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A general configuration for realizing all-pass or notch filters using a grounded operational amplifier

AHMED M. SOLIMAN
College of Steubenville, Steubenville, Ohio 43952, U.S.A.

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A new structure for realizing an all-pass transfer function is given here. By adjusting one resistor the same configuration can realize a notch filter. Two special circuits using a minimum number of capacitors are derived from the general configuration, both are capable of realizing complex poles.

1. Introduction

Many realizations are available for realizing special types of the 2π all-pass transfer function using the operational amplifier as the active element. Some circuits are derived from a general configuration based on the Wien bridge, an example is Genin's circuit (1968). Other circuits are based on the dual-input configuration proposed by Sen Roy (1969), an example is Dutta Roy's realization (1970).

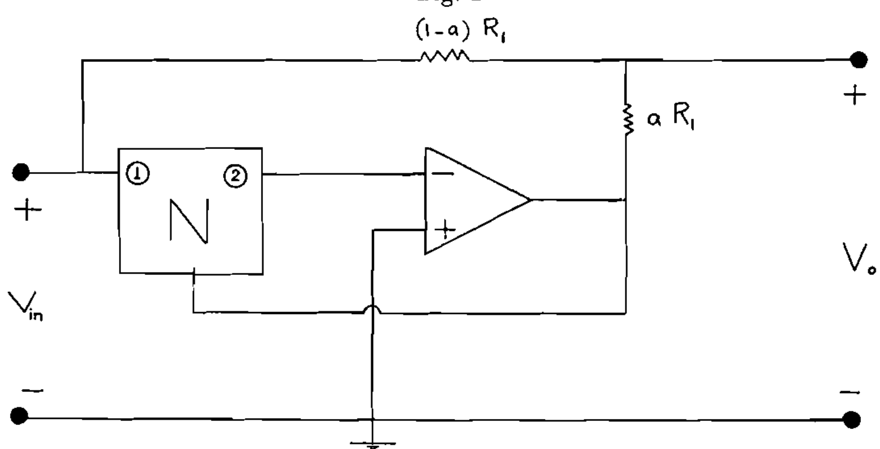
In this paper a new general configuration is given which realizes all-pass or notch filters.

2. General configuration

Figure 1 represents the general circuit. Assuming ideal operational amplifier, it follows that the voltage transfer function of this structure is given by :

$$G(s)=\frac{V_o}{V_{in}}=\frac{a-T(s),}{1-T(s)} \tag{1}$$

Fig. 1



A general configuration for realizing an all-pass or a notch filter.

where $T(s)$ is the voltage transfer function of the three terminal RC network N.

If

$$T(s)=\frac{K\omega_p s}{s^2+\frac{\omega_p}{q_p}s+\omega_p^2}, \tag{2}$$

where q_p is the pole Q of the passive RC bandpass network N, $0<q_p<0{\cdot}5$. Hence,

$$G(s)=a\,\frac{s^2+\omega_p\left(\frac{1}{q_p}-\frac{K}{a}\right)s+\omega_p^2}{s^2+\omega_p\left(\frac{1}{q_p}-K\right)s+\omega_p^2}. \tag{3}$$

If

$$a=\frac{q_pK}{2-q_pK} \tag{4}$$

an all-pass transfer function of magnitude a results. Its phase shift is given by

$$\phi=2\tan^{-1}\left(\frac{\frac{1}{q_p}-K}{\frac{\omega}{\omega_p}-\frac{\omega_p}{\omega}}\right). \tag{5}$$

The same circuit realizes a notch filter if

$$a=Kq_p. \tag{6}$$

The pole Q of the active network is given by

$$Q=\frac{q_p}{1-Kq_p} \tag{7}$$

which can be controlled by varying K or q_p or both as is demonstrated next.

3. Example: minimal realization

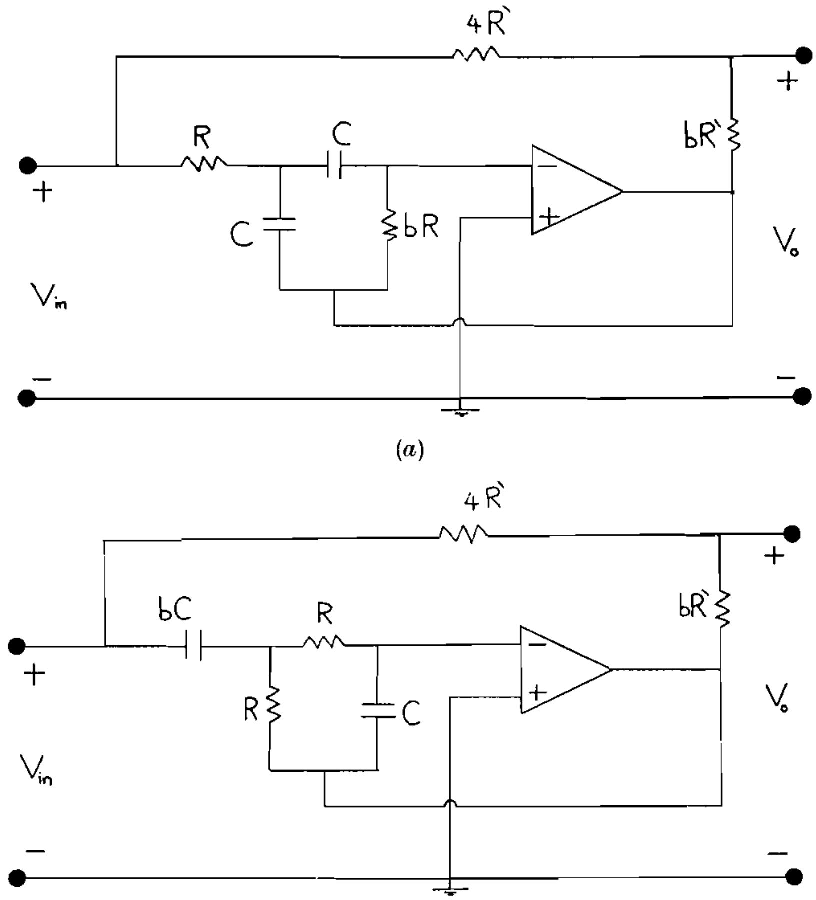
The circuit components of each of the passive RC bandpass circuits used in fig. 2 are chosen with one variable parameter b (to control Q) so that both networks have the same transfer function given by :

$$T(s)=\frac{\frac{s}{CR}}{s^2+\frac{b+2}{bCR}s+\frac{1}{bC^2R^2}}. \tag{8}$$

Hence

$$\omega_p=\frac{1}{CR\sqrt{b}}, \tag{9}$$

Fig. 2



(*b*)

Two alternative all-pass networks.

$$q_p = \frac{\sqrt{b}}{b+2}, \tag{10}$$

$$K = \sqrt{b}. \tag{11}$$

Using eqn. (4), hence if

$$a = \frac{b}{b+4} \tag{12}$$

all-pass transfer function results.

For a notch filter,

$$a = \frac{b}{b+2}.$$

The circuit is capable of realizing complex poles, and for a specified Q, $b = 4Q^2$.

4. Conclusions

A new configuration for realizing all-pass or notch filters using a grounded operational amplifier has been given. A very high input impedance and a very low output impedance can be achieved practically by using two additional operational amplifiers at the input and output ports to act as voltage followers (Genin 1968).

References

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Sen Roy, N., 1969, *Proc. I.E.E.E.*, **57**, 836.