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The Signal Validation method of Digital Process Instrumentation System on signal conditioner for SMART

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1. Introduction

The function of PIS(Process Instrumentation System) for SMART is to acquire the process data from sensor or transmitter. The PIS consists of signal conditioner, A/D converter, DSP(Digital Signal Process) and NIC(Network Interface Card). So, It is fully digital system after A/D converter. The PI cabinet and PDAS(Plant Data Acquisition System) in commercial plant is responsible for data acquisition of the sensor or transmitter include RTD, TC, level, flow, pressure and so on. The PDAS has the software that processes each sensor data and PI cabinet has the signal conditioner, which is need for maintenance and test. The signal conditioner has the potentiometer to adjust the span and zero for test and maintenance. The PIS of SMART also has the signal conditioner which has the span and zero adjust same as the commercial plant because the signal conditioner perform the signal condition for AD converter such as 0~10Vdc. But, To adjust span and zero is manual test and calibration. So, This paper presents the method of signal validation and calibration, which is used by digital feature in SMART. There are I/E(current to voltage), R/E(resistor to voltage), F/E(frequency to voltage), V/V(voltage to voltage). Etc. In this paper show only the signal validation and calibration about I/E converter that convert level, pressure, flow such as 4~20mA into signal for AD conversion such as 0~10Vdc.

2. The analysis of Uncertainty Factor on Signal Conditioner

The object of uncertainty factor analysis is to find the point for signal validation. So, The figure 1 is shown to circuit simulation and the table 1 is shown to the result of the simulation of the circuit. There are the differences between ideal result and real result. That means, there is the uncertainty factor on the circuit. To analysis of uncertainty factor is calculate the transfer function.
According to figure1, The I/E converter is consist of current to voltage converter part, isolator and inverting amplifier and buffer. The transfer function of inverting amplifier on I/E converter is shown below.
Ein : input voltage, Eout : output voltage
Z1: resistor of the input, Z2 : resistor of the feedback
Vref : voltage between Ein and Eout

$$V_{ref} = \left(\frac{E_{in}}{z_1} + \frac{E_{out}}{z_2}\right) / \left(\frac{1}{z_1} + \frac{1}{z_2}\right) \quad (1)$$

$$V_{ref} = (E_{in} z_2 + E_{out} z_1) / (z_1 + z_2) \quad (2)$$

According to OP amp characteristic, the voltage value of the between positive and negative port on the I/E converter is almost zero[1]. So, Vref equals zero.
And then,

$$0 = E_{in} z_2 + E_{out} z_1 \quad (3)$$

so, the transfer function is

$$E_{out} / E_{in} = -z_2 / z_1 \quad (4)$$

According to transfer function is depend on the value of Z2 and z1[2]. So, the uncertainty factors of I/E converter are Z2 and Z1. And Z2 and Z1 are need for adjust point same as potentiometer. To reduce the differences between real output and ideal output are possible to reduce the difference to adjust the Z2 and Z1. So, next chapter is shown to reduce the signal uncertainty.

3. The design hardware and software for signal validation using the digital potentiometer

The signal conditioner has analog type potentiometer for adjust the span and offset. But, PIS is consist of A/D converter and DSP. So, PIS replace analog potentiometer by the digital potentiometer respect Z1 and Z2. This function is need for new design concept about hardware and software. The figure 2 is shown to hardware design using the digital potentiometer. The digital potentiometer is controlled by software from DSP through VME bus. The algorithm of the auto calibration and validation is shown to the Figure 3.
The algorithm is firstly the read of data. And then, check the difference between output data and input of the gain control range. If the output is less than gain control range, and the Z1 is adjust the resistor value until the difference is allowable limitation. And then, algorithm checks the difference between output data and input of the zero control range. If the output is less than zero control range, and the Z2 is adjust the resistor value until the difference

is almost same. This algorithm is for signal calibration and it is used by not only signal auto calibration but also the signal validation.

4. Conclusion

The signal conditioner has span and offset adjust. So, operator is adjust the span and offset during the test period. In the analog system, there are no signal validation and auto calibration on the card level but this paper is shown the signal validation and auto calibration method that is used by digital feature on the signal conditioner.
The character of this method is on-line signal of auto calibration on the card level. Additional to, this method is help for operator during the operating and test period.

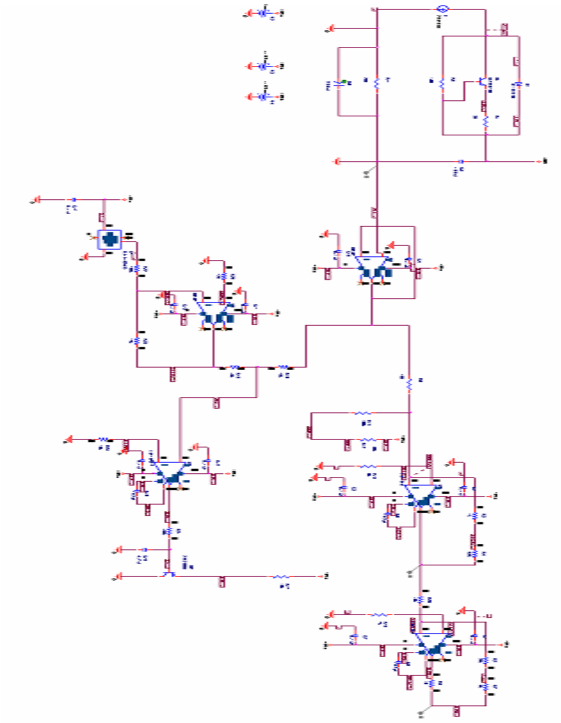

Figure 1. The circuit simulation of I/E converter

Input Range(%)	Input	Output of Simulation	Ideal Output
0%	4mA	-0.4 V	0V
6.25%	5mA	252mV	0.625V
12.5	6mA	908mV	1.25V
18.75	7mA	1.565V	1.875V
25%	8mA	2.221V	2.5V
31.25	9mA	2.877V	3.125V
37.5	10mA	3.534V	3.75V
43.75	11mA	4.19V	4.375V
50%	12mA	4.846V	5V
56.25	13mA	5.502V	5.626V
62.5	14mA	6.158V	6.25V
68.75	15mA	6.815V	6.875V
75%	16mA	7.471V	7.5V
81.25	17mA	8.127V	8.125V
87.5	18mA	8.783V	8.75V
93.75	19mA	9.44V	9.375V
100%	20mA	10.1V	10V

Table 1. The result of the circuit simulation about I/E converter

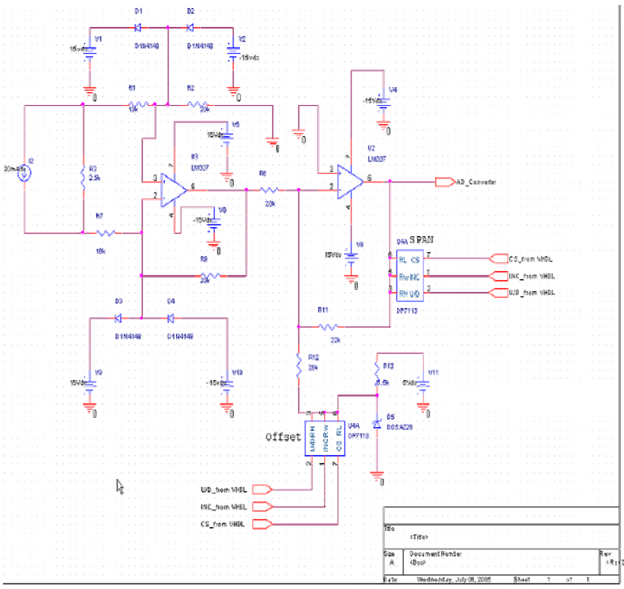

Figure 2. The design of the I/E converter that used by the digital potent meter

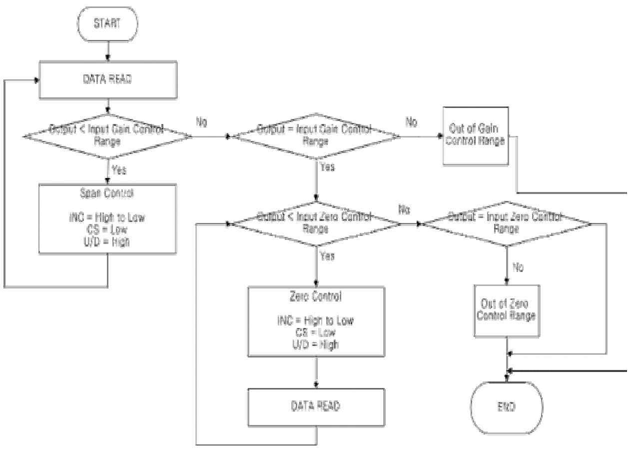

Figure 3. The design of Algorithm for signal validation and auto calibration

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[1] Robert F. Coughlin, Frederick F. Driscoll, third edition, 1997, "Operational Amplifiers and Linear Integrated Circuits"
[2] Tony R, Forth edition, 2002, “Lesson in Electric Circuits”