

## 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  $180^\circ$  out of phase. Hence, the output goes to zero. Figure 3 shows the response plot for the circuit shown in Figure 2 where  $f_o = 60\text{Hz}$  and  $Q = 6$ .

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

$$f_{NOTCH} = \sqrt{(A_{LP} / A_{HP} \cdot R_{Z2} / R_{Z1})} \cdot f_o$$

where,

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

$A_{HP}$  = gain from input to high-pass out of  $f \gg f_o$ .

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

$$f_{NOTCH} = f_o$$

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

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  $-3\text{dB}$  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,

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

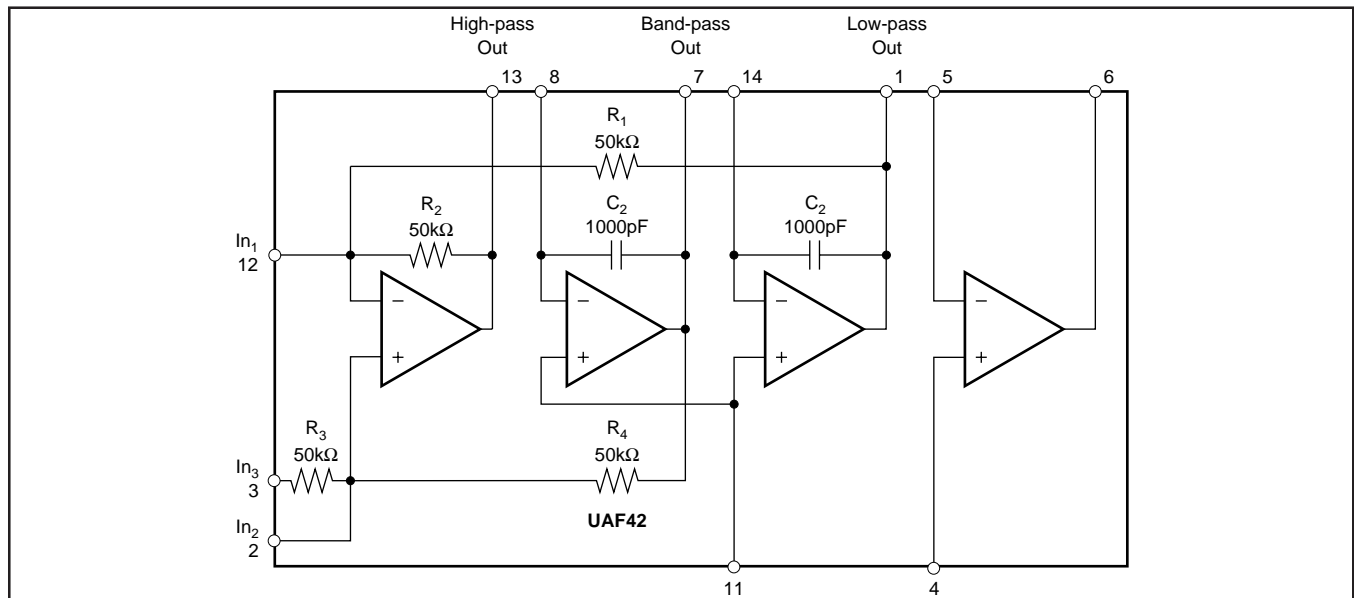


FIGURE 1. UAF42 Universal Active Filter with High-pass, Band-pass and Low-pass Outputs.

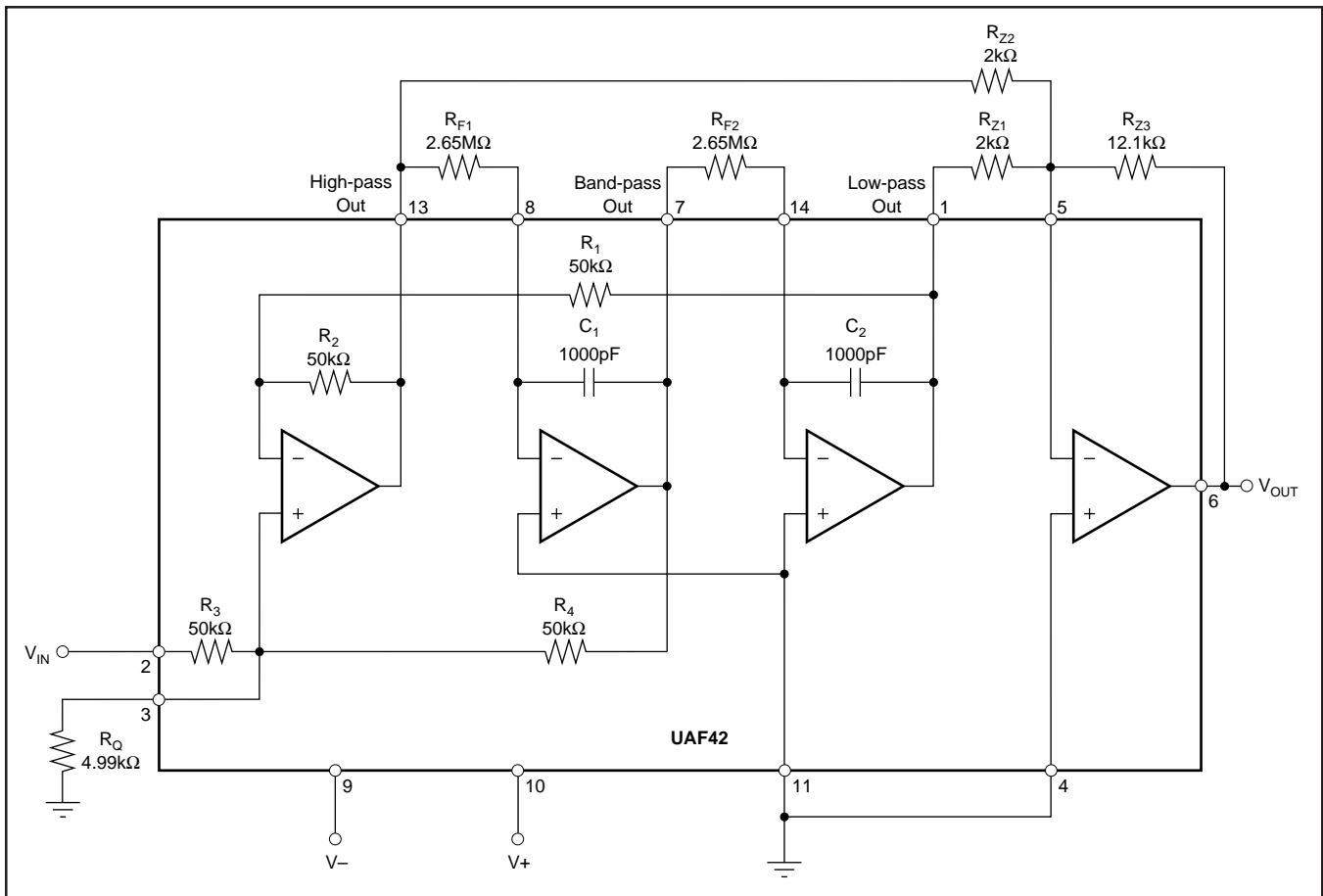


FIGURE 2. UAF42 Configured as a 60Hz Notch Filter.

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 Chebyshev, etc). Response plots, component values and circuit topology information is all provided.

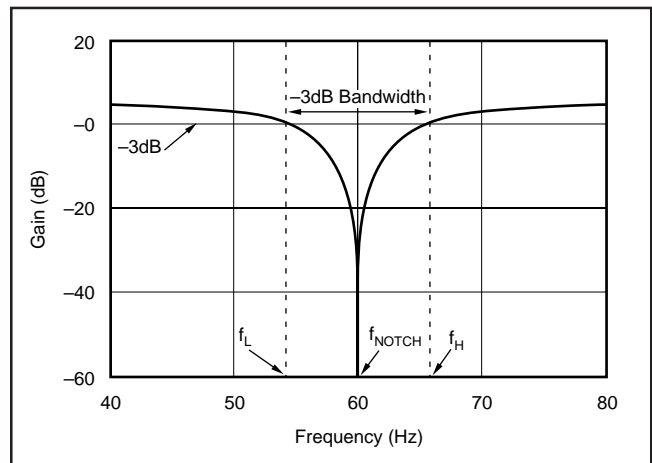


FIGURE 3. 60Hz Notch Filter Response.

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