PROGRAMMABLE CURRENT-CONVEYOR-BASED OSCILLATOR EMPLOYING GROUNDED RESISTORS AND CAPACITORS

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A new programmable oscillator using two negative first-generation current-conveyors, three grounded capacitors, and two grounded resistors is presented. The proposed circuit enjoys independent oscillation control through a single grounded resistor and independent frequency control through a single grounded capacitor. Replacing one of the grounded resistors by a digitally programmable resistor results in a programmable oscillator.

INTRODUCTION

In a recent letter, Chang [1] proposed a single-resistance-controlled, current-conveyor-based oscillator. The proposed circuit uses three grounded resistors and two grounded capacitors and enjoys independent oscillation and frequency control. However, the major disadvantage of the circuit is the use of three current conveyors, two of them are positive second-generation current-conveyors (CCII+) and the third is a negative first-generation current-conveyor (CCI-).

The purpose of this paper is to propose a new current-conveyor-based single-element controlled oscillator using only two CCI-, two grounded resistors, and three grounded capacitors. The circuit enjoys independent control of oscillation and frequency and can be easily converted to a voltage-controlled oscillator. By replacing one of the grounded resistors by an operational transconductance amplifier (OTA)-based resistor a digitally programmable oscillator can be realized.

PROPOSED CIRCUIT

The proposed circuit is shown in Fig. 1. Assuming ideal CCI- with $v_x = v_y$, $i_x = i_y = i_z$ routine analysis shows that the characteristic equation of the circuit can be expressed as

$$s^2 C_1 C_2 + s G_4 (C_3 - C_2) + G_3 G_4 = 0 \quad (1)$$

FIGURE 1 Proposed current-conveyor sinusoidal oscillator circuit.

Using (1), the condition of oscillation and the frequency of oscillation can be expressed as

$$\omega_0^2 = \frac{1}{C_1 C_2 R_3 R_4} \quad (2)$$

and

$$C_2 = C_3 \quad (3)$$

From (2) and (3), it is easy to see that the frequency of oscillation can be adjusted by tuning R_3 or R_4 or C_1 without disturbing the condition of oscillation while the condition of oscillation can be adjusted by tuning C_3 without disturbing the frequency of oscillation. Thus, the circuit enjoys independent oscillation and frequency control.

By defining the passive sensitivity of a parameter F to the element of variation x_i by

$$S_{x_i}^F = \frac{dF}{dx_i} \frac{x_i}{F},$$

it is easy to show that the sensitivity of the frequency of oscillation ω_o to the variation in passive elements is given by

$$S_{C_1}^{\omega_0} = S_{C_2}^{\omega_0} = S_{R_3}^{\omega_0} = S_{R_4}^{\omega_0} = -\frac{1}{2}$$

FIGURE 2 Operational-transconductance-amplifier-based realisation of a programmable grounded resistor.

Thus, the ω_o -sensitivity to passive elements is low.

The resistor R_{41} can be realized using the operational transconductance amplifier (OTA)-based resistor shown in Fig. 2. Assuming ideal OTA with $i_o = g_m v_{input}$ where i_o is the output current, $g_m = I_{ABC}/2V_T$ is the transconductance of the OTA, I_{ABC} is the auxiliary bias current of the OTA, V_T is the thermal voltage, and v_{input} is the input voltage of the OTA. By obtaining the current I_{ABC} from the output of the microcontroller, one can see that the frequency of oscillation can be digitally-programmed.

PROPOSED SYSTEM HARDWARE

The hardware architecture consists of a microcontroller, an 8-bit digital-to-analog converter (DAC), an OTA, and two CCI-. The microcontroller is a single chip 8-bit microprocessor that monitors and controls the frequency of oscillation. It has a built-in 256-byte RAM, an 8-kilobyte EPROM, 512-byte EEPROM, 29 input-output digital ports, and an 8-channel 8-bit ADC. Through the microcontroller, the

user is provided complete control over the frequency of oscillation of the oscillator. The user would make his selection through a software menu. The microcontroller would then change the bias current of the OTA, thus changing the value of the resistance R_4 and thereby changing the frequency of oscillation. The 8-bit DAC provides 256 digital combinations and allows fine tuning and, hence, more programming options. The heart of the system is the MC68HC11 microprocessor. It is used in the single chip mode which requires no external storage. The RAM is used for temporary storage of data processing. The EPROM is used to host the main program that controls the whole procedure. Having the EPROM makes it easy to change the software algorithms for future modification and reboot the new program without adding any new components to the system.

The software for the system was developed in Motorola assembly language. The flowchart shown in Fig. 3 outlines the steps involved. Upon reset, the microprocessor reads the user option and then commands the right digital word to the ADC, which changes the biasing voltage and, hence, the biasing current I_{ABC} of the OTA. This changes the value of the resistance R_4 and, hence, the frequency of oscillation

FIGURE 3 Software flow-chart.

FIGURE 4 Digital-to-analog converter circuitry.

of the oscillator. The menu displayed for the user allows very fine change of the voltage. The voltage levels are between 0.0 to 9.1 V and they can be changed in 256 steps.

EXPERIMENTAL RESULTS

The proposed circuit is designed to give an output frequency in the range of 8–10 MHz. This range can be controlled in 256 steps with 1LSB corresponding to $\approx 7\text{kHz}$. Higher resolutions, and consequently, lower errors can be obtained by using the 10-, 12- or even 16-bit DAC. For example, using a 16-bit DAC leads to a frequency step of $\approx 29\text{Hz}$. The DAC circuit connections are shown in Fig. 4. The CCI– was implemented using the circuit shown in Fig. 5 [2] built around the OTA CA3080 and the operational amplifier LF356. Although there are other higher performance CCI– realizations, the kernel of the work presented in this paper does not depend on the particular implementation of the CCI–. The CA3080 was also used for realizing the digitally programmable resistance R_{41} .

A typical output waveform is shown in Fig. 6. The circuit is designed for an output frequency in the range 7.710 MHz to 9.826 MHz when the DAC output is changing from 00 to FF.

CONCLUSION

In this paper a new current-conveyor-based oscillator has been presented. The circuit uses two negative first-generation current conveyors, two grounded resistors,

FIGURE 5 Realization of the CCI-[2].

and three grounded capacitors. The circuit enjoys low sensitivities to passive components and independent control of the frequency and the condition of oscillation. The use of grounded capacitors makes the circuit attractive for integration and the use of grounded resistors for independent control of the frequency of oscillation makes the circuit attractive for the realization of voltage controlled oscillators. The circuit can be easily interfaced to a microcontroller,

FIGURE 6 A typical output waveform obtained from the circuit of Fig. 1.

which can monitor and control the frequency of oscillation. Another attractive feature of the circuit is the use of two similar current conveyors. Thus, the circuit appears to be very attractive for integration.

REFERENCES

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