Translinear-C Function Generator

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***Abstract*— A novel function generator is realized using a multi output current controlled current conveyors (MOCCCIIs) based current mode band-pass filter, which can simultaneously provide four phase sinusoidal quadrature current outputs, square and triangular voltage outputs. The circuit basically uses only four MOCCCIIs and four grounded capacitors. The function generator enjoys attractive features such as use of grounded capacitors, wide range electronic tunability, low sensitivity figures and load insensitive current outputs. Moreover due to the absence of external resistors the circuit is very much suitable for monolithic implementation. The proposed function generator is designed and verified with excellent results.**

Index Terms—**Current conveyors, current-mode circuits, function generators, oscillators**

I. Introduction

NOW-A-DAYS the second generation current controlled current conveyor (CCCII) has become a popular active device in the design of current mode (CM) analog circuits. It enjoys attractive realization features and broad frequency range of operation without any external resistor. Such class of circuits are referred to as translinear-C circuits. Many translinear-C current mode filters and oscillators are reported in technical literature [1] – [9].

Moreover, like filters and sinusoidal oscillators, triangular / square wave generators are also widely used in a wide range of applications in instrumentation and measurement systems, due to which a large number of triangular / square wave generators have been developed using a wide variety of active devices [10], [11]. However not much work is available in technical literature on good quality current mode function generators, especially on current mode translinear-C function generators.

In this paper, a novel and versatile translinear-C function generator (TCFG), using a multi-output current controlled current conveyors (MOCCCIIs) based band pass filter (BPF) as its basic building block has been proposed. The basic building block i.e., the current mode BPF is realized using three MOCCCIIs and grounded capacitors. The TCFG is realized simply by providing a direct feedback from the output to the input of this BPF. The realized function generator uses only four MOCCCIIs and only four grounded capacitors. The versatility of the circuit justifies the use of the number of these devices. The realized function generator exhibits four phase sinusoidal quadrature current outputs, a square and two opposite phase triangular output voltages. It also provides sufficiently wide range independent electronic control of its operating frequency, attractive sensitivity figures and is compatible for monolithic implementation in contemporary IC technologies. The realized TCFG was designed and verified using PSPICE with excellent results.

II. The Proposed Circuit

The electrical symbol of the MOCCCII used in the realization of the proposed circuits is shown in Fig. 1.

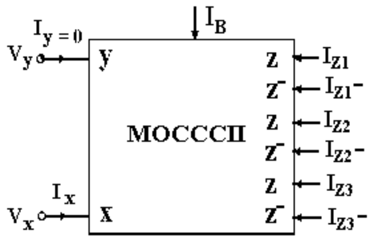

Fig. 1. Electrical symbol of the MOCCCII.

The port relations of this MOCCCII, can be given by the following matrix

$$\begin{bmatrix} Iy \\ Vx \\ Izi \\ Izi^- \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 1 & Rx & 0 & 0 \\ 0 & +1 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{bmatrix} \begin{bmatrix} Vy \\ Ix \\ Vzi \\ Vzi^- \end{bmatrix} \quad (1)$$

where, R_X is the parasitic resistance at the x-input terminal of the MOCCCII and i = 1,2,3. Vzi and Vzi^- are the voltages at zi and zi^- terminals respectively.

The band-pass filter used as the basic building block for the realization of the TCFG, was realized using three MOCCCIIs as shown in Fig. 2. This band-pass filter is in fact a modified version of the current mode universal filter available in literature[12].

Routine analysis yields the transfer gain of the current mode band-pass filter as follows:

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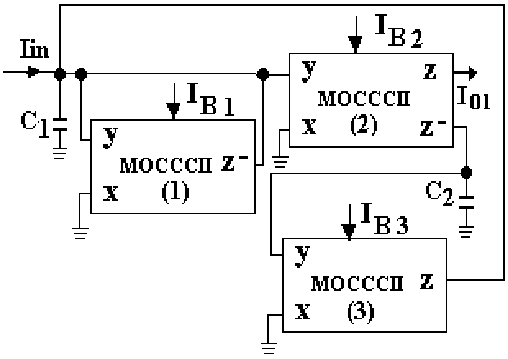

Fig. 2. Current mode translinear-C band pass filter.

$$\frac{I_{01}}{I_{in}} = \frac{s\frac{1}{R_{x2}C_1}}{s^2 + s\frac{1}{R_{x1}C_1} + \frac{1}{R_{x2}R_{x3}C_1C_2}} \qquad (2)$$

where, R_{xi} [= V_T / (2 I_{Bi}) , i = 1,2,3, …] is the parasitic resistance at the x-input terminal of the MOCCCIIs, V_T is the thermal voltage and I_{Bi} is the bias current of the i^{th} MOCCCII, which is tunable over several decades [5].

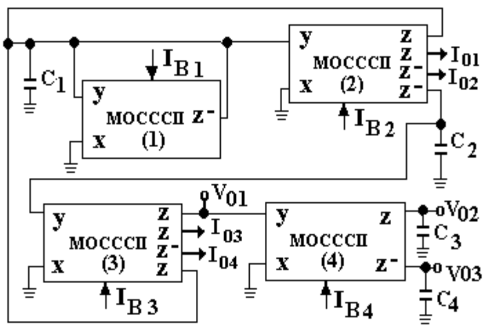

Fig. 3. Translinear-C function generator (TCFG) circuit.

The TCFG is realized by providing a direct feedback from the output (I_{o1}) to the input of the basic building block as shown in Fig. 3. For obtaining the various currents and voltages, additional appropriate output (z) terminals from the MOCCCIIs are included[6]. It is to be noted that I_{o1} = - I_{o2} and I_{o3} = - I_{04}.

The characteristic equation, from Fig. 3 can be analyzed as,

$$s^2 + s\left[\frac{1}{R_{x1}C_1} - \frac{1}{R_{x2}C_1}\right] + \frac{1}{R_{x2}R_{x3}C_1C_2} = 0 \qquad (3)$$

which yields the condition of oscillation as

$$R_{x2} = R_{x1} \qquad (4)$$

and the frequency of oscillation as

$$\omega_O = \left[\frac{1}{R_{x2}R_{x3}C_1C_2}\right]^{1/2} \qquad (5)$$

Hence, with $I_{B1} = I_{B2} = I_{B3} = I_{B4} = I_B$, (5) reduces to

$$\omega_O = \frac{2I_B}{V_T}\left[\frac{1}{C_1C_2}\right]^{1/2} \qquad (6)$$

It is clear from (6) that the frequency of oscillation ω_o can be tuned electronically over a wide range by varying the bias current I_B, which can easily be achieved by implementing all the MOCCCIIs on the same chip. It is to be noted that in such oscillators ω_o is temperature sensitive, hence temperature compensation of translinear current conveyors is essential under varying environmental conditions. This can be accomplished using the technique available in literature[13].

From Fig. 3., at oscillating frequency it can easily be shown that

$$I_{o3} = JI_{o2} \qquad (7)$$

which results in two quadrature outputs. The additional current outputs I_{o1} and I_{o4} in Fig. 3 form the four phase quadrature outputs as shown in the phaser diagram of Fig. 4.

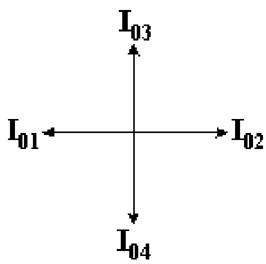

Fig. 4. The phaser outputs of the TCFG.

To obtain the square and triangular voltage outputs, an MOCCCII based integrator is connected at the output(z) terminal of the third MOCCCII as shown in Fig. 3. This is achieved as the current from this terminal flows to the high impedance of the y-terminal of the integrator's MOCCCII, causing the voltage to saturate, thereby providing a square wave. The integration of this square wave voltage then provides the triangular voltage waveforms of the TCFG as shown in Fig. 3.

III. SENSITIVITY ANALYSIS

The incremental sensitivity measure on the TCFG's frequency of oscillation was analyzed and given as follows:

$$S^{\omega_0}_{R_{xi},C_i} = -\frac{1}{2} \qquad (8)$$

where i = 1, 2,3,4. Equation (8) shows that the proposed function generator exhibits low sensitivity properties, i.e. less than unity in magnitude.

IV. SIMULATION RESULTS

The proposed oscillator circuit of Fig. 3 was designed initially for an oscillating frequency, f_o = 122.46KHz using (6). The designed values were found as $C_1 = C_2 = C_3 = C_4 =$ 100 pF. At room temperature of 27^0C, (6) yields I_B = 1 µA. The MOCCCII circuit used is obtained from the circuit available in technical literature[6].The output waveforms obtained through PSPICE simulation are given in Fig. 5 and Fig. 6.

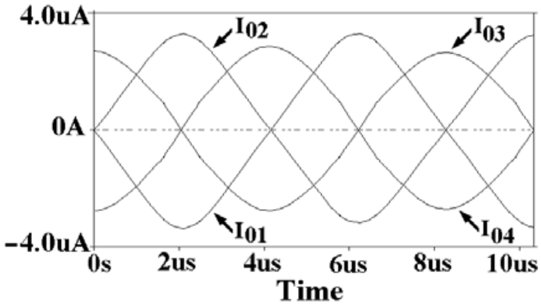

Fig. 5. Four phase quadrature current output waveforms of the TCFG.

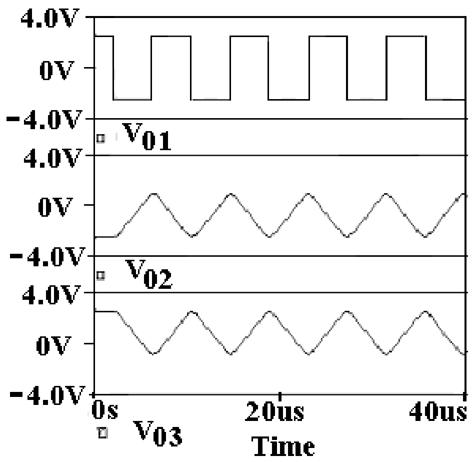

Fig. 6. Various voltage output waveforms of the TCFG.

It is to be noted that all the outputs are of almost equal magnitudes. The TCFG was then tuned by varying the bias current I_B and results obtained are shown in Fig. 7, which illustrates the electronic tuning of the frequency. Thus, the results of Fig. 5 through Fig. 7, justify the theory.

Amplitude variation of the various currents and voltages with I_B were carried out and the observations given in Fig. 8 and Fig. 9 indicate that the current amplitudes remain almost equal throughout the entire tuning range. The voltage amplitude initially increases and then becomes constant for the rest of the tuning range. These properties further enhance the qualities of the TCFG.

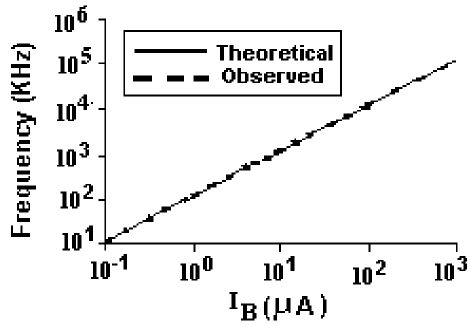

Fig. 7. Frequency variation with bias current (I_B).

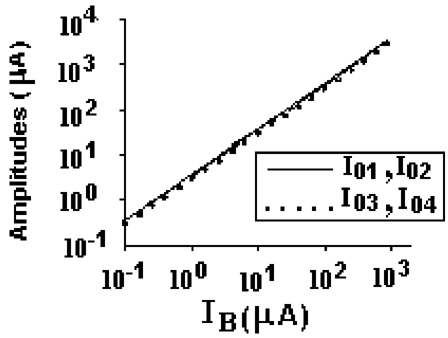

Fig. 8. Variation of output currents with (I_B).

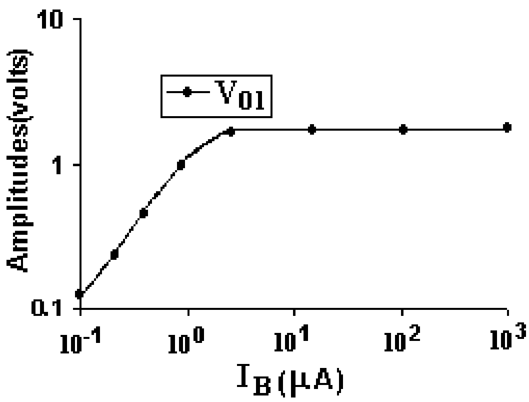

Fig. 9. Variation of output voltage with bias current (I_B).

V. CONCLUSION

A novel versatile translinear-C function generator is realized using a multi output current controlled second generation current conveyor (MOCCCIIs) based band-pass filter. The realized function generator uses only four MOCCCIIs and only four grounded capacitors. The circuit possesses attractive sensitivity performance and electronic frequency control over a wide range, and is compatible for monolithic implementation in contemporary IC technologies. The simulation results of the function generator verify the theory.

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