Design Biquad Filter with Electronic Controllable Quality Factor Using VDCC

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Abstract: This paper article presents a biquad frequency filter circuit. Standard frequency filter with five functions in voltage mode. Using the VDCC device, the voltage is ±5VDC with multiple-input, single-output in the form of a parallel passive RLC configuration. And with 2 capacitors and 2 resistors, it can filter five standard frequency functions without changing the structure: AP, BP, HP, LP, and BR. It has the outstanding feature of having a simple circuit structure. can adjust the quality factor by adjusting the bias current and controlling the natural frequency by adjusting the capacitor. It was found that the synthesis of the circuit was consistent with theory. Confirm the results by simulating the results using the PSPICE program.

Keywords — **Biquad filter, VDCC, Electronically Controllable, ABB, MISO.**

I. Introduction

Numerous applications for analog filters can be found in measuring systems, biomedical systems, electrical and electronic systems, and telecommunication systems [1]. The second-order or biquad filter in particular can realize many functions within the same topology. Multiple-input single-output (MISO) filters are among the most often used biquad filters. The output filter functions include low pass filter (LP), high pass filter (HP), band pass filter (BP), band reject filter (BR), and all-pass filter (AP). The primary purpose of the biquad filter in this filtering arrangement is to serve as a universal filter [2-6]. For the synthesis and design of the biquad filter, a variety of techniques have been put forth, including two integrator loop design [7], series RLC topologies [8], parallel RLC circuits [9-10], etc.

A popular design of multi-function frequency filter circuits will have more advantages than the general frequency filter circuit design [11-13]. Modern filter circuit design techniques favor the use of active building block (ABB) formats to enable precise control of parameters. and effective in modern research work [14-15]. From a variety of analog circuits, ABB devices include a device that is of interest to research such as the Voltage differencing current conveyor (VDCC) [16-18]. The VDCC can transmit both voltage and current signals simultaneously. This unique feature allows circuit designers to create compact electronic circuits. It saves energy and has high efficiency It addresses the challenges posed by many commercial applications, due to its electronically adjustable gain feature.

Realizing multifunction biquad filters has garnered increasing attention in recent times. Nevertheless, more than one active element is used in the biquad filters in [19-22], and the Q is not adjusted [21].

A This paper describes a biquad filter's design circuit in voltage mode using only a single VDCC as a MISO of a parallel passive RLC and an active device, two capacitors, and two resistors. It has the distinctive feature of being able to change the frequency filtering in five functions. Without having to change the structure of the circuit, including AP, BP, HP, LP, and BR, the quality factor can be adjusted electronically at bias current, and the natural frequency value can be adjusted by adjusting the capacitor value.

II. Procedures For Paper Submission

A. Overview of VDCC

Based on the symbols presented, this is VDCC as shown in Fig. 1. The components of VDCC are Active with 6 terminals, The *P*, *N* terminals as input terminals with high impedance, the *Z*, W_P, W_N connectors serving as high impedance output terminals. But the direction of the current W_P will be positive, while the W_N terminal will have negative current. The *X* terminal is a terminal that can be both. The VDCC equivalent circuit is depicted in Fig. 2.

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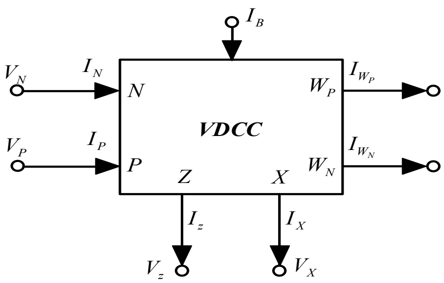

Fig. 1 Symbol of VDCC.

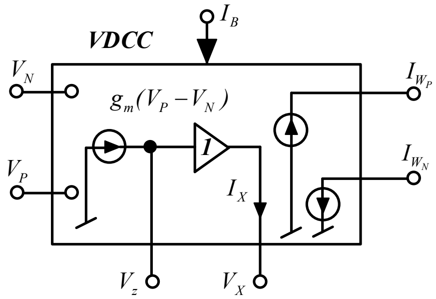

Fig. 2 Equivalent circuit.

The following will provide a hybrid matrix description of VDCC electrical properties:

$$\begin{bmatrix} I_N \\ I_P \\ I_Z \\ V_X \\ I_{W_P} \\ I_{W_N} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & -g_m & 0 & g_m \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \\ -1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} I_X \\ V_N \\ V_Z \\ V_P \end{bmatrix} \tag{1}$$

The Parameter g_m of the transconductance amplifier is obtained as $g_m = \frac{I_B}{2V_T}$

B. Proposed biquad filter

Numerous methods have been suggested for creating the biquadratic active filter. The parallel RLC design shown in Fig. 3 is the basis for the biquad filter synthesis used in this paper.

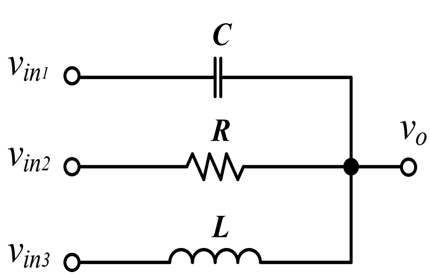

Fig. 3 Parallel RLC

From the Fig. 3 the output voltage is obtained as follows:

$$V_O = \frac{s^2 V_{in1} + s\frac{1}{RC}V_{in2} + \frac{1}{LC}V_{in3}}{s^2 + s\frac{1}{RC} + \frac{1}{LC}} \tag{2}$$

The study describes a biquad filter that is multipurpose and was created using the parallel RLC circuit concept. The inductance simulators (L_{eq}) using just two passive elements and one VDCC are shown in Fig. 3 [23]. The value of the L_{eq} is obtained as follows:

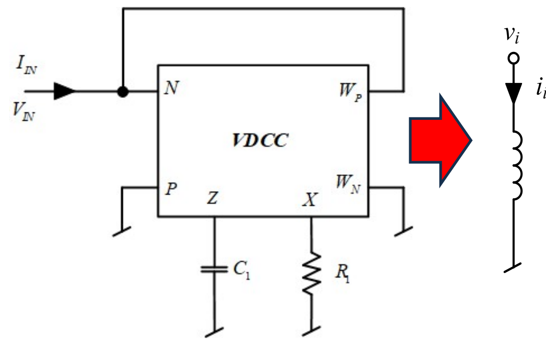

Fig. 4 Inductance L_{eq} [23]

$$L_{eq} = \frac{C_1 R_1}{g_m} \tag{3}$$

By joining capacitors C_1 and R_1 to the input node of the inductance simulator in Fig. 4 , we can apply the parallel RLC circuit concept shown in Fig 3 , the design of the biquad filter as shown in Fig 5.

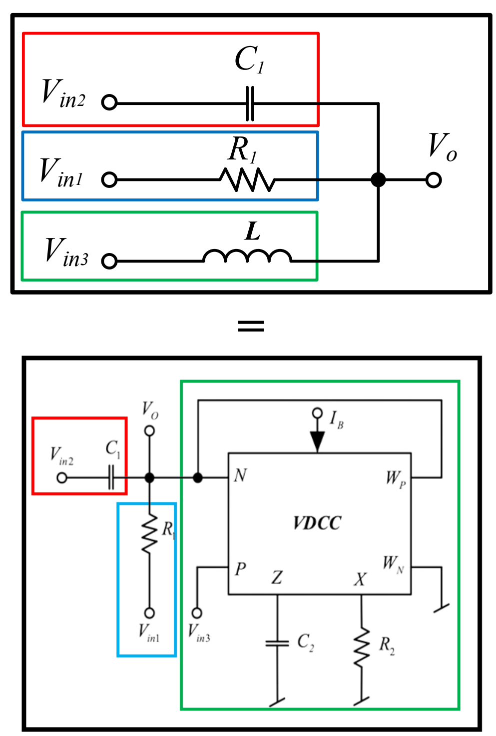

Fig. 5 Biquad filters.

Fig. 6 shows a flexible biquad filter that employs two resistors, two capacitors, and one VDCC. With C_2 and R_2 connected to ground, there are three input terminals, V_{in1}, V_{in2}, and V_{in3}, a single output terminal of V_O with terminal I_B used as a bias current.

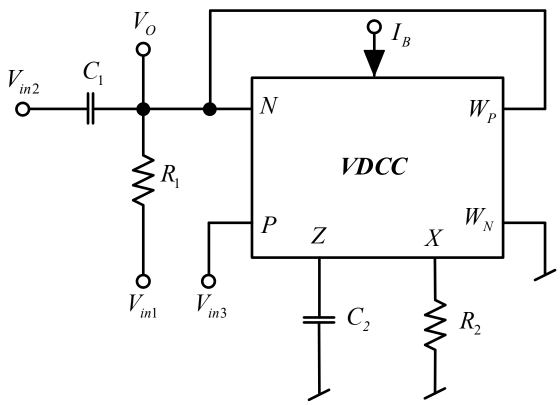

Fig. 6 Proposed biquad filters.

From Fig.4 the output voltage of the biquad filter according to (4)

$$V_O = \frac{S\frac{1}{C_1R_1}V_{in1} + S^2V_{in2} + S\frac{g_m}{C_1C_2R_2}V_{in3}}{S^2 + S\frac{1}{C_1R_1} + \frac{g_m}{C_1C_2R_2}} \quad (4)$$

From (4), the natural frequency (ω_c) will be obtained according to (5) and the quality factor (Q) according to (6), with $R_1 = R_2 = R$ and $C_1 = C_2 = C$.

$$\omega_c = \frac{1}{C}\sqrt{\frac{g_m}{R}} \quad (5)$$

$$Q = \sqrt{g_m R} \quad (6)$$

The five suggested universal filtering responses are shown in Table 1. When the input is connected to the ground as 0, and the input voltage signal is connected as 1. Realize the AP for V_{in1}=-1, V_{in2}=1, and V_{in3}=1 the output voltage according to (7)

$$V_O = \frac{-s\frac{1}{C_1R_1}V_{in1} + s^2V_{in2} + s\frac{g_m}{C_1C_2R_2}V_{in3}}{s^2 + s\frac{1}{C_1R} + \frac{g_m}{C_1C_2R_2}} \quad (7)$$

If realize the BP for V_{in1}=1, V_{in2}=0, and V_{in3}=0 the output voltage according to (8)

$$V_O = \frac{s\frac{1}{C_1R_1}V_{in1}}{s^2 + s\frac{1}{C_1R} + \frac{g_m}{C_1C_2R_2}} \quad (8)$$

If realize the HP for V_{in1}=0, V_{in2}=1, and V_{in3}=0 the output voltage according to (9)

$$V_O = \frac{s^2V_{in2}}{s^2 + s\frac{1}{C_1R} + \frac{g_m}{C_1C_2R_2}} \quad (9)$$

If realize the LP for V_{in1}=0, V_{in2}=0, and V_{in3}=1, the output voltage according to (10)

$$V_O = \frac{s\frac{g_m}{C_1C_2R_2}V_{in3}}{s^2 + s\frac{1}{C_1R} + \frac{g_m}{C_1C_2R_2}} \quad (10)$$

If realize the BR for V_{in1}=0, V_{in2}=1, and V_{in3}=1. the output voltage according to (11)

$$V_O = \frac{s^2V_{in2} + s\frac{g_m}{C_1C_2R_2}V_{in3}}{s^2 + s\frac{1}{C_1R} + \frac{g_m}{C_1C_2R_2}} \quad (11)$$

TABLE I
THE REALIZABLE OF BIQUAD FILTERS.

Response Filter	*Vin1*	*Vin2*	*Vin3*
AP	-1	1	1
BP	1	0	0
HP	0	1	0
LP	0	0	1
BR	0	1	1

III. SIMULATED RESULTS

To prove the proposed five-filter biquad frequency filter circuit. LM13700 [24] and AD844 [25], which are created as VDCC supplied with ±5VDC, are used in a variety of PSPICE simulations to test the functions of the proposed filter. There will be a value for passive accessories, $C_1=C_2=C=1.5\,nF$, $R_1=R_2=R=1k\Omega$, and the current bias as 50μ*A*. The angular frequency in (5) (f_0=104.04kHz) is the goal of the suggested filter's design and the quality factor in (6) the quality factor, (Q≈1). The suggested filter's phase and frequency responses, as displayed in Figs. 7 –1 1. The AP show in Fig. 7, the BP show in Fig. 8, the HP show in Fig. 9, the LP show in Fig. 10, and the BR show in Fig. 11. From (4), the angular frequency (f_o) can be adjusted by the value of the capacitor. The quality factor (Q) in (6) can be electronic control achieved through g_m shown in Figs.12-14.

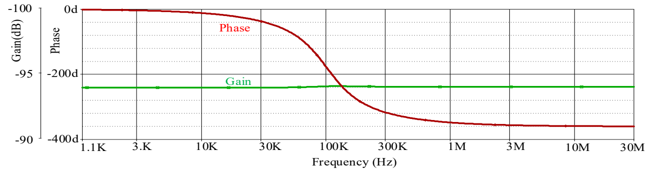

Fig. 7 Gain and phase response of AP

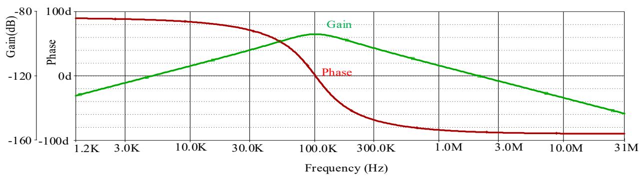

Fig. 8 Gain and phase response of BP

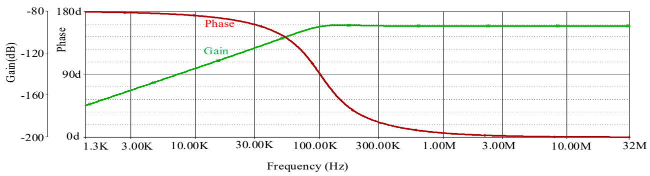

Fig. 9 Gain and phase response of HP

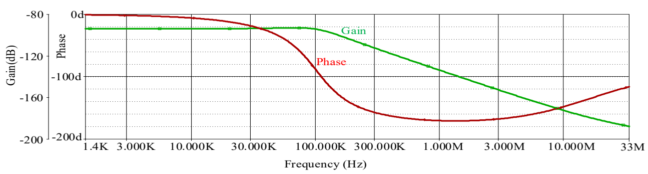

Fig. 10 Gain and phase response of LP

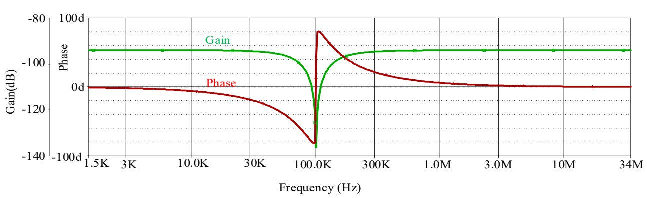

Fig. 11 Gain and phase response of BR

From Fig. 12, which shows the Q value response results, controlled by the I_B current setting is set to three values, *50uA*, *60uA* and *70uA*. From the design of this circuit in (5), the tuning of ω_c can also be adjusted, without affecting the Q value from Fig. 13 by adjusting the capacitor value. Three values are set 1*nF*, 1.5*nF*, and 2*nF*. From simulation. The natural frequency values are 75.86*kHz,* 102.33*kHz,* and 151.36*kHz*, respectively. Fig. 14 is a comparison of the input and output signals for AP filtering by entering the input frequency value, is a sinusoidal signal of 179.6*kHz*.

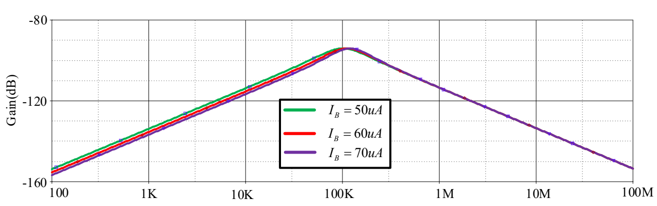

Fig. 12 BP response adjusting the current bias three value.

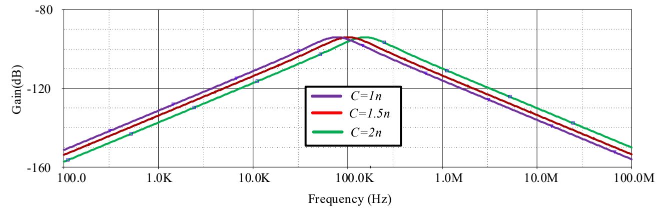

Fig. 13 BP response adjusting the capacitor three value.

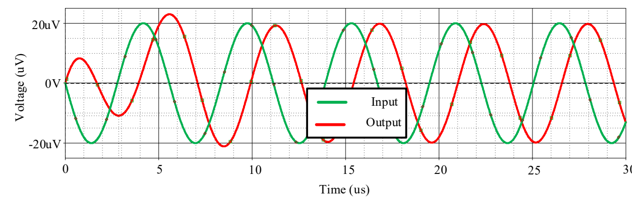

Fig. 14 AP response at frequency 179.6kHz.

IV. Conclusion

This research article presents Five standard biquad filters in voltage mode. Using the VDCC device, the voltage is ±5VDC with multiple-input, single-output in the form of a parallel passive RLC configuration and has 2 capacitors and 2 resistors. Frequency filtering can be selected by entering a preset voltage. The quality factor can be adjusted electronically at bias current, and the natural frequency value can be adjusted by adjusting the capacitor value. From the results of the simulation experiment using the PSPICE program, it was found that the results responded to all 5 functions, which were well confirmed according to the designed theory.

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