DESIGN A 60Hz NOTCH FILTER WITH THE UAF42

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The UAF42 is a monolithic, time-continuous, 2nd-order active filter building block for complex and simple filter designs. It uses the classical state-variable analog architecture with a summing amplifier plus two integrators. This topology offers low sensitivity of filter design parameters f_o (natural frequency) and Q to external component variations along with simultaneous high-pass, low-pass and band-pass outputs. An auxiliary high performance operational amplifier is also provided which can be used for buffering, gain, real pole circuits, or for summing the high-pass and low-pass outputs to create a band reject (notch) filter (see Figure 1).

A notch filter is easily realized with the UAF42 and six external resistors. Figure 2 shows the UAF42 configured into a 60Hz notch filter. The auxiliary operational amplifier is used to sum both the high-pass and low-pass outputs. At f = f_NOTCH, both of these outputs times their respective gain at the summing circuit are equal in magnitude but 180° out of phase. Hence, the output goes to zero. Figure 3 shows the response plot for the circuit shown in Figure 2 where f_o = 60Hz and Q = 6.

The notch frequency for the notch filter is set by the following calculations:

\[ f_{\text{NOTCH}} = \sqrt{\left(\frac{A_{\text{LP}}}{A_{\text{HP}}} \cdot \frac{R_{Z2}}{R_{Z1}}\right)} \cdot f_o \]

where,

\[ A_{\text{LP}} = \text{gain from input to low-pass out at } f = 0\text{Hz.} \]

\[ A_{\text{HP}} = \text{gain from input to high-pass out of } f >> f_o. \]

Typically, \( \frac{A_{\text{LP}}}{A_{\text{HP}}} \cdot \frac{R_{Z2}}{R_{Z1}} \) is equal to one. This simplifies \( f_{\text{NOTCH}} \) to be,

\[ f_{\text{NOTCH}} = f_o \]

\[ f_o \text{ is given by, } f_o = \frac{1}{R_F \cdot C \cdot 2\pi} \]

where, \( R_F = R_{F1} = R_{F2} \) and \( C = C_1 = C_2 \).

Note that the notch frequency can be modified by simply changing the \( R_F \) resistors and/or adding external capacitors. NPO ceramic, mica or a good film capacitor with low dissipation factor characteristics is recommended.

The –3dB bandwidth, as shown in Figure 3, can be set by the following calculations.

\[ \text{BW}_{-3dB} = \frac{f_{\text{NOTCH}}}{Q} \]

where, \( \text{BW}_{-3dB} = f_H - f_L \)

The filter Q can be determined by setting \( R_Q \) to a value given by,

\[ R_Q = \frac{25k\Omega}{Q - 1} \]

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**FIGURE 1.** UAF42 Universal Active Filter with High-pass, Band-pass and Low-pass Outputs.
The pass-band gain of the notch filter is influenced by the filter Q and should be adjusted for unity by setting the summing circuit feedback and input resistor ratios such that,

$$Q = \frac{R_{Z1}}{R_{Z2}}$$

Note that both filter parameters $f_0$ and Q can be independently set with the proper selection of external components $R_{F1}$, $R_{F2}$ and $R_Q$.

A UAF42 filter design program, FILTER42, along with application bulletin AB-035 is available at no cost which greatly simplifies the design process. A spreadsheet-style "what if" approach can be used to design a variety of filter approximations (Butterworth, Inverse Chebyshev, etc). Response plots, component values and circuit topology information is all provided.

FIGURE 2. UAF42 Configured as a 60Hz Notch Filter.

FIGURE 3. 60Hz Notch Filter Response.
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