Grounded capacitors single resistance controlled oscillator using single FTFNTA

Dinesh Prasad, Ravendra Singh, Ashish Ranjan & Huirem Tarun Kumar

Department of Electronics & Communication Engineering, Faculty of Engineering & Technology, Jamia Millia Islamia, New Delhi 110 025, India
Department of Electrical & Electronics Engineering, Galgotia College of Engineering & Technology, Greater Noida 201 310, India
Department of Electronics & Communication Engineering, National Institute of Technology Manipur, Imphal 795 001, India

Received 11 December 2019; accepted 1 June 2020

In this manuscript, grounded capacitor single resistance controlled oscillator using four terminal floating Nullor transconductance amplifier (FTFNTA) is presented. It requires only one FTFNTA, two grounded resistors and two grounded capacitors. Oscillation condition (OC) and oscillation frequency (OF) are solely controlled through resistors. The non-ideal behaviour of the proposed structure has also been analyzed. Sensitivity analysis shows that the proposed structure is insensitive to component variations. The simulation results have been demonstrated and discussed using a SPICE simulation using 180 nm TSMC technologies. Monte Carlo analysis is also analysed for the proposed structure.

Keywords: FTFNTA, Sinusoidal oscillator, SRCO

1 Introduction

An oscillator is a very important part of the various applications such as mixture, SSB generation, in a telecommunication system, in vector generation, and selective voltmeters. So due to large application uses; oscillator is always an area of interest for researchers. An enormous variety of oscillators present in the literature reported by different authors. The oscillators manifest one or more of the following flaws such as: use of two or more active building blocks (ABBs), intertemporal use of passive elements, dependency of OC and OF, use of floating components and non-availability of the condition of oscillation which causes instability. These oscillators were designed by using various different active building blocks (ABB). But till now no oscillator structure is reported in the literature using FTFNTA ABB. So an SRCO using FTFNTA is proposed here. Detailed comparison on the basis of number of passive components used, only grounded elements are used or not and independent control of OC and OF is given in Table 1.

In this manuscript, an endeavour is made to suggest a new topology for a sinusoidal oscillator using only one FTFNTA ABB and four grounded passive components (2R+2C).

2 FTFNTA

The FTFNTA, a recently introduced CM active block reported in, is a combination of FTFN at i/p stage accompanied with OTA at the o/p stage. The circuit schematic of a FTFNTA is shown in Fig. 1. It is a six-port device. Amongst the available ports, the X and Y are I/P ports and Z, W, O+ and O- are the O/P ports. Port W evinces low impedance while all other port has high impedance. Both X and Y ports are buffered, i.e. no current will flow through these ports. The output current I0 and I0 has a transconductance gain incorporated with it. The characteristic equation of FTFNTA is stated in Eq. (1).

\[
\begin{pmatrix}
I_X \\
I_Y \\
V_X \\
I_Z \\
I_{o+} \\
I_{o-}
\end{pmatrix} = \begin{pmatrix}
0 & 0 & 0 \\
0 & 0 & 0 \\
\alpha & 0 & 0 \\
0 & -\beta & 0 \\
0 & 0 & \gamma g_m \\
0 & 0 & \gamma g_m
\end{pmatrix} \begin{pmatrix}
V_Y \\
I_W \\
V_Z
\end{pmatrix}
\]  

...(1)

\[
g_m = \sqrt{\frac{I_B \mu_n C_{ox} W}{L}}
\]  

where \(I_B\) is bias current, \(\mu_n\) is Mobility of free charge carrier present in the channel, \(C_{ox}\) is gate-oxide layer capacitance, W is channel width, L is channel length.
$s^2 + s \left( \frac{1}{c_1} \left( \frac{1}{R_1} - g_m \right) \right) + \frac{g_m}{R_2 c_1 c_2} = 0 \quad \text{(3)}$

So, oscillation frequency (OF) and oscillation condition (OC) are determined as:

\[ \text{OF: } \omega_0 = \sqrt{\frac{g_m}{R_2 c_1 c_2}} \quad \text{(4)} \]
From Eqs (4) and (5) it is clear that OF is solely controlled by $g_m$, and OC is solely controlled by $R_1$. Due to this, it is a single resistance controlled oscillator (SRCO).

### 4 Nonideal and Sensitivity Analysis

Due to the nonidealities present in ABBs the port characteristics of these ABBs are deviated from its ideal characteristic\(^\text{14,33}\). The primary nonideality in FTFNTA is due to $\alpha$, $\beta$ and $\gamma$. By considering the effects of parameters $\alpha$, $\beta$ and $\gamma$, the modified OC and OF of the oscillator will be:

**OC:**
\[
\frac{1}{R_1} - g_m \leq 0 \quad \text{...(6a)}
\]

**OF:**
\[
\omega_0 = \sqrt{\frac{g_m^2}{\alpha R_2 c_1 c_2}} \quad \text{...(6b)}
\]

So it is evident from Eqs (6a) and (6b) that nonideality will affect the OC and OF. This can be curtailed by minimising the tracking errors $\alpha = 1 - \epsilon_\alpha$, $\beta = 1 - \epsilon_\beta$, and $\gamma = 1 - \epsilon_\gamma$.

Nonideality also arises due to the parasitic resistor and capacitor connected in parallel with each terminal. Figure 3 shows the general schematic of nonideal parasitic of FTFNTA.

The schematic of the proposed oscillator with nonideality is given in Fig. 4.

At Y-W terminal
\[
R_{eq1} = R_2 || R_Y || R_W \quad \text{...(7)}
\]

At X-O+ terminal
\[
R_{eq2} = R_O || R_X \quad \text{...(9)}
\]

\[
C_{eq2} = C_O + C_X + C_2 \quad \text{...(10)}
\]

At Z-O+ terminal
\[
R_{eq3} = R_Z || R_{O'} || R_1 \quad \text{...(11)}
\]

\[
C_{eq3} = C_O + C_Z + C_1 \quad \text{...(12)}
\]

The characteristic Equation of the oscillator under nonideal condition is:
\[
s^2 C_{eq2} g_{eq2} + s(C_{eq3} g_{eq3} + C_{eq2} g_{eq2} + C_{eq1} g_m - C_{eq2} g_m) + g_{eq1} g_m - g_{eq2} g_m = 0
\]
\[
\quad \text{...(13)}
\]

**OC:**
\[
C_{eq1} = C_Y + C_W \quad \text{...(8)}
\]

**OF:**
\[
\omega_0 = \sqrt{\frac{g_{eq1} g_m - g_{eq2} g_m}{C_{eq2} C_{eq3}}} \quad \text{...(15)}
\]

where $g_{eq1}$, $g_{eq2}$ and $g_{eq3}$ is the inverse of equivalent resistance $R_{eq1}$, $R_{eq2}$ and $R_{eq3}$ respectively.

It is evident that the OC and OF are pretentious by parasitic of FTFNTA. The ramification of parasitic

---

Fig. 3 – Schematic of nonideal parasitic FTFNTA\(^\text{32}\).

Fig. 4 – Schematic of proposed oscillator with nonideality.
capacitors $C_{eq2}$ and $C_{eq3}$ can be neglected as they are parallely connected with $C_1$ and $C_2$ by calibrating the designed value. Effect of resistance $R_{eq1}$ and $R_{eq2}$ are eliminated by external resistance $R_1$ and $R_2$. $C_{eq1}$ and $R_{eq2}$ are compensated by the coupling capacitor $C_c$ and resistance $R_c$.

The sensitivity $\omega_0$ of for the designed oscillator is analysed w.r.t the passive components and nonideal parameters. Equations (16) and (17) give the sensitivities of $\omega_0$, and all the values are lying in the specified range from -1 to 1.

\[
S_{\omega_0}^{C_{eq1}} = S_{\omega_0}^{C_{eq2}} = S_{\omega_0}^{R_{eq2}} = -0.5 \\
S_{\omega_0}^{R_{eq1}} = S_{\omega_0}^{C_{eq1}} = 0.5; S_{\omega_0}^{R_{eq2}} = -0.5 \tag{16}
\]

5 Simulation Results and Discussion

To verify the response of the oscillator PSPICE simulation is performed using 0.18 μm CMOS technology. The theoretical computation of the proposed oscillator out-turn that the frequency of oscillation is 653 kHz. The specifications for designed oscillator is $g_m = 679$ μA/V (for $I_B = 600$ μA) and $R_1 = 1.5 \, K\Omega$, $R_2 = 4 \, K\Omega$, $C_1 = C_2 = 0.1 \, nF$. The transient and steady state response of oscillator is furnished in Figs 5 and 6. The simulated OF is approximately 640 kHz furnished in Fig. 7.

The Monte Carlo simulation effectuates to examine the robustness of the proposed oscillator by considering the outcome of ten samples for 10% Gaussian deviation on resistor $R_1$. Figure 8 shows that
there is a very low alteration in OC by modifying the resistor R₁. Figure 9 shows the histogram in which OF remains around to its standard value 640 kHz for a deviation of 10% or less.

6 Conclusions

An extensive comparison is given in Table 1 which reveals that the proposed oscillator is more preferable than the previously existing oscillators. In this manuscript, an SRCO employing only one active building block i.e. FTFNTA has been presented. FTFNTA is a new and versatile ABB. Previously, no oscillator circuit was reported, using FTFNTA in the literature. The presented oscillator circuit offers the independent control on OC and OF through resistors. It uses all grounded passive elements. Monte Carlo analysis is carried out which shows that the higher stability of the oscillator with respect to the parameter variation for 10%.

References