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A New Approach to Design & Implication of Colpitts Oscillator Using CCCII

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Abstract—**In this paper, an inductor-less tunable Colpitts oscillator is designed using second generation current controlled current conveyor (CCCII) as active block. The circuit contains three AD844/AD ICs and three capacitors. The inductor has been replaced by an active mode inductor connected to ground designed using second generation current controlled current conveyor. The main advantage of proposed Colpitts oscillator circuit is that it is free from resistor and inductor. The oscillation frequency has been made tunable electronically by adjusting the capacitor value and through the bias current. The simulation has verified using ORCAD v10.5 and experiment has also been performed with AD844/AD IC.**

Index Terms—**CCCII, Colpitts oscillator, Op- Amp, ORCAD v 10.5**

I. Introduction

In particular, the voltage operational amplifier rapidly become the main analogue block and dominated the market since the invention of the first analogue integrated circuit. Nowadays, the situations are changing because there is a new impulse towards these called current mode circuits, which are able to overcome the limitations of a constant gain-bandwidth product and relationship between speed and bandwidth, so that performance can be improved in terms of low-voltage characteristics and of slew-rate and bandwidth.

The concept of integrated circuit first gave by a physicist namely G. W. A. Dummer in 1952 and later discovered by Jack Kilby in 1959 in which he coincided with the development of planner technology. Everything near to us that we see, hear and sense in physical life is analog like our voice, music, audio and physical activity etc. Analog IC design becomes more familiar and popular in daily life like in our laptop, cellular phones, hearing aid, nanotechnology probes, unmanned aerial vehicles, robots, electronic gadgets etc. The improvement of integrated circuits (ICs) containing mixed analog and digital functions on a single silicon chip give a new approach for the analog designer. Recent advances in analogue ICs design becomes "technology specific" due to the effective use of MOSFETs, BJTs, Bipolar and complementary metal oxide semiconductor field effect transistor devices (BiCMOS) and high speed Gallium Arsenide (GaAs) devices [1]. Also, in Very Large Scale Integration technology, analog circuit plays an effective role for the demand of the analog and digital processing ICs which provides a better reliability and to reduce hardware cost. Hence, it attracts the attention to fabricate a large number of analog as well as digital circuits on a single silicon wafer (chip). So, the digital designer also comfortable with the analog circuit design because in digital, few sub designs are first converted in s-domain then converted into z-domain.

The Figure 1 shows a rough flow steps for the analog circuit design in which fundamental laws of circuit and the design concept of transistors, their property and the essential design parameters as well as semiconductor technology plays important role for the improvement of the analog IC design.

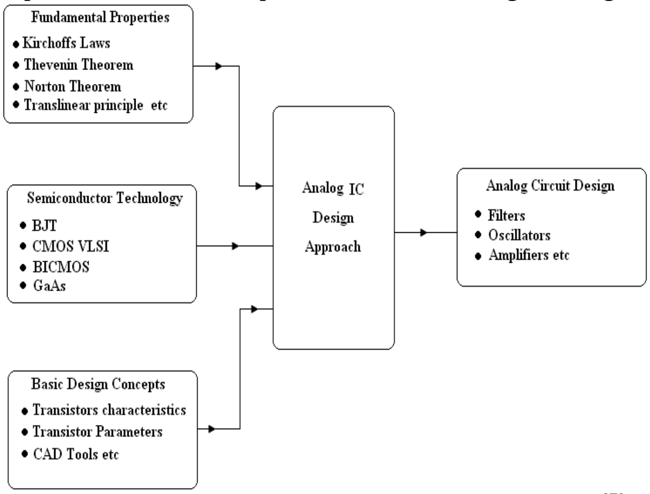

Figure1 Schematic diagram of Analog circuit design [7]

Active Colpitts oscillator designed in current controlled current conveyor (CCCII) technology has been new idea for VLSI technology. In this paper an inductor-less tunable Colpitts oscillator designed using second generation current controlled current conveyor as an active block. The circuit has three CCCIIs and three capacitors. The inductor has been replaced by an active mode inductor which is connected to ground and designed using CCCII. The main advantage of proposed Colpitts oscillator is free from resistance and an inductor that causes suitable for monolithic integrated circuit design. The oscillation frequency has been made tunable electronically by adjusting the capacitor value and through the bias current. The simulation has verified using ORCAD v10.5.

II. Description of Current Building Blocks and Colpitts Oscillator

A. *Second Generation Current Conveyor*

In 1968, Sedra and Smith introduced a three terminal analog device called the first generation current conveyor (CCI). The three terminals of CCI labelled as x, y and z are characterized by the equations in matrix form written as:

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$$\begin{bmatrix} I_y \\ V_X \\ I_Z \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ \pm 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} I_X \\ I_Y \\ V_Y \end{bmatrix} \quad (1)$$

Here, the plus and minus signs represent positive and negative CCI. The emergence of second generation current conveyor (CCII) is just the modification of the first generation current conveyor. The circuit symbol for CCII is shown in Figure 2. It increases the versatility in comparison to CCI because the Y terminal exhibits infinite input impedance i.e. $I_Y = 0$ and other two terminals characteristics remain the same, the equations is in matrix form written as:

$$\begin{bmatrix} I_y \\ V_X \\ I_Z \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ \pm 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} I \\ I_Y \\ V_Y \end{bmatrix} \quad (2)$$

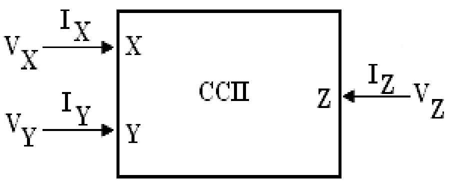

Figure 2 Circuit symbol for CCII [2]

The CCII can be used for various applications like controlled sources, impedance converters, impedance inverters, and gyrator and as various analog operational elements (Sedra et al. 1970)[9].

B. Practical View of CCCII

The frequency performance of practical CCCII differs from the ideal one because of non-idealities. Figure 3. shows the practical equivalent circuit of CCCII with its parasitic components for a fixed value of bias current. This is similar to practical CCII but it differs at terminal X where an inductance Lx is connected in series with the variable resistance to take an account of the variation of the impedance at terminal X as a function of frequency.

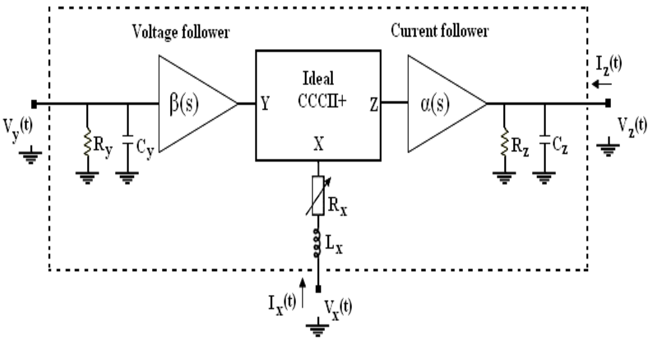

Figure 3 Practical CCCII with its parasitic components [9]

A dual output current controlled current conveyor (DOCCCII±)[13] having both positive and negative current transfers may be obtained by adding cross coupled current mirror in order to reverse the current direction through the Z-terminal as shown in Figure 4.

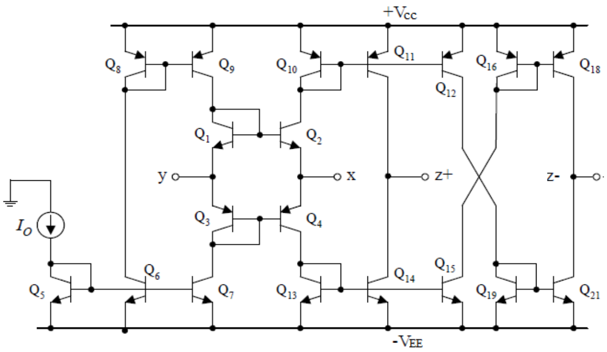

Figure 4. BJT based internal structure of DOCCCII± [13]

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III. Implementation of COLPITTS Oscillator

A. Second Generation Current Controlled Current Conveyor

Second generation current controlled current conveyor (CCCII) can provide electronic control in various circuits like in filter sinusoidal oscillator etc. The circuit symbol of the CCCII and its trans-linear circuit is as shown in Figure 5. Further use I_X and I_Y to denote currents and V_X and V_Y to denote the voltages at terminal X and Y respectively. $R_x = \frac{V_T}{2I_o}$ denotes intrinsic series input resistance of a trans-linear mixed loop (Q1 to Q4) at the X port which can be electronically tuned via I_0 and V_T =26 mV, the thermal voltage at room temperature. Hence, the electronically controlled intrinsic resistance, R_x at terminal X can be changed by the bias current of current controlled current conveyor (CCCII).

B. Inductor Based On Current Conveyor CCCII

Here, an inductor based on two current conveyors, one with positive transfer and the other with negative transfer and capacitor used. The implementation of this inductance is illustrated in Figure 5 Taking into account the presence of parasitic resistors R_{x1} and R_{x2}:

$$V_{in} = V_{x1} = -R_{x1} I_{x1} \quad (3)$$

$$V_{y2} = V_{x2} = \frac{-1}{j\omega C} I_{x1} = R_{x2} I_{in} \quad (4)$$

According to equation (4), we have:

$$I_{x1} = -jR_{x2} C\omega I_{in} \quad (5)$$

These two equations (4) and (5) give:

$$V_{in} = V_{x1} = R_{x1} R_{x2}\, j\omega C\, I_{in} \quad (6)$$

The input impedance is given by the following equation:

$$Z_{in} = \frac{V_{in}}{I_{in}} = R_{x1} R_{x2}\, j\omega C \quad (7)$$

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It is equivalent to an inductance L for:

$$L_{eq} = R_{x1} R_{x2}\, j\omega C \qquad (8)$$

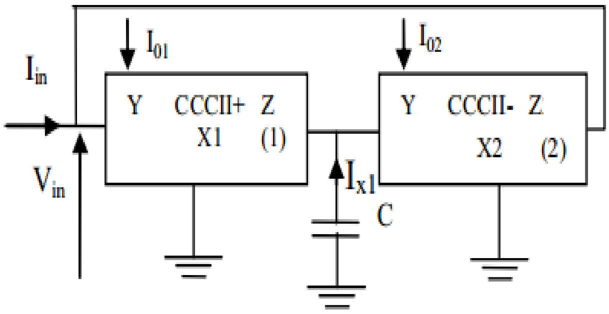

Figure 5 The realization of an active inductor connected to ground [16]

C. Inductor-Less Colpitts Oscillator Circuit and Tunable Frequency

Inductor-less active mode Colpitts oscillator, well designed using two grounded capacitors and tunable active mode inductor with analog building block CCCII as the active device.

The CCCII based active mode amplifiers X terminal has connected to the junction of capacitors, series connection of C_1 and C_2 (centre of the two grounded capacitors) which placed across a common inductor L act as a simple voltage divider. The amount of feedback depends on the values of C_1 and C_2. The required external phase shift has obtained with the positive feedback obtained for sustained un-damped oscillations. The characteristic equation of active mode inductor less Colpitts oscillator written as:

$$s^2 + \frac{1}{R_X C_1 R_{x2} R_{x3} C_3} s + \frac{C_1 + C_2}{C_1 C_2 R_{x2} R_{x3} C_3} = 0 \qquad (9)$$

C_{eq} is the equivalent capacitor of C_1 and C_2 connected in series given as:

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} \text{ Or } C_{eq} = \frac{C_1 C_2}{C_1 + C_2} \qquad (10)$$

The frequency of oscillations for active mode inductor-less Colpitts oscillator has determined by the resonant tunable frequency given as:

$$f_r = \frac{1}{2\pi\sqrt{R_{x2} R_{x3} C_3 C_{eq}}} \qquad (11)$$

Where, R_{x2}, R_{x3} represent the intrinsic series input resistance of the current conveyor at the X terminal of CCCII which is electronically tunable via I_0 and $R_{x2} R_{x3} C_3$ gives the tunable active inductance value. If $R_{X2} = R_{X3} = R_X$ ($R_X = \frac{V_T}{2I_o}$), resonant tunable frequency f_r given as:

$$f_r = \frac{1}{2\pi R_x \sqrt{C_3 C_{eq}}}$$

Also written as:

$$f_r = \frac{I_0}{\pi V_T \sqrt{C_3 C_{eq}}} \qquad (12)$$

Here, above equations proved that the frequency of oscillations for active mode inductor-less Colpitts oscillator have directly controlled by bias current I_0 and grounded capacitors, which provides a suitable advantage of monolithic integrated circuit (IC) implementation. The frequency of oscillation can be adjusted independently by I_0 where frequency of oscillation has varied without changing the passive component and electronically using capacitor thus the circuit can work as a current controlled oscillator.

IV. Results and Discussion

In first step, we replace the op amp with active block of second generation current conveyor (CCII). Also for practical implementation of the circuit, AD844/AD IC is used.

In next step, we replace active block of second generation current conveyor (CCII) with the active block of second generation current controlled current conveyor (CCCII). Similarly, AD844/AD IC and passive components such as inductor and capacitors are used for practical implementation.

In proposed work, we replace the inductor with the active block of inductor which is designed by using CCCII. We also use three AD844/AD ICs and capacitors for the practical analysis. The simulation showed for two different values 1pF and 10pF. Above obtained results verified the theory that for the constant value of passive component (capacitor), also frequency has been increased with the values of bias current.

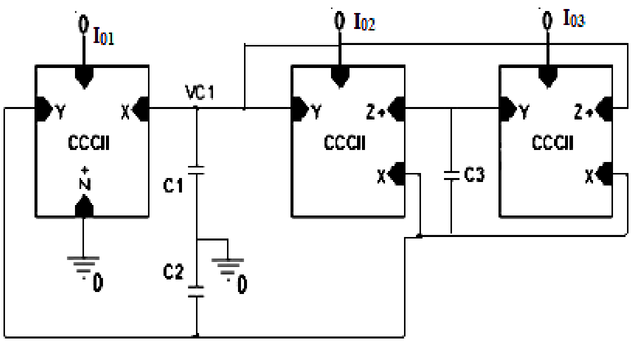

Figure 6 Colpitts oscillator tank circuit and proposed Inductor-less Colpitts oscillator using CCCII

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A. Colpitts Oscillator Using Op- Amp and its Simulation Results.

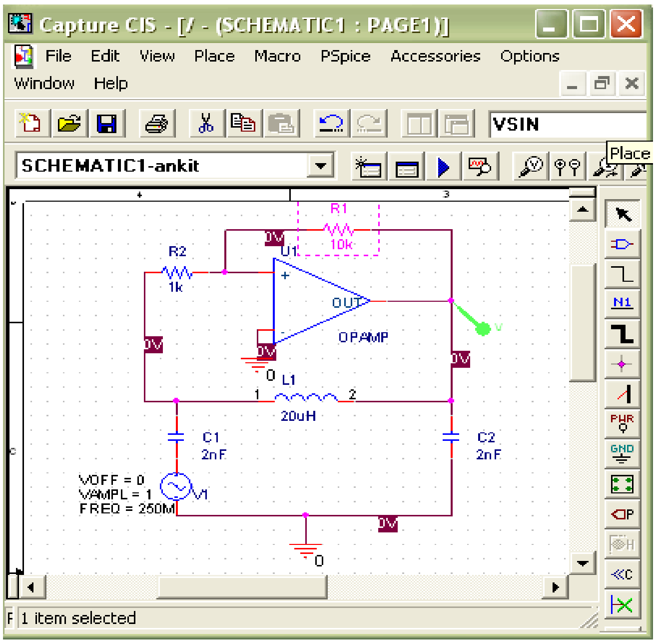

Figure 7 Colpitts oscillator using op amp (L1=20uH, C1=C2=2nF)

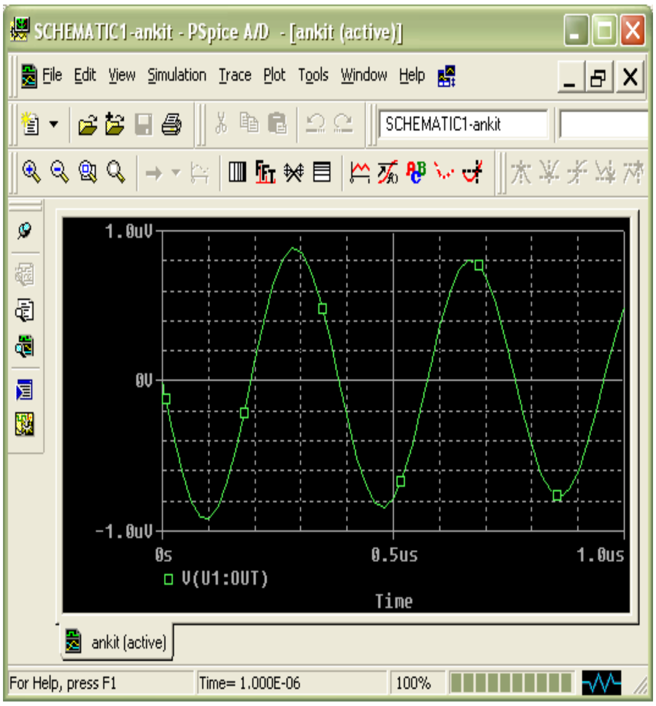

Figure 8 Simulation Result

In Figure 7 & 8, Colpitts oscillator with op amp circuit and its response is given. The various Component's values are given as R1=10K, R2= 1K, L1=20uH, C1=C2=2nF & Freq. = 250M.

Now we replace the op amp with active block of CCII/CCCII and IC AD844/AD. Also we obtain the respected results as shown in the figure 9 with the various components values

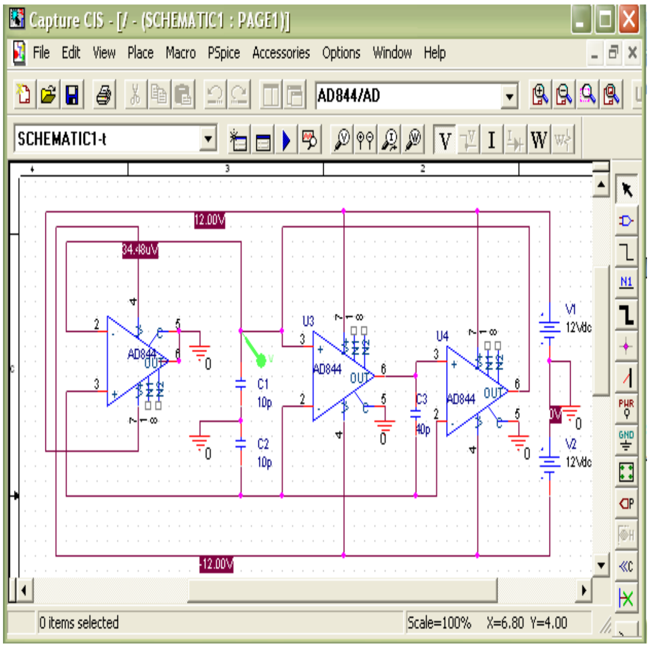

Figure 9 Triple AD844/AD and components value C1= C2= C3=10p

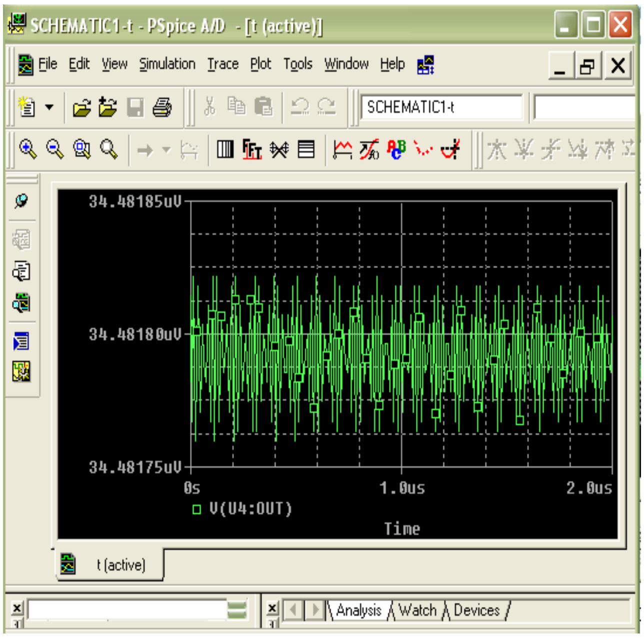

Figure 10 Simulation Result

In figure 9 & 10, three AD844/AD ICs are replaced by the complete Colpitts oscillator circuit using op amp. Here, an active block of inductor which is designed by using two AD844/AD ICs is used as shown. In this design, three capacitors C1, C2 & C3 with 10p values are used. The simulation result shows the waveform variation with respect to time. In figure 11, capacitor values are varied respectively as C1=2p C2=2p & C3=160p. Also two resistors may be used as R1=30 & R2=30 to obtain more improved simulation result.

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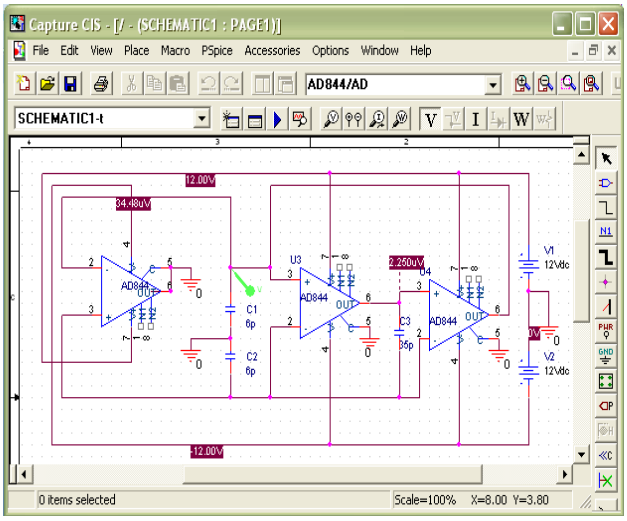

Figure 11 Single AD844/AD and components value C1= C2=10n, L=1uH

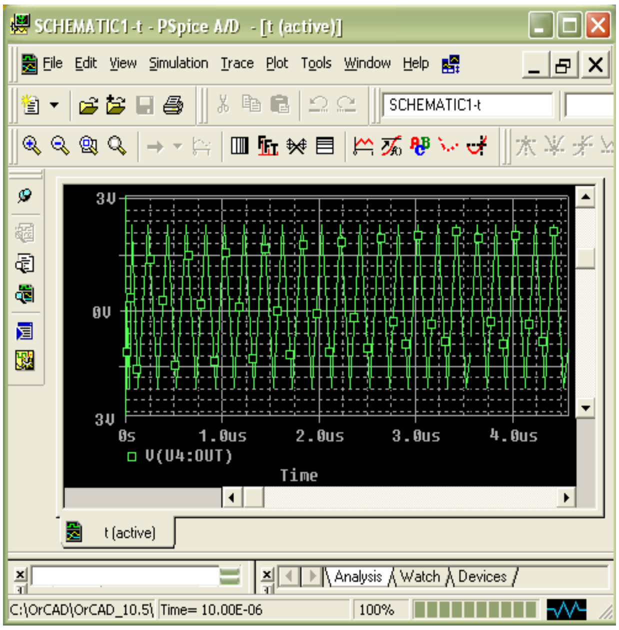

Figure 12 Simulation result

V. Conclusion

The proposed structures are designed with the help of ORCAD v10.5 simulator which produces very accurate results. In this work the characteristics of active mode inductor less Colpitts oscillator is obtained by solving the equation which is obtained by applying Kirchhoff's voltage law and current law. Active mode Inductor less Colpitts oscillator is designed using current controlled current conveyor (CCCII) which provides electronic controlled via bias current. Active mode inductor-less Colpitts oscillator circuit using CCCII was proposed with apart from offering almost all the advantage like less number of hardware only capacitor are used no inductor and resistor is used for simulation which is best for IC fabrication. The design has been simulated using circuit simulator ORCAD v10.5 in which the active block made of a BJT based structure of current controlled current conveyor CCCII using the mode parameter NR100N and PR100N. Also practical realization for experiment is done using commercially available analog IC AD844/AD and standard value components.

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