ELECTRONOTES
1 PHEASANT LANE
ITHACA, NY 14850
(607)-273-8030

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A STATE-VARIABLE CONFIGURATION WITH CONSTANT PEAK RESPONSE

Several state-variable filter configurations are popular, and for fixed filter applications, they are all about the same, or can be made so. In the case where we want to vary the characteristic, the Q of the filter, we may run into a few problems. Suppose for example that we have a fixed input waveform and that we want to process it with bandpass filtering of a variable bandwidth. With the standard configurations, the Q can be easily changed, but at the same time, as the Q goes up so does the peak response. To maintain a constant output level, you would have to cut back on the input level. That this happens can be seen from the typical configuration (in block form) shown in Fig. 1.

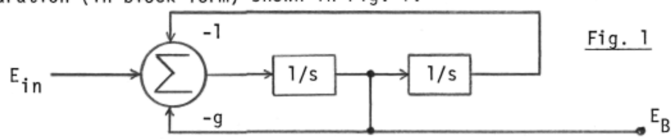

Fig. 1

It is easy to show that the bandpass transfer function is:

$$T_B(s) = E_B(s)/E_{in}(s) = \frac{s}{s^2 + gs + 1} \qquad (1)$$

At the resonant frequency, $s_o = j\omega_o$ and things have already been normalized so $\omega_o = 1$. Thus at resonance $s = j$, and substituting this into (1) we get:

$$|T_B(s)|_{resonance} = [T_B(s{=}j)\cdot T_B(s{=}{-j})]^{1/2} = 1/g = Q \qquad (2)$$

where Q = 1/g as shown in AN-11. Thus, in an actual configuration, the gain at resonance is equal to, or at least proportional to Q. The problem with this is that if for example we start with a Q = 1 and a signal peak at resonance of 5 volts, and then change the Q to 10, the peak would like to be 50 volts, but will have to settle for saturation at 15 volts. It is clear that if we want to change Q and maintain the peak level, we will need to cut back the overall gain.

We could do this with a dual pot used to cut back on the input level at the same time the Q is increased by cutting back on the feedback gain from the bandpass to the input (the gain g). However, dual pots are expensive and op-amps aren't, so we can consider a configuration with two summers as in Fig. 2.

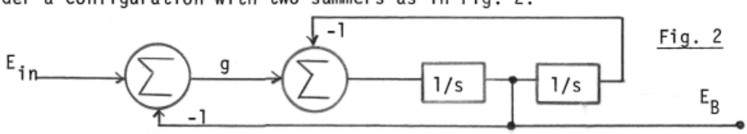

Fig. 2

It is by no means difficult to solve this network out, but we can just observe that in effect we have created one overall summer out of two, and that all that is changed is that E_{in} is multiplied by g, exactly what we wanted so that the transfer function becomes:

$$T_B(s) = \frac{gs}{s^2 + gs + 1} \qquad (3)$$

In the same way that we got equation (2) we can show that the gain at the resonant frequency is now 1, or a constant in the general case, just what we were looking for.

We now seek an actual configuration to realize Fig. 2. It is convenient to use one op-amp to sum the input and the bandpass (we really need the inversion anyway), use one pot to set g, and then use the usual second op-amp summer. The result is shown in Fig. 3.

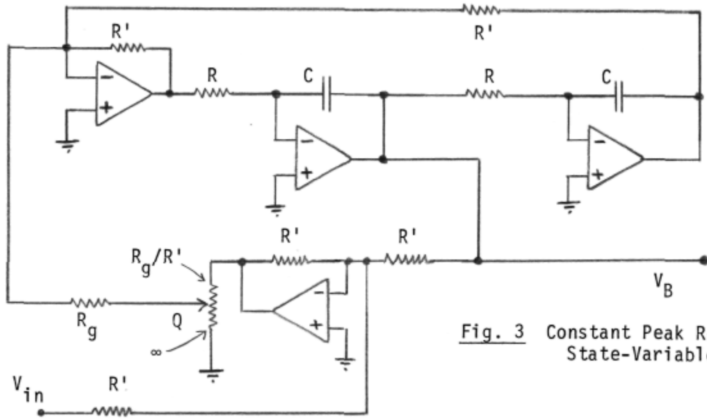

Fig. 3 Constant Peak Response State-Variable

From direct analysis or from comparison with previous state-variable filters it is easy to show that:

$$T_B(s) = V_B(s)/V_{in}(s) = \frac{-gs/RC}{s^2 + gs/RC + 1/R^2C^2} \quad (4)$$

The resonant frequency is $1/2\pi RC$, the peak gain is -1 (magnitude = 1), and the Q can be varied from ∞ (pot at bottom) to $Q_{min} = 1/g_{max} = 1/(R'/R_g) = R_g/R'$ (with pot at the top). Some typical experimental curves are shown below in Fig. 4:

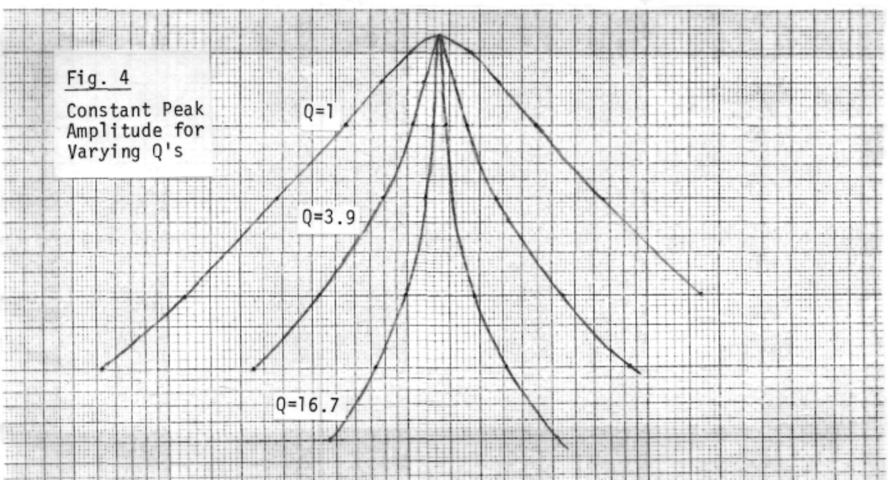

Fig. 4
Constant Peak Amplitude for Varying Q's