Experimental Study:Ranging of Sensor and Actuator Data for Real Time Interfacing

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Research Article

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Abstract

The primary purpose of the paper is to provide a guideline to process control researchers who are interested in the design controllers by their own. This article gives a simple technique to real time sensor and actuator interfacing in and to computer; it is tested in LabVIEW software. It mainly highlights the process of mapping the values of input signal and output signal values to process.

Introduction

Controller design is the most important part for process control researchers [1]. For effective closed control system, the researchers were proposed various control algorithms and analyze the response in closed loop environment [2, 3]. In closed loop, interfacing of sensor and actuating element is the most important process for process control researchers. It mainly depends on the experience and process knowledge of the researcher. In general, sensor output signal range is (4–20) mA and actuator input signal is (4–20) mA [4]. In market data acquisition systems (DAQ) are available to acquire and generate signals in the range of (-10 to + 10) V. The sensor output signal range is (4–20) mA, it is highly need to convert the (4–20) mA to the range of (1–10) V to send signal to computer through DAQ. Similarly, the output signal from the computer should be in the range of same (1–10) V should be converted into (4–20) mA. For converting both input and output signal to the required range, the researchers have to design an appropriate electronic circuit with necessary components [6, 7]. Many research are working directly on inbuilt real time interfaced process station [8]. So, there is no need for them to design interfacing circuit. This lacks the researchers' knowledge in electronic circuit design for interfacing and some are interested in designing those circuit are facing problem due to availability of circuit components. This paper proposed a simple method to map the input and output signal using simple electronic circuit.

Interface Circuit

The circuit shown in Fig. 1. It not only quite simple and has the advantage of using simple laboratory level components like variable resistor (DRB), power supply, and a basic level DAQ interfacing system.

In Fig.1, process variable level was measured from the process station using sensor (transmitter). Signal from computer was given to process station through current to pressure (I/P) converter and as pressure signal (3–15) was given to control valve as control signal. For sensor needs a supply voltage of 24V, is supplied using power source (V). 'R' represents the variable resistor value.

In the case studies, National Instruments Engineering Laboratory Virtual Instrumentation Suite (NI-ELVIS) was used and it has four analog channels and two analog channels to acquire and generate electrical signals respectively. NI-ELVIS module is designed to operate in the range of (-10 to + 10) V accommodating both positive and negative terminals to acquiring and generating analog signals.

PROPOSED MAPPING FORMULA

For the effective controller design, a researcher needs to map the input and output signal range. For this, the simple method was proposed and given in table 1.

Result And Discussion

For evaluating the proposed method, for cases were considered and results were given in table 3, table 4, table 5 and table 6. The sensor and actuator was connected as shown in figure 1 and output voltage values were noted using multi-meter (DMM) or voltmeter before connecting to DAQ. Before started working on propose, the user needs to find the full operating range of the process.

In this study, Level sensor and control valve were considered, the full operating range was measured by supplying a water into the process tank of 1.28 V for 0 cm and 5.14 V for 90 cm liquid level. These values were obtained by varying the DRB (R_1) to appropriate value, the value in the DRB is adjusted as per the requirement of the user, the objective is to convert the (4-20)mA current signal to (1-10)V. Simply by adjusting the DRB the user can get some random values. But the user must ensure the value should in the range of (1-10) V.

In similar way, for (0 to 100) % control valve i.e., (open to close) signal range was measured by adjusting the DRB resistance values to appropriate values and the respective voltage values were given in table 2. Four cases were considered for analysis based on output signal range, (1-9) V for case 1, (1-8) V for case 2, (1-7) V for case 3 and (1-6) V for case 4.

After obtaining the input and output signal range values, the user were framed four step formula in the LabVIEW and respective values were given in table 3, table 4, table 5 and table 6.

From the above cases 1 to 4, it can be seen that the sensor range (4-20) mA was initially converted to (1.28-5.41) V and by considering the output signal range as desired range values, the formula was framed for four different output ranges. It clearly shows that the mapping of input and output signal was done and gives a greater result in real time application. Once the formula given in table 2 was implemented, the controller design will be easy for the user to get proper closed loop results.

Conclusion

Based on case studies considered in this work, the proposed mapping formula is quite simple and allow the end user to design their own controllers and can be possible to check the performance of the controllers. The method can be easily adopted by many researchers and can be extended for on-line implementation for all the process.

Declarations

CONFLICT OF INTEREST

All authors declare no conflict of interest

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Tables

Table 1 Conversion formula for real time interfacing

Iteration (i)	Step 1	Step 2	Step 3	Step 4
	$X_{a(i)}$	$X_{b(i)}$	$X_{c(i)}$	$X_{d(i)}$
1	X_{a1}	$X_{b1}=(X_{a1})-(X_{a1})$	$X_{c1}=((X_{an}-X_{ai})/n)$	$X_{d1}=(X_{c1})/(X_{c1})$
2	$X_{a2}= (X_{a1})+ X_{div}$	$X_{b2}=(X_{a2})-(X_{a1})$	$X_{c2}=(X_{c1})+(X_{an}-X_{ai})/n)$	$X_{d2}=(X_{c2})/(X_{c1})$
3	$X_{a3} = (X_{a2})+ X_{div}$	$x_{b3}=(X_{a3})-(X_{a1})$	$X_{c3}=(X_{c2})+(X_{an}-X_{ai})/n)$	$X_{d3}=(X_{c3})/(X_{c1})$
4	$X_{a4} = (X_{a3})+ X_{div}$	$X_{b4}=(X_{a4})-(X_{a1})$	$X_{c4}=(X_{c3})+(X_{an}-X_{ai})/n)$	$X_{d4}=(X_{c4})/(X_{c1})$
5	$X_{a5}=(X_{a3})+ X_{div}$	$X_{b5}=(X_{a5})-(X_{a1})$	$X_{c5}=(X_{c4})+(X_{an}-X_{ai})/n)$	$X_{d5}=(X_{c5})/(X_{c1})$
:	:	:	:	:
:	:	:	:	:
:	:	:	:	:
n	$X_{an}=(X_{a(n-1)})+ X_{div}$	$X_{bn}=(X_{an})-(X_{a1})$	$X_{cn}=(X_{c(n-1)})+(X_{an}-X_{ai})/n)$	$X_{dn}=(X_{cn})/(X_{c1})$

Where,

X_a is first step value (designed circuit output given to computer), X_b is second step value, X_c is third step value, and X_d is fourth step value (mapped input sensor reading to output control signal range) , with respect to iteration, i (1, 2, 3, 4, 5….n) it varies.

n= number of division we need to make for effective process, value decide based R_2 value,

X_{ai} is initial value, (i=1), X_{an} is final value,(i=n), X_{diff} is difference between initial and final value, X_{div} is X_{diff} divided by number of division (n).

Table 2. Values of operating parameters

Parameters	Case 1	Case 2	Case 3	Case 4
X_{ai}	1.28 V	1.28 V	1.28 V	1.28 V
X_{an}	5.41 V	5.41 V	5.41 V	5.41 V
X_{diff}	4.13 V	4.13 V	4.13 V	4.13 V
n	9	8	7	6
X_{div}	0.458889	0.51625	0.59	0.688333
Output range	(1-9) V	(1-8) V	(1-7) V	(1-6) V

Table 3 Mapped values for case 1

Iteration (i)	Step 1	Step 2	Step 3	Step 4
	$X_{a(i)}$	$X_{b(i)}$	$X_{c(i)}$	$X_{d(i)}$
1	1.28	0	0.458889	1
2	1.738888889	0.458888889	0.917778	2
3	2.197777778	0.917777778	1.376667	3
4	2.656667778	1.376667778	1.835556	4
5	3.115557778	1.835557778	2.294445	5
6	3.574447778	2.294447778	2.753334	6
7	4.033337778	2.753337778	3.212223	7
8	4.492227778	3.212227778	3.671112	8
9	4.951117778	3.671117778	4.130001	9
10	5.410007778	4.130007778		

Table 4 Mapped values for case 2

Iteration (i)	Step 1	Step 2	Step 3	Step 4
	$X_{a(i)}$	$X_{b(i)}$	$X_{c(i)}$	$X_{d(i)}$
1	1.28	0	0.51625	1
2	1.79625	0.51625	1.0325	2
3	2.3125	1.0325	1.54875	3
4	2.82875	1.54875	2.065	4
5	3.345	2.065	2.58125	5
6	3.86125	2.58125	3.0975	6
7	4.3775	3.0975	3.61375	7
8	4.89375	3.61375	4.13	8
9	5.41	4.13		

Table 5 Mapped values for case 3

Iteration (i)	Step 1	Step 2	Step 3	Step 4
	$X_{a(i)}$	$X_{b(i)}$	$X_{c(i)}$	$X_{d(i)}$
1	1.28	0	0.59	1
2	1.87	0.59	1.18	2
3	2.46	1.18	1.77	3
4	3.05	1.77	2.36	4
5	3.64	2.36	2.95	5
6	4.23	2.95	3.54	6
7	4.82	3.54	4.13	7
8	5.41	4.13		

Table 6 Mapped values for case 4

Iteration (i)	Step 1	Step 2	Step 3	Step 4
	$X_{a(i)}$	$X_{b(i)}$	$X_{c(i)}$	$X_{d(i)}$
1	1.28	0	0.688333	1
2	1.968333	0.688333	1.376667	2
3	2.656667	1.376667	2.065	3
4	3.345	2.065	2.753333	4
5	4.033333	2.753333	3.441667	5
6	4.721667	3.441667	4.13	6
7	5.41	4.13		

Figures

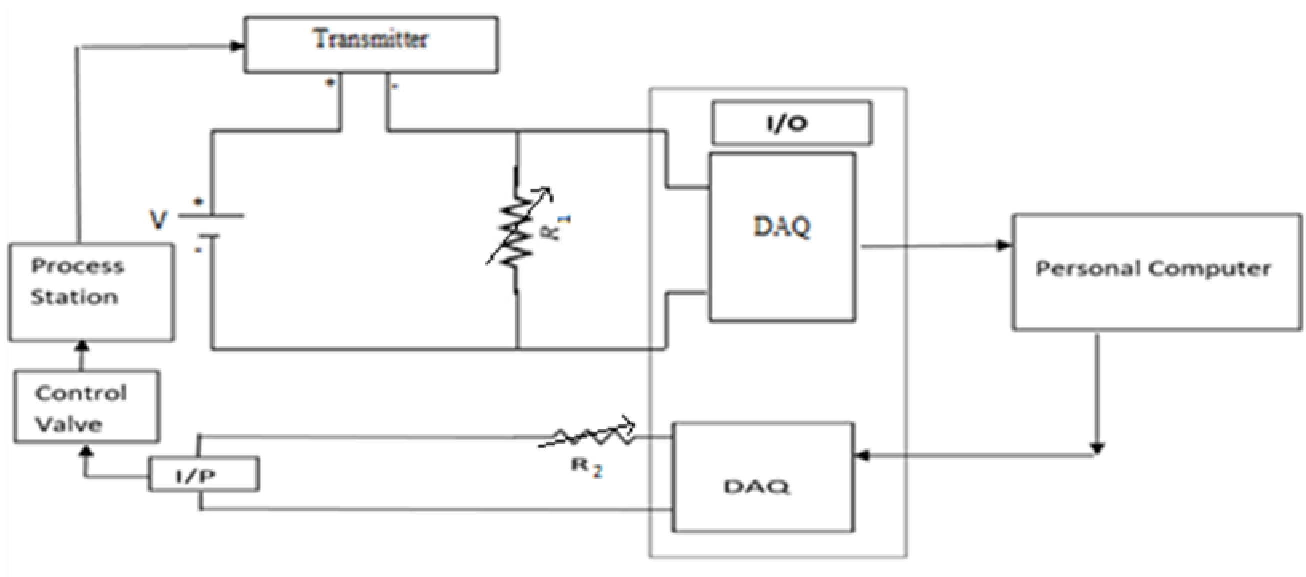

Figure 1

Interfacing of sensor and actuating element