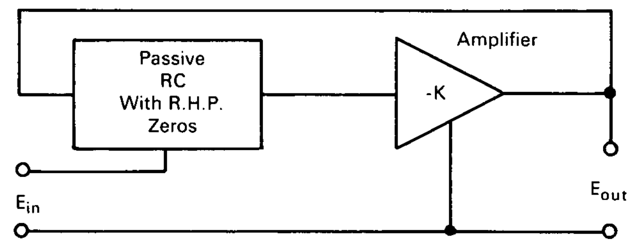
NASA TECH BRIEF

Active RC Filter Permits Easy Trade-Off of Amplifier Gain and Sensitivity to Gain



The problem:

Active RC filter amplifiers are preferred to RLC filters in applications where the presence of inductors is undesirable for reasons of size, weight, cost, or magnetic field considerations. They are required if the circuit is to be integrated monolithically. However, the performance of active RC filters tends to be sensitive to component values and particularly to the gain of the amplifier. Designs which reduce this sensitivity to acceptable values often require amplifiers of very high gain or operational amplifiers (which may prohibit applications at intermediate radio frequencies).

The solution:

A passive RC network with zeros of transmission in the right half of the complex frequency plane used in the feedback loop of a simple negative-gain amplifier. These "phantom zeros" do not appear in the overall system transfer function, but their proper positioning provides any desired trade-off between amplifier gain and Q sensitivity to amplifier gain.

How it's done:

The desired rational transfer function can always be realized by a cascade of filter amplifiers each of which realizes, at most, two poles. Here we consider a single bandpass stage having two complex poles. For this application, a twin-tee RC network or a distributed RC notch network may be used to generate the phantom zeros. Position of the phantom zeros can be controlled by using the results of closed-form analysis of the twin-tee or of a computer analysis that has been carried out for the uniformly distributed notch network.

The amplifier can be a simple phase-inverting design permitting reliable operation in the radio frequency range. For example, when a Q of 50 is desired, a tapered (10:1) twin-tee passive structure requires an amplifier gain of only -10.3 if the phantom zeros are positioned at $+0.1 \pm i\ 0.995$ (normalized values) a position which reduces the Q sensitivity to amplifier gain, S^Q_K, to 10.3 or 0.206 Q (compared with about 2Q for some well known circuits). A model of this design with the center frequency scaled up to 4.78 MHz has been successfully tested in the laboratory.

A design chart is given in reference 1 for the version using a uniformly distributed notch network and several models have been successfully tested. However, the uniform line increases the gain required (over the tapered twin-tee) for the same Q and S^Q_K.

For low frequency applications where operational amplifiers can be used, the state variable method described in reference 2 can be used, and is capable of

(continued overleaf)

exceptionally low sensitivity to both amplifier gain and components.

References:

1. "An Integrable IF Amplifier of High Stability," by W. J. Kerwin and Charles V. Shaffer presented at Eleventh Midwest Symposium on Circuit Theory, University of Notre Dame, Notre Dame, Indiana, May 13–14, 1968.
2. "State-Variable Synthesis for Insensitive Integrated Circuit Transfer Functions" by William J. Kerwin, Lawrence P. Huelsman, and Robert W. Newcomb printed in *IEE Journal of Solid-State Circuits,* Vol. SC-2, No. 3, September 1967.

Note:

Documentation for this invention, consisting of the two reference papers, is available from:

Clearinghouse for Federal Scientific
and Technical Information
Springfield, Virginia 22151
Price $3.00
Reference: B68-10539

Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

Source: William J. Kerwin
and Charles V. Shaffer
Ames Research Center
(ARC-10042)