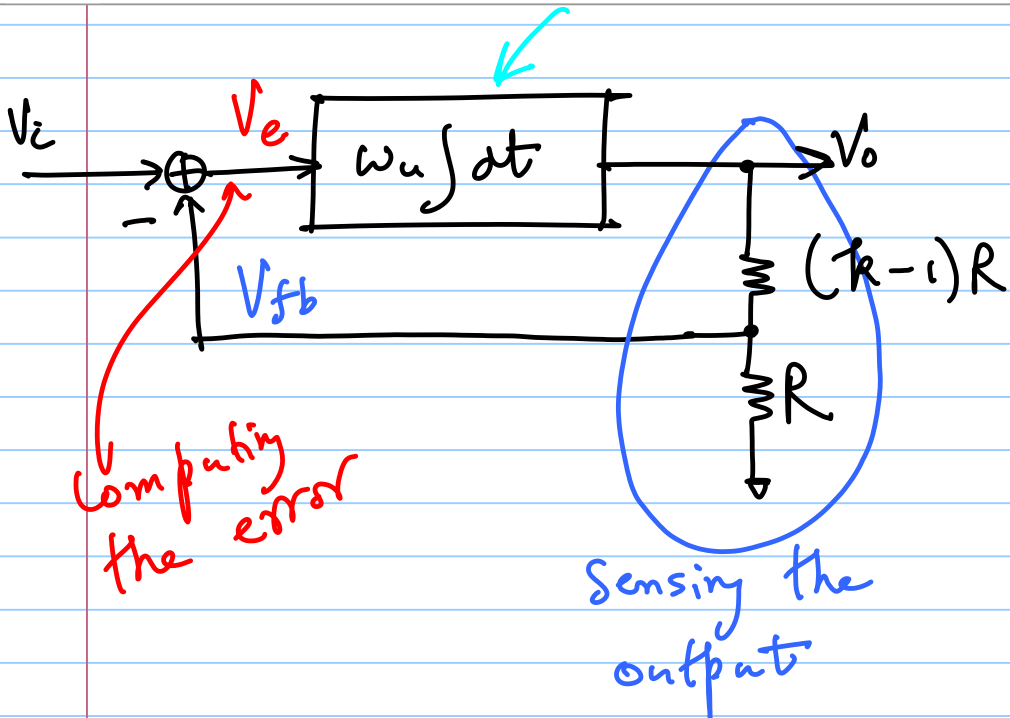
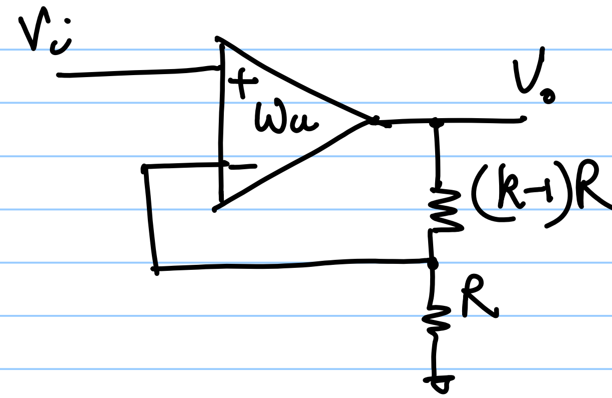
ECE 4/504 - Lecture 2

Note Title 8/24/2016





desired value $\rightarrow V_i$

sensed value $\rightarrow V_{fb} = \dfrac{V_o}{k}$

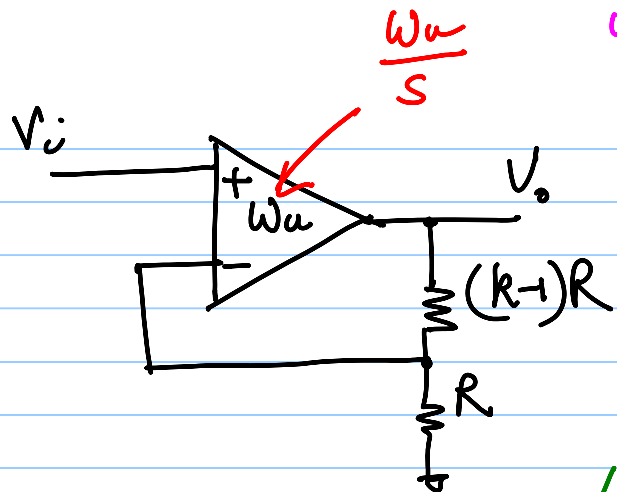
when $V_e = V_i - V_{fb} \rightarrow 0$

$\Rightarrow \quad V_i \rightarrow \frac{V_o}{k}$

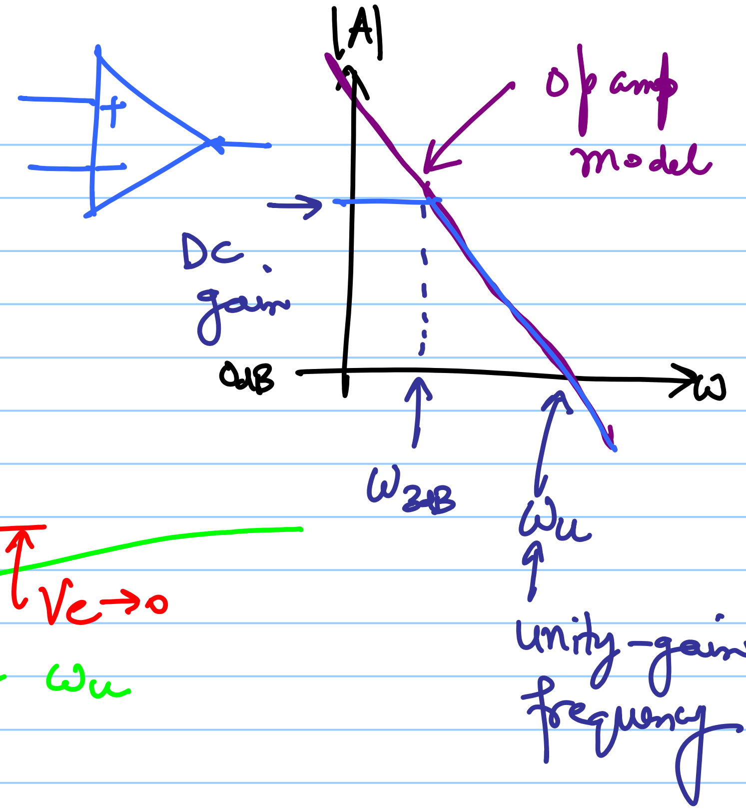
$\Rightarrow \quad \boxed{V_o \rightarrow k V_i}$

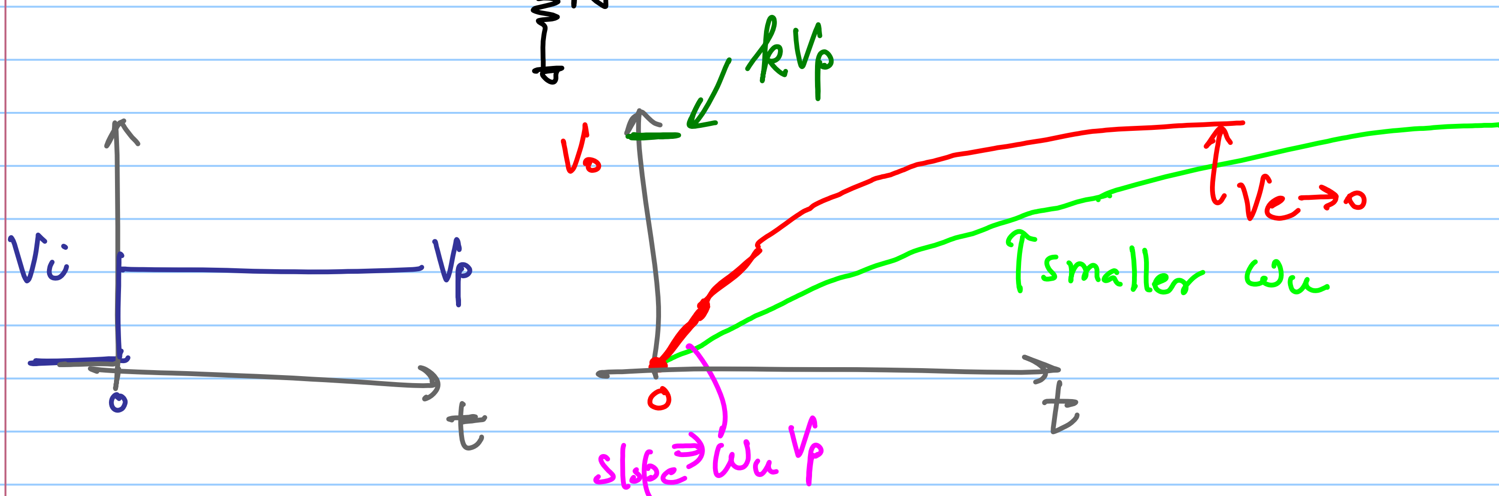
In steady-state error $\rightarrow 0 \Rightarrow V_o = k V_i$

for any other error $\neq 0$, the output will change continuously.



$\omega_u \int dt$





Diff Eqⁿ:

$$\frac{dV_o}{dt} = \omega_u V_e = \omega_u \left(V_i - \frac{V_o}{k}\right)$$

$$\Rightarrow \quad \frac{1}{\omega_u} \cdot \frac{dV_o}{dt} = V_i - \frac{V_o}{k}$$

$$V_o(t) = kV_p \left(1 - e^{-\frac{\omega_u t}{k}}\right) \cdot u(t)$$

$$\frac{1}{\tau}$$

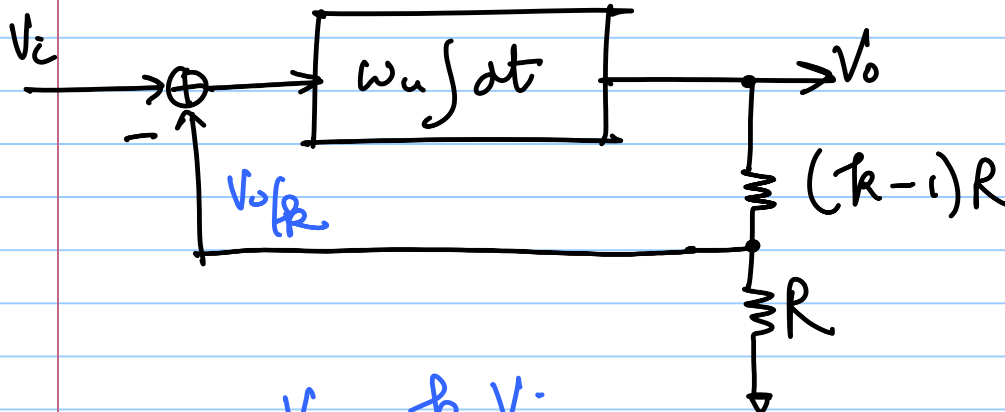
time constant $\tau = \dfrac{k}{\omega_u}$

Closed-loop Gain $\times$ BW $=$

$$\cancel{k} \times \frac{\omega_u}{\cancel{k}} = \omega_u \quad \Rightarrow \text{Gain-BW product}$$

Detailed information on stamps

http://lumerink.com/pages/teaching_arxiv.html

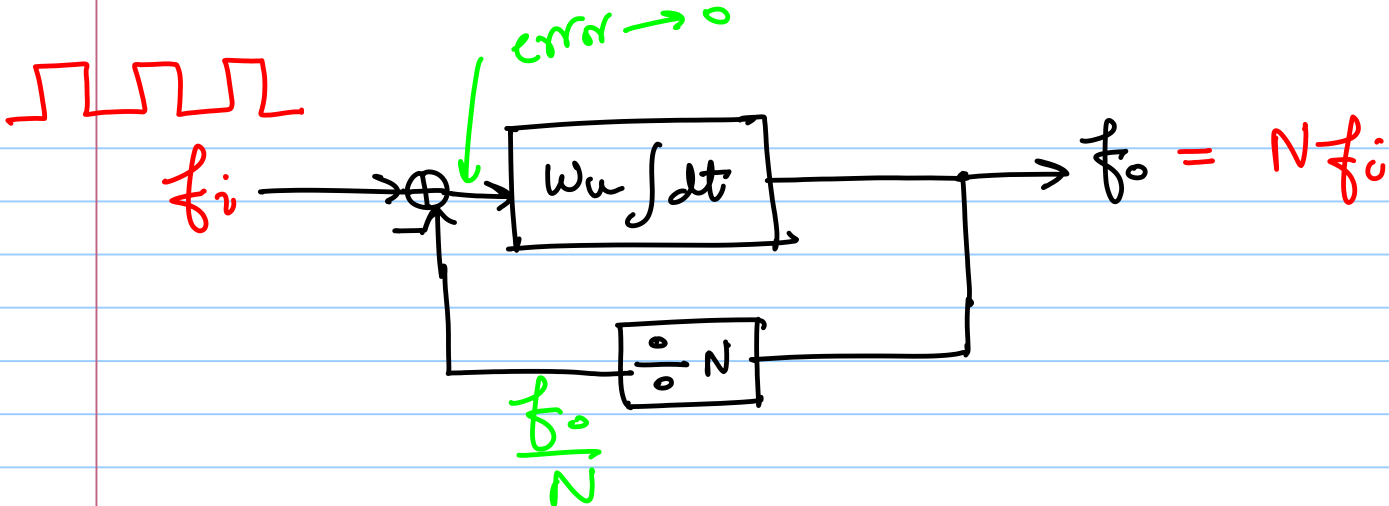


desire $f_o = k \times f_i$ input frequency

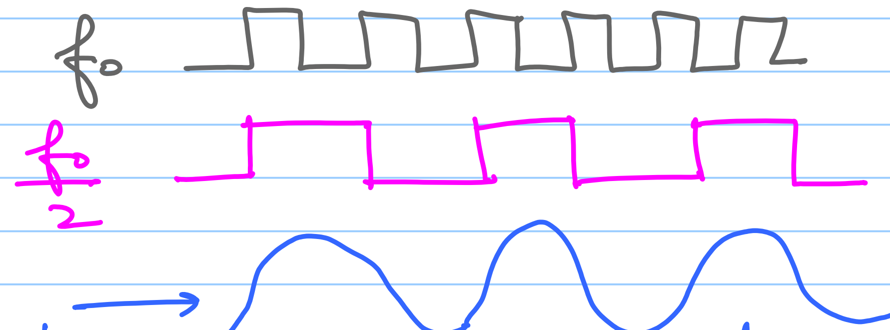
$V_o = k V_i$

Comparing $\frac{V_o}{k}$ & V_i

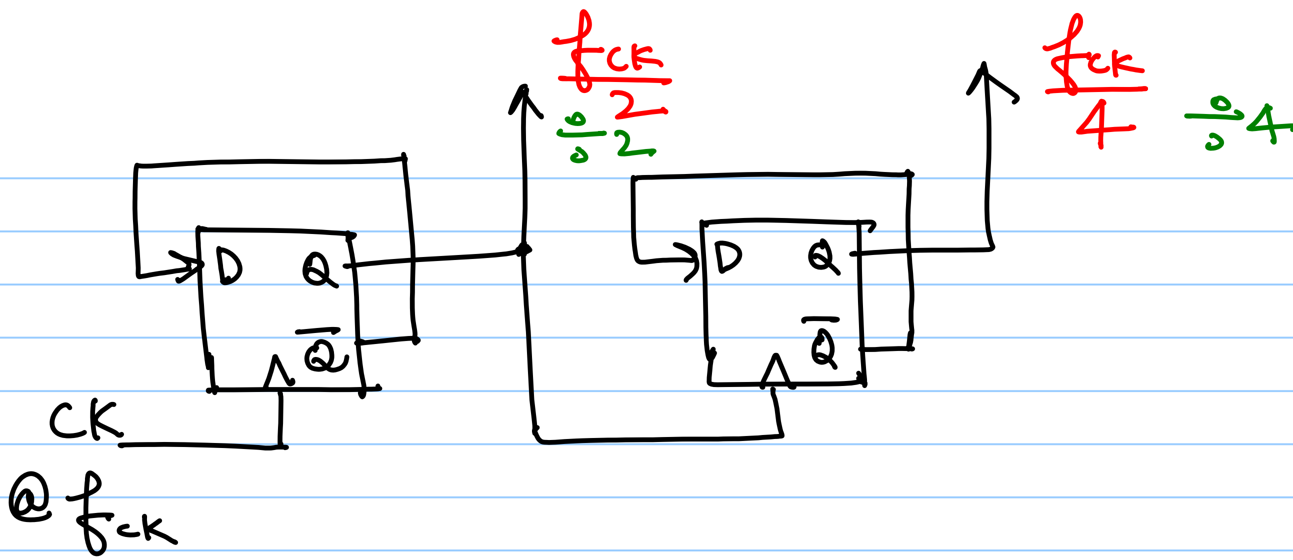
integrating V_e till $V_e \to 0$



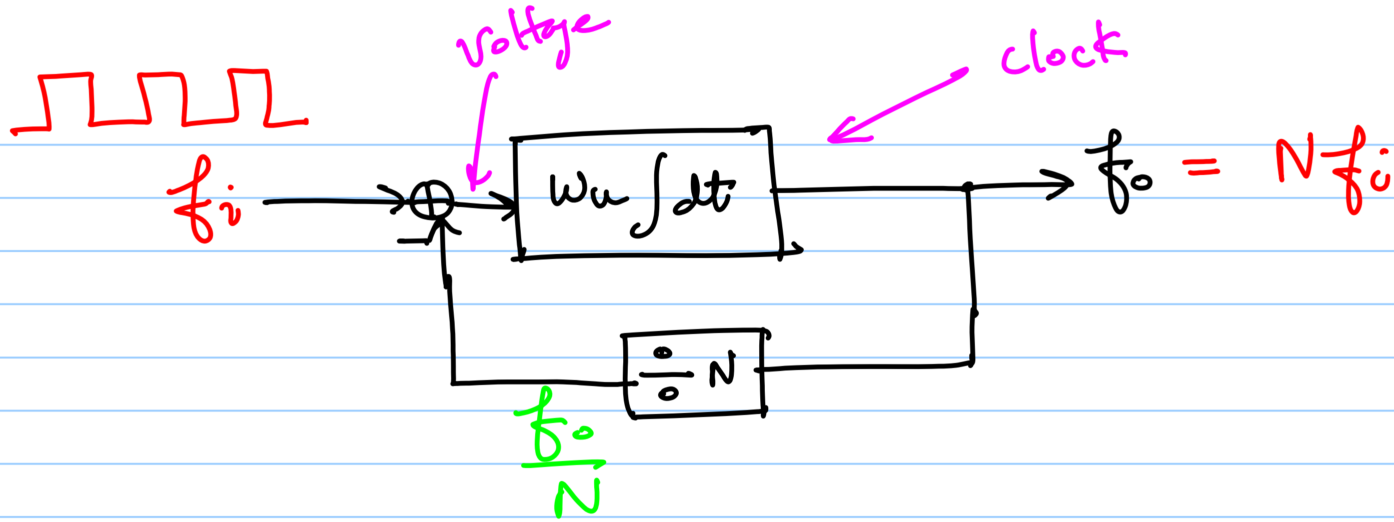
frequency Divider?



clock can be sinusoidal also

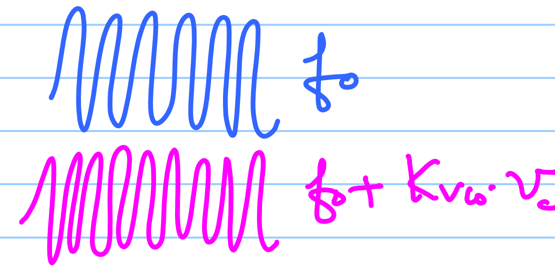


D
Q
$\overline{Q}$
D
Q
$\overline{Q}$
CK
@ f_{ck}
$\frac{f_{ck}}{2}$
÷2
$\frac{f_{ck}}{4}$
÷4



voltage
clock
f_i
$\omega_u \int dt$
$\div N$
$f_o = N f_i$
$\frac{f_o}{N}$

Voltage Controlled Oscillator (VCO)



$$\overbrace{V_{CO} + v_c}^{\text{VCO control voltage}} \longrightarrow (\sim) \longrightarrow f_0 + K_{vco} \cdot v_c$$

V_{CO}: D.C. Bias point

v_c: small voltage

f_0: free running frequency

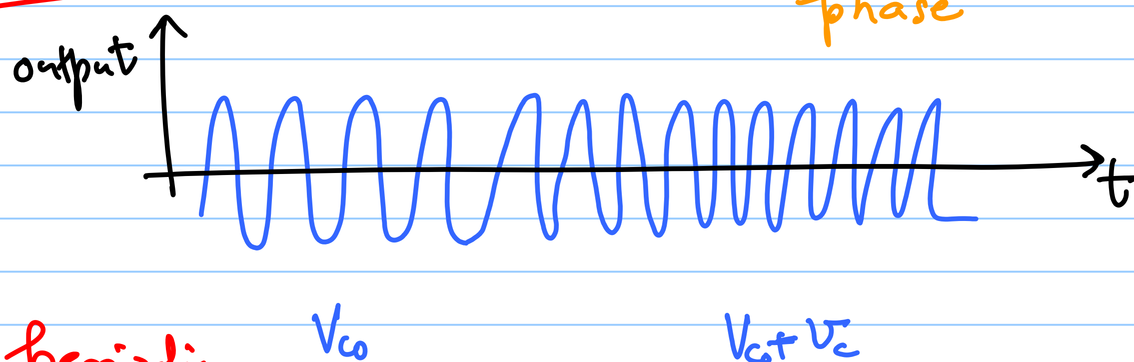
K_{vco}: VCO gain $\left(\frac{Hz}{V}\right)$

output $\rightarrow$ $\cos(\underbrace{2\pi f_0 t + \cancel{2\pi K_{vco} \cdot v_c \cdot t}}_{\text{phase}})$

In reality, phase is always continuous

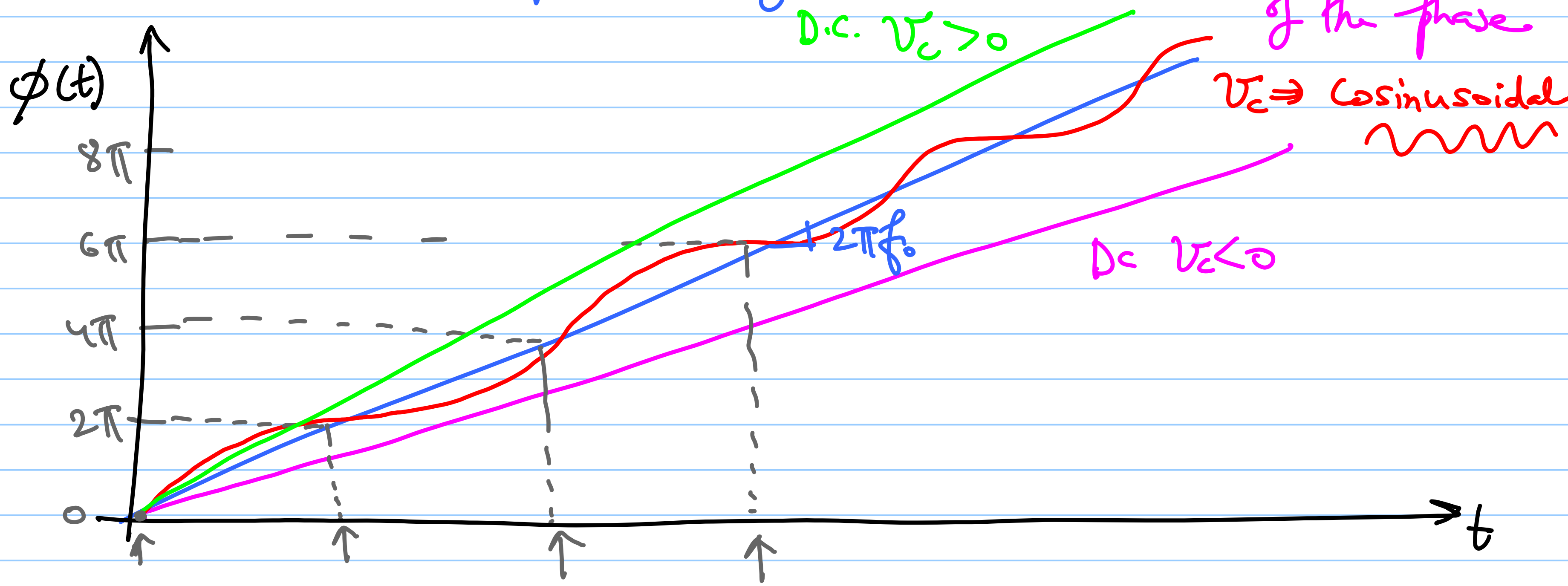
$$\text{output} \Rightarrow \cos\Big(\underbrace{2\pi f_0 t + 2\pi K_{vco}\int_0^t v_c(t)\,dt}_{\text{phase}}\Big)$$

pulse shape
can be any periodic
pulse



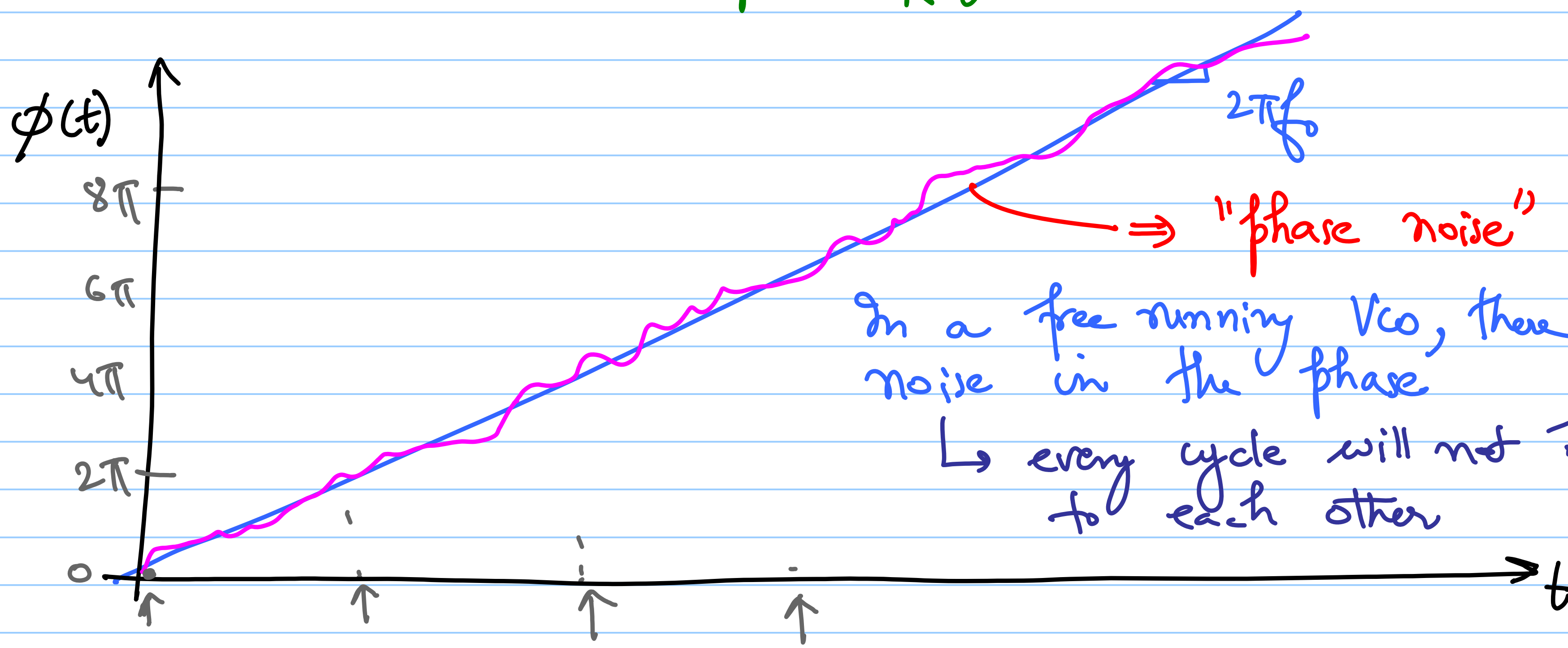
The frequency change doesn't happen instantaneously.

$$\text{Vco output: } \cos\Big(\overbrace{\underbrace{2\pi f_0 t}_{\text{free running}} + \underbrace{2\pi K_{vco}\int_0^t v_c(t)\,dt}_{\text{incremental part of the phase}}}^{\text{phase: } \phi(t)}\Big)$$



In a real amplifier

output $\Rightarrow kV_i + \text{noise}$



$\Rightarrow$ "phase noise"

In a free running VCO, there will be noise in the phase

↳ every cycle will not be equal to each other

* We choose phase $\phi(t)$ as the basic variable in PLL design

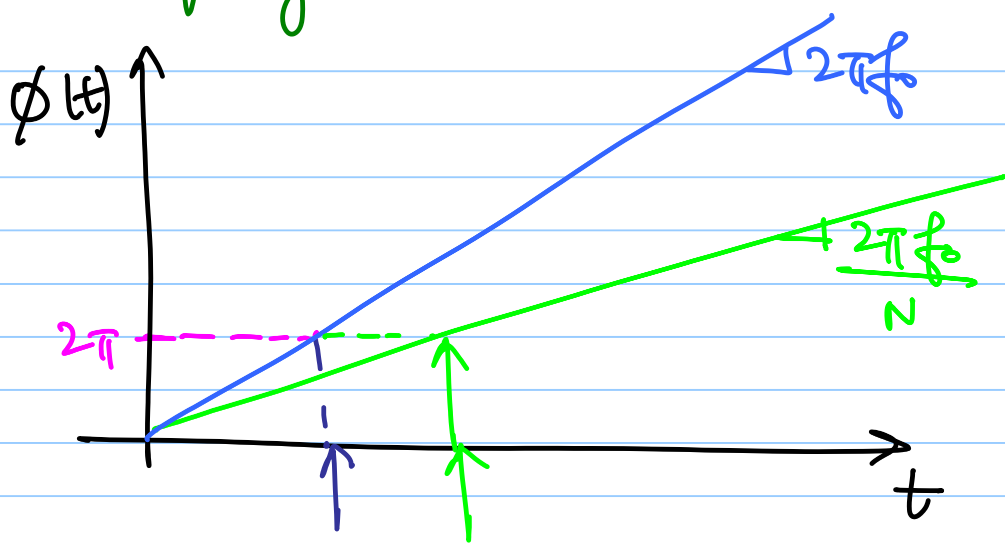
instantaneous frequency; $\boxed{f_i(t) = \frac{1}{2\pi}\frac{d\phi(t)}{dt}}$

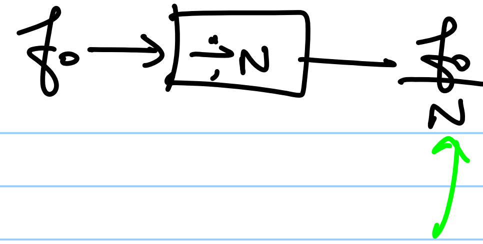
$$\phi(t) = 2\pi f_o t + 2\pi K_{vco}\int^{t} v_c(t)\,dt$$

$$\Rightarrow \quad \frac{d\phi(t)}{dt} = 2\pi f_o + 2\pi K_{vco}\, v_c(t)$$

instantaneous frequency $f_i(t) = f_o + K_{vco}\cdot v_c(t)$

Frequency Divider





The divided phase (÷N) takes "N" longer steps than the output of the VCO.