선형 OTA를 이용한 삼각파/구형파 발생기

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A Triangular/Square Waveforms Generator Using Linear OTA's

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Abstract

A triangular/square waveforms generator with current controllable frequency is described. The genertor utilizes operational transconductance amplifiers as switching elements. The circuit built with commercially available components exhibits good linearity of current to frequency and relatively low temperature sensitivity.

I. Introduction

A triangular/square waveforms generator with current controllable frequency can easily be realized by using an operational transconductance amplifier (OTA) as a switching current source to charge and discharge a grounded timing capacitor followed by a OTA-based Schmitt trigger[1]. It features simple configuration and wide sweep capability. A main drawback of this realization is that it is impossible to control the amplitude of the square waveform output by a dc current without affecting the oscillation frequency. This leads to restricting the usefulness of the generator in such applications that a variable and precise amplitude control is important. In this paper, a new scheme is presented which does not suffer

II. Circuit Description and Operation

The circuit diagram of the proposed triangular/square waveforms generator is shown in Fig. 1. Two voltage amplifiers (one is composed of OTA_1 and R_1 and the other of OTA_2 and R_2) connected in a positive-feedback manner form a Schmitt trigger, whose transfer characteristic is shown in Fig. 2. Note that the saturation level of the Schmitt trigger is directly proportional to the bias current of OTA_1, I_{B1} whereas the threshold voltage is directly proportional to the bias current of OTA_2, I_{B2}. OTA_3 and the timing capacitor C form an integrator whose time constant is proportional to

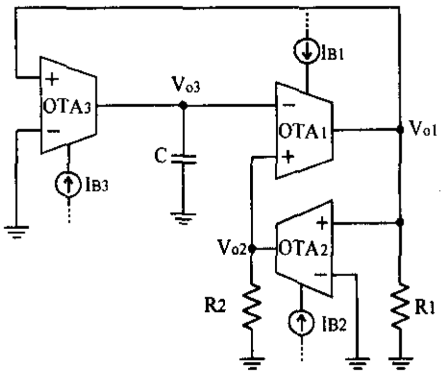

Fig. 1. Circuit diagram of the proposed triangular/square waveform generator.

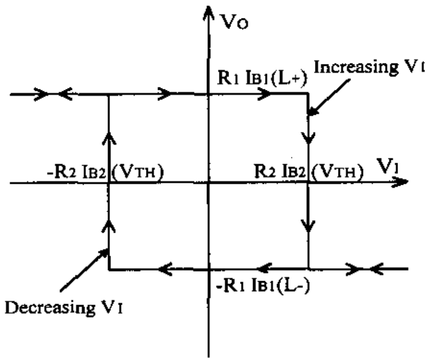

Fig. 2. Tranfer characteristic of the Schmitt trigger composed of two OTA-R voltage amplifiers connected in positive-feedback manner.

the bias current I_{B3}. The waveforms associated with the generator is shown in Fig. 3. To see how the generator operates, let the output of the Schmitt trigger be at its positive saturation level $L_{+} = R_1 I_{B1}$. This voltage level makes OTA$_3$ saturate, and thus a saturation current equal to I_{B3} will flow through the capacitor C, causing the output of the integrator to linearly increase with a slope of I_{B3}/C. This will continue until the integrator reaches the high threshold $V_{TH} = R_2 I_{B2}$ of the Schmitt trigger, at which

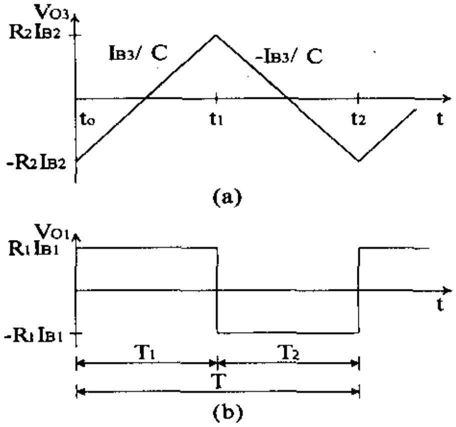

Fig. 3. Output waveforms of the generator.

point the Schmitt trigger will switch states and its output becoming negative and equals . A $L_{-} = -R_1 I_{B1}$t this moment the current through C will reverse its direction. It follows that the integrator output will start to decrease linearly with a negative slope of $-I_{B3}/C$. This will continue until the integrator output voltage reaches the low threshold voltage of the Schmitt trigger, $V_{TL} = -R_2 I_{B2}$. At this point the Schmitt trigger switches, its output becomes positive ($L_{+} = R_1 I_{B1}$), the current through C reverses its direction, and the output of integrator starts to increase linearly, beginning a new cycle. From the above description it is easy to derive an expression for the period of the square and triangular waveforms. During the interval T_1 we have, from Fig. 3(a),

$$\frac{R_2 I_{B2} - (-R_2 I_{B2})}{T_1} = \frac{I_{B3}}{C} \qquad (1)$$

Rearranging the equation gives

$$T_1 = 2CR_2\frac{I_{B2}}{I_{B3}} \qquad (2)$$

Similarly, during T_2 we have

$$\frac{-R_2 I_{B2} - (R_2 I_{B2})}{T_2} = -\frac{I_{B3}}{C} \tag{3}$$

from which we obtain

$$T_2 = 2CR_2\frac{I_{B2}}{I_{B3}} \tag{4}$$

Equations (2) and (4) can be combined to obtain the period T of the output waves as

$$T = T_1 + T_2 = 4CR_2\frac{I_{B2}}{I_{B3}} \tag{5}$$

from which we obtain the oscillation frequency given by

$$f = \frac{1}{4CR_2}\frac{I_{B3}}{I_{B2}} \tag{6}$$

Ⅲ. Experimental Results and Discussion

The generator shown in Fig. 1 was built using conventional OTA's[2] shown in Fig. 4, in which the transistors used were Q2N2222 (*npn*) and Q2N2907 (*pnp*).

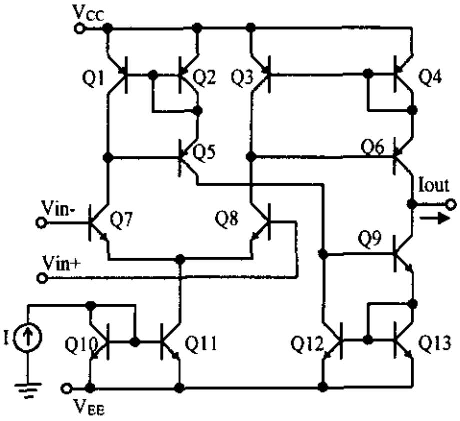

Fig. 4. Circuit diagram of the OTA used for the generator.

The resistors used $R_1 = R_2 = 50\ \text{k}\Omega$ and the capacitor $C = 1$ nF. The bias current I_{B2} was set to 25 μA for convenience and All experiments were performed at supply voltages of ±5 V. Plots of measured oscillation frequency against bias current I_{B3} are shown in Fig. 5. The nonlinearity is caused by the nonlinear relation between bias current and output current of OTA_3 and the switching delay of the Schmitt trigger (OTA_1 and OTA_2). The temperature stability of the oscillation frequency is also plotted in Fig. 5 with the dashed line, indicating that the stability is maintained to within 300 ppm/℃ over the frequency range 2~17 kHz.

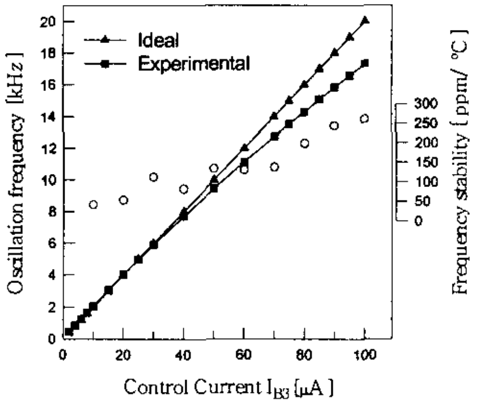

Fig. 5. Measured frequency against control current and the frequency stability of the generator.

The square waveform amplitude against bias current I_{B1} was also measured. The result is shown in Fig. 6, which indicates that the amplitude of the square waveform is linearly controllable up to ±4 V by the bias current I_{B1}. Fig. 6 also shows that the temperature stability of the amplitude is seen to be about -300 ppm/℃ (dased line).

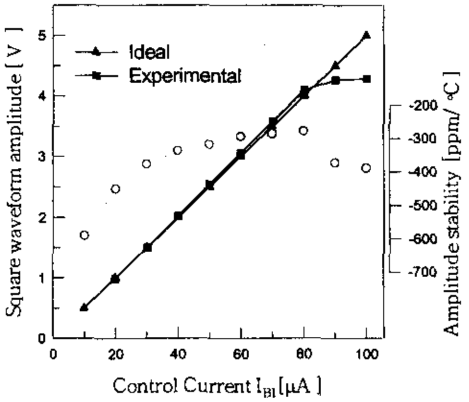

Fig. 6. Measured square waveform amplitude against control current and the amplitude stability of the square waveform.

IV. Conclusion

A OTA-based generator with triangular/ square outputs has been described. It features a simple configuration. An additional feature is that its frequency and amplitude can be independently and linearly controlled by dc currents. Because of these properties, the proposed generator is expected to find wide applications in communication and instrumentation systems.

References

[1] W.-S. Chung, H.-W. Cha, and K.-H. Kim, "Temperature-stable VCO based on operational transconductance amplifiers", *Electron. Lett.,* vol. 26, pp. 1900- 1901, October. 1990

[2] *"National Operational Amplifiers" Databook,* National Semiconductor Corporation, Santa Clara, CA, 1995