A New Active R Bandpass Filter

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ABSTRACT: *A new active R filter which realizes a second order bandpass 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 and experimental results are also included.*

I. 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 highpass characteristics at an alternative output terminal.

II. Basic Circuit

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

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

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

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

where

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

Taking

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

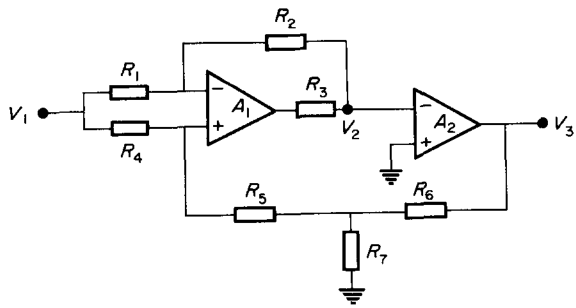

FIG. 1. A bandpass and highpass filter.

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

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

which realizes an inverting bandpass characteristics having

$$\omega_0 = \sqrt{\left[m \cdot n \cdot GB_1 \cdot GB_2 \cdot \left(\frac{b-a}{b}\right)\right]} \tag{9}$$

$$Q = \sqrt{\left[m \cdot n \cdot \frac{GB_2}{GB_1} \cdot b(b-a)\right]} \tag{10}$$

$$K = |\text{gain}|_{\omega_0} = a \cdot \left(\frac{GB_2}{GB_1}\right). \tag{11}$$

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.

III. Design Equations

For a specified ω_0, Q and K the design equations of the bandpass filter are given by

$$\frac{R_3}{R_1}=K\cdot\frac{GB_1}{GB_2} \tag{12}$$

$$\frac{R_2}{R_1}=\frac{R_5}{R_4}=Q\cdot\frac{GB_1}{\omega_0}-\left(1+K\cdot\frac{GB_1}{GB_2}\right) \tag{13}$$

$$\frac{R_6}{R_7}=\frac{GB_2}{\omega_0 Q}-1\,. \tag{14}$$

IV. Sensitivities

The ω_0 and Q sensitivities with respect to all active and passive circuit components are obtained from Eqs. (9) and (10) and are summarized in Table 1. It is seen that

$$\left|\overset{\omega_0}{\underset{x}{S}}\right|\leq 0.5 \quad\text{and}\quad \left|\overset{Q}{\underset{x}{S}}\right|<1$$

where x stands for any active or passive circuit element, that is all the sensitivities are very low.

TABLE I

x	$S_x^{W_0}$	S_x^Q
GB_1	$\frac{1}{2}$	$-\frac{1}{2}$
GB_2	$\frac{1}{2}$	$\frac{1}{2}$
R_1	$\frac{1}{2}\frac{a}{b(b-a)}$	$-\frac{1}{2}\left(\frac{b-a-1}{b-a}+\frac{b-1}{b}\right)$
R_2	$\frac{1}{2}\cdot\frac{a}{b}\cdot\frac{b-a-1}{b-a}$	$\frac{1}{2}\left(\frac{b-a-1}{b-a}+\frac{b-a-1}{b}\right)$
R_3	$-\frac{1}{2}\frac{a}{b}$	$\frac{1}{2}\frac{a}{b}$
R_4	$\frac{1}{2}(1-m)$	$\frac{1}{2}(1-m)$
R_5	$-\frac{1}{2}(1-m)$	$-\frac{1}{2}(1-m)$
R_6	$-\frac{1}{2}(1-n)$	$-\frac{1}{2}(1-n)$
R_7	$\frac{1}{2}(1-n)$	$\frac{1}{2}(1-n)$

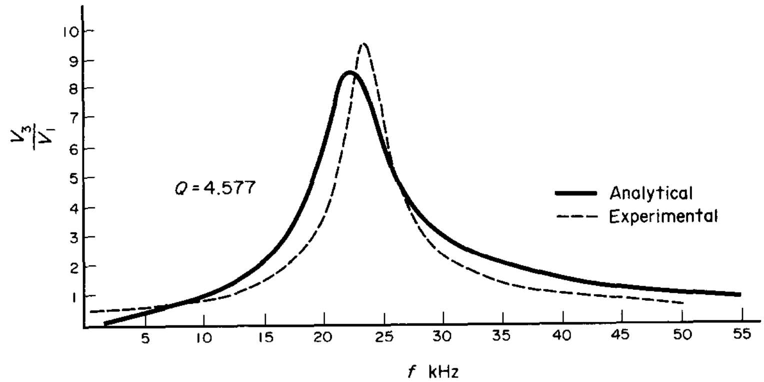

FIG. 2. Measured and theoretical bandpass response.

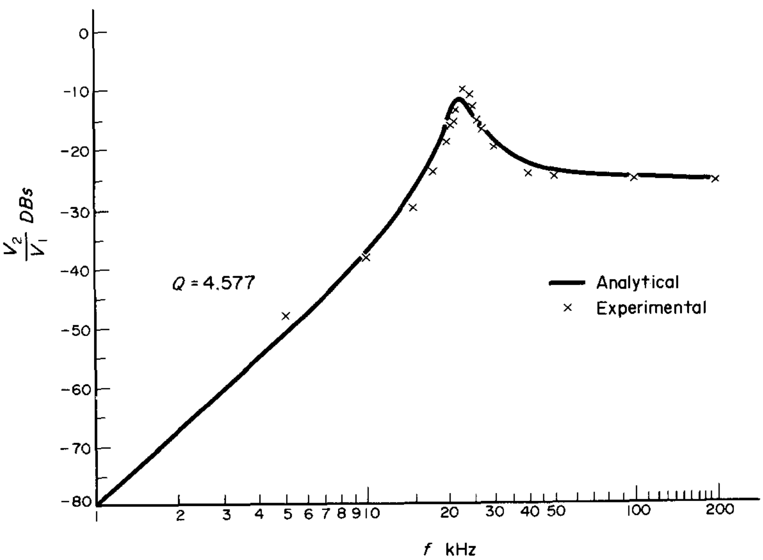

FIG. 3. Measured and theoretical highpass response.

V. *Experimental Results*

The circuit is constructed using the standard 10% tolerance resistors of values, i.e.

$$R_1 = R_4 = 1\ k\Omega$$
$$R_2 = R_5 = 180\ k\Omega$$
$$R_3 = 10\ k\Omega$$
$$R_7 = 1\ k\Omega$$
$$R_6 = 6.8\ k\Omega.$$

The parameters of the two OAs used are $f_{c_1} = 935$ kHz and $f_{c_2} = 800$ kHz.

The analytical and the experimental results of the bandpass and highpass responses are shown in Figs. 2 and 3 respectively.

VI. Conclusion

A tunable active filter has been described which eliminates completely the need for external capacitors. The filter provides bandpass and highpass responses at two different outputs. ω_0 and Q sensitivities with respect to all circuit components are very low. Experimental results are also included.

References

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