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An Optical Instrumentation Using a Sensor with a Sensordummy Against Noises on Sensor and Transmission Line

Katsutoshi Mine*, Nobuhisa Kubota*, Fumio Morimoto*, Mizuho Sanada*, Zhang Qi**
* Kyushu kyoritsu University, Department of Electrical Engineering
1-8 Jiyugaoka, Yahatanishi-ku, Kitakyushu city, 807, JAPAN
** Shengyang College of Technology, Shengyang city, 110044, P.R. CHINA

Abstract

Methods of Alternating Noise Canceling were previously developed for the optical instrumentation; one using a dual photo sensor and another using a single photo sensor that could cancel normal mode noise on a transmission line, even if the noise was of equal status noise. But the methods could not remove noise on sensor line. This paper discusses a new method of using a photo sensor with a resistance sensordummy, effectively canceling equal status normal mode noise not only on a sensor line but also on a transmission line of an optical instrumentation. The accuracy of this method has been verified by experiments using sinusoidal wave as an equal status noise on a sensor line and/or rectangular wave as an equal status wide band noise on a transmission line respectively.

1 Introduction

In industrial working condition, signal measurements by an instrumentation with an optical sensor are inaccurate because of noise. An Alternating Noise Canceling (ANC) method [1] using dual sensor[2] and a sensor[3] on an optical instrumentation was previously developed that could cancel normal mode noise (NMN) on the transmission line, even if the noise was equal status noise.

These methods had some imperfections, for example it could not remove noise on sensor line. Therefore, a method using a sensor with a sensordummy was developed using ANC method with a pair of hybrid ICs against NMN not only a transmission line but also on a sensor line.

The signal, a photo sensor output is made to radiate by an incandescent lamp using commercial power supply, AC 100V, 60Hz. If a conductive noise, n_1, and inductive noise, n_2 ride on the sensor line and the transmission line respectively, then two signals are made by alternating the switching between the sensor output signal and the sensordummy both with n_1 and n_2. An input of a receiver is the output of the photo sensor, n_1 and n_2. Another input of the receiver is only n_1 and n_2. Therefore, the two signals received using interpolation can be subtracted by ANC-R hybrid IC in order to obtain a signal without noise.

The impedance changing range of photo sensor is very big. Therefore, the sensordummy resistance should be adjusted to suitable averaging value against the changing impedance. In this case, the switching frequency of the analog switch in the ANC-T hybrid IC should be four times in the Nyquist frequency, the maximum frequency of the noise to be canceled.

2 ANC and Experiments

2.1 ANC method

In this experiment, the first signal was made from a photo sensor. The second signal was zero volt as a sensordummy output. Timings of the two alternative signals had different values. Therefore the sensordummy output was interpolated, based on averaging method. The interpolated second signal was subtracted from the first signal and a reliable signal without any noise could be obtained. In this case "any noise" is NMN under a quarter frequency of the switching which generates a synchronous pulse train.

Figure 1 shows a schematic diagram of the ANC system for an optical instrumentation with a sensor and a sensor-dummy using a pair of hybrid ICs against NMN not only on a transmission line but also on a sensor line. In this case, the photo sensor changed its resistance according to light changing frequency of 120 Hz. Therefore the resistance of the sensordummy was adjusted to an equivalent value of the changing resistance of the photo sensor. Photo I shows ANC-T and ANC-R hybrid ICs. In figure 1, V_1 is sensor output signal, n'_1 and n''_1 are NMN on the sensorline, n_2 is NMN on the transmission line and V_a is an input of ANC-R hybrid IC.

From Figure 1,

$$(V_a)_i = (V_1 + n'_1 + n_2)_i \quad \text{at } t = i \qquad (1)$$

$$(V_a)_{i-1} = (V_2 + n_1 + n_2)_{i-1} \quad \text{at } t = i-1 \qquad (2)$$

The following is the interpolation value.

$$\begin{aligned}(\widehat{Va})_{i-1} &= \{(V_a)_i + (V_a)_{i-2}\}/2 \\ &= \widehat{(V_1 + n'_1 + n_2)}_{i-1} \\ &= (\widehat{V_1})_{i-1} + (\widehat{n'_1})_{i-1} + (\widehat{n_2})_{i-1} \qquad (3)\end{aligned}$$

$$\begin{aligned}(\widehat{V_a})_{i-1} - (V_a)_{i-1} &\doteqdot (\widehat{V_1})_{i-1} + (\widehat{n'_1})_{i-1} + (\widehat{n_2})_{i-1} \\ &- (V_2)_{i-1} - (n''_1)_{i-1} - (n_2)_{i-1} \\ &\doteqdot (\widehat{V_1})_{i-1} \doteqdot (V_1)_{i-1} \qquad (4)\end{aligned}$$

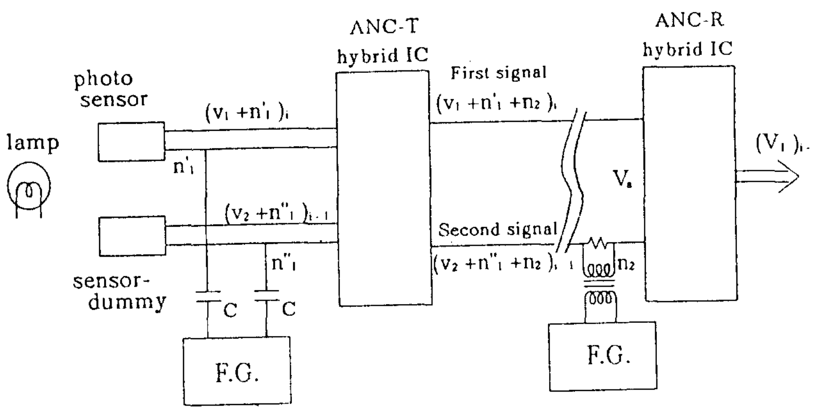

Fig.1 Schematic diagram of the ANC method for an optical instrumentation, and analog switching in the ANC-T is 25kHz.

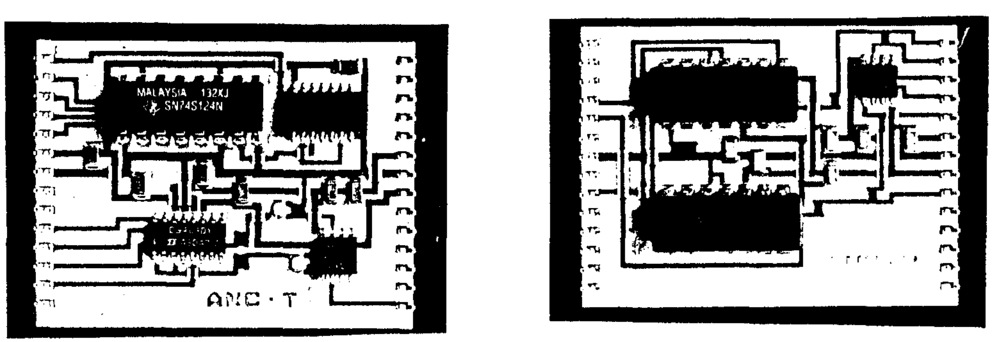

Photo 1 Hybrid ICs of ANC method.

Where,

$$n_1' \doteqdot n_1'' = n_1, \quad (V_2)_{i-1} = 0,$$
$$(\widehat{n_1})_{i-1} \doteqdot (n_1)_{i-1}, \quad (\widehat{n_2})_{i-1} \doteqdot (n_2)_{i-1} \tag{5}$$

If the function, (V_a) the signal with noise, can be made into infinte derivations, then the error, ε , at t=i-2, based on Taylor expansion, is expressed in the following equation.

$$\varepsilon = (\widehat{V_a})_{i-1} - (V_a)_{i-1} = \sum_{n=2}^{\infty} \frac{-(V_a)_{i-2}^{(n)}}{n!} h^n \tag{6}$$

If the maximum frequency of the signal is B, then the sampling period, h is determined in the following equation[4].

$$h \leq \frac{1}{4}\frac{2\pi}{B} \tag{7}$$

2.2 Experiments

Several experiments were done for this research. Table 1 shows the devices and elements used in the experiments. Fig.2, Fig.3 and Fig.4 show three examples of these experiments. In the first experiment wave noise (100Hz) was added on the sensor line and the sensordummy line, in the second, rectangular wave noise (120Hz) was added on the transmission line and in the third experiment the both noises added not only to the sensor line and the sensordummy line but also to the transmission line as shown in Fig.2, Fig.3 and Fig.4 respectively. In this case the switching frequency was 25kHz. Table 1 shows the instruments used in this experiment.

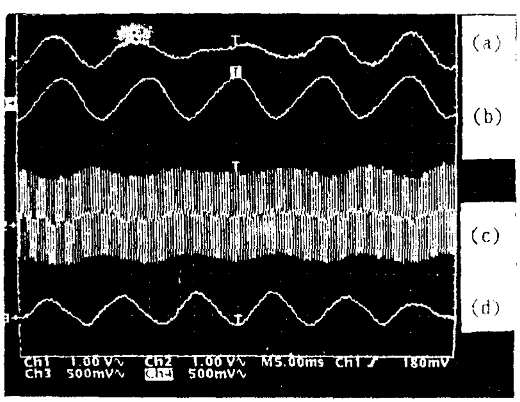

Fig.2 The result of the first experiment, where (a) $v_1 + n_1$ befor ANC-T, (b) n_1 (500mVp-p, 100Hz) (c) $v_1 + n_1$ input of ANC-R, (d) output of ANC-R

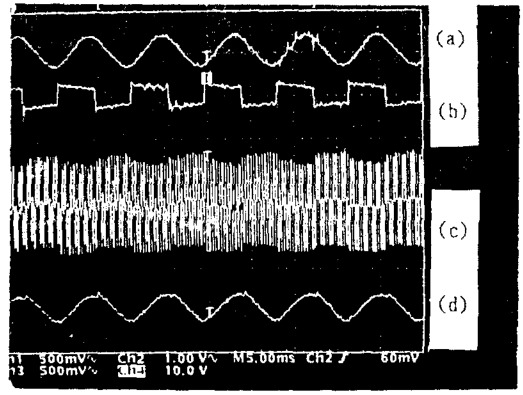

Fig.3 The result of the second experiment, where (a) v_1, (b) n_2 (810mVp-p, 120Hz) (c) $v_1 + n_2$ input of ANC-R, (d) output of ANC-R

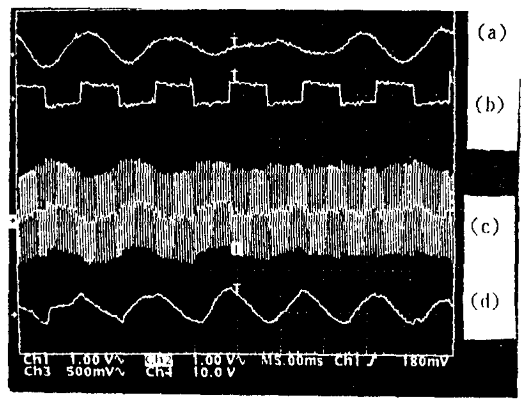

Fig.4 The result of the third experiment, where (a) $v_1 + n_1$, (b) n_2, (c) $v_1 + n_1 + n_2$ input of ANC-R, (d) output of ANC-R

Table 1 Devices and elements used in the experiments.

Photo sensor	TPS 601 TOSHIBA Co.LTD
ANC hybrid IC	ANC-T and ANC-R YASKAWA Control Co.LTD

3 . Concluding Remarks

The accuracy of this method has been verified by experiments using sinusoidal wave as an equal status noise on a sensor line and/or rectangular wave as an equal status wide band noise on a transmission line respectively.

1. In this research a method of noise canceling in an instrumentation was developed using a photo sensor, a sensordummy, an ANC-T hybrid IC, and an ANC-R hybrid IC.

2. This method is the most reliable because it has successfully canceled noises not only on a sensor line, but also on a transmission line. Therefore, this method is better than a dual sensor system [2] and single sensor system[3] as optical instrumentations against noises.

3. This method allows us to obtain a reliable signal without any noise on the transmission line. In this case, the switching frequency of the analog switch should be more than four times (meaning by Nyquist frequency) over the maximum frequency of the noise which is canceled using this method.

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