

UNIVERSIDADE FEDERAL DE CAMPINA GRANDE
CENTRO DE ENGENHARIA ELÉTRICA E INFORMÁTICA
UNIDADE ACADÊMICA DE ENGENHARIA ELÉTRICA
DISCIPLINA: CIRCUITOS ELÉTRICOS 2
Projeto de Filtro Ativo

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INSTRUÇÕES

Projete um filtro **Multiple Feedback passa-alta**, conforme instruções em anexo, que obtenha as seguintes características:

- Frequência de Corte: 8 kHz.
- Ganho na faixa de passagem: $V_0/V_i = 2.2$

*Caso não encontre os dispositivos eletrônicos adequados para projeto do filtro acima indicado, realize o projeto do filtro mais próximo possível, de acordo com os componentes encontrados, e indique a escolha com justificativa.

Questão 1. Apresente a função de Transferência do Circuito e o memorial de cálculo para escolha dos componentes.

Questão 2. Plote no Matlab, Octave ou software de sua preferência, a função de transferência do circuito junto com o filtro passivo de igual característica (para efeito comparativo).

Questão 3. Realize a montagem do circuito em placa protoboard. Para tanto, utilize os componentes adequados, assim como as ligações e adequações necessárias para utilização do(s) amplificador(es) operacional(ais), conforme *datasheet* do mesmo.

Questão 4. Realize o teste do circuito junto com o professor da disciplina.

Multiple Feedback Filters

by Hank Zumbahlen,
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IN THIS MINI TUTORIAL

Three sample multiple feedback filters are designed in this mini tutorial, one in a series of mini tutorials describing discrete circuits for precision op amps.

The multiple feedback filter, a popular configuration, uses an op amp as an integrator as shown in Figure 1. Therefore, the dependence of the transfer function on the op amp parameters is greater than in the Sallen-Key realization.

It is difficult to generate high Q, high frequency sections due to the limitations of the open-loop gain of the op amp. A rule of thumb is that the open-loop gain of the op amp must be at least 20 dB ($\times 10$) above the amplitude response at the resonant (or cut-off) frequency, including the peaking caused by the Q of the filter. The peaking due to Q causes an amplitude, A_0 .

$$A_0 = HQ \quad (1)$$

where H is the gain of the circuit. The multiple feedback filter inverts the phase of the signal. This is equivalent to adding the resulting 180° phase shift to the phase shift of the filter itself.

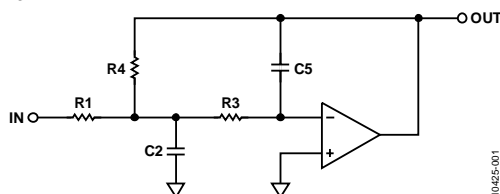


Figure 1. Multiple Feedback Low-Pass Filter

The maximum-to-minimum component value ratio is higher in the multiple feedback case than in the Sallen-Key realization. The design equations for the multiple feedback low-pass filter are given in the Multiple Feedback Low-Pass Design Equations section.

Comments regarding the multiple feedback low-pass filter can apply to the high-pass filter as well (see Figure 2). Again, resistors and capacitors are swapped to convert the low-pass case to the high-pass case. The design equations for the multiple feedback high-pass filter are given in the Multiple Feedback High-Pass Design Equations section.

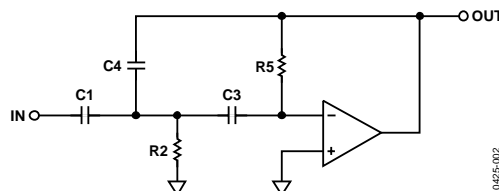


Figure 2. Multiple Feedback High-Pass Filter

The design equations for the multiple feedback band-pass filter are detailed in the Multiple Feedback Band-Pass Design Equations section.

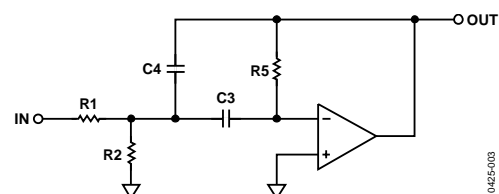


Figure 3. Multiple Feedback Band-Pass Filter

This circuit is widely used in low Q (< 20) applications. It allows some tuning of the resonant frequency, F_0 , by making R2 variable. Q can be adjusted (with R5) as well, but this also changes F_0 .

One way to tune the filter F_0 is by monitoring the output of the filter with the horizontal channel of an oscilloscope, with the input to the filter connected to the vertical channel. The display is a Lissajous pattern. This pattern is an ellipse that collapses to a straight line at resonance because the phase shift is 180° . In addition, adjust the output for maximum output, which occurs at resonance; however, this is usually not as precise, especially at lower values of Q, where there is a less pronounced peak.

MULTIPLE FEEDBACK LOW-PASS DESIGN EQUATIONS

$$\frac{-H \omega_0^2}{s^2 + \alpha \omega_0 s + \omega_0^2}$$

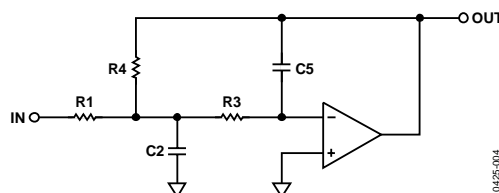


Figure 4.

$$\frac{V_O}{V_{IN}} = \frac{-H \frac{1}{R1 R3 C2 C5}}{s^2 + s \frac{1}{C2} \left(\frac{1}{R1} + \frac{1}{R3} + \frac{1}{R4} \right) + \frac{1}{R3 R4 C2 C5}}$$

To design the filter, choose $C5$. Then,

$$\alpha = 1/Q$$

$$k = 2 \pi F_0 C5$$

$$C2 = \frac{4}{\alpha^2} (H + 1) C5$$

$$R1 = \alpha / (2 \times H \times k)$$

$$R3 = \frac{\alpha}{2 (H + 1) k}$$

$$R4 = \alpha / (2k)$$

MULTIPLE FEEDBACK HIGH-PASS DESIGN EQUATIONS

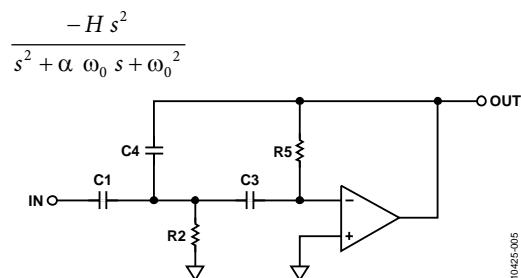


Figure 5.

$$\frac{V_O}{V_{IN}} = \frac{-s^2 \frac{C1}{C4}}{s^2 + s \left(\frac{C1 + C3 + C4}{C3 C4 R5} \right) + \frac{1}{R2 R5 C3 C4}}$$

To design the filter, choose $C1$. Then,

$$\alpha = 1/Q$$

$$k = 2 \pi F_0 C1$$

$$C3 = C1$$

$$C4 = C1/H$$

$$R2 = \frac{\alpha}{k \left(2 + \frac{1}{H} \right)}$$

$$R5 = \frac{H \left(2 + \frac{1}{H} \right)}{\alpha k}$$

MULTIPLE FEEDBACK BAND-PASS DESIGN EQUATIONS

$$\frac{-H \omega_0 s}{s^2 + \alpha \omega_0 s + \omega_0^2}$$

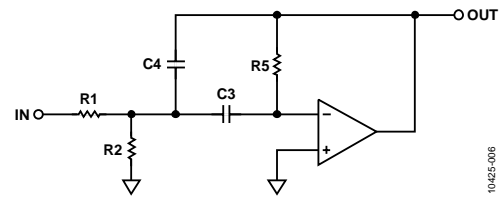


Figure 6.

$$\frac{V_O}{V_{IN}} = \frac{-1}{s^2 + s \frac{C3 + C4}{C3 C4 R5} + \frac{1}{R5 C3 C4} \left(\frac{1}{R1} + \frac{1}{R2} \right)}$$

To design the filter, choose $C3$. Then,

$$k = 2 \pi F_0 C3$$

$$C4 = C3$$

$H = A_0/Q$, where A_0 is the gain at the center frequency

$$R1 = 1/Hk$$

$$R2 = \frac{1}{k (2Q - H)}$$

$$R5 = 2Q/k$$

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REVISION HISTORY

2/2022—Rev. A to Rev. B

Changes to Multiple Feedback Low-Pass Design Equations Section and Multiple Feedback High-Pass Design Equations Section.....2

12/2017—Rev. 0 to Rev. A

Changes to Multiple Feedback Low-Pass Design Equations Section and Multiple Feedback Band-Pass Design Equations Section2

3/2012—Revision 0: Initial Version