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COMPARISON OF KHN FILTER AND TOW-THOMAS BIQUAD FILTER

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Abstract

This Paper presents the comparison of Kerwin, Huelsman and Newcomb (KHN) filter with Tow Thomas filter in its basic form. Both filters are realized using with operational amplifier. KHN Filter has better performance, low sensitivities and these are flexible in nature. As KHN filter verifies its High pass, Band pass and Low pass response whereas Tow Thomas filter verifies only bandpass and low pass response only. Performances of both filters are analyses using PSPICE simulation.

I. Introduction

In active filter design, voltage mode approach is much popular by offering the advantages of realizing second order filter (biquadratic filter) is that by cascading the number of second order filters high order filter i.e. 4^{th} order or higher can be designed [10]. Voltage amplifiers are usually employed as active devices in active filter designing [4-8]. Voltage mode approach is

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utilized for realization of both (KHN and Tow Thomas biquadratic filter) presented in this paper. The Kerwin Huelsman and Newcomb is a state variable type filter [1-3]. In the realization of this filter, differential equations are solved by using state variable method. It consist two integrators and a differential summer. HP, Band pass and LP responses occurs simultaneously. In comparison to KHN filter Tow Thomas Biquad filter also has two integrators and one differential summer. But Tow Thomas produces only Band pass and Low pass filter response simultaneously. Both structure are the single input multi-output (SIMO) structures [9] i.e. the signal is applied at one input node of the circuit, while filter responses of distinct characteristics (HP, BP and LP) are produced at different O/P node. Voltage mode analyses of both filters are presented in this paper.

II. Proposed Design Configuration

A. KHN filter

KHN filter circuit diagram is shown in figure 1. It uses three operational amplifier, six resistances and two capacitors. In this circuit HP, Band pass and LP response appears at the output of op-amp first, Second and third respectively.

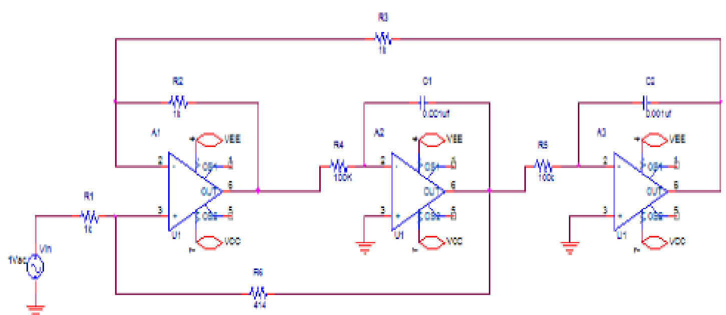

Figure 1. KHN filter structure.

The O/P of Op-amp first, Second and third is given as:

$$V_{HP}/V_{in} = V_{o1}/V_{in} = [(1 + R_2/R_3)/(1 + R_1/R_6)]S^2/D(S) \tag{1}$$

$$V_{HP}/V_{in} = V_{o2}/V_{in} = [(1 + R_2/R_3)/(1 + R_1/R_6)][S/R_4C_1]/D(S) \tag{2}$$

$$V_{LP}/V_{in} = V_{o3}/V_{in} = [(1 + R_2/R_3)/(1 + R_1/R_6)][1/R_4R_5C_1C_2]/D(S). \quad (3)$$

Where $D(S)$ is given by:

$$D(S) = S^2 + (S/R_4C_1)(1 + R_2/R_3)/(1 + R_6/R_1) + (R_2/R_3)/R_4R_5C_1C_2. \quad (4)$$

From Equations (1), (2), (3) and (4), cut off frequency ω_P and quality factor Q_p is given as:

$$\omega_P = \sqrt{(R_2/R_3)/(R_4R_5C_1C_2)} \quad (5)$$

$$Q_P = (1 + R_6/R_1/1 + R_2/R_3\sqrt{(R_2/R_3)/(R_4R_5C_1C_2)}. \quad (6)$$

B. Tow Thomas filter

Figure 2 represents the Circuit diagram of Tow Thomas filter. It also consists of three op-amps, two capacitor and six resistances. Band pass filter response appears at the output of op-amp A1 and Op-amp A2 and A3 outputs represent the low pass filter response. Output of A2 and A3 will be same if resistance r4 and r5 has selected with equal value.

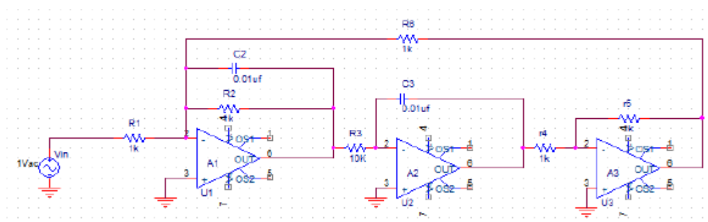

Figure 2. Tow Thomas filter structure.

The output of Op-amp A1, A2 and A3 is given as:

$$V_{BP}/V_{in} = V_{o1}/V_{in} = (S/R_1, C_2)/D(S) \quad (7)$$

$$V_{LP}/V_{in} = V_{o2}/V_{in} = (1/R_1R_3C_2C_3)/D(S) \quad (8)$$

$$V_{LP}/V_{in} = V_{o3}/V_{in} = (r_5/r_4)(1/R_1R_3C_2C_3)./D(S). \quad (9)$$

Denominator is given by:

$$D(S) = S^2 + S/R_2C_2 + r_5/r_4R_3R_6C_2C_3. \quad (10)$$

From equations (7) to (9), cut off frequency ω_P and $QF\, Q_P$ of Tow Thomas filter is given by:

$$\omega_P = \sqrt{(r_5/r_4)/(R_3R_6C_2C_3)} \tag{11}$$

$$Q_P = R_2C_2\sqrt{r_5/r_4R_3R_6C_2C_3}. \tag{12}$$

III. Simulation Result

Proposed circuit has been simulated using PSPICE to verify the theoretical analysis. Both filters are designed with cut of frequency 10 rad per second. In figure 1 i.e. KHN filter is designed with quality factor of 0.707 for this purpose the components values are selected as $R_4 = R_5 = 100K\Omega$, $R_1 = R_2 = R_3 = 1K\Omega$, $C_1 = C_2 = 0.001\mu F$ and $R_6 = 414\Omega$. The figure 3 shows simulated HP, BP and LP filter response.

Tow thomas filter is also designed for above said cut off frequency. The components are as $R_1 = R_2 = r_4 = r_5 = R_6 = 1K\Omega$, $R_3 = 10K\Omega$ and $C_2 = C_3 = 0.01\mu F$. The simulation results are shown in figure 4. Results verifies it bandpass filter and low pass filter response at its distinct output node.

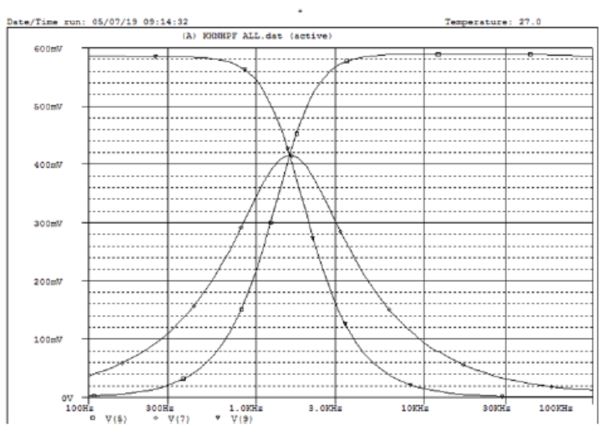

Figure 3. Simulated results of KHN filter.

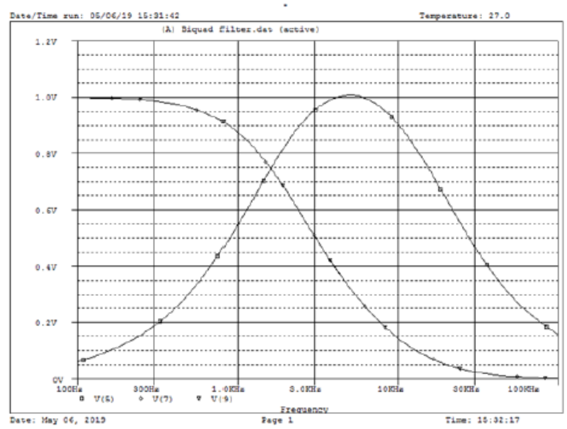

Figure 4. Simulated results of Tow Thomas filter.

IV. Conclusion

The comparison of Kerwin Huelsman and Newcomb and Tow Thomas filter is presented in this paper. The proposed structure uses equal number of op-amps and equal number of passive components for realization of different filter responses. The KHN filter produces HP, BP and LP responses simultaneously but Tow Thomas is able to produce Band pass and Low pass filter response only.

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