Bi-directional current transceiver

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Abstract: The current-mode circuit technique to design a bi-directional current transceiver for remote control systems and telemetering systems is presented in this paper. The proposed transceiver can transmit and receive the industrial standard current signal 4-20mA at the same time using two wires connection. The realization method is based on a second generation current conveyor (CCII) and a current mirror, which can be implemented using a commercially available device. To demonstrate the performance of the proposed scheme, the transceiver was simulated by the use of the PSPICE analog simulation program. The simulation results verifying the circuit performance are agreed with the expected values. The crosstalk of the proposed transceiver of about –63dB is observed.

Keywords: CCII, Current transceiver, Telemetering, Current-mode circuit

1. INTRODUCTION

The transmission signals presented in the industrial control system are traditionally broken into two-portion, voltage signal, and current signal. It is well known that a current signal transmission presents a superior than a voltage signal transmission [1]. For the remote control system and the telemetering system, the voltage signal transmission will occur an error of the sending signal. This is due to the series resistance that causes by the output resistance of the transmitter, the resistance at the destination or the load and the resistance of the wire used. The use of current signal transmission will eliminate the effect of series resistance to ensure that the destination will receive the sending signal without lost. In many industrial applications, the control signal and sensing signal or feedback signal are transmitted and received from the distant station and in the form of current signal. The flow of the current signal in the transmission loop, which is two wire structure, allows only one direction flow or only one signal. Thus the control signal and feedback signal are impossible to combine the current signal more than one signal in the same transmission loop. For the industrial control system, the process variable is usually sent to the controller by one process variable per one signal transmission loop. It should be noted that the transmission loop will be double for the redundant system. If two current signals or bi-directional current signal can be applied to the transmission loop, then the advantage will be gained.

In this article, bi-directional current transceiver is presented. The proposed transceiver can transmit and receive a current signal using only one transmission loop at the same time. The proposed structure is based on the use of the second-generation current conveyor [2-4] to transmit and receive the current signal via the standard current 4 to 20mA. The basic performances of the proposed circuit are demonstrated using PSPICE simulation program. The cross talk of about –63dB is observed. The frequency response of the proposed circuit is about 445kHz. It should be noted that the proposed transceiver is suitable for the real time transmitted and received current signal in the industrial applications using single transmission loop.

2. CIRCUIT DISCRIPTION

The second generation current conveyor (CCII) has been introduced in 1970 [5]. It is a three-part network defined by the following matrix equation:

$$\begin{bmatrix} i_y \\ v_x \\ i_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} v_y \\ i_x \\ v_z \end{bmatrix} \quad (1)$$

The structure of the CCII is similar to the voltage-to-current converter. The proposed bi-directional transceiver structure (TR) using CCII is shown in Fig. 1. where CA_i is the two-output current amplifier. The operating of the transceiver can be explained as follows. Assuming that the pairs of CCII and CA are well matched. From Fig. 1 the input port Y of $CCII_1$ and $CCII_2$ are connected to ground, that cause the voltage at node A and B equal to zero. When node A is connected with node B via the signal transmission loop, the output port X of the $CCII_1$ and $CCII_2$ are connected together. Therefore the current i_{x1} and i_{x2} are equal. The current at node A and B can be written as :

$$i_{12} + i_{22} = i_{x1} + i_{x2} \quad (2)$$

The current i_{in1} and i_{in2} are transferred to the current i_{12} and i_{22} by the current amplifier CA_1 and CA_2, respectively, with the current gain equal to two. Thus the current i_{x1} and i_{x2} can be stated as:

$$i_{x1} = i_{x2} = i_{in1} + i_{in2} \quad (3)$$

The current i_{x1} and i_{x2} are transferred to the current i_{z1} and i_{z2} at port Z of the $CCII_1$ and $CCII_2$, respectively, with the unity current gain ($i_{z1} = i_{x1}$, $i_{z2} = i_{x2}$). The current i_{11} and i_{21} are forced to equal the current i_{in1} and i_{in2} by the current amplifier CA_1 and CA_2, respectively. Therefore the currents i_{out1}, and i_{out2} can be stated as:

$$i_{out1} = i_{z1} - i_{11} = i_{in2} \quad (4a)$$

$$i_{out2} = i_{z2} - i_{22} = i_{in1} \quad (4b)$$

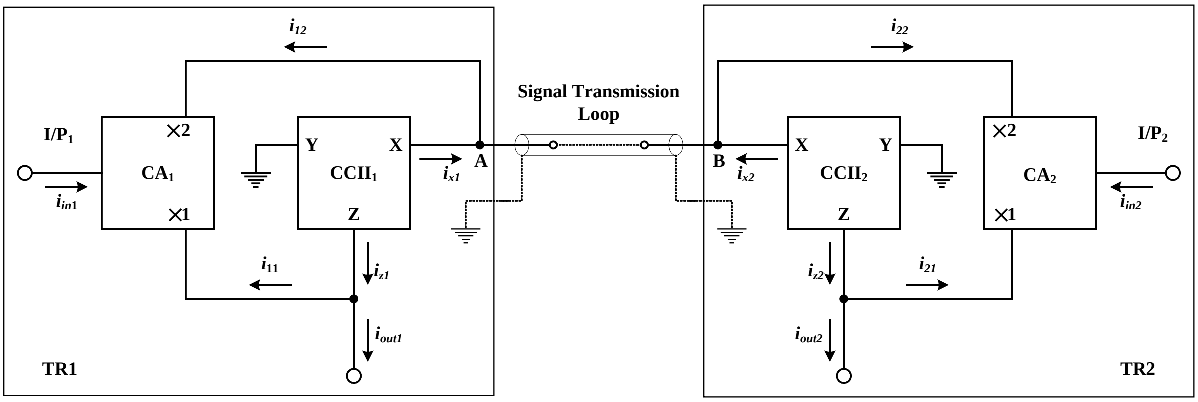


Fig. 1 Bi-directional Transceiver

It can be seen that the signal current i_{in1} of transceiver TR_1 is transmitted to the output current i_{out2} of the transceiver TR_2. Similarly, the current i_{in2} is transmitted to the current i_{out1}. From the operation of the proposed structure, both of the input signal currents i_{in1} and i_{in2} of the transceiver TR_1 and TR_2, respectively, can be transmitted to each other using only one transmission loop. The CCII used in the proposed transceiver is depicted in Fig. 2(a). From Fig. 2(a), an operational amplifier (opamp) A_1, diodes D_1 and D_2, transistors Q_1 and Q_2 form as a class AB power amplifier. The inverting input of an opamp A_1 is connected with node C to form a unity gain amplifier. The voltage at port y will be accurately transferred to port x. If the current i_x is applied to port x, then the collector current I_{c1} and I_{c2} of the transistors Q_1 and Q_2 can be approximated as [6].

$$I_{C1} = \left\{(4I_B^2 + i_x^2)^{\frac{1}{2}} - i_x\right\}/2 \qquad 5(a)$$

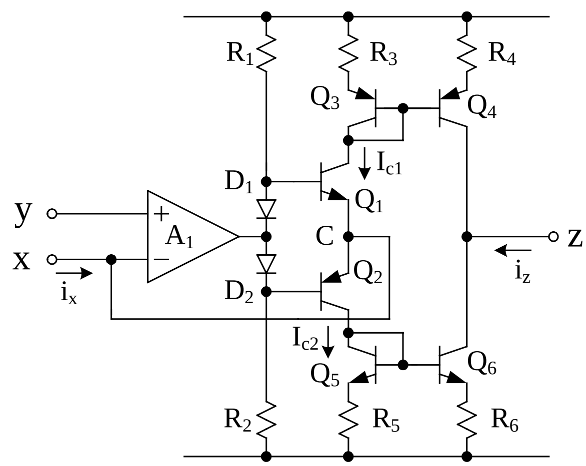
and

$$I_{C2} = \left\{(4I_B^2 + i_x^2)^{\frac{1}{2}} + i_x\right\}/2 \qquad 5(b)$$

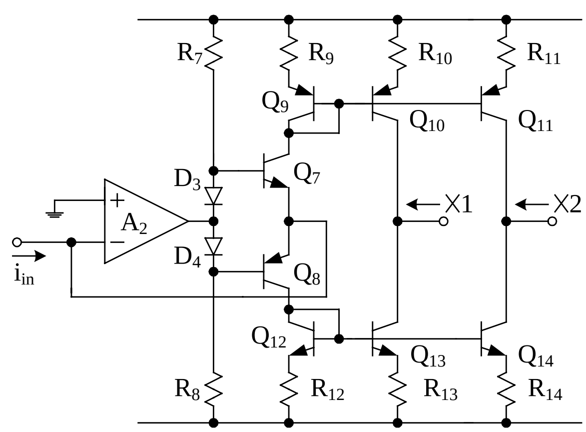
Where I_B is the quiescent current of the transistors Q_1 and Q_2. Transistors Q_3-Q_4, resistors R_3-R_4 and transistors Q_5-Q_6, resistors R_5-R_6 form as unity gain positive and negative current mirrors. The currents I_{c1} and I_{c2} are reflected to port z and the output current i_z can be stated as :

$$i_z = I_{C2} - I_{C1} = i_x \qquad (6)$$

The current i_z is now equal to the current i_x. Fig. 2(b) shows the multiple output current amplifier CA. From Fig. 2(b), the current gain of the output x1 and x2 are unity gain and twice gain, respectively. The circuit operation is similar to the circuit in Fig. 2(a). The noninverting input of an opamp A_2 is connected to ground. Thus the inverting input becomes virtual ground and the current i_{in} can be transferred to the output x1 and x2. The positive and negative unity gain current mirrors are formed by transistors Q_9-Q_{10}, resistors R_9-R_{10} and transistors Q_{12}-Q_{13}, resistors R_{12}-R_{13} respectively. Consequently, the value of the resistors R_{11} and R_{14} are set to half value of the resistors R_9 and R_{12}, respectively, generate the current $2i_{in}$ at the output node x2.



(a)

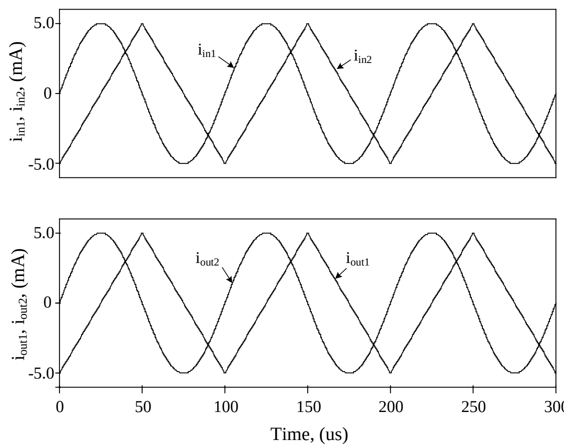


(b)

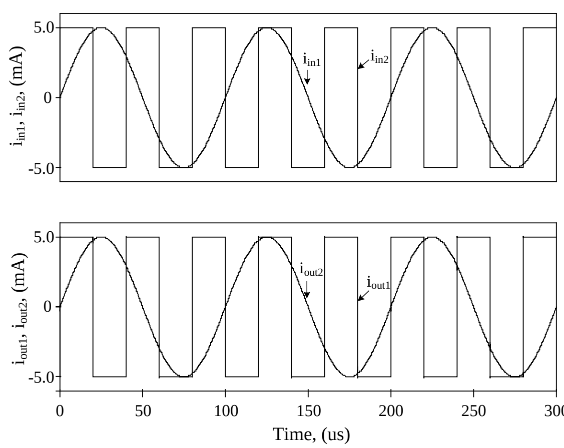
Fig. 2 (a) Second generation current conveyor (CCII)
(b) Multiple output current amplifier (CA)

3. SIMULATION RESULTS

The performance of the proposed transceiver was simulated using PSPICE analog simulation program. The simulation was carried out using the transistor parameters of 2N3904 and 2N3906 for NPN and PNP transistors, respectively, and the op-amp parameters of AD818. The supply voltages V_{CC} = $-V_{EE}$ were set to 15V.



(a)



(b)

Fig.. 3 (a) Sinusoidal wave i_{in1} = 10kHz, 5mA
Triangular wave i_{in2} = 10kHz, 5mA
(b) Sinusoidal wave i_{in1} = 10kHz, 5mA
Square wave i_{in2} = 10kHz, 5mA

Fig. 3(a) shows the test of two frequency waveform, sinusoidal and triangular wave with 10kHz and peak amplitude of 5mA. The sinusoidal wave is applied to the current signal i_{in1} and transmitted to the output current signal i_{out2}. Similarly, the triangular wave of the signal current i_{in2} is transmitted to the output signal current i_{out1}. The test of the sinusoidal and square wave is also shown in Fig. 3(b). It should be noted that two signals can be transmitted using only into one transmission loop. The leakage signal from the input current i_{in1} to the output current i_{out1} is verified in the term of crosstalk. The crosstalk of the proposed transceiver is shown in Fig. 4. It should be noted that the average value of the crosstalk is about –63dB and the worse-case crosstalk about –59dB is observed. The frequency response of the proposed transceiver is about 445kHz as shown in Fig. 5.

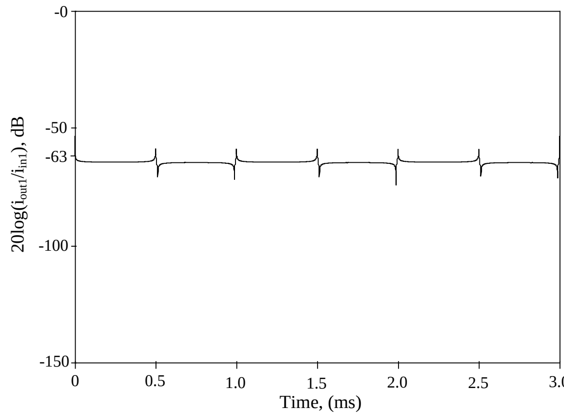


Fig. 4 Crosstalk

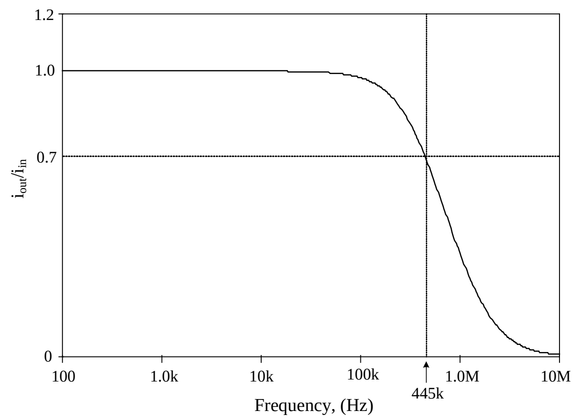


Fig. 5 Frequency response

4. CONCLUSION

A bi-directional current transceiver based on CCII has been presented. The proposed transceiver can be implemented using the commercially available devices. Two current signals can be transmitted using only one transmission loop with industrial standard current signal 4-20mA. The crosstalk of the transceiver is very low. The proposed transceiver is suitable for remote control and telemetering systems.

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