

Design and Implementation of Two Tank Level Control System

Dr Manoj Kumar Mittal

Associate Professor, Shri Ram College, Muzaffar Nagar

Abstract

This paper designs the electrically based solenoid control valve to controls the level, based on the error voltage from the MATLAB (Matrix Laboratory) control algorithm. Various control algorithms are derived for two tank system. Those algorithms are derived only on simulation data. Most of algorithms are coded using microcontroller. This proposed system is a live model of two tank level system controlled through MATLAB m-code. It consists of components such as level sensor, Digital-to-Analog Converter (DAC) Data acquisition module and solenoid control valve. The sensor used for level measurement is ultrasonic level sensor, to give level feedback of a system. The DAC module converts the digital output from the MATLAB into analog voltage to drive the solenoid control valve. The entire system is interfaced with MATLAB and suitable driver serial (RS-232) and parallel (LPT-1) lively connected. The system is applicable in many process industries such a Chemical industries, Fertilizer industries, Petroleum refineries, Pharmaceutical industries and Power plants.

Keywords: solenoid valve, microcontroller, level control and sensor, control valve design, single tank system, interacting tank system

I. INTRODUCTION

The Two tank interacting system shows sluggish response compared to non-interacting system [1]. The liquid level is sensed by the ultrasonic sensor and the data are compared with the MATLAB (Matrix Laboratory). The data are then taken as feedback and compared with data stored in the MATLAB tool to give error voltage. The output of the MATLAB is digital and need to convert in to analog in order to drive Solenoid Valve.

Project Implementation

The Block diagram of PC based level control using MATLAB software is shown in Figure 1. The power amplifier and DAC converts digital signal into analog signal with amplification. The implementation of the project comprises of three sections, viz. Ultra Sonic Sensor, Data Acquisition from Matlab, Electrically Controlled Valve.

ULTRA SONIC SENSOR

The transducer (Sensor) measures the length of time from the transmission to reception of the ultrasonic signal (pulse), reflected from an object that was transmitted from the sensor, thereby it calculates the distance and level between the sensor and the object its distance or level to be measured.

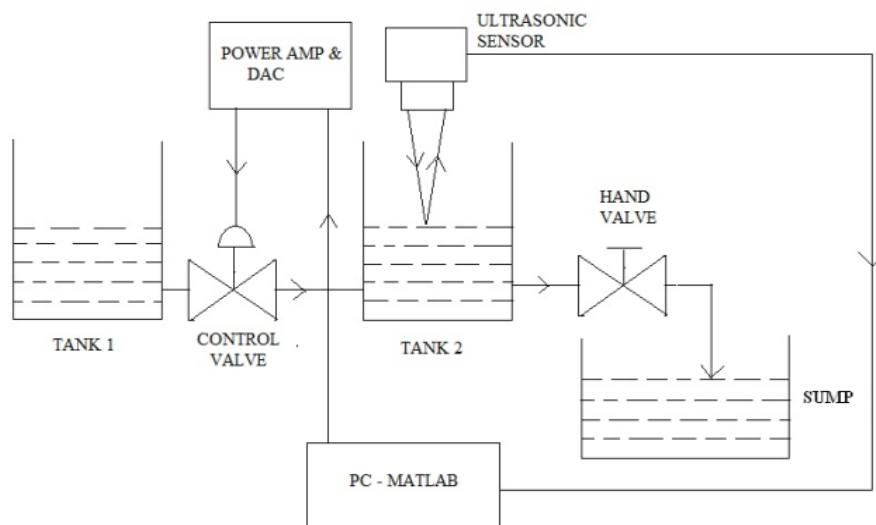


Fig. 1: Block Diagram of PC Based Level Control using MATLAB Software.

The schematic of liquid level measurement is shown in Figure 2. The level measurement is calculated based on the time taken by the ultrasonic signal transmission and reception.

- Distance [m] = {Pulse Delay Time x the Velocity of Sound}/2
- The velocity of Sound in Air [m/sec] = 331.5 + 0.6 x Temperature

Ultrasonic sensors (also known as transceivers when they both send and receive) work on a principle similar to radar or sonar which evaluate attributes of a target by interpreting the echoes from radio or sound waves, respectively.

Ultrasonic sensors generate high frequency sound waves and evaluate the echo which is received back by the sensor. Sensors calculate the time interval between sending the signal and receiving the echo to determine the distance to an object.

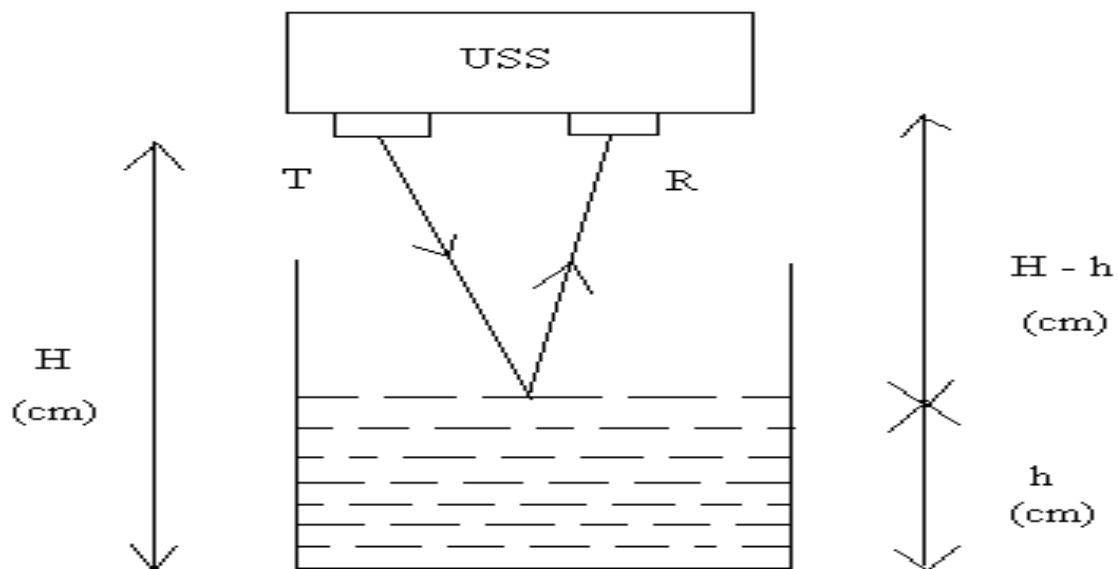


Fig. 2: UV Based Level Measurement.

DATA ACQUISITION FROM MATLAB

From the control valve o/p tabulation we can set the control valve voltage which gives a proportional response. Here, we got from 6 volts to the maximum of 12 to 14 volts.

Therefore, the valve operating voltage is between 6 and 14 V. The DAC input values 0 to 255 corresponds to 0 to 14 V, respectively.

$$\Rightarrow 255/15 \approx 16 \text{ and } 1V \text{ o/p} = 16$$

Count of dac i/p, the valve operating DAC i/p range is (6×16) to 255, i.e. ≈ 100 to 255 counts. Therefore, 100 to 255 counts of dac i/p correspond to proportional 0 to 100% opening of the electrically controlled solenoid valve [2]. As we know that the full scale o/p current is around 2mA, this can be converted into required voltage range. Here, we require 0 to 14V.

In electronics, the Darlington pair is a compound structure consisting of two bipolar transistors (either integrated or separated devices) connected in such a way that the current amplified by the first transistor is amplified further by the second one.

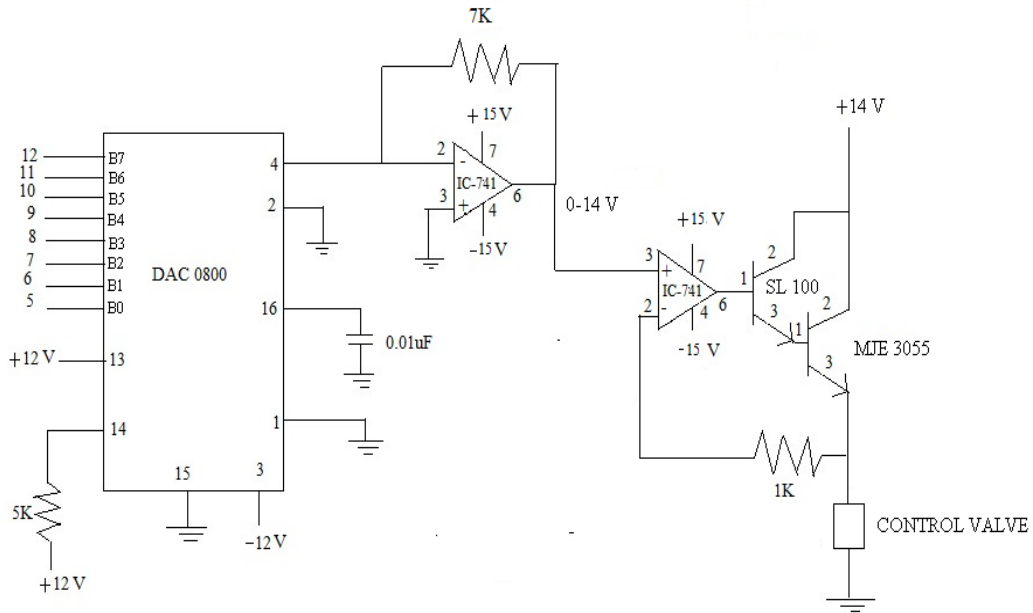


Fig. 3: DAC Circuit.

The Digital to analog converter added to Darlington pair is shown in Figure 3.

The Table 1 shows the analog output error voltage for the given digital error signal from MATLAB Integrated Darlington pairs come packaged singly in transistor-like packages or as an array of devices (usually eight) in an integrated circuit.

The Darlington pair connection can be used to acquire more current with constant required voltage.

Table 1: DAC Output.

Sl.No	DAC Input(D ₁₀)	O/P Voltage(V)
1	0	0.23
2	25	1.67
3	50	3.12
4	75	4.58
5	100	5.8
6	125	7.24
7	150	8.7
8	175	10.14
9	200	11.83
10	225	13.28
11	250	14.09

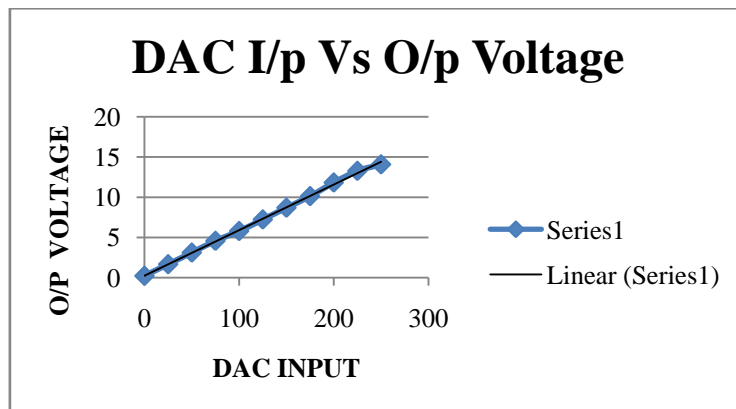


Fig 4: Graphical Representation of DAC Output.

The graph has been plotted between DAC input Vs output voltage shown in Figure 4.

ELECTRICALLY CONTROLLED VALVE

Valve Principle

The flow rate in a fluid delivery system is regulated by a control valve [3]. In general, a closed relation exists between the pressure along a pipe and the flow rate so that if pressure is changed, then the flow rate is also change. A control valve [4] changes flow rate by changing the pressure in a flow system shown in Figure 5, because it introduces a constriction in the delivery system. The flow rate through a constriction is given by,

$$Q = k\sqrt{\Delta P} \quad (1)$$

where, k is proportionality constant (m³/sec/pa),

$\Delta p = p_1 - p_2$ denotes pressure drop.

Factors for designing a flow control valve:

- Exceptional linearity
- Low power consumption
- Long life and low hysteresis
- High turn down ratio
- Zero leakage

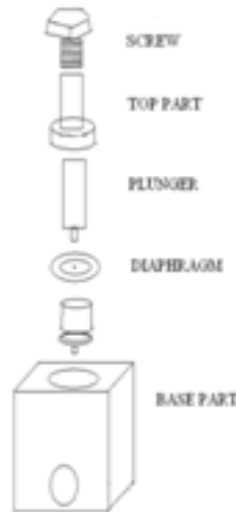


Fig. 5: Proposed Electrically Controlled Solenoid Valve.

The schematic of proposed electrically controlled solenoid valve is shown in Figure 5.

Control Valve Design Calculation

Inlet diameter (d_1) = 5 mm

$$\begin{aligned} \text{Inlet area } (a_1) &= 3.14d^2 \\ &= 3.14(5 \times 10^{-3})^2 \\ a_1 &= 1.96 \times 10^{-5} \text{ m}^2 \end{aligned}$$

Orifice diameter (d_o) = 2.5 mm

$$\begin{aligned} \text{Orifice area } (a_o) &= 3.14d_o^2 \\ &= 3.14(2.5 \times 10^{-3})^2 \\ a_o &= 4.9 \times 10^{-6} \text{ m}^2 \end{aligned}$$

$$C_d = (C_c(1 - (a_o/a_1)^2)^{0.5}) / ((1 - (a_o/a_1)^2)C_c^2)^{0.5}$$

$$C_d = C_c * C_v$$

where, C_c is the coefficient of contraction ranges from 0.61 to 0.69 we take it as 0.64; a_o is area of orifice m²; a_1 is area of inlet m²;

$$\text{Orifice diameter } (d_o) = 2.5 \text{ mm} \quad \text{Orifice area } (a_o) = 3.14d_o^2$$

$$C_d = 0.64 * C_v, \quad C_v = (C_c(1 - (a_o/a_1)^2)^{0.5}) / ((1 - (a_o/a_1)^2)C_c^2)^{0.5}$$

$$C_v = (.9375)^{0.5} / (.9744)^{0.5}$$

$$\Rightarrow C_v = 0.981$$

$$C_d = 0.64 \times 0.981 = 0.627$$

II. RESULTS AND DISCUSSION

Synthesis Results

$$C_v = 0.981 \quad C_d = 0.627$$

With all these necessary materials and calculations derived from the orifice metre design, the control valve is designed and fabricated. The values are noted for 1 cm rise for a tank of dimension 15 x 15 x 40.

The Table 2 for the electrically controlled proportional solenoid valve is given below. The graph shown in Figure 6 briefly explains the performance of the designed electrically controlled proportional solenoid valve [5] and shows that valve starts proportional response from 6 volts till 12 to 14 volts.

The process flow is controlled in MATLAB software [6] through MATLAB coding. We can use MATLAB in a wide range of applications, including signal and image processing, communications, control design, financial modelling and analysis.

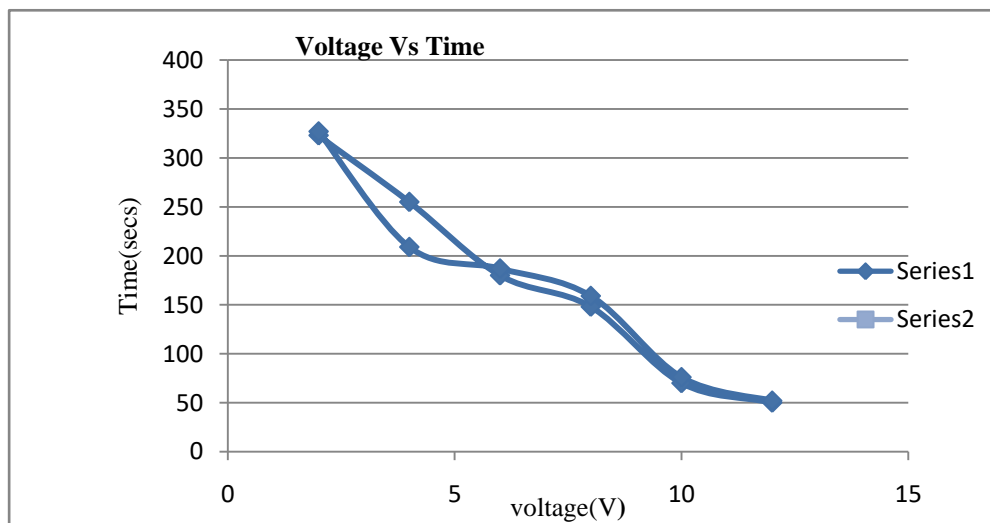


Fig. 6: Graph for the Proportional Control Valve.

Add-on toolboxes (collections of special-purpose MATLAB functions, available separately) extend the MATLAB environment to solve particular classes of problems in these application areas. The Table 2 clearly denotes the time taken for 1 cm rise in the process tank with our dimension required. MATLAB provides a number of features for documenting and sharing our work. We can integrate our MATLAB code with other languages and applications, and distribute our MATLAB algorithms and applications.

Table 2: Time vs. Controller Output Voltage.

S.No	Voltage (Controller) (V)	Time (Secs)
1	12	50
2	10	70
3	8	148
4	6	180
5	4	255
6	2	323
7	2	327
8	4	209
9	6	187
10	8	159
11	10	76
12	12	52

III. CONCLUSION

The capability of designing and implementing the Solenoid Control Value is proposed in this work. Based on above discussion it can be concluded that Designed Electrically Solenoid control value controls the level, based on the error voltage from the MATLAB control algorithm. Electrical Solenoid control value has been designed and implemented successfully with varying electrical voltage for Chemical industries, Fertilizer industries, Petroleum refineries, Pharmaceutical industries and Power plants. In future work, the control value can be enhanced to implement the level control in various heights of the tanks.

REFERENCES

- [1]. [Kubal cik, M., Bobal, V.,](#) Fault Tolerant Measurement and Monitoring of a Nonlinear Two-Tank System [Control and Automation, 2008 16th Mediterranean Conference on](#) 25–27 June 2008.
- [2]. George Stephanopoulos, *Chemical Process Control an Introduction to Theory and Practice* 1983.
- [3]. Thomas Heckenthaler, Sebastian Engell, Approximately Time-Optimal Fuzzy Control of a Two-Tank System, *IEEE Control Systems* 1994; 1: 0272–1, 708/94/\$04.000.
- [4]. VI. Utkin, *Sliding Modes in Control and Optimization*, Springer-Verlag: Berlin; 1992.
- [5]. [Mahmoud, S.M., Chrifi-Alaoui, L., Bussy, P., et al.](#) Controller Design using Second Order Sliding Mode Algorithm with an Application Coupled-Tank Liquid-Level System, [Control and Automation, ICCA 2009. IEEE International Conference on](#) 9–11 Dec. 2009.
- [6]. M.K. Khan, SK. Spurgeon, Robust MIMO Water Level Control in Interconnected Twin Tanks using Second Order Sliding Mode Control, *Control Eng Pract J.* 2006; 14: 375–86p.
- [7]. [Kubal cik, M., Bobal, V.,](#) Fault Tolerant Measurement and Monitoring of a Nonlinear Two-Tank System [Control and Automation, 2008 16th Mediterranean Conference on](#) 25–27 June 2008.
- [8]. K. BarrilJawatha Adaptive Control Technique for Two Tanks Conical Interacting System International Conference on Computing and Control Engineering (ICCCE 2012), 12 & 13 April, 2012.