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ERICSSON TEI - T DIVISION

HW DEPARTMENT

Analog HW Design Seminar n.1

AGENDA

1 Introduzione

2 Circuiti PLL

Generalita'
Oscillatori
Divisori di frequenza
Moltiplicatori di frequenza
Comparatori di fase
Filtri

3 Linee di trasmissione

Strip lines
Microstrip
Linee di ritardo
Linee a cavo

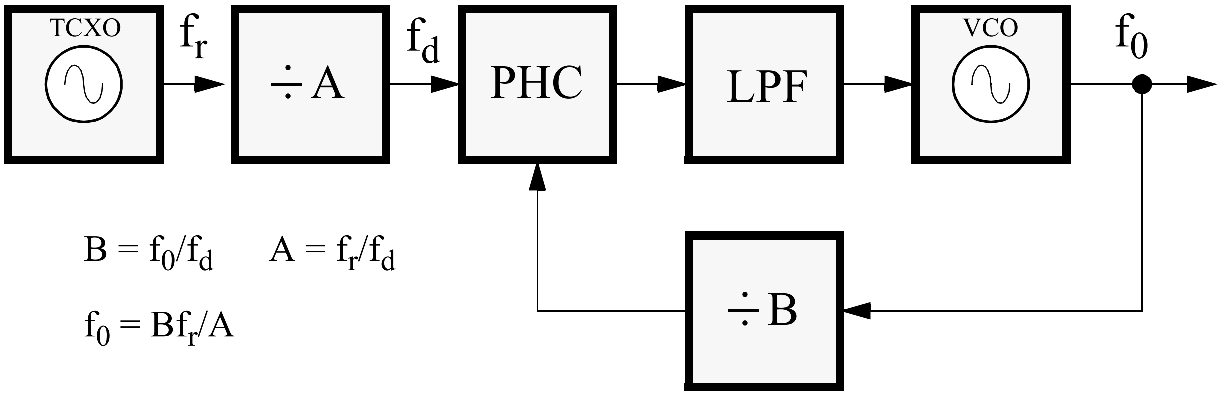
4 Interfacce seriali ad alto bit-rate

Dispositivi ECL / PECL
Segnali codificati e non codificati
Concetto di equalizzazione
Ricostruzione dell'offset
Estrazione della temporizzazione

5 Esempi di circuiti di base

Circuiti a transistors
Circuiti con amplificatori operazionali

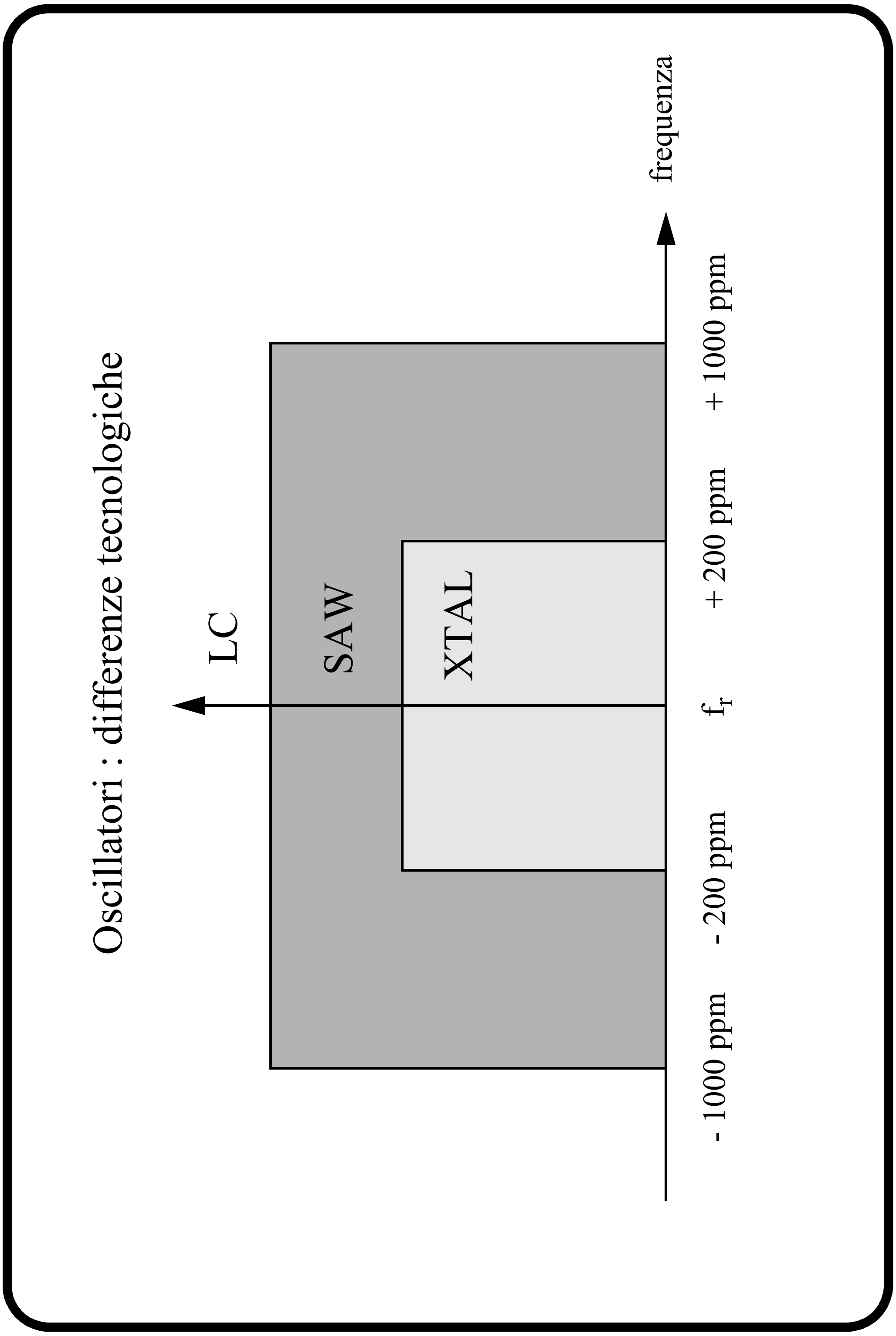
Schema a blocchi di un circuito PLL (Phase Locked Loop)



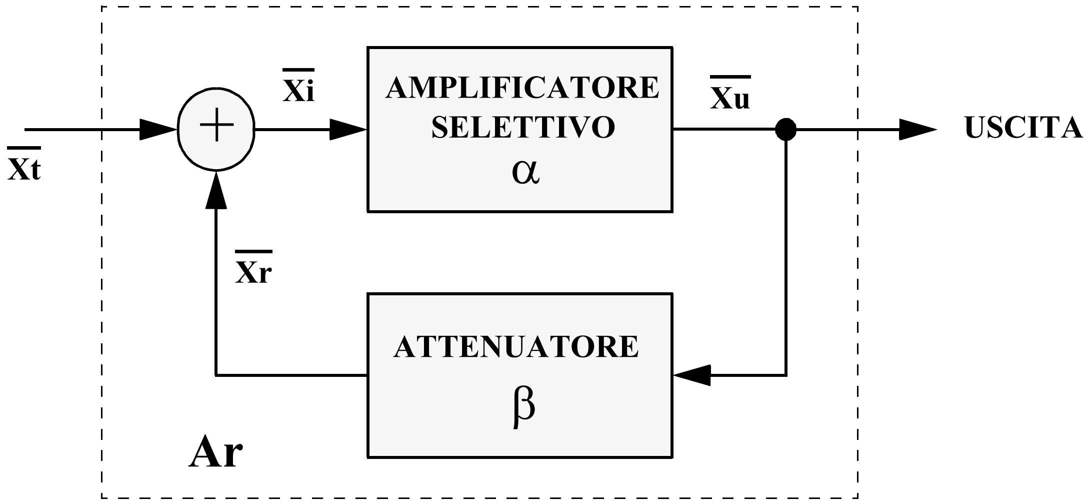
$B = f_0/f_d \qquad A = f_r/f_d$

$f_0 = Bf_r/A$

PHC = PHase Comparator
LPF = Low Pass Filter
VCO = Voltage Controlled Oscillator
TCXO = Temperature Controlled Xtal Oscillator


Oscillatori : differenze tecnologiche
LC
SAW
XTAL
frequenza
- 1000 ppm
- 200 ppm
f_r
+ 200 ppm
+ 1000 ppm

Oscillatori : reazione positiva

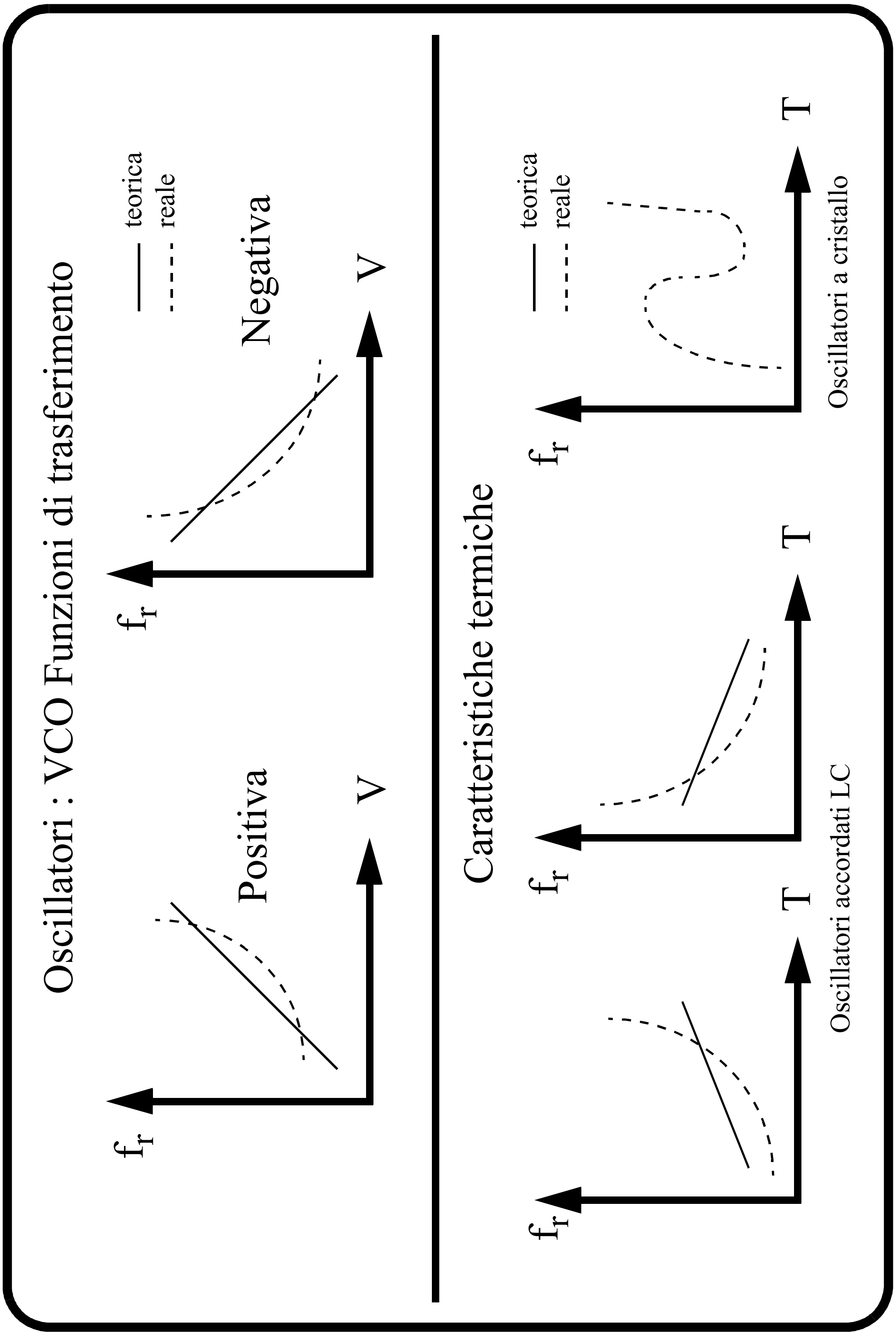


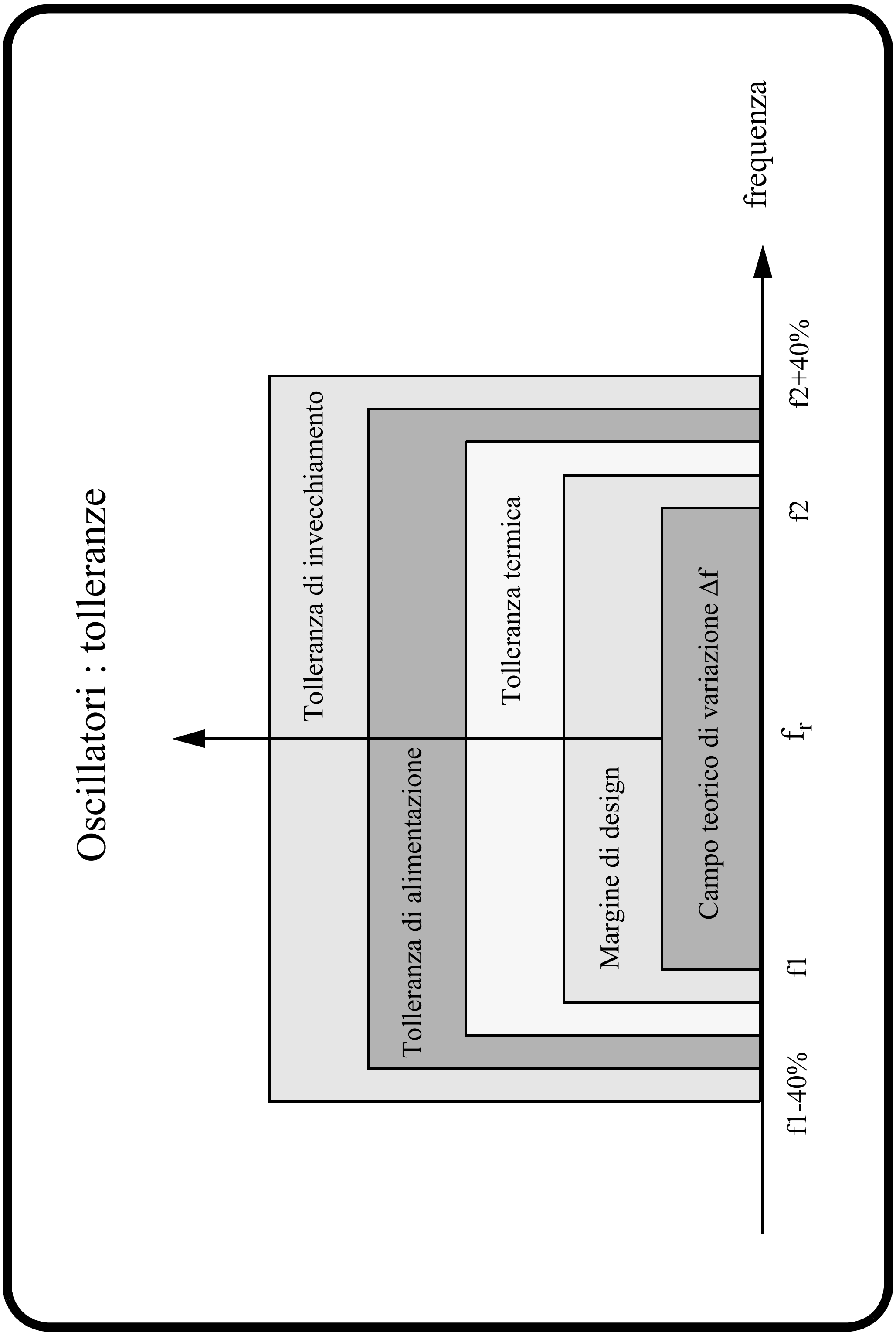
$$\bar{\alpha} = \frac{\overline{Xu}}{\overline{Xi}} \qquad \bar{\beta} = \frac{\overline{Xr}}{\overline{Xu}} \longrightarrow \overline{Xu} = \bar{\alpha}\overline{Xi} \qquad \overline{Xr} = \bar{\beta}\overline{Xu}$$

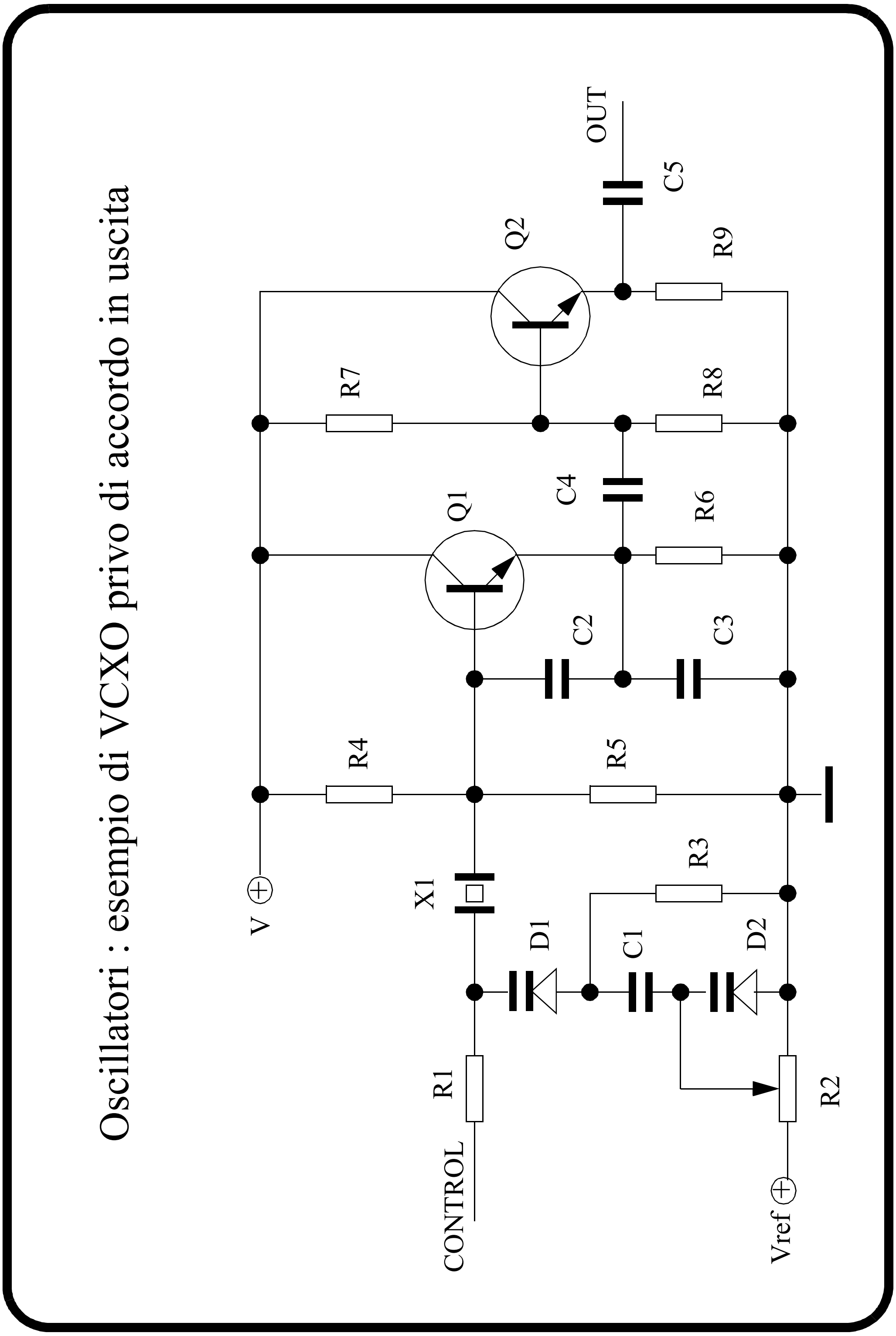
ma $\overline{Xt} = \overline{Xi} - \overline{Xr}$ *e* $\overline{Ar} = \frac{\overline{Xu}}{\overline{Xt}} \longrightarrow \overline{Ar} = \frac{\bar{\alpha}\overline{Xi}}{\overline{Xi} - \overline{Xr}}$

quindi $\overline{Ar} = \frac{\bar{\alpha}\overline{Xi}}{\overline{Xi} - \bar{\alpha}\bar{\beta}\overline{Xi}} = \frac{\bar{\alpha}}{1 - \bar{\alpha}\bar{\beta}}$ (1)

$$\begin{cases} \angle\bar{\alpha}\bar{\beta} = 0 \\ |\alpha\beta| \geq 1 \end{cases}$$ (2)


Oscillatori : VCO Funzioni di trasferimento
teorica
reale
Positiva
Negativa
V
V
f_r
f_r
Caratteristiche termiche
teorica
reale
T
T
T
f_r
f_r
f_r
Oscillatori accordati LC
Oscillatori a cristallo


Oscillatori : tolleranze
frequenza
Tolleranza di invecchiamento
Tolleranza di alimentazione
Tolleranza termica
Margine di design
Campo teorico di variazione Δf
f2+40%
f2
f_r
f1
f1-40%


Oscillatori : esempio di VCXO privo di accordo in uscita
OUT
C5
Q2
R9
R7
R8
C4
Q1
R6
C2
C3
R4
R5
R3
V
X1
D1
C1
D2
R1
R2
CONTROL
Vref

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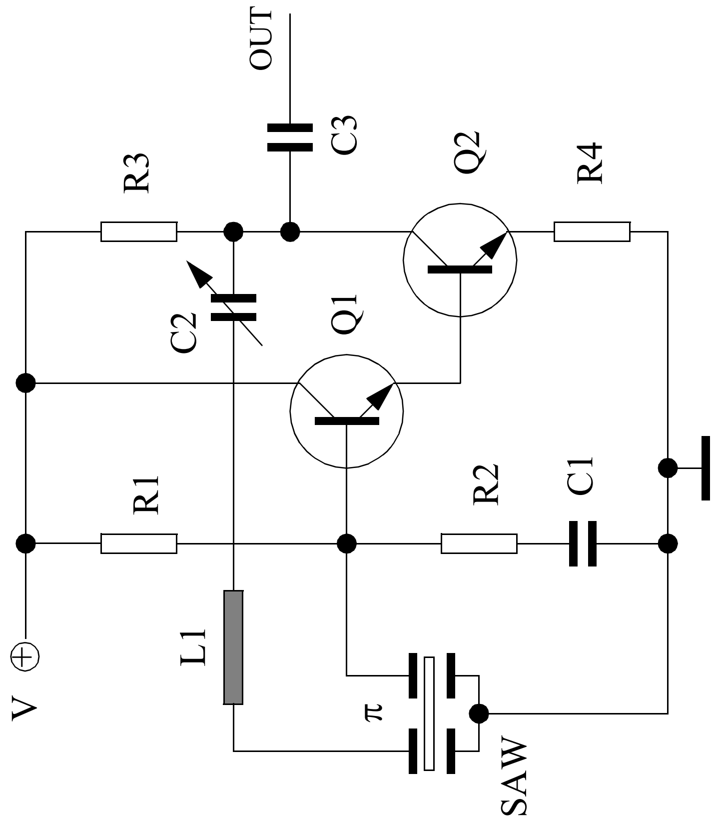
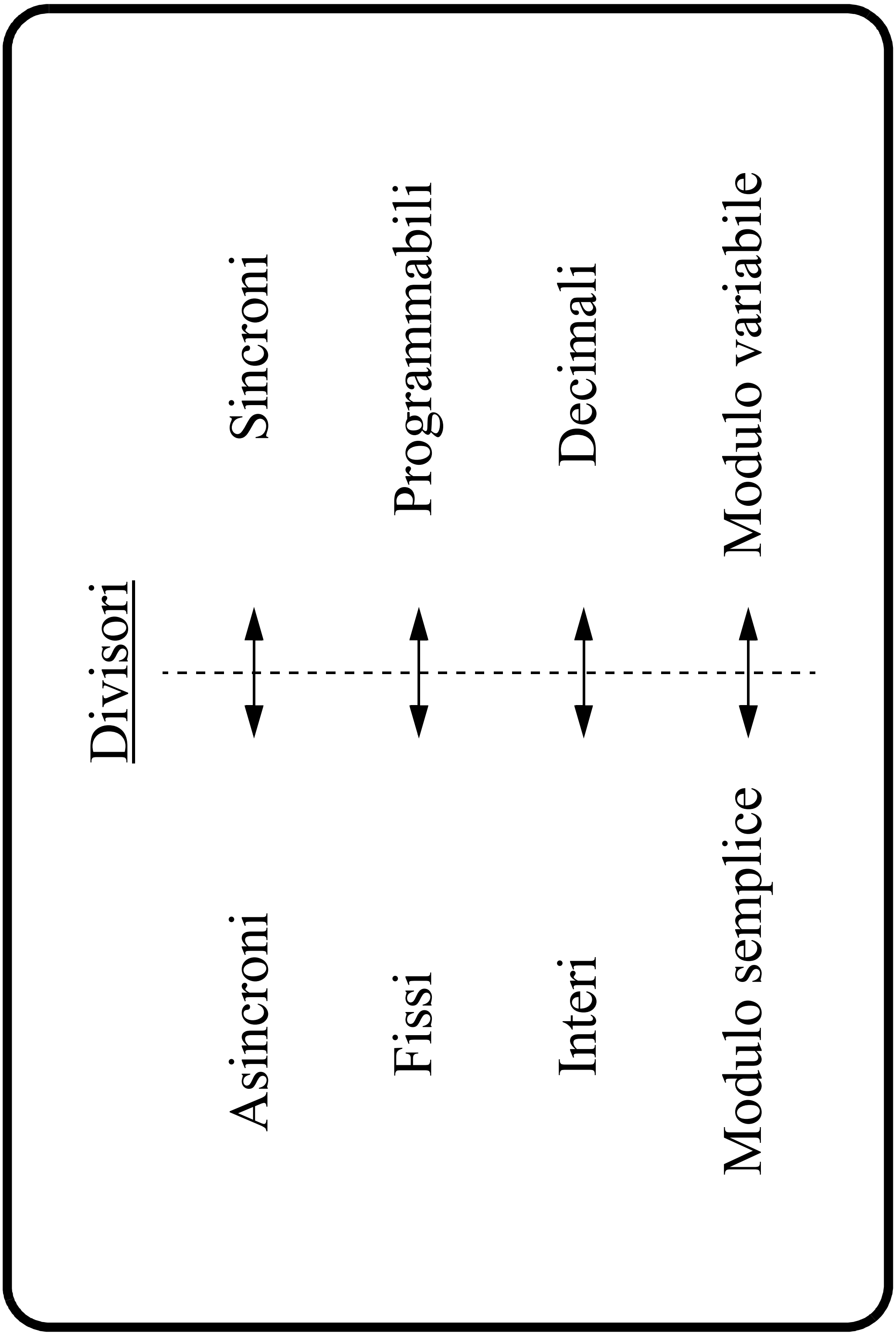
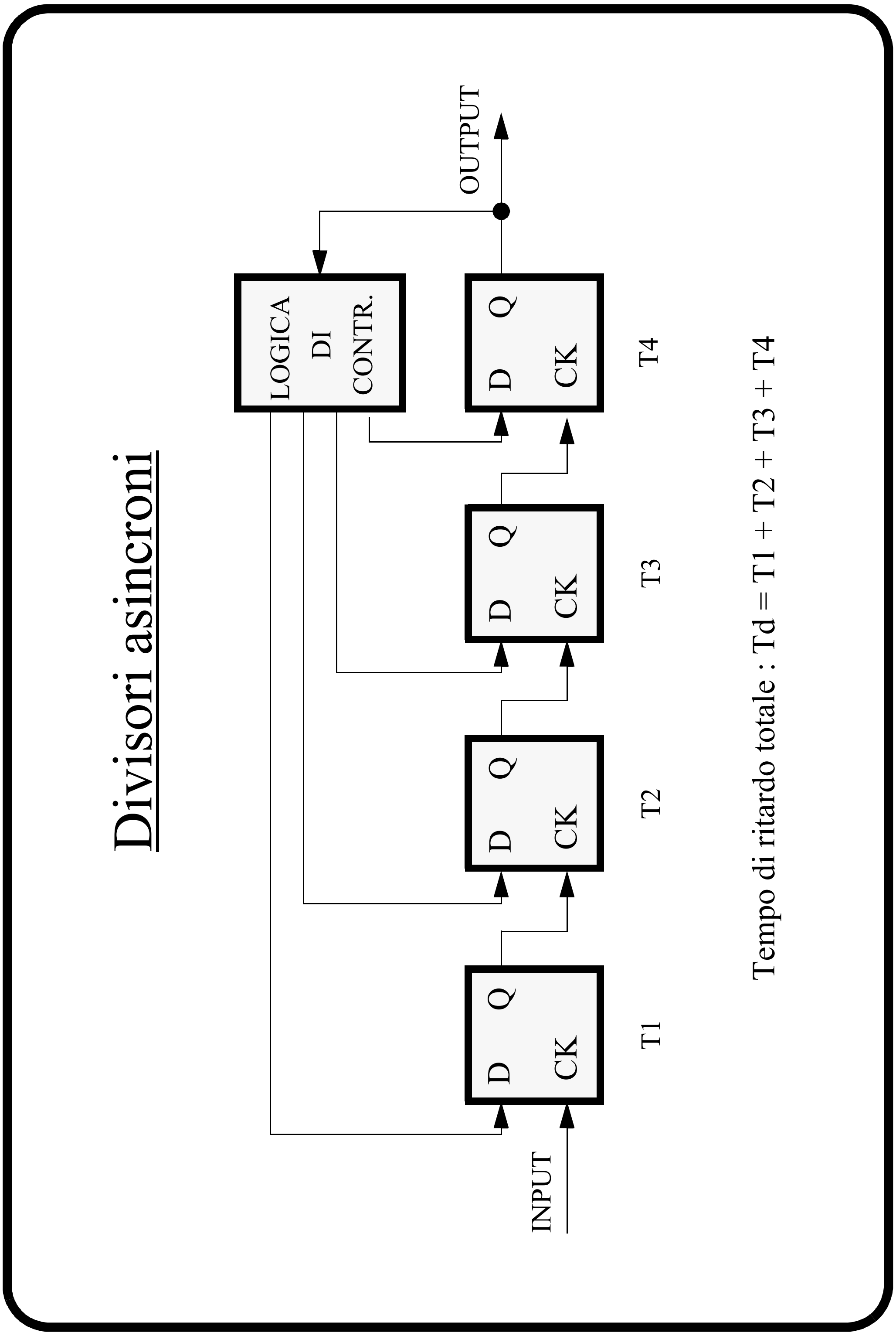
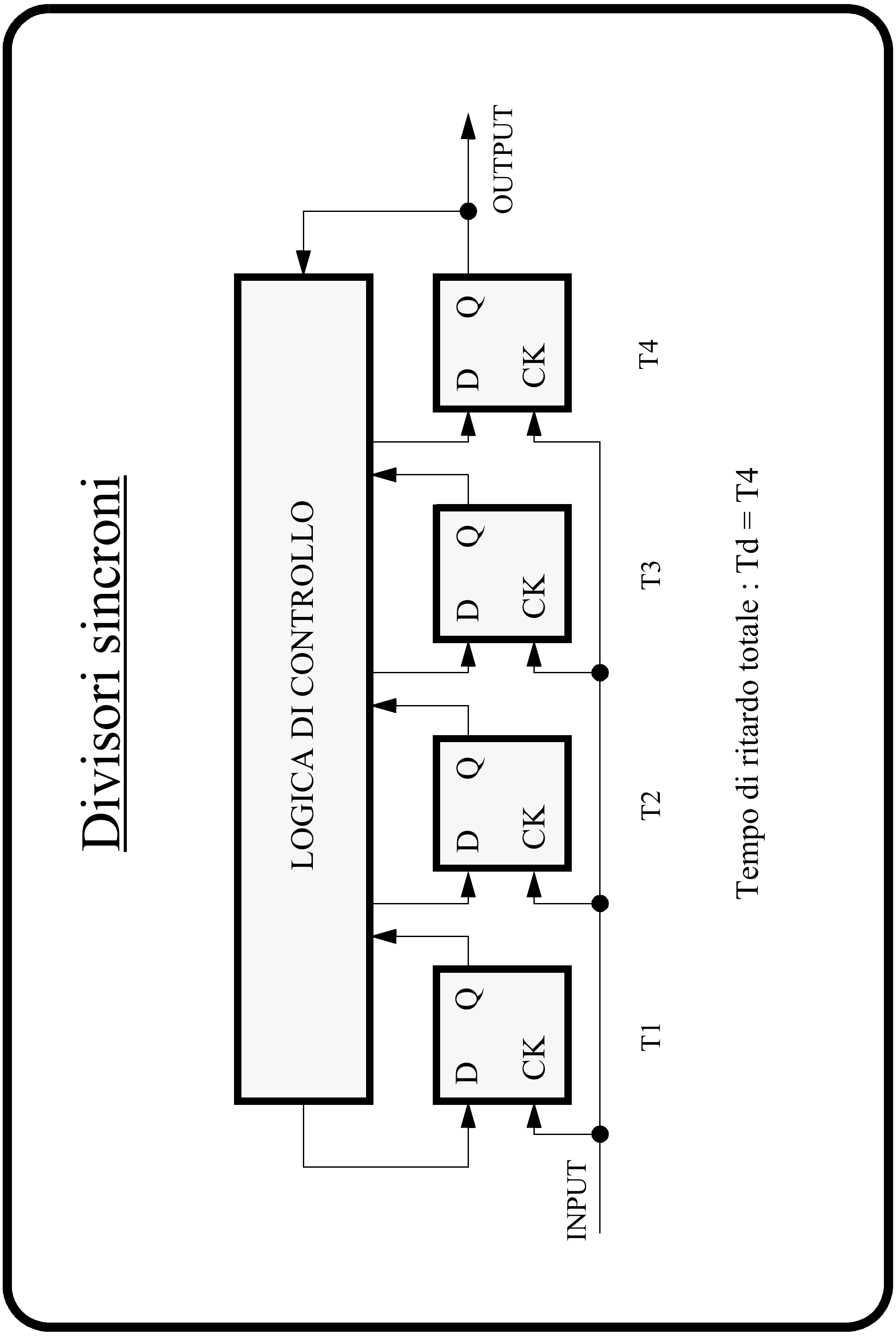
Oscillatori : esempio di oscillatore con filtro SAW a sfasamento π

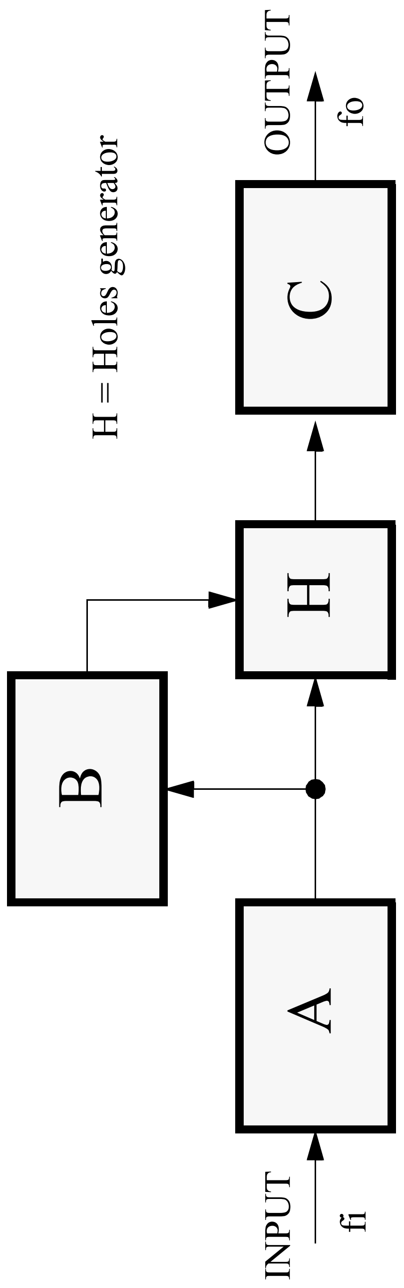



Divisori
Asincroni
Sincroni
Fissi
Programmabili
Interi
Decimali
Modulo semplice
Modulo variabile

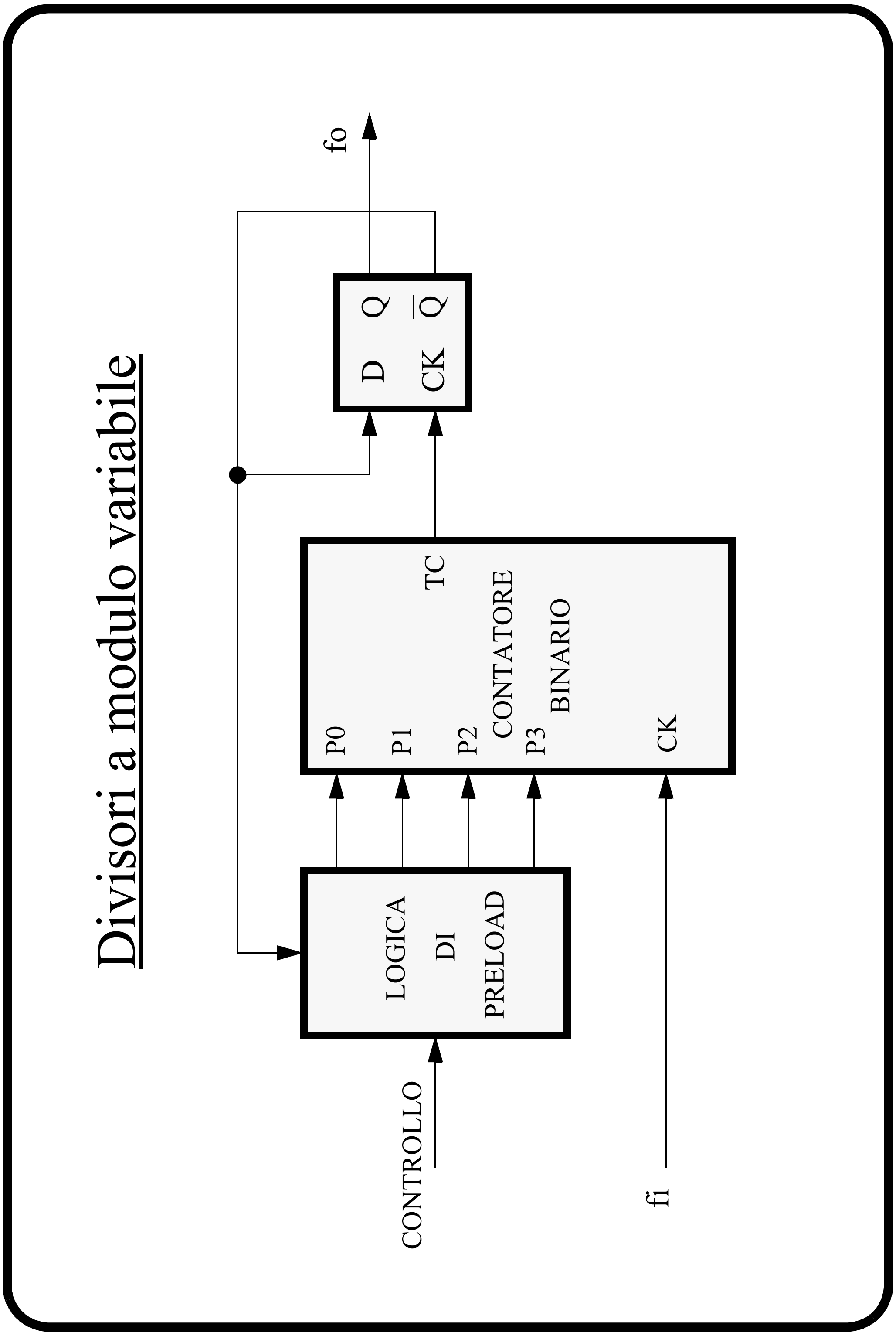

Divisori asincroni
LOGICA DI CONTR.
OUTPUT
INPUT
D Q CK
T1
T2
T3
T4
Tempo di ritardo totale : Td = T1 + T2 + T3 + T4


Divisori sincroni
LOGICA DI CONTROLLO
D Q CK
T1
T2
T3
T4
INPUT
OUTPUT
Tempo di ritardo totale : Td = T4

Divisori decimali



$$fo = \frac{\frac{fi}{A}\left(1 - \frac{1}{B}\right)}{C}$$



Divisori a modulo variabile
fo
D
Q
CK
Q̄
TC
CONTATORE
BINARIO
P0
P1
P2
P3
CK
LOGICA
DI
PRELOAD
CONTROLLO
fi

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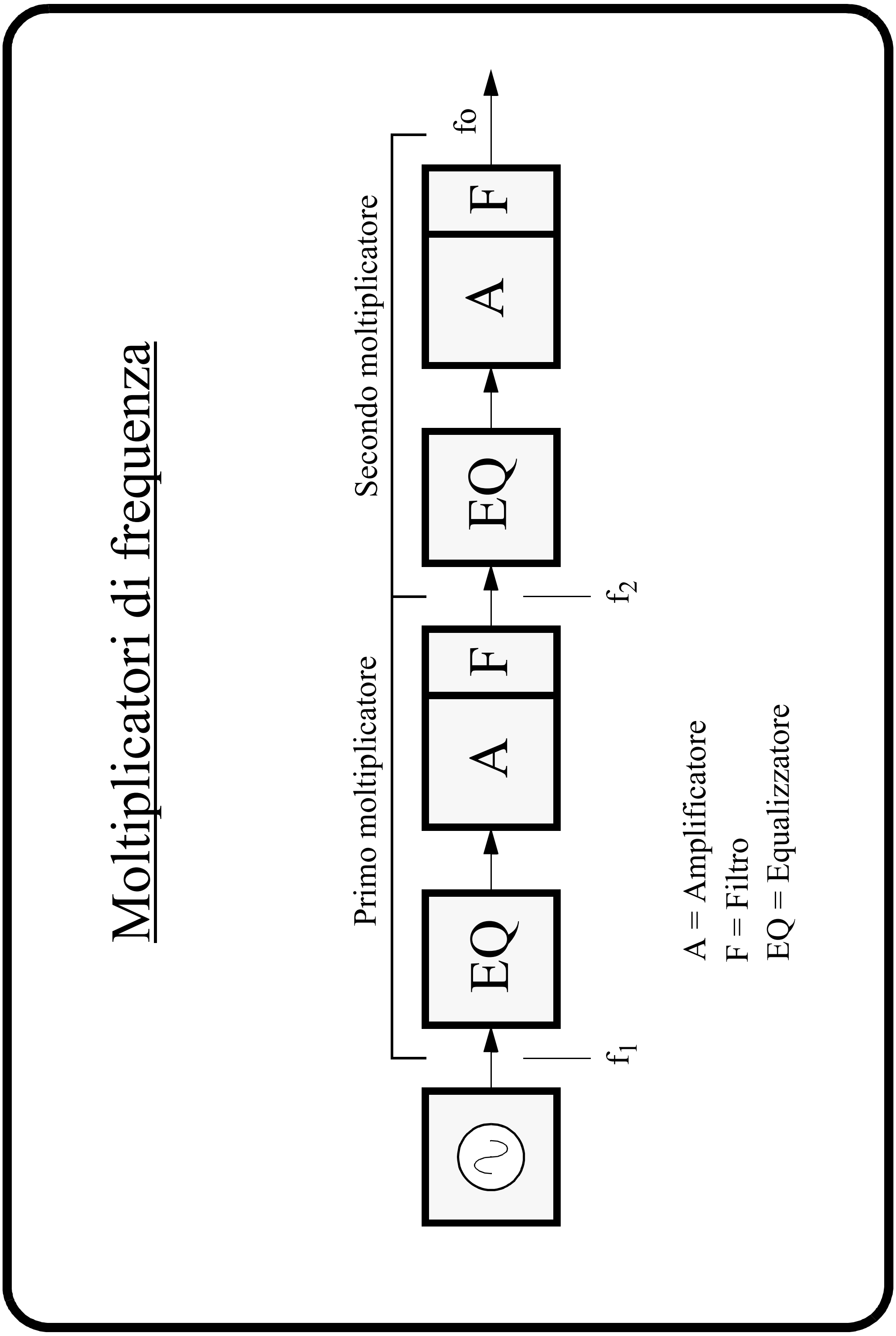

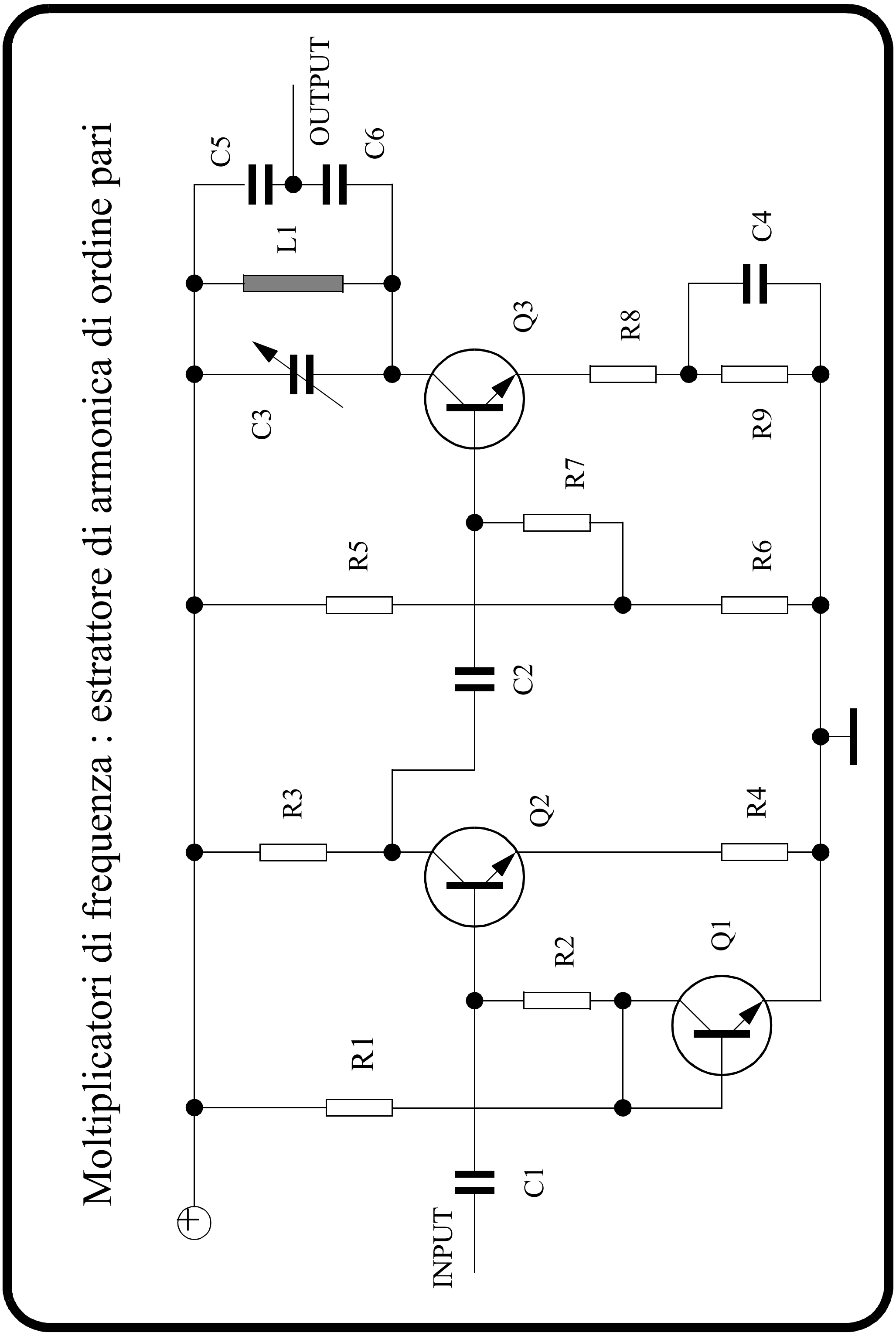
Moltiplicatori di frequenza : estrattore di armonica di ordine pari
OUTPUT
C5
C6
L1
C4
C3
Q3
R8
R9
R7
R5
R6
C2
R3
Q2
R4
R2
Q1
R1
C1
INPUT

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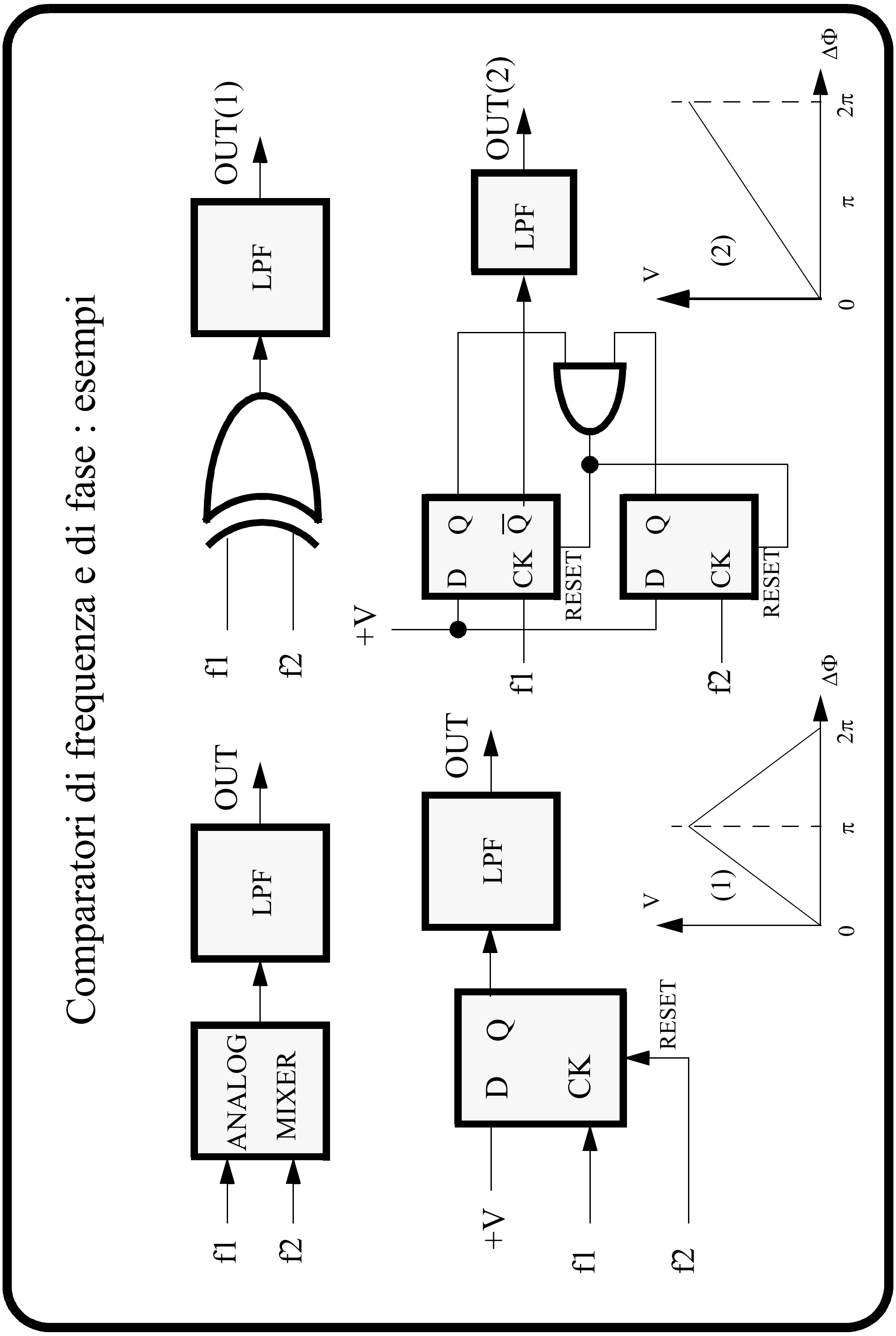
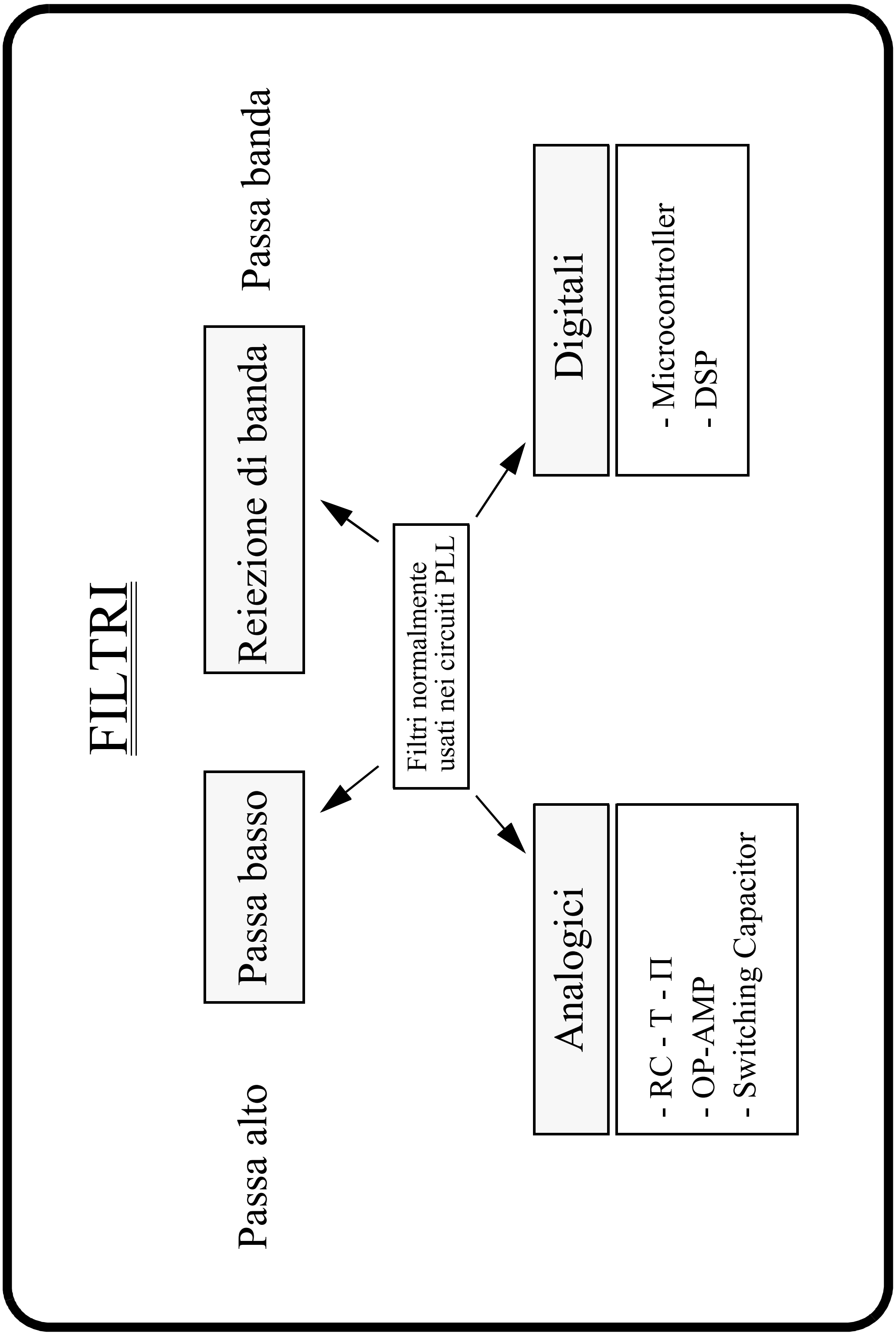
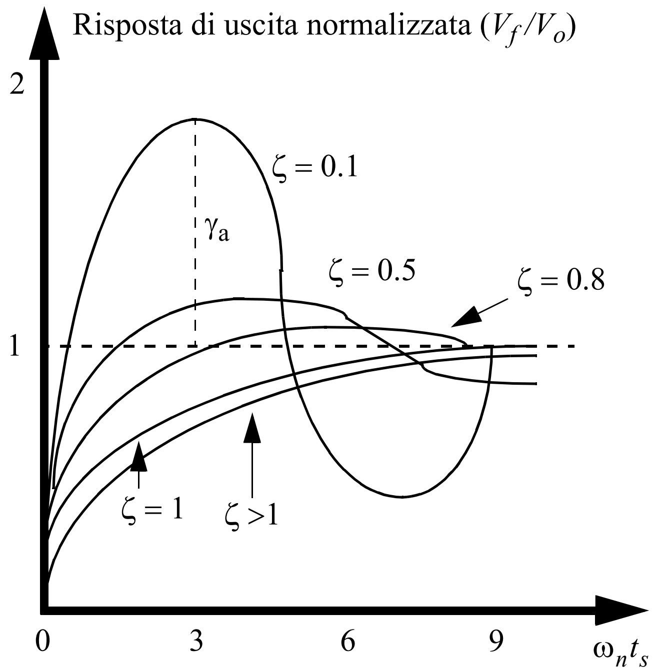



FILTRI
Passa alto
Passa basso
Reiezione di banda
Passa banda
Filtri normalmente usati nei circuiti PLL
Analogici
- RC - T - Π
- OP-AMP
- Switching Capacitor
Digitali
- Microcontroller
- DSP

Filtri : fattore di smorzamento



Frequenza naturale : $\omega_n = \sqrt{(K_0 K_\phi \omega_{LPF})}$

Freq. nat. smorzata : $\omega_d = \omega_n \sqrt{1 - \zeta^2}$

Fattore di smorzamento : $\zeta = \dfrac{\gamma}{\sqrt{1 + \gamma^2}}$

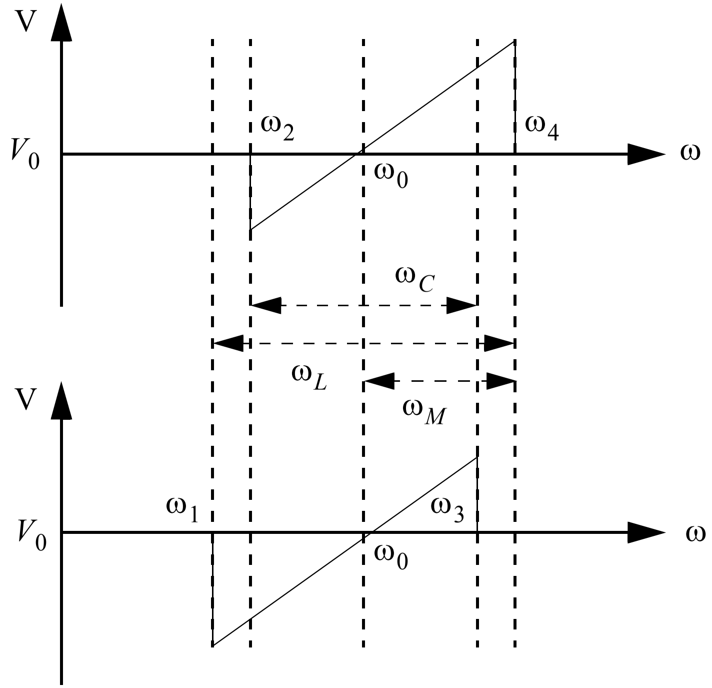
$$\zeta = \frac{1}{2}\sqrt{\frac{\omega_{LPF}}{K_0 K_\phi}}$$

Dove : $\gamma = \dfrac{1}{2\pi} \ln\left(\dfrac{\gamma_a}{\gamma_b}\right)$

$$K_0 = \frac{\omega_0}{V_f}$$

$$K_\phi = \frac{\Delta V_0}{\Delta_\phi}$$

PLL : campo di aggancio e campo di cattura



Campo di aggancio : $\omega_L = K_0 K_\phi$

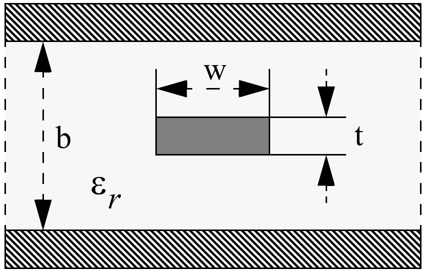
Campo di cattura : $\omega_C = 2\left(\frac{\omega_L}{2} - \Gamma\right)$

Campo di mantenimento : $\omega_M = \frac{\omega_L}{2}$

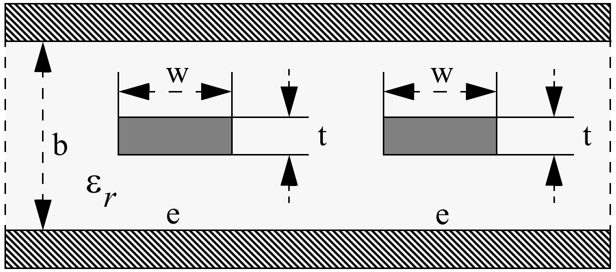
dove : $\Gamma = f(\zeta)$

Strip lines

Singole (sbilanciate)



Accoppiate (bilanciate)



se : $\dfrac{w}{b-t} \leq 0{,}35$ allora $Z_0 = \dfrac{60}{\sqrt{\varepsilon_r}} \ln \dfrac{4b}{\pi d_0}$

se : $\dfrac{w}{b-t} \geq 0{,}35$ allora $Z_0 = \dfrac{94{,}15}{\sqrt{\varepsilon_r}[(w/ba) + C]}$

dove $C = \dfrac{1}{\pi}\left[\dfrac{2}{a}\ln\left(\dfrac{1}{a}+1\right) - \left(\dfrac{1}{a}-1\right)\ln\left(\dfrac{1}{a^2}-1\right)\right]$

e $a = \left(1 - \dfrac{t}{b}\right)$

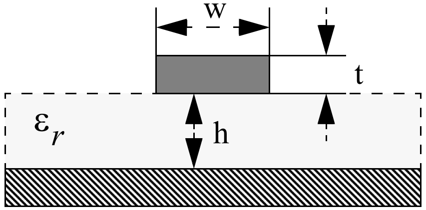
Impedenza even (e) : $Z_{0e} = Z_0\sqrt{\dfrac{1+P}{1-P}}$

Impedenza odd (o) : $Z_{0o} = Z_0\sqrt{\dfrac{1-P}{1+P}}$

dove P rappresenta l'accoppiamento tra i due conduttori

Microstrips

Singole (sbilanciate)



per $\frac{w}{h} < 3{,}3$ $\qquad Z_0 = A(C - B)$

$$A = \frac{119{,}9}{\sqrt{2(\varepsilon_r + 1)}} \qquad B = \frac{1}{2}\left(\frac{\varepsilon_r - 1}{\varepsilon_r + 1}\right)\left(\ln\frac{\pi}{2} + \frac{\ln 4/\pi}{\varepsilon_r}\right)$$

$$C = \ln\left(\frac{4h}{w} + \sqrt{\left(\frac{4h}{w}\right)^2 + 2}\right)$$

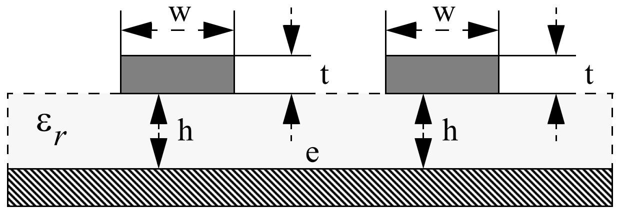
per $\frac{w}{h} < 1{,}3$ $\quad \varepsilon_{eff} = \dfrac{\varepsilon_r + 1}{2\left(1 - \frac{B}{C}\right)^2}$

per $\frac{w}{h} > 1{,}3$ $\quad \varepsilon_{eff} = \dfrac{\varepsilon_r + 1}{2} + \dfrac{\varepsilon_r - 1}{2\left(1 + \frac{10h}{w}\right)^{0{,}555}}$

per $\frac{w}{h} > 3{,}3$

$$Z_0 = \frac{D}{\left[\frac{w}{2h} + 0{,}44127 + \frac{0{,}08226(\varepsilon_r - 1)}{\varepsilon_r^{\,2}} + \frac{(\varepsilon_r + 1)}{2\pi\varepsilon_r}\left(1{,}4516 + \ln\left(\frac{w}{2h} + 0{,}94\right)\right)\right]} \qquad D = \frac{59{,}95\pi}{\sqrt{\varepsilon_r}}$$

Accoppiate (bilanciate)



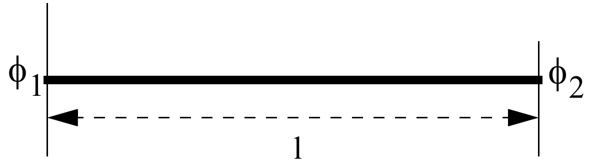
Impedenza even (e) : $Z_{0e} = Z_0\sqrt{\dfrac{1 + P}{1 - P}}$

Impedenza odd (o) : $Z_{0o} = Z_0\sqrt{\dfrac{1 - P}{1 + P}}$

Linee di ritardo

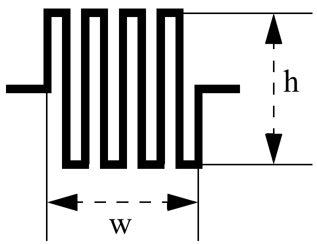
Elettriche	Piezoelettriche
Piccoli ritardi	Grandi ritardi

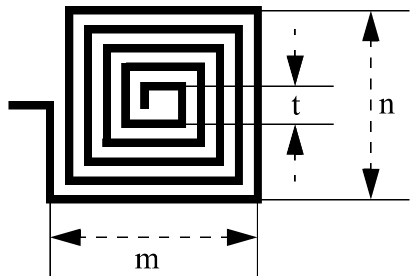
Linee di ritardo elettriche



$$\lambda_v = \frac{c}{f} \qquad \lambda_l = \frac{\lambda_v}{\sqrt{\varepsilon_r}}$$

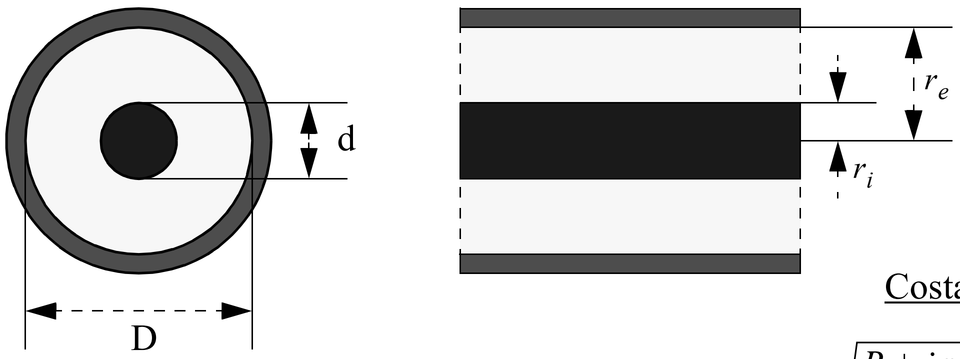
$$\Delta_\phi = \phi_2 - \phi_1 = 2\pi \frac{l}{\lambda_l}$$





Ericsson Telecomunicazioni SpA

Linee a cavo



$$Z_0 = 60\sqrt{\frac{1}{\varepsilon_r}}\ln\left(\frac{r_e}{r_i}\right)$$

Costanti secondarie

$$\overline{Z_o} = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$ Impedenza

Costante di propagazione

$$\gamma = \alpha + j\beta = \sqrt{(R + j\omega L)(G + j\omega C)}$$

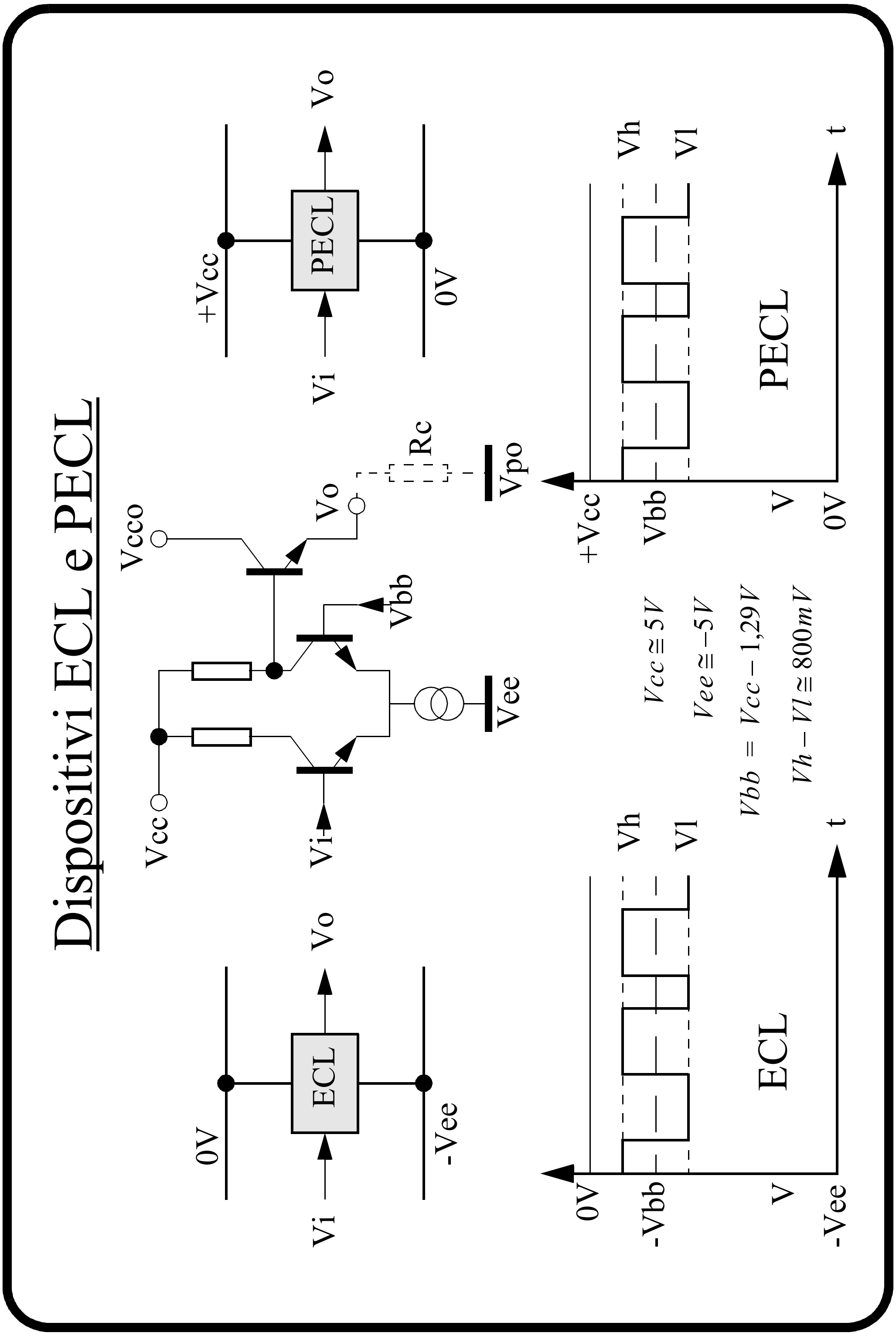
Costanti primarie

$$R = 4{,}2 \cdot 10^{-6}\sqrt{f}\left(\frac{1}{r_e} + \frac{1}{r_i}\right) \qquad L = \frac{\mu_0}{2\pi}\ln\frac{r_e}{r_i}$$

$$C = \frac{2\pi\varepsilon_r}{\ln\frac{r_e}{r_i}} \qquad G = \frac{2\pi\sigma_d}{\ln\frac{r_e}{r_i}}$$

$$\alpha = \sqrt{\frac{1}{2}\left[\sqrt{(R^2 + \omega^2 L^2)(G^2 + \omega^2 C^2)} + (RG - \omega^2 LC)\right]}$$

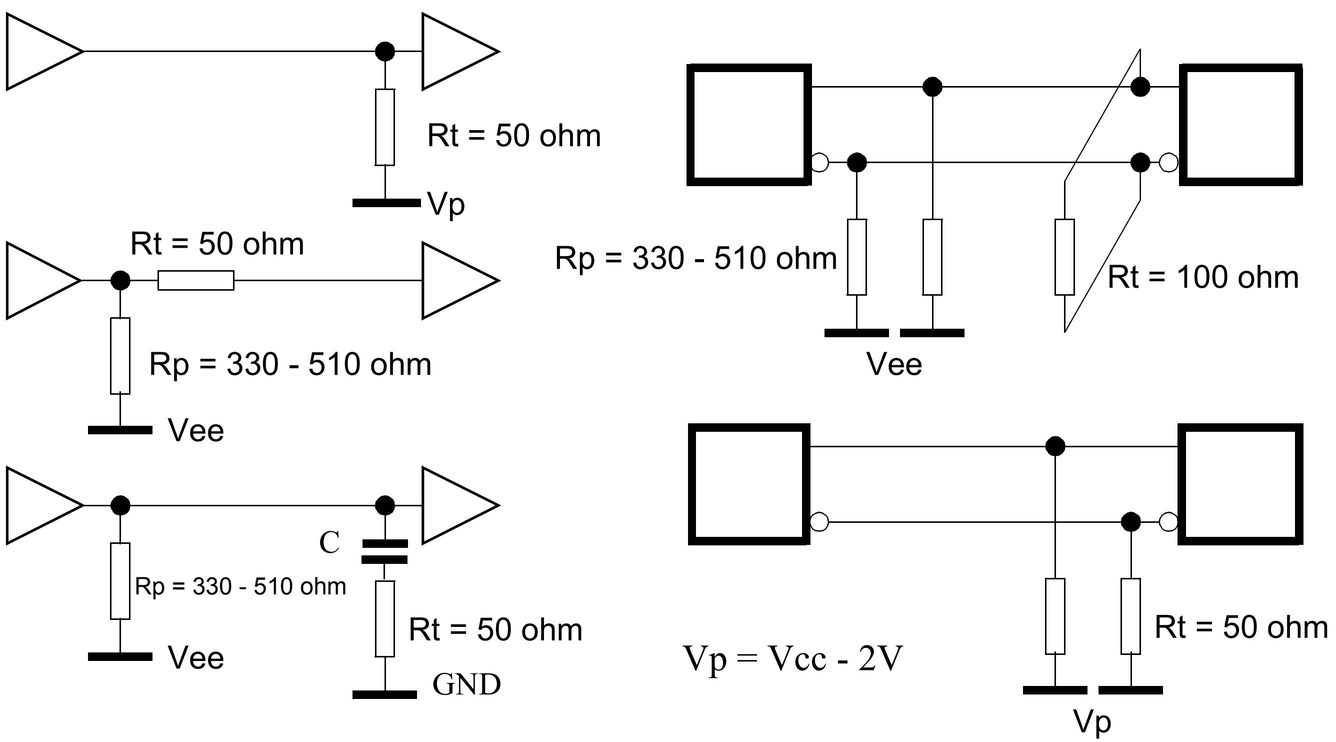
$$\beta = \sqrt{\frac{1}{2}\left[\sqrt{(R^2 + \omega^2 L^2)(G^2 + \omega^2 C^2)} - (RG - \omega^2 LC)\right]}$$


Dispositivi ECL e PECL
ECL
0V
-Vee
Vi
Vo
PECL
+Vcc
0V
Vi
Vo
Vcc
Vcco
Vbb
Vee
Vi
Vo
Rc
Vpo
0V
-Vbb
V
-Vee
Vh
Vl
t
ECL
+Vcc
Vbb
V
0V
Vh
Vl
t
PECL
$Vcc \cong 5V$
$Vee \cong -5V$
$Vbb = Vcc - 1{,}29V$
$Vh - Vl \cong 800mV$

Dispositivi ECL/PECL : strutture e polarizzazioni

Strutture single ended

Strutture differenziali



Dati trasmessi in modo seriale

Non codificati

NRZ

- Non e' possibile estrarre la temporizzazione.
- Il valor medio in continua puo' essere nullo, fluttuante, mediamente positivo o negativo.
- La sua trasmissione e' contemplabile solo per brevi distanze ove possa essere controllata la lunghezza delle linee che trasportano i dati e la temporizzazione (clock).

Codificati

AMI

CMI

Manchester

HDB3

- E' possibile estrarre la temporizzazione.
- Il valor medio in continua e' nullo

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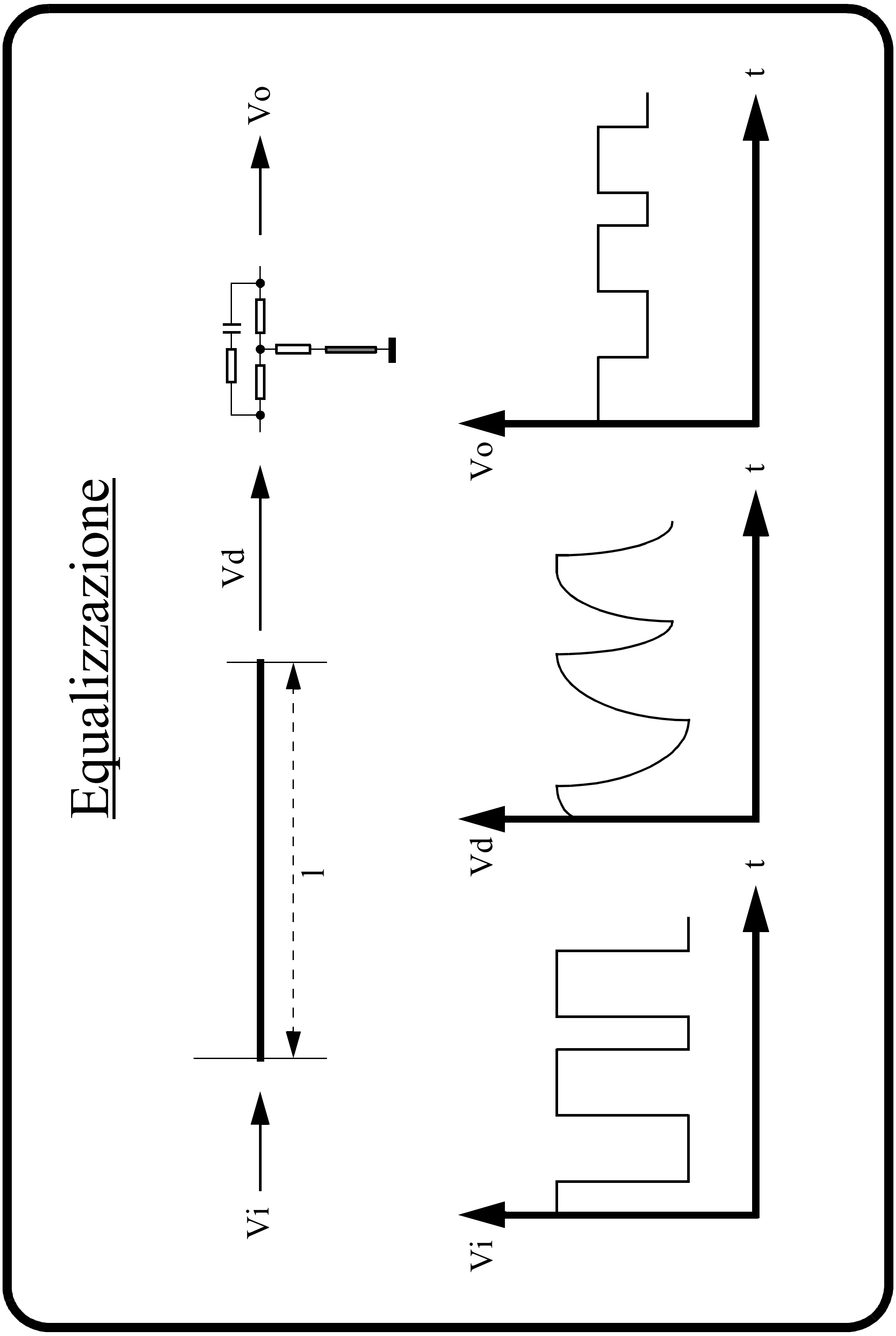

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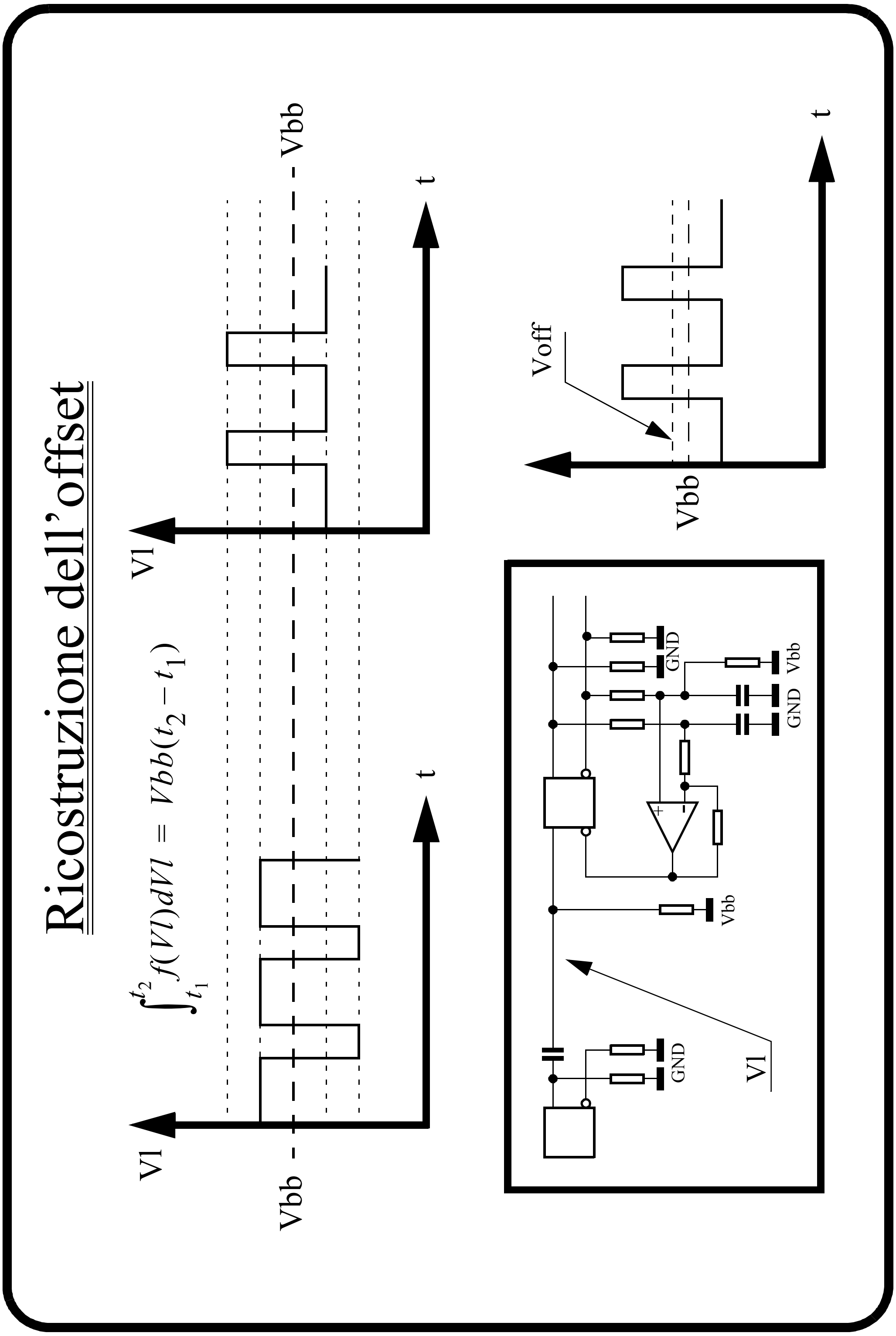
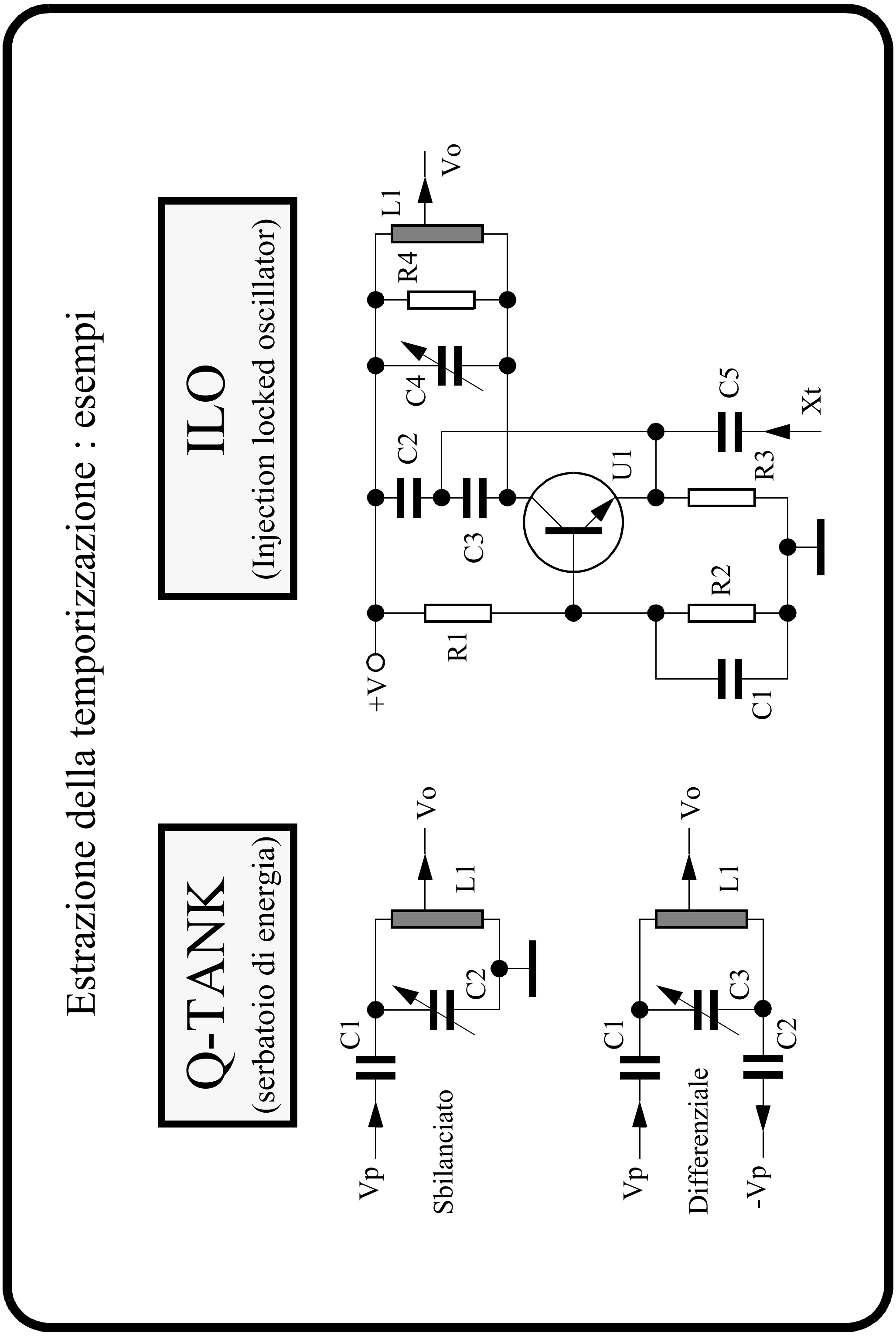


Estrazione della temporizzazione (clock)

PLL (Phase locked loop)	Q-TANK (serbatoio di energia)	ILO (Injection locked oscillator)
Attivo	Passivo	Attivo
Vantaggi: Riduzione del jitter Ingombro minimo	**Vantaggi:** Costo Assorbimento	**Vantaggi:** Costo Prestazioni
Svantaggi: Costo Flessibilita’	**Svantaggi:** Jitter elevato Flessibilita’	**Svantaggi:** Criticita’ di sviluppo Assorbimento


Estrazione della temporizzazione : esempi
Q-TANK
(serbatoio di energia)
Vp
C1
C2
L1
Vo
Sbilanciato
Vp
C1
C3
C2
L1
Vo
Differenziale
-Vp
ILO
(Injection locked oscillator)
+V
R1
C2
C3
C4
R4
L1
Vo
U1
R2
C1
R3
C5
Xt

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Document: Analog HW Design Seminar
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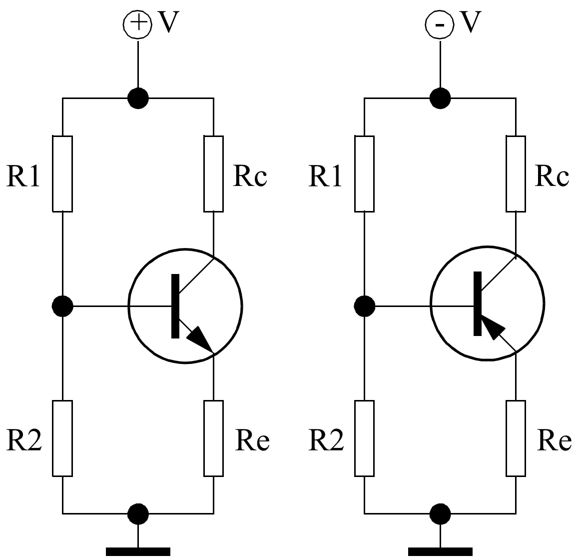
Date: 1995-04-14
Rev: A
File
Sheet: 31(42)

Transistor BJT : esempio di polarizzazione

DRIVER *Ic = Icmax/5*
PREAMP *Ic = Icmax/50*



$$V_c = \frac{V}{2} \qquad R_c = \frac{V_c}{I_c} \qquad R_e = \frac{R_c}{G_v}$$

$$\beta \cong h_{fe}$$

$$I_p \geq 7I_b \qquad I_b = \frac{I_c}{\beta}$$

$$R_p = \frac{V}{I_p} \qquad R_p = R_1 + R_2$$

$$V_b = V_e \pm V_{be}$$

$$R_2 = \frac{V_b}{I_p} \qquad R_1 = \frac{V - V_b}{I_p + I_b}$$

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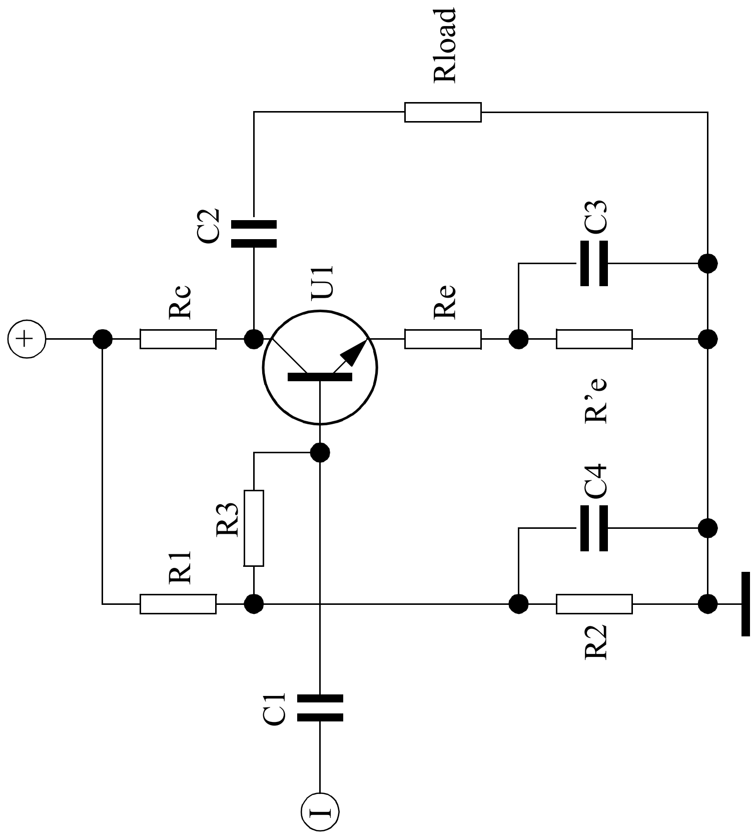
Amplificatore a transistor : esempio di architettura



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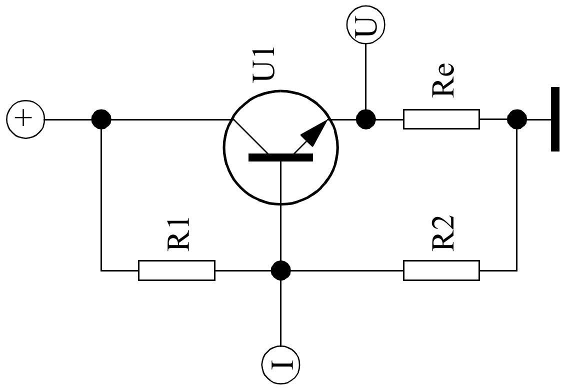
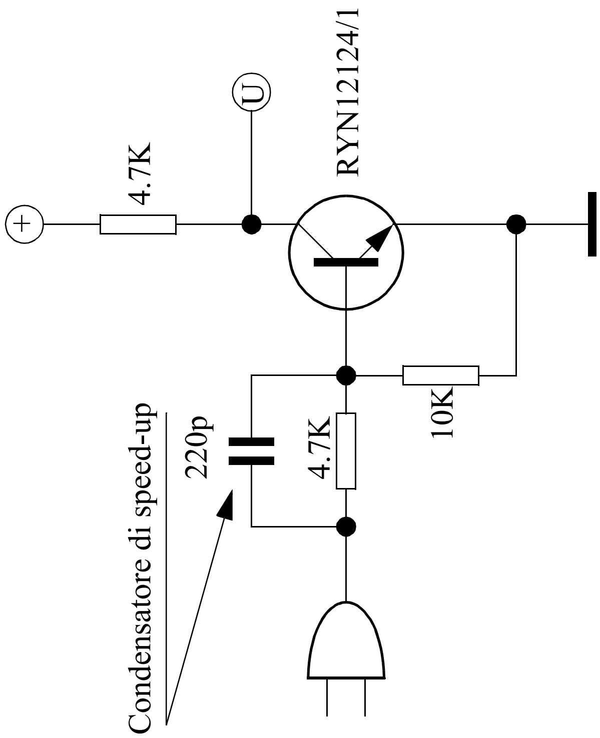
Amplificatore a transistor : voltage follower

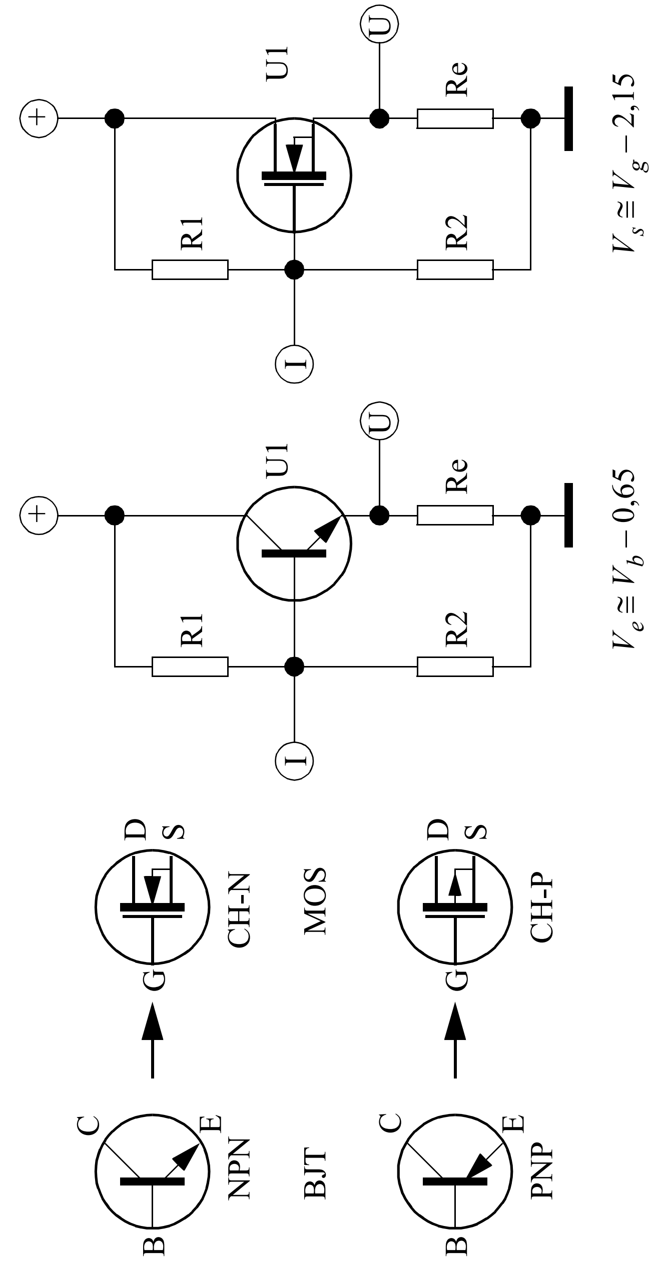
$G_v \cong 1$



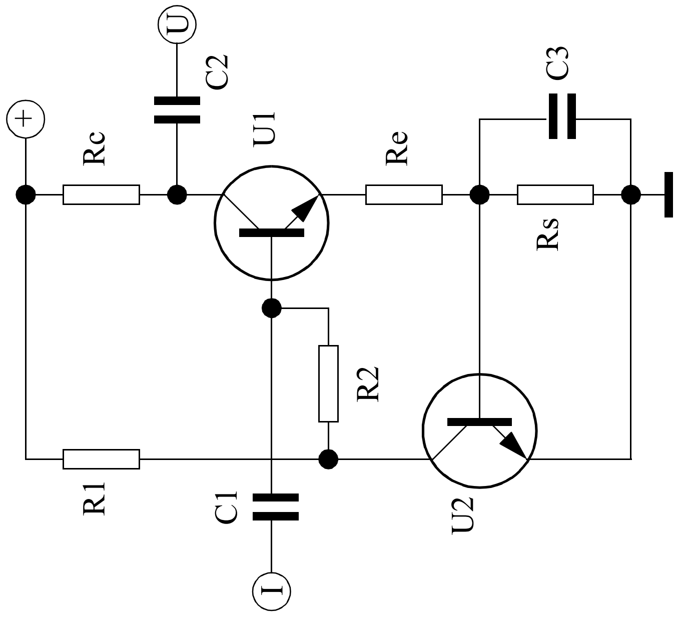
Invertitore di logica TTL/CMOS a transistor



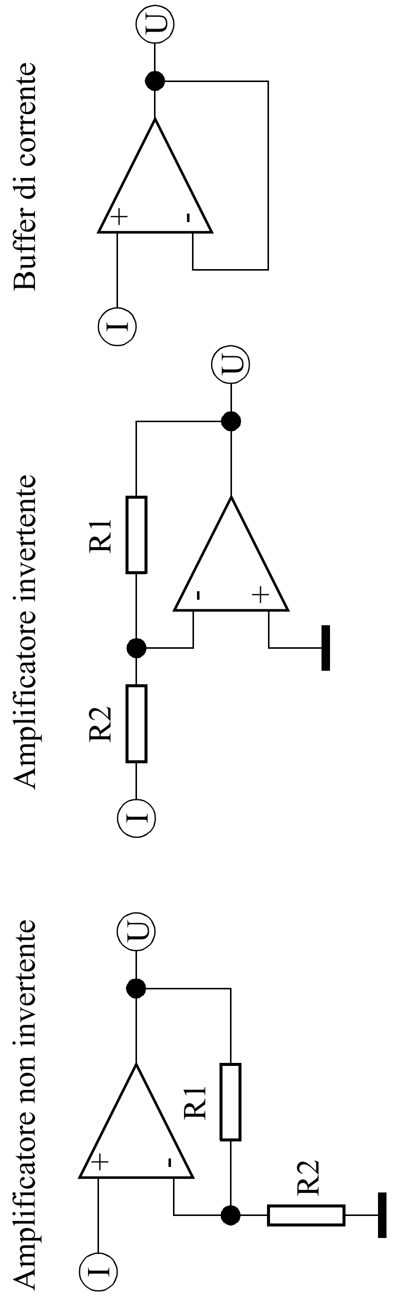
Transistors : differenze tra BJT e MOS



Amplificatore a transistor stabilizzato in corrente



Amplificatori operazionali : circuiti di base



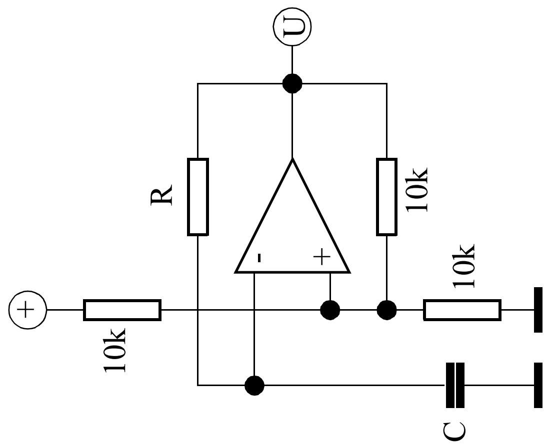
$$G_v = 1 + \frac{R_1}{R_2}$$

$$G_v = -\frac{R_1}{R_2}$$

$$G_v = 1$$

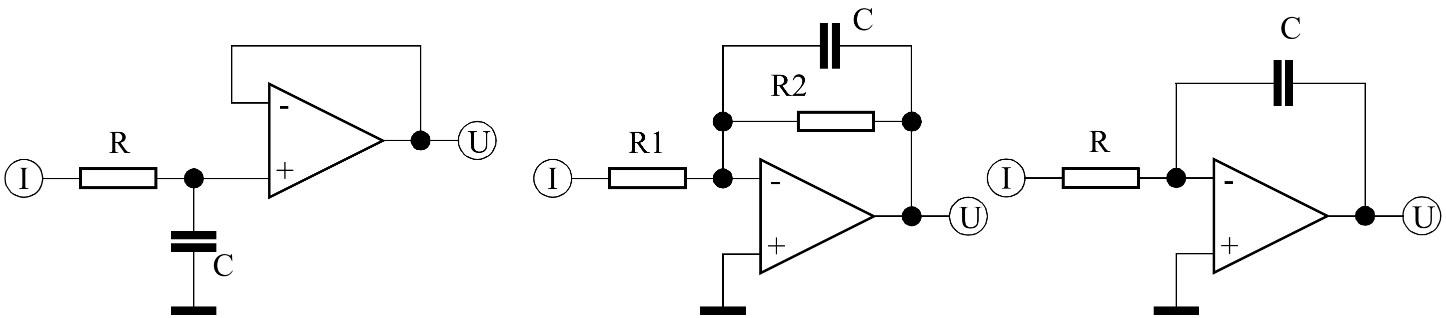
Amplificatori operazionali : oscillatore a rilassamento

$$f_o \cong 1{,}1RC$$



Amplificatori operazionali : filtri passa basso del primo ordine

Non invertente — Invertente — Integratore



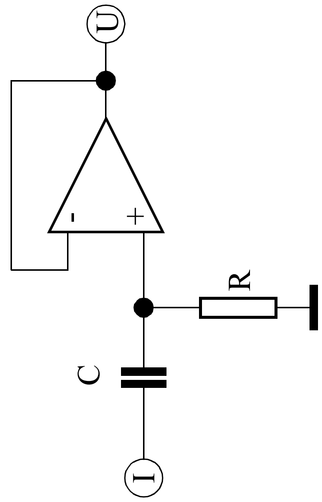
$$f_t = \frac{1}{2\pi RC}$$

$$f_t = \frac{1}{2\pi \langle R1 \parallel R2 \rangle C}$$

$$f_t = \frac{1}{2\pi RC}$$

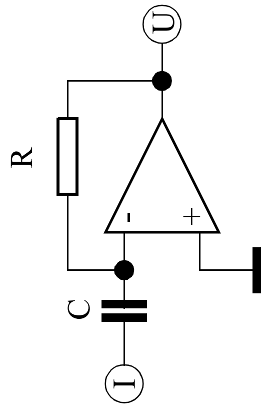
Amplificatori operazionali : filtri passa alto del primo ordine

Non invertente



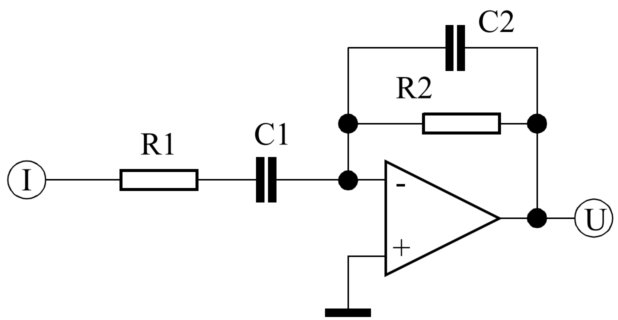
$$f_t = \frac{1}{2\pi RC}$$

Invertente
(derivatore)



$$f_t = \frac{1}{2\pi RC}$$

Amplificatori operazionali : filtro passa banda del primo ordine

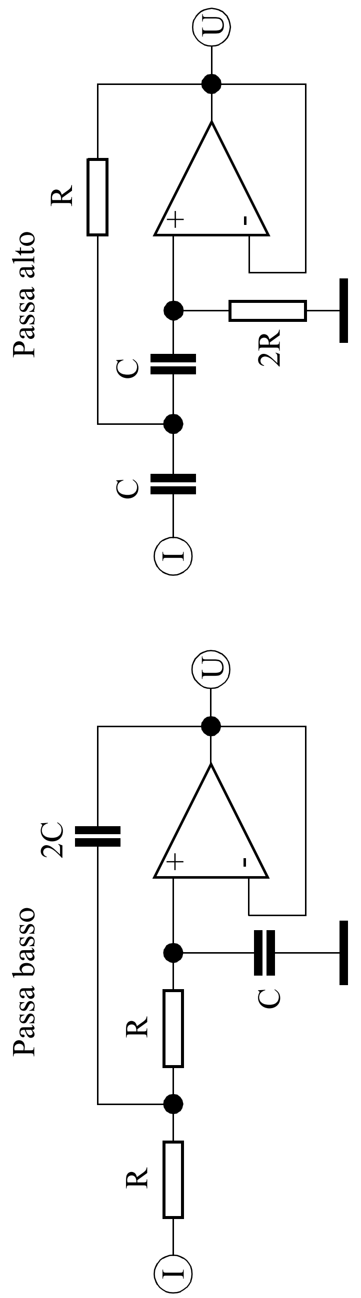


$$f_1 = \frac{1}{2\pi R_1 C_1}$$

$$f_2 = \frac{1}{2\pi R_2 C_2}$$

$$A_v = \frac{R_2}{R_1} \frac{1}{\sqrt{1 + (\omega R_2 C_2)^2}} \frac{1}{\sqrt{1 + (1/\omega R_1 C_1)^2}}$$

Amplificatori operazionali : filtri VCVS del secondo ordine



Passa basso: $f_t = \frac{1}{2\pi\sqrt{2C^2R^2}}$

Passa alto: $f_t = \frac{1}{2\pi\sqrt{2R^2C^2}}$