COMPARISON OF KHN BIQUADS USING DIAMOND TRANSISTORS AND BUFFERS IN VOLTAGE AND CURRENT MODE

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ABSTRACT

Design and computer analysis of the multifunctional second order active filters in the voltage and current mode is presented in this paper. Described structures realize high pass (HP), band pass (BP) and low pass (LP) transfer functions. Both circuit realizations are discussed (tuning, adjusting quality *Q*) and compared. Experimental verifications using PSpice simulation with professional macro-models are presented.

1. INTRODUCTION

The multifunctional active frequency filter of the Kerwin-Hueslman-Newcomb (KHN) [1] structure using classical opamps (OA) is well-known. Disadvantage is impossibility of electronic tuning. The second order structure is based on two integrators and input summation of specific feedback branches transferring signal from the integrator outputs. Advantage of this canonical structure of the follow the leader feedback is easy expansion to higher order transfer function [2]. Some modern integrated active blocks have electronic control of their parameters. It is possible to use this principle for adjusting of parameters of the filter. The typical active blocks [3], [4], [5] are the operational transconductance amplifiers (OTA-s), some types of commercially available current conveyors (CCII-s) or current multipliers, etc. These active elements allow realization of the KHN filter in standard voltage mode (VM) or current mode (CM) [6]. Typical integrated circuits representing the OTA-s are LT 1228 [7], OPA 660 (OPA 860) [8] and CCII-s for example EL 2082 [9].

2. DIAMOND TRANSISTOR

Because of excellent features as bandwidth, very high slew rate, transconductance, etc. the integrated circuit OPA 860 is called diamond transistor (DT) in some literature. The OPA 860 contain diamond transistor and voltage buffer and may be used as CCII+, OTA – DISO (dual voltage input and single current output), OTA – SISO (single voltage input and single current output), CFA (current feedback amplifier) respectively TIOA (transimpedance amplifier) or simply transistor [8]. DC control current I_{QADJ} or resistor R_{QADJ} between control pin and negative supply voltage gives possibility of changing of g_{m} (transconductance) value.

3. KHN FILTER USING DIAMOND TRANSITORS IN VOLTAGE MODE

The multifunctional filter in Fig. 1 has one voltage input and three voltage outputs (HP, BP and LP), similar circuits are in [8], [10]. Inverting amplifier using CCII+ (DT_1) and buffer make input summation. Following integrators contain CCII+ (DT_2, DT_3) and buffers. Alternative view: The integrators are based on buffered OTA – SISO if R_1 and R_2 belong to OTA. Buffers separate low impedance current input of DT_1 and next inputs of other circuits.

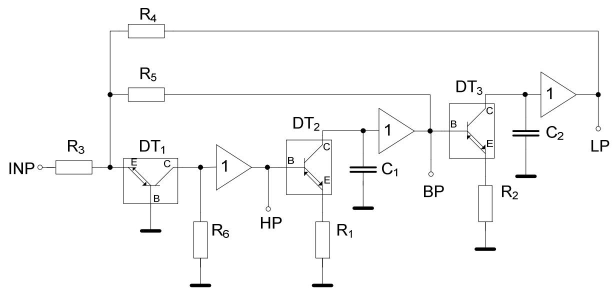


Figure 1: Multifunctional KHN filter using DT-s and buffers in VM.

If $R_3 = R_4 = R_6 = R$, then transfer functions are

$$K_{HP}(s) = \frac{-s^2}{s^2 + \dfrac{Rg_1}{R_5C_1}s + \dfrac{g_1g_2}{C_1C_2}} = \frac{-s^2}{s^2 + \dfrac{R}{R_5R_1^*C_1}s + \dfrac{1}{R_1^*R_2^*C_1C_2}}, \tag{1}$$

$$K_{BP}(s) = \frac{-\dfrac{g_1}{C_1}s}{s^2 + \dfrac{Rg_1}{R_5C_1}s + \dfrac{g_1g_2}{C_1C_2}}, \quad K_{LP}(s) = \frac{-\dfrac{g_1g_2}{C_1C_2}}{s^2 + \dfrac{Rg_1}{R_5C_1}s + \dfrac{g_1g_2}{C_1C_2}}, \qquad (2), (3)$$

where $R_1^* = \dfrac{1}{g_1} = R_1 + r_E = R_1 + \dfrac{1}{g_{me}}$. Parameter r_{E} is given by I_{QADJ} (R_{QADJ}) approximately 8 Ω for g_{me} = 125 mS [8].

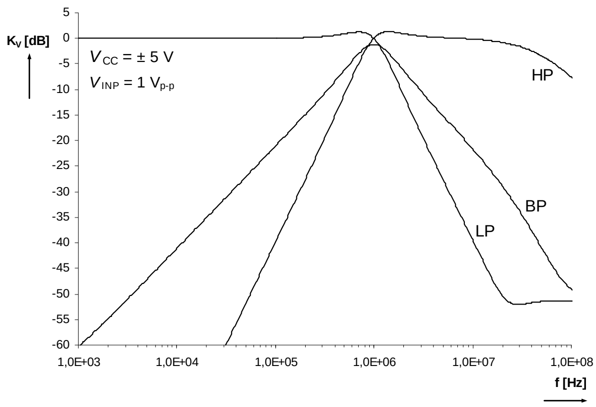


Figure 2: Magnitude responses

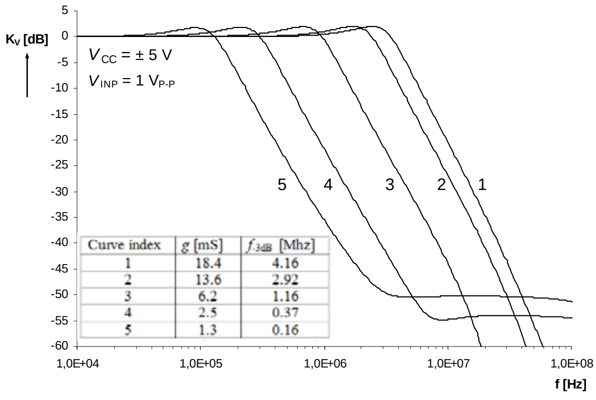
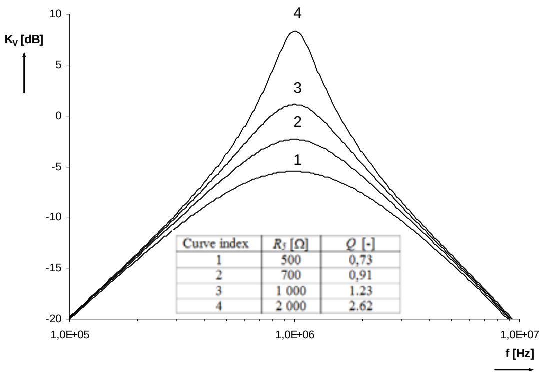


Figure 3: Tuning of the LP filter



Curve index	R_5 [Ω]	Q [-]
1	500	0,73
2	700	0,91
3	1 000	1.23
4	2 000	2.62

Figure 4: Adjusting of the quality factor

The characteristic frequency (f_C) an quality factor (Q) are

$$\omega_C = \sqrt{\frac{g_1 g_2}{C_1 C_2}}, \; Q = \frac{R_5 C_1}{R g_1}\sqrt{\frac{g_1 g_2}{C_1 C_2}}. \tag{4), (5}$$

Filter is designed for f_C = 1 MHz, Q = 1. If $C_1 = C_2 = C$ = 1 nF, R = 1 kΩ and $g_1 = g_2 = g$ we obtain (4) g = 6.2 mS. Magnitude response (simulation with macro-models OPA 860) is shown in Fig. 2 and Fig. 3 presents tuning of the LP filter. Adjusting of the quality factor by changing of R_5 is shown in Fig. 4

4. KHN FILTER USING DIAMOND TRANSISTORS IN CURRENT MODE

Multifunctional filter using CM is in Fig. 5. Similar circuits with multi-output OTA-s are in [2], [11]. The filter has HP, BP, LP and band reject (BR) current response. Due to necessity of distributions of the current responses to specific outputs and input summation (only node), seven DT-s is needed in the circuit.

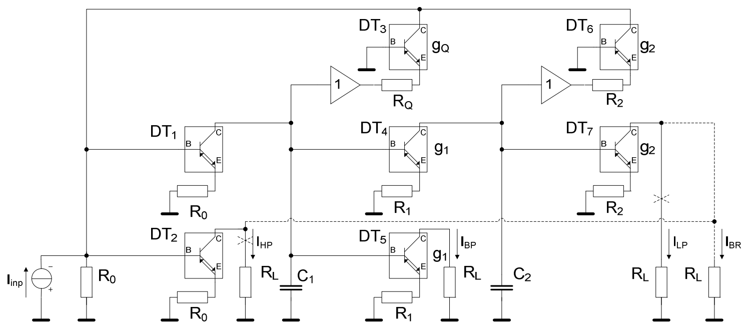


Figure 5: KHN filter using DT-s and buffers in CM

Transfer functions are similar as in previous case in voltage mode

$$K_{HP}(s) = \frac{s^2}{s^2 + \frac{g_Q}{C_1}s + \frac{g_1 g_2}{C_1 C_2}} = \frac{s^2}{s^2 + \frac{1}{R_Q^* C_1}s + \frac{1}{R_1^* R_2^* C_1 C_2}}, \tag{6}$$

$$K_{BP}(s) = \frac{\frac{g_1}{C_1}s}{s^2 + \frac{g_Q}{C_1}s + \frac{g_1 g_2}{C_1 C_2}}, \; K_{LP}(s) = \frac{\frac{g_1 g_2}{C_1 C_2}}{s^2 + \frac{g_Q}{C_1}s + \frac{g_1 g_2}{C_1 C_2}}, \; K_{BR}(s) = \frac{s^2 + \frac{g_1 g_2}{C_1 C_2}}{s^2 + \frac{g_Q}{C_1}s + \frac{g_1 g_2}{C_1 C_2}}. \tag{7), (8), (9}$$

Characteristic frequency has the same equation as in previous case (4), but quality factor is

$$Q = \frac{C_1}{g_Q}\sqrt{\frac{g_1 g_2}{C_1 C_2}}. \tag{10}$$

Using simplification $C_1 = C_2 = C$, $g_1 = g_2 = g$, quality factor is $Q = \frac{g}{g_Q}$. For keeping constant Q while f_C is varying, it is necessary to keep this ratio at the same value. Parameters of the filter design are same as in previous case (f_C, Q…) and $g = g_Q$ for $Q = 1$. All resistors are set to 56 Ω. Magnitude responses, tuning of the BP response and adjusting quality factor are shown in Fig. 6, Fig. 7 and Fig. 8. Comparison VM and CM HP response is in Fig. 9.

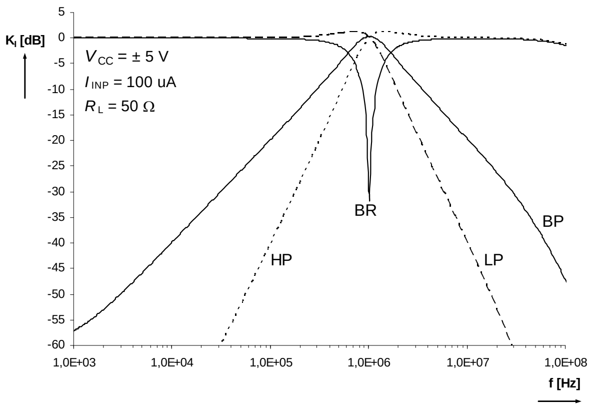


Figure 6: Magnitude responses

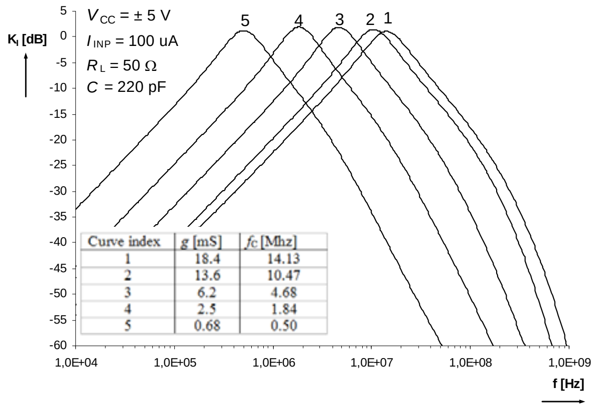


Figure 7: Tuning of the BP filter (for lower value $C = 220$ pF)

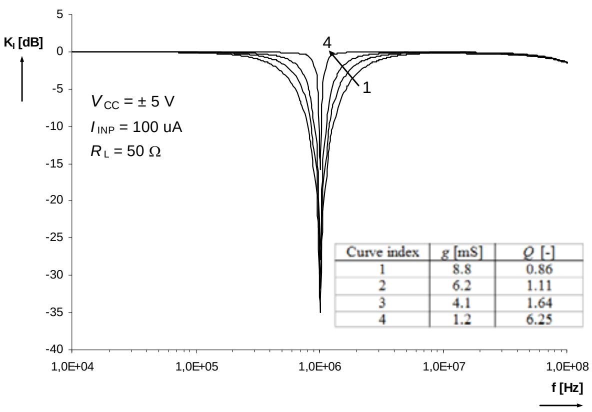


Figure 8: Adjusting of the quality factor

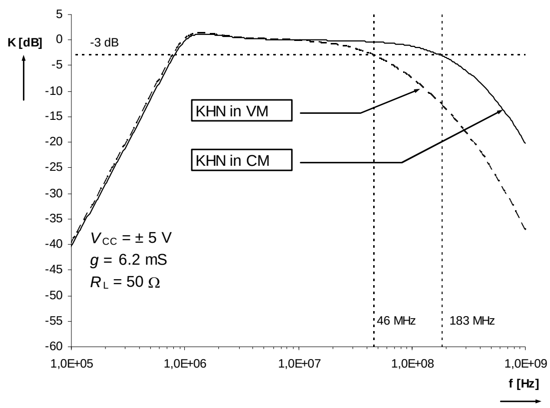


Figure 9: Comparison of the HP response in VM and CM

5. CONCLUSION

There were shown two realizations of the KHN multifunctional filter with diamond transistors OPA 860. Both realizations are simulated in PSpice and compared in frequency domain. Advantages of first realization in VM are simplicity, minimum passive and active elements and electronic tuning of f_C. Disadvantage is impossibility of electronic adjusting

Q (possible only adjusting floating resistor R_5) and parasite zero caused by low adjusted f_C of LP response (Fig. 3). Advantage of second realization in CM is greater bandwidth (over one hundred MHz), than in first case, see Fig. 9. Next advantages are grounded passive elements, easy electronic tuning f_C, adjusting Q and BR is easily obtained. Second realization need a lot of active blocks and passive elements (here R) which comes from principle of CM. This is big disadvantage for discrete realizations, but in IC [11] it is quite easy. The voltage to current conversion is practically needed at current input. Analyses confirm qualities of current mode.

6. ACKNOWLEDGEMENT

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