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APPLICATION BULLETIN
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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:

$$f_{NOTCH} = \sqrt{\left(A_{LP} / A_{HP} \bullet R_{Z2} / R_{Z1}\right)} \bullet f_O$$

where,

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

A_{HP} = gain from input to high-pass out of f >> f_O.

Typically, $A_{LP}/A_{HP} \bullet R_{Z2}/R_{Z1}$ is equal to one. This simplifies f_{NOTCH} to be,

$$f_{NOTCH} = f_O$$

$$f_O \text{ is given by, } f_O = \frac{1}{R_F \bullet C \bullet 2\pi}$$

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.

$$BW_{-3dB} = f_{NOTCH}/Q$$

$$\text{where, } BW_{-3dB} = f_H - f_L$$

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

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

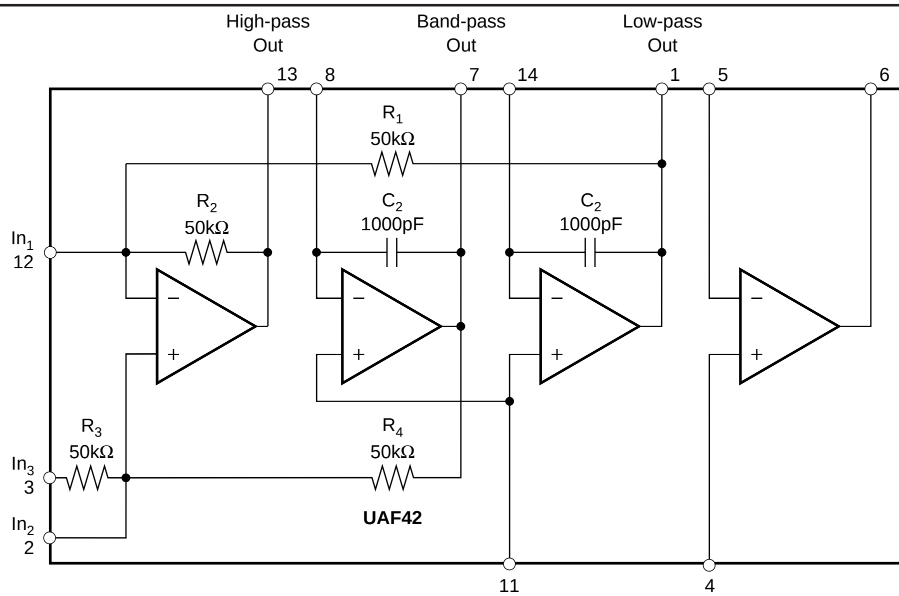

FIGURE 1. UAF42 Universal Active Filter with High-pass, Band-pass and Low-pass Outputs.

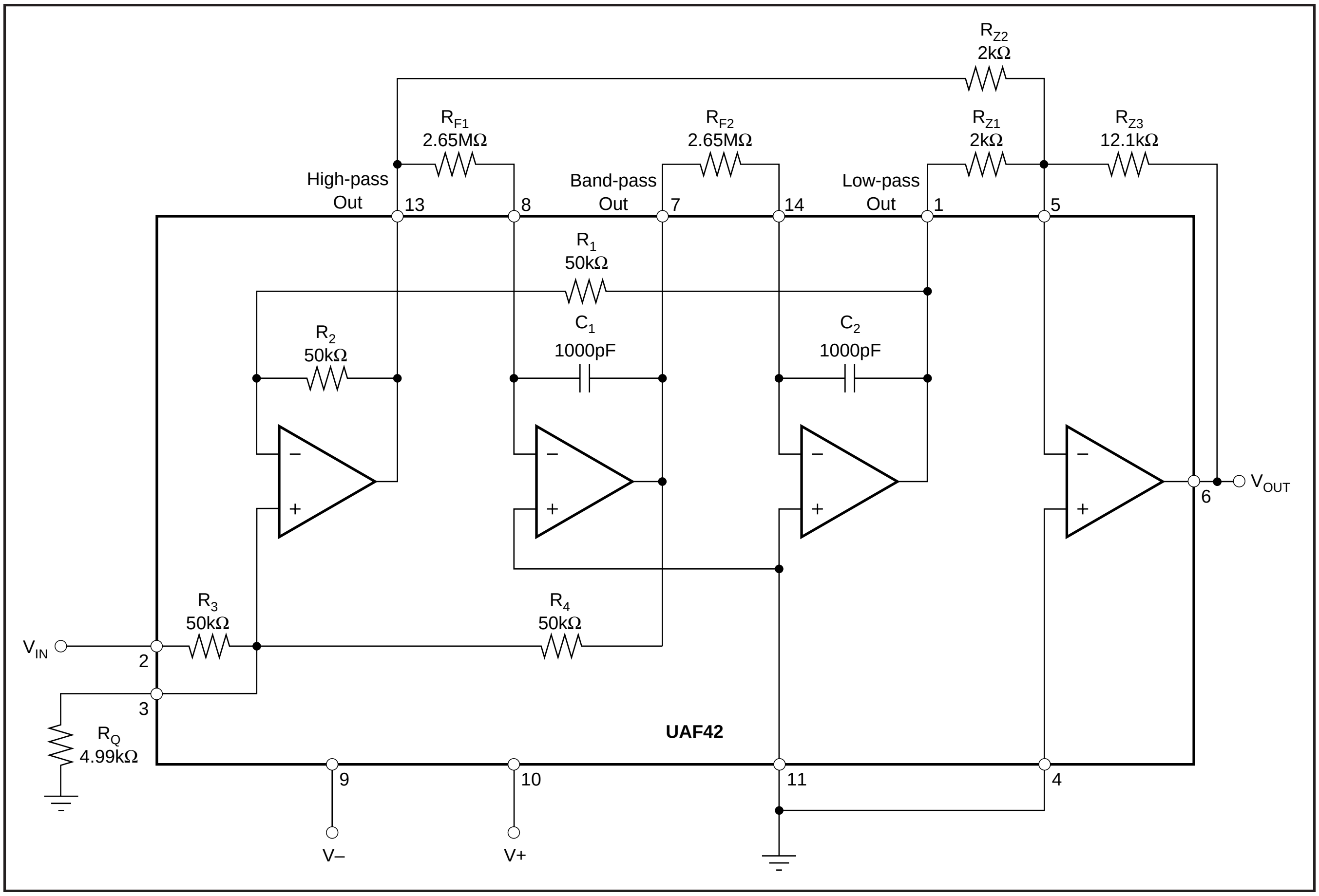

FIGURE 2. UAF42 Configured as a 60Hz Notch Filter.

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,

$$Q = \frac{R_{Z3}}{R_{Z1}} = \frac{R_{Z3}}{R_{Z2}}$$

Note that both filter parameters f_O 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 Chebyschev, etc). Response plots, component values and circuit topology information is all provided.

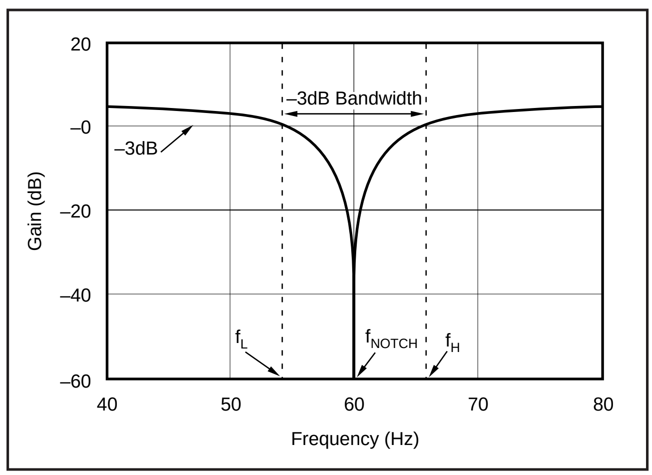

FIGURE 3. 60Hz Notch Filter Response.