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A NOVEL EXPLICIT HIGH FREQUENCY TUNABLE OSCILLATOR USING SINGLE CCCII+

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ABSTRACT

The work presented in this paper is to give a big picture on sinusoidal oscillator using single tunable second generation current controlled conveyor (CCCII+) with three passive components. A practical circuit is realized using IC AD844 along with LM 13700 configured as second generation current conveyor (CCCII+). The proposed oscillator circuit is designed using minimum number of passive components along with one single active element. The condition of frequency as well as the condition of oscillation can be varied by exploiting the input parasitic resistance which is tuned by external bias current.

Keywords: CCCII; oscillator; high frequency; IC AD844 AN, LM13700

I. INTRODUCTION

Sinusoidal oscillators play an important role in instrumentation, communication systems and signal processing applications. Enormous number of oscillator circuits has been proposed using op-amp as an active element but the limitation of fixed bandwidth, gain and slew rate affects the condition of oscillation, frequency of oscillation and cannot operate at high frequencies. To overcome all these limitations several sinusoidal oscillators using current conveyors (CC) and current feedback operational amplifiers (CFOA) has been proposed.

Current Conveyors (CC) represents the emerging class of high performance analogue circuit design based on current-mode approach. They have simple structure, wide bandwidth and capability to operate at low voltages. Current conveyors are unity gain active elements exhibiting higher linearity, wider dynamic range and better high frequency performance.

Most of the oscillator circuits proposed so far make use of more than one active element which reaps the circuit to consume more power and occupies more area. In this regard we are proposing a sinusoidal oscillator which is stark based on using single active element along with three passive components. The novel circuit is designed in such a way that we are capable of controlling the frequency and amplitude by tuning the external bias current.

The active element can be realized by using Current Feedback Operational Amplifier (CFOA) IC AD844 and Operational Transconductance Amplifier (OTA) IC LM13700. The AD844 can be used in place of traditional op amps, but its current feedback architecture results in much better AC performance, high linearity and an exceptionally clean pulse response. The AD844 is free from slew rate limitations, peak output rate of change can be over 2000v/μs from a full 20 Volts output step. The LM13700 series consist of two current controlled transconductance amplifiers, each with differential inputs and a push-pull output. The output buffers of the LM13700 differ from those of the LM13600 in that their input bias currents are independent, results in superior performance than that of LM13600 in audio applications.

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II. CURRENT CONVEYOR

2.1 Current Mode Circuits

Current-mode circuits have been gaining the attention of analog designers over the last decades as an important class of analog circuits. Using current as the medium of signal processing allows to influence the power supply rejection ratio as well as to set the signal range more effective than it is done in voltage processing circuits, where the maximal signal range is solidly given by the size of the supply voltage. The key performance feature of current-mode circuits is however their inherent wide bandwidth capability. This is due to the fact that current-mode circuits do not include any internal high-impedance node and because of this all poles and zeroes of their transfer function lie very high on the frequency axis.

2.2 Second Generation Current Controlled Conveyor

Second generation current controlled conveyor(CCCII+) is current mode active building block, where the considerable parasitic resistance appears at the current input node and is controllable by the tuning the bias current.

An outlook of well known characteristics of an ideal CCCII+ is shown below in matrix form.

$$\begin{bmatrix} I_Y \\ V_x \\ I_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & R_x & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} V_y \\ I_x \\ V_z \end{bmatrix}$$

From the matrix, we can conclude that both and can be flowing into or out of the element simultaneously. is the input intrinsic resistance at node X of the element and can be varied by varying the bias current. Infinite input impedance is present at the node Y thus the current *Iy* at node Y is ideally zero. So, the current supplied at node X is conveyed to the high impedance node Z.

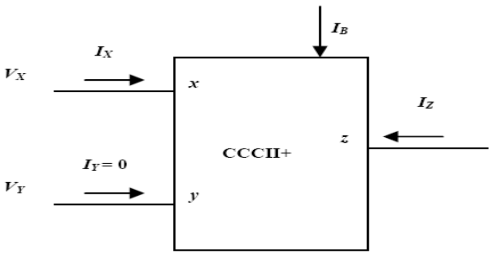

Fig. 1.Block diagram of CCCII+

The CCCII+ is designed using CMOS version and the circuit is realized as [5].

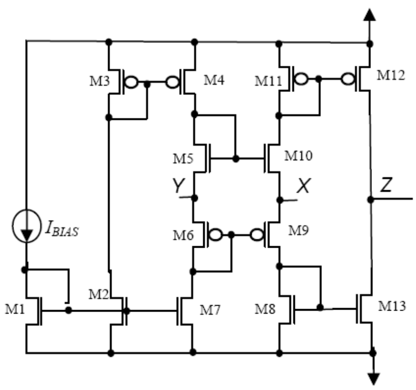

Fig. 2. Internal Structure of CCCII+

The transistors M5, M10, M6 and M9 forms a translinear loop, M1, M2, M3, M4 and M7 provides necessary controllable bias to the circuit and M11, M12, M8 and M13 are two complementary current mirrors make the current flowing through the terminal Z duplicates the current flowing through X.

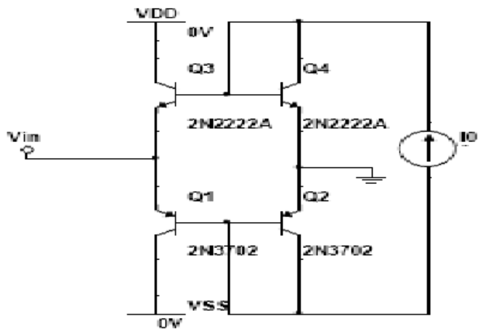

Fig. 3. Bias Current Generator Circuit

The bias current can be produced by using the **Figure 3** which controls the intrinsic resistance by utilizing the provided input voltage [2].

III. CIRCUIT DESCRIPTION AND OPERATION

This novel oscillator scheme is proposed as depicted in **Figure 4** .This scheme is elegant and simple that it incorporate only one active element i.e. second generation current controlled conveyor(CCCII+) with a possible minimum passive components[4].

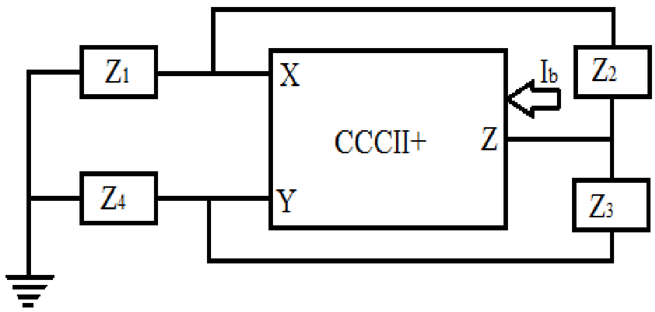

Fig. 4. Oscillator Circuit Using CCCII+

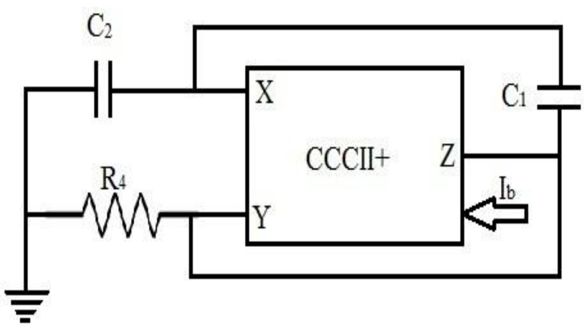

Fig. 5. Proposed Oscillator Circuit 1

The proposed circuit consist of two capacitors and one resistor along with internal resistance *Rx* controlled by external bias current. The circuit offers high frequency in the range of 1.33 MHz's.

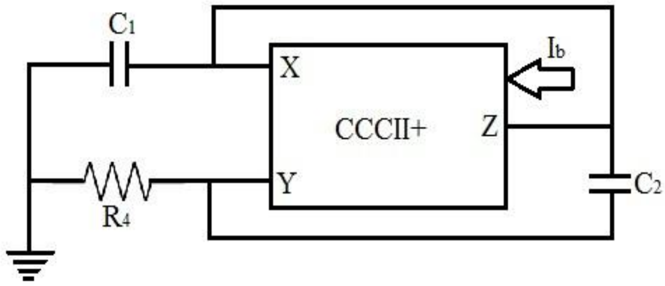

Fig. 6. Proposed Oscillator Circuit 2

The proposed circuit 2 consists of one grounded capacitor, grounded resistor and feedback capacitor which offers high frequency up to 4 MHz

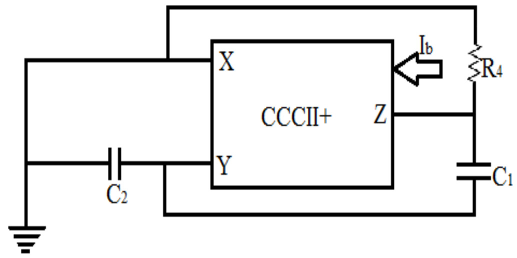

Fig. 7. Proposed Oscillator Circuit 3

The proposed circuit consist of two capacitors and one resistor along with internal resistance *Rx* controlled by external bias current. The circuit offers high frequency in the range of 9.09 MHz

3.1 Analysis

The characteristic equation of the oscillator circuit as shown in **Figure 4** can be given as

$$6Z_1Z_4 + 2Z_1Z_3 + Z_1Z_2 + 2Z_2Z_4 + Z_3Z_4 = -R_x[Z_1 + Z_2 + Z_3 + Z_4] \quad (1)$$

For proposed oscillator circuit as show in **Figure 5,**

Substitute $Z_2 = C_2, Z_3 = R_3$ we get,

$$S^2[C_1C_2R_3R_4 + R_xC_1C_2R_3 + R_xC_1C_2R_4] + S[6C_2R_4 + 2C_2R_4 + 2C_1R_4 + R_xC_2 + R_xC_1] + 1 = 0 \quad (2)$$

The condition for oscillation is

$$6C_2R_4 + 2C_2R_3 + 2C_1R_4 + R_xC_2 + R \quad (3)$$

The condition for frequency is

$$S^2[C_1C_2R_3R_4 + C_1C_2R_3R_x + C_1C_2R_xR_4] + \quad (4)$$

Substituting $C_1 = C_2 = C, R_3 =$ (5)

For proposed oscillator circuit as shown in **Figure 6,** substitute $Z_2 = R_3, Z_3 = C_2$

we get,

$$S^2[2C_1C_2R_3R_4 + R_xC_1C_2R_3 + R_xC_1C_2R_4] + S[6C_2R_4 + C_2R_3 + C_1R_4 + R_xC_2 + R_xC_1] + 2 = 0 \quad (6)$$

The condition for oscillation is

$$6C_2R_4 + C_2R_3 + C_1R_4 + R_xC_2 + \quad (7)$$

The condition for frequency is

$S^2[2C_1C_2R_3R_4 + C_1C_2R_3R_x + C_1C_2R_xR_4] + 1 =$ (8)

Substituting $C_1 = C_2 = C$, $R_3 =$ we get (9)

For proposed oscillator circuit as show in **Figure 7,**

Substitute $Z_2 = R_4$, $Z_3 = C_1$ we get,

The condition for oscillation is

$$6C_1R_3 + 2C_2R_3 + 2C_1R_4 + R_xC_2 + R \quad (10)$$

The condition for frequency is

$$S^2[C_1C_2R_3R_4 + C_1C_2R_3R_x + C_1C_2R_xR_4] + \quad (11)$$

Substituting $C_1 = C_2 = C$, $R_3 =$ (12)

IV. IMPLEMENTATION OF CCCII+

The CCCII+ can be realized by using commercially available ICs, which are AD844 as a current conveyor and LM13700 AN (OTA) as an electronically tunable floating resistance simulator which acts as the parasitic resistance at the node X of the current conveyor. By varying the external bias current which is applied to LM13700 (OTA) the amplitude and the frequency of the oscillations are tuned.

The interconnections are made as shown in the below **Figure 8**[3].

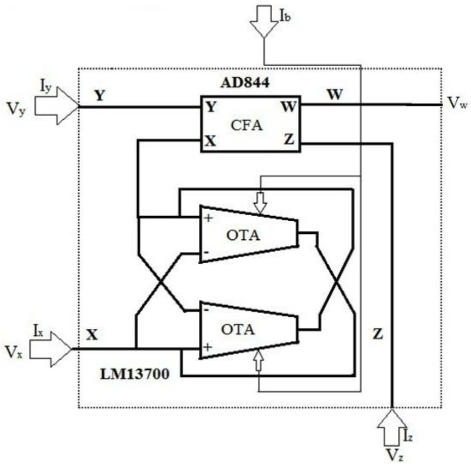

Fig. 8. Implementation of CCCII+

The CCCII+ is realized by using ICs AD844 and LM13700 as shown in **Figure 8**.The power supply volatges of ±5v is applied to AD844 and ±9v is applied to LM13700. The simulation results of respective circuits are shown in **Table III** and **Table IV** and **Table V**.From the **Tables** it is clear that as the bias current is varied frequency is varying proportionately.

Table I: Condition of oscillation & Frequency of Oscillation

Proposed Designs	Z1	Z2	Z3	Z4	Condition of Oscillation	Frequency of Oscillation[ ]
1	sC_1	sC_2	0	R_4	$6C_2R_4 + 2C_2R_3 + 2C_1R_4 + RxC_2 + RxC_1 =$	$\frac{1}{c^2R_4R_x}$
2	sC_1	0	sC_2	R_4	$6R_4C_2 + R_3C_2 + R_4C_1 + R_xC_2 + R_xC_1 = 0$	$\frac{2}{c^2R_4R_x}$
3	**0**	R_4	sC_1	sC_2	$6R_3C_1 + 2R_3C_2 + 2R_4C_1 + R_xC_2 = 0$	$\frac{1}{C^2R_4R_x}$

Table III: Comparative Performance Analysis of Candidate Designs

Oscillator designs [Ref]	**No. of active elements**	**Total number of passive components**	**No. of R and C**	**No. of components grounded**	**Hardware result impemented with commercial ICs**	**No. of Bias currents [Ib]**
[11]	1 CCII	6	3,3	All grounded except 1 resistor	No	No
[12]	3 CCII	6	5,1	All grounded except 1 resistor	Yes	No
[13]	5 AD844 AN	5	5,0	Only one floating	Yes	No
[14]	4 MOCCCII	4	0,4	All grounded	No	4
[15]	2-AD844 AN 1-OPAMP	8	5,3	4 Resistors not grounded	Yes	No
[16]	3-DXCCII	12	9,3	All grounded	No	No
[17]	1-CCI 1-CCII	5	3,2	All grounded	No	No
[18]	3-CCVC	2	0,2	All grounded	No	3
[19]	2-CCCII	5	3,2	All grounded	No	No
[20]	2-CCCII 2-MO CCCII	5	0,5	All grounded	No	4
[21]	2-CCCII	2	0,2	All grounded	No	2
[22]	1-CCCII 3-MO CCCII	6	2,4	All grounded	No	4
[23]	2- CCCII	2	0,2	All grounded	No	2
Candidate Method	**1-CCCII**	**3**	**1,2**	**1 Capacitor floating and remaining grounded**	**Yes**	**1**

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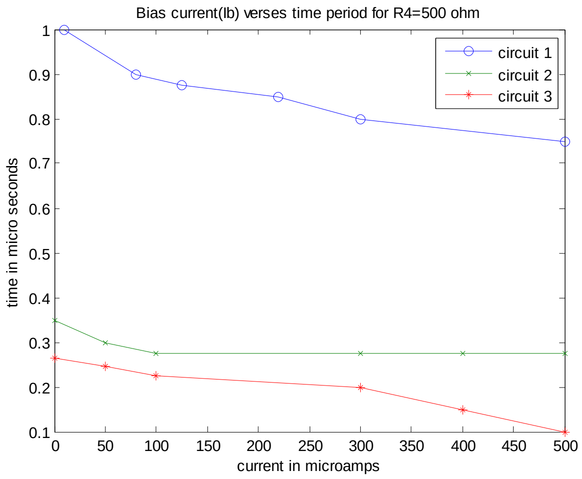

Fig.9. Bias Current Vs Time Period for all Three Proposed Circuits Where

The **Figure 9** compares internal resistance Vs time period for both proposed oscillators circuits. The **Figures 10** and **Figure 11** shows the desired sinusoidal results which is accomplished by taking the values of and .

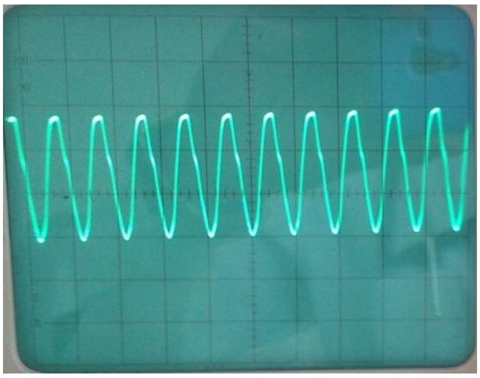

Fig. 7 Output of the proposed oscillator circuit I, Scale: X axis is Time period in 1µs/div and Y axis is Amplitude in 1Volt/div

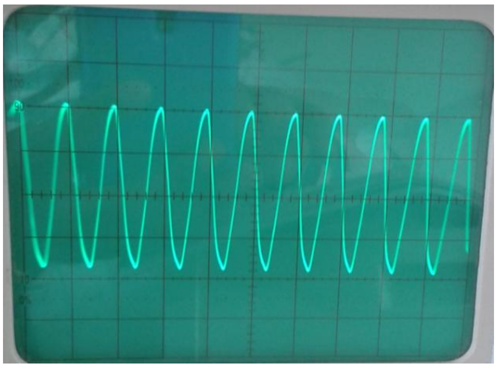

Fig.8 Output of the proposed oscillator circuit II, Scale: X axis is Time period in 1µs/div and Y axis is Amplitude in 1Volt/div

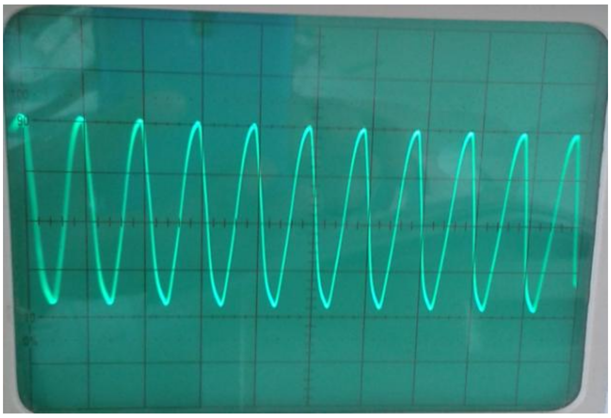

Fig. 12. Output of the proposed oscillator circuit III, Scale: X axis is Time period in 1μs/div and Y axis is Amplitude in 1Volt/div

Bias current Vs Internal resistance Vs Frequency		
Bias Current(μA)	*Resistance(Ω)*	*Frequency(MHz)*
10	1300	1
20	650	1.05
80	163	1.09
100	130	1.11
125	104	1.143
220	60	1.176
300	44	1.25
500	26	1.33

Table III: Bias Current Vs Internal Resistance Vs Frequency (Proposed Circuit I)

Bias current Vs Internal resistance Vs Frequency		
Bias Current(μA)	*Resistance(Ω)*	*Frequency(MHz)*
10	1500	4
50	260	3.83
100	130	3.63
150	98	3.63
300	87	3.63
400	44	3.63
500	33	3.63

Table IV: Bias Current Vs Internal Resistance Vs Frequency (Proposed Circuit II)

Bias Current(μA)	*Resistance(Ω)*	*Frequency (Practical)(Hz)*
5	2600	50K
25	520	55.55K
50	260	1.22M
100	130	2.44M
200	65	4.67M
300	44	7.41M
400	33	8.33M
500	26	9.09M

Table IV: Bias Current Vs Internal Resistance Vs Frequency (Proposed Circuit III)

V. CONCLUSION

In this proposed work we have designed an oscillator circuit which makes use of one active element and three passive components i.e. two capacitors and one resistor. We can vary the frequency of oscillation and condition of oscillation by varying bias current which is suitable for fabrication of monolithic ICs. Both the proposed circuits have their own limitations as well as advantages. For the proposed circuit I we can vary the amplitude and frequency of the oscillations to a larger extent i.e. from 1MHz to 1.33 MHz but the maximum frequency we could obtain is 1.33 MHz while for the proposed circuit II we can get maximum frequency up to 4MHz.

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