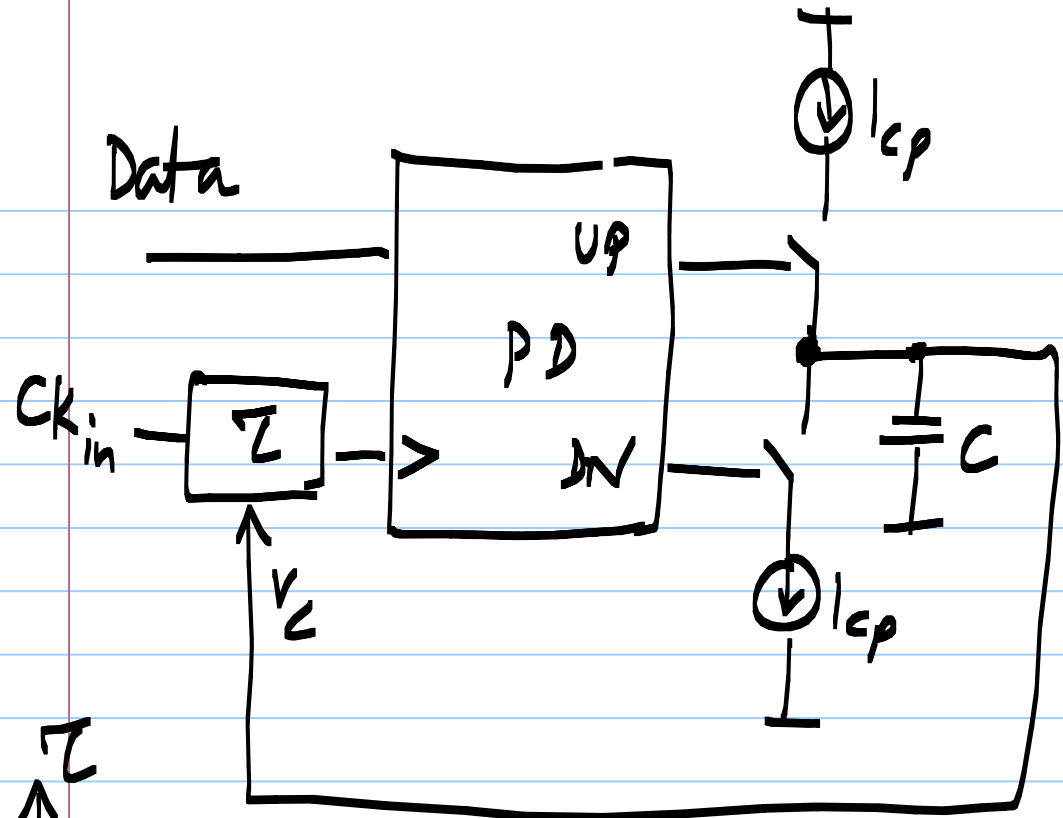
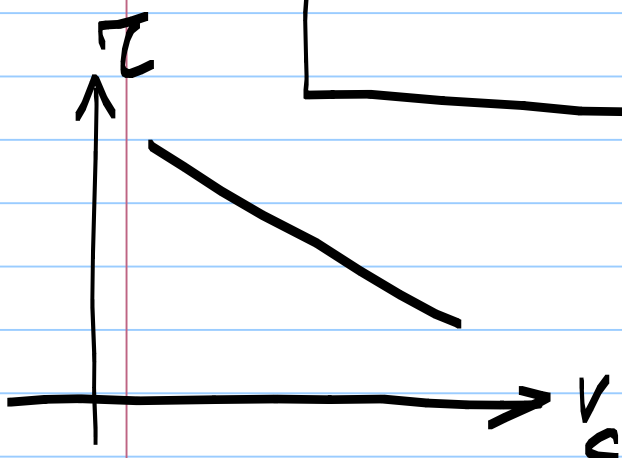
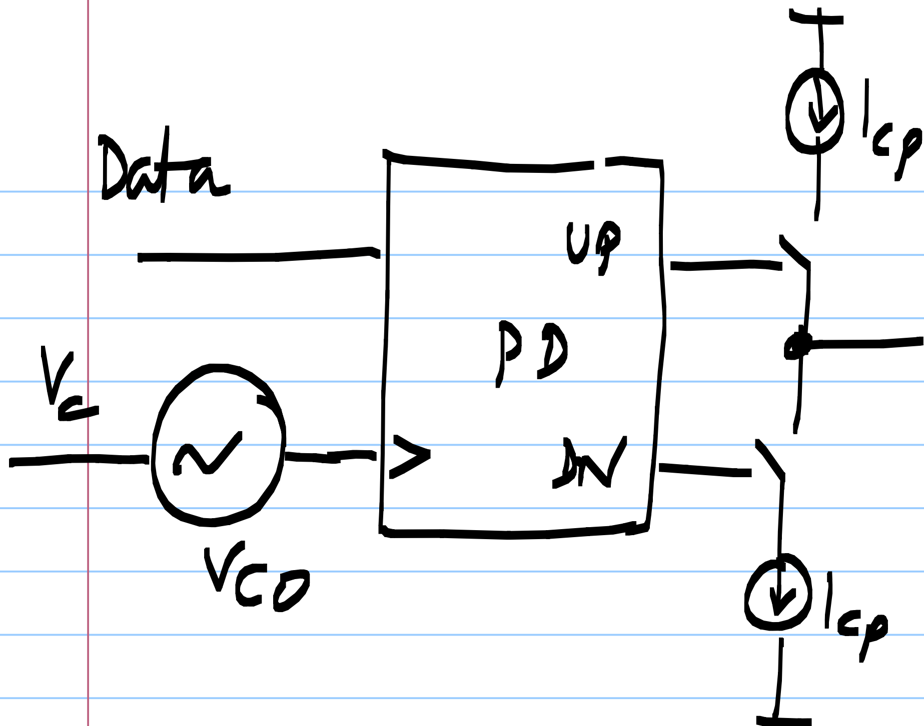

Data
Ck_in
τ
V_c
PD
UP
DN
I_cp
I_cp
C


τ
V_c



Data
V_c
VCO
PD
UP
DN
I_{cp}
I_{cp}

Periodic signals

$\mathrm{sgn}(\cos(\theta))$

Periodic function: $\cos(\theta)$: periodic with 2π

θ ← phase

$p(\theta)$: p: periodic with 2π

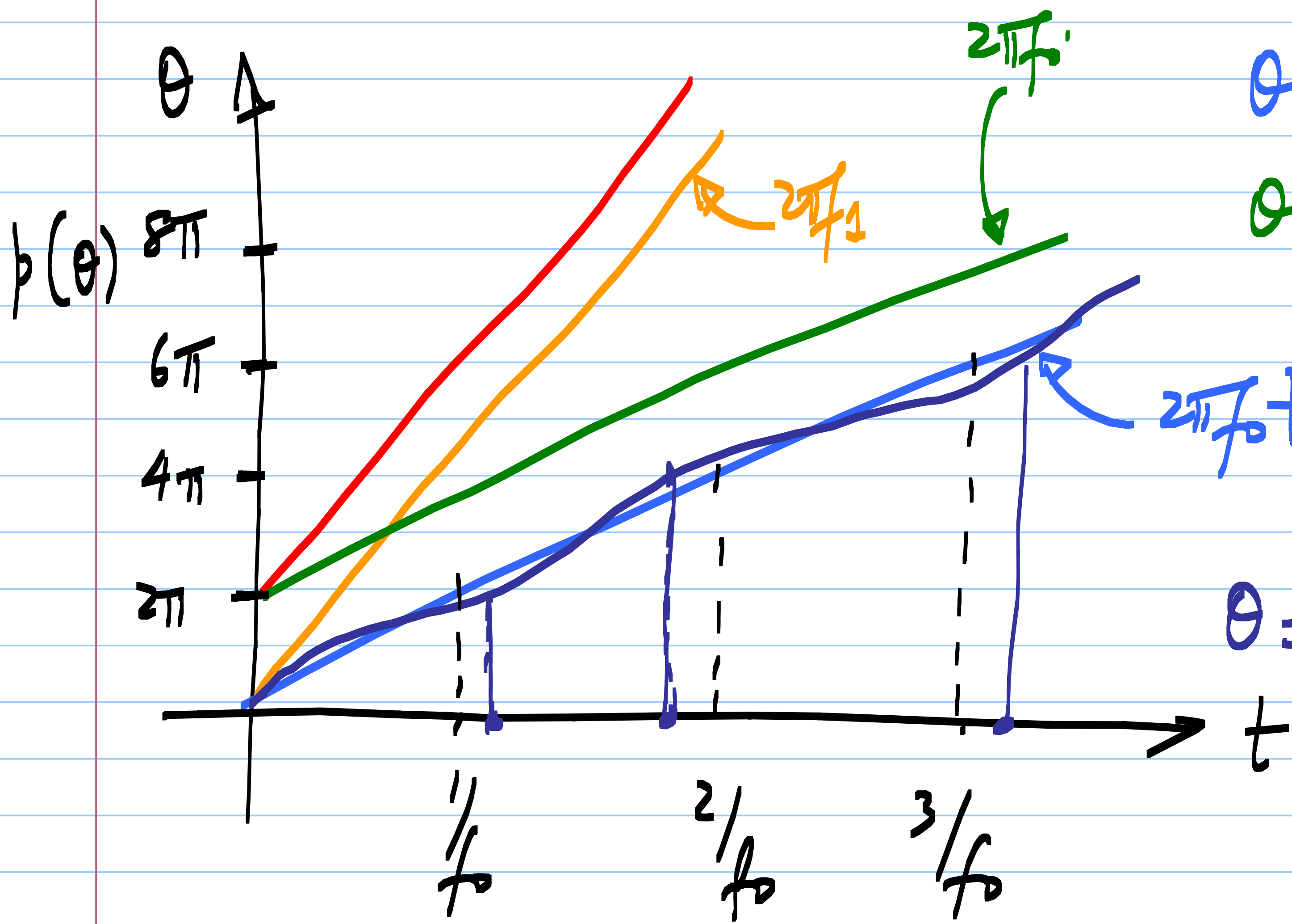
Periodic in time t $\quad \theta = 2\pi f_0 t + \Phi_0$

$\cos(2\pi f_0 t + \Phi_0 + \phi(t))$

Periodic in t[illegible] with [illegible] a period $1/f_0 = T_0$

$p(2\pi f_0 t)$

Phase of a signal periodic in time:



$\theta = 2\pi f_0 t$

$\theta = 2\pi f_0 t + \Phi_0$

$2\pi f_1 t$, $f_1 > f_0$

$\theta = 2\pi f_0 t + \phi(t)$

Phase and frequency of (Quasi) periodic signals

$p(\theta)$: periodic in θ with a period 2π

Phase $\theta(t) = \underbrace{2\pi f_0 t + \Phi_0}_{\text{periodic signal}} + \underbrace{\phi(t)}_{\text{zero-average}}$

θ vs. t is a straight line

Deviation from periodicity

Radian Frequency $= \dfrac{d\theta}{dt} = 2\pi f_0 + \dfrac{d\phi(t)}{dt}$

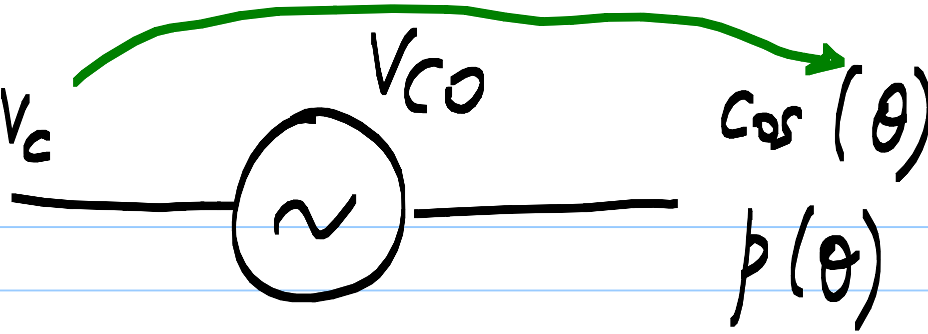
cyclic frequency

$$f = \frac{1}{2\pi}\frac{d\theta}{dt} = f_0 + \frac{1}{2\pi}\cdot\frac{d\phi}{dt}$$

Instantaneous frequency

$\propto t$ if f is a constant different from f_0

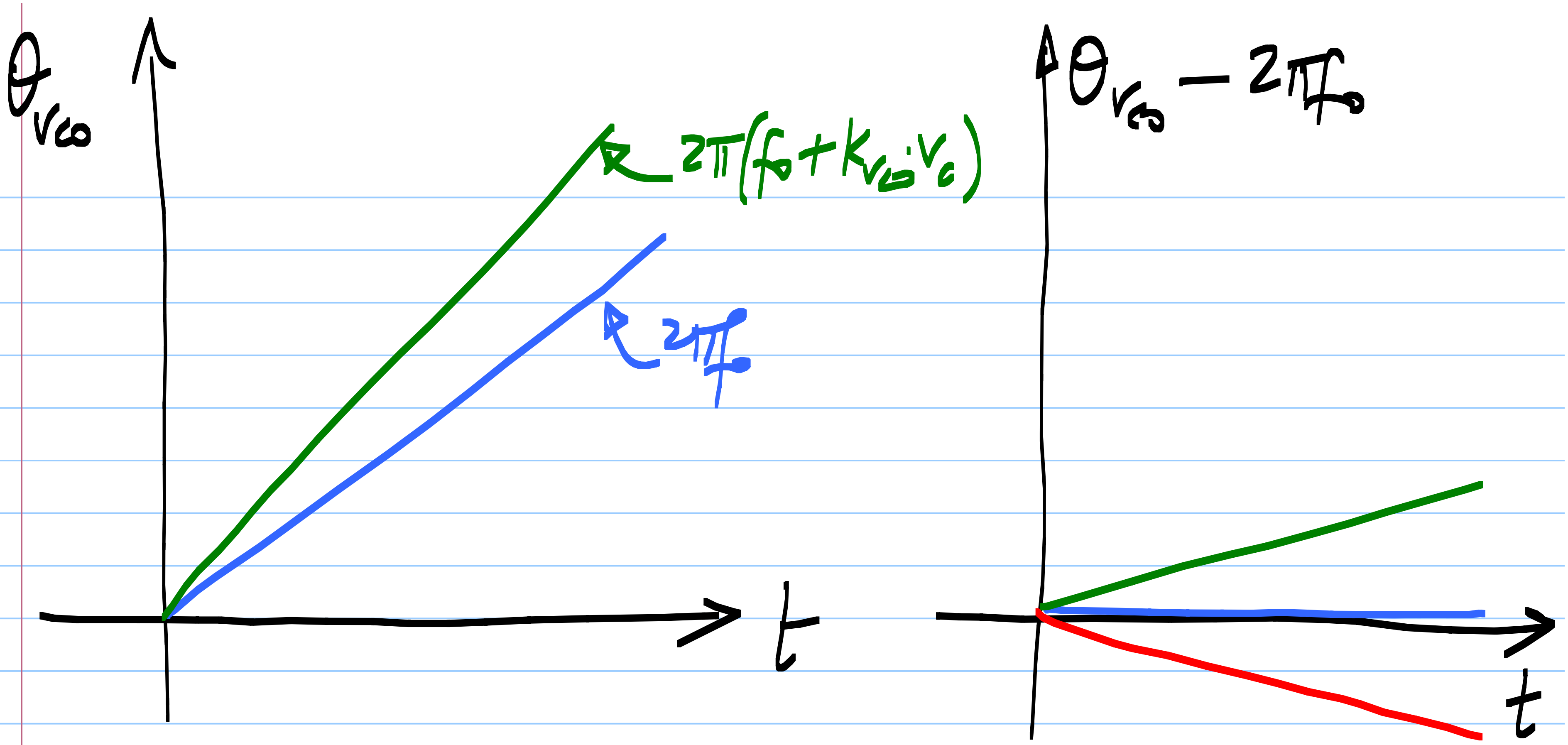
Voltage Controlled Oscillator



$$f_{vco} = \frac{1}{2\pi} \cdot \frac{d\theta}{dt} = \underbrace{f_0}_{\text{free-running frequency}} + \underbrace{K_{vco}}_{\text{VCO gain Hz/V}} \cdot \overbrace{V_c}^{\text{control voltage}}$$

$$\theta = 2\pi \int f_{vco} \cdot dt$$

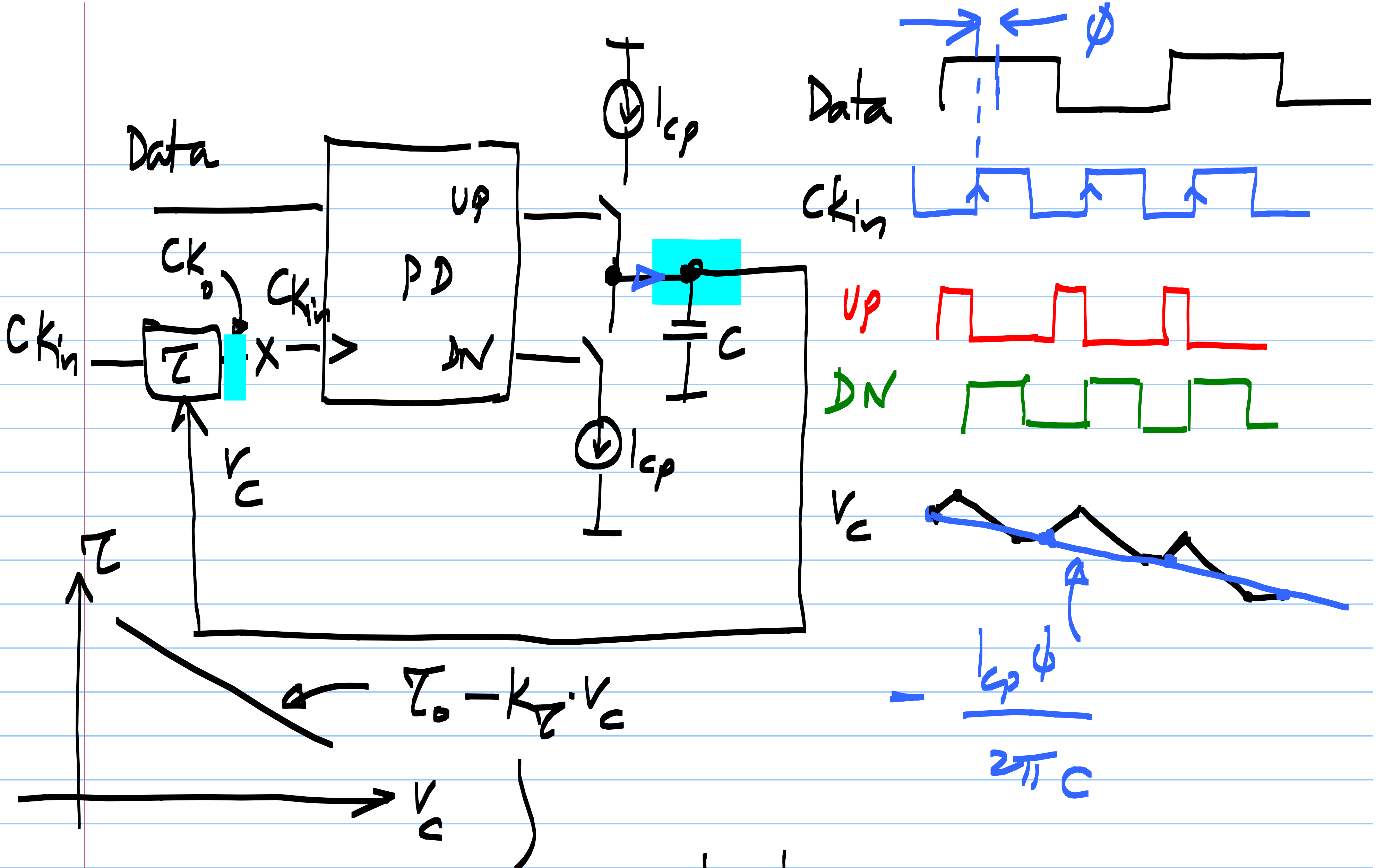
$$\theta(t) = 2\pi f_0 t + \Phi_0 + 2\pi K_{vco} \int_0^t V_c \cdot dt$$



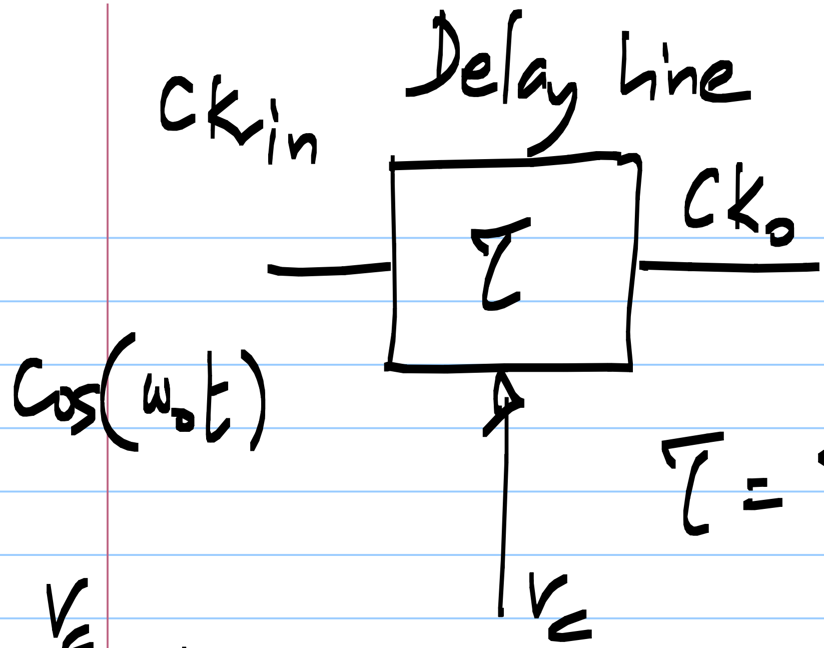
$v_c = 0$ $v_c = 0$

$v_c > 0$ (dc) $v_c > 0$ (dc)

$v_c < 0$ (dc)



gain of the delay line: > 0



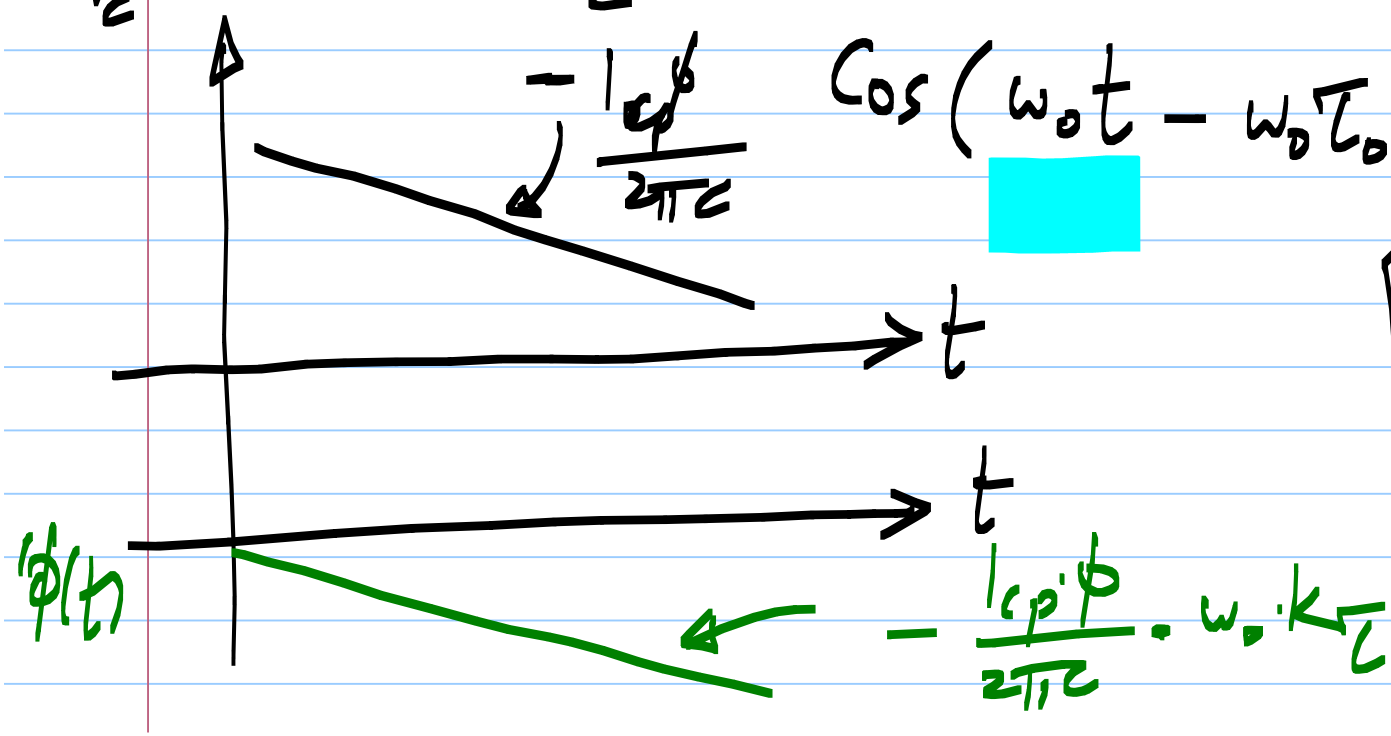
$$\cos(\omega_o(t-\tau))$$

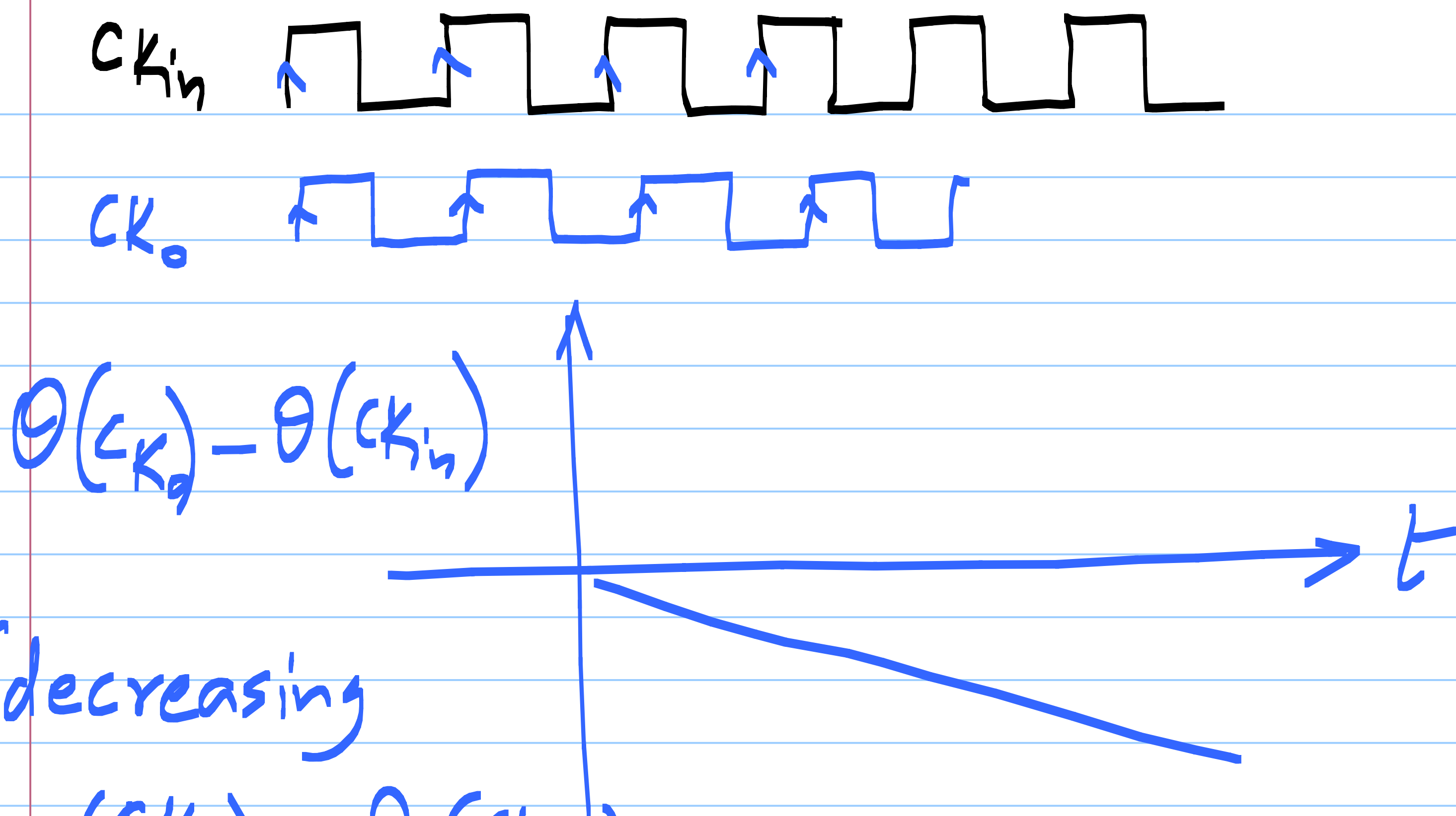
$$\tau = \tau_o - k_\tau \cdot V_c$$

$$\cos(\omega_o t - \omega_o \tau_o + \omega_o k_\tau \cdot V_c)$$

where $\omega_o k_\tau \cdot V_c = \phi(t)$

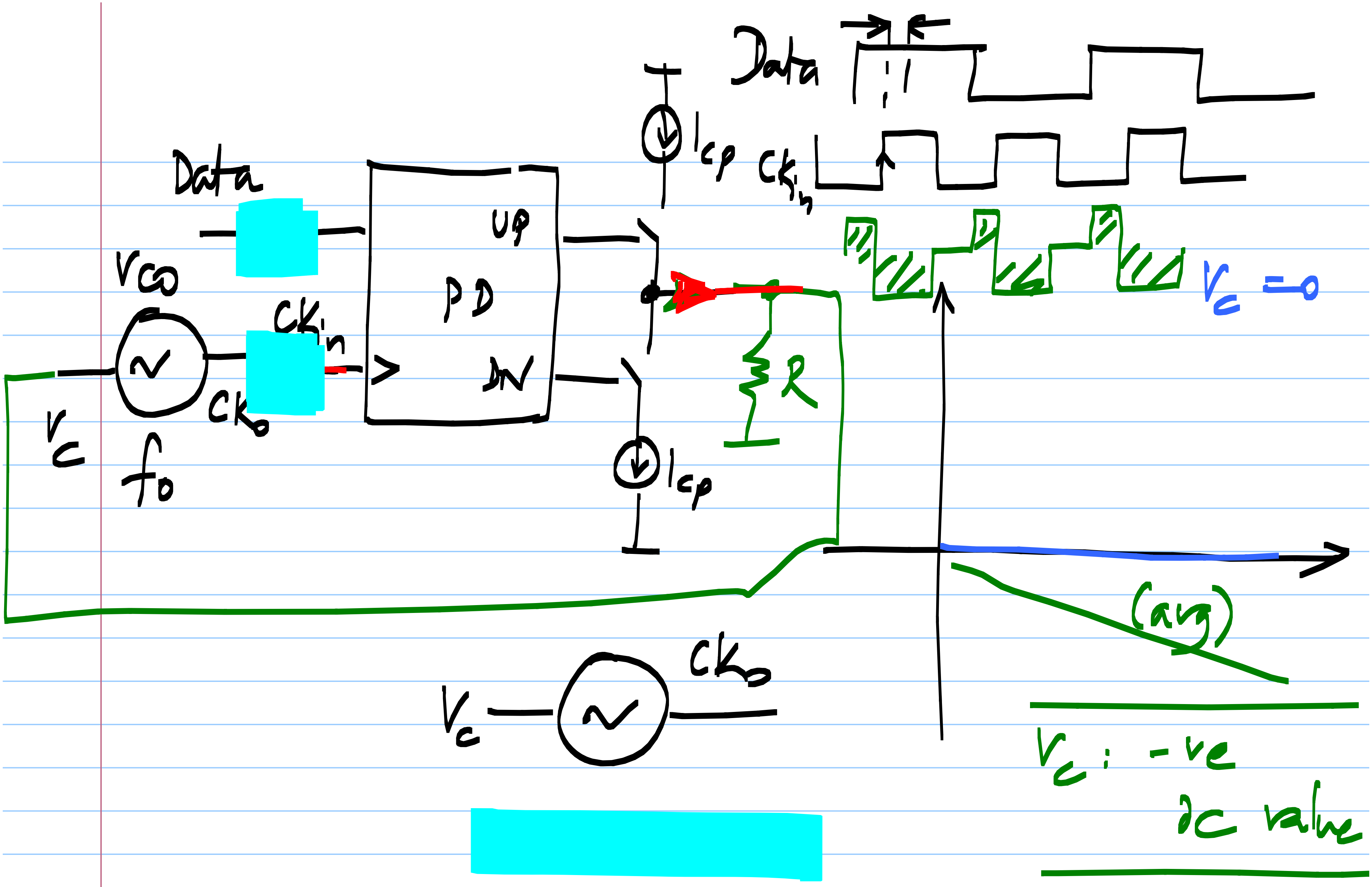
(Excess phase controlled by V_c)





decreasing $\theta(CK_o) - \theta(CK_{in})$

→ Rising edge of CK_o keeps moving to the right compared to rising edge of CK_{in}



Data
VCO
CK_in
CK_o
V_c
f_o
PD
UP
DN
I_cp
I_cp
R
Data
CK_in
V_c = 0
(avg)
CK_o
V_c
V_c : -ve
dc value

Locking condition (with free-running freq = data rate)