Chapter 51
Non-Inverting CCII-based Astable Multivibrator and Its Application as Uncalibrated Wide-Range Capacitive Sensor Interface

Andrea De Marcellis, Giuseppe Ferri and Paolo Mantenuto

A novel wide-range capacitive sensor interface employing a non-inverting Second Generation Current Conveyor (*CCII*)-based astable multivibrator is here presented. With respect to typical Capacitance-to-time (*C-T*) conversion techniques, the circuit has been designed employing a reduced number of both active (only one *CCII*) and passive (three resistances and the capacitive sensor) devices, in order to keep power consumption reduced and allowing the development of a long-life portable tool. Test results, conducted on PCB, through the commercial AD844, have shown that the circuit is able to estimate large capacitance variations within [100 pF–10 μF] (about 5 decades), maintaining a reduced relative error. This makes the interface *uncalibrated* since a number of capacitive sensors can be employed maintaining the same oscillator features and making it suitable in those applications where the sensor baseline cannot be accurately estimated or is not well known a priori.

51.1 Introduction

Circuit miniaturization developments have led to the design of high accurate and small size sensor devices as MEMS [1–3]. They can be, typically, described as a planar capacitor (i.e., $C=\varepsilon A/d$, being ε the relative dielectric constant, A the actual parallel surface involved by the electric field and d the distance between capacitor metal plates) whose mechanical features are temporarily changed due to the measurand variation. In the literature, capacitive sensor interfaces typically concern

A. De Marcellis (✉) · G. Ferri · P. Mantenuto
Department of Industrial and Information Engineering and Economics—DIIIE,
University of L'Aquila, L'Aquila, Italy
e-mail: andrea.demarcellis@univaq.it

G. Ferri
e-mail: giuseppe.ferri@univaq.it

P. Mantenuto
e-mail: paolo.mantenuto@univaq.it

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Capacitance-to-time (*C-T*) conversion techniques [4–6], where the measurand detection is possible through the output waveform period tracking. Here, a novel current-mode non-inverting astable multivibrator, based on a Second Generation Current Conveyor (*CCII*) [7–12], and its application as wide-range capacitive sensor interface [3], has been presented. The interface consists of only one *CCII*, three resistances and one capacitance (i.e., the capacitive sensor). The circuit working principle is based on a *CCII*-based inverting Schmitt trigger design [13–15]. Preliminary experimental tests on discrete PCB, performed by employing the AD844 as *CCII* [16, 17] and simple passive components, have shown good linearity and accuracy in the estimation of about 5 capacitive decades, within the interval [100 pF–10 μF].

51.2 CCII-based Proposed Interface

The CCII, whose symbol is shown in Fig. 51.1a, represents the fundamental block in the current-mode circuit design. Its ideal constitutive relationships are expressed in Eq. 51.1 and show that Y terminal voltage is buffered to X terminal while X node current is mirrored to the Z node. In particular, we refer to *CCII*+/− when current at Z terminal has the same/opposite X current flow. In Fig. 51.1b the proposed inverting Schmitt trigger-based oscillator is shown.

$$\begin{bmatrix} I_Y \\ V_X \\ I_Z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} V_Y \\ I_X \\ V_Z \end{bmatrix} \tag{51.1}$$

According to Fig. 51.1b, the capacitance C_{SENS} is charged through the current which flows from both X and Z nodes, while R_1, R_2 and R_3 resistances have to be properly

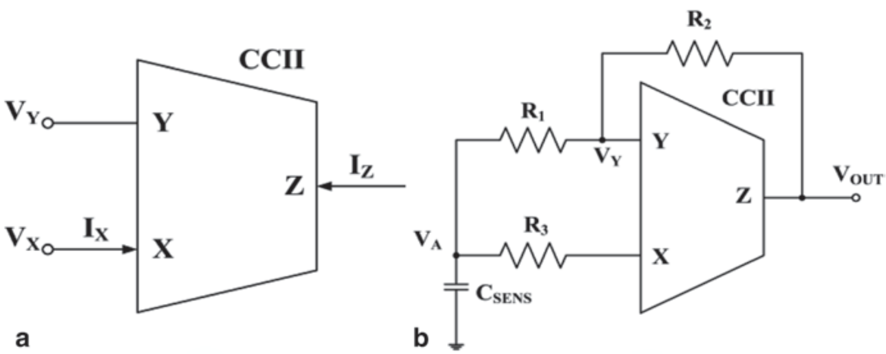

Fig. 51.1 **a** CCII symbol. **b** proposed current-mode non-inverting Schmitt oscillator configuration

set in order to impose I_Z and I_X maximum current values (i.e., the circuit power consumption and device life). In this manner, a current flows into the capacitor until the voltage V_A reaches the correspondent upper threshold voltage. This causes a current flux inversion, which discharges the capacitance until the lower threshold is reached, and so on. In particular, the resistance values set both the comparator threshold (see Eq. 51.2, where V_{OUT} is the output saturation voltage, $V_{SAT}^{\pm}$) and the output waveform period. In particular, by setting R_1»(R_2,R_3), the circuit oscillation period equation can be simplified, as shown in Eq. 51.3, performing a linear relationship with respect to C_{SENS}, R_1 and R_2.

$$V_{TH} = V_{OUT} \cdot \left(\frac{R_1 - R_3}{R_2 + R_3} \right) \tag{51.2}$$

$$T \approx \left(R_1 + R_2 \right) \cdot C_{SENS} \tag{51.3}$$

51.3 Experimental Results

Figure 51.2 shows the oscillator main nodes time behavior. When V_A voltage arrives at the upper threshold, the output commutates until the lower threshold is reached and so on. Theoretical time responses and experimental measurements related to the period T of the output square waveform vs. capacitive sensor C_{SENS}, conducted through the use of the AD844 as *CCII*, are shown in Fig. 51.3. It can be seen that these quantities are in good agreement and a linear correspondence between the two trends is obtained for about 5 variation capacitive decades [100 pF, 10 μF], maintaining a reduced relative error in the range (−8 %, +6 %).

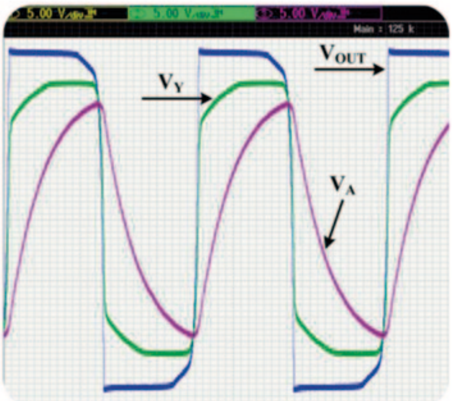

Fig. 51.2 Experimental circuit main nodes behavior

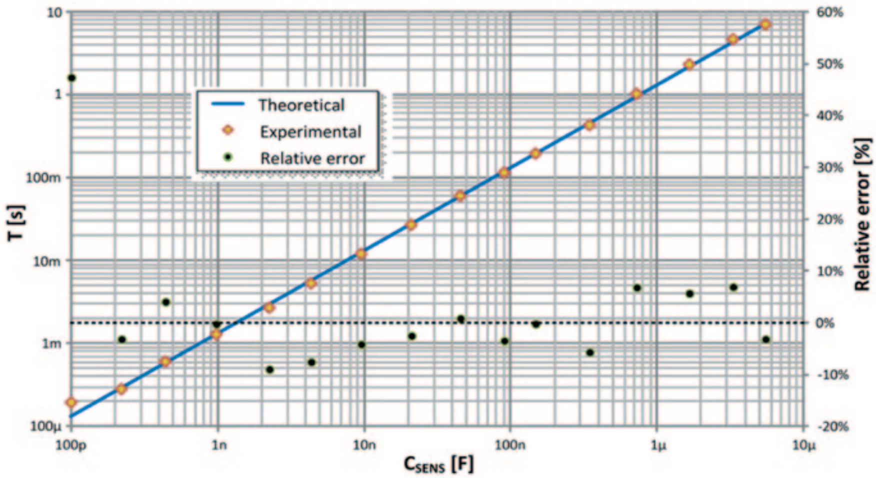

Fig. 51.3 Theoretical (continuous) and experimental (*yellow diamonds*) output waveform period (*left axis*) and relative error (*black dots, right axis*) vs. sensor capacitive value

51.4 Conclusions

In this paper, a novel simple architecture for a *CCII*-based non-inverting Schmitt trigger astable multivibrator has been proposed. Experimental tests conducted on a PCB, employing the commercial AD844, have shown the circuit capability to be employed as a capacitive interface performing the Capacitive-to-Time conversion. In particular, good linearity and accuracy in the estimation of about 5 capacitive decades have been provided.

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