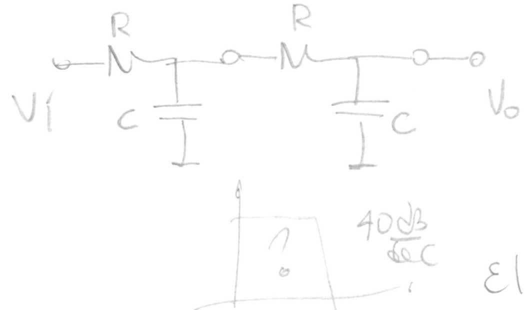
ACTIVE FILTERS

FILTROS PASSIVOS :

cai muito pouco ...

solução: cascata → duplico # pólos



... MAS entra o problema do loading nos estagios. Eles se "carregam"

posso:

← na saída gera ZOUT ≅ 0

BUFFER ISOLA estagios

posso colocar na entrada p/ dar $Z_i = \infty$

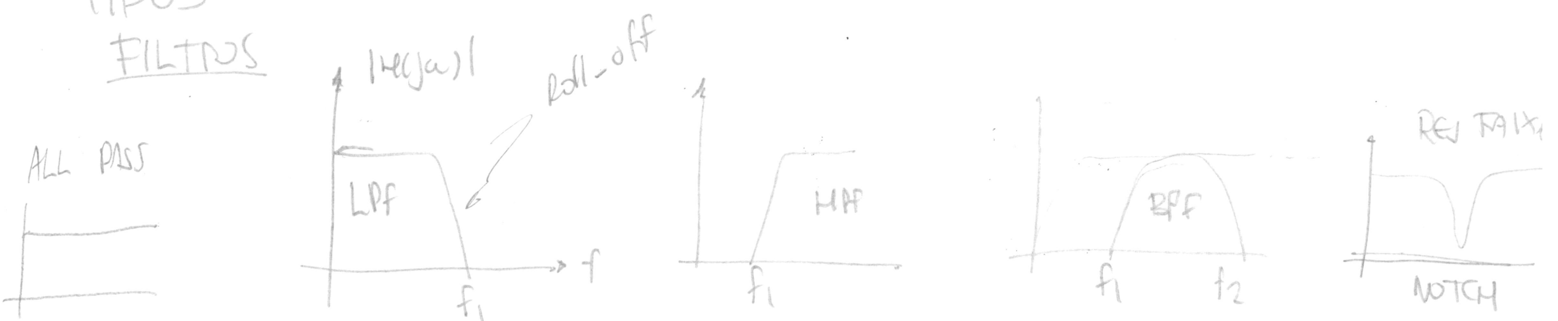
$Z_i = \infty$

ACTIVE FILTERS → usam opamps. Outra vantagem podem resultar em ganhos, Passivos não conseguem ir além do ∅ dB.

Ponto negativo → opamps ñ chegam freqs. altas (max ≈ 1 MHz)

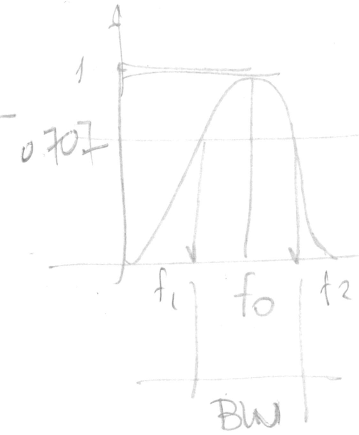
TIPOS FILTROS

ALL PASS



mexe só na fase (equalização)

Lembrando



BW = banda passagem

Linear: cai 0,707 do máximo

dB: cai −3 dB

Q = Fator qualidade = f_0/BW $\quad Q : 1/\alpha$

α: damping factor

Protótipos

observações → Trade off

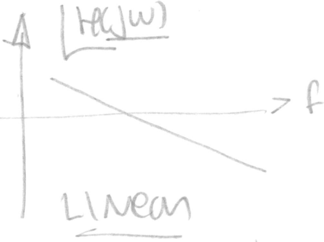
obs: mesmo nº pólos/zeros

Chebyshev → cai + rápido (Bom) mas pago o preço com ripple na banda de passagem. Phase not flat. (>20 dB/dec)

Butterworth → suave, sem ripple, mas cai devagar. Phase not flat. (20 dB/dec)

Bessel: Linear phase charact., sem overshoot/undershoot. Não distorce shape Dt!

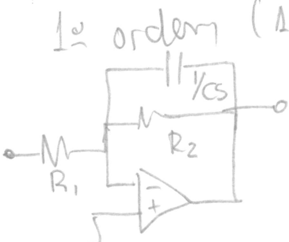
Linear phase → distortionless



pois daí $\tau_g = -\frac{\partial \phi}{\partial \omega} = cte$!

tabelas contém coeficientes p/ cada filtro Chebyshev ... N

LPF 1ª ordem (1 polo)

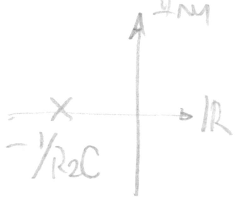


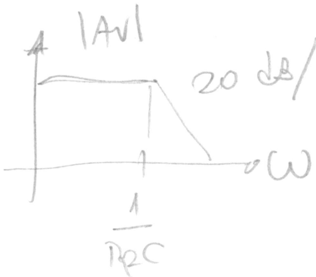
=

$Zp = R_2 // 1/CS = R_2/(R_2CS+1)$

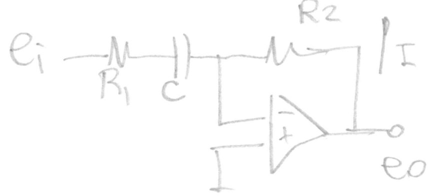
$I = \frac{e_o}{Zp} = -\frac{e_i}{R_1} \rightarrow \frac{e_o}{e_i} = H(s) = \frac{-1/R_1C}{\left[s + \frac{1}{R_2C}\right]}$

polo simples: $-1/R_2C$



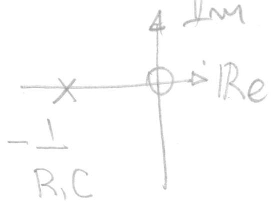


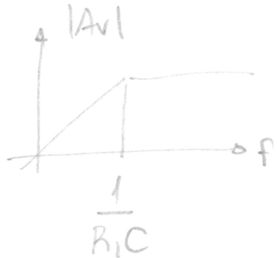
HPF 1ª ordem



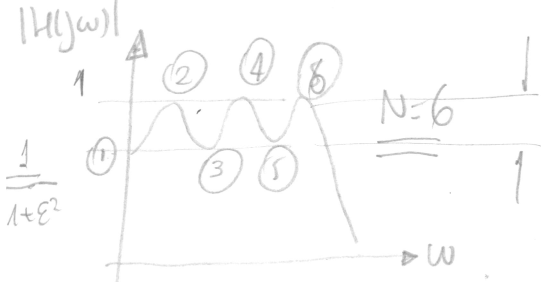
$$Z_S = R_1 + (1/CS) = \frac{R_1CS+1}{CS} \qquad I = \frac{e_o}{R_2} = -\frac{e_I}{Z_S}$$

$$\frac{e_o}{e_i}(S) = H(S) = -\frac{R_2}{Z_S} = -\frac{R_2}{R_1}\cdot\frac{S}{S+\frac{1}{R_1C}}$$





Chebyshev – melhor solução em termos tamanho (# polos) vs. rolloff (pago preço resposta D+ no shape contudo)



N=6 ripple banda passagem

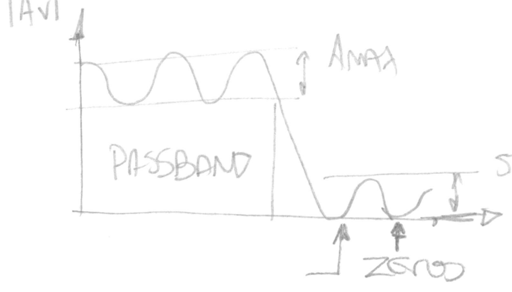
typ → 1 dB
3 dB
5 dB

quanto menor ripple melhor mas filtro fica + complicado

$$|T(j\omega)| = \frac{1}{\sqrt{1+\varepsilon^2\cos^2[N\,a\cos(\omega/\omega_p)]}}$$

$\omega<\omega_p$ cos
$\omega>\omega_p$ cosh

protótipo: encaixa ckt nessa resposta

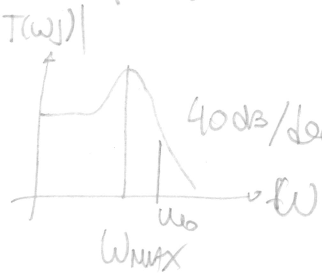


quanto + polos (N) mais rápido "cai" mas mais complexo é o filtro

FILTROS 2º ordem

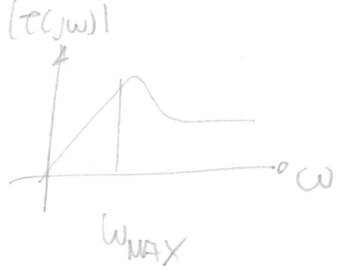
$$T(s) = \frac{a_2 s^2 + a_1 s + a_0}{s^2 + \left(\frac{\omega_0}{Q}\right) s + \omega_0^2}$$

LPF → $T(s) = \dfrac{a_0}{s^2 + s\frac{\omega_0}{Q} + \omega_0^2}$



zero = ∄
polos: 2 complexos conjugados

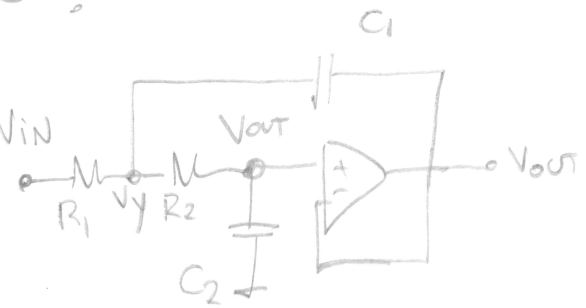
HPF $T(s) = \dfrac{a_2 s^2}{s^2 + s\frac{\omega_0}{Q} + \omega_0^2}$



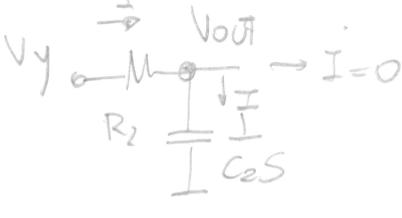
2 zeros origem
2 polos complexos conjugados

FILTROS PASSIVOS → 2º ordem precisa L
vantagem opamp active filter → SINTETIZO efeito L com R C !

SALLEN KEY:
(LPF)

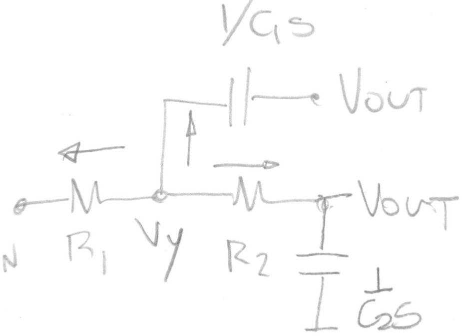


opamp → buffer
Logo Vout sobre o capacitor



$$\frac{V_y - V_{OUT}}{R_2} = \frac{V_{OUT}}{1/C_2 s} \rightarrow V_y = V_{OUT}\left[R_2 C_2 s + 1\right]$$

Analisando nó Vy:



$$\frac{V_y - V_{IN}}{R_1} + V_{OUT} C_2 s + (V_y - V_{OUT}) C_1 s = 0$$

+ facil que usar $V_y - \dfrac{V_{OUT}}{R_2}$!
corrente é a mesma...!

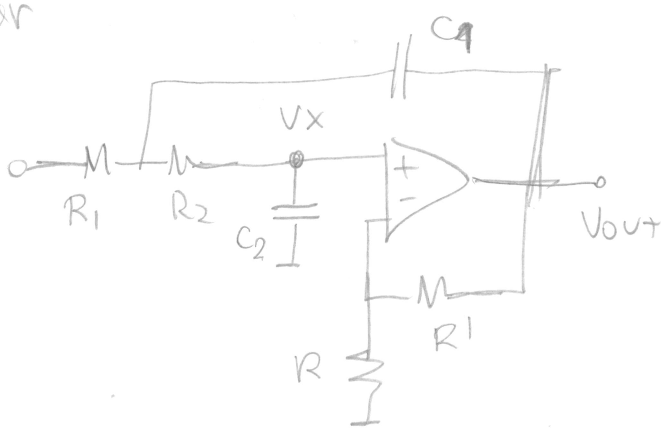
$$\frac{V_{OUT}(R_2C_2S+1)-V_{IN}}{R_1} + V_{OUT}C_2S + \left[V_{OUT}(R_2C_2S\cancel{+1)}\cancel{-V_{OUT}}\right]C_1S = 0$$

Resolvo e agrupo os termos:

$$\frac{V_{OUT}}{V_{IN}}(s) = H(s) = \frac{1}{R_1R_2C_1C_2S^2+(R_1+R_2)C_2S+1}$$

2º ordem <u>SEM</u> indutores

Posso inclusive adicionar ganho!

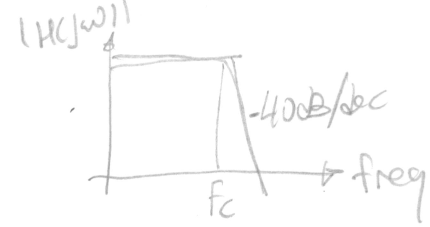


agora:

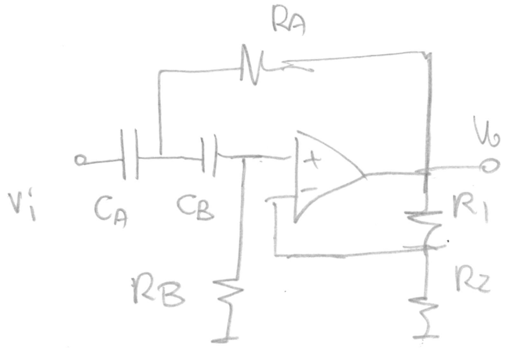
configuração amplificadora não inversora: $V_{OUT} = V_x\left[1+\frac{R'}{R}\right]$

$$f_c = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}$$ cutoff freq

Roll-off: 40dB/dec



SALLENKEY HPF

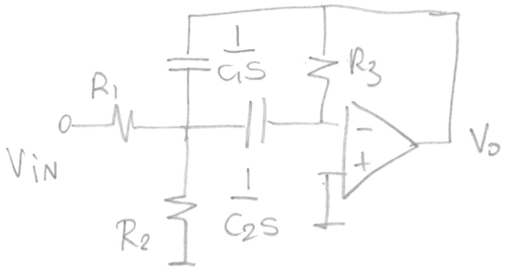


$$\frac{V_o}{V_i} = \frac{S^2[R_AR_BC_AC_B]\left[1+\frac{R_1}{R_2}\right]}{1+S\left[R_A(C_A+C_B)-\frac{R_1}{R_2}R_BC_B\right] + S^2[R_AR_BC_AC_B]}$$

$$\omega_0 = \frac{1}{\sqrt{R_AR_BC_AC_B}}$$

BPF

MULTIPLE FEEDBACK FILTER



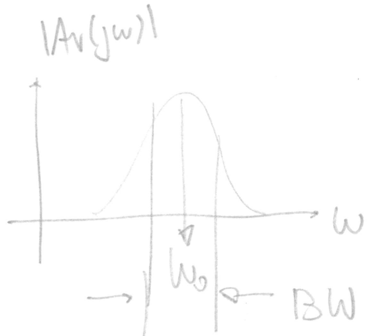
$$\frac{V_o}{V_{IN}}(s) = \frac{-R_2 R_3 C_2 s}{R_1 R_2 R_3 C_1 C_2 s^2 + R_1 R_2 (C_1 + C_2) s + (R_1 + R_2)}$$

passando p/ formato

$$\frac{-K \omega_0 s}{s^2 + \alpha \omega_0 s + \omega_0^2} \rightarrow \frac{-\frac{1}{R_1 C_1} s}{s^2 + \frac{C_1 + C_2}{R_3 C_1 C_2} s + \frac{R_1 + R_2}{R_1 R_2 R_3 C_1 C_2}}$$

$$\omega_0 = \frac{1}{C}\sqrt{\frac{1 + R_1/R_2}{R_1 R_3}} \qquad Q = \frac{1}{2}\sqrt{\frac{R_3}{R_1}}\sqrt{\left(1 + \frac{R_1}{R_2}\right)}$$

$$BW = 2/R_3 C$$



Referências

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Hernando L. F. Conque, Analog Electronics Applications, ch. 20 "Filters"

Sedra Smith, Microelectronics, 7th ed, ch 17, "Filters & Tuned Amplifiers"