Electronically Controllable Sinusoidal Oscillators Employing VDIBAs

Kanhaiya Lal PUSHKAR

Department of Electronics and Communication Engineering, Maharaja Agrasen Institute of Technology, Rohini, New Delhi-110086, India

klpushkar17@gmail.com

DOI: 10.15598/aeee.v15i5.2448

Abstract. *Two new electronically controllable sinusoidal oscillators each employing two Voltage Differencing Inverting Buffered Amplifiers (VDIBAs), two capacitors, and a single resistor have been proposed. The presented oscillators offer independent electronic control of Condition of Oscillation (CO) and Frequency of Oscillation (FO), and low active and passive sensitivities. The effect of non-idealities of the VDIBAs on the proposed oscillators is also investigated. The validity of the proposed structures has been confirmed by SPICE simulation with TSMC 0.18 μm process parameters.*

Keywords

Sinusoidal oscillator, voltage differencing inverting buffered amplifier, voltage-mode.

1. Introduction

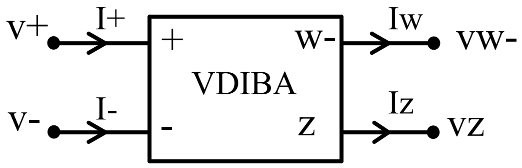
Sinusoidal oscillators have the wide range of applications in signal processing, instrumentation and measurement, control systems, and communications. Recently, number of oscillators, have been proposed by the various researchers, see [1], [2], [3], [4], [5], [6], [7], [8], [9] and [10], and the references cited therein. In [11], authors proposed electronically controllable sinusoidal oscillator employing CMOS VD-DIBAs in which the CO is controlled through a resistance, whereas FO is electronically controllable by the transconductance of the VD-DIBA. A fully uncoupled electronically controllable sinusoidal oscillator employing VD-DIBAs was presented in [12], where CO and FO both are electronically controllable through a separate transconductance of the VD-DIBAs but the circuit uses four passive elements (two capacitors and two resistors). In reference [13], a fully uncoupled electronically controllable sinusoidal oscillator was presented employing four Current Controlled Current Conveyors (CCCIIs) and two capacitors. Two VDIBAs based single resistance controlled oscillator with two capacitors and a resistance has been proposed in [14], where only CO is electronically controllable. Thus, the purpose of this article is to propose two new sinusoidal oscillators having electronic control of both CO and FO by separate transconductance of the VDIBAs. This feature is very attractive for realizing current-controlled oscillators as FO can be adjusted independently without disturbing CO, whereas the flexibility of being able to control CO independently is useful in amplitude stabilization. The proposed structures also offer low active and passive sensitivities. The feasibility of the proposed sinusoidal oscillators has been confirmed by SPICE simulation with TSMC 0.18 µm process parameters.

2. The Proposed New Configurations

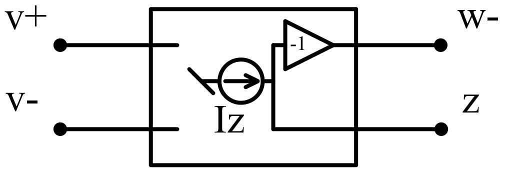
Many new active building blocks such as VDBA, CD-DIBA, etc. were introduced for the first time in [15]. It may be noted that VDIBA [10] is a modified form of VDBA introduced in [15], not all possible variants of the various active building blocks were mentioned to save the space. Thus, VDIBA, a four terminal active building block with electronic tuning, was subsequently generated [10] based upon the methodology of [15].The symbolic notation and equivalent model of the VDIBA are shown in Fig. 1(a) and Fig. 1(b), respectively [10]. Using standard notations, the voltage-current relations of VDIBA can be described by the following set of equations:

$$I_+ = 0 = I_-, I_2 = g_m(V_+ - V_-) \text{ and } V_w = -\beta V_2, \quad (1)$$

where β is a non-ideal voltage gain of VDIBA. The value of β in an ideal VDIBA is unity and g_m is the transconductance of the VDIBA.



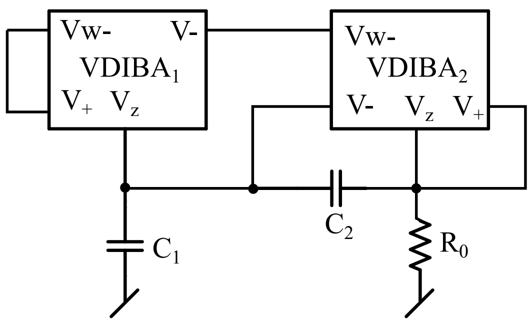
(a)



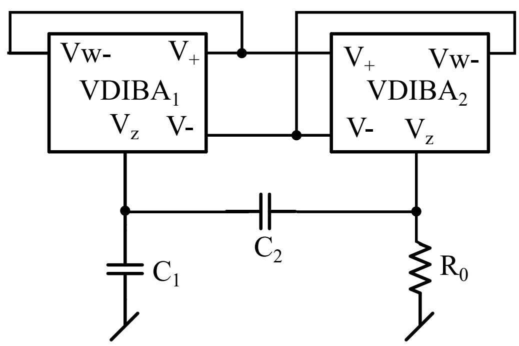
(b)

Fig. 1: (a) Symbolic notation, (b) equivalent model of VDIBA.

Figure 2 shows the proposed new sinusoidal oscillators with independent electronic control of CO and FO.



(a)



(b)

Fig. 2: Proposed sinusoidal oscillators with electronic control of both CO and FO.

A routine circuit analysis of the circuits in Fig. 2 yields the following Characteristic Equation (CE), CO, and FO for both the oscillators:

$$\text{CE: } s^2 + s\left\{\frac{1}{R_0}\left(\frac{1}{C_1}+\frac{1}{C_2}\right) - \frac{g_{m_2}}{C_2}\right\} + \frac{g_{m_1}}{C_1C_2R_0} = 0, \quad (2)$$

$$\text{CO: } \left(\frac{C_1+C_2}{R_0} - C_1 g_{m_2}\right) \le 0, \quad (3)$$

$$\text{FO: } f = \frac{1}{2\pi}\sqrt{\frac{g_{m_1}}{C_1C_2R_0}}. \quad (4)$$

From Eq. (3) and Eq. (4), it is seen that CO is electronically controllable by the transconductance g_{m_2}, where as FO is electronically controllable through the transconductance g_{m_1}. Thus both CO and FO are independently electronically controllable by two separate transconductances.

3. Non-Ideal Analysis and Sensitivity Performance

Let R_z and C_z denote the parasitic resistance and parasitic capacitance of the Z-terminal of VDIBA. Taking the non-idealities into account, namely the voltage of W-terminal $V_w- = (-\beta^+ V_z)$, where $\beta^+ = 1-\epsilon_p(\epsilon_p << 1)$ denotes the voltage tracking error, then the expressions for CE, CO and FO, respectively, become:

- For the circuit given in Fig. 2(a) is CE in Eq. (5), CO in Eq. (6) and FO in Eq. (7).
- For the circuit shown in Fig. 2(b) is CE in Eq. (8), CO in Eq. (9) and FO in Eq. (10).

The various active and passive sensitivities of FO are given by:

- For the circuit of Fig. 2(a):

$$S^{\omega_0}_{R_0} = -\frac{1}{2}\cdot \frac{R_z(1+R_z\beta^+g_{m_1})}{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_zg_{m_2})}, \quad (11)$$

$$S^{\omega_0}_{R_z} = -\frac{1}{2}\cdot \frac{2R_0+R_z-R_zR_0(\beta^+g_{m_1}-g_{m_2})}{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_zg_{m_2})}, \quad (12)$$

$$S^{\omega_0}_{g_{m_1}} = \frac{1}{2}\cdot \frac{R_z(R_0+R_z)\beta^+g_{m_1}}{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_zg_{m_2})}, \quad (13)$$

$$S^{\omega_0}_{g_{m_2}} = -\frac{1}{2}\cdot \frac{R_zR_0g_{m_2}}{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_zg_{m_2})}, \quad (14)$$

$$\begin{gathered}\text{CE: } s^2(C_1C_2+C_1C_z+2C_2C_z+C_z^2)+\\ +s\left\{\left(\frac{C_1+2C_2+C_z}{R_z}+\frac{C_1+C_2+C_z}{R_0}\right)+C_z\beta^+G_{m_1}-(C_1+C_z)g_{m_2}\right\}+\\ +\frac{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_zg_{m_2})}{R_0R_z^2}=0.\end{gathered}\tag{5}$$

$$\text{CO: }\left\{\left(\frac{C_1+2C_2+C_z}{R_z}+\frac{C_1+C_2+C_z}{R_0}\right)+C_z\beta^+G_{m_1}-(C_1+C_z)g_{m_2}\right\}\le 0.\tag{6}$$

$$\text{FO: }\omega_0=\sqrt{\frac{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_zg_{m_2})}{R_0R_z^2(C_1C_2+C_1C_z+2C_2C_z+C_z^2)}}.\tag{7}$$

$$\begin{gathered}\text{CE: } s^2(C_1C_2+C_1C_z+2C_2C_z+C_z^2)+\\ +s\left\{\left(\frac{C_1+2C_2+C_z}{R_z}+\frac{C_1+C_2+C_z}{R_0}\right)+C_z\beta^+G_{m_1}-(C_1+C_z)\beta^+g_{m_2}\right\}+\\ +\frac{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_z\beta^+g_{m_2})}{R_0R_z^2}=0.\end{gathered}\tag{8}$$

$$\text{CO: }\left\{\left(\frac{C_1+2C_2+C_z}{R_z}+\frac{C_1+C_2+C_z}{R_0}\right)+C_z\beta^+G_{m_1}-(C_1+C_z)\beta^+g_{m_2}\right\}\le 0.\tag{9}$$

$$\text{FO: }\omega_0=\sqrt{\frac{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_z\beta^+g_{m_2})}{R_0R_z^2(C_1C_2+C_1C_z+2C_2C_z+C_z^2)}}.\tag{10}$$

$$S_{C_1}^{\omega_0}=-\frac{1}{2}\cdot\frac{C_1(C_2+C_z)}{(C_1C_2+C_1C_z+2C_2C_z+C_z^2)},\tag{15}$$

$$S_{C_2}^{\omega_0}=-\frac{1}{2}\cdot\frac{C_2(C_1+2C_z)}{(C_1C_2+C_1C_z+2C_2C_z+C_z^2)},\tag{16}$$

$$S_{C_z}^{\omega_0}=-\frac{1}{2}\cdot\frac{C_z(C_1+2C_2+2C_z)}{(C_1C_2+C_1C_z+2C_2C_z+C_z^2)},\tag{17}$$

$$\begin{gathered}S_{\beta^+}^{\omega_0}=\frac{1}{2}\cdot\\ \cdot\left\{\frac{R_z(R_0+R_z)\beta^+g_{m_1}}{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_zg_{m_2})}\right\}.\end{gathered}\tag{18}$$

- For the oscillator of Fig. 2(b):

$$\begin{gathered}S_{R_0}^{\omega_0}=-\frac{1}{2}\cdot\\ \cdot\frac{R_z(1+R_z\beta^+g_{m_1})}{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_z\beta^+g_{m_2})},\end{gathered}\tag{19}$$

$$\begin{gathered}S_{R_z}^{\omega_0}=-\frac{1}{2}\cdot\\ \cdot\frac{2R_0+R_z-R_zR_0\beta^+(g_{m_1}-g_{m_2})}{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_z\beta^+g_{m_2})},\end{gathered}\tag{20}$$

$$\begin{gathered}S_{g_{m_1}}^{\omega_0}=\frac{1}{2}\cdot\\ \cdot\frac{R_z(R_0+R_z)\beta^+g_{m_1}}{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_z\beta^+g_{m_2})},\end{gathered}\tag{21}$$

$$\begin{gathered}S_{g_{m_2}}^{\omega_0}=-\frac{1}{2}\cdot\\ \cdot\frac{R_zR_0\beta^+g_{m_2}}{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_z\beta^+g_{m_2})},\end{gathered}\tag{22}$$

$$S_{C_1}^{\omega_0}=-\frac{1}{2}\cdot\frac{C_1(C_2+C_z)}{(C_1C_2+C_1C_z+2C_2C_z+C_z^2)},\tag{23}$$

$$S_{C_2}^{\omega_0}=-\frac{1}{2}\cdot\frac{C_2(C_1+2C_z)}{(C_1C_2+C_1C_z+2C_2C_z+C_z^2)},\tag{24}$$

$$S_{C_z}^{\omega_0}=-\frac{1}{2}\cdot\frac{C_z(C_1+2C_2+2C_z)}{(C_1C_2+C_1C_z+2C_2C_z+C_z^2)},\tag{25}$$

$$\begin{gathered}S_{\beta^+}^{\omega_0}=\frac{1}{2}\cdot\\ \cdot\left\{\frac{R_z^2\beta^+g_{m_1}+R_0R_z(g_{m_1}-g_{m_2})\beta^+}{R_z(R_0+R_z)\beta^+g_{m_1}+(R_0+R_z-R_0R_z\beta^+g_{m_2})}\right\}.\end{gathered}\tag{26}$$

In the ideal case, the various sensitivities of FO with respect to R_0, R_z, C_1, C_2, g_{m_1}, g_{m_2}, g_{m_2}, and C_z for both the oscillators are found to be:

$$\begin{gathered}S_{R_0}^{\omega_0}=S_{C_1}^{\omega_0}=S_{C_2}^{\omega_0}=-\frac{1}{2},\\ S_{g_{m_1}}^{\omega_0}=S_{\beta^+}^{\omega_0}=\frac{1}{2},\\ S_{R_z}^{\omega_0}=S_{C_z}^{\omega_0}=S_{g_{m_2}}^{\omega_0}=0.\end{gathered}\tag{27}$$

Considering the typical values of various parasitic as given in [10], e.g. $C_z=0.367$ pF, $R_z=131.93$ kΩ,

$R_w = 42.36\ \Omega$, $\beta^+ = 1$, $g_{m_1} = 600\ \mu\text{S}$, and $g_{m_2} = 704.7\ \mu\text{S}$ along with $C_1 = C_2 = 10$ nF, and $R_0 = 3.333$ kΩ, the various sensitivities are found to be:

- For the circuit of Fig. 2(a):

$$\begin{gathered} S_{C_1}^{\omega_0} = -0.5,\ S_{C_2}^{\omega_0} = -0.5,\ S_{C_z}^{\omega_0} = 0, \\ S_{R_0}^{\omega_0} = -0.5,\ S_{R_z}^{\omega_0} = -0.0087,\ S_{g_{m1}}^{\omega_0} = 0.508, \\ S_{g_{m2}}^{\omega_0} = 0.0147 \text{ and } S_{\beta+}^{\omega_0} = 0.508 \\ \text{which are all low.} \end{gathered} \tag{28}$$

- For the circuit of Fig. 2(b):

$$\begin{gathered} S_{C_2}^{\omega_0} = -0.5,\ S_{C_z}^{\omega_0} = 0,\ S_{R_0}^{\omega_0} = -0.502, \\ S_{R_z}^{\omega_0} = -0.0087,\ S_{g_{m_1}}^{\omega_0} = 0.508 \text{ and} \\ S_{g_{m_2}}^{\omega_0} = -0.0147 \text{ and } S_{\beta+}^{\omega_0} = 0.498 \\ \text{which are all low.} \end{gathered} \tag{29}$$

4. SPICE Simulation Results

To confirm theoretical analysis, the proposed oscillators were simulated using CMOS VDIBA (as shown in Fig. 3). The CMOS VDIBA is implemented using 0.18 µm TSMC real transistor models which are listed in Tab. 2. Table 1 shows the aspect ratios of transistors used in Fig. 3. The passive elements were selected as $C_1 = C_2 = 10$ nF, $R_0 = 3.333$ kΩ. The transconductances of VDIBAs were controlled by the bias currents $I_{b_1} = 100\ \mu\text{A}$ and $I_{b_2} = 110\ \mu\text{A}$, respectively. PSPICE generated output waveforms indicating transient and steady state responses of circuits in Fig. 2 are shown in Fig. 4 and Fig. 5, respectively. These results, thus, confirm the validity of the proposed configurations. Figure 6 shows the output spectrum of circuits shown in Fig. 2; whereas the Total Harmonic Distortions (THD) for both circuits are found to be 1.0542 % and 1.049 %, respectively. Figure 7 shows the variation of frequency with the transconductance g_{m_1} for both circuits in Fig. 2.

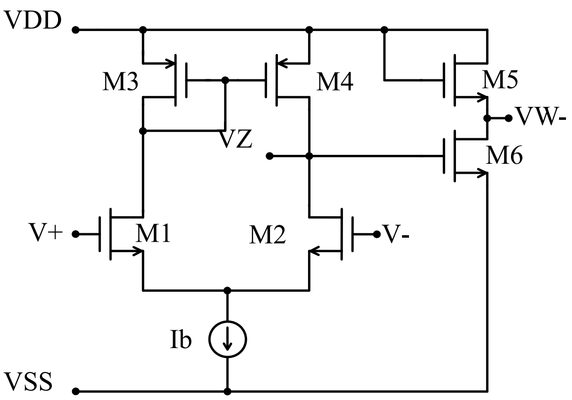


Fig. 3: An exemplary CMOS implementation of VDIBA [10], $V_{DD} = V_{SS} = 0.9$ V.

Tab. 1: The aspect ratios of MOSFETs.

Transistors	$\frac{W}{L}$ (µm)
M1–M4	$\frac{18}{1.08}$
M5–M6	$\frac{54}{0.18}$

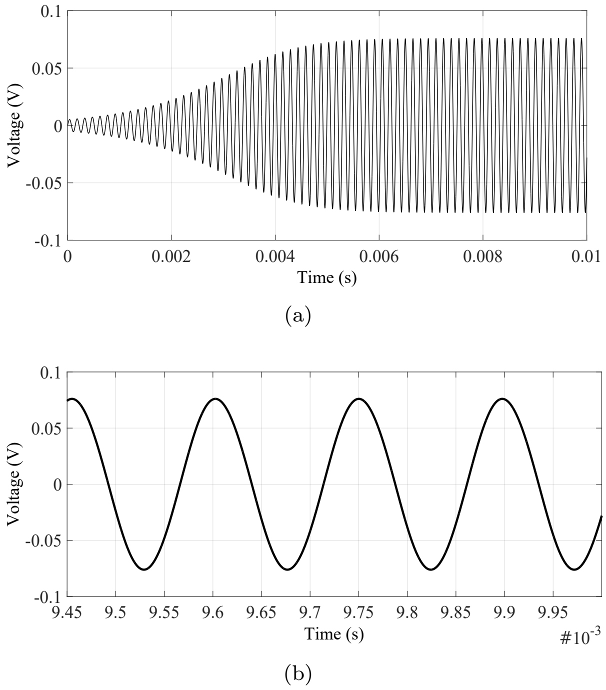


Fig. 4: (a) Transient response of Fig. 2(a), (b) Steady state response of the circuit of Fig. 2(a).

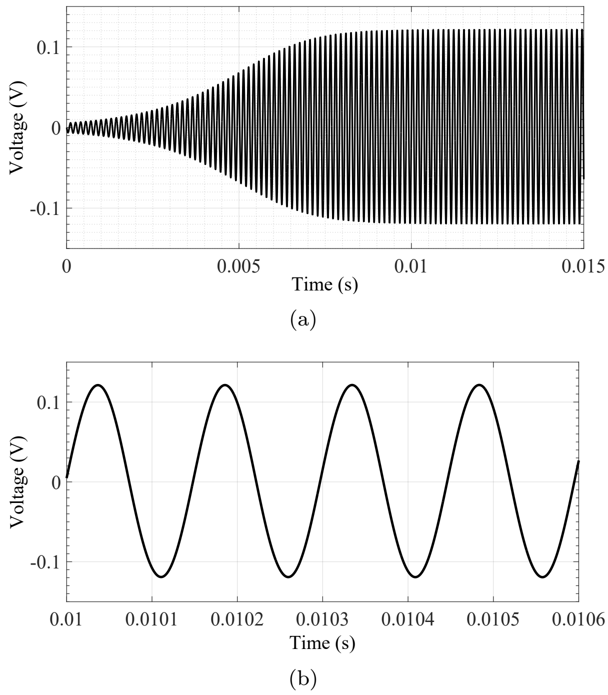
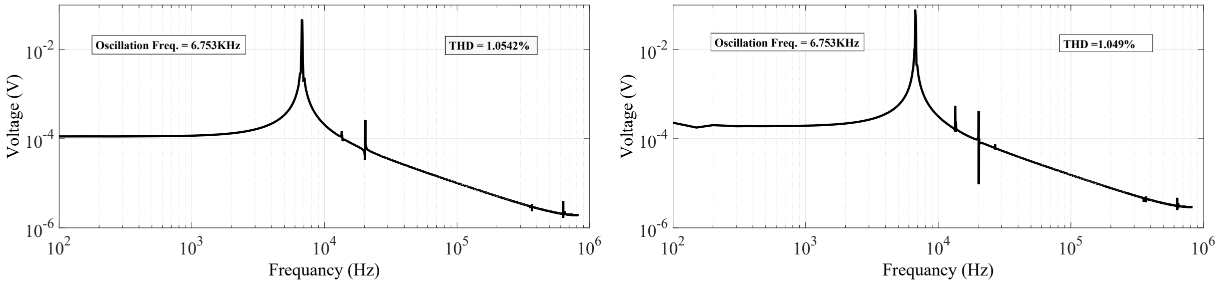


Fig. 5: (a) Transient response of Fig. 2(b), (b) Steady state response of the circuit of Fig. 2(b).



(a) (b)

Fig. 6: Circuit frequency response of: (a) Fig. 2(a), (b) Fig. 2(b).

Tab. 2: 0.18 µm TSMC CMOS model parameters.

.MODEL N NMOS (LEVEL = 7, VERSION=3.1 TNOM=27
TOX=4.1E-9 XJ=1E-7 NCH=2.3549E17 VTH0=0.3725327 K1=0.5933684 K2=2.050755E-3
K3=1E-3 K3B=4.5116437 W0=1E-7 NLX=1.870758E-7 DVT0W=0 DVT1W=0 DVT2W=0
DVT0=1.3621338 DVT1=0.3845146 DVT2=0.0577255 U0=259.5304169 UA=-1.413292E-9
UB=2.229959E-18 UC=4.525942E-11 VSAT=9.411671E4, A0=1.7572867 AGS=0.3740333
B0=-7.087476E-9 B1=-1E-7 KETA=-4.331915E-3 A1=0 A2=1 RDSW=111.886044 PRWG=0.5
PRWB=-0.2 WR=1 WINT=0 LINT=1.701524E-8 XL=0 XW=-1E-8 DWG=-1.365589E-8
DWB=1.045599E-8 VOFF=-0.0927546,NFACTOR=2.4494296 CIT=0 CDSC=2.4E-4 CDSCD=0
CDSCB=0 ETA0=3.175457E-3 ETAB=3.494694E-5 DSUB=0.0175288 PCLM=0.7273497
PDIBLC1=0.1886574 PDIBLC2=2.617136E-3 PDIBLCB=-0.1 DROUT=0.7779462
PSCBE1=3.488238E10 PSCBE2=6.841553E-10 PVAG=0.0162206 DELTA=0.01 RSH=6.5
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=8.53E-10 CGSO=8.53E-10 CGBO=1E-12 CJ=9.513993E-4
PB=0.8 MJ=0.3773625 CJSW=2.600853E-10 PBSW=0.8157101 MJSW=0.1004233 CJSWG=3.3E-10
PBSWG=0.8157101 MJSWG=0.1004233 CF=0 PVTH0=-8.863347E-4 PRDSW=-3.6877287
PK2=3.730349E-4 WKETA=6.284186E-3 LKETA=-0.0106193 PU0=16.6114107
PUA=6.572846E-11 PUB=0 PVSAT=1.112243E3 PETA0=1.002968E-4 PKETA=-2.906037E-3)

.MODEL P PMOS (LEVEL=7, VERSION=3.1
TNOM=27 TOX=4.1E-9 XJ=1E-7 NCH=4.1589E17 VTH0=-0.3948389 K1=0.5763529
K2=0.0289236 K3=0 K3B=13.8420955 W0=1E-6 NLX=1.337719E-7 DVT0W=0 DVT1W=0
DVT2W=0 DVT0=0.5281977 DVT1=0.2185978 DVT2=0.1 U0=109.9762536 UA=1.325075E-9
UB=1.577494E-21 UC=-1E-10 VSAT=1.910164E5 A0=1.7233027 AGS=0.3631032 B0=2.336565E-7
B1=5.517259E-7 KETA=0.0217218 A1=0.3935816 A2=0.401311 RDSW=252.7123939 PRWG=0.5
PRWB=0.0158894 WR=1 WINT=0 LINT=2.718137E-8 XL=0 XW=-1E-8 DWG=-4.363993E-8
DWB=8.876273E-10 VOFF=-0.0942201 NFACTOR=2 CIT=0 CDSC=2.4E-4 CDSCD=0 CDSCB=0
ETA0=0.2091053 ETAB=-0.1097233 DSUB=1.2513945 PCLM=2.1999615 PDIBLC1=1.238047E-3
PDIBLC2=0.0402861 PDIBLCB=-1E-3 DROUT=0 PSCBE1=1.034924E10 PSCBE2=2.991339E-9
PVAG=15 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=6.28E-10 CGSO=6.28E-10
CGBO=1E-12 CJ=1.160855E-3 PB=0.8484374 MJ=0.4079216 CJSW=2.306564E-10
PBSW=0.842712 MJSW=0.3673317 CJSWG=4.22E-10 PBSWG=0.842712 MJSWG=0.3673317
CF=0 PVTH0=2.619929E-3 PRDSW=1.0634509 PK2=1.940657E-3 WKETA=0.0355444
LKETA=-3.037019E-3 PU0=-1.0227548 PUA=-4.36707E-11 PUB=1E-21 PVSAT=-50
PETA0=1E-4 PKETA=-5.167295E-3)

Table 3 shows the comparison with other previously known oscillators using different active building blocks.

Tab. 3: Comparison with other previously known fully uncoupled sinusoidal oscillators.

Reference Number	No. of active Building Blocks	No. of Passive Components	Independent Electronic Tunability in Both CO and FO
[1]	2	6	NO
[2]	3	04.VI	NO
[5]	3	2	NO
[6]	01.III	02.III	NO
[7]	3	2	NO
[8]	4	2	YES
[9]	2	2	YES
[11]	2	3	NO
[12]	2	4	YES
[13]	4	2	YES
[14]	2	3	NO
Proposed	2	3	YES

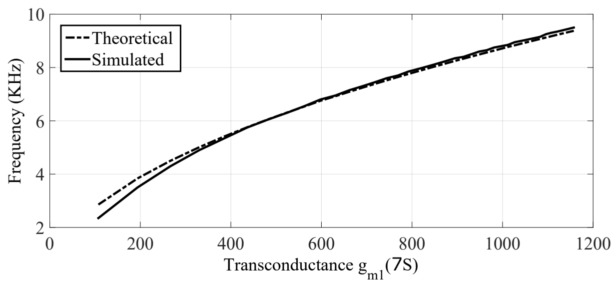


Fig. 7: Variation of frequency with g_{m_1} for both the circuits of Fig. 2.

5. Conclusion

In this paper, two new circuit configurations employing two VDIBAs along with a minimum number of passive elements (i.e. two capacitors and only one resistor) have been presented. The proposed oscillators offer independent electronic control of both CO and FO, and have low active and passive sensitivities. The validity of both oscillators was established by SPICE simulations with a CMOS VDIBA architecture implementable in 0.18 µm TSMC CMOS technology.

Acknowledgment

The author gratefully acknowledges Professor R. Senani for his valuable and constructive suggestions/modifications in the preparation of this manuscript. The author also wishes to thank the anonymous reviewers for their comments and suggestions which have been very useful in improving the presentation of the manuscript.

References

[1] TANGSRIRAT, W. and S. PISITCHALERMPONG. CDBA-Based Quadrature Sinusoidal Oscillator. *Journal of RF-Engineering and Telecommunication.* 2007, vol. 61, iss. 3–4, pp. 102–104. ISSN 0016-1136. DOI: 10.1515/FREQ.2007.61.3-4.102.

[2] ABUELMATTI, M. T. New Sinusoidal Oscillators with Fully Uncoupled Control of Oscillation Frequency and Condition Using Three CCII+s. *Analog Integrated Circuits and Signal Processing.* 2000, vol. 24, iss. 3, pp. 253–261. ISSN 1573-1979. DOI: 10.1023/A:1008321911123.

[3] PUSHKAR, K. L., D. R. BHASKAR and D. PRASAD. Single-Resistance Controlled Sinusoidal Oscillator Using Single VD-DIBA. *Active and Passive Electronic Components.* 2013, vol. 2013, iss. 1, pp. 1–5. ISSN 0882-7516. DOI: 10.1155/2013/971936.

[4] PUSHKAR, K. L., R. K. GOEL, K. GUPTA, P. VIVEK and J. ASHRAF. New VD-DIBA-Based Single-Resistance-Controlled Sinusoidal Oscillator. *Circuits and Systems.* 2016, vol. 7, iss. 13, pp. 4145–4153. ISSN 2113-1932. DOI: 10.4236/cs.2016.713341.

[5] BHASKAR, D. R., S. S. GUPTA, R. SENANI and A. K. SINGH. New CFOA-Based Sinusoidal Oscillators Retaining Independent Control of Oscillation Frequency Even under the Influence of Parasitic Impedances. *Analog Integrated Circuits and Signal Processing.* 2012, vol. 73, iss. 1, pp. 427–437. ISSN 1573-1979. DOI: 10.1007/s10470-012-9896-6.

[6] SOLIMAN, A. M. Current Feedback Operational Amplifier Based Oscillators. *Analog Integrated Circuits and Signal Processing.* 2000, vol. 23, iss. 3, pp. 45–55. ISSN 1573-1979. DOI: 10.1023/A:1008391606459.

[7] BHASKAR, D. R. Realization of Second Order Sinusoidal Oscillator/Filters with Non-Interacting Controls Using CFAs. *Journal of RF-Engineering and Telecommunication.* 2003, vol. 57, iss. 1–2, pp. 12–14. ISSN 2191-6349. DOI: 10.1515/FREQ.2003.57.1-2.12.

[8] BHASKAR, D. R. and R. SENANI. New Linearly Tunable CMOS-Compatible OTA-C Oscillators with Non-Interacting Controls. *Microelectronics Journal.* 1994, vol. 25, iss. 2, pp. 115–123. ISSN 0026-2692. DOI: 10.1016/0026-2692(94)90108-2.

[9] PRASAD, D., M. SRIVASTAVA and D. R. BHASKAR. Electronically Controllable Fully Uncoupled Explicit Current-Mode Quadrature Oscillator Using VDTAs and Grounded Capacitors. *Circuits and Systems*. 2013, vol. 4, iss. 2, pp. 169–172. ISSN 2153-1293. DOI: 10.4236/cs.2013.42023.

[10] HERENCSAR, N., S. MINAEI, J. KOTON, E. YUCE and K. VRBA. New Resistorless and Electronically Tunable Realization of Dual-Output VM All-Pass Filter Using VDIBA. *Analog Integrated Circuits and Signal Processing*. 2013, vol. 74, iss. 1, pp. 141–154. ISSN 1573-1979. DOI: 10.1007/s10470-012-9936-2.

[11] PRASAD, D., D. R. BHASKAR and K. L. PUSHKAR. Electronically Controllable Sinusoidal Oscillator Employing CMOS VD-DIBAs. *ISRN Electronics*. 2013, vol. 2013, iss. 1, pp. 1–6. ISSN 2356-1293. DOI: 10.1155/2013/823630.

[12] BHASKAR, D. R., D. PRASAD and K. L. PUSHKAR. Fully Uncoupled Electronically Controllable Sinusoidal Oscillator Employing VD-DIBAs. *Circuits and Systems*. 2013, vol. 4, iss. 3, pp. 264–268. ISSN 2153-1293. DOI: 10.4236/cs.2013.43035.

[13] BHASKAR, D. R., D. PRASAD, R. SENANI, M. K. JAIN, V. K. SINGH and D. K. SRIVASTAVA. New Fully-Uncoupled Current-Controlled Sinusoidal Oscillator Employing Grounded Capacitors. *American Journal of Electrical and Electronic Engineering*. 2016, vol. 4, iss. 3, pp. 81–84. ISSN 2328-7357. DOI: 10.12691/ajeee-4-3-2.

[14] PUSHKAR, K. L., G. SINGH and R. K. GOEL. CMOS VDIBAs-based Single-Resistance-Controlled Voltage-Mode Sinusoidal Oscillator. *Circuits and Systems*. 2017, vol. 8, iss. 1, pp. 14–22. ISSN 2153-1293. DOI: 10.4236/cs.2017.81002.

[15] BIOLEK, D., R. SENANI, V. BIOLKOVA and Z. KOLKA. Active Elements for Analog signal processing: Classification, review, and new proposals. *Radioengineering*. 2008, vol. 17, iss. 4, pp. 15–32. ISSN 1210-2512.

About Authors

Kanhaiya Lal PUSHKAR was born in village Roshangpur, Auraiya, U.P., India, on 17th August 1969. He received B.Tech. in Electronics Engineering from I.E.T. Lucknow in 1994, M.E. in communication systems from IIT Roorkee (erstwhile University of Roorkee) in 1999, and additional M.E. in ECE from Delhi Technological University (erstwhile Delhi College of Engineering) in 2008. He completed his Ph.D. from Jamia Millia Islamia (A Central University), Delhi in 2014. Currently, he is working as Assistant Professor in Maharaja Agrasen Institute of Technology, Rohini, New Delhi. His current research interest is in Analog Signal Processing and Generation employing modern active building blocks.