

UAF42 Universal Active Filter -Based 60 Hz Notch Filter

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Abstract

Power-line interference at 60 Hz is a common and serious problem for sensitive electronic systems like biological apparatus (like ECG), precision measurement sets, and audio processing circuits. Traditional filtering methods typically don't work to get rid of this narrowband noise without also lowering the levels of relevant frequency components that are close by. A notch filter is a good choice since it aggressively cuts out a small frequency band while keeping the remainder of the signal spectrum. In this work, a 60 Hz notch filter is designed and implemented using the UAF42 Universal Active Filter IC. The UAF42's state-variable architecture lets you set frequency, which makes the performance more stable and less sensitive to changes in components. The proposed design is examined theoretically and validated by circuit modeling in the eSim software. The results show that the UAF42-based notch filter works well to get rid of 60 Hz interference without changing the signal, which makes it great for biomedical, audio, and precision measurement uses.

1 Introduction

A notch filter is a type of electronic filter designed to significantly attenuate a specific frequency or a narrow band of frequencies while allowing other frequencies to pass through relatively unaffected. This makes it ideal for removing unwanted noise or interference from a signal. At 60 Hz, power-line interference often affects biological and electrical systems. Although active filters are vital in modern electronics, their design and verification can be tedious and time consuming. Using the UAF42 it is easy to design and implement all kinds of active filters. The UAF42 is a monolithic IC which contains the op amps, matched resistors, and precision capacitors needed for a state-variable filter pole-pair. In this work, a 60 Hz notch filter is designed and implemented using the UAF42 IC. The choice of UAF42 enables accurate tuning of the notch frequency.

2 Working Principle

The UAF42 is a building block for a monolithic second-order active filter that uses a state-variable architecture. It has a summing amplifier and two integrators. This setup gives you low-pass, high-pass, and band-pass outputs all at once, with very low sensitivity of the natural frequency f_0 .

The auxiliary high-performance op-amp of the UAF42 is used to add the low-pass and high-pass outputs together to make a 60 Hz notch filter. The low-pass and high-pass signals have the same strength at the notch frequency ($f=f_{NOTCH}$), but they are 180° out of phase. When these are added together, they cancel each other out, and the output is zero at the notch frequency. So, by choosing the right external resistors and capacitors, the UAF42 blocks 60 Hz power-line noise while leaving most other frequencies alone.

3 Design Methodology

An operational amplifier is used 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. A notch filter is easily realized with the UAF42 and six external resistors. The circuit 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.

The notch frequency for the UAF42-based filter is determined by the relationship between the low-pass and high-pass paths. It is given as:

$$f_{NOTCH} = \left(\frac{A_{LP}}{A_{HP}} \cdot \frac{R_{Z2}}{R_{Z1}} \right) \cdot f_O \quad (1)$$

where:

- A_{LP} = gain from input to low-pass output at $f = 0 \text{ Hz}$
- A_{HP} = gain from input to high-pass output at $f \gg f_O$

Since typically,

$$\frac{A_{LP}}{A_{HP}} \cdot \frac{R_{Z2}}{R_{Z1}} = 1, \quad (2)$$

the notch frequency simplifies to:

$$f_{NOTCH} = f_O \quad (3)$$

The natural frequency f_O is given by:

$$f_O = \frac{1}{2\pi R_F C} \quad (4)$$

where $R_F = R_6 = R_{10}$ and $C = C_1 = C_2$.

4 Proposed System and eSim Realization

Figure 1 shows a 60Hz Notch Filter implemented using Universal active filter.

The state-variable filter has a low-pass and a high-pass section made up of op-amps (U1, U2, U3), resistors (R1, R4, R5, R6, R10), and capacitors (C1, C2). Each capacitor has a value of 1000 pF. The extra op-amp U4 (with resistors R7, R8, and R9) adds the low-pass and high-pass outputs together. The low-pass and high-pass signals are the same size at the notch frequency (target: 60 Hz), but they are 180° out of phase. When

you combine them together, they cancel each other out, therefore the output is zero at 60 Hz. Signals can still get through at frequencies other than 60 Hz since cancellation isn't complete. So, the output (V_{out}) is a 60 Hz notch filter response that cuts down on 60 Hz noise while letting neighbouring frequencies through.

The design is implemented and validated in eSim.

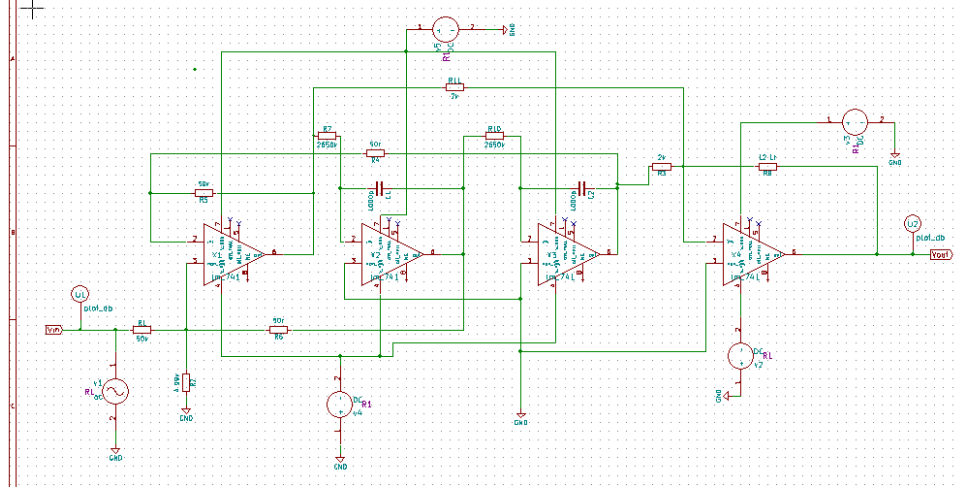


Figure 1: UAF42 Configured as a 60Hz Notch Filter in eSim.

5 Simulation Results

Figure 2 shows a typical simulated output waveform. Due to practical op amp configuration, the F_{notch} obtained is at 63Hz.

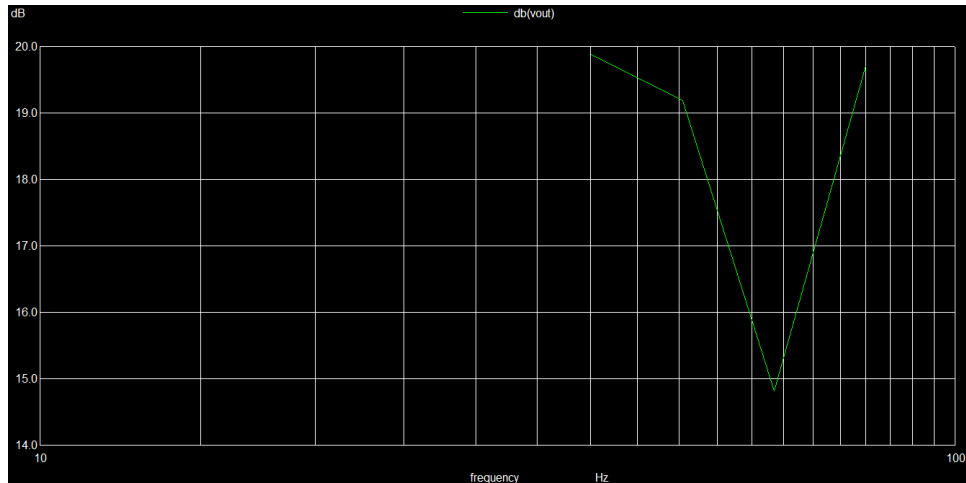


Figure 2: Frequency response of UAF42 Configured as a 60Hz Notch Filter in eSim

6 Conclusion

Using the UAF42 architecture and op-amps in eSim, a 60 Hz notch filter was designed and tested. The filter worked well to block power-line interference by adding the low-pass and

high-pass outputs together to get rid of the notch frequency. The notch frequency was 63 Hz instead of exactly 60 Hz because of real op-amp limits and component tolerances. This still proves that the design technique is legitimate and shows that it may be used for biomedical and precision measurement applications.

References

1. Filter Design Program For The UAF42 Universal Active Filter
2. Design a 60Hz Notch Filter with the UAF42