Indian Journal of Engineering & Materials Sciences
Vol. 11, October 2004, pp. 397-400

Applications of new FGMOS based CCII in low voltage analog filters

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Received 4 July 2003; accepted 23 July 2004

This paper aims at to develop floating gate MOSFET (FGMOS) based low voltage, voltage-mode and current-mode circuits operating at ± 0.75 V supply voltages. The utility of FGMOS for low voltage applications lies in its threshold voltage tunability. FGMOS based low voltage current mirror and its subsequent use in the development of second-generation current conveyor is presented which in turn has been used to realize low voltage all-pass and low-pass filters. The performance of these circuits has been verified by using PSpice simulations for 0.5 μm CMOS technology.

IPC Code: Int. Cl.[7] H03H 15/02

Filters are essential building blocks for communication, instrumentation and control systems. For mobile applications low voltage and low power circuits are preferred[1,2]. A general technique is to use low voltage elements to have low voltage circuit structures and the most frequently used low voltage element is a current mirror (CM). It is desirable for a CM circuit to have low input and output compliance voltages. Some of the recently published CM structures based on level shifter approach though offer low compliance voltages both at the input and output ports, but suffer from high offset currents[3,4]. The other promising low voltage design technique is the use of FGMOS, which may result in high performance low voltage CMs[5,6]. These low voltage circuits rely on the precise control of threshold voltage of MOSFETs.

A FGMOS is a proven technology for digital circuits, in which a second gate generally called floating gate is electrically isolated but capacitively coupled to the input gates. A control voltage present at one of multi-input FGMOS, results in tunability of threshold voltage. This feature of the FGMOS makes it suitable for low voltage applications[1,5]. In this paper we present a low voltage FGMOS based CM circuit, which has been employed in the development of CCII. The workability of CCII is demonstrated through the realization of some analog filters.

FGMOS based Low Voltage Current Mirror

FGMOS based low voltage current mirror (LVCM) has been derived by modifying the LVCM given by Rajput and Jamuar[4,6]. The input characteristics of the LVCM in contrast with a conventional CM are shown in Fig. 1. The input compliance voltage is found to be 0.65 V for the entire input current range, which is quite lower than that of a conventional CM. The input current is much wider and extends upto 500 μA. The offset current of this current mirror is negligibly small (< 58 nA). The current transfer ratio is almost unity with error less than ± 0.1%. The output resistance of the LVCM is moderately high (1.3 MΩ at 500 μA). The circuit consumes 1.26 mW power. The bandwidth of LVCM is found to be 500 MHz.

FGMOS based Current Conveyor (CCII)

FGMOS based LVCM has been used to replace the LVCMs in the CCII circuit[7]. The resultant CCII has been simulated using level 3 PSpice parameters for

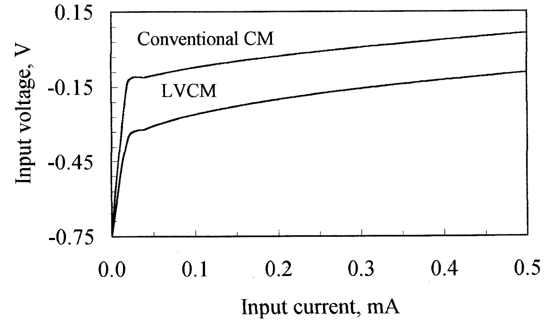

Fig. 1— Comparative input characteristics of CM

0.5 μm technology with supply voltage of ± 0.75 V. The simulation results show the intrinsic resistance (R_X) of the CCII to be extremely low (≈ 1.2 Ω). However, the input impedance (R_Y) at terminal Y is expectedly very high (10^{20} Ω). The output impedance (R_{out}) was found moderately high which equals 120 MΩ. This circuit consumes 1.6 mW power. The voltage transfer takes place from rail to rail (–0.75 to 0.75 V) and the percentage error in the voltage transfer is less than ± 0.2% for the entire input range except below – 0.65 V where the percentage error increases to 2%. The bandwidth for voltage transfer is found to be 250 MHz. The error in current transfer between terminals X and Z is almost zero for all values of input current range from –0.5 to 0.38 mA. This error is found to be –0.12% as the input current increases from 0.38 to 0.5 mA. The current transfer bandwidth is found to be 250 MHz.

CCII based filters

All types of filters can be realized using CCII. Since the available CCII operate relatively at higher voltages, the resultant CCII based filters are as such high voltage ones. Therefore, it is desirable to have low voltage counterparts of these circuits, which is the need for present day communication circuits and systems.

All-pass filters

All-pass filters are used as phase shifters and delay equalizers[8]. These circuits can be realized using CCII, by modifying the op amp based all-pass configurations. The voltage-mode first-order all-pass CCII based configuration is shown in Fig. 2, which can be derived from op amp based circuits by using transformation theorem[9].

The transfer function of this circuit is given by

$$T(s) = \frac{V_o(s)}{V_i(s)} = -\frac{sCR-1}{sCR+1} \qquad \ldots (1)$$

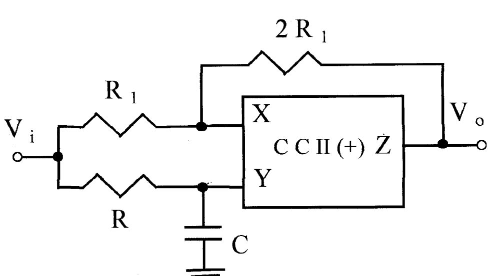

Fig. 2— Voltage-mode all-pass circuit

This circuit has been simulated by assuming R = 10 kΩ and C = 10 nF. The voltage gain and phase response are shown in Figs 3 and 4 respectively. The voltage transfer ratio is found to be almost unity. The phase shift varies from 180° to 0° in frequency range from 0 to 500 kHz. The input resistance offered is 20 MΩ whereas the output resistance is 10 kΩ and circuit dissipates 1.6 mW power. Under *R: C* interchange, all-pass phase lag network results whose phase shift can be varied from 0° to –180° and its transfer function is given by

$$T(s) = \frac{(sCR-1)}{(sCR+1)} \qquad \ldots (2)$$

The current transfer function for CCII (+) based all-pass circuit shown in Fig. 5 is given by

$$T(s) = \frac{I_o(s)}{I_i(s)} = -\frac{1}{2}\left[\frac{sCR-1}{sCR+1}\right] \ \& \ T(0) = \frac{1}{2} \qquad \ldots (3)$$

This circuit has been simulated for elemental values R = 10 kΩ and C = 10 nF. The simulation results

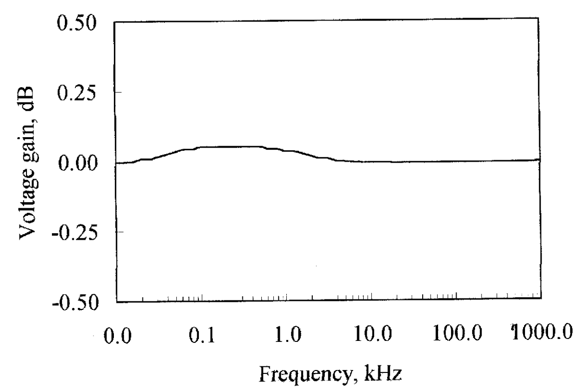

Fig. 3— Magnitude response of voltage-mode circuit

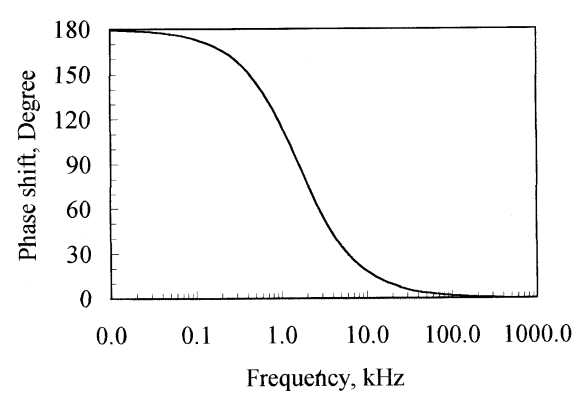

Fig. 4— Phase shift response of voltage-mode circuit

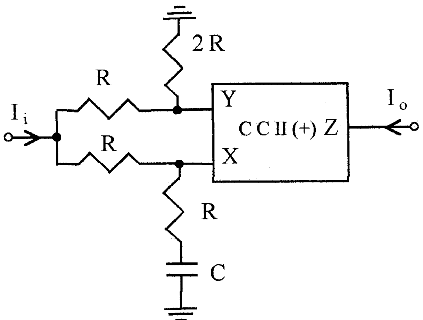

Fig. 5— Current-mode all-pass circuit

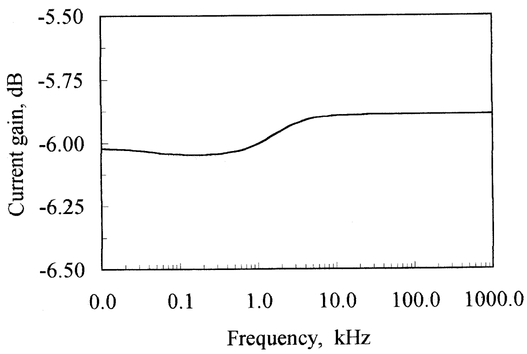

Fig. 6— Magnitude response of current-mode circuit

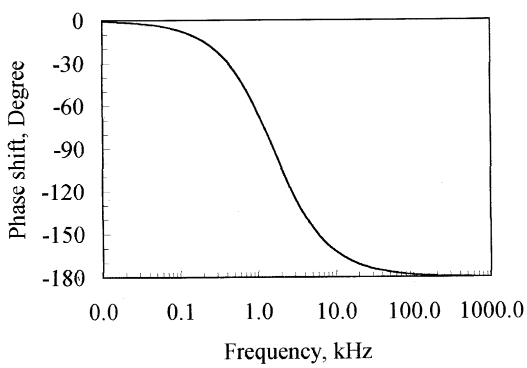

Fig. 7— Phase shift response of current-mode circuit

for current gain and phase response are shown in Figs 6 and 7. The current transfer ratio is found to be 0.5. The percentage error in magnitude plot lies between ± 1.5% and phase shift varies from 0^o to -180^o in frequency range from 0 to 630 kHz. The circuit offers input and output resistance of 15 kΩ and 120 MΩ respectively and dissipates 1.6 mW power.

Current-mode low-pass filter

The second order current-mode low-pass filter shown in Fig. 8 is obtained from op amp based Sallen-Key unity gain filter by using the adjoint network theorem[10,11].

The current transfer function is given by

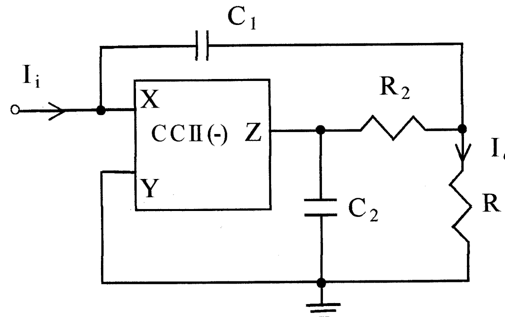

Fig. 8— Current-mode low-pass filter

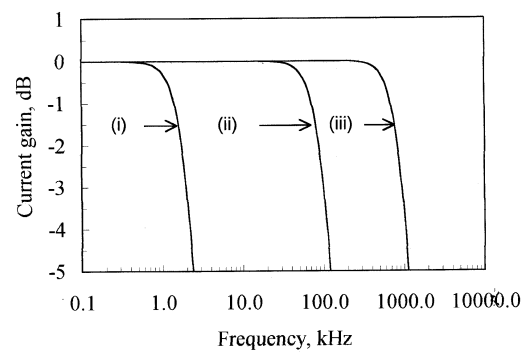

Fig. 9—Magnitude response of current-mode low-pass filter (i) f_o = 2 kHz, (ii) f_o = 100 kHz, and (iii) f_o = 1 MHz

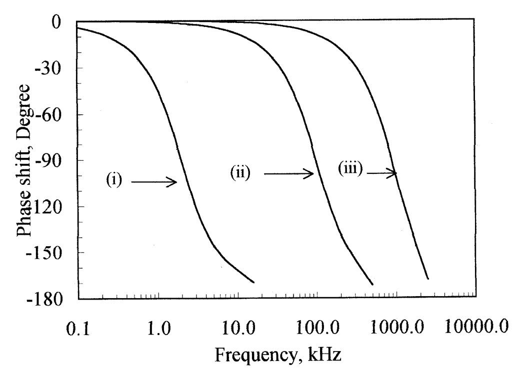

Fig. 10— Phase shift response of current-mode low-pass filter (i) f_o = 2 kHz, (ii) f_o = 100 kHz, and (iii) f_o = 1 MHz

$$T(s)=\frac{I_o(s)}{I_i(s)}=\frac{1/C_1C_2R_1R_2}{s^2+s\left(\frac{1}{R_1}+\frac{1}{R_2}\right)1/C_1+1/C_1C_2R_1R_2} \quad \ldots (4)$$

For $R_1=R_2=R$, the angular frequency $\omega_0=\frac{1}{R\sqrt{C_1C_2}}$ and quality factor $Q=\frac{1}{2}\sqrt{\frac{C_1}{C_2}}$ gives $C_1=\frac{2Q}{\omega_0 R}$ and $C_2=\frac{1}{2Q\omega_0 R}$.

The circuit is simulated for Q = 0.707 to obtain Butterworth response and for different values of angular frequency as shown in Figs 9 and 10. The current transfer ratio is found to be unity. It is observed that for higher critical frequency of 1 MHz, -90^o phase shift occurs at 890 kHz, which may be attributed to the presence of parasitic capacitances in the circuit at higher operating frequency. The circuit presents input resistance of 2.5 Ω and output resistance of 240 MΩ and consumes 2 mW power.

Conclusions

In this paper a high performance FGMOS current mirror suitable for low voltage applications is presented which operates at ± 0.75 V. This circuit has been used in realizing both CCII (+) and CCII (-) structures, which are in turn used to realize low voltage continuous time filters.

References

1 Sanchez-Sinencio E & Andreou A G, *Low voltage/low power integrated circuits and systems*, (IEEE Press, New York), 1999.

2 Yan S & Sanchez -Sinencio E, *IEICE Trans Analog Int Circuits Syst*, E00-A (2000) 1-17.

3 Rajput S S & Jamuar S S, *IEE Proc Circuits Devices Syst*, 148 (2001) 273-278.

4 Rajput S S & Jamuar S S, *A high performance current mirror for low voltage designs*, Proc APCCAS/IEEE, China, 2000, 170-173.

5 Ramirez-Angulo J, Choi S C & Altamirano G G, *IEEE Trans Circuits Syst I*, 42 (1995) 971-974.

6 Sharma Susheel, Rajput S S, Magotra L K & Jamuar S S, *FGMOS based wide range low voltage current mirror and its applications*, Proc APCCAS/IEEE, Singapore, 2002, 331-334.

7 Rajput S S, *Low voltage current-mode analog circuit structures and their applications*, Ph.D. Thesis, Indian Institute of Technology, New Delhi, 2002.

8 Van Valkenberg M E, *Analog Filter Design*, (Holt, Rinehart & Winston, New York), 1982.

9 Soliman A M, *IEEE Trans Circuits Syst II*, 44 (1997) 324-330.

10 Soliman A M, *Microelectronics J*, 29 (1998) 133-149.

11 Roberts G W & Sedra A S, *Electron Lett*, 25 (1989) 759-761.