Università degli Studi di Firenze

Facoltà d' Ingegneria
Dipartimento di Elettronica e Telecomunicazioni

Sintetizzatori ad aggancio di fase (PLL)

Massimiliano Pieraccini

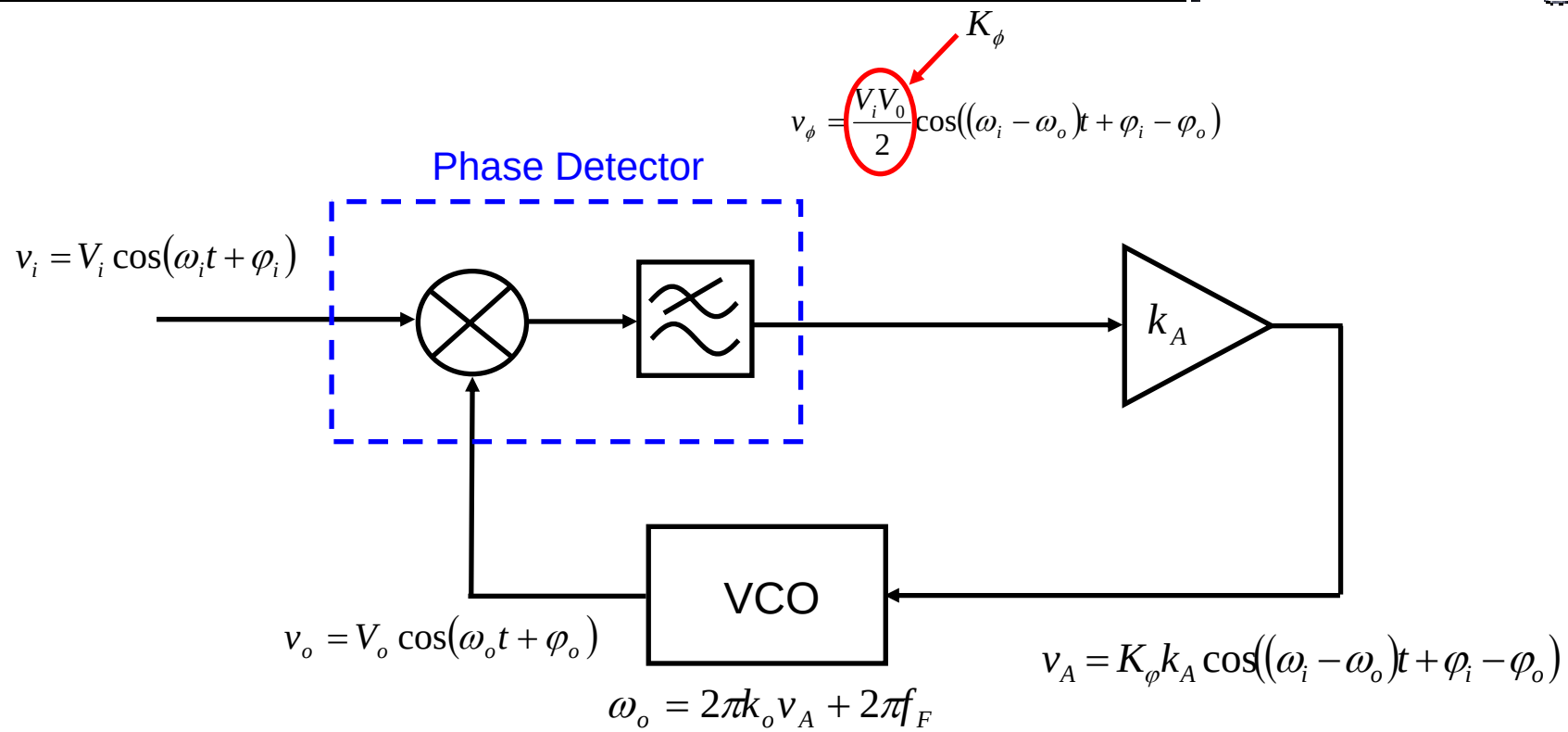
Sintetizzatore

Demodulatore FM

Sistema di aggancio della portante per demodulatori coerenti

Filtro inseguitore

PLL



$\omega_o = \omega_i$

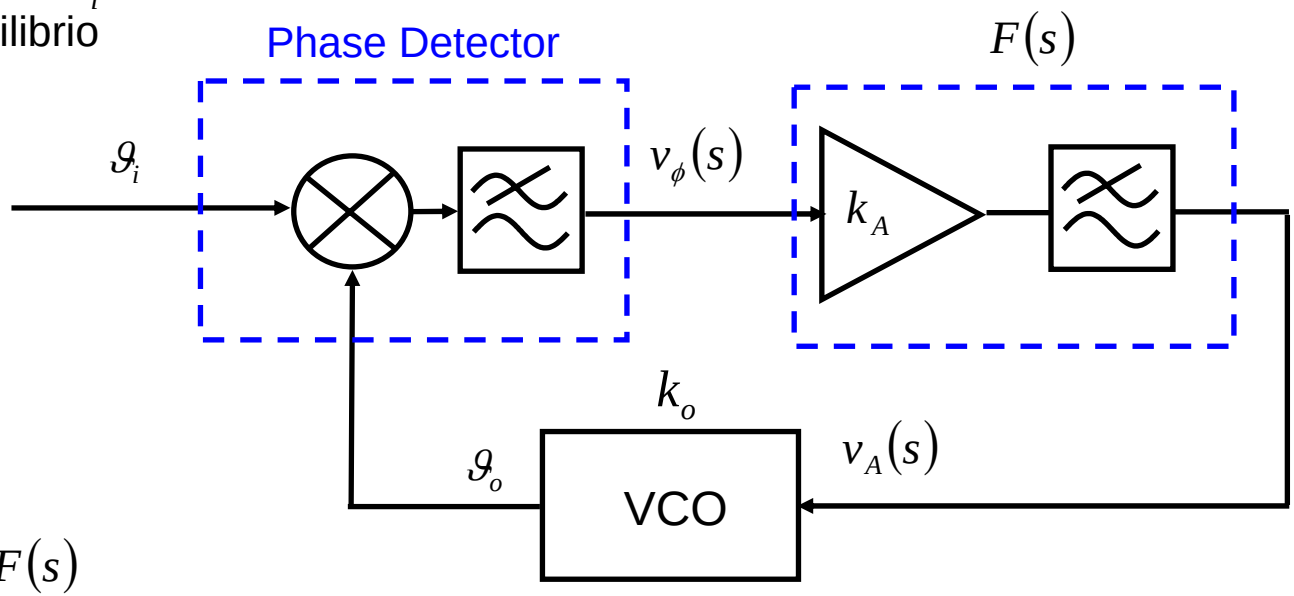
$v_A = K_\varphi k_A \cos(\varphi_i - \varphi_o)$

$\omega_i = 2\pi k_o v_A + 2\pi f_F \rightarrow v_A = \frac{f_i - f_F}{k_0}$

la condizione $\omega_o = \omega_i$ è un punto di equilibrio stabile

Analisi nel tempo

la condizione $\omega_o = \omega_i$
è un punto di equilibrio stabile



$$v_A(s) = v_\phi(s) F(s)$$

$$v_A(t) = v_A(0) + \int_0^t v_\phi(u) f(t-u) du$$

$f(t)$ antitrasformata di F(s)

$$\frac{d\vartheta_o}{dt} = K_o v_A \qquad v_\phi = \frac{V_i V_o}{2}\cos(\vartheta_e) \qquad \vartheta_e = \vartheta_i - \vartheta_o$$

$$\frac{d\vartheta_o}{dt} = K_o v_A(0) + K_o \frac{V_i V_o}{2} \int_0^t \cos(\vartheta_e(u)) f(t-u) du$$

Analisi nel tempo

$$\frac{d\vartheta_o}{dt} = K_o v_A(0) + K_o \frac{V_i V_o}{2} \int_0^t \cos(\vartheta_e(u)) f(t-u) du$$

$$\frac{d\vartheta_e}{dt} = \frac{d\vartheta_i}{dt} - \frac{d\vartheta_o}{dt} \qquad \Delta\omega_i = \frac{d\vartheta_i}{dt}$$

$$\frac{d\vartheta_e}{dt} = \Delta\omega_i - K_v \int_0^t \cos(\vartheta_e(u)) f(t-u) du \qquad K_v = K_o \frac{V_i V_o}{2}$$

Anello del primo ordine

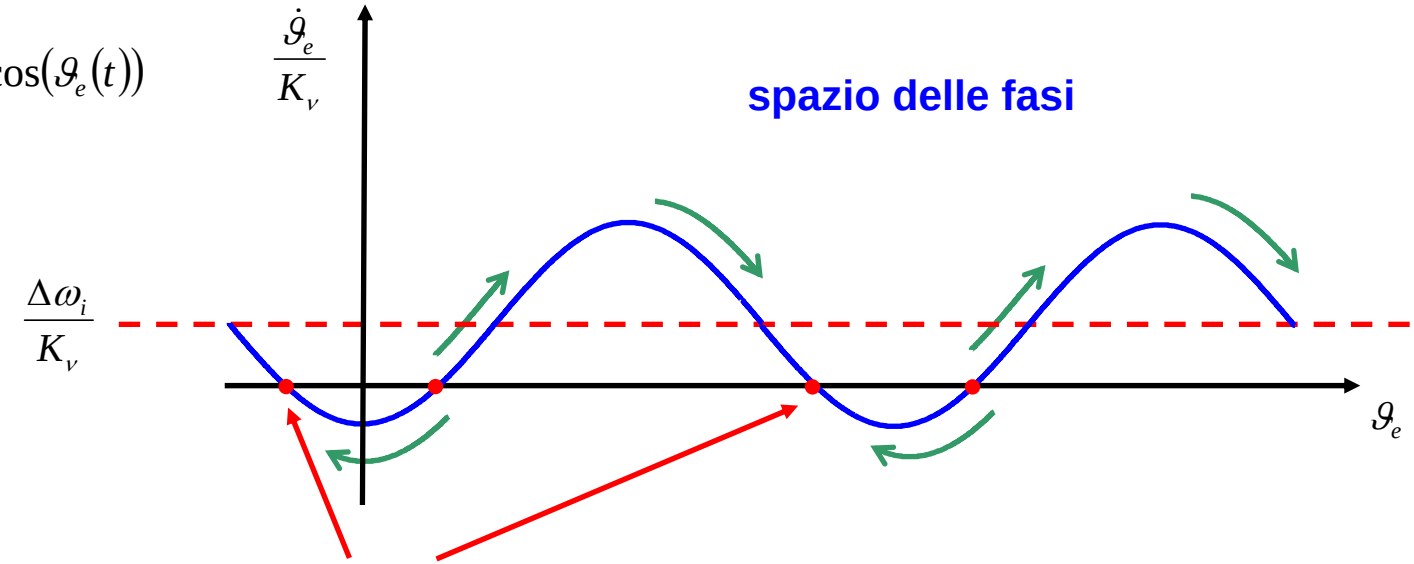
$$f(t-u) = \delta(t-u)$$

$$\frac{d\vartheta_e}{dt} = \Delta\omega_i - K_v \cos(\vartheta_e(t))$$

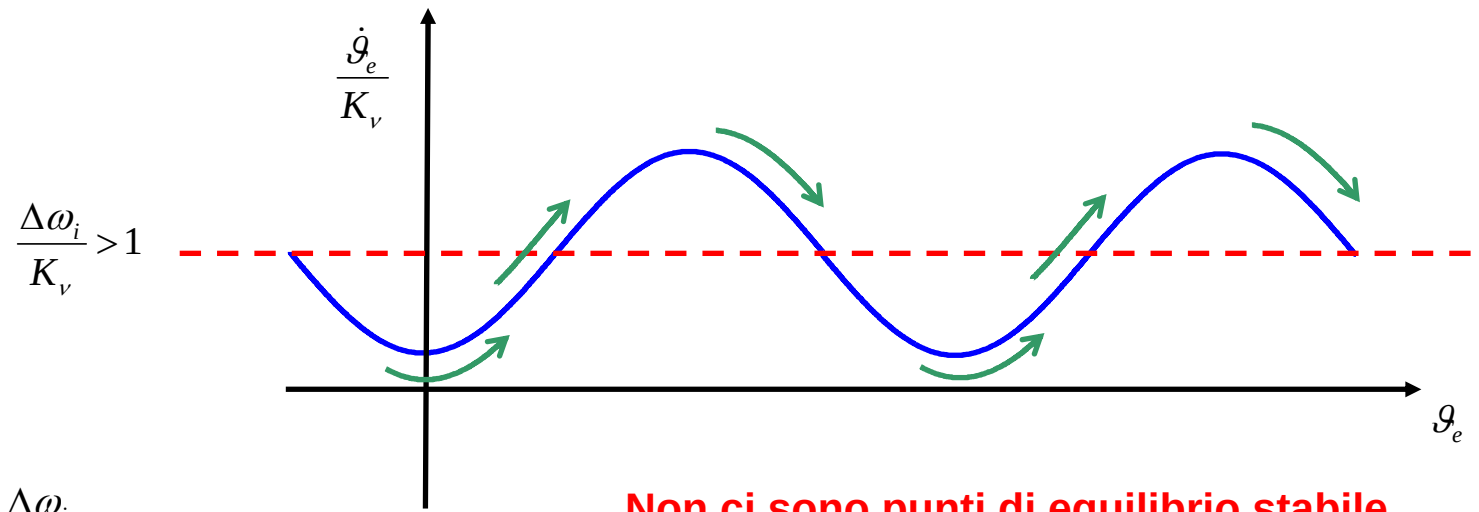
$$\frac{\dot{\vartheta}_e}{K_v} = \frac{\Delta\omega_i}{K_v} - \cos(\vartheta_e(t))$$

Analisi nel tempo

$$\frac{\dot{\vartheta}_e}{K_v} = \frac{\Delta\omega_i}{K_v} - \cos\left(\vartheta_e(t)\right)$$



punti di equilibrio stabili



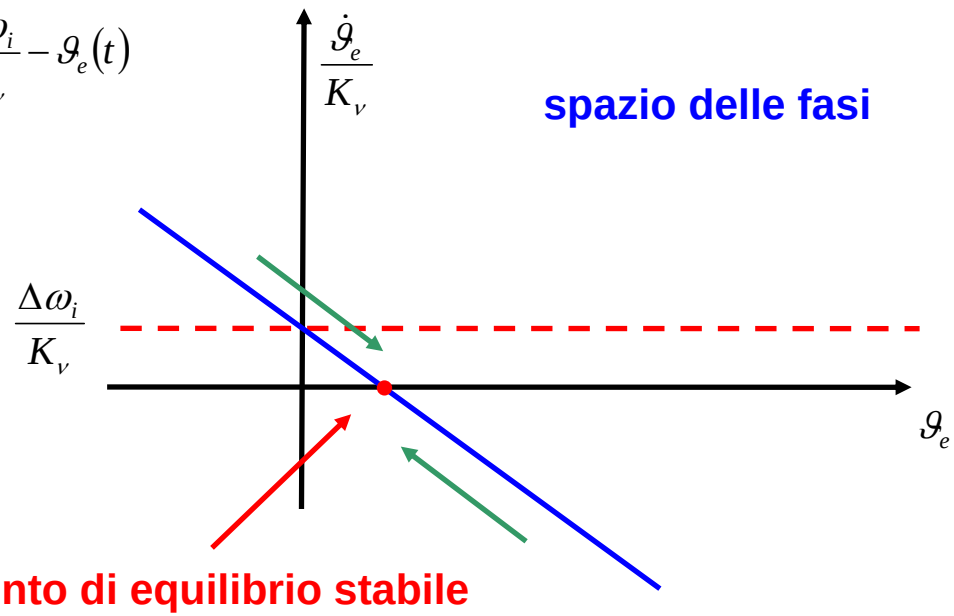
$\frac{\Delta\omega_i}{K_v} < -1$

Non ci sono punti di equilibrio stabile

Anello del primo ordine con rivelatore di fase lineare

$$v_\phi = \frac{V_i V_o}{2}\vartheta_e$$

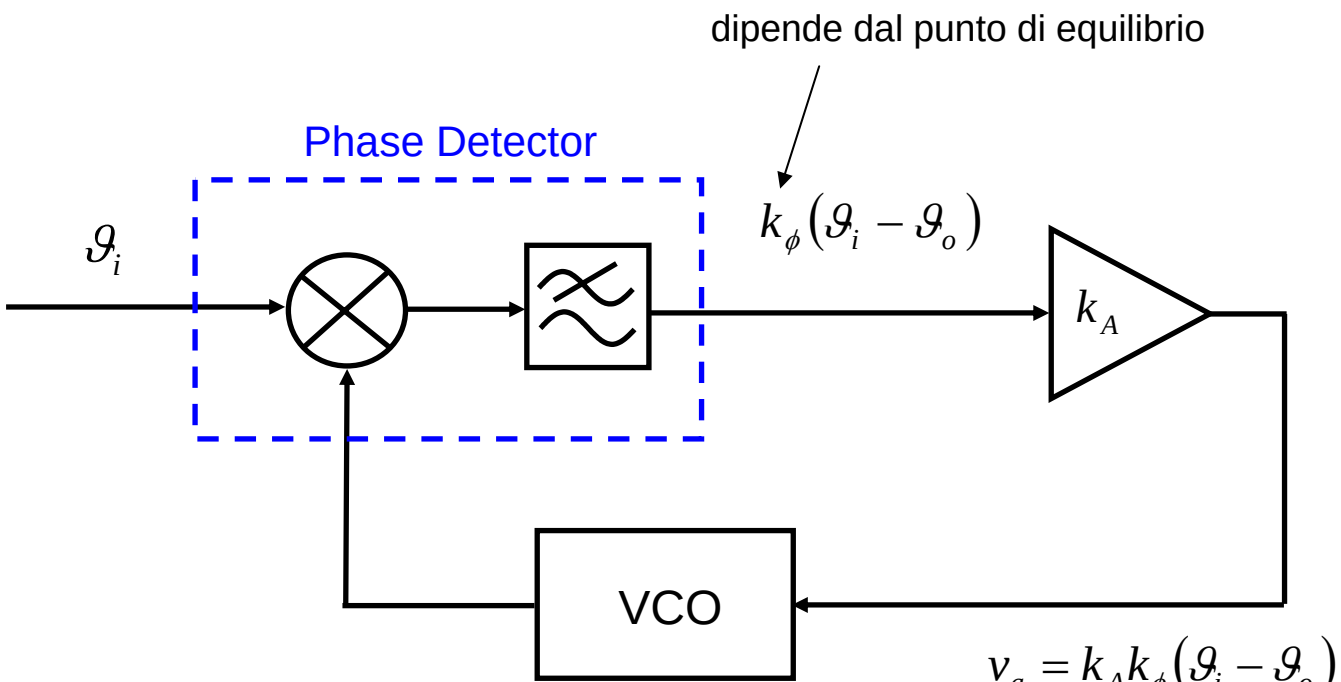
$$\frac{\dot{\vartheta}_e}{K_v} = \frac{\Delta\omega_i}{K_v} - \vartheta_e(t)$$



spazio delle fasi

punto di equilibrio stabile

Analisi delle piccole variazioni intorno al punto di equilibrio stabile



$$\delta\omega_o = 2\pi k_o k_A k_\phi(\vartheta_i - \vartheta_o) \qquad \delta\omega_o = 2\pi k_o v_a$$

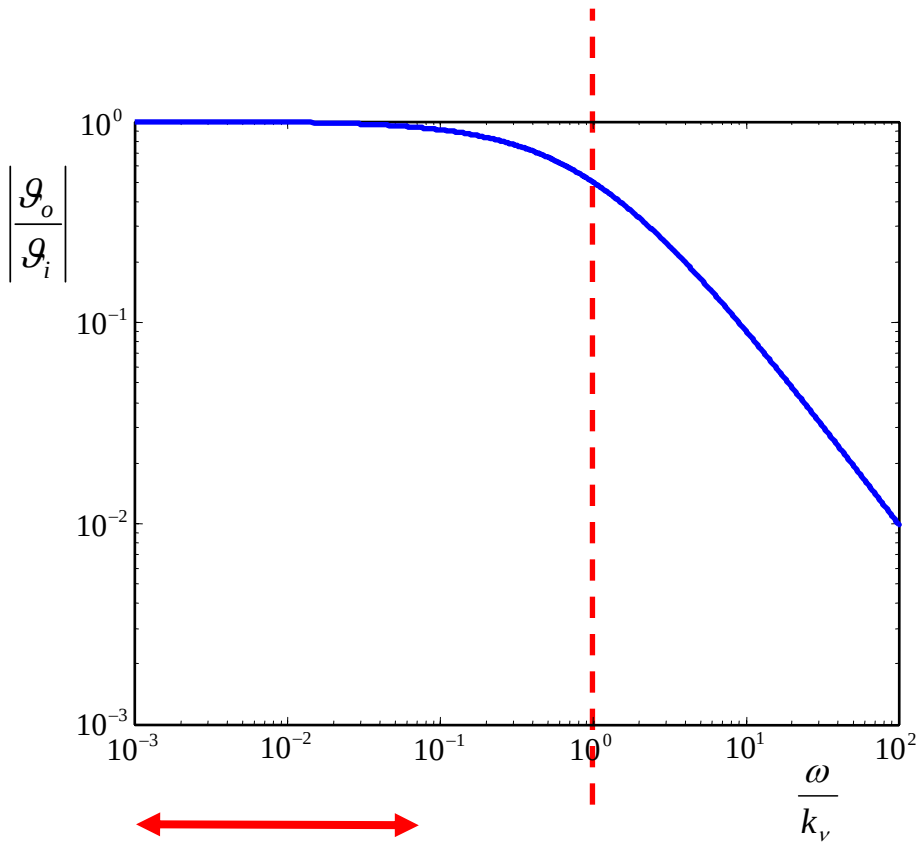
$$\frac{d\vartheta_o}{dt} = 2\pi k_o k_A k_\phi(\vartheta_i - \vartheta_o)$$

$$s\vartheta_0 = 2\pi k_o k_A k_\phi(\vartheta_i - \vartheta_o) \qquad \boxed{k_v = 2\pi k_o k_A k_\phi}$$

$$s\vartheta_0 = k_v(\vartheta_i - \vartheta_o) \longrightarrow \boxed{\frac{\vartheta_o}{\vartheta_i} = \frac{1}{1 + \frac{s}{k_v}}}$$

Analisi delle piccole variazioni intorno al punto di equilibrio stabile

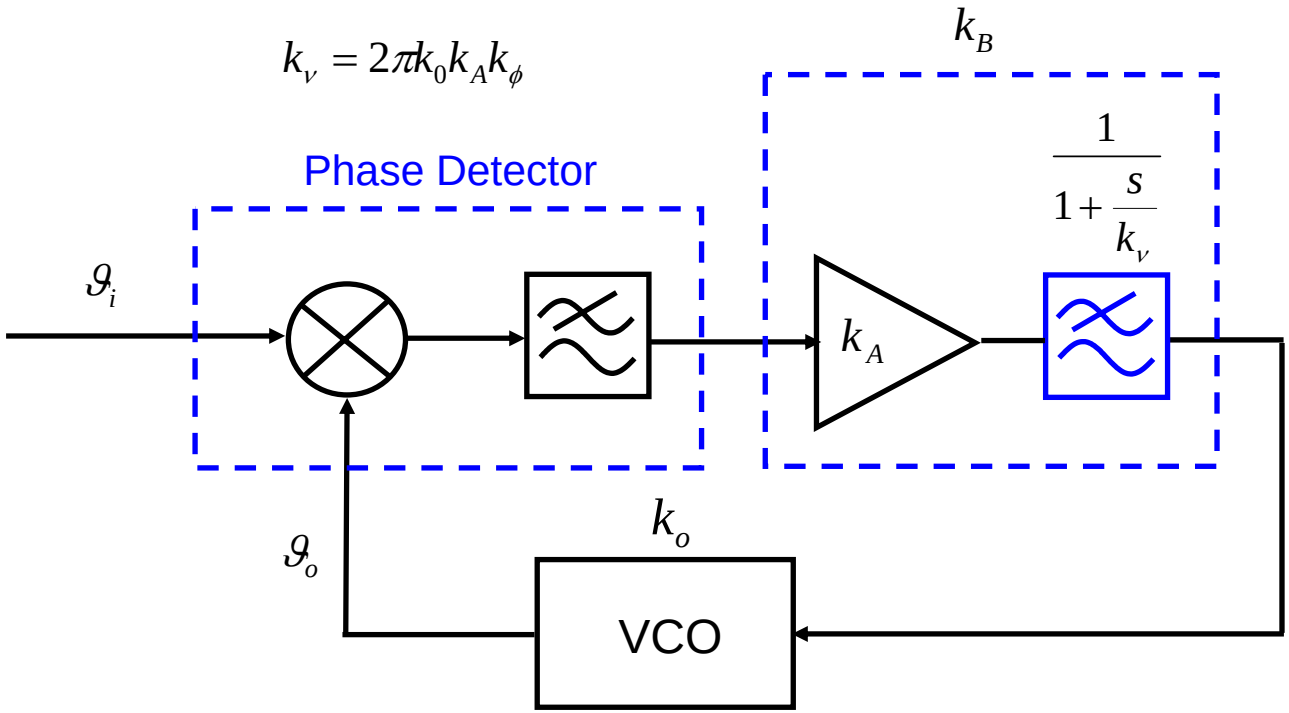
$$\frac{\vartheta_o}{\vartheta_i} = \frac{1}{1+\frac{s}{k_\nu}}$$



Demodulatore FM

Analisi delle piccole variazioni intorno al punto di equilibrio stabile

$$k_\nu = 2\pi k_0 k_A k_\phi$$



$$\frac{\vartheta_o}{\vartheta_i} = \frac{1}{1+\frac{s}{k_q}}$$

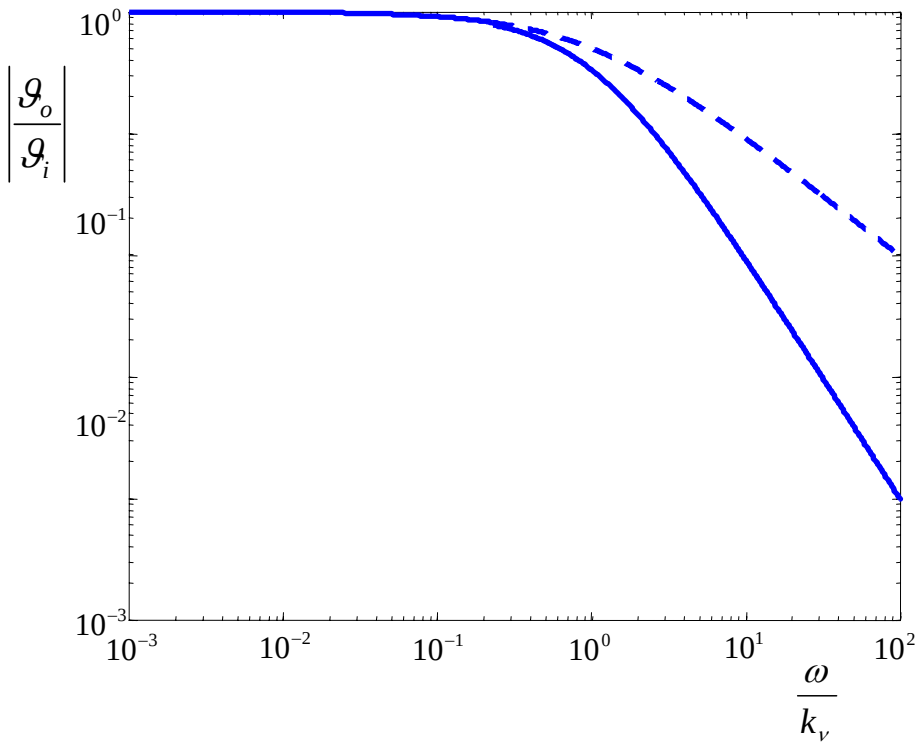
$$k_q = 2\pi k_o k_B k_\phi$$

$$k_q = 2\pi k_o k_A k_\phi \frac{1}{1+\frac{s}{k_\nu}} \longrightarrow k_q = k_\nu \frac{1}{1+\frac{s}{k_\nu}}$$

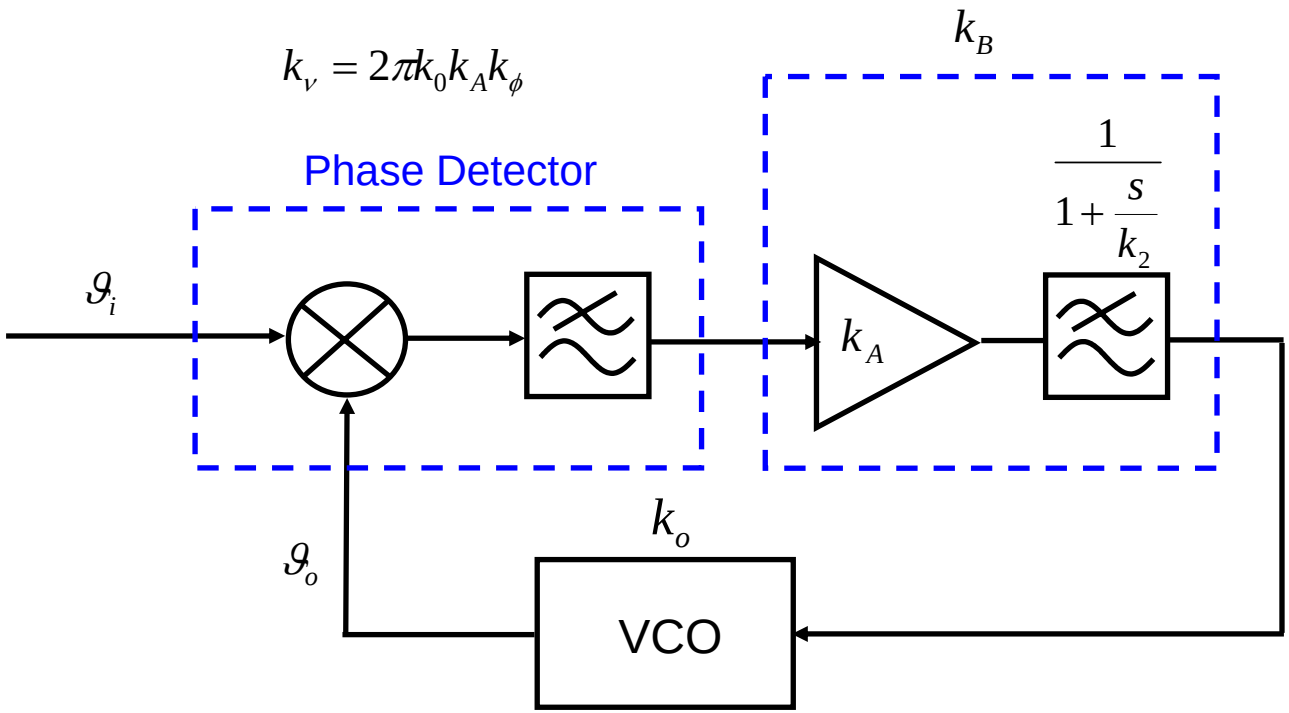
$$\frac{\vartheta_o}{\vartheta_i} = \frac{1}{1+\frac{s}{k_\nu}+\left(\frac{s}{k_\nu}\right)^2}$$

Analisi delle piccole variazioni intorno al punto di equilibrio stabile

$$\frac{\vartheta_o}{\vartheta_i} = \frac{1}{1 + \frac{s}{k_v} + \left(\frac{s}{k_v}\right)^2}$$



Compensazione dell'anello



$$\frac{\vartheta_o}{\vartheta_i} = \frac{1}{1+\frac{s}{k_q}}$$

$$k_q = 2\pi k_o k_B k_\phi \longrightarrow k_q = k_\nu \frac{1}{1+\frac{s}{k_2}}$$

$$\frac{\vartheta_o}{\vartheta_i} = \frac{k_\nu k_2}{s^2 + s k_2 + k_2 k_\nu}$$

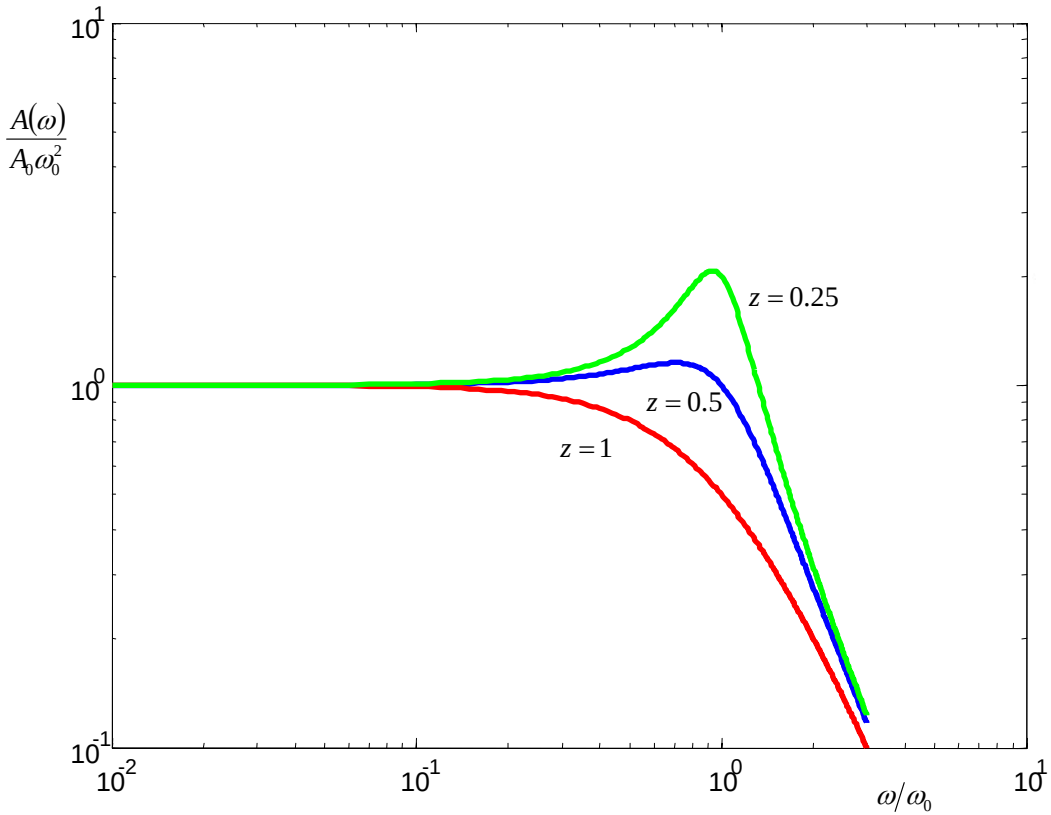
$$A(s) = \frac{A_0 \omega_0^2}{s^2 + 2z\omega_0 s + \omega_0^2}$$

$$\omega_0 = \sqrt{k_\nu k_2}$$

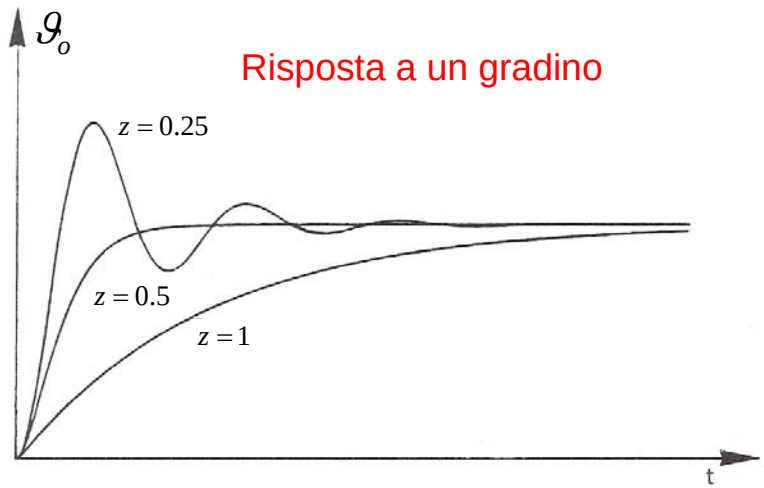
$$z = \sqrt{\frac{k_2}{k_\nu}}$$

Compensazione dell'anello

$$A(s) = \frac{A_0\omega_0^2}{s^2 + 2z\omega_0 s + \omega_0^2} \qquad \omega_0 = \sqrt{k_v k_2} \qquad z = \sqrt{\frac{k_2}{k_v}}$$



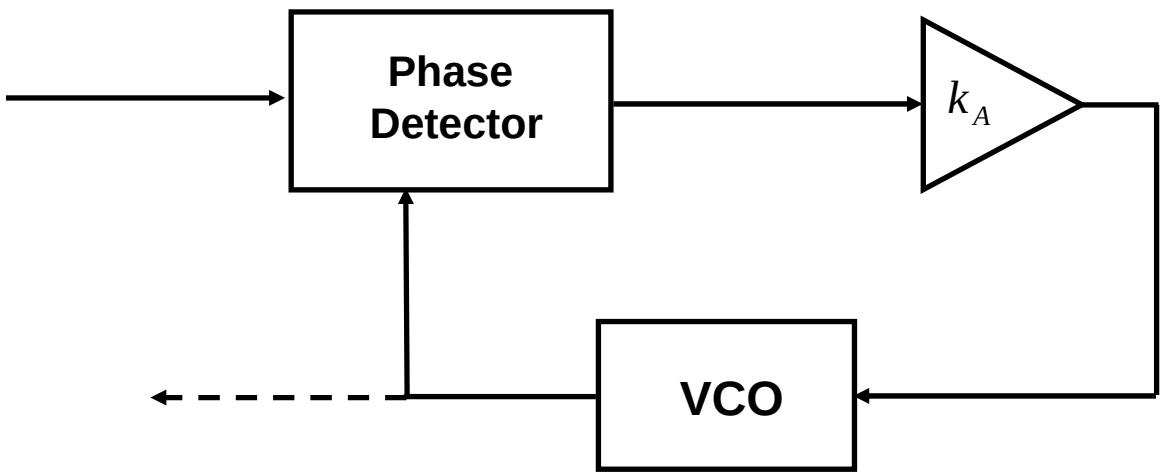
Risposta a un gradino



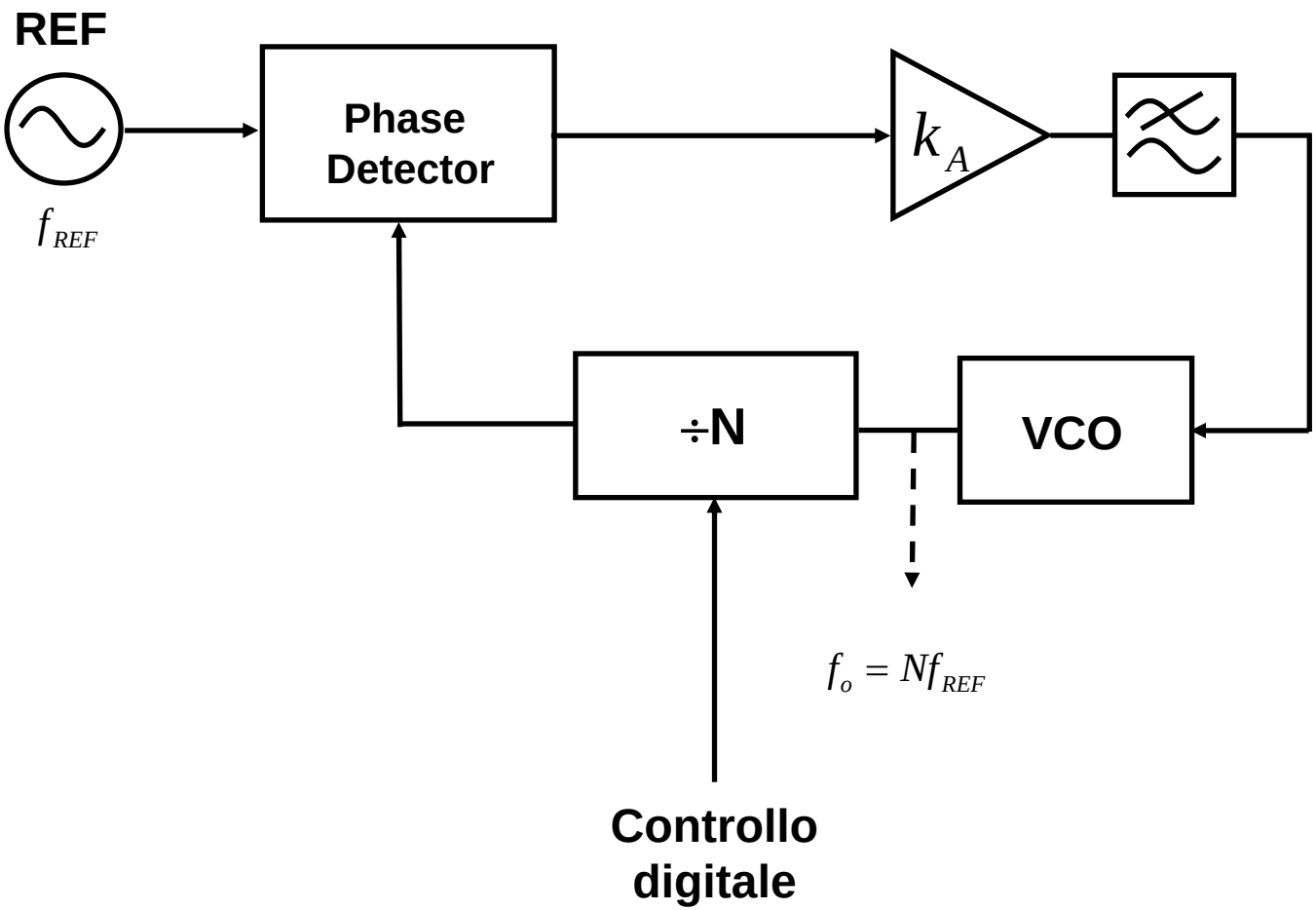
Demodulatore FM

$$v_A = \frac{f_i - f_F}{k_0} \longrightarrow \delta v_A = \frac{\delta f_i}{k_0} \qquad f_m < \frac{k_v}{2\pi}$$

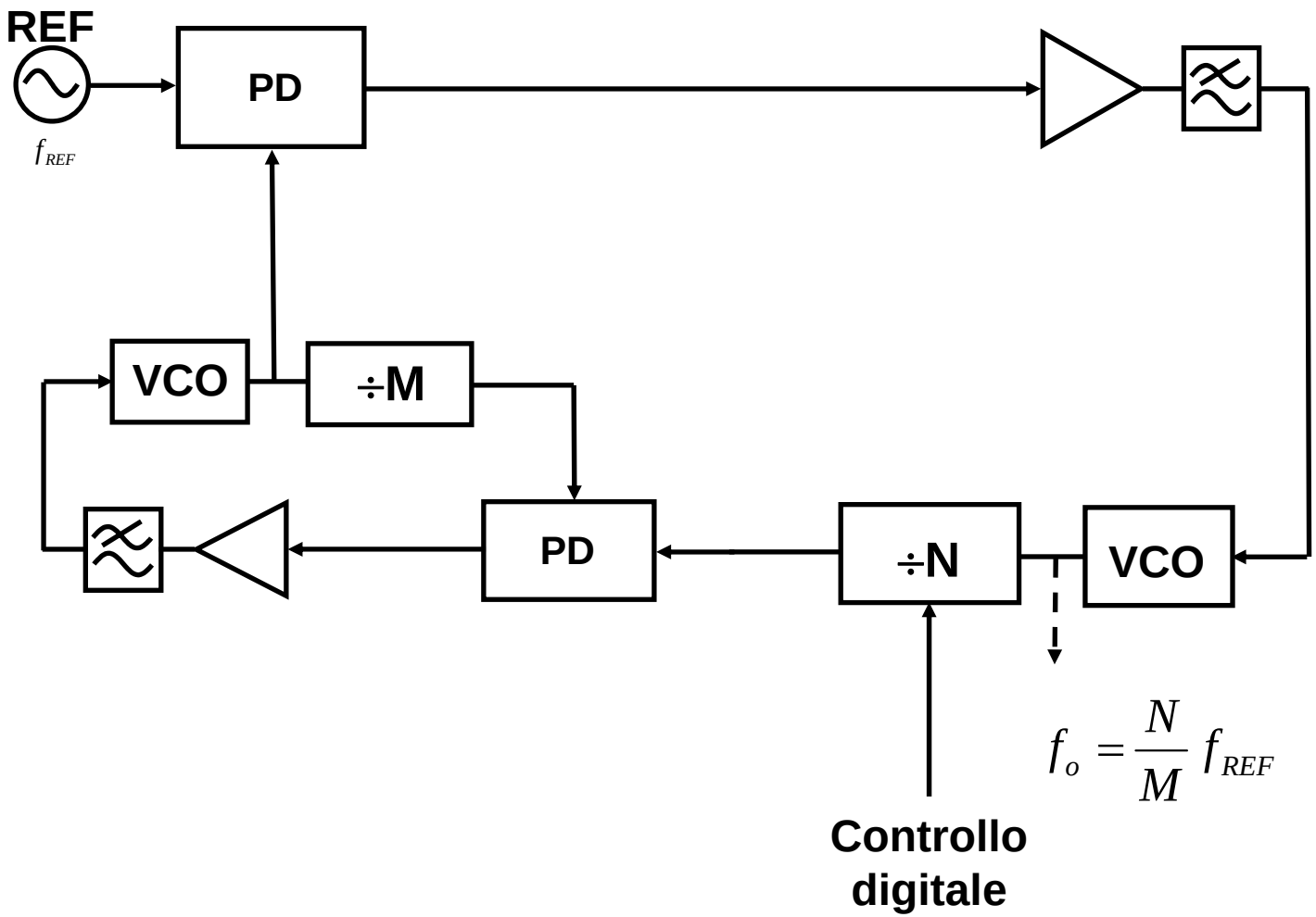
Aggancio della portante per demodulazione coerente (filtro)



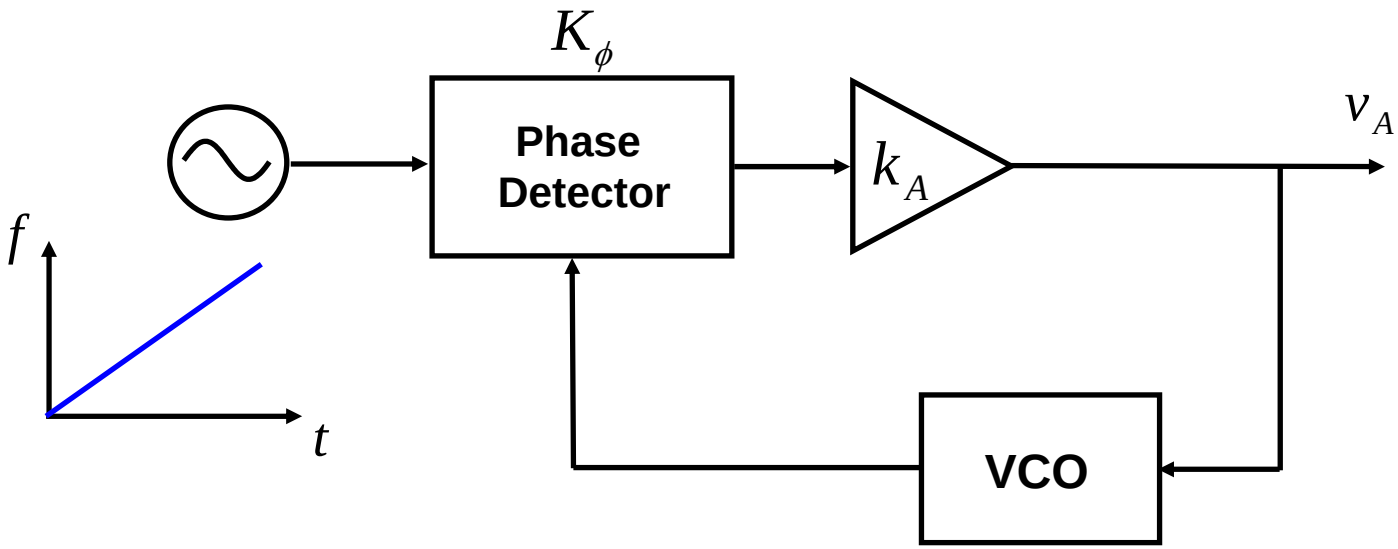
Sintetizzatore

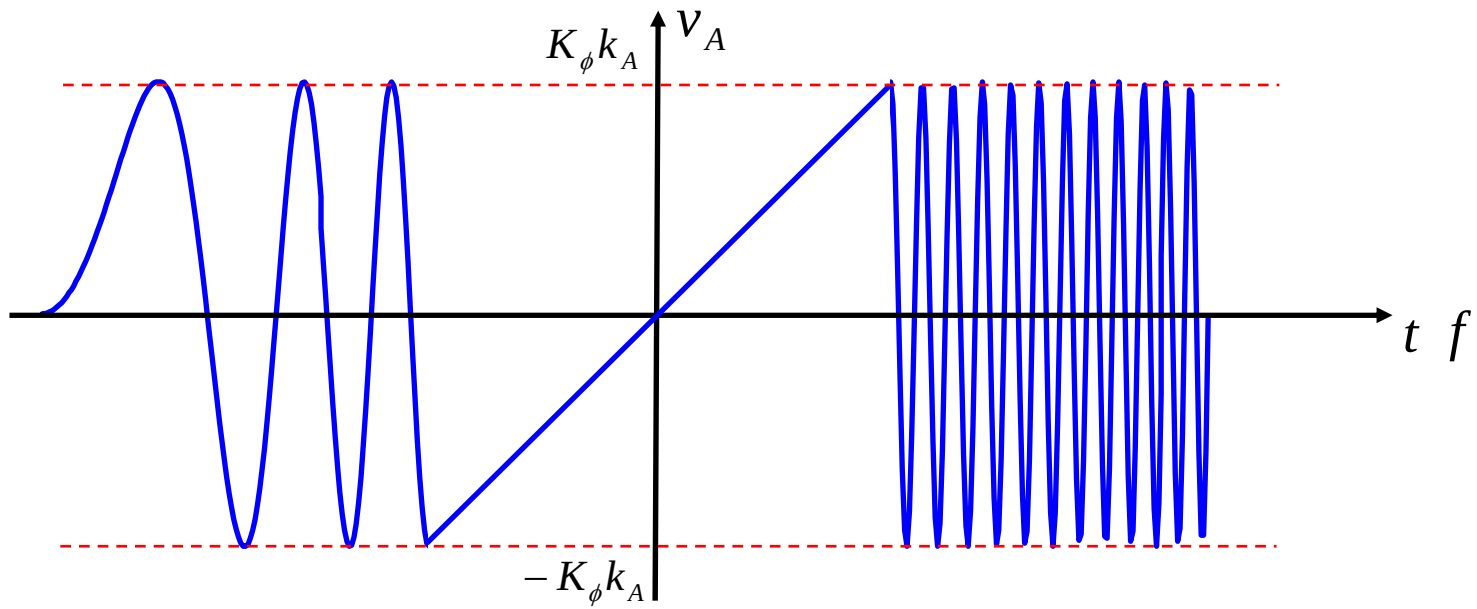


Sintetizzatore multianello

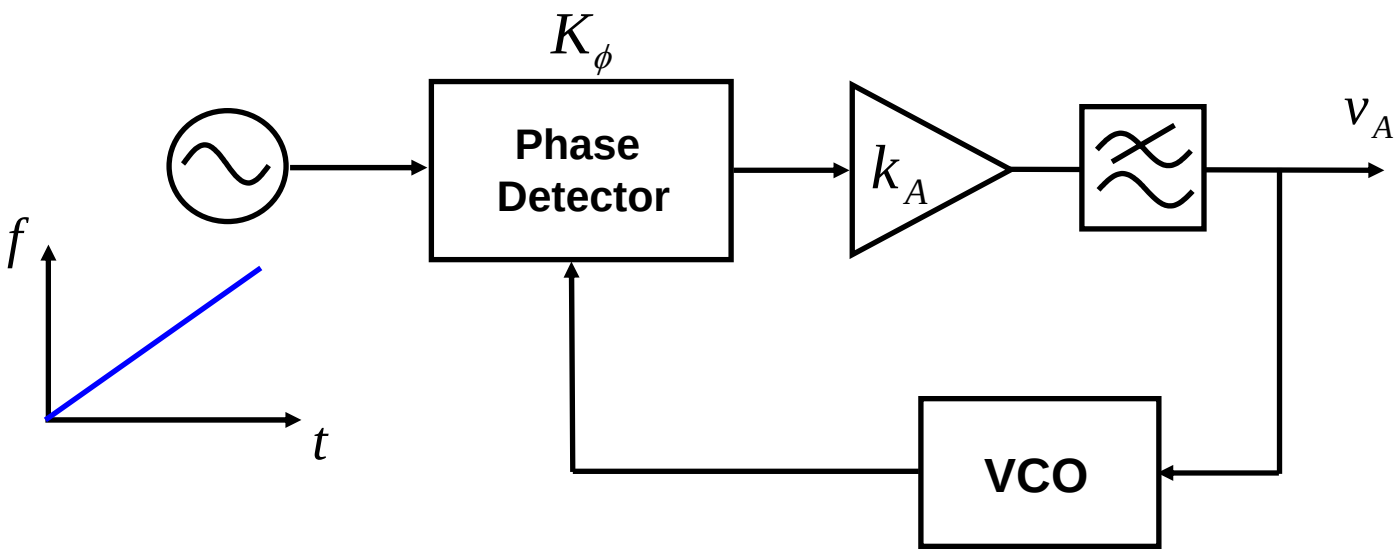


Caratteristica a farfalla





Caratteristica a farfalla



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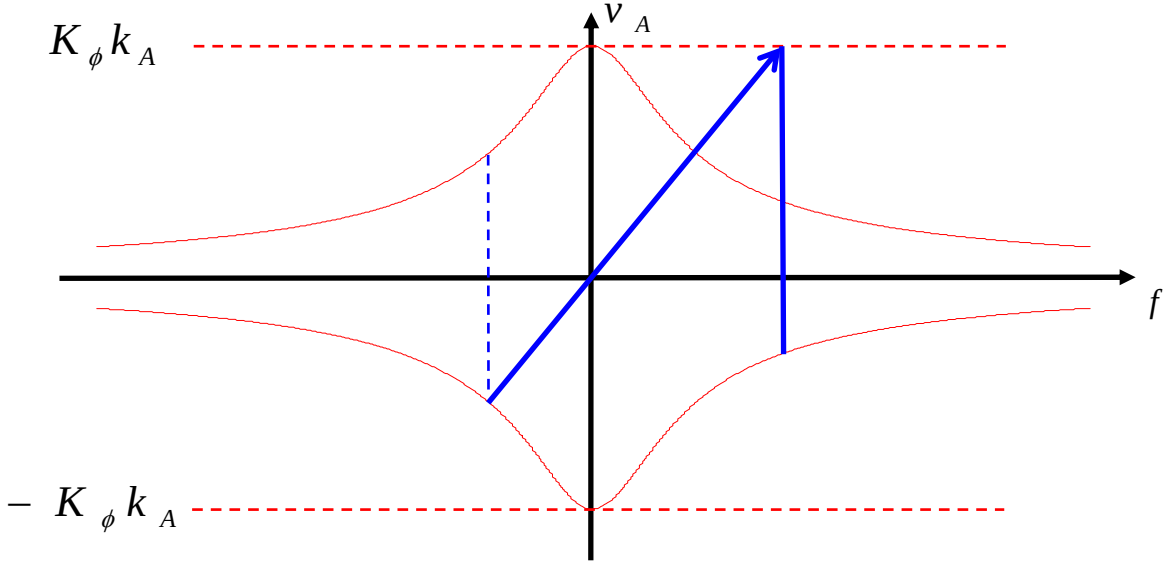
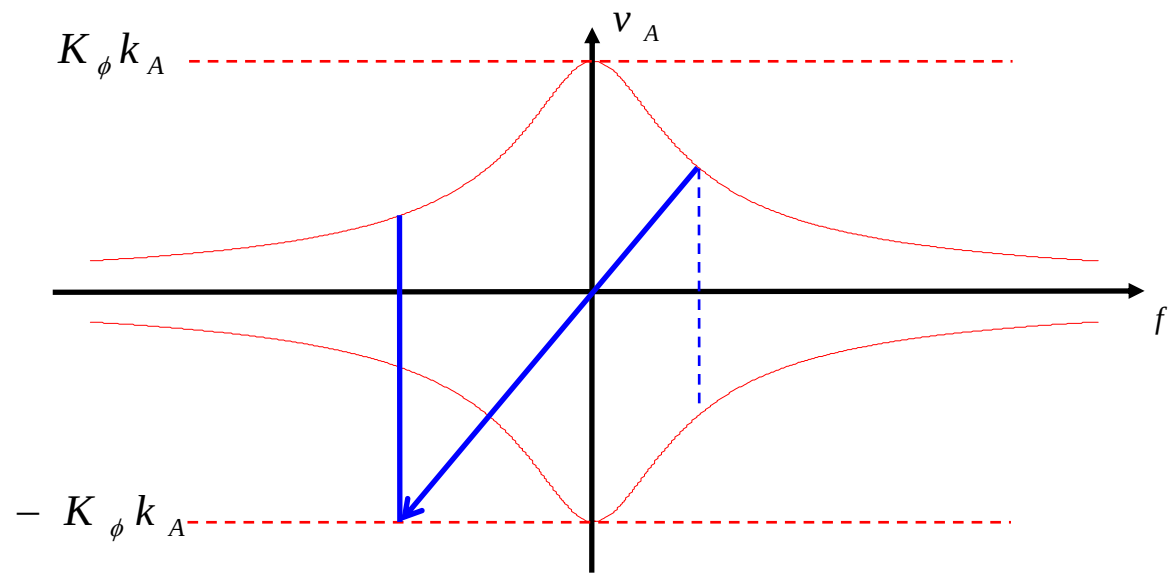
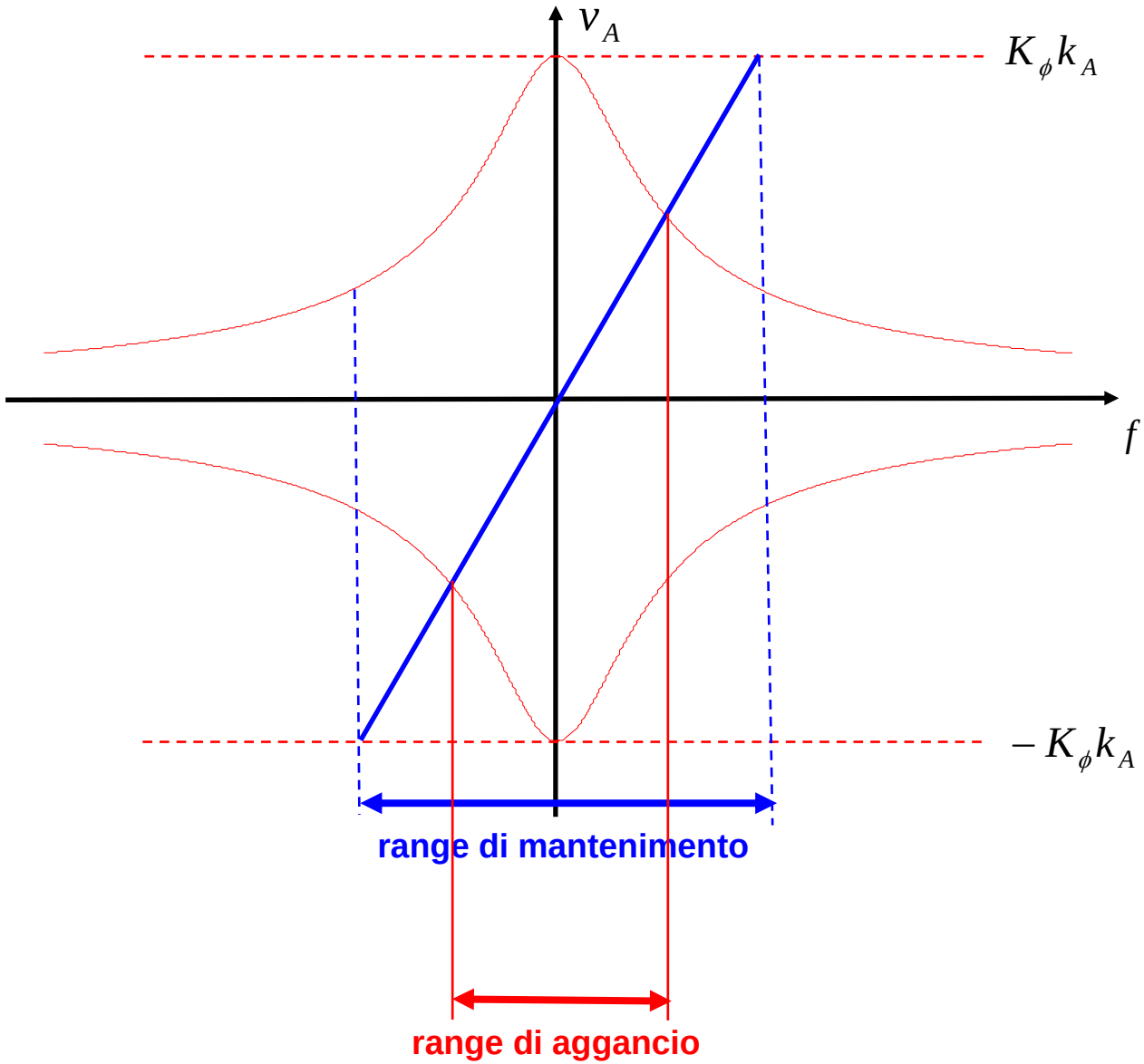
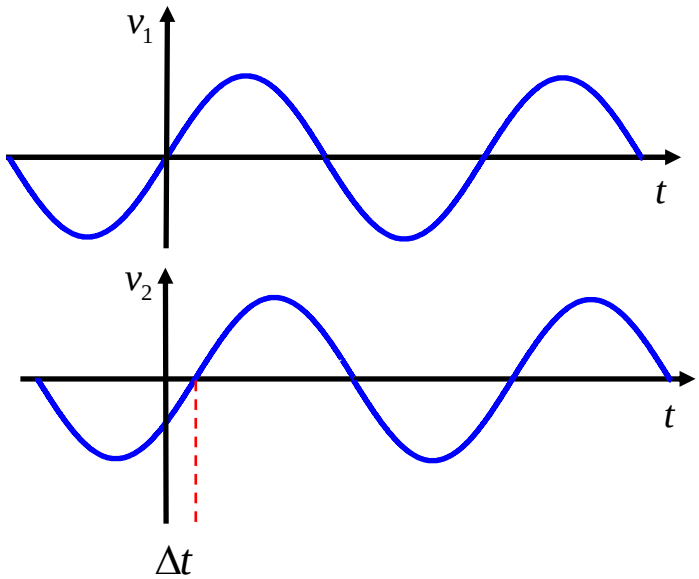


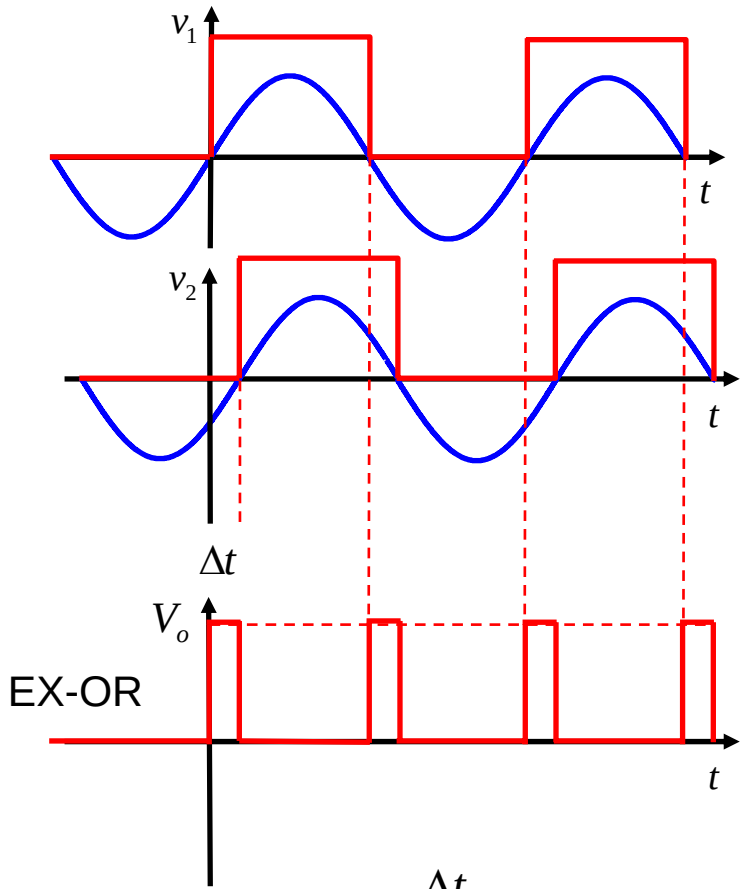


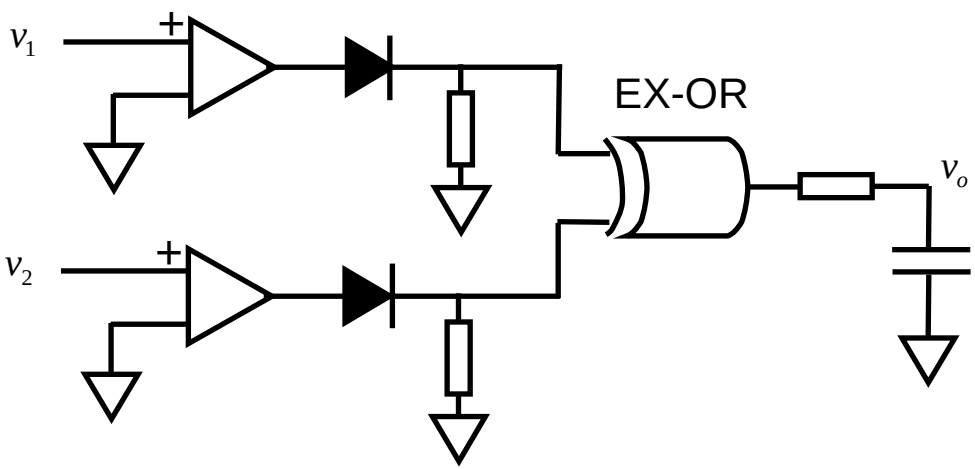
Caratteristica a farfalla



Rivelatori di fase lineari



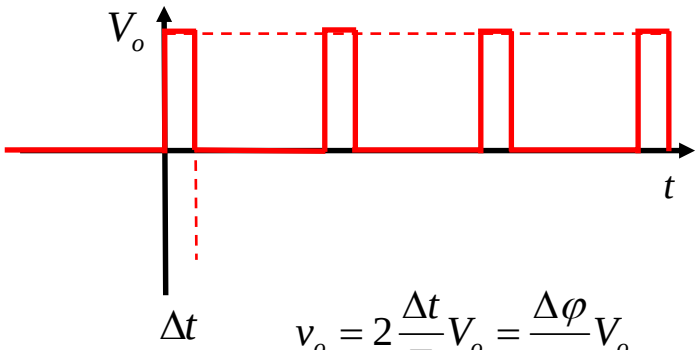




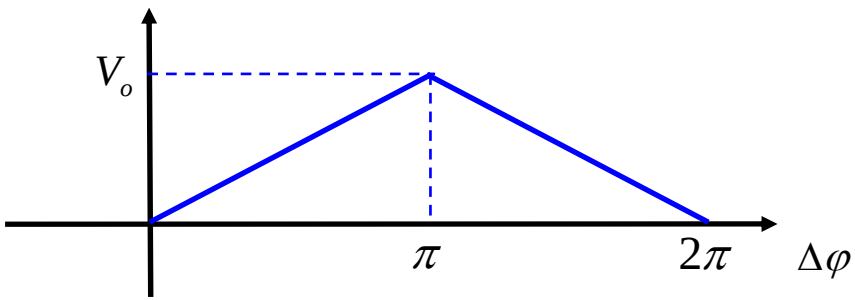
$$v_o = 2\frac{\Delta t}{T}V_o$$

$$v_o = 2\frac{\Delta\varphi}{2\pi}V_o = \frac{\Delta\varphi}{\pi}V_o$$

Rivelatori di fase lineari



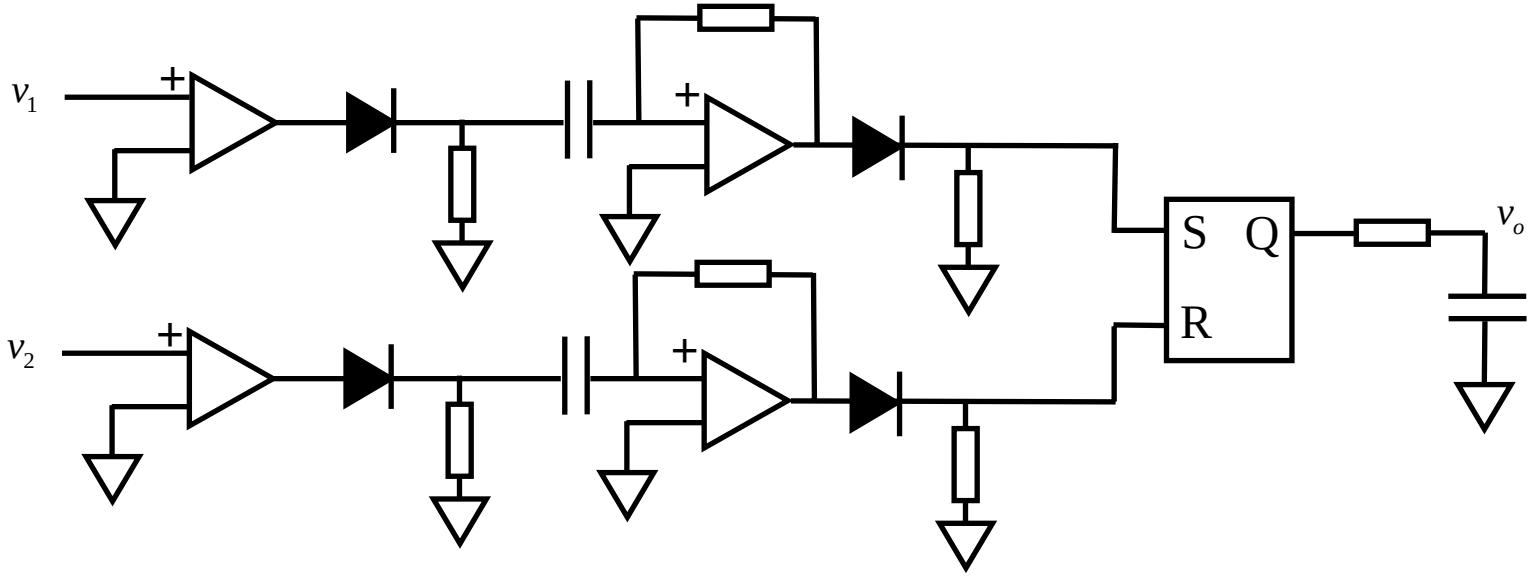
$$v_o = 2\frac{\Delta t}{T}V_o = \frac{\Delta\varphi}{\pi}V_o$$

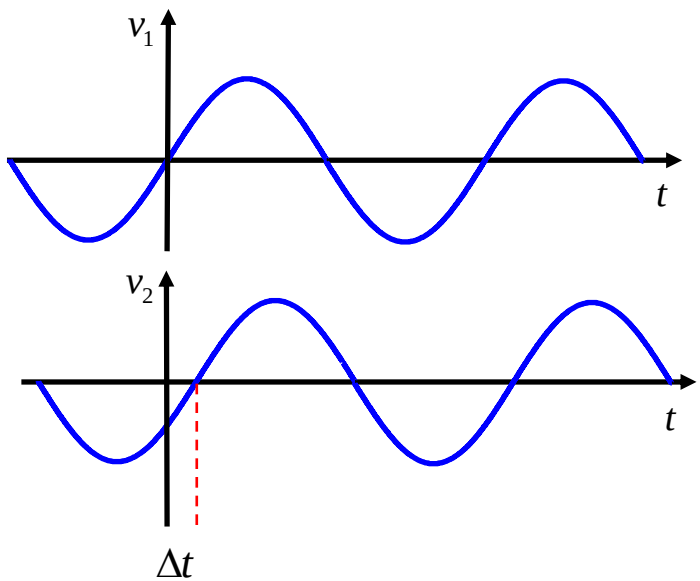


1) range: π

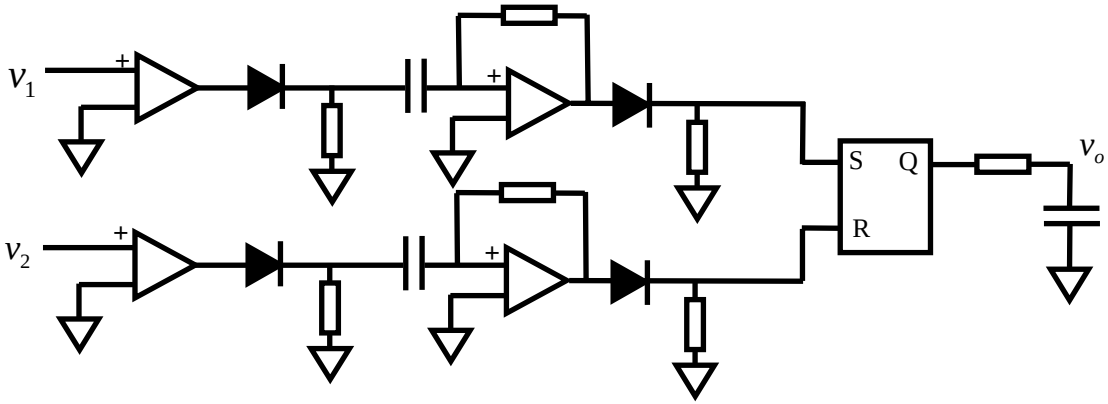
2) duty cycle: 50%

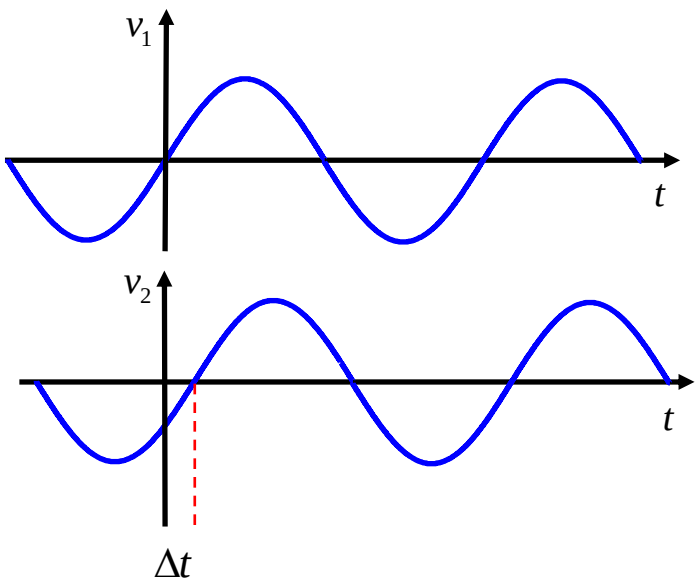
Rivelatori di fase lineari

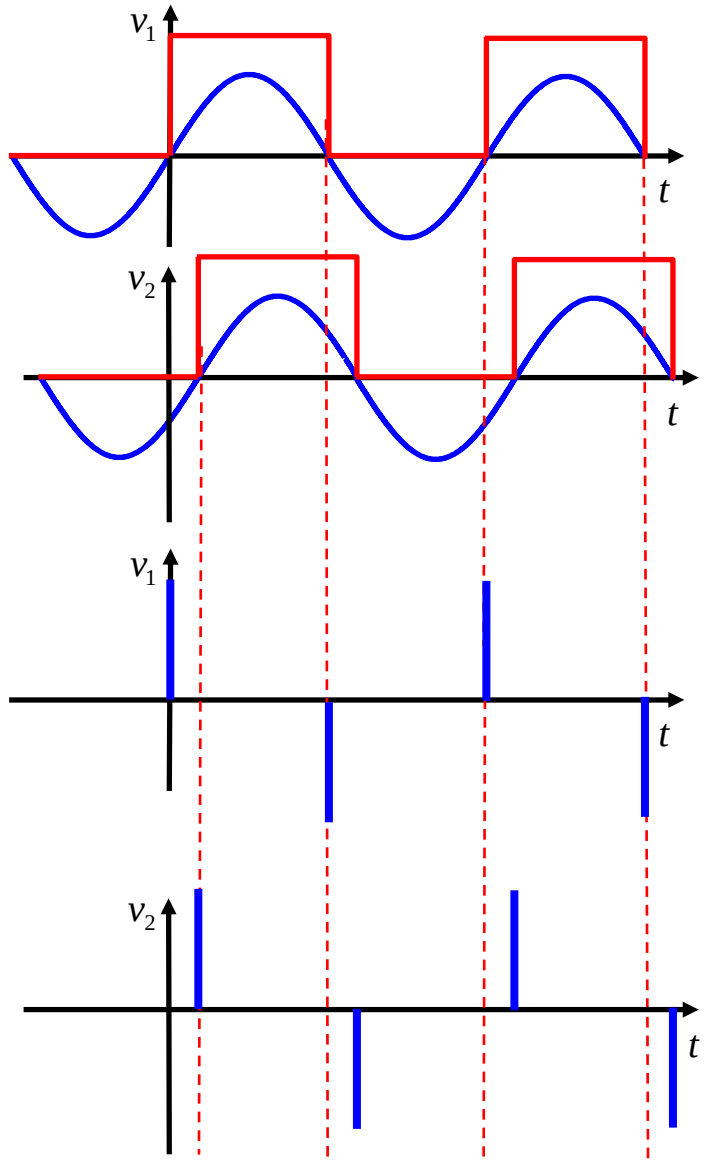




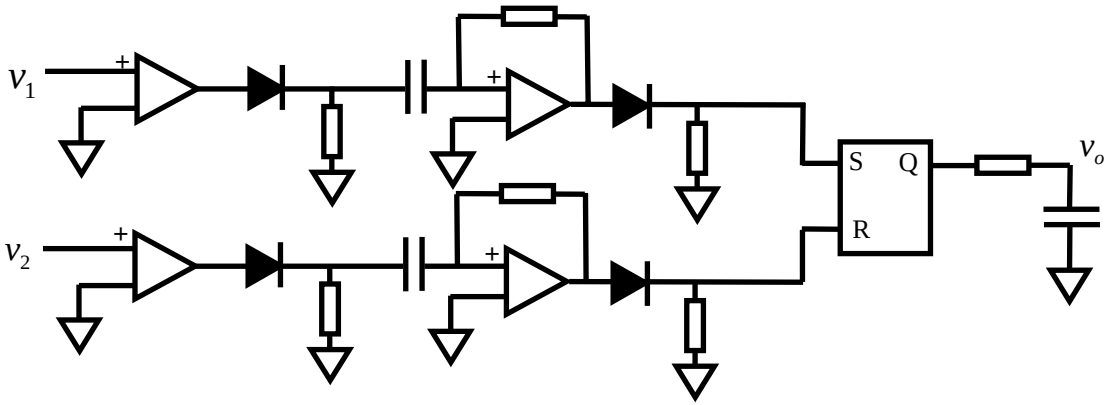
Rivelatori di fase lineari

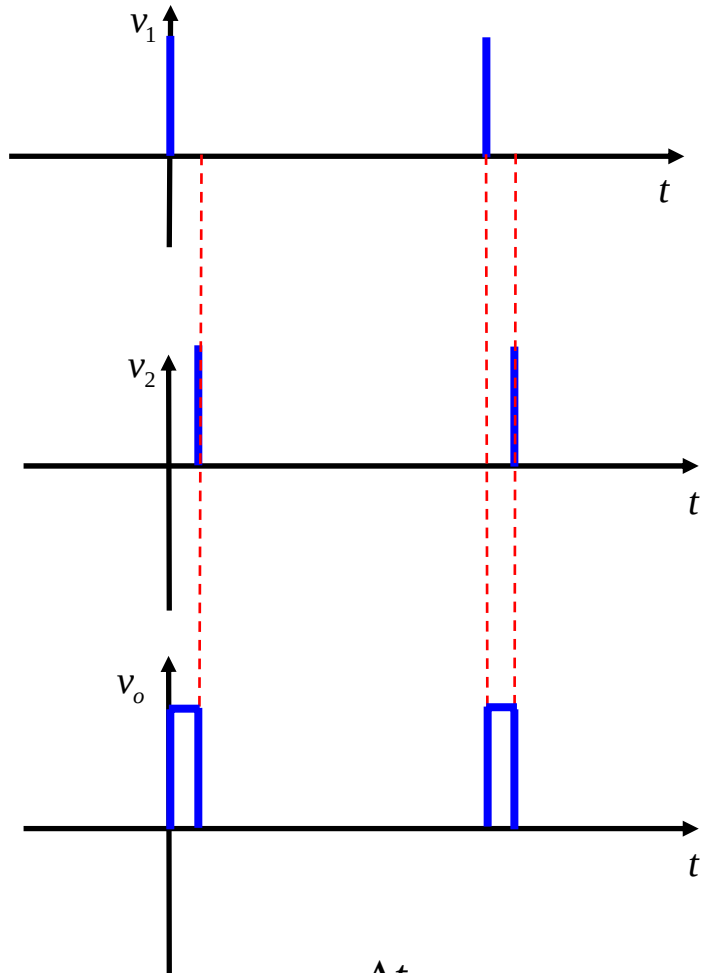


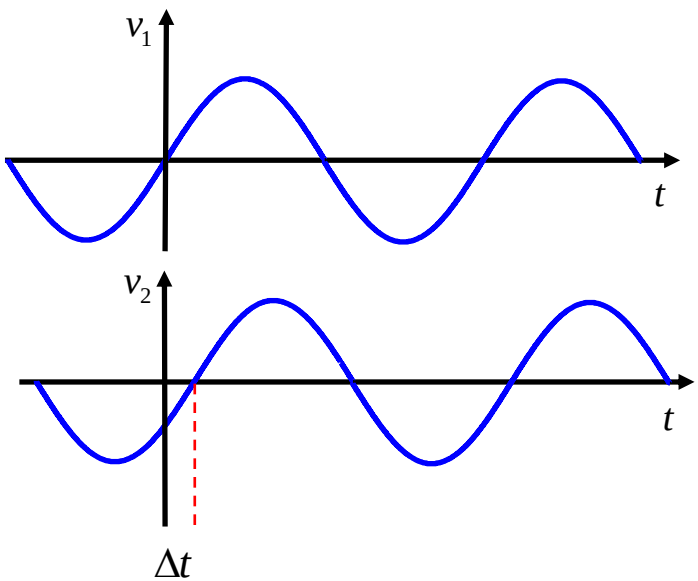




Rivelatori di fase lineari



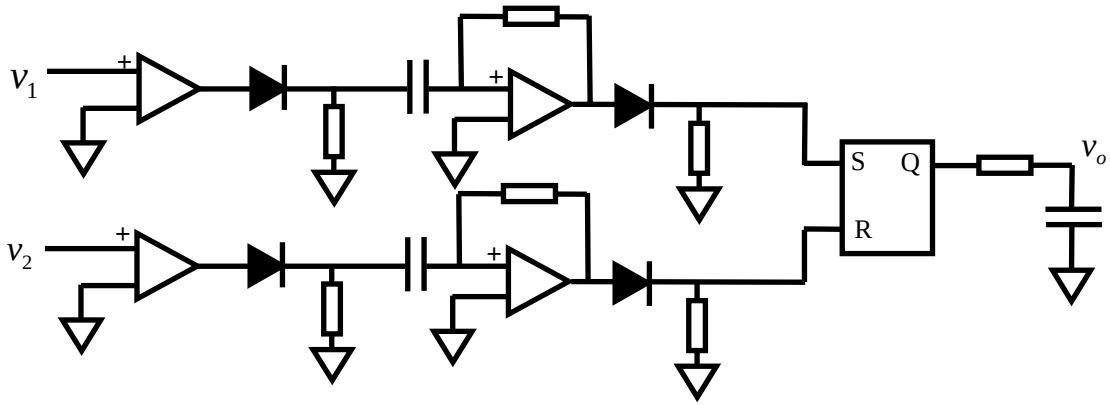




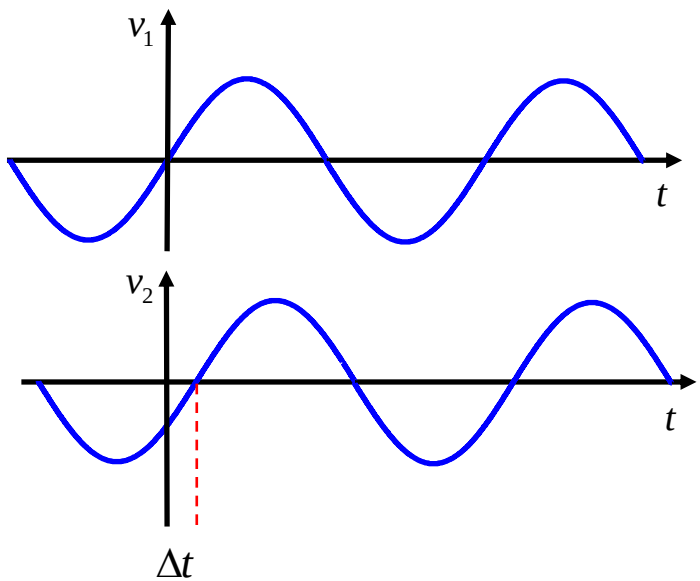
$$v_o = \frac{\Delta t}{T} V_o$$

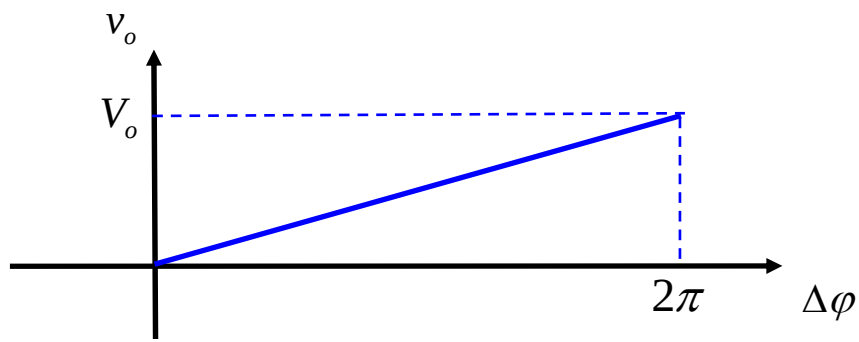
$$v_o = \frac{\Delta \varphi}{2\pi} V_o$$

Rivelatori di fase lineari



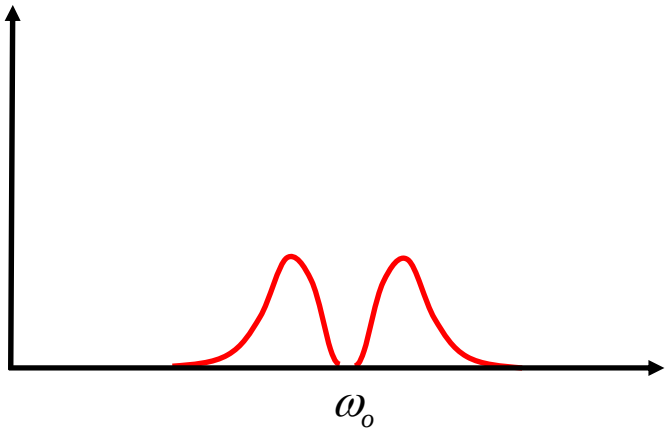
$$v_o = \frac{\Delta t}{T} V_o \qquad v_o = \frac{\Delta \varphi}{2\pi} V_o$$





Aggancio della portante soppressa

(SC DSB) Suppresed Carrier Double Side Band



AM SC DSB: $v_1 = V_1 \cos(\omega_1 t)\cos(\omega_m t)$

Anello di Costas