



A NOVEL APPROACH TO INTERFACE SENSOR AND ACTUATOR USING NI DAQ HARDWARE

Aravind Pitchai Venkataraman^{1*}, Khalid Ali Khan², Suleyman Malikmyradovich Nokerov³, Subramanian Pitchai Venkataraman⁴, Perman Ezzigulyyevich Hojagulyyev⁵

¹Saranathan College of Engineering, Thiruchirappalli, Tamil Nadu, India.

²Department of Electrical and Computer Engineering, Mattu University, Mettu, Ethiopia.

^{3,5}Oguz Han Engineering and Technology University of Turkmenistan, Ashgabat, Turkmenistan.

⁴M.A.M School of Engineering, Thiruchirappalli, Tamil Nadu, India.

*Corresponding author

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Controller design for the interfacing of sensor and actuating element in closed loop is the most important part for process control researchers. For effective closed control system, the researchers were proposed various control algorithms and analyze the response in closed loop environment. In general, sensor output signal range is (4-20) mA and actuator input signal is (4-20) mA. In market data acquisition systems (DAQ) are available to acquire and generate signals in the range of (-10 to +10) V. It is highly need to convert the sensor output range of (4-20) mA to the range of (1-10) V to send signal to computer through DAQ and vice versa. For converting both input and output signal to the required range, the researchers have to design an appropriate electronic circuit with necessary components [1-7]. Many researchers are working directly on inbuilt real time interfaced process station. 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.

The proposed interface circuit is shown in figure 1. Illustrated circuit is 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. For evaluating the proposed method, two cases (table 1) were considered and results were given in table 3, and table 4. Output voltage values were noted using multi-meter (DMM) or voltmeter before connecting to DAQ.

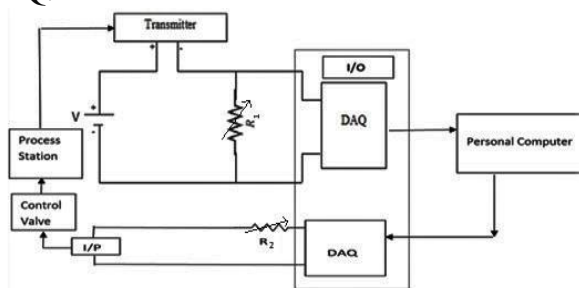


Figure 1. Interfacing of sensor and actuating element

Table 1. Values of operating parameters

Parameters	Case 1	Case 2
X_{ai}	1.28 V	1.28 V
X_{an}	5.41 V	5.41 V
X_{diff}	4.13 V	4.13 V
n	9	8
X_{div}	0.458889	0.51625
Output signal range	(1-9) V	(1-8) V

In figure 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. For the effective controller design, a researcher needs to map the input and output signal range. For this, the simple method was proposed and mapping formulas given in table 2.

Table 2. 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	$X_{a2}=(X_{a1})+ X_{div}$	$X_{b2}=(X_{a2})-(X_{a1})$	$X_{c2}=((X_{c1})+(X_{an}-X_{ai})/n)$	$X_{d2}=(X_{c2})/(X_{c1})$
⋮	⋮	⋮	⋮	⋮
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 , X_b , X_c , and X_d are accordingly first, second, third and fourth step values with respect to iteration i (1, 2, 3, ... n) it varies; n is the number of division we need to make for effective process, value decide based $R2$ value; X_{a1} is initial value, ($i=1$); X_{an} is final value, ($i=n$); X_{div} is X_{diff} divided by number of division n , ($X_{div}= X_{diff}/n$); X_{diff} is difference between initial and final values.

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 ($R1$) 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. 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 1. After obtaining the input and output signal range values, the user was framed four step formula in the LabVIEW and respective values were given in table 3, and table 4.

Table 3. Mapped values for case 1

Iteration n (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	0,46	1
2	1,74	0,46	0,92	2
3	2,20	0,92	1,38	3
4	2,66	1,38	1,84	4
5	3,12	1,84	2,29	5
6	3,57	2,29	2,75	6
7	4,03	2,75	3,21	7
8	4,49	3,21	3,67	8
9	4,95	3,67	4,13	9
10	5,41	4,13		

Table 4. Mapped values for case 2

Iteration n (i)	Step 1	Step 2	Step 3	Step 4
	$X_{a(i)}$	$X_{b(i)}$	$X_{c(i)}$	$X_{d(i)}$
1	1,28	0,00	0,52	1
2	1,80	0,52	1,03	2
3	2,31	1,03	1,55	3
4	2,83	1,55	2,07	4
5	3,35	2,07	2,58	5
6	3,86	2,58	3,10	6
7	4,38	3,10	3,61	7
8	4,89	3,61	4,13	8
9	5,41	4,13		

From the above cases 1 to 2, 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.

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.

REFERENCES

- [1]. Ming-Tzu Ho and Chia-Yi Lin, "PID controller design for robust performance," in *IEEE Transactions on Automatic Control*, vol. 48, no. 8, pp. 1404-1409, Aug. 2003, doi: 10.1109/TAC.2003.815028.
- [2]. H. E. Musch and M. Steiner, "Robust PID control for an industrial distillation column," in *IEEE Control Systems Magazine*, vol. 15, no. 4, pp. 46-55, Aug. 1995, doi: 10.1109/37.408461.
- [3]. W. K. Ho, O. P. Gan, E. B. Tay and E. L. Ang, "Performance and gain and phase margins of well-known PID tuning formulas," in *IEEE Transactions on Control Systems Technology*, vol. 4, no. 4, pp. 473-477, July 1996, doi: 10.1109/87.508897.
- [4]. Giriraj Kumar, S.M., Sivasankar, R., Radhakrishnan, T.K., Dharmalingam, V., Anantharaman, N. (2008). Particle swarm optimization technique based design of Pi controller for a real-time non-linear process. *Instrumentation Science & Technology*, 36(5): 525-542. <https://doi.org/10.1080/10739140802234980>.
- [5]. Jain, R., Sivakumaran, N., Radhakrishnan, T.K. (2011). Design of self tuning fuzzy controllers for nonlinear systems. *Expert Systems with Applications*, 38(4): 4466-4476. <https://doi.org/10.1016/j.eswa.2010.09.118>
- [6]. João Cavalcanti Santos , Maira Martins da Silva (2021), Redundancy Resolution of Kinematically Redundant Parallel Manipulators Via Differential Dynamic Programing, *Journal of Mechanisms and Robotics*, <https://doi.org/10.1115/1.405093.1>
- [7]. Elias Brassitos , Nader Jalili (2017), Design and Development of a Compact High-Torque Robotic Actuator for Space Mechanisms, *Journal of Mechanisms and Robotics*, J. Mechanisms Robotics. Dec 2017, 9(6): 061002 (11 pages), <https://doi.org/10.1115/1.4037567>