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Multiple-input Single-output Biquadratic Filter with Adjustable Amplitude

***Abstract**. This article introduces a latest multiple-input single-output (MISO) biquadratic filter by using MO-CCCCTA, grounded resistor and capacitors. The proposed MISO construction consists of 3 inputs and 1 output; the output responses of filter can choose by using digital process. It allows five function of biquadratic filter with same circuit construction. Additionally, the output signals' amplitude can be changed by biasing of current which provides no effects on the quality factor and natural frequency. The performance of proposed circuits can be proved by PSPICE simulation program; the results are good approval with the theoretical prediction.*

Streszczenie.** W artkule przedstawiono bikwadratowy filtr o wielu wejściach i jednym wyjściu MISO. Do projektu filtru wykorzystano układ MO-CCCCTA, uziemiony rezystor i kondensatory. Filtr umożliwia pracę w wielu trybach I przy kontrolowanym prądzie. **Filtr bikwadratowy o wielu wejściach I jednym wyjściu z ustalanym prądem wyjściowym

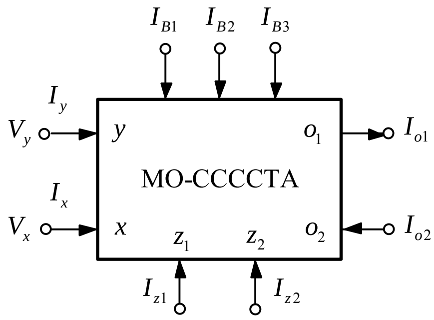
Key words : MISO Filter, Adjustable Amplitude, MO-CCCCTA.
Słowa kluczowe : filtr bikwadratowy, układ MO-CCCCTA.

Introduction

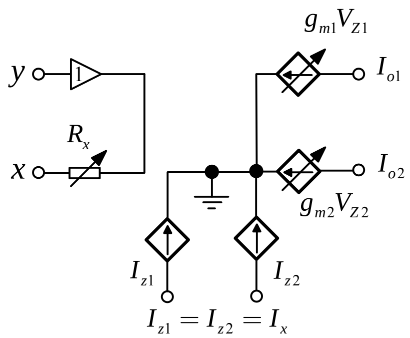
The filter is one of circuits providing appropriate qualifications variously used for electrical and electronic applications; such as, communications, instrumentation and control system [1]. Then, there were papers concerning the designs of filter circuits by introducing the current-mode technique. It is stated that the circuit designed from current-mode technique can give the advantageous for designing; larger dynamic range, spontaneously wide bandwidth, higher slew-rate, higher linearity and lower rate of power consumption [2-3].

MISO filter is one of second-order filter circuits that provides standard function; low-pass (LP), high-pass (HP), band-pass (BP), band-reject (BR) and all-pass (AP) by selecting condition of input currents (digital selection). Normally, the MISO filter consists of three-inputs and one-output [4]. So, a number of MISO current-mode biquadratic filters using active building block and new prominent point for designing circuit has been presented. Electronic control of natural frequency ω_0 and quality factor Q_0 are one of good point of designing MISO filter, it uses new active device which are controlled the transconductance or parasitic resistance by controlling current such as OTA [5], CDTA [6-7] and CCCDTA [8-9]. Some techniques present how to implement passive devices; a circuit uses grounded capacitor/resistor which is agreeable for further fabrication in integrated circuits [5-12]. Moreover, a number of devices must be reduced. The circuit used more devices for bringing higher of power consumption. Therefore, the designing of circuit by using one active element has been exhibited [8-12]. Though there were papers previously introducing the filter circuits; none of them reported the filter circuits that are controlling the amplitude of signal.

The intention of this research is to suggest the simple current-mode MISO filter along with new good point of filter circuit. The universal filter can adapt amplitude of output signal by controlling bias current then the output current can be accrued without adding current amplifier. It is such a good point of the presented filter to connect to any circuits in electrical and electronic applications. Furthermore, the MISO circuit has simple construction; it uses one active component namely MO-CCCCTA and 3 passive devices. The output port of MO-CCCCTA was used to an output of filter circuit, it is appropriate to cascade connection in current-mode circuits which is capable of directly driving load without using buffering device. Moreover, it uses an only grounded component that is suitable for development into an integrated circuit [13-15].



a) symbol of MO-CCCCTA



b) equivalent circuit of MO-CCCCTA.

Fig.1. Symbol and equivalent circuit of MO-CCCCTA

Basic concept of MO-CCCCTA

In 2007, a new active building block namely CCCCTA is presented for analogue signal processing [16]. Multiple-output current-controlled current conveyor transconductance amplifier (MO-CCCCTA) was modified from CCCCTA by adding the transconductace (g_m) at output terminal. The characteristics of ideal MO-CCCCTA can be indicated in equation (1). From equation (1), R_x is parasitic resistance at x terminal, the parameter R_x, g_{m1} and g_{m2} can be explained in equation (2).

(1) $$I_{z1} = I_{z2} = I_x \quad , \quad V_x = R_x I_x + V_y$$
$$I_{o1} = g_{m1} V_{z1} \quad , \quad I_{o2} = g_{m2} V_{z2}$$

(2) $$R_x = \frac{V_T}{2I_{B1}}, \quad g_{m1} = \frac{I_{B2}}{2V_T}, \quad g_{m2} = \frac{I_{B3}}{2V_T}$$

V_T is the thermal voltage. I_B is bias current used to control parasitic resistance/tranconductance value of MO-CCCCTA, the symbol and equivalent circuit are demonstrate in Fig.1. Furthermore, the BJT internal construction is demonstrated in Fig.2.

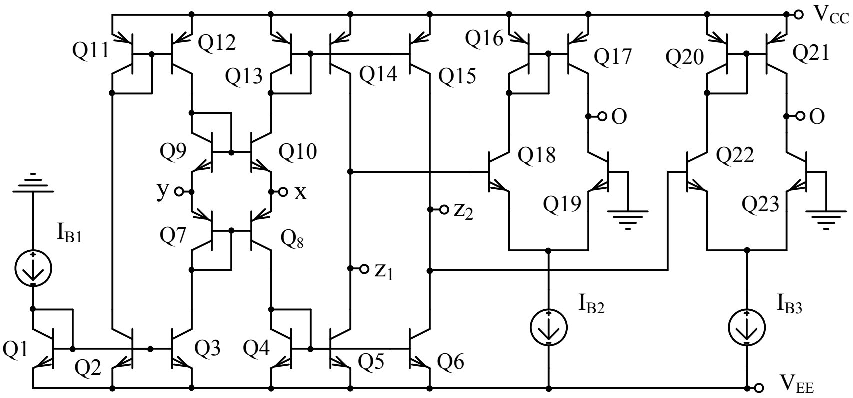


Fig.2. Circuit construction of MO-CCCCTA

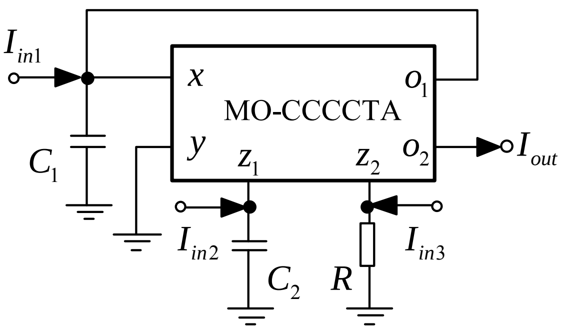


Fig.3. The proposed current-mode MISO biquadratic filter

Table 1. The I_{in1}, I_{in2} and I_{in3} values selection for filter function :

Input selections			Filter Responses
I_{in1}	I_{in2}	I_{in3}	I_{out}
0	1	0	LP
1	1	1	HP
1	0	0	BP
1	0	1	BR
2	0	1	AP

Multiple-Input Single-Output Universal Filter

The proposed current-mode MISO biquadratic filter illustrates in Fig.3, it includes 1 MO-CCCCTA, 2 capacitors and 1 resistor. The equation of characteristic of filter can be illustrated in equation (3).

(3) $$I_{out} = k\frac{-s\frac{1}{R_x C_1} I_{in1} - \frac{g_{m1}}{R_x C_1 C_2} I_{in2} + \left(s^2 + s\frac{1}{R_x C_1} + \frac{g_{m1}}{R_x C_1 C_2}\right) I_{in3}}{s^2 + s\frac{1}{R_x C_1} + \frac{g_{m1}}{R_x C_1 C_2}}$$

From equation (3), the condition of input currents I_{in1}, I_{in2} and I_{in3} was selected by Table 1, it can give output functions of biquadratic filter by proposing the same circuit construction. The current gain (k), ω_0 and Q_0 are indicated as

(4) $$k = Rg_{m2} = \frac{RI_{B3}}{2V_T}$$

(5) $$\omega_o = \sqrt{\frac{g_{m1}}{R_x C_1 C_2}} = \frac{1}{V_T}\sqrt{\frac{I_{B1} I_{B2}}{C_1 C_2}}$$

(6) $$Q_o = R_x C_1 \sqrt{\frac{g_{m1}}{R_x C_1 C_2}} = \frac{C_1 V_T}{2I_{B1}}\sqrt{\frac{I_{B1} I_{B2}}{C_1 C_2}}$$

From equations (4) – (6) found that the amplitude of current can change by adjusting bias current I_{B3} and R without influence to the ω_0 and Q_0.

Analysis of voltage/current transfer and parasitic components

For non-ideal case, the characteristic equation of MO-CCCCTA in equation (1) is

(7) $$I_{z1} = \alpha_1 I_x \ , \quad I_{z2} = \alpha_2 I_x \ , \quad V_x = R_x I_x + \beta V_y$$
$$I_{o1} = \gamma_1 g_{m1} V_{z1} \ , \quad I_{o2} = \gamma_2 g_{m2} V_{z2}$$

The parameters β, γ_1 and γ_2 are the voltage transfer, α_1 and α_2 are the current transfer. These parameters were changing on the intrinsic impedances and temperatures. In addition, MO-CCCCTA consists of parasitic elements R_x, R_y, C_y, R_z, C_z, R_o and C_o, as indicated in Fig.4 equations (3) – (6).

$$I_{out}=k\frac{-\left(s\alpha_1\frac{R_{z1}\left(C_2+C_{z1}\right)+1}{R_xR_{z1}\left(C_1+C_{o1}\right)\left(C_2+C_{z1}\right)}\right)I_{in1}-\left(\frac{\alpha_1\gamma_1 g_{m1}}{R_x\left(C_1+C_{o1}\right)\left(C_2+C_{z1}\right)}\right)I_{in2}+\left(s^2+s\left(\frac{R_{o1}R_{z1}\left(C_2+C_{z1}\right)+R_xR_{o1}\left(C_1+C_{o1}\right)+R_xR_{z1}\left(C_2+C_{z1}\right)}{R_xR_{o1}R_{z1}\left(C_1+C_{o1}\right)\left(C_2+C_{z1}\right)}\right)+\left(\frac{\alpha_1\gamma_1R_{o1}R_{z1}g_{m1}+R_{o1}+R_x}{R_xR_{o1}R_{z1}\left(C_1+C_{o1}\right)\left(C_2+C_{z1}\right)}\right)\right)I_{in3}}{s^2+s\left(\frac{R_{o1}R_{z1}\left(C_2+C_{z1}\right)+R_xR_{o1}\left(C_1+C_{o1}\right)+R_xR_{z1}\left(C_2+C_{z1}\right)}{R_xR_{o1}R_{z1}\left(C_1+C_{o1}\right)\left(C_2+C_{z1}\right)}\right)+\left(\frac{\alpha_1\gamma_1R_{o1}R_{z1}g_{m1}+R_{o1}+R_x}{R_xR_{o1}R_{z1}\left(C_1+C_{o1}\right)\left(C_2+C_{z1}\right)}\right)} \tag{8}$$

$$k=\frac{\alpha_2\gamma_2 g_{m2}RR_{z2}}{\alpha_1\left(sC_{z2}RR_{z2}+R+R_{z2}\right)} \tag{9}$$

$$\omega_0=\sqrt{\frac{\alpha_1\gamma_1R_{o1}R_{z1}g_{m1}+R_{o1}+R_x}{R_xR_{o1}R_{z1}\left(C_1+C_{o1}\right)\left(C_2+C_{z1}\right)}} \tag{10}$$

(11)

$$Q_0=\left(\frac{\left(R_xR_{o1}R_{z1}\left(C_1+C_{o1}\right)\left(C_2+C_{z1}\right)\right)\left(\sqrt{\frac{\alpha_1\gamma_1R_{o1}R_{z1}g_{m1}+R_{o1}+R_x}{R_xR_{o1}R_{z1}\left(C_1+C_{o1}\right)\left(C_2+C_{z1}\right)}}\right)}{R_{o1}R_{z1}\left(C_2+C_{z1}\right)+R_xR_{o1}\left(C_1+C_{o1}\right)+R_xR_{z1}\left(C_2+C_{z1}\right)}\right)$$

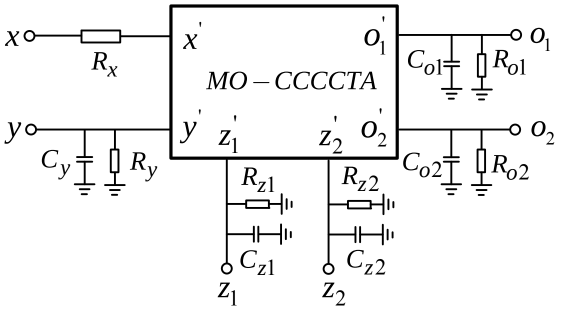


Fig.4. Parasitic component of MO-CCCCTA.

Simulation results

To investigate, the constancy of MISO filter was introduced, the PSPICE program is to be used. The parameter of transistor in [17] is used for the simulation and the implementation of MO-CCCCTA internal circuit construction shows in Fig. 3. The simulation was set with $\pm1.5\mathrm{V}$, $I_{B1}=I_{B2}=100\mu\mathrm{A}$, $I_{B3}=50\mu\mathrm{A}$, $R=1\mathrm{k}\Omega$ and $C_1=C_2=1\mathrm{nF}$. Fig. 5. demonstrates the biquadratic functions of MISO filter at the natural frequency are about $570.164\mathrm{kHz}$. Fig.6 displays band-pass function which is setting I_{B3} are $50\mu\mathrm{A}$, $100\mu\mathrm{A}$, $150\mu\mathrm{A}$, $200\mu\mathrm{A}$, $250\mu\mathrm{A}$ and $300\mu\mathrm{A}$, respectively. It is especially to demonstrate adjusting of amplitude of filter, by setting I_{in2} with $10\mu\mathrm{A}$ sine wave signal at natural frequency ($I_{in1}=I_{in2}=0\mu\mathrm{A}$; BP responses) become and by adjusting values of I_{B3} to $100\mu\mathrm{A}$, $150\mu\mathrm{A}$, $200\mu\mathrm{A}$, $250\mu\mathrm{A}$ and $300\mu\mathrm{A}$, respectively. The signal amplitude is adjusted by bias current of MO-CCCCTA at the total harmonic distortion (THD) of I_{out} is about 0.650% ; the result is represented in Fig.7. Moreover, Mote-Carlo simulation is employed to consider the stillness of MISO filter. The bata of transistors (β), capacitance of capacitor (C_1, C_2) and resistance of resistor (R) are deviated 5%, the consequence of simulation is demonstrated in Fig.8..

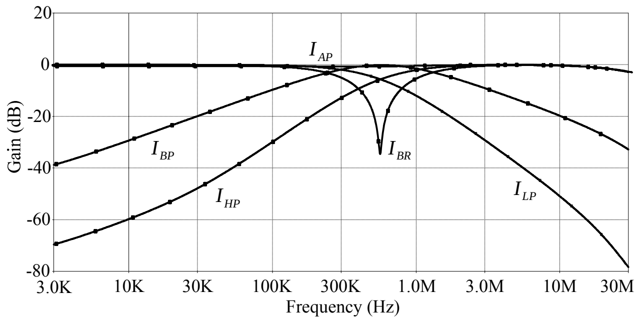


Fig.5. Output functions of the MISO filter.

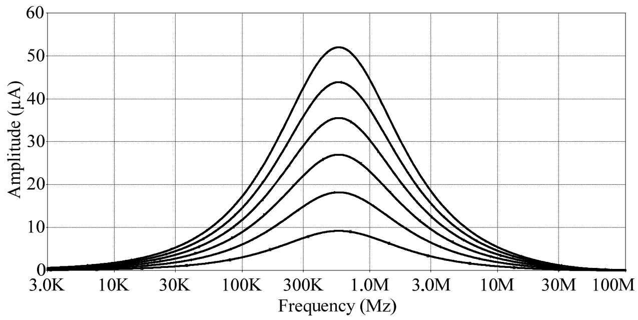


Fig.6. Amplitude adjust of band-pass by varying values of I_{B3} .

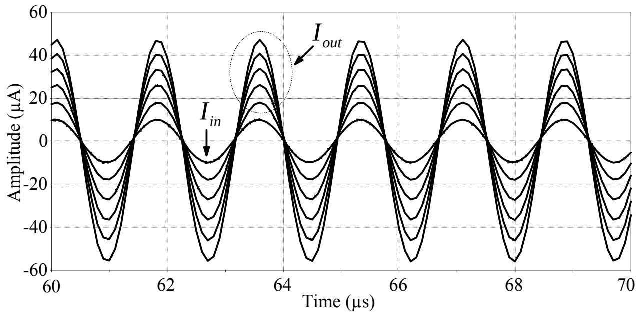
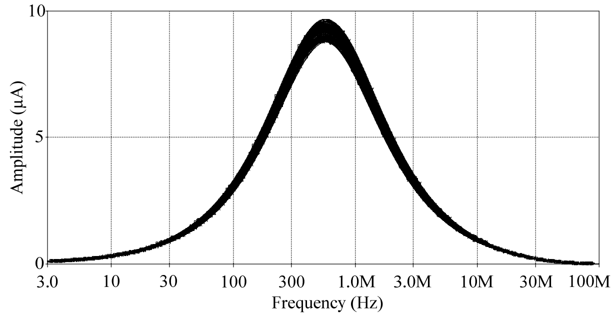


Fig.7. Simulation result of sinusoidal input signal.

a)



b)

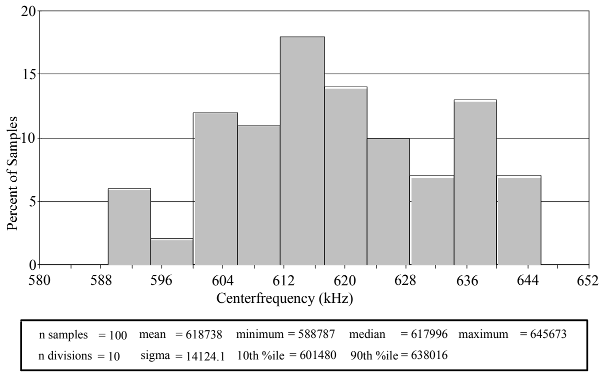


Fig.8. Result of Monte-carlo simulation

Conclusion

This research study proposes the MISO current-mode biquadratic filter. The filter can give 5 functions of biquadratic filter and it is able to adjust the amplitude of current by adjusting bias current of MO-CCCCTA which is the special point of this work. The natural frequency, quality factor and amplitude of current signals are controlled with electronic method or biasing current. Apart from that, the proposed MISO filter has not complicated construction because its uses 1 active device. PSPICE simulation was applied to substantiate the theoretical method.

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