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A current conveyor-based relaxation oscillator as a versatile electronic interface for capacitive and resistive sensors

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A new electronic interface circuit is presented. The circuit is built around a single plus-type second-generation current conveyor (CCII+) and can be used with resistive, capacitive and resistive-capacitive sensors. Experimental results are provided.

Keywords: Current conveyor; Relaxation oscillator; Interface for sensors

1. Introduction

Oscillators are widely used as electronic interface for sensors (Filanovsky 1994). This is attributed to their simplicity and immunity to electromagnetic interference (Pallas-Areny and Webster 1991). While harmonic oscillators, widely used with capacitive and inductive sensors, have a very high sensitivity due to their resonant nature, relaxation oscillators are simpler and less sensitive (Pallas-Areny and Webster 1991). This explains the growing interest in designing relaxation oscillators using operational amplifiers (Passeraub *et al.* 1997, Liu *et al.* 2000, Nihtianov *et al.* 2001), operational transconductance amplifiers (Goes and Meijer 1996, Filanovsky 1989), bipolar junction transistor (Elwakil 2000), current conveyors, and current-feedback operational amplifiers (Abuelma'atti and Al-Shahrani 1998, Cicekoglu and Kuntman 1998, Cicekoglu and Toker 1999, Almashary and Alhokail 2000). Of particular interest here is the relaxation oscillators using current conveyors. This is attributed to their higher signal bandwidths, greater linearity, wider dynamic range, simple circuitry, and low power consumption (Roberts and Sedra 1989).

Inspection of the available current conveyor-based relaxation oscillators (Abuelma'atti and Al-Shahrani 1998, Cicekoglu and Kuntman 1998, Cicekoglu and Toker 1999, Almashary and Alhokail 2000) shows that a Schmitt trigger is required for each circuit implementation. While the implementation reported in (Cicekoglu and Toker 1999) uses the current-in current-out Schmitt trigger proposed in (Coban and Allen 1974), the implementations reported in (Abuelma'atti and Al-Shahrani 1998, Cicekoglu and Kuntman 1998, Almashary and Alhokail 2000) use the voltage-mode Schmitt trigger proposed in (Di Cataldo *et al.* 1995) and shown in figure 1. By connecting a capacitor to terminal x of the second-generation

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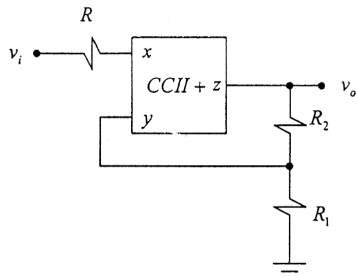

Figure 1. Schmitt trigger circuit proposed in (Di Cataldo *et al.* 1995).

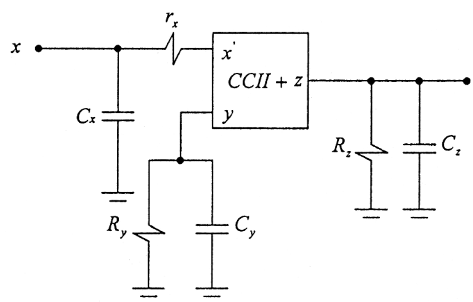

Figure 2. Simplified model for the AD844 ($r_x = 50\,\Omega, R_y = 10\,\text{M}\Omega, R_z = 3\,\text{M}\Omega, C_x = C_y = 2\,\text{pF}, C_z = 4.5\,\text{pF}$).

plus-type current conveyor (CCII+), a relaxation oscillator can be obtained. Using the simplified model of the CCII+ shown in figure 2, the oscillation period can be expressed as (Almashary and Alhokail 2000)

$$T = \frac{1}{f} = 2C_T r_x \ln\left(2\frac{R_1}{r_x} - 1\right) \tag{1}$$

where $C_T = C + C_x$. Equation (1) clearly shows that the period of oscillation is a function of the external capacitance C and the resistances r_x and R_1. This raises the following question: can the circuit of figure 1 be used as an electronic interface for capacitive and resistive sensors? The work described in this paper has been motivated by this question.

2. Proposed Circuit

Figure 3 shows the proposed capacitive and resistive sensor electronic interface. This circuit is built around the Schmitt trigger shown in figure 1. The dotted box, can be:

(a) A resistive sensor with resistance R_s connected in series with the reference capacitance C_r; that is with terminal 1 connected to terminal 4 and terminal 2 connected to terminal 3.

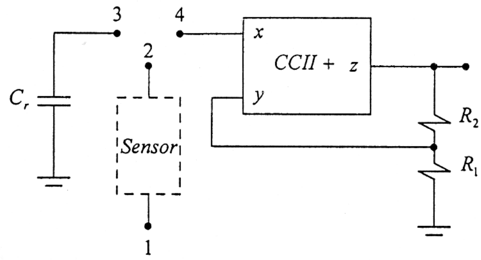

Figure 3. Proposed capacitive and resistive sensor electronic interface.

(b) A capacitive sensor with a capacitance C_s connected in parallel with the reference capacitance C_r; that is with terminals 2, 3 and 4 connected together and terminal 1 grounded.
(c) A capacitive sensor with a capacitance C_s connected in series with the reference capacitance C_r.
(d) A capacitive–resistive impedance sensor, with capacitance C_s in series with a resistance R_s, connected in series with the reference capacitance C_r.

Thus, in general, equation (1) can be rewritten as

$$T = \frac{1}{f} = 2C_T R_T \ln\left(2\frac{R_1}{R_T} - 1\right) \tag{2}$$

where

(a) $C_T \cong C_r$ and $R_T \cong R_s$ when a resistive sensor is connected in series with the reference capacitance (case a).
(b) $C_T = C_s + C_r + C_x$ and $R_T = r_x$ when a capacitive sensor is connected in parallel with the reference capacitance (case b).
(c) $C_T = C_s C_r/(C_s + C_r) + C_x$ and $R_T = r_x$ when a capacitive sensor is connected in series with the reference capacitance (case c).
(d) $C_T \cong C_s C_r/(C_s + C_r)$ and $R_T \cong R_s$ when the capacitive–resistive sensor is connected in series with the reference capacitance (case d).

The approximations made in cases (a) and (d) are based on the assumption that the time constant $C_x r_x$ is too small compared to the $C_T R_s$.

3. Experimental results

The proposed circuit of figure 3 was tested using the AD844 configured as CCII+. With an additional built-in voltage buffer, the AD844 provides a low-output impedance square wave for further processing. The results obtained with $R_1 = 1.0\,k\Omega$, $R_2 = 0.8\,k\Omega$, $C_r = 300\,\text{pF}$ and DC supply voltage $= \pm 10\,\text{V}$ are shown in figures 4 and 5 for resistive sensor connected in series with the reference capacitance and capacitive sensor connected in parallel with the reference capacitance.

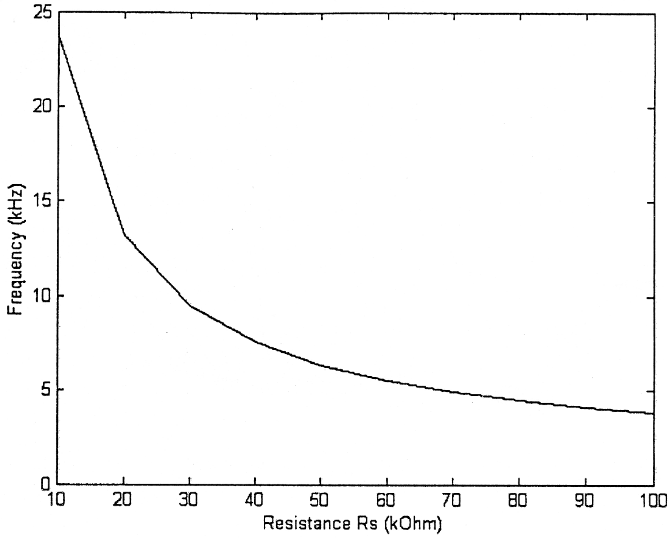

Figure 4. Variation of the frequency of oscillation with the resistance of a resistive sensor connected in series with the reference capacitance $C_r = 300\,\text{pF}$.

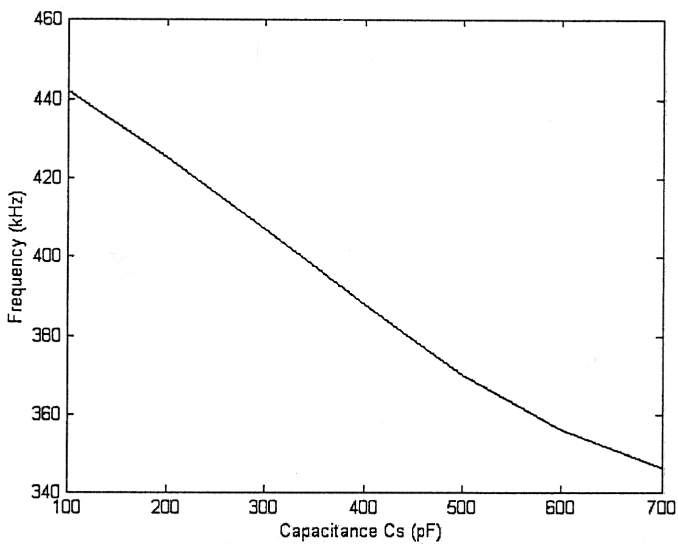

Figure 5. Variation of the frequency of oscillation with the capacitance of a capacitive sensor connected in parallel with the reference capacitance $C_r = 300\,\text{pF}$.

4. Conclusion

In this paper, a simple electronic interface circuit has been presented. The circuit is built around a single (CCII+) and uses two additional resistances plus a reference capacitance. The circuit can be used as an interface with capacitive, resistive and resistive–capacitive-sensors. Compared with the similar operational-amplifier based and operational transconductance amplifier-based circuits the present one enjoys the following advantages; attributed to the use of current conveyor:

(1) Higher frequencies of operation.
(2) Wider dynamic range.
(3) Low power consumption.
(4) Higher slew rate.

Moreover, with availability of built-in buffer circuit in the commercially available CCII+ (AD844), the output square-wave voltage is associated with a low-impedance. This facilitates further processing in the voltage domain.

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