Realization of MOSFET-C Filter and Sinusoidal Oscillator using FTFN

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Abstract

U. Cam and H. Kuntman presented a band pass filter and Ro-Min Weng presented a sinusoidal oscillator using FTFN previously. Both the proposed circuits were designed using passive components. The objective of this manuscript is to modify the circuits using 180nm CMOS technology parameters. SPICE simulation results are verifying the proposed modification.

Keywords - *CFOA, FTFN, BPF, sinusoidal oscillator.*

I. INTRODUCTION

Current-mode circuits are more useful as compare to voltage mode counterpart because they have the potential advantages such as inherently wider bandwidth, higher slew-rate, greater linearity, wider dynamic range, simple circuitry and low power consumption. The current-mode circuits can be formed by using active devices such as current conveyor and CFOA etc. when we combine analog and digital parts noise immunity is great concern. So we use fully balanced architecture to design analog circuits. The active device such as FTFN, DDA, OFA etc have fully balanced architecture. In these FTFN is popular because it is more flexible and versatile than the operational amplifier or the second-generation current conveyor. It has been used in several applications ranging from current amplifiers, voltage to current converters, gyrators, floating immittances and sinusoidal oscillators.

FTFN has remained still a theoretical element but the coming of different technologies and current mode circuit evolution implementation of FTFN became possible. At present FTFN is not commercially available in chip form. Still, there are various methods for the realization of FTFN using available active devices such as Op-amp, OTA, CCII, etc. The discrete I.C. AD844 is used for the realization of FTFN. The commercial availability of AD844 makes the implementation of FTFN simple.

II. MODIFIED BPF AND SINUSOIDAL OSCILLATOR

FTFN is a four terminal building block, which internally contains two AD844, characterized by the following equation term as

$$I_y = I_x = 0,\ V_x = V_y,\ I_z = -I_w \qquad \text{(i)}$$

The symbollic notation and the equivalent circuit of PFTFN and NFTFN are shown in figure 1.

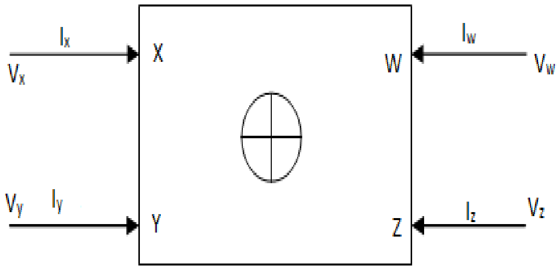

Fig 1(a): Symbolic notation of FTFN [3]

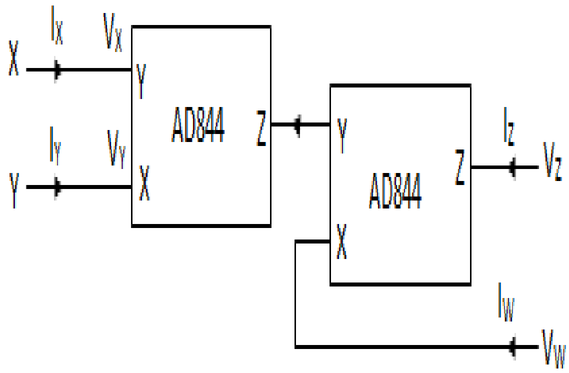

Fig 1(b): PFTFN using AD844 [3]

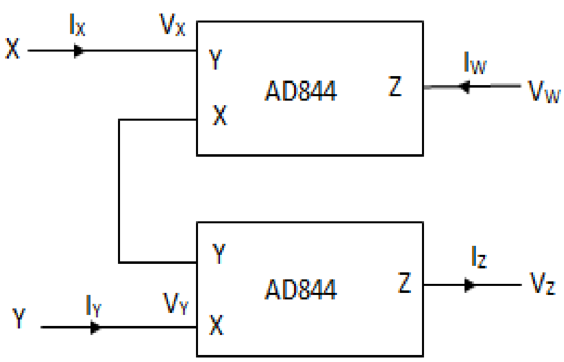

Fig 1(c): NFTFN using ASD844 [3]

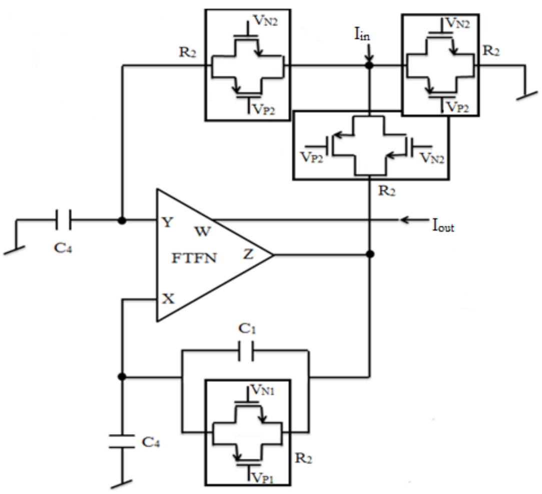

Fig 2: The proposed MOS-C band pass filter using FTFN

The proposed BPF as shown in figure (2) has single NFTFN, eight MOSFETs replacing four resistors and two grounded capacitors suitable for IC implementation. The transfer function of the band pass filter is given as:

$$\frac{I_{out}}{I_{in}} = \frac{s/3C_1R_2}{s^2 + \left(\frac{1}{C_1R_1} + \frac{1}{3C_4R_2} - \frac{1}{3C_1R_2}\right) + \frac{1}{C_1C_4R_1R_2}}$$

The analysis for BPF reveals, the frequency of oscillation (f_o) and quality factor (Q) is given by

$$\omega_o = \frac{1}{\sqrt{C_1C_4R_1R_2}} \qquad (iii)$$

$$Q = \frac{\sqrt{3C_1C_4R_1R_2}}{3C_4R_2 + C_1R_1 - C_4R_1} \qquad (iv)$$

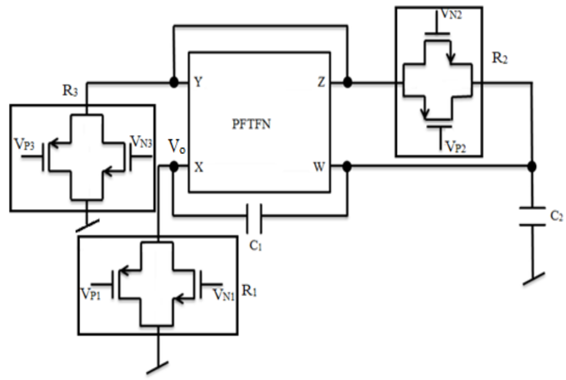

Fig 3: The proposed MOS-C sinusoidal oscillator using PFTFN

The sinusoidal oscillator using single PFTFN, six MOSFETs replacing two passive grounded resistors and one passive floating resistors, one passive and one grounded capacitor shown in figure (3). The characteristic equation of the sinusoidal oscillator is expressed as:

$$s^2C_1C_2 + \frac{2}{R_1R_2} + s\left(\frac{C_1}{R_1} + \frac{C_2}{R_1} - \frac{C_1}{R_3}\right) = 0 \qquad (v)$$

The analysis for sinusoidal oscillator gives the condition of oscillation and frequency of oscillation given by

$$\omega_o = \sqrt{\frac{2}{C_1C_2R_1R_2}} \qquad (vi)$$

$$1 + \frac{C_2}{C_1} = \frac{R_3}{R_1} \qquad (vii)$$

III. CMOS VERSION OF BPF AND SINUSOIDAL OSCILLATOR CMOS

For the realization of MOS-C band pass filter and sinusoidal oscillator, the FTFN (PFTFN and NFTFN) and passive resistors needs to be replaced by CMOS FTFN and MOS-C resistor. The FTFN can be easily realized using two AD844, therefore in the present work, CMOS CFOA is utilized [7], which is shown in figure (2) and figure (3) respectively.

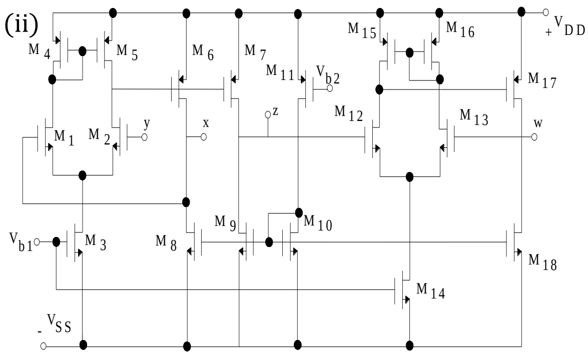

Figure 4: CMOS CFOA [7]

Table 1: W/L ratio of MOSFETs used for CMOS CFOA for band pass filter given as follows:

Type of MOSFET	MOSFETs	W (µm)	L (µm)
PMOS	M_{41}- M_{42}, M_{51}- M_{52}, M_{61}- M_{62}, M_{71}- M_{72}, M_{111}- M_{112}, M_{151}- M_{152}, M_{161}- M_{162}, M_{171}- M_{172},	10.8	0.54
NMOS	M_{11}, M_{21}, M_{31}, M_{91}, M_{101}, M_{121}- M_{122}, M_{131}- M_{132}, M_{141}- M_{142}, M_{181}-M_{182}	8.1	0.54
NMOS	M_{12}, M_{22}, M_{32}, M_{82}, M_{92}	9.5	0.54
NMOS	M_{102}	98.1	0.54
NMOS	M_{81}	0.1	0.54

Table 2: W/L ratio of MOSFETs used for CMOS CFOA for sinusoidal oscillator given as follows:

Type of MOSFET	MOSFETs	W (µm)	L (µm)
PMOS	M_{41}- $M_{42,}$ M_{51}- $M_{52,}$ M_{61}- $M_{62,}$ M_{71}- $M_{72,}$ M_{111}- $M_{112,}$ M_{151}- $M_{152,}$ M_{161}- $M_{162,}$ M_{171}- $M_{172,}$	10.8	0.54
NMOS	M_{11}- $M_{12,}$ M_{21}- $M_{22,}$ M_{31}- $M_{32,}$ M_{81}- $M_{82,}$ M_{91}- $M_{92,}$ M_{101}- $M_{102,}$ M_{121}- $M_{122,}$ M_{131}- $M_{132,}$ M_{141}- $M_{142,}$ M_{181}-M_{182}	8.1	0.54

Table 3: W/L Ratios of the MOSFETs in CMOS VCR for band pass filter given as follows:

Type of MOSFET	W (µm)	L (µm)
PMOS	3.9	0.54
NMOS	2.1	0.54

Table 4: W/L Ratios of the MOSFETs in CMOS VCR for sinusoidal oscillator given as follows:

Type of MOSFET	W (µm)	L (µm)
PMOS	2.5	0.54
NMOS	1.5	0.54

Table 5: Level 7 SPICE parameter for 0.18µm CMOS process is as below:

.MODEL CMOSN NMOS(LEVEL = 7

+VERSION = 3.1 TNOM = 27 TOX = 4E-9 XJ = 1E-7 NCH = 2.3549E17 VTH0 = 00.3662648

+K1 = 0.5802748 K2 = 3.124029E-3 K3 = 1E-3 K3B = 3.3886871 W0 = 1E-7 NLX = 1.766159E-7 DVT0W = 0 DVT1W = 0 DVT2W = 0 DVT0 = 1.2312416 DVT1 = 0.3849841 +DVT2 = 0.0161351 U0 = 265.1889031 UA = -1.506402E-9 UB = 2.489393E-18 UC = 5.621884E-11 VSAT = 1.017932E5 A0 = 2 AGS = 0.4543117 B0 = 3.433489E-7 B1 = 5E-6

+KETA = -0.0127714 A1 = 1.158074E-3 A2 = 1 RDSW = 136.5582806 PRWG = 0.5 +PRWB = -0.2 WR = 1 WINT = 0 LINT = 1.702415E-8 XL = 0 XW = -1E-8 DWG = -4.211574E-9 DWB = 1.107719E-8 VOFF = -0.0948017 NFACTOR = 2.1860065 CIT = 0 +CDSC = 2.4E-4 CDSCD = 0 CDSCB = 0 ETA0 = 3.335516E-3 ETAB = 6.028975E-5

+DSUB = 0.0214781 PCLM = 0.6602119 PDIBLC1 = 0.1605325PDIBLC2 = 3.287142E-3 +PDIBLCB = -0.1 DROUT = 0.7917811 PSCBE1 = 6.420235E9 PSCBE2 = 4.122516E-9 +PVAG = 0.0347169 DELTA = 0.01 RSH = 6.6 MOBMOD = 1 PRT = 0 UTE = -1.5 +KT1 = -0.11 KT1L = 0 KT2 = 0.022 UA1 = 4.31E-9 UB1 = -7.61E-18 UC1 = -5.6E-11 +AT = 3.3E4 WL = 0 WLN = 1 WW = 0 WWN = 1 WWL = 0 LL = 0 LLN = 1 +LW = 0 LWN = 1 LWL = 0 CAPMOD = 2 XPART = 0.5 CGDO = 8.06E-10 +CGSO = 8.06E-10 CGBO = 1E-12 CJ = 9.895609E-4 PB = 0.8 MJ = 0.3736889 CJSW = 2.393608E-10 PBSW = 0.8 MJSW = 0.1537892 CJSWG = 3.3E-10 PBSWG = 0.8 +MJSWG = 0.1537892 CF = 0 PVTH0 = -1.73163E-3 PRDSW = -1.4173554 PK2 = 1.600729E-3 WKETA = 1.601517E-3 LKETA = -3.255127E-3 PU0 = 5.2024473 PUA = 1.584315E-12 PUB = 7.446142E-25PVSAT = 1.686297E3 PETA0 = 1.001594E-4 +PKETA = -2.039532E-3)

.MODEL CMOSP PMOS(LEVEL = 7

+VERSION = 3.1 TNOM = 27 TOX = 4E-9 XJ = 1E-7 NCH = 4.1589E17 VTH0 = -0.3708038 K1 = 0.5895473 K2 = 0.0235946 K3 = 0 K3B = 13.8642028 W0 = 1E-6 NLX = 1.517201E-7 DVT0W = 0 DVT1W = 0 DVT2W = 0 DVT0 = 0.7885088 DVT1 = 0.2564577 DVT2 = 0.1U0 = 103.0478426 UA = 1.049312E-9 +UB = 2.545758E-21 UC = -1E-10 VSAT = 1.645114E5 A0 = 1.627879 AGS = 0.3295499 B0 = 5.207699E-7 B1 = 1.370868E-6 KETA = 0.0296157 A1 = 0.4449009 +A2 = 0.3 RDSW = 306.5789827 PRWG = 0.5 PRWB = 0.5 WR = 1 +WINT = 0 LINT = 2.761033E-8 XL = 0 XW = -1E-8 DWG = -2.433889E-8 +DWB = -9.34648E-11 VOFF = -0.0867009 NFACTOR = 2 CIT = 0 CDSC = 2.4E-4 +CDSCD = 0 CDSCB = 0 ETA0 = 1.018318E-3 ETAB = -3.206319E-4 DSUB = 1.094521E-3 PCLM = 1.3281073 PDIBLC1 = 2.394169E-3PDIBLC2 = -3.255915E-6 +PDIBLCB = -1E-3 DROUT = 0 PSCBE1 = 4.881933E10 PSCBE2 = 5E-10 PVAG = 2.0932623 DELTA = 0.01 RSH = 7.5 MOBMOD = 1 PRT = 0 UTE = -1.5 +KT1 = -0.11 KT1L = 0 KT2 = 0.022 UA1 = 4.31E-9 UB1 = -7.61E-18 UC1 = -5.6E-11 AT = 3.3E4 WL = 0 WLN = 1 WW = 0 WWN = 1 WWL = 0 +LL = 0 LLN = 1 LW = 0 LWN = 1 LWL = 0 CAPMOD = 2 XPART = 0.5 +CGDO = 6.52E-10 CGSO = 6.52E-10 CGBO = 1E-12 CJ = 1.157423E-3 PB = 0.8444261 MJ = 0.4063933 CJSW = 1.902456E-10 PBSW = 0.8 MJSW = 0.3550788

+CJSWG = 4.22E-10 PBSWG = 0.8 MJSWG = 0.3550788 CF = 0 PVTH0 = 1.4398E-3 PRDSW = 0.5073407 PK2 = 2.190431E-3 WKETA = 0.0442978 LKETA = -2.936093E-3 PU0 = -0.9769623 PUA = -4.34529E-11 PUB = 1E-21PVSAT = -50 +PETA0 = 1.002762E-4 PKETA = -

6.740436E-3)

IV. SIMULATION RESULT

Result of simulated band pass filter and sinusoidal oscillator employing using CMOS CFOA shown in figure 8 and figure 9. The aspect ratios of NMOS and PMOS transistors for band pass filter and sinusoidal oscillator are shown in table 1 and table 2 respectively. The value of supply voltage V_{DD}= -V_{SS} = 1.5V. The passive elements for band pass filter are R_1= 23kΩ, R_2= 1kΩ, R_3= 1.1kΩ, R_4 = 0.65kΩ and C_1=C_4=0.5nF and for sinusoidal oscillator are R_1=R_2= 1kΩ and C_1=C_4=10nF.

After replacing all the passive resistances in the band pass filter and sinusoidal oscillator circuit is being replaced by voltage controlled resistors. The cut off frequency for filter is obtained to be 19.953 kHz and for sinusoidal oscillator is to be 22.485 kHz. Aspect ratios for the CMOS based VCRs the NMOS and PMOS transistor for band pass filter and sinusoidal oscillator are given in table 3 and table 4 respectively. The voltage of PMOS that is V_P= -0.9V fixed; whereas the voltage of NMOS may vary by transistor to transistor. Thus, frequency response obtained by replacing all passive resistances with equivalent VCRs is shown below.

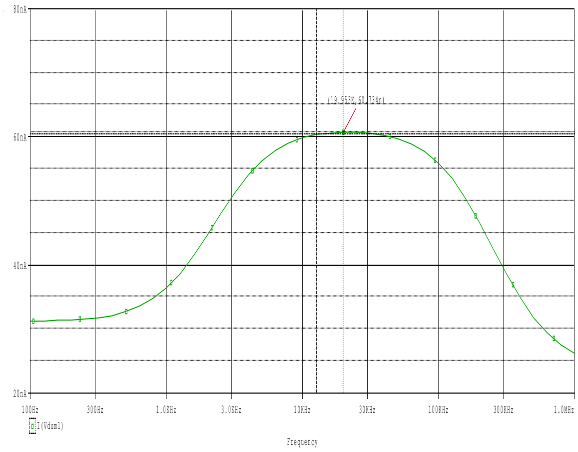

Fig 8: simulation result for band pass filter

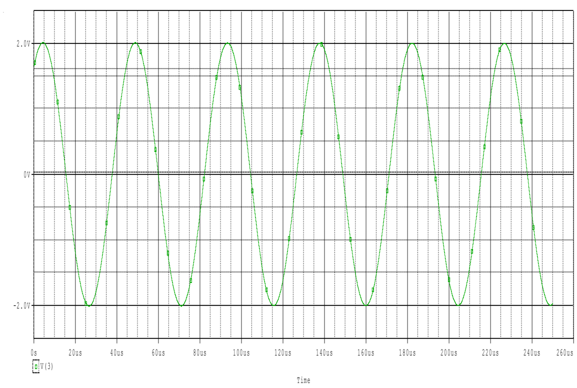

Fig 9: simulation result for sinusoidal oscillator

V. COMPARISON

The comparison between the previous published band pass filter and sinusoidal oscillator with the new designed band pass filter and sinusoidal oscillator using FTFN. It is found to be the proposed circuit required four MOS resistors in BPF and three MOS resistors in sinusoidal oscillator having a nature to control the voltages according to the designer for tuning purpose, use of capacitor (for IC implementation) and the voltages is to be at 1.25V. The previous is designed using the passive resistors as in the analog electronics, are very bulky in nature that's why use of active resistors removes the drawback of required elements in previous one.

VI. CONCLUDING REMARKS

New band pass filter and sinusoidal oscillator circuits are designed using only one four terminal floating nullor. Circuits are simulated on PSPICE simulation program using 0.18µm CMOS technology. PSPICE simulation result which we have got is a good agreement with the predicted theory. The proposed simulated FTFN can be used for design of various types of filters and oscillators used in analog electronics as one of the application in communication system.

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