Active filter has separate band and frequency controls

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The bandwidth and center frequency of an active bandpass filter can be controlled independently by two separate resistors. Moreover, the filter's gain remains at unity over its full tuning range. Filter Q range is 2 to 200, while center frequency is 1 to 10 kilohertz.

The circuit shown in (a) has these properties, but it requires a variable inductor, which is usually difficult to tune, can be large, and cannot provide good temperature stability. The transfer function for this LC filter is:

$e_o/e_i = (s/R_1C_1)/(s^2+s/R_1C_1+1/LC_1)$

Replacing the inductor with an active RC network, as illustrated in (b), yields a temperature-stable circuit. If all the components are ideal and $R_2C_2 = R_3C_3$, the equivalent inductance can be expressed as:

$L_{eq} = R_2C_2R_f$ henries

and the 3-decibel bandwidth as:

$BW = 1/(2\pi R_1C_1)$ hertz

and the center frequency as:

$f_o = 1/[2\pi(R_fC_1R_2C_2)^{1/2}]$ Hz

A wide range of component values can be used in the circuit, which is easy to design, once the desired filter specifications are established. As an example, a filter will be designed with a 5-Hz bandwidth, a center frequency of 1 kHz, and a maximum output voltage of 1 volt peak-to-peak. A few important operational amplifier specifications must also be known. Typically, input resistance (R_i) is greater than 40 kilohms, output resistance (R_o) is less than 200 ohms, voltage gain (G_v) is more than 10,000, and output voltage swing (V_{os}) exceeds 20 v pk-pk.

To solve the design equations, let:

$K_1 = (R_fC_1R_2C_2)^{1/2} = 1/(2\pi f_o) = 1.59 \times 10^{-4}$

$K_2 = R_1C_1 = 1/(2\pi BW) = 3.18 \times 10^{-2}$

$K_3 = (R_fC_1/R_2C_2)^{1/2}$

$= [(V_{os2}/e_{omax})^2 - 1]^{1/2} = 19.98$

then the filter's time constants can be computed:

$R_1C_1 = K_2 = 3.18 \times 10^{-2}$

$R_2C_2 = K_1/K_3 = 7.96 \times 10^{-6}$

$R_fC_1 = K_1K_3 = 3.18 \times 10^{-3}$

$R_f/R_1 = K_1K_3/K_2 = 0.1$

For most applications, a few simplified guidelines can be followed to choose component values: resistor R_1 should be less than 400 kilohms, resistor R_2 should lie between R_{i2} (about 40 kilohms) and 1 kilohm, the load resistance should be greater than 1 kilohm, and factor $(1 - R_3C_3/R_2C_2)$ should range between 0 and resistance ratio $(R_f/R_1) \times 10^{-2}$.

This last constraint requires that time constant R_2C_2 track R_3C_3 within +0% and –0.1%. Therefore, these resistors and capacitors must have closely matched temperature coefficients and operating temperatures. Metal-film resistors and NPO-type capacitors that are mounted close together can be used. (The R_2C_2 and R_3C_3 time constants can be aligned by first opening the filter's input to obtain maximum Q, then increasing R_3 until oscillation occurs, and then decreasing R_3 until oscillation just stops.)

A set of typical component values is noted in (b). As indicated, resistor R_1 tunes filter bandwidth, while resistor R_f adjusts center frequency. □

Active circuit ousts variable inductor. Bandpass filter (a) offers independent center frequency and bandwidth adjustments. Hard-to-tune variable inductor can be replaced by active circuit (b) that provides an equivalent inductance and better temperature stability. Fully active filter is easy to design and will operate over a broad range of component values. General-purpose amplifiers can be used.