Dual Input All-Pass Networks Using MO-OTA and its Application

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Abstract—This paper presents a realization of grounded passive elements first order all-pass networks using a multiple-output operational transconductance amplifier (MO-OTA) and three grounded passive elements. The proposed circuit is operated in current-mode for the good benefit as well as high output impedance and cascadability. Therefore, it can be directly employed as a subsystem of monolithic circuit without additional matching circuits. Furthermore, a new quadrature oscillator is presented as an application for confirmed the theory and realistic practically. The PSpice simulation results verifying of theoretical are also included.

I. INTRODUCTION

Current mode signal processing circuits have recently demonstrated many advantages over their voltage mode counterparts including increased bandwidth, higher dynamic range and better suitability for operation in reduced supply environment [1]. In many papers, current mode circuits are presented by using CCII based [2]-[4]. Unfortunately, CCII does not have a differential input. The OTA is a familiar device for voltage-mode and current-mode applications. The OTA provides a highly linear electronic tunability and a wide frequency range. Moreover, OTA-based circuits require no resistors and therefore, are suitable for monolithic implementation and small die area [5]-[6]. The MO-OTA has been proposed in previous paper [7]. From the strong points, due to many output of OTA, the MO-OTA has more flexible to use in term of a modern analog signal processing as well.

The previously presented all-pass filter topologies employing conventional OPAMP [8-9] that ensure the low bandwidth and voltage-mode are achieved. The FTFN [10], Current Differencing Buffer Amplifier (CDBA) [11] and CCII [2]-[4] are also introduced but some of these reports suffer from floating passive components. The floating components are trade-off in the practical realizations, parasitic capacitances, bandwidth restrictions, complicated adjustment. The floating node passive devices have to avoid in the design for minimized the error reasons.

This paper presents the design of all grounded passive elements all-pass network using one MO-OTA and three grounded passive elements. The presented topologies can be designed by using both in CMOS or bipolar technology. The circuits comprise phase lead and phase lag Moreover, current gain can be adjust by a transconductance (gm) through I_{abc}.

II. THEORY AND PRINCIPLE

The OTA is a simple device that has been found in many recently reports. The benefit of OTA is a voltage and current mode realization can be done with a simple structure. The tunable characteristic is a strong excellent point for the future applications. The single output OTA is a conventional device that might be has some restrictions on the design. The modification of OTA can be eliminated that restrictions by extended the output port namely a multiple-output OTA (MO-OTA).

A. Multiple-output operational transconductance amplifier

The OTA has input as voltage and current output. The simple structure of the well-known OTA, having used only four transistors and current source. Figure 1 shows the symbol of MO-OTA. The output current of MO-OTA yields

$$I_o = \pm g_m(V_+ - V_-)$$

The transconductance $g_m$ is variable by bias current $I_{abc}$. Note that the transconductance base on CMOS and bipolar technology are equal to $(\beta I_{abc})/2$ and $I_{abc}/2V_T$ respectively. A possible implementation of OTA using multiple output operation transconductance amplifiers was proposed [12].

Fig.1. (a) CMOS MO-OTA structure and (b) symbol
The transconductance of above CMOS OTA can be expressed as:

$$g_m = \sqrt{\beta I_{dc}} = \sqrt{\mu N W L}$$

(2)

The realization of the proposed all-pass network filter using OTA is shown in Fig.2. The circuit comprises one MO-OTA, 2 grounded resistors and a grounded capacitor. From this point of view, the proposed structure is simpler than the other existing all-pass realizations [2]-[4]. In Fig.2(a) and Fig.2(b), the all-pass transfer functions are realized as eq.3 and eq.4 respectively.

Gain ($K$) is a constant and defined as

$$K = \frac{g_m R}{2}$$

(5)

From Eq.(3), the phase shift are varying between 180° to 0° while (4), the phase shift are varying between 0° to -180°. The pole frequency ($\omega_p$) can be expressed as

$$\omega_p = \frac{1}{RC}$$

(6)

The passive sensitivities can be obtained as

$$S_{R}^{00} = S_{C}^{00} = -1$$

(7)

In Fig. 2, it can be seen that the output impedance of the circuit is very high due to the OTA current output; hence it can be directly interconnection with load or any current mode circuits without the buffer circuit. The output current gain can be adjusted by $g_m$ through the bias current $I_{dc}$.

The circuit model of a non-ideal OTA operating in saturation region is shown in figure 3, where $C_i$ is the input capacitance, $C_o$ is the output capacitance and $G_o$ is the output conductance. Generally $G_o$ is less than $g_m$. The proposed circuits in figure 2(a) and 2(b) can be express in term of high frequency as eq(8) and eq(9), respectively.

From (8)-(9) imply that the parasitic capacitances affect to the poles and zeros of the transfer function at the high frequency.

III. QUADRATURE OSCILLATOR APPLICATION

The quadrature oscillator based on all-pass network is shown in Fig. 4. The circuit consists of phase-lead and phase-lag all-pass network configurations in Figs. 2(a) and (b). In Fig. 4, the circuit can be oscillated due to the loop-gain is unity, the transfer function can be expressed as

$$T_1(s)T_2(s) = K_1K_2 \frac{1-sC_2R_2}{1+sC_2R_2} \frac{sC_1R_1-1}{sC_1R_1+1} = 1$$

(10)

Where the constants are $K_1=g_m R_1/2$ and $K_2=g_m R_2/2$, loop-gain is unity independent with the any transconductances, $g_m$. The phase of first all-pass network is written as

$$\phi(\omega) = -2\tan^{-1}(\omega \tau) , \tau_1 = C_1 R_1$$

(11)

Likewise, the phase of second all-pass network is

$$\phi(\omega) = 180° - 2\tan^{-1}(\omega \tau_2) , \tau_2 = C_2 R_2$$

(12)
The frequency of oscillation can be given as

\[ \omega = \frac{1}{\sqrt{C_1 C_2 R_1 R_2}} \]  

(13a)

or

\[ \omega = \frac{1}{\sqrt{\tau_1 \tau_2}} \]  

(13b)

From (13), the oscillation frequency is depended on passive elements, \( R_1, R_2, C_1 \) and \( C_2 \). The components are defined identically as \( R_1 = R_2 = R \) and \( C_1 = C_2 = C \). The oscillation frequency is actually becomes

\[ \omega = \frac{1}{\sqrt{CR}} \]  

(14)

### IV. Simulation Results

In order to confirm the validity of the proposed circuits, PSpice simulation was carried out. The parameters used in simulation are 0.5\( \mu \)m CMOS model obtained through MIETEC as listed in table 1. The W/L parameters of MOS transistors are assumed of 20\( \mu \)m/1\( \mu \)m for NMOS and 60\( \mu \)m/1\( \mu \)m for PMOS. The supplied voltages are \( V_{DD} = V_{SS} = 1.5 \) V. The corner frequency of 15.9 kHz are obtained with such passive elements setting as \( R = 10 k\Omega \) and \( C = 10 nF \). The simulation results are illustrated for the current transfer function characteristic in Fig.6 (a) and Fig.6 (b). The characteristics represent for the phase response of phase-lead and phase-lag all-pass filter, respectively. It can be observed that the circuits provide a bandwidth for a several MHz. From Fig.6, the effective of parasitic capacitances at output of OTA are taken in order to the high frequency according to eq. (8) and (9).

The application of proposed all-pass networks is a quadrature oscillator as shown in Fig.4. The simulation result of proposed oscillator application has shown in Fig. 7. The 2 outputs can be obtained for a quadrature behavior. The phase different is about 90° according with the theoretical. The waveform of the quadrature oscillator are in the assuming conditions, \( g_{m1}=g_{m2}=200 \mu A, R_1=R_2=10 k\Omega \) and \( C_1=C_2=0.01\mu F \). The oscillation frequency can be obtained ensure that are in agreement with the above theoretical about 16 kHz.
V. CONCLUSION

The dual input multiple-output OTA all-pass filter topologies with all grounded passive elements are presented. The phase-lead and phase-lag can be simply modification with a few passive components changed. The proposed topologies does not limit for the implementation in bipolar or CMOS technology. The proposed circuits tried to use the MOS transistors for OTA realization. The output current can be applied to next circuit without the any matching devices. The cascadable topology is a benefit of proposed current mode schemes. The cascade of proposed both types can be obtained a quadrature oscillator as an application. Due to the minimized component, decreasing components can be done by the electronic resistors [13] that implemented from only 2 MOS transistors. The oscillator will used only 2 capacitors for the passive elements. The filter and oscillator simulation results are obtained a good agreement with the theories suitable for further IC fabrication.

REFERENCES