A BANDPASS AND A HIGHPASS ACTIVE R FILTER

Ahmed M. Soliman and Mahmoud Fawzy
Electronics and Communications Engineering Department
Cairo University
Giza, Egypt

Abstract

A new active R filter which realizes a second order bandpass and a highpass transfer function is given. The network employs only resistors and two operational amplifiers. Sensitivities to all passive and active circuit components are very low. Design equations are given.

1. INTRODUCTION

Recently there has been a great interest in the new class of filters termed active R filters[1-5], which is based upon the one pole model of the operational amplifier.

Here a new active R filter is given. The network realizes an inverting bandpass transfer function of any arbitrary gain. The same circuit can provide a highpass characteristics at an alternative output terminal.

2. BASIC CIRCUIT

Fig. 1 represents the new active filter which uses two operational amplifiers (OAs) and seven resistors. By direct analysis of the network taking

$$A_i = \frac{GB_i}{s} \tag{1}$$

where GB is the gain-bandwidth product of the OA, and assuming $R_5 >> R_7$, the transfer function is given by

$$\frac{V_3}{V_1} = \frac{-GB_2 R_3}{(R_1+R_2+R_3)s} \cdot \frac{s^2 + sGB_1\left(\frac{R_1+R_2}{R_3}\right)\left(\frac{R_5}{R_4+R_5} - \frac{R_2}{R_1+R_2}\right)}{s^2 + s\left(\frac{GB_1 R_1}{R_1+R_2+R_3}\right) + \frac{nGB_1 GB_2 R_4 (R_1+R_2)}{(R_4+R_5)(R_1+R_2+R_3)}} \tag{2}$$

where

$$n = \frac{R_7}{R_6 + R_7} \tag{3}$$

Taking

$$\frac{R_5}{R_4} = \frac{R_2}{R_1} \tag{4}$$

and defining

$$a = \frac{R_3}{R_1} \tag{5}$$

$$b = 1 + a + \frac{R_2}{R_1} \tag{6}$$

$$m = \frac{R_4}{R_4 + R_5} \tag{7}$$

The transfer function reduces to:

$$\frac{V_3}{V_1} = \frac{-\frac{a}{b} GB_2 s}{s^2 + s\left(\frac{GB_1}{b}\right) + m.n.GB_1.GB_2.\left(\frac{b-a}{b}\right)} \tag{8}$$

which realizes an inverting bandpass characteristics having

$$\omega_o = \sqrt{m.n.GB_1.GB_2.\left(\frac{b-a}{b}\right)} \tag{9}$$

$$Q = \sqrt{m.n.\frac{GB_2}{GB_1}.b(b-a)} \qquad (10)$$

$$K = |gain|_{\omega_o} = a.(\frac{GB_2}{GB_1}) \qquad (11)$$

It is seen that the gain K can take any arbitrary value.

The same circuit realizes a highpass response at terminal 2. The use of this highpass filter is limited unless an ideal voltage follower is used at terminal 2 to provide the desirable low output impedance.

3. DESIGN EQUATIONS

For a specified ω_o, Q and K the design equations of the bandpass filter are given by:

$$\frac{R_3}{R_1} = K.\frac{GB_1}{GB_2} \qquad (12)$$

$$\frac{R_2}{R_1} = \frac{R_5}{R_4} = Q.\frac{GB_1}{\omega_o} - (1 + K.\frac{GB_1}{GB_2}) \qquad (13)$$

$$\frac{R_6}{R_7} = \frac{GB_2}{\omega_o Q} - 1 \qquad (14)$$

For a highpass filter given ω_o, Q and H, the design equations are

$$\frac{R_3}{R_1} = HQ\frac{GB_1}{\omega_o} \qquad (15)$$

$$\frac{R_2}{R_1} = \frac{R_5}{R_4} = Q\frac{GB_1}{\omega_o}(1 - H) - 1 \qquad (16)$$

$$\frac{R_6}{R_7} = \frac{GB_2}{\omega_o Q} - 1 \qquad (17)$$

where $H = \frac{a}{b}$ is the highpass gain.

4. SENSITIVITIES

The ω_o and Q sensitivities with respect to all active and passive circuit components are obtained from equations (9) and (10) and are given by:

$$S^{\omega_o}_{GB_1} = S^{\omega_o}_{GB_2} = \frac{1}{2}$$

$$S^{\omega_o}_{R_1} = \frac{1}{2}\cdot\frac{a}{b(b - a)}$$

$$S^{\omega_o}_{R_2} = \frac{1}{2}\cdot\frac{a(b - a - 1)}{b(b - a)}$$

$$S^{\omega_o}_{R_3} = -\frac{1}{2}\cdot\frac{a}{b}$$

$$S^{\omega_o}_{R_4} = -S^{\omega_o}_{R_5} = \frac{1}{2}(1 - m)$$

$$S^{\omega_o}_{R_6} = -S^{\omega_o}_{R_7} = -\frac{1}{2}(1 - n)$$

$$S^{Q}_{GB_1} = -S^{Q}_{GB_2} = -\frac{1}{2}$$

$$S^{Q}_{R_1} = -\frac{1}{2}[\frac{b - a - 1}{(b - a)} + \frac{b - 1}{b}]$$

$$S^{Q}_{R_2} = \frac{1}{2}[\frac{b - a - 1}{(b - a)} + \frac{b - a - 1}{b}]$$

$$S^{Q}_{R_3} = \frac{1}{2}\cdot\frac{a}{b}$$

$$S^{Q}_{R_4} = -S^{Q}_{R_5} = \frac{1}{2}(1 - m)$$

$$S^{Q}_{R_6} = -S^{Q}_{R_7} = -\frac{1}{2}(1 - n)$$

It is seen that $|S^{\omega_o}_{x}| \leq 0.5$ and $|S^{Q}_{x}| < 1$ where x stands for any active or passive circuit element, that is all sensitivities are very low.

5. CONCLUSIONS

A tunable active filter has been described which eliminates completely the need for external capacitors. The filter provides a bandpass and a highpass responses at two different outputs. The ω_o and Q sensitivities with respect to all active and passive circuit components are very low.

6. REFERENCES

(1) K.R. Rao and S. Srinivisan, "Low-sensitivity active filters using the operational amplifier pole", IEEE Trans. Circuits and systems, Vol. CAS-21, pp. 260-262, March 1974.

(2) K.R. Rao and S. Srinivisan, "A high-Q temperature insensitive bandpass filters using the operational amplifier pole", Proceedings of the IEEE (Letters), pp. 1713-1714, December 1974.

(3) R. Schaumann, "Low-sensitivity high-frequency tunable active filter without external capacitors", IEEE Transactions on circuits and systems, Vol. CAS-22, pp. 39-44, January 1975.

(4) R. Schaumann, "A note on state variable type active R filters", Proc. 1975 Midwest Symp. on Circuits and Systems, pp. 594-597, 1975.

(5) J.R. Brand and R. Schaumann, "A temperature-compensated high frequency tunable active R filter using programmable operational amplifiers", ibid, pp. 603-607.

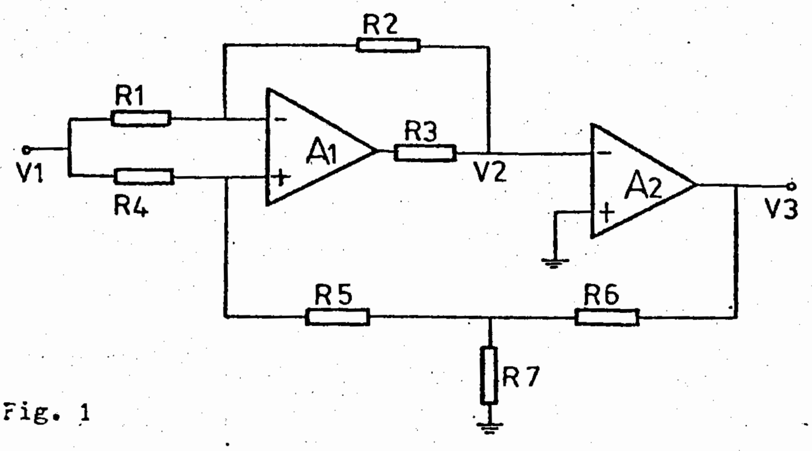

Fig. 1