Single-Element-Controlled Sine-Wave Oscillator Using Single VDIBA

Ramnish Kumar
Department of Electronics and Communication Engineering,
Guru Jhambheshwar University of Science and Technology
Hisar, Haryana, India

***ABSTRACT*- This study presents a new canonic, simple voltage-mode resistor less single element-controlled oscillator (SECO) topology based upon a single voltage differencing inverting buffered amplifier (VDIBA). The proposed configuration employs two capacitors and one NMOS transistor and transistor operating in triode region. The proposed structure having independent control of frequency of oscillation and low active and passive sensitivities. To validate the performance of the presented new SECO has been evaluated through SPICE simulations results, utilizing 0.18µm CMOS technology.**

***Keywords*: VDIBA, Sinusoidal Oscillator, Voltage-Mode, and Analog Circuit Design**

I. INRODUCTION

Sinusoidal oscillators remain useful now many electronic systems. They can be used as test oscillators for radio receivers testing, signal to noise ratio measurement, standing wave ratio, as transducer oscillators [1]. Sinusoidal oscillators having single-element-control (SEC) are significant oscillators as they are very advantageous in the areas of instrumentation and measurements [2]-[6]. Biolek et al. presented a number of new analog ABBs [2]. The VDIBA is one, which are evolving as a very flexible and multipurpose active building block for signal processing and analog signal generation applications. However, although a number of SECOs employing a single ABB have been presented earlier (see [4]-[16] and the references cited therein) with different active elements, to the best knowledge of the author, any resistor less SECO using a single VDIBA has not yet been presented in the open literature so far. In recent times, VDIBA has been frequently used in numerous analog signal processing and signal generation applications; see for example [18], [19], [21]-[26]. A brief explanation of former work done on SECOs is as given.

Singh, Sharma, Singh, Bhaskar and Senani have presented two new canonic single current feedback configurations with three resistors and two capacitors in which CO and FO are independently well-regulated [5]. Celma, Martinez, and Carlosena presented a SECO using a second-generation current conveyor (CC-II), three resistors and two capacitors [6] with self-regulating of CO and FO. Lee, and Wang have proposed a single four-terminal floating nullor (FTFN)-based SECO with three resistors and two capacitors in which CO and FO are adjusted independently [7]. In [8], Bhaskar has presented single positive FTFN (PFTFN)-based a SECO using four resistors and two grounded capacitors (GCs) which provides self-regulating of CO and FO. In [9], Gupta and Senani presented a SECO using single DVCCC, three resistors and two GCs where CO and FO are adjusted independently. In [10], Aggarwal, Kilinc and Cam introduced two SECOs with single DVCCC, three resistors and two GCs for first oscillator and two resistors and two GCs for second one, both oscillators provide self-regulating of CO and FO. Ozcan, Toker, Acar, Kuntman, and Cicekoglu reported six oscillators using single current differencing buffered amplifier (CDBA) in which only one circuit provides self-regulating of CO and FO [11]. In [12], Cam, presented SECO employing single operational trans resistance amplifier (OTRA), three resistors and two capacitors in which only FO is individually controllable. In [13], Prasad, Bhaskar, and Singh presented a SECO employing single current differencing transconductance amplifier (CDTA), two resistors and two capacitors which provides self-regulating of both CO and FO. Biolek, Keskin, Biolkova [14] proposed SECO using single modified-CDTA, two resistors and two GCs which yields self-regulating of CO and FO. In [15], Pushkar et al. Published a SECO employing single VD-DIBA, two resistors and two GCs in which CO and FO are tuned independently. Pushkar, Goel, Gupta, Vivek, and Ashraf [16] proposed a SECO using single VD-DIBA, two resistors and two capacitors which provides self-regulating of CO and FO. In [17], Bhaskar and Senani have presented a SECO using negative CCII, three resistors, one voltage follower and two GCs providing self-regulating of both CO and FO. In [18], Herencsar, Minaei, Koton, Yuce, and Vrba presented an oscillator using two VDIBAs, a resistor and two capacitors (one floating and one grounded) in which CO and FO are not individually controllable. Channumsin and Tangsrirat [19] have introduced a quadrature oscillator using two VDIBAs, a NMOS resistor and two capacitors (one floating and one grounded) where CO and FO are individually regulated.Therefore, the aim of this communication is, to introduce a different and simple resistorless SECO using a single VDIBA (having bare minimum number of MOS transistors) alongside a few of passive components (only two capacitors and an electronic resistor). The performance of the presented new SECO has been evaluated through SPICE simulations results, utilizing 0.18µm CMOS technology.

II. THE PROPOSED NEW CONFIGURATION

The ideal VDIBA described by the subsequent equations:

$$\begin{aligned} &I_z = g_m(V_+ - V_-),\\ &V_{w^-} = -\beta V_z,\\ &I_+ = 0, I_- = 0 \end{aligned} \quad (1)$$

where β is known as a non-ideal voltage gain of VDIBA. The β is one for ideal VDIBA and g_m is the transconductance of the VDIBA. Basically, the VDIBA is a cascade of a differential voltage controlled current source and a unity gain inverting amplifier. The proposed new resistorless single-element-controlled (SEC) sinusoidal oscillator structure based on VDIBA is displayed in Fig.1. The presented SECO employs only single VDIBA, two capacitors and one NMOS transistor (R_{MOS}). The NMOS transistor is operating in triode-mode with its small-signal resistance R_{MOS} is given as

$$R_{MOS} = \frac{1}{\mu_n C_{ox}(V_C - V_{TH})\left(\frac{W}{L}\right)} \quad (2)$$

Where μ_n is the mobility of the free electron, C_{ox} is the gate-oxide capacitance per unit area, W and L are the effective channel width and length, V_{TH} is the threshold voltage of the NMOS, and V_C is the DC voltage used for tuning of R_{MOS}.

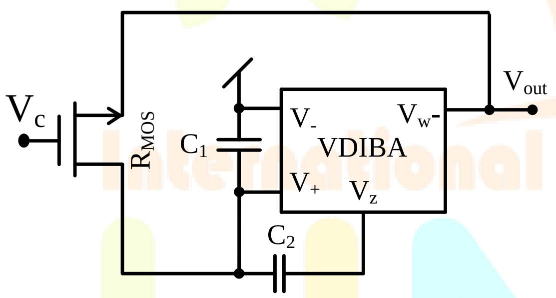


Fig. 1. The proposed SECO configuration

A circuit investigation of the proposed configuration provides the following CE:

$$s^2 + \frac{s}{C_1}\left\{\frac{2}{R_{MOS}} - g_m\right\} + \frac{g_m}{C_1 C_2 R_{MOS}} = 0 \quad (3)$$

Condition of oscillation: $\left\{\frac{2}{R_{MOS}} - g_m\right\} \le 0$ (4)

And

Frequency of oscillation:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{g_m}{C_1 C_2 R_{MOS}}} \quad (5)$$

So, it is realized that Frequency of oscillation is autonomously controllable by either C_1 or C_2. FO can also be varied by simultaneous change of C_1 and C_2.

III. FREQUENCY STABILITY ANALYSIS

Frequency stability is an imperative quality of an oscillator. The frequency stability factor is well-defined as $S^F = d\phi(u)/du$, where $u = \omega/\omega_0$ is the normalized frequency, and $\phi(u)$ represents the phase function of the open loop transfer function of the oscillator circuit. With $C_1 = nC$, $C_2 = C$, $R_{MOS} = 2/g_m$, frequency stability for the proposed oscillator is found to be:

$$S^F = \frac{\sqrt{8n}}{n+2} \quad (6)$$

Therefore, the frequency stability factor is better than other classical oscillators.

IV. SENSITIVITY AND NON-IDEAL ANALYSIS

Considering the parasitics on the Z and W-terminals. Capacitance denoted by C_z and parasitic resistance denoted by R_z and the parasitic resistance denoted by R_w of VDIBA. The voltage of W-terminal $V_{W-} = (-\beta^+ V_Z + I_w R_w)$ where $\beta^+ = 1-\varepsilon_p$ (ε_p<<1), by taking the non-idealities into account, denotes the voltage tracking errors of VDIBA, the expressions for CE, CO and FO correspondingly become:

$$s^2\{C_z(C_1+C_2)+C_1C_2\} + s\left\{\begin{array}{l}\frac{C_1+C_2}{R_z} + \frac{C_2+C_z}{R_{MOS}} + \frac{C_2\beta^+}{R_{MOS}+2R_w}\\ -\frac{(C_2+C_z)2R_w}{R_{MOS}(R_{MOS}+2R_w)} - C_2 g_m\end{array}\right\} + \frac{\beta^+ g_m R_{MOS} R_z - 2R_w}{R_{MOS} R_z (R_{MOS}+2R_w)} = 0 \quad (7)$$

CO:

$$\left\{\begin{array}{l}\frac{C_1+C_2}{R_z} + \frac{C_2+C_z}{R_{MOS}} + \frac{C_2\beta^+}{R_{MOS}+2R_w}\\ -\frac{(C_2+C_z)2R_w}{R_{MOS}(R_{MOS}+2R_w)} - C_2 g_m\end{array}\right\} \le 0 \quad (8)$$

FO:

$$\omega_0 = \sqrt{\frac{\beta^+ g_m R_{MOS} R_z - 2R_w}{R_{MOS} R_z (R_{MOS} + 2R_w) \times \{C_z(C_1 + C_2) + C_1 C_2\}}} \tag{9}$$

The equation (4) calculated using the values R_{MOS} = 6.786kΩ and g_m = 359μS (I_b = 45μA) and got -0.064275. Which is according to given in equation 4 (<0). On the other hand, when equation (8) is calculated using the values C_z = 0.367pF, R_z = 131.93kΩ, β^+ =1, R_w = 42.36Ω along with $C_1 = C_2$ = 50pF, and R_{MOS} = 6.786 kΩ, is turned out to be -0.04911. It is realized that both the values are relatively close. Furthermore, considering C_1, C_2 >>C_Z, R_{MOS}<<R_Z and R_w assumed to be negligibly small as compared to R_{MOS} and R_z, the equation (8) becomes

$$\left\{\frac{C_1 + C_2}{R_z} + \frac{C_2}{R_{MOS}} + \frac{C_2\beta^+}{R_{MOS}} - C_2 g_m\right\} \le 0$$

which is quite close to equation (4).

The various active and passive sensitivities are found to be:

$$S_{C_1}^{\omega_0} = -\frac{1}{2}\frac{1}{1 + \cfrac{1}{C_1\left(\cfrac{1}{C_2} + \cfrac{1}{C_z}\right)}} \tag{10a}$$

$$S_{C_2}^{\omega_0} = -\frac{1}{2}\frac{1}{1 + \cfrac{1}{C_2\left(\cfrac{1}{C_1} + \cfrac{1}{C_z}\right)}} \tag{10b}$$

$$S_{C_Z}^{\omega_0} = -\frac{1}{2}\frac{1}{1 + \cfrac{1}{C_z\left(\cfrac{1}{C_1} + \cfrac{1}{C_2}\right)}} \tag{10c}$$

$$S_{R_{MOS}}^{\omega_0} = \frac{1}{2}\left(\frac{\beta^+ g_m R_{MOS} R_z}{\beta^+ g_m R_{MOS} R_z - 2R_w} - \frac{2(R_{MOS} + R_w)}{(R_{MOS} + 2R_w)}\right) \tag{10d}$$

$$S_{R_Z}^{\omega_0} = \frac{R_w}{(\beta^+ g_m R_{MOS} R_z - 2R_w)} \tag{10e}$$

$$S_{\beta^+}^{\omega_0} = -\frac{1}{2}\left\{\frac{\beta^+ g_m R_{MOS} R_z}{(\beta^+ g_m R_{MOS} R_z - 2R_w)}\right\} = S_{g_m}^{\omega_0} \tag{10f}$$

$$S_{R_w}^{\omega_0} = \frac{2R_w}{(R_{MOS} + 2R_w)} \tag{10g}$$

Ideally, the various sensitivities of FO with respect to C_z, C_1, and C_2 are found to be

$$S_{C_z}^{\omega_0} = 0, \; S_{C_1}^{\omega_0} = S_{C_2}^{\omega_0} = -\frac{1}{2} \tag{11}$$

As the usual values of different parasitics as C_z = 0.367pF, R_z = 131.93kΩ, R_w = 42.36Ω, β^+ =1 along with $C_1 = C_2$ = 50pF, g_m = 359μA/Vand R_{MOS} = 6.786kΩ the various sensitivities are found to be $S_{C_1}^{\omega_0} = -0.4964$, $S_{C_2}^{\omega_0} = -0.4964$, $S_{C_Z}^{\omega_0} = -0.0073$, $S_{R_{MOS}}^{\omega_0} = -0.4938$, $S_{R_Z}^{\omega_0} = 0.0001$, $S_{\beta^+}^{\omega_0} = 0.5$, $S_{R_w}^{\omega_0} = 0.01234$ and $S_{g_m}^{\omega_0} = 0.5$ which are all found to be low.

V. SPICE SIMULATION RESULTS

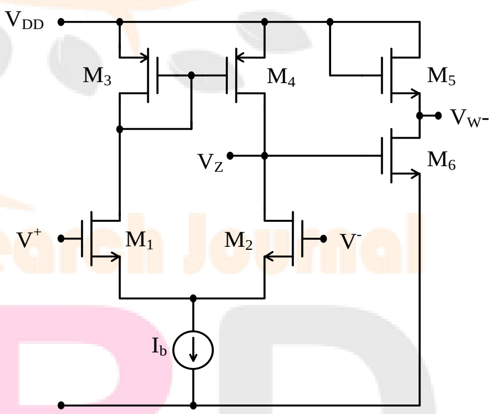


Fig 2. Internal structure of VDIBA [18], $V_{DD} = -V_{SS}$ = 0.9V, I_b= 45μA

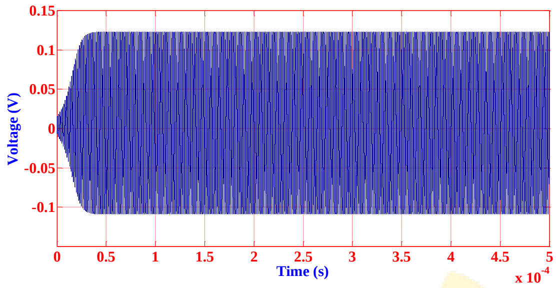
To authenticate the hypothetical analysis, the new SECO be present, simulated using CMOS VDIBA as shown in Fig. 2. The W/L ratios of transistors used in Fig. 2 are given in Table 1.

Table 1 Aspect ratios of transistors used in CMOS implementation of VDIBA

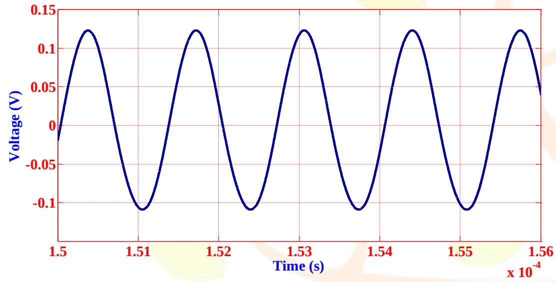
Transistor	W (μm)	L (μm)
M1-M4	18	1.08
M5, M6	54	0.18

The proposed oscillator was designed for frequency f_0 = 744 kHz by selecting $C_1 = C_2$ = 50pF, I_b = 45μA (g_m = 359μA/V), and R_{MOS} = 6.786 kΩ found with aspect ratio

W/L = 3.6 µm/2.52 µm, and DC control voltage V_C = 0.84V. The g_m (transconductance) of VDIBA was set by the biasing current I_b. Fig. 3(a) and Fig. 3(b) shows the transient and steady state responses i.e., SPICE generated output waveforms. These output waveforms, validate the proposed configuration. Fig. 4 displays the frequency spectrum of output signal, wherever the THD is produce to be 1.05%. Variations of oscillation frequency with capacitance C_1 is shown in Fig. 5.



(a)



(b)

Fig 3. (a) Transient output waveform, (b) Steady state response of the output

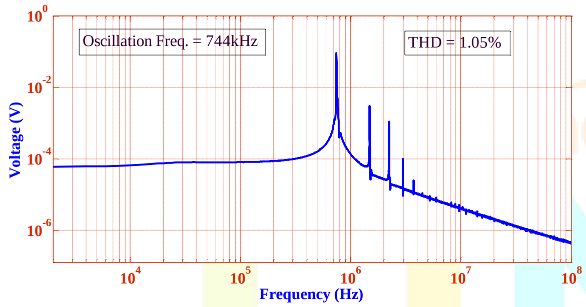


Fig 4. Simulation results of the output spectrum

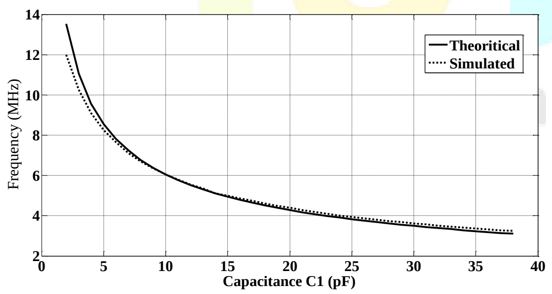


Fig 5. Variations of oscillation frequency with capacitance C_1

Table 2, shows comparison with the presented SECO with previously described SECOs using different ABBs has been provided in, from where it is clear that among all the considered single ABB based oscillators of [5]-[16], the proposed circuit is the only one which needs only a single NMOS transistor, two capacitors along with a single VDIBA while the other SECOs known earlier [18], [19] require two capacitors, two VDIBAs along with a resistor or a NMOS transistor.

Table 2 Comparison of the presented SECO with previously described SECOs

Reference	Active building blocks	Number of CMOS transistors used	Passive Components used		Are FO independently controllable?
			R	C	
[5]	1 CFOA	39	3	2	YES
[6]	1CC-II	16	3	2	YES
[7]	1FTFN	24	3	2	YES
[8]	1PFTFN	32	4	2	NO
[9]	1DVCCC	14	3	2	YES
[10]	1DVCCC	14	3/2	2	YES
[11]	1CDBA	20	3	2	YES
[12]	1OTRA	14	3	2	NO
[13]	1CDTA	24	2	2	YES
[14]	1CDTA	24	2	2	YES
[15]	1VD-DIBA	22	2	2	YES
[16]	1VD-DIBA	22	2	2	YES
[18]	2VDIBA	12	1	2	NO
[19]	2VDIBA	12+2	-	2	YES
Proposed	**1VDIBA**	**6+1**	-	**2**	**YES**

From Table 2, following are the observations:

(1) The proposed circuit is resistor less with a single ABB.
(2) The topologies [5-19] use a greater number of CMOS transistors
(3) The structures presented in [5-18] require a greater number of passive components
(4) FO is not independently controllable in the circuits of [8, 11, 12 and 18].

VI. CONCLUSIONS

The proposed circuit introduces a new and simple, single element controlled sinusoidal oscillator based on a single VDIBA. The configuration employs a few numbers of components (only one electronic resistor and two capacitors) and so far, deals independent tunability of frequency of oscillation through a grounded capacitor C_1. The circuit having low sensitivities (less than unity) and good frequency stability as compared to number of classical oscillators. This paper has, thus, supplemented a different submission circuit to the current catalogue of VDIBA-based use circuits [18], [19], [21]-[26]. Simulation results confirm the validity of this new SECO using CMOS VDIBA architecture implementable in 0.18µm CMOS technology.

REFERENCES

[1] D. R. Bhaskar, & R. Senani, "New CFOA-based Single-element-controlled sinusoidal oscillators," IEEE Transactions on Instrumentation and Measurement, Vol.55, no.6, pp. 2014-1, 2006.

[2] D. Biolek, R. Senani, V. Biolkova, Z. Kolka, "Active elements for analog signal processing; classification, review and new proposals," Radio engineering, Vol. 17, no.4, pp.15-32, 2008.

[3] R. Senani, "New types of sine wave oscillators," IEEE Transactions on Instrumentation and Measurement (USA), Vol. 34, no.3, pp.461-3, 1985.

[4] R. Senani, D. R. Bhaskar, "Single-op-amp sinusoidal oscillators suitable for generation of very low frequencies," IEEE Transactions on Instrumentation and Measurement, Vol.40, no.4, pp. 777-9, 1991.

[5] V.K. Singh, R.K. Sharma, A.K. Singh, D.R. Bhaskar, R.Senani, "Two new canonic single-CFOA oscillators with single resistor controls," IEEE Transactions on Circuits and Systems II: Express Brief (USA). Vol.52, no. 12, pp. 860-4, 2005.

[6] S. Celma, P.A. Martinez, A. Carlosena, "Minimal realisation for single resistor controlled sinusoidal oscillator using single CCII. Electronics Letters, Vol. 28, no.5, pp.443-4, 1992.

[7] C.T. Lee, "Wang HY. Minimum realization for FTFN-based SRCO," Electronics Letters, IEE (UK), Vol.37, no.20, pp.1207-8, 2001.

[8] D. R. Bhaskar, "Grounded-capacitor SRCO using only one PFTFN," Electronics Letters, IEE (UK). Vol.38, no. 20, pp.1156-7, 2002.

[9] S. S. Gupta, R. Senani, "Grounded-capacitor current-mode SRCO Novel application of DVCCC," Electronics Letters, IEE (UK). Vol. 36, no. 3, pp.195-6, 2000.

[10] V. Aggarwal, S. Kilinc, U. Cam, "Minimum component SRCO and VFO using a single DVCCC," Analog Integrated Circuits and Signal Processing, Vol. 49, pp.181-5,2006.

[11] S. Ozcan, A. Toker, C. Acar, H. Kuntman, O. Cicekoglu, "Single resistance-controlled sinusoidal oscillators employing current differencing buffered amplifier," Microelectronics Journal. Vol.31, no. 3, pp. 169-4, 2000.

[12] U. Cam, "A novel single-resistance-controlled sinusoidal oscillator employing single operational trans resistance amplifier," Analog Integrated Circuits and Signal Processing, Vol.32, pp.183–6, 2002.

[13] D. Prasad, D.R. Bhaskar, A.K.Singh, "Realisation of single–resistance-controlled sinusoidal oscillator A new application of the CDTA," WSEAS Trans. Electronics, Vol.6, no.5, pp.257-9, 2008.

[14] D. Biolek, A.U Keskin, V. Biolkova, "Grounded capacitor current mode single resistance-controlled oscillator using single modified current differencing transconductance amplifier," IET Circuits Devices System. Vol. 4, no.6, pp.496-2, 2010.

[15] K. L. Pushkar, D. R. Bhaskar, D. Prasad, "Single-resistance controlled sinusoidal oscillator using single VD-DIBA," Active and Passive Electronic Components," pp. 1-5 Article ID 971936, 2013.

[16] K. L. Pushkar, R. K Goel, K. Gupta, P. Vivek, J. Ashraf, "New VD-DIBA-Based Single-Resistance-Controlled Sinusoidal Oscillator," Circuits and Systems.Vol.7, no.13, pp. 4145-3, 2016.

[17] D. R. Bhaskar, R. Senani, "New current-conveyor-basedsingle-resistance-controlled/voltagecontrolled oscillator employing grounded capacitors. Electronics Letters, IEE (UK), Vol.29, no. 7, pp. 612-4, 1993.

[18] N. Herencsar, S. Minaei, J. Koton, E. Yuce, K. Vrba, "New resistor less and electronically tunable realization of dual-output VM all-pass filter using VDIBA," Analog Integrated Circuits and Signal Processing, Vol.74, pp. 141-4, 2020.

[19] O. Channumsin, W. Tangsrirat, "VDIBA-based sinusoidal quadrature oscillator," Przeglad Elektrotechniczny, Vol. 93, no.3, pp. 248-1,2017.

[20] S. Minaei, E. Yuce, "Novel voltage-mode all-pass filter based on using DVCCs," Circuits, System and Signal Processing, Vol. 29, pp. 391-2,2010.

[21] N. Herencsar, O. Cicekoglu, R. Sotner, J. Koton, K. Vrba, "New resistorless tunable voltage-mode universal filter using single VDIBA," Analog Integrated Circuits and Signal Processing, Vol. 76, pp. 251-0,2013.

[22] K. L. Pushkar, D.R. Bhaskar, D. Prasad, "Voltage-mode new universal biquad filter configuration using a single VDIBA," Circuits, Systems, and Signal Processing, Vol. 33, no. 1, pp. 275-5,2020.

[23] W. Tangsrirat, "Synthetic grounded lossy inductance simulators using single VDIBA," IETE Journal of Research, Vol. 63, no. 1, pp.134-1, 2017.

[24] K.L. Pushkar, D.R. Bhaskar, "Voltage-mode third order quadrature oscillator using VDIBAs," Analog Integrated Circuits and Signal Processing, Vol. 98, no. 1, pp. 201-7, 2018.

[25] K.L.Pushkar, G. Singh, R. K. Goel, "CMOS VDIBAs-based single-resistance-controlled voltage-mode sinusoidal oscillator. Circuits and Systems, Vol. 8, no. 1, pp.14-2, 2017.

[26] K.L.Pushkar,"Electronically controllable sinusoidal oscillator employing VDIBAs," Theoretical and Applied Electrical Engineering, Vol. 15, no. 5, pp. 799-5, 2017.