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A Method for Biasing a Temperature Independent Current Conveyor Precision Rectifier

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Abstract

The method for biasing the temperature independent current conveyor precision rectifier is presented. The objective of biasing diodes in the current conveyor rectifier is to improve an error at the output of the rectifier during the zero crossing. The proposed method uses two diodes, a voltage buffer, and a constant current source to create the diode bias voltage. Simulated rectifier performance using PSPICE program with the models of commercial current conveyors (AD844) and diodes (1N4148) demonstrates that the proposed biasing method yields higher temperature stability than previously reported methods.

1. Introduction

Rectifiers are extensively used in wattmeters, AC voltmeters, RF demodulators, piecewise linear function generators, and various nonlinear analog signal-processing circuits. The operation of the rectifier using only diodes is limited by the threshold voltages of diodes, approximately 0.3 V for germanium diode and 0.7 V for silicon diode, thus they are used in some applications of which the precision in the range of threshold voltage is insignificant, such as radio frequency demodulators and DC voltage supply rectifiers. Nevertheless for the application requiring high accuracy, the rectifier using only diodes cannot be used for the purpose. Using MOS or bipolar integrated circuit rectifier instead can solve this problem.

One advantage of the integrated circuit rectifiers designed using the simple seen devices such as opamps, current conveyors, transistors, diodes, and resistors as components, is they can be built in almost all countries. The classical problem with conventional precision rectifiers based on diodes and opamps is that during the non-conduction/conduction transition of the diodes the opamps must recover with a finite small-signal dV/dt resulting in significant distortion during the zero crossing of the input signal. The use of the high slew-rate opamps does not solve this fundamental drawback because it is a small-signal transient problem [1]. Conventional rectifiers are thus limited to a frequency performance well below the gain-bandwidth product or f_T of the amplifier [2]. This limitation is improved by designing the rectifier with the use of current mode technique [1-5]. Recently, the current mode full-wave rectifier using the current conveyors as the voltage to current converter has received wide attention. For example, LTP Electronics Ltd. [3] and Khan *et al.* [5] proposed the same current conveyor full-wave rectifiers as shown in Fig. 1a. This full-wave rectifier is developed to reduce the distortion during the zero crossing at high frequency in the next time by Toumazou *et al.* [2] with the addition of a DC voltage source as shown in Fig. 1b. Hayatleh *et al.* [4] developed this full-wave rectifier later on to reduce the effect of temperature on the zero crossing performance by with using a constant current source and a resistor in place of the voltage source as shown in Fig. 1c.

In this paper, the author presents the method for biasing diodes in the current conveyor rectifier that produces higher temperature stability than the previously reported methods.

2. Proposed biasing method

From the current conveyor rectifiers in Fig. 1b and Fig. 1c, assuming that all diodes have the same characteristics, the bias voltage for node A must equal to $2V_T$, where V_T is the threshold voltage of diodes. If the bias voltage is lower than $2V_T$, it is the cause of no turning on of diodes all the time. Inversely, if the bias voltage higher than $2V_T$, it is the cause of the output offset voltage. The threshold voltage V_T is given by

$$V_T = \left(\frac{kT}{q}\right)\ln\left(\frac{I_D}{I_s}\right) \qquad (1)$$

where k is Boltzmann's constant, T is the absolute temperature in degrees Kelvin, q is the charge of an electron, I_D is the forward diode current, and I_s is the reverse leakage current that is given by

$$I_s \propto T^3 \exp\left(-\frac{V_g q}{kT}\right)$$

where V_g is the bandgap voltage at absolute zero ($V_g = 1.205$ V for the silicon diode [6]).

As you can see in the equation (1), the threshold voltage depends on the temperature. Thus, the use of the constant bias voltage of the rectifiers in Fig. 1b and Fig. 1c results in bad temperature stability.

To avoid this drawback, the proposed biasing method yields the bias voltage $2V_T$ that depends on the temperature, the same as the voltage $2V_T$ at the bridge. The current conveyor precision rectifier with the proposed biasing method is shown in Fig. 1d. This method uses two diodes, a voltage buffer, and a constant current source to operate as a bias voltage source. The operation of the bias voltage source is as follows: The constant current source supplies a current through two diodes producing the bias voltage. In order to protect the effect of the outputs of current conveyors and the effect of the load on this bias voltage, the voltage buffer is used. The bias voltage $2V_T$ is carried out by adjusting the constant current source I. In the proposed biasing method, the bias voltage is the voltage at two diodes (D_5 and D_6) the same as the voltage at two diodes in the bridge (D_1 and D_2 as well as D_3 and D_4). Thus when the temperature changes, the changes of the voltages at the bias voltage source and at two diodes in the bridge are equal. Therefore, there is no the change of the output voltage during the zero crossing.

3. Simulated results

To verify the proposed biasing method, the current conveyor precision rectifiers using the proposed biasing method and using the previously reported biasing methods were simulated by the PSPICE program with the models of commercial current conveyors (AD844) and diodes (1N4148). The voltage supply used is ± 10 V. The circuit in Fig. 1b was simulated with the bias voltage of 0.9 V. The circuit in Fig. 1c was simulated with the constant current source of 200 μA and the resister of 8 kΩ. The proposed circuit in Fig. 1d was simulated with the constant current source of 5 μA and LM 741 opamp voltage buffer. Sine wave inputs (100 mV_P, 1 MHz) were applied to all the simulated circuits. The full-wave outputs in case when not when the bias voltage (Fig. 1a) and in case when using the bias voltage (Fig. 1d) are shown in Fig. 2 in which shows the increment of the operating frequency of the rectifier when using the bias voltage. The zero crossings of the full-wave outputs of the circuits in Fig. 1b, Fig. 1c, and Fig. 1d at the temperatures: 27°C, 50°C, and 70°C were magnified and shown in Fig. 3, Fig. 4, and Fig. 5, respectively. Fig. 3 to Fig. 5 show that the proposed biasing method yields higher temperature stability than the previously reported biasing methods.

4. Conclusions

The method for biasing the temperature independent current conveyor precision rectifier has been described and simulated. The simulated results show that using the proposed biasing method we obtain higher temperature stability than using the previously reported biasing methods.

5. Acknowledgement

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6. References

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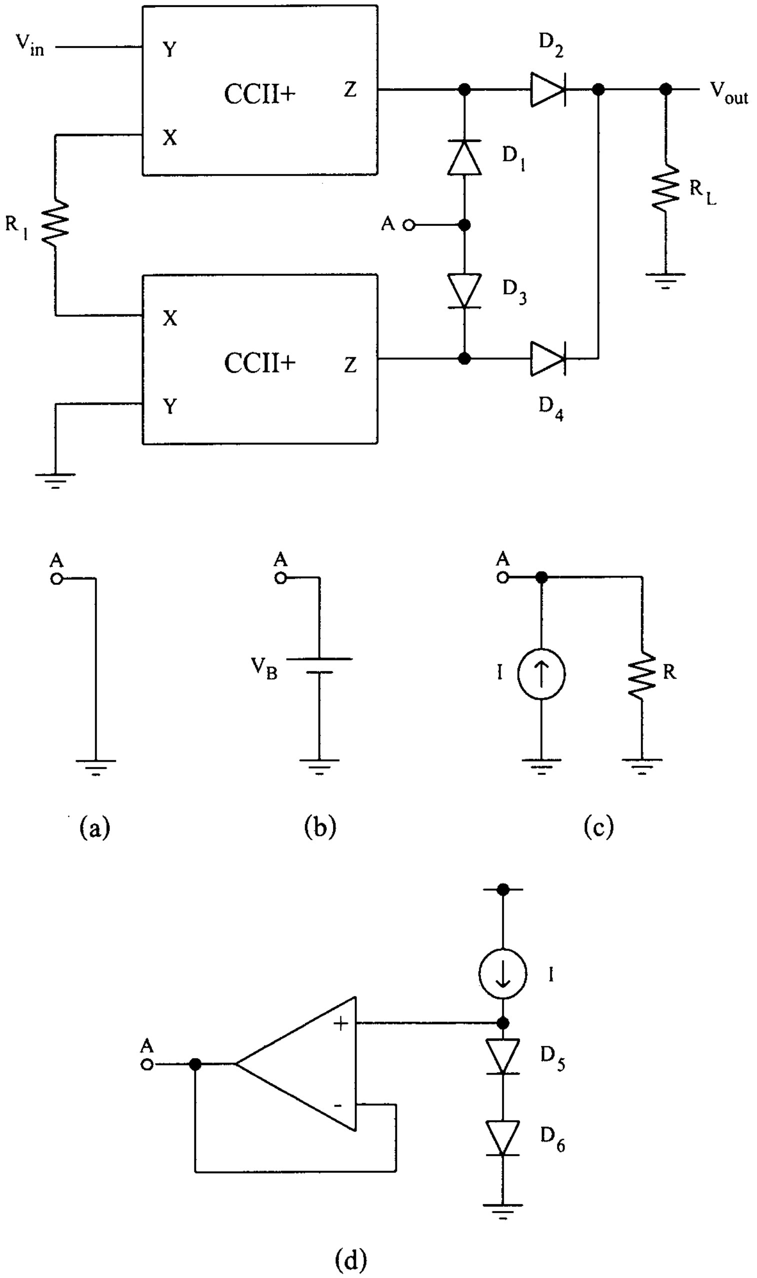

Fig. 1 Current conveyor precision rectifiers: (a) proposed by LTP Electronics Ltd. and Khan *et al.*, (b) proposed by Toumazou *et al.*, (c) proposed by Hayatleh *et al.*, and (d) proposed in this paper.

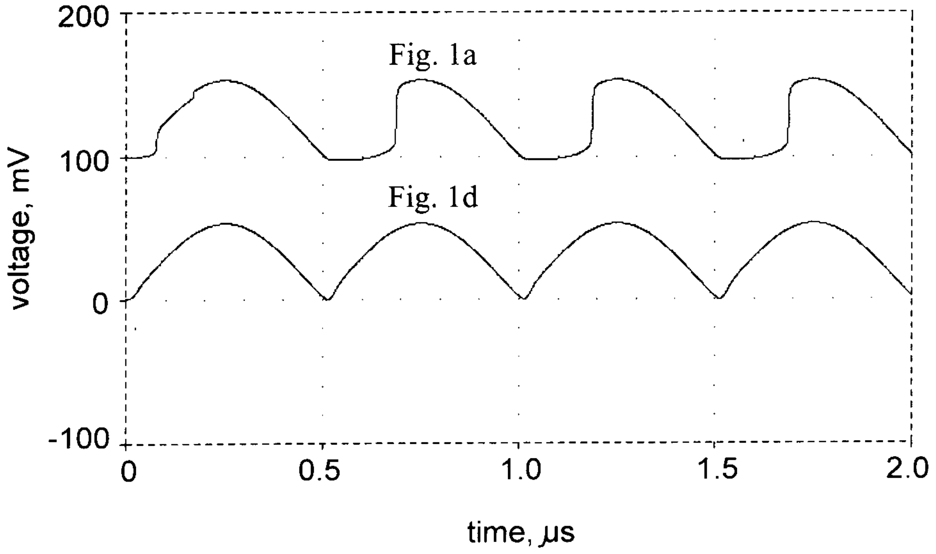

Fig. 2 Outputs of the circuits in Fig. 1a with DC offset of 100 mV and in Fig. 1d, both simulated at 27°C.

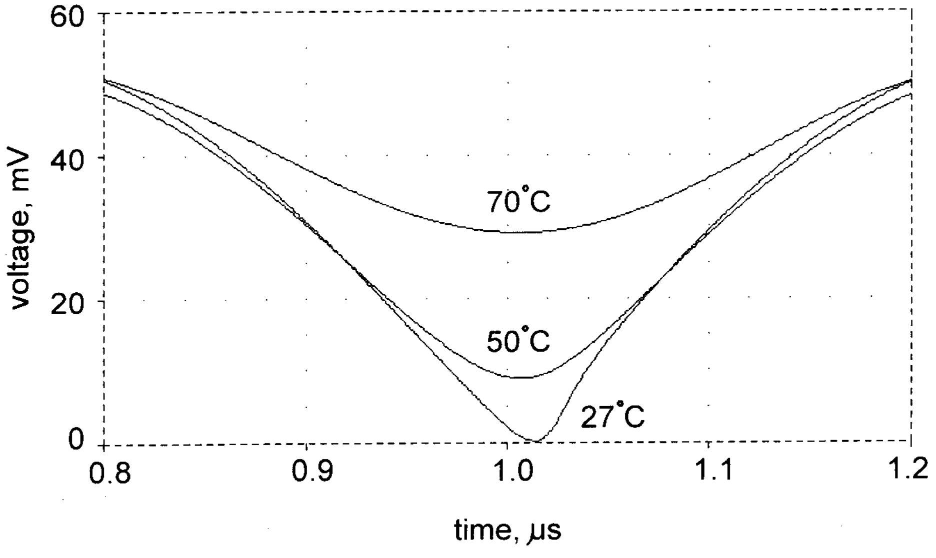

Fig. 3 Zero crossing performance for several temperatures of the circuit in Fig. 1b.

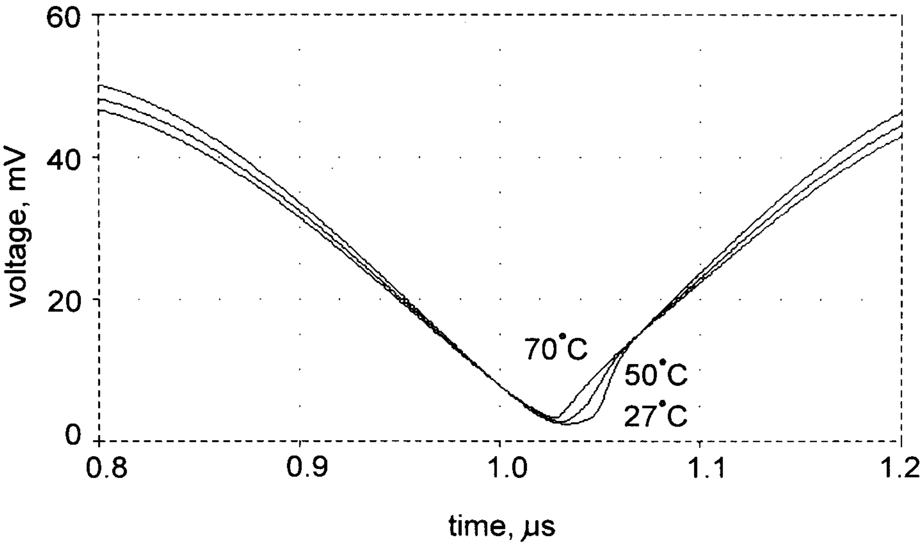

Fig. 4 Zero crossing performance for several temperatures of the circuit in Fig. 1c.

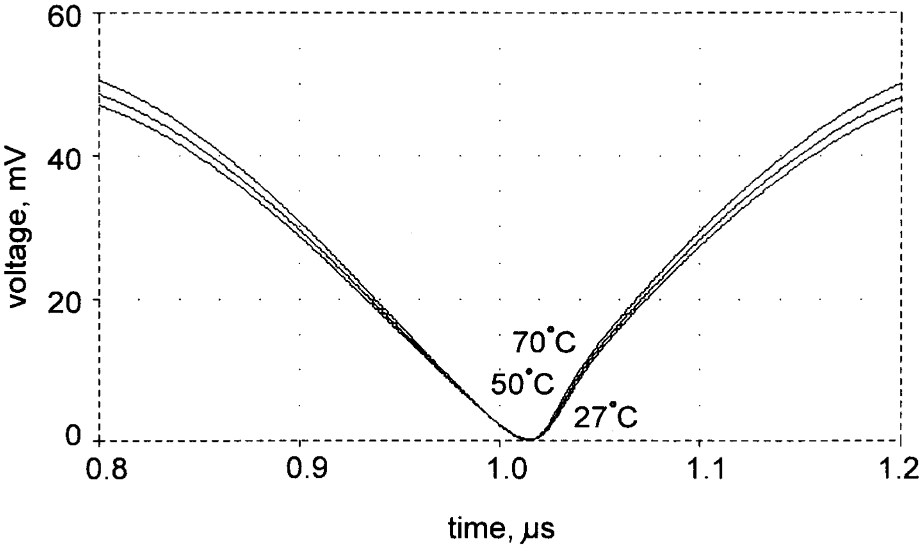

Fig. 5 Zero crossing performance for several temperatures of the circuit in Fig. 1d.