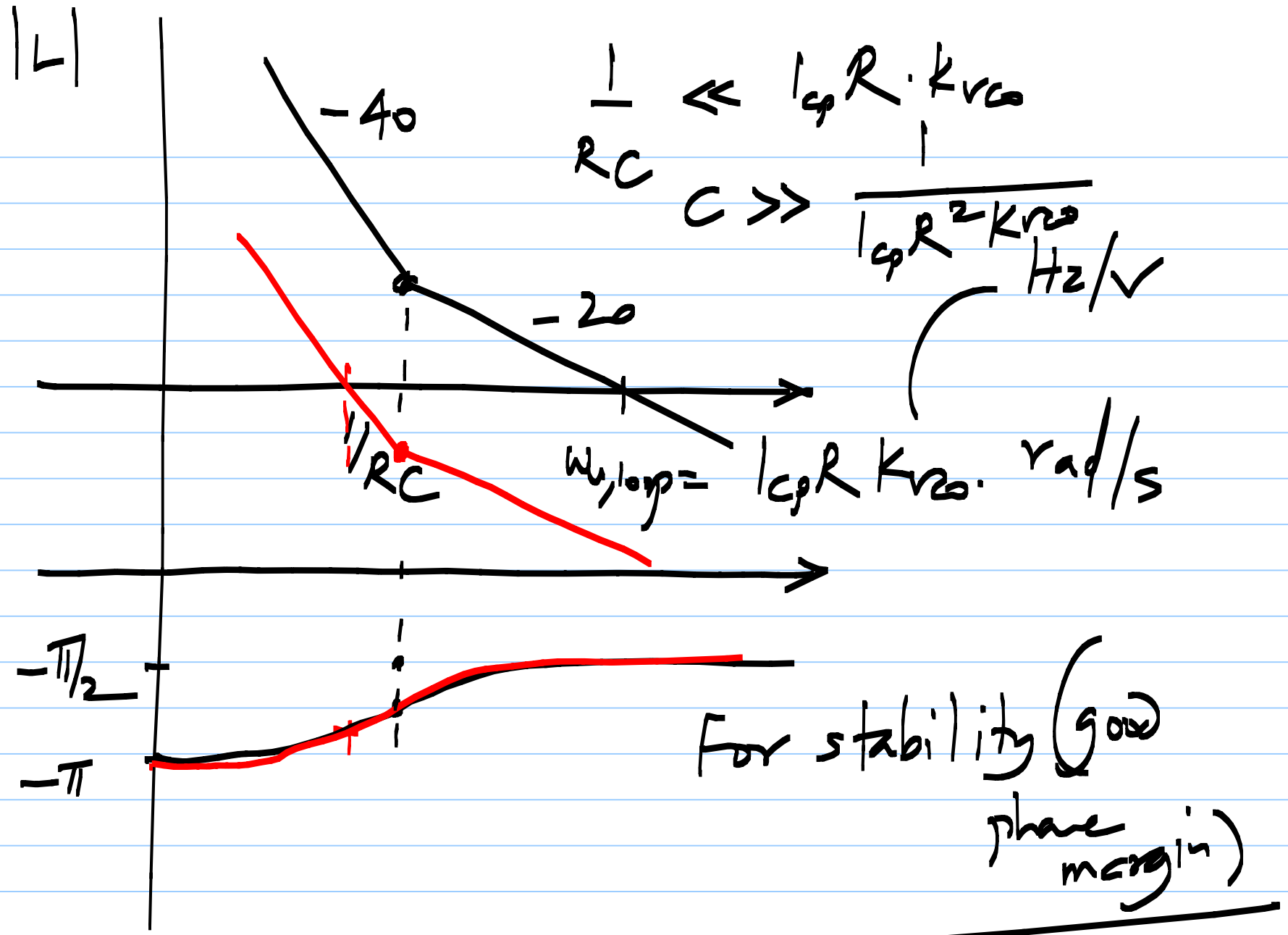
$$L(s) = \frac{I_{cp}}{2\pi}\left(R + \frac{1}{sC}\right) \cdot \frac{2\pi K_{VCO}}{s}$$

$$= \frac{I_{cp} R K_{VCO}}{s}\left(1 + \frac{1}{sCR}\right)$$

$$= \frac{I_{cp} R K_{VCO}}{s} \cdot \left(\frac{1+sCR}{sCR}\right)$$

$$H(s) = \frac{L}{1+L}$$

poles, zeros, Quality / damping factor



$$\frac{1}{RC} \ll I_{cp} R \cdot K_{VCO}$$

$$C \gg \frac{1}{I_{cp} R^2 K_{VCO}}$$

K_{VCO}: Hz/V

$\omega_{u,loop} = I_{cp} R K_{VCO}$ rad/s

For stability (good phase margin)