UNIVERSIDADE TECNOLÓGICA FEDERAL DO PARANÁ

Amplificadores operacionais - filtros ativos

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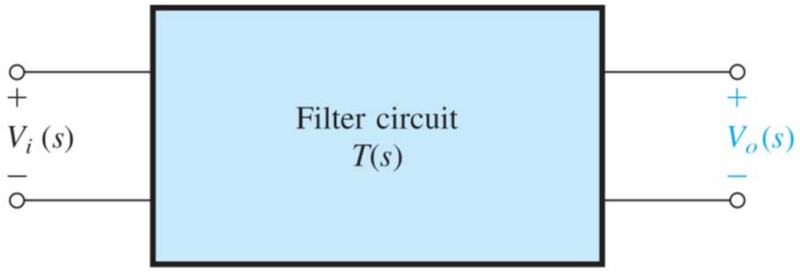
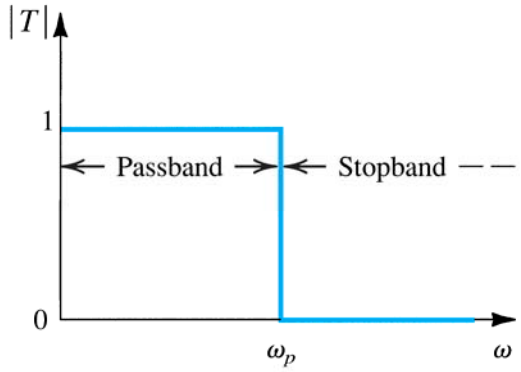
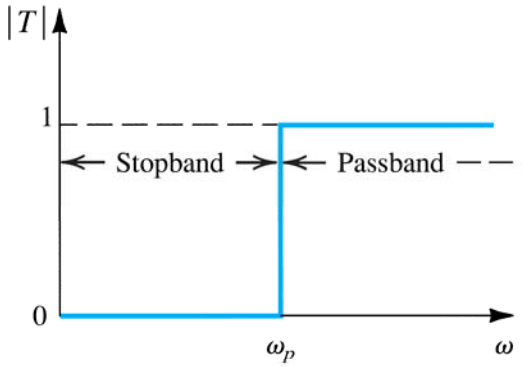
Tipos de filtros ideias



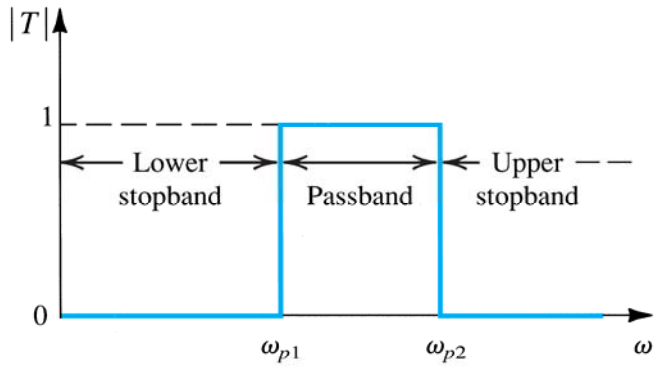
$T(s)=V_o(s)/V_i(s)$



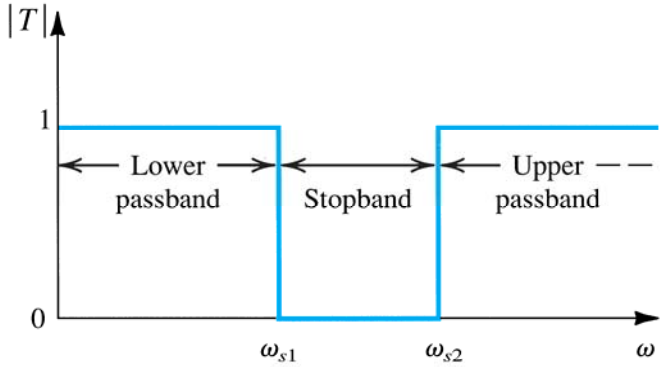
(a) Low-pass (LP)



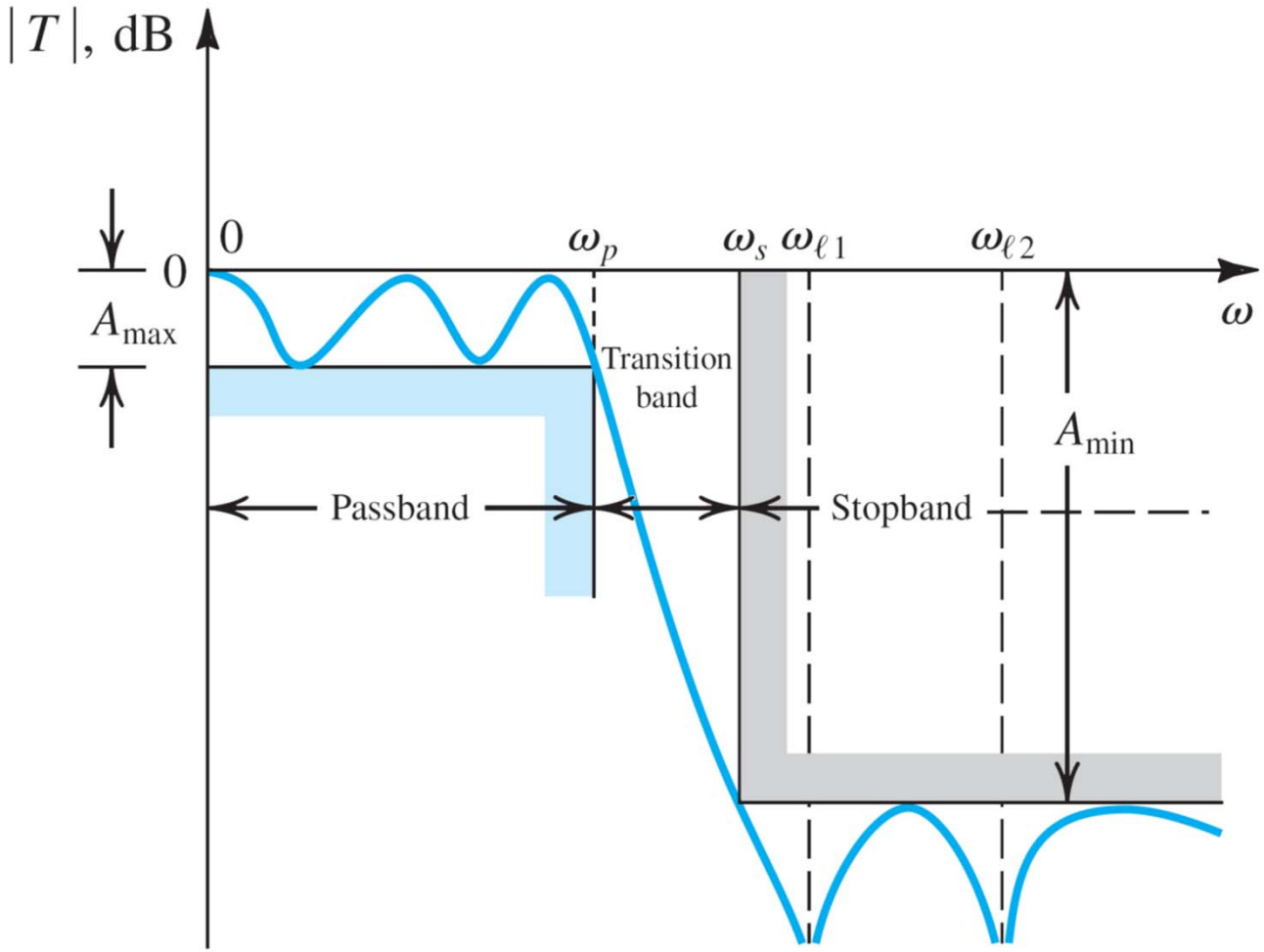
(b) High-pass (HP)



(c) Bandpass (BP)



(d) Bandstop (BS)

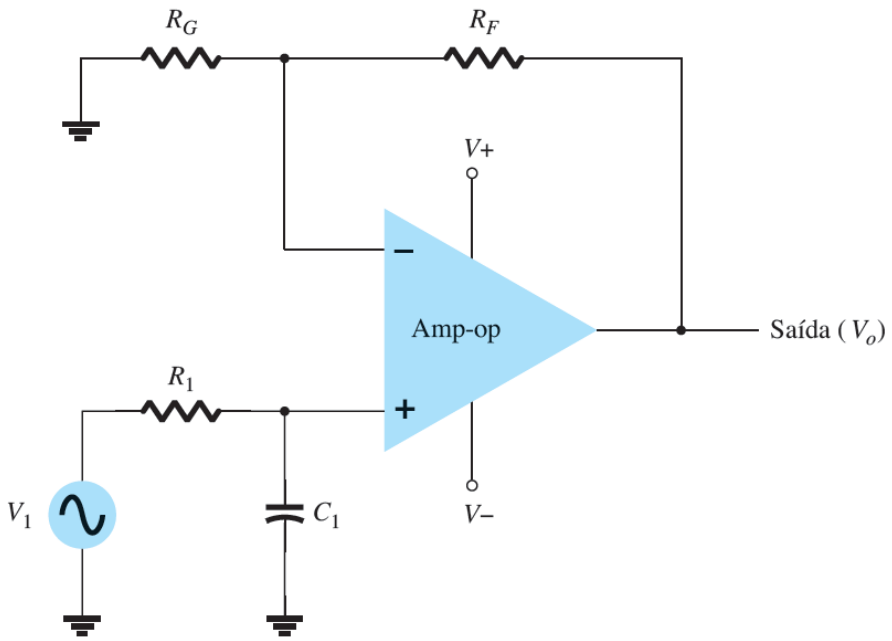

|T|, dB
0
0
A_{max}
ω_p
ω_s $\omega_{\ell 1}$
$\omega_{\ell 2}$
ω
Transition band
A_{min}
Passband
Stopband

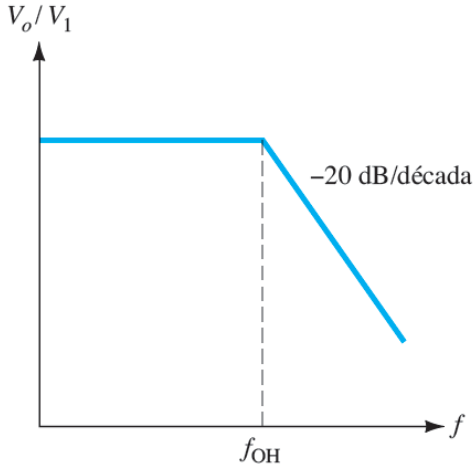
Filtros ativos

• Adicionar capacitores aos circuitos amp-op fornece controle externo das frequências de corte. O filtro ativo do amp-op tem ganho de frequências de corte controlável.

- **Filto passa-baixas**
- **Filtro passa-altas**
- **Filtro passa-banda ou passa-faixa**
- **Filtro rejeita-banda ou rejeita-faixa**

Filtro passa-baixas, de primeira ordem



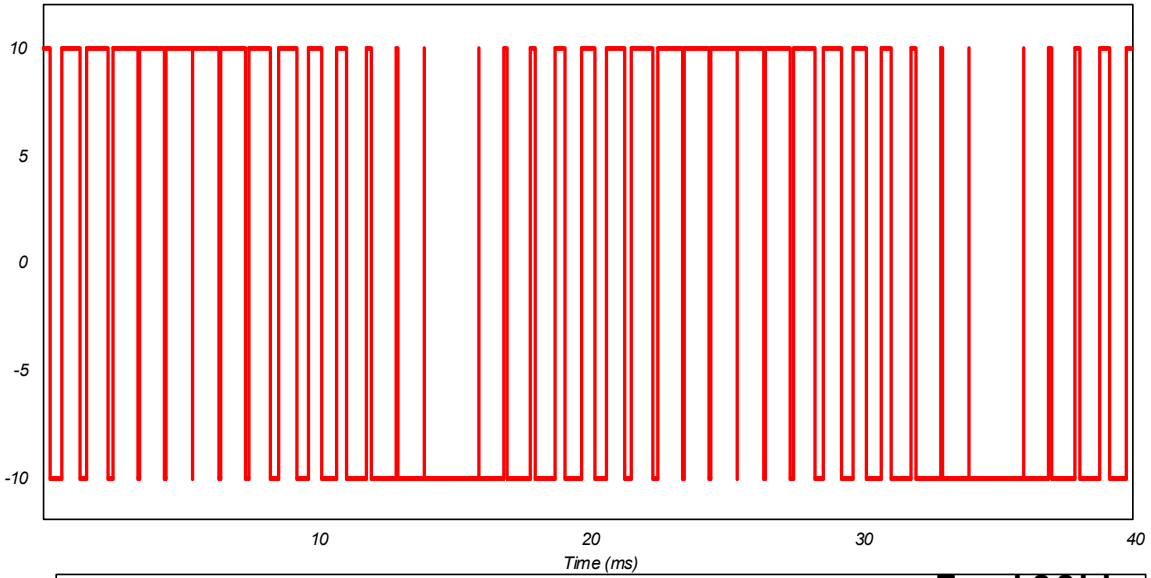


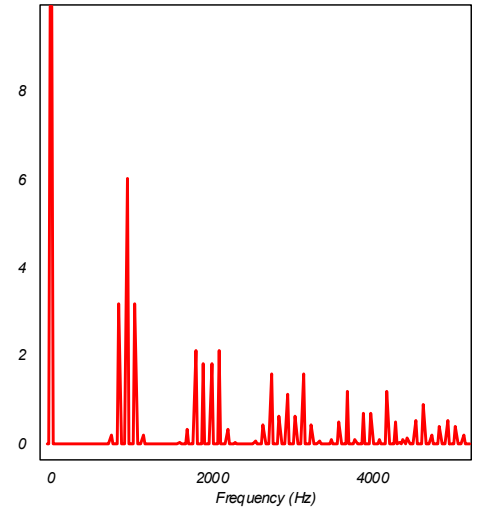
• A frequência de corte superior e o ganho de tensão são dados por:

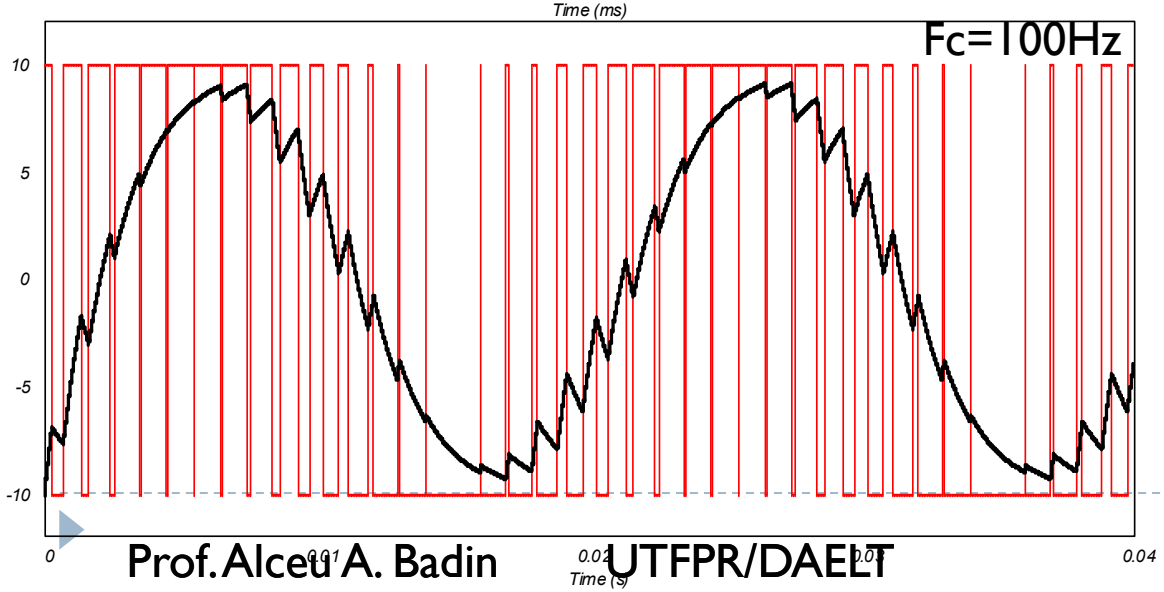
$$f_{OH} = \frac{1}{2\pi R_1 C_1}$$

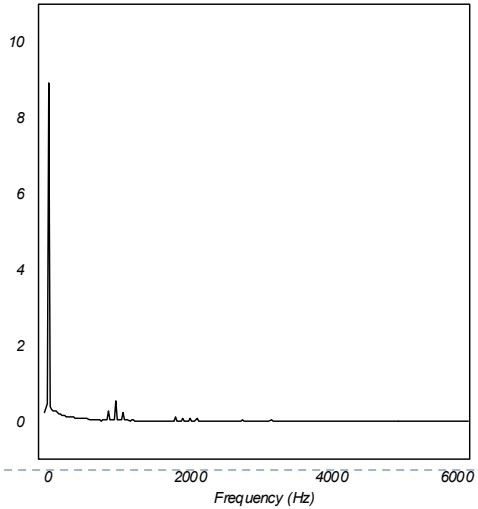
$$A_v = 1 + \frac{R_f}{R_1}$$

Filtro passa-baixas, de primeira ordem



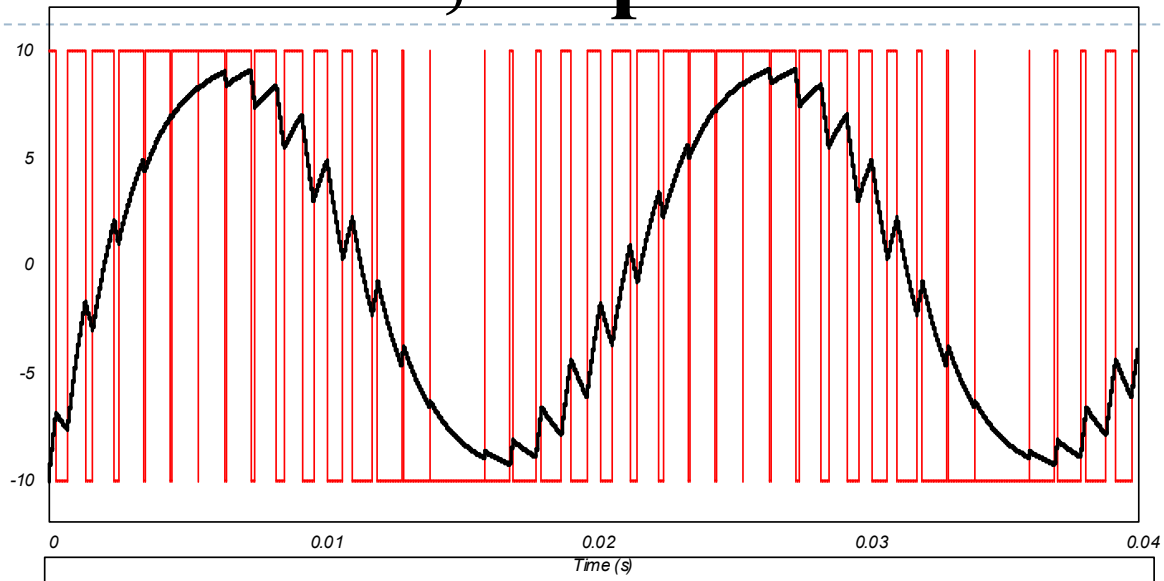






Filtro passa-baixas, de primeira ordem

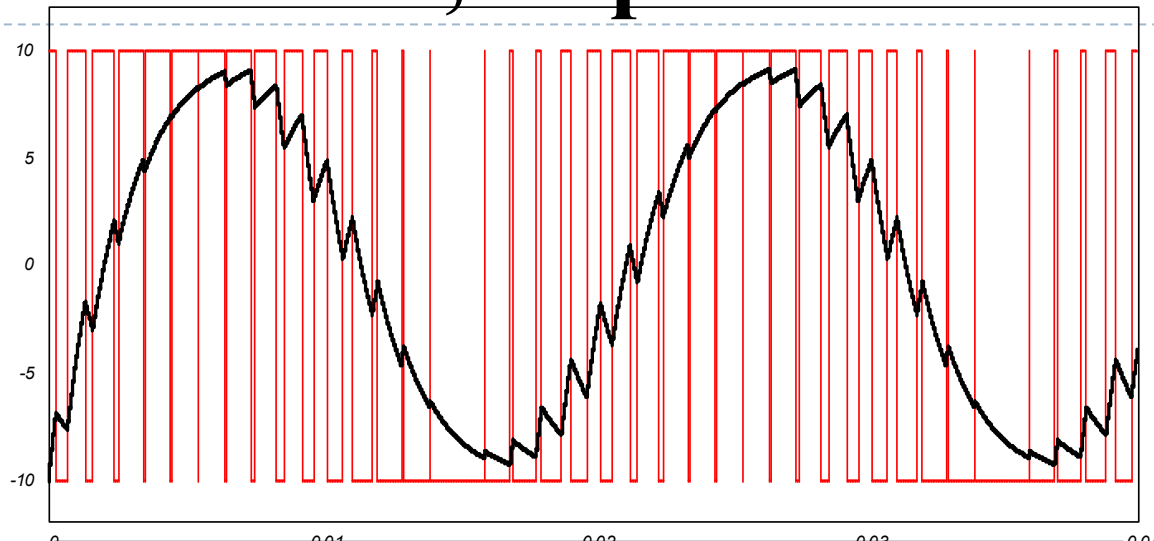
f_c=100Hz



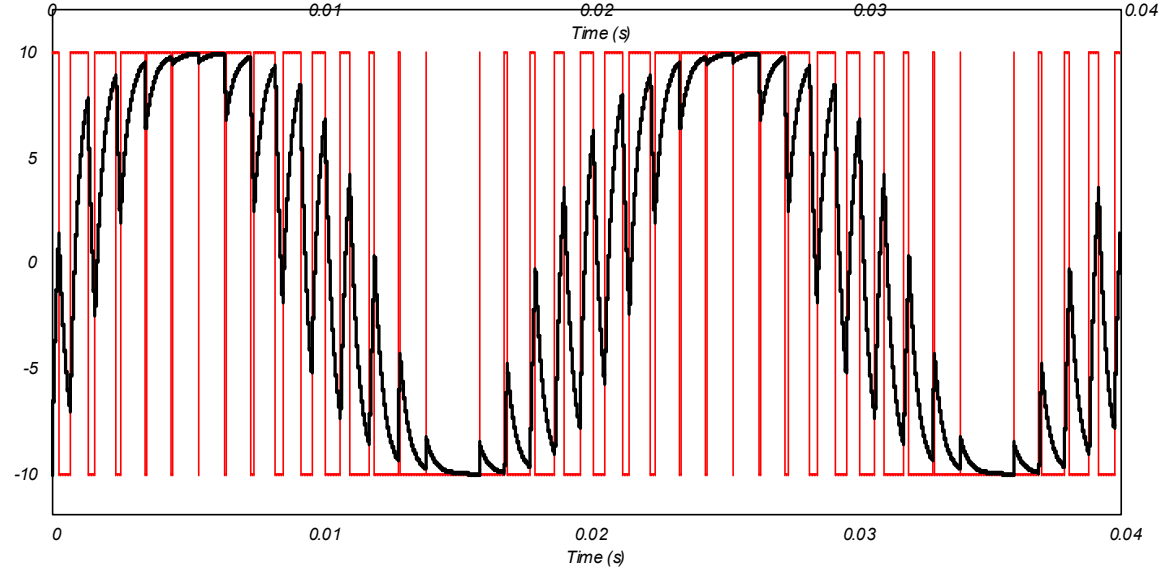
f_c=50Hz

Filtro passa-baixas, de primeira ordem

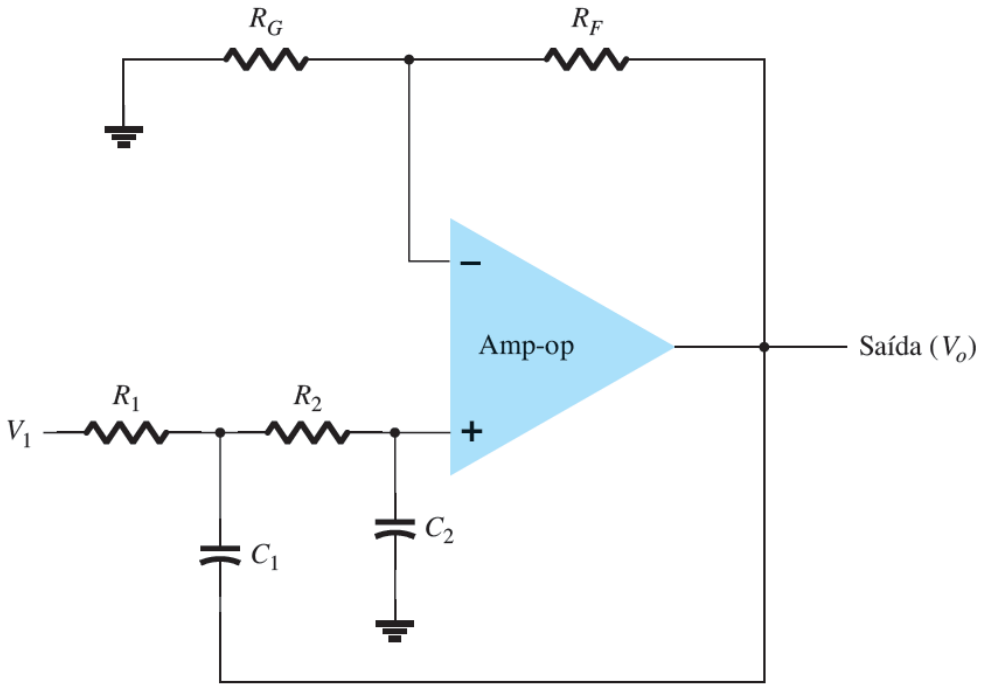
f_c=100Hz



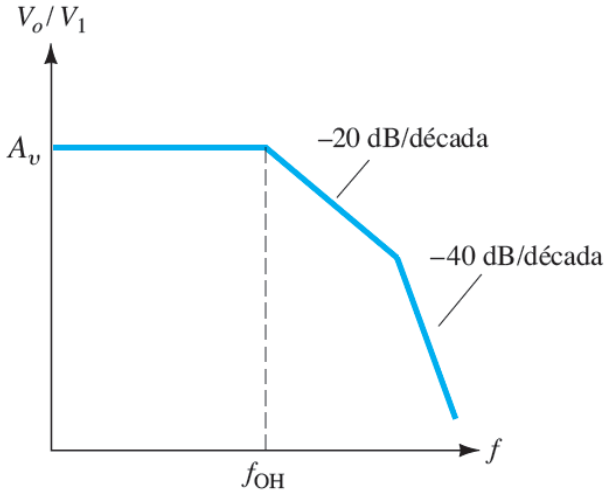
f_c=500Hz



Filtro passa-baixas, segunda ordem



(a)

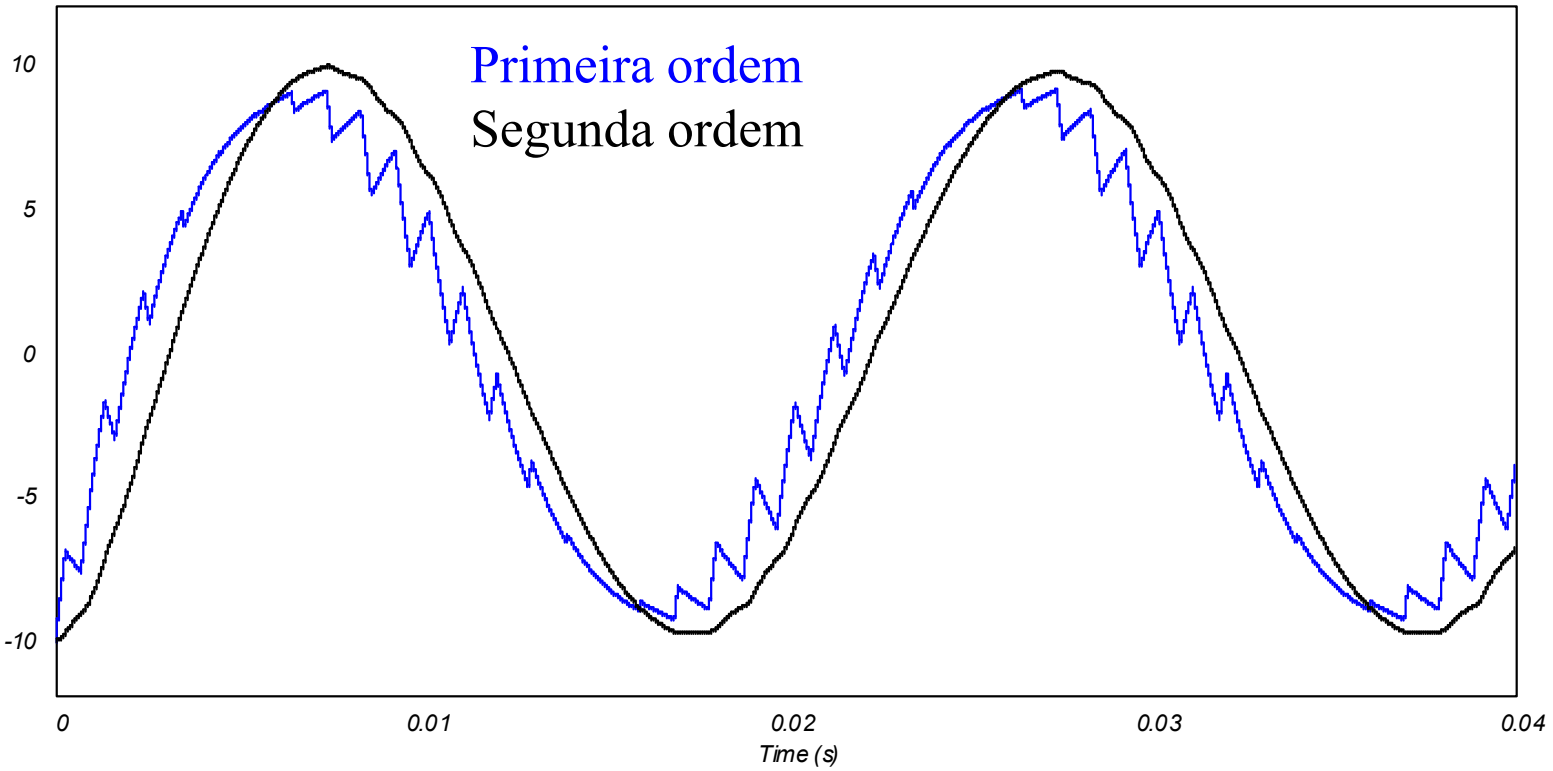


(b)

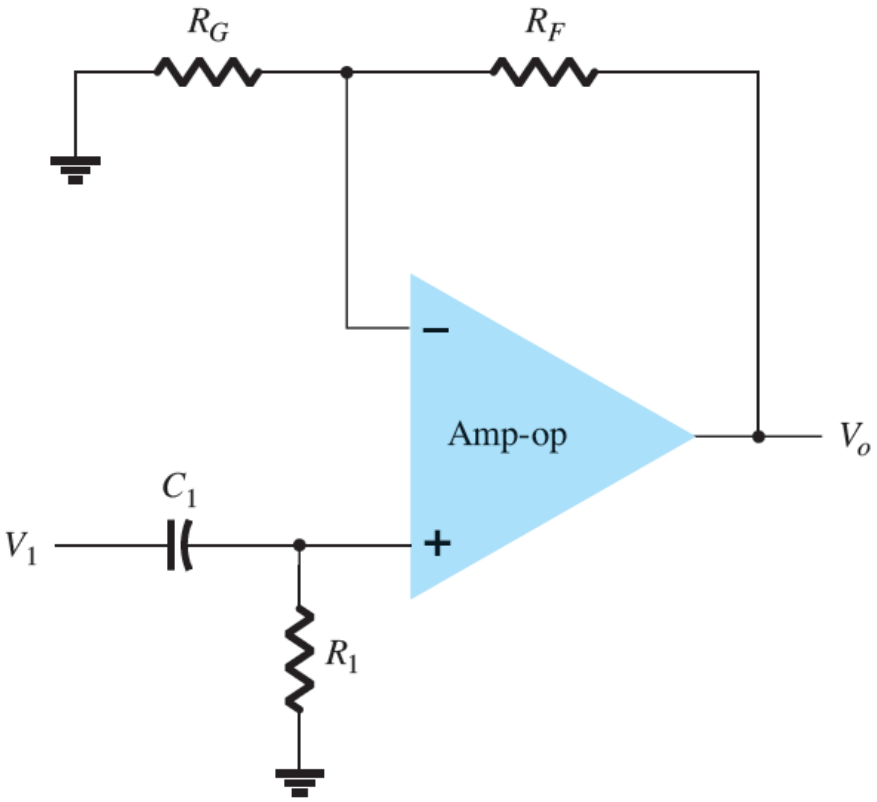
- O roll-off pode ser maior se adicionadas mais redes RC.

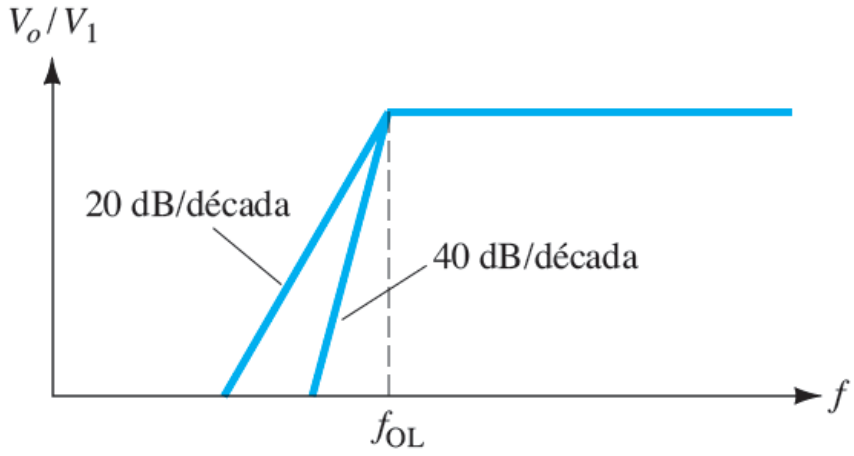
Filtro passa-baixas, segunda ordem

f_c=100Hz



Filtro passa-altas





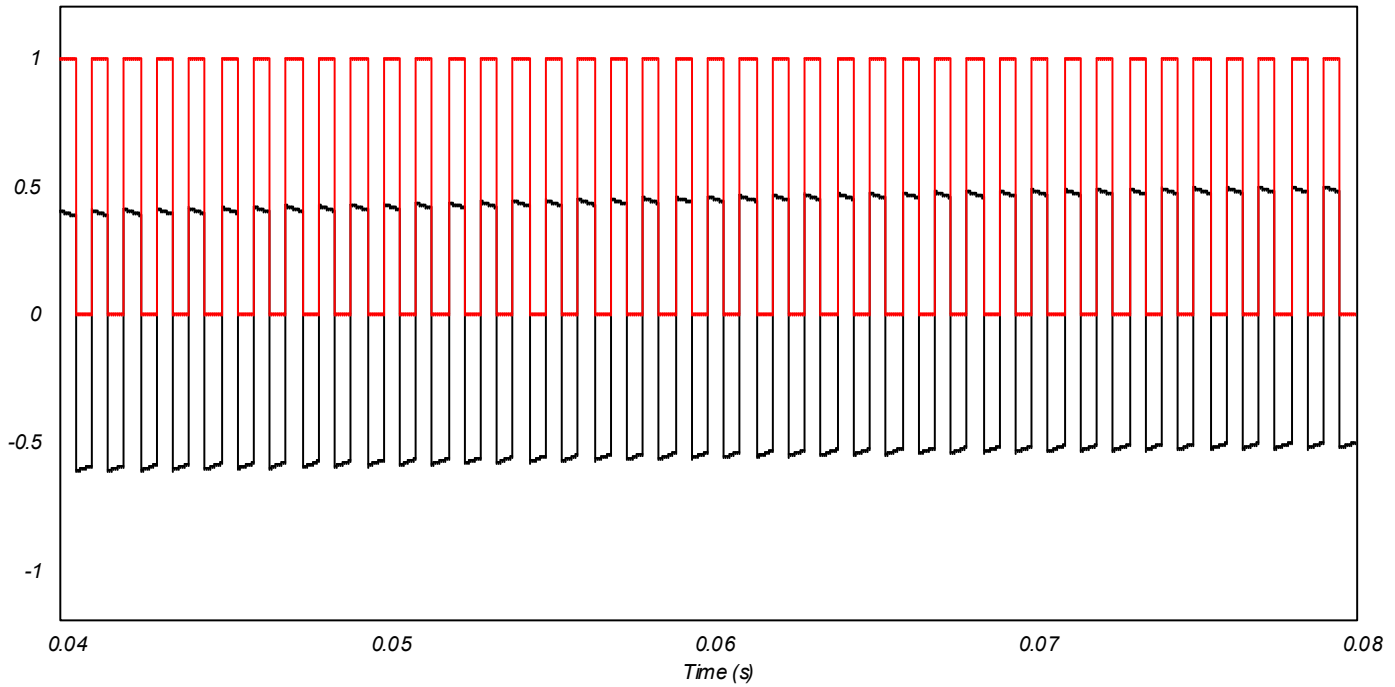
- A frequência de corte é determinada por:

$$f_{OL} = \frac{1}{2\pi R_1 C_1}$$

Filtro passa-altas

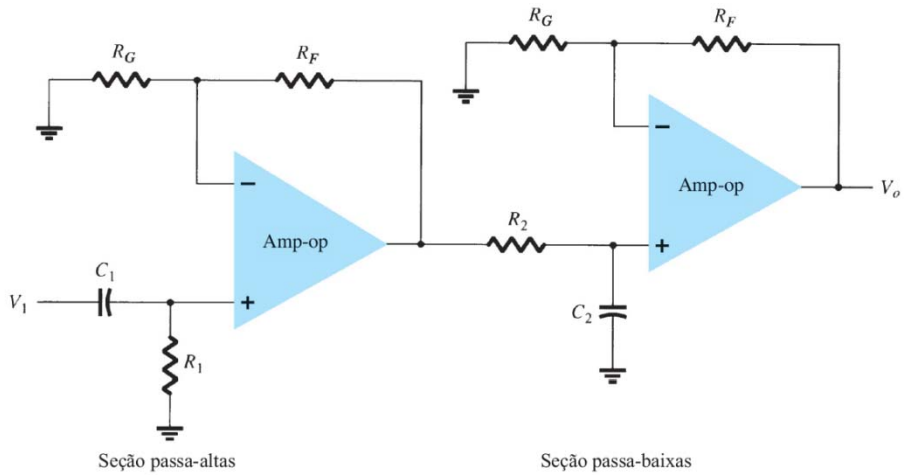
Sinal entrada

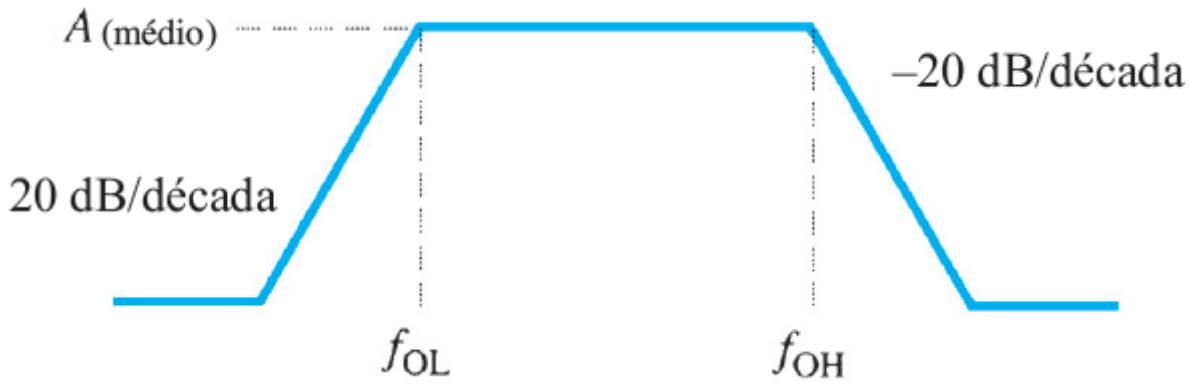
f_c=100Hz Sinal de saída

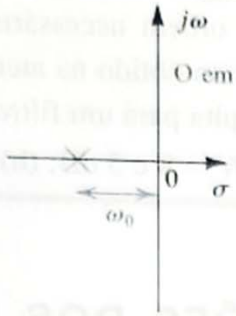
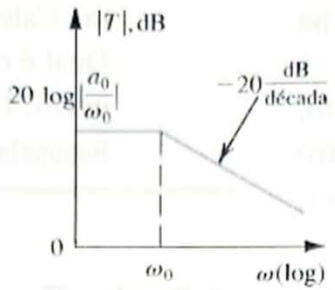
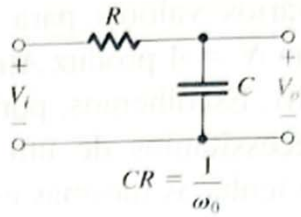
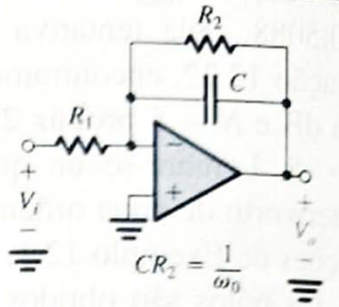
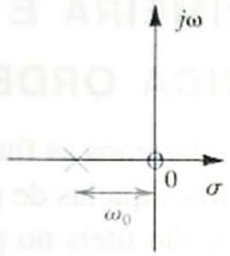
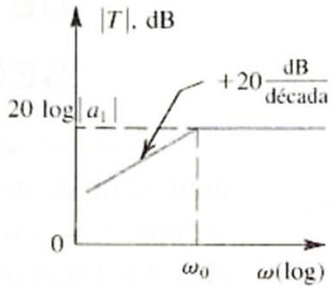
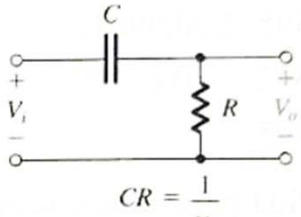
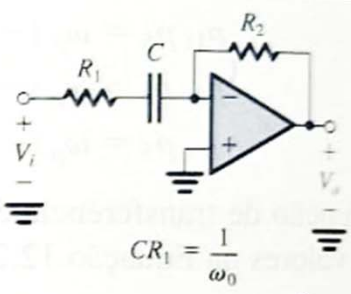
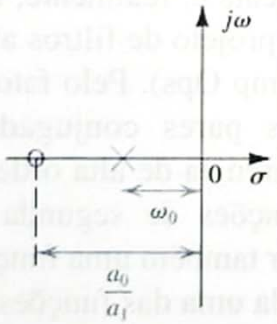
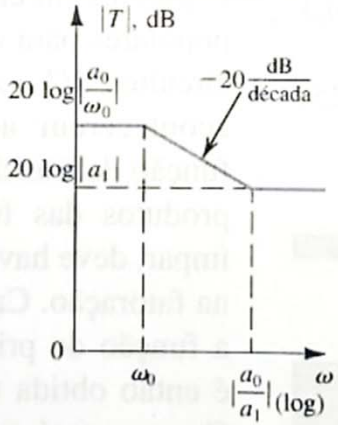
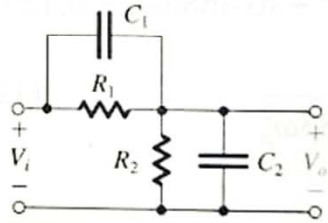
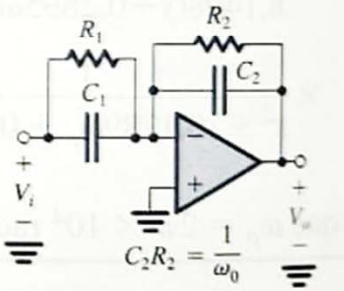


Filtro passa-banda

• Há duas frequências de corte: a superior e a inferior.





Tipo de filtro e $T(s)$	Singularidades no plano s	Curvas de bode para $\lvert T\rvert$	Implementação passiva	Implementação RC-amp op
(a) Passa-baixas (PB) $T(s) = \frac{a_0}{s + \omega_0}$			 $CR = \frac{1}{\omega_0}$ Ganho $cc = 1$	 $CR_2 = \frac{1}{\omega_0}$ Ganho $cc = -\frac{R_2}{R_1}$
(b) Passa-altas (PA) $T(s) = \frac{a_1 s}{s + \omega_0}$			 $CR = \frac{1}{\omega_0}$ Ganho em AF = 1	 $CR_1 = \frac{1}{\omega_0}$ Ganho em AF = $-\frac{R_2}{R_1}$
(c) Genérico $T(s) = \frac{a_1 s + a_0}{s + \omega_0}$			 $(C_1 + C_2)(R_1 // R_2) = \frac{1}{\omega_0}$ $C_1 R_1 = \frac{a_1}{a_0}$ Ganho $cc = \frac{R_2}{R_1 + R_2}$ Ganho em AF = $\frac{C_1}{C_1 + C_2}$	 $C_2 R_2 = \frac{1}{\omega_0}$ $C_1 R_1 = \frac{a_1}{a_0}$ Ganho $cc = -\frac{R_2}{R_1}$ Ganho em AF = $-\frac{C_1}{C_2}$

Parâmetros de frequência de um ampop

• Um amp-op é amplificador com ampla largura de banda.
•Os fatores seguintes afetam a largura da banda do amp-op:

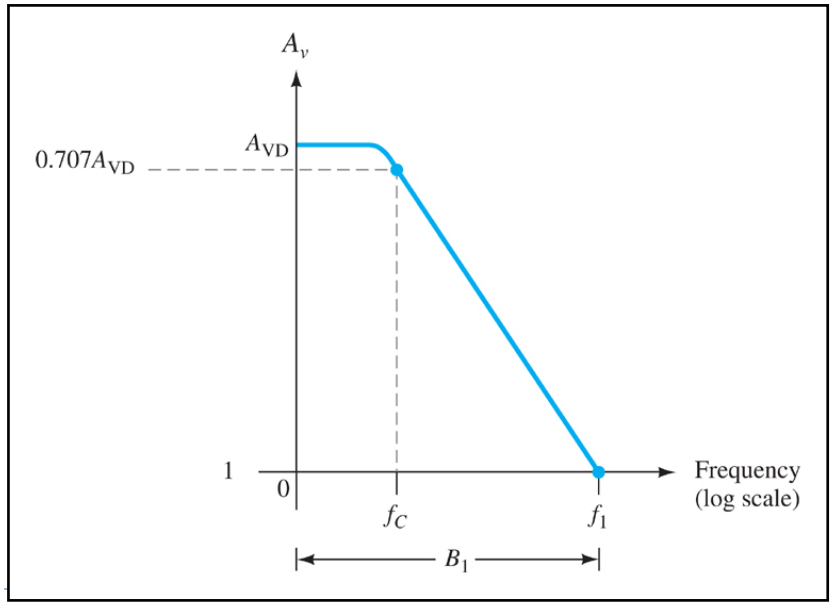
- **Ganho**

- **Taxa de inclinação**

Ganho e largura de banda

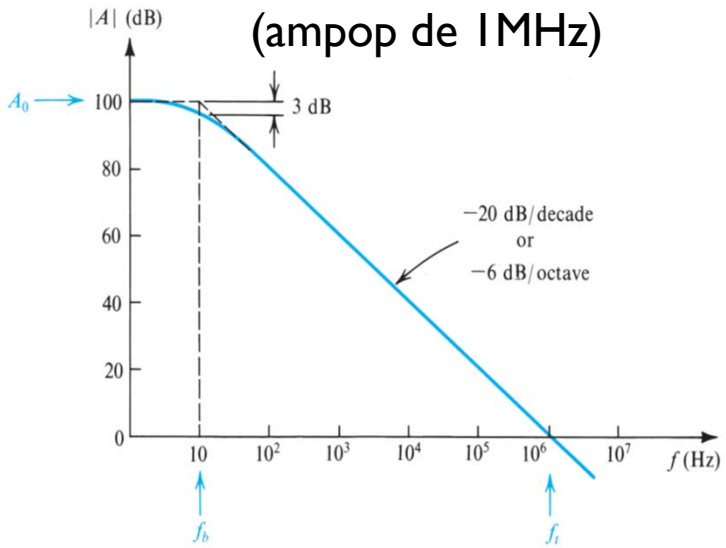
• A alta resposta em frequência do amp-op é limitada por seus circuitos internos. O gráfico mostrado é para um ganho de malha aberta (A_{OL} ou A_{VD}). Isso significa que o amp-op está operando com o mais alto ganho possível sem resistor com realimentação.

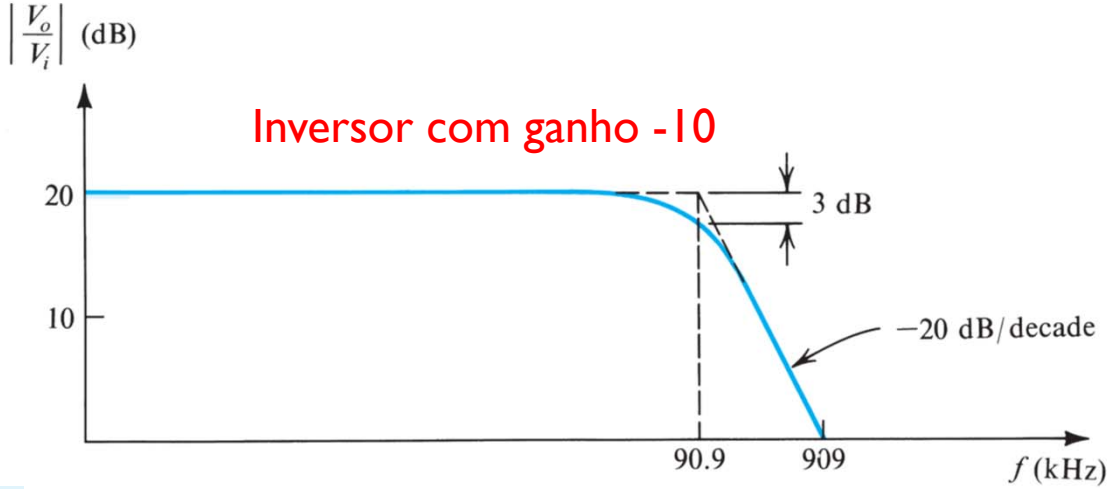
• No modo de malha aberta, um amp-op tem uma largura de banda estreita. A largura da banda aumenta no modo de malha fechada, mas o ganho é inferior.



Ganho e largura de banda

(ampop de 1MHz)





Closed-Loop Gain	R_2/R_1	$f_{3\,dB} = f_t/(1 + R_2/R_1)$
+1000	999	1 kHz
+100	99	10 kHz
+10	9	100 kHz
+ 1	0	1 MHz
− 1	1	0.5 MHz
−10	10	90.9 kHz
−100	100	9.9 kHz
−1000	1000	≃ 1 kHz