A CCII-Based Wide Frequency Range Square/Triangular Wave Generator

Shahid Malik[1], Kaushal Kishore[1], Dharmendra Sharma[1], Maneesh Maharana[A1], S.A. Akbar[1B], Tarikul Islam[2]
[1] Research Scholar, CSIR-CEERI, Pilani, India-333031
[1B]Chief Scientist, CSIR-CEERI, Pilani, India
[A1] BITS Pilani, Goa Campus, India- 403726
[2]Professor, Electrical Engineering Dept., Jamia Millia Islamia, New Delhi, India- 110025

***Abstract*—In this paper, we propose a current-mode based solution suitable for triangular/square wave generator using second generation current conveyor. The proposed oscillator, which utilizes two second generation current conveyor (CCII) as active elements, three resistors and a capacitor, is based on resistance-capacitance (RC) cell and found to be effective alternate of voltage-mode based oscillators. Experimental results were obtained by implementing the proposed circuit using commercially available CCII (AD844) and passive components. Simulation and experimental results have confirmed the theoretical expectations, showing good linearity in wide oscillation frequency range. The sensitivity and operating frequency of the proposed oscillator can be adjusted using passive components. The proposed configuration finds useful applications in wide range capacitive/resistive sensor front end.**

Keywords—Waveform generator, Current conveyor (CCII), Current mode oscillator, Wide frequency range, AD844, RC circuits

I. INTRODUCTION

Oscillators are most useful electronic circuits that generates periodic AC waveforms (e.g., sinusoidal, square or triangular. Square/triangular waveform generators of variable frequency has a wide range of applications in the field of signal processing, telecommunication, control systems, measurement system and sensor interfacing, particularly depending on their operating frequency range [1]- [3]. A number of square/triangular wave generator circuits using voltage- mode operational amplifier (OA) as active element are available in the literature [4]-[6]. These circuits generate the waveform by charging and discharging effect of resistance-capacitance (R-C) cell, followed by a hysteresis comparator.

It is well known that the dynamic range of voltage-mode oscillators is dictated by frequency- dependent gain of operational amplifier. This problem can be solved using current mode (CM) approach of signal processing, second generation current conveyor (CCII), which shows large dynamic range, wide bandwidth, high linearity, possibility of design using low power consumption and simple analog circuit designing [6]-[8]. Variety of different oscillator has been proposed in the literature based on CM approach, the present focus of researchers is to decrease the number of active and passive components while maintaining wide operating frequency range [9]-[12].

In this paper, a novel CM based square/ triangular generator wave using two CCIIs, three grounded resistor and a grounded capacitance is proposed which neglect the effect of voltage/current saturation thus provide wide dynamic range. Its main operation is basically adopted from voltage mode approach of current integration, and the configuration is designed in such a specific way that minimizes the effect of parasitic components of CCIIs. The effect of parasitic component at node X is reduced by avoiding capacitive loads, keeping only grounded resistive load of slightly higher value than parasitic resistance at the same terminal. In this way, there is no limitation in wide frequency range and it is also possible to set the circuit sensitivity and operating frequency range externally using passive components. Experimental measurements have been performed by implementing the proposed circuit on fabricated PCB using AD844 (commercially available CCII) and passive components. Simulation and experimental results shows a good agreement with theoretical expectations with good linearity in wide dynamic frequency range for both resistance and capacitance variations. Resultant, the proposed scheme can be used as resistive/capacitive interface, performing impedance to frequency conversion with good precision and linearity in wide range.

In comparison to other solutions proposed in literature [9]-[12], the benefits of our proposal are following: capability of providing wide oscillating frequency range with acceptable non-linearity, required less number of active and passive components, architecture simplicity and easiness of adjusting oscillation frequency and sensitivity through external components.

II. CCII BASIC THEORY

The current conveyor was first presented by sedra and smith in 1968, named as first generation current conveyor (CCI); however the effectiveness of current mode design was realized only after the introduction of CCII, two years later than CCII [13]-[14]. Due to its unique and useful ways of realizing complex circuit functions, CCII is sometimes claimed to be the standard building block for CM operations as far as signal processing applications are concerned [8] [14].

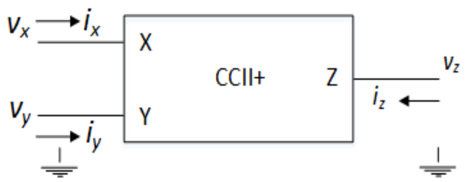

Fig. 1. Symbol for second-generation current conveyor

Fig. 1 shows the symbol of CCII, whose characteristics can be described by following set of equations.

$$i_z= \pm\alpha_i i_x \text{ , } v_x = v_y, \; i_y=0 \qquad (1)$$

The '±' symbol of current transfer ratio α_i indicates whether the conveyor is framed as non-inverting or inverting circuits, labelled as CCII+ and CCII-, respectively. The output current i_z depends on input current $i_{x,}$ which may be directly injected by applying voltage at X node, or by copy the input voltage from terminal Y.

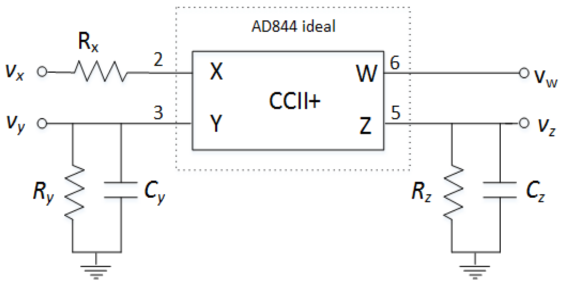

Fig. 2. IC 844 with parasitic elements.

AD844 from Analog Devices can be implemented as practical CCII, having unity current gain, parasitic input-output impedance and a unity gain voltage buffer [15]. Fig. 2 Shows the schematic diagram of practical model of AD844, having parasitic components values C_z= 4.5pF, C_y= 2pF, R_z = 3MΩ, R_y = 10MΩ and R_x = 50Ω.

III. The Proposed Oscillator: Analysis and Simulation

Fig. 3 shows the proposed square/ triangular wave generator at block level. Basically, it consists of a voltage to current converter (CCII+'A') and a hysteresis comparator (CCII+'B').

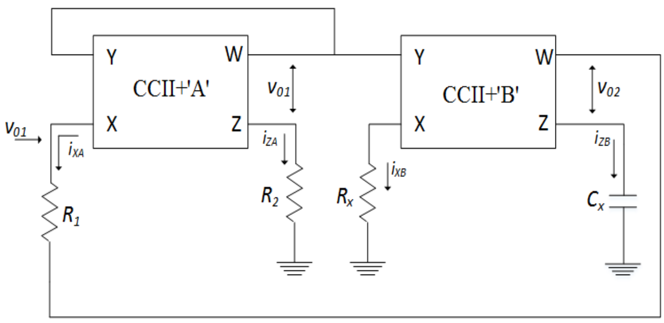

Fig. 3 Proposed square/triangular wave generator.

CCII+ 'A' generates square wave by converting the saturation current i_{ZA} into saturation voltage v_{01} ($v_{01} = \pm V_s$). The same signal is applied to input terminal of CCII+'B' which generates the AC current for capacitor.

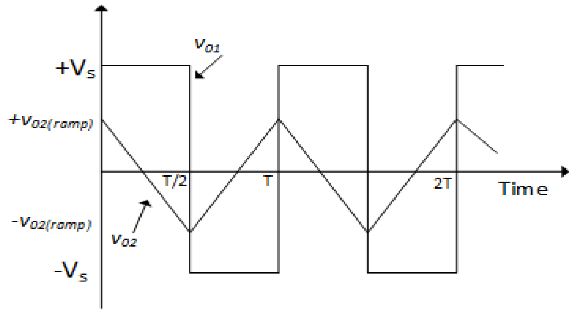

Fig. 4 Graphical representation of node waveform

Assuming ideal condition, and referring to the notation in Fiq. 3, one can write the network equation as

$$i_{XA} = i_{ZA} \qquad (2)$$

$$i_{XB} = i_{z2} \qquad (3)$$

$$i_{XA} = \frac{v_{01}-v_{02}}{R_1} \qquad (4)$$

$$i_{XB} = \frac{v_{01}}{R_x} \qquad (5)$$

$$v_{01} = i_{ZA}.R_2 \qquad (6)$$

Manipulating equation (2) to (6) we can write the voltage v_{02} as

$$v_{02} = v_{01}\left(\frac{R_2-R_1}{R_2}\right) \qquad (7)$$

v_{01} is the saturated output voltage of CCII+ 'A' as shown in Fiq. 4. The saturated level is +V_s for positive going ramp and -V_s for negative going ramp. Thus the peak to peak voltage at output of CCII+ 'A' is

$$v_{02\,(p-p)} = V_s \left(\frac{R_2-R_1}{R_2}\right) \qquad (8)$$

A portion of voltage v_{01} is applied at Y node of CCII+ 'B', which generates current i_{XB} that flows through capacitor C_x at node Z. The voltage across capacitor due to current i_{XB} can be expressed as

$$v_{02\,(P-P)} = \frac{1}{R_x\, C_x}\int_0^{\frac{T}{2}} v_{01}.dt = \frac{V_s}{2R_x\, C_x}T \qquad (9)$$

From equation (8) and (9) we can conclude the expression of T as

$$\text{T}= 4R_x\, C_x \frac{R_2-R_1}{R_2} \qquad (10)$$

Considering the parasitic resistance of CCIIs available on node X of CCII+'A' and CCII+'B', namely R_{XA} and R_{XB}, respectively, equation (10) can be modified as

$$T = 4(R_x + R_{XB})C_x \frac{R_2 - (R_1 + R_{XA})}{R_2} \quad (11)$$

More in detail, time domain simulation was performed to verify the oscillation period variation with respect to passive components R_x and C_x while keeping R_1=6.8kΩ and R_2=10kΩ; the related results and waveform are presented in table I, II and fig. 5, respectively.

Table I

Theoretical and measured time Period for C_x Variation

C_x	Theoretical Period [s]	Measured Period [s]	Relative Error (%)
50pF	1.08µ	1.14µ	5.56
500pF	10.81µ	10.42µ	3.74
5nF	0.108m	0.102m	5.80
50nF	1.08m	1.02m	5.54
500nF	10.8m	10.10m	6.48

Table II

Theoretical and measured time Period for R_x Variation

R_1 [Ω]	Theoretical Period [µs]	Measured Period [µs]	Relative Error (%)
10k	2.56	2.70	5.18
100k	5.31	5.40	1.67
500k	27.54	27.01	1.96
1M	57.57	54.05	6.11
2M	119.47	107.41	10.09

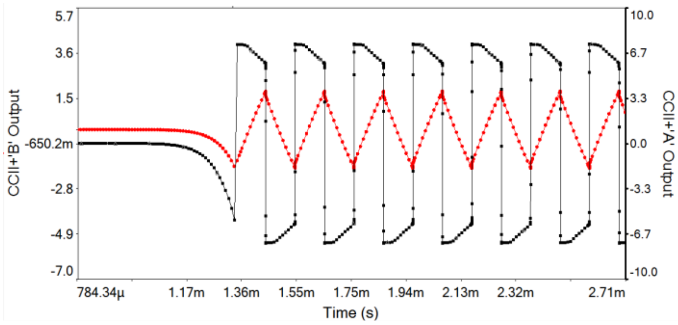

Fig. 5 Simulated waveform of square and triangular signal

In particular, for the R_x variation, C_x has been set to 50pF, while R_x has been varied from 10KΩ to 2MΩ, obtain a frequency range of 9 kHz to 372 kHz. On other hand, oscillation frequency range from 850 kHz down to 99Hz was obtained by varying C_x from 50pF to 500nF; keeping R_x fixed to 20kΩ. Simulation results confirm the validity of proposed circuit, showing good linearity for both resistances R_x and Capacitance C_x variation in wide range of frequency.

IV. Experimental Results

For experimental purpose, the proposed circuit was first implemented on bread board and then fabricated over copper PCB using chemical etching process. AD844 and passive samples of resistance/ capacitance was used for experimental purpose. All the passive components (resistors and capacitor) have been first measured using LCR meter (Agilent 4294A) and found to be in the form of ±1% tolerance. A typical waveform of square/ triangular wave from the oscilloscope screen is presented in Fig. 6, which have been obtained with *R1*=8.2kΩ, *R2*=10kΩ, *Rx*= 100kΩ, *Cx* = 1nF and a supply voltage of ±9V.

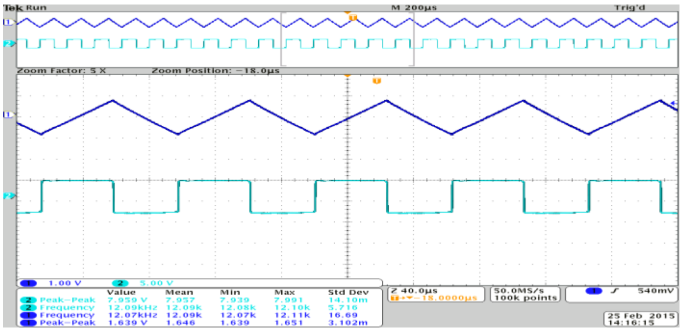

Fig. 6 An example of generated square and triangular wave signal on oscilloscope screen

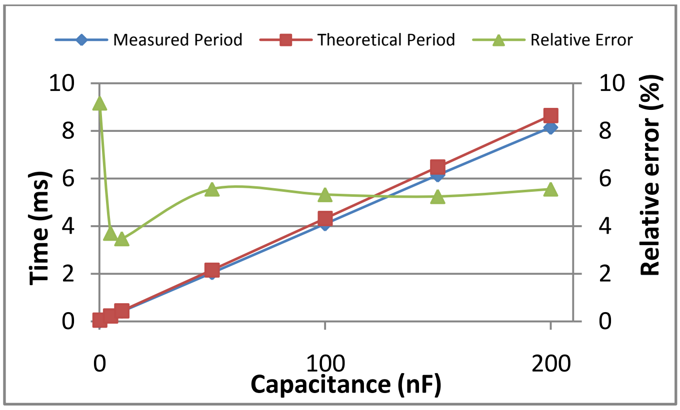

Fig. 7 Variation of time period for variation in capacitance

In order to test the tunability of the oscillator against passive components *Rx* and *Cx*, the variation in oscillation frequency was observed. For capacitance C_x, the parameters selected were R_1=6.8kΩ, R_2=10kΩ and R_x= 40kΩ. Oscillation frequency range of DC to 250 KHz was observed on the screen of oscilloscope by varying C_x from 100pF to 200nF, which is presented in Fig. 7.

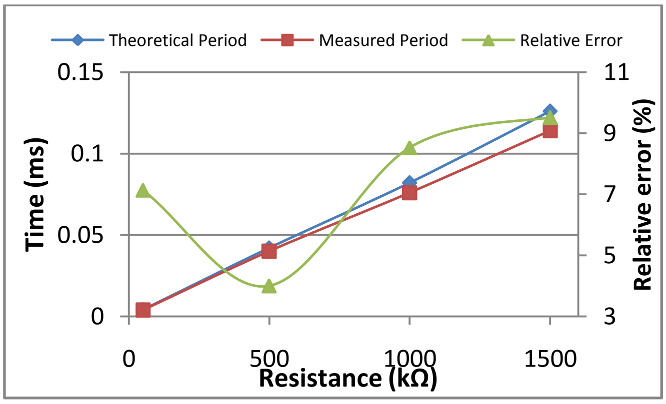

Fig. 8 Variation of time period for variation in capacitance R_x

Similarly, for R_x, the parameters selected were R_1=7.4kΩ, R_2=10kΩ and C_x = 100pF. A linear oscillation frequency range of 8 KHz to 238 KHz was obtained by varying R_x from 1.5MΩ to 50kΩ, plotted in Fig. 8.

Finally, a detailed comparison with other oscillator circuits presented in the literature was performed in order to show the advantages and validity of the proposed circuit as reported in table III. In specific, the point that can be highlighted from table III are: The proposed system requires only two CCIIs and four passive components, provide wide oscillation frequency with little non-linearity.

V. Conclusion

CCII (+) based square/ triangular waveform generator is designed, developed, tested and compared with other solutions available in the literature. It is based on charging/discharging effect of resistance-capacitance (RC) cell, having a simple circuit topology, implemented using two CCII and four passive components. The theoretical expression of time period is verified using both SPICE simulation and experimentally. The proposed circuit found is working faithfully in wide oscillation frequency range with acceptable linearity for both capacitive and resistive load variation. The sensitivity and operating frequency range of oscillator can be adjusted externally using passive components. The proposed configuration can be used as alternate of voltage-mode interface for capacitive and resistive sensor because of its wide dynamic range. Another important area of its applications is in folding ADCs, tuneable oscillators and analog and mixed mode designing.

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Table III

Comparative analysis of the proposed circuit with another solution presented in literature

Characteristics	Frequency range	Number of active components	Number of passive components	Output signal	Prototyping and Experimental
Proposed Design	100Hz to 850kHz	Two	Four	Square and triangular wave	Yes
CCII(+) based design [12]	25Hz to 225kHz	Two	Four	Square and triangular wave	Yes
CMOS/CCII(+) differentiation Based [10]	128mHz to 737 kHz	Two	Six	Square	Yes
CMOS based design [11]	25Hz to 260 kHz	Two	Two	Square	No
CCII(+) based design [9]	100Hz to 100 kHz	One	Four	Square/triangular	yes