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Time Response Analysis of a DC Motor Speed Control with PI and Fuzzy Logic Using LAB View Compact RIO

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Abstract - ***This paper presents the implementation of speed control of a DC motor using classical PI control and rule based Fuzzy Logic by with LABView compactRIO and comparative analysis of its time response parameters. Control of a DC motor can be implemented by different methods with either microcontrollers or discrete IC's and FPGA, but implementation with FPGA has advantage because of its parallel computation of the logic blocks increase the speed of execution and reduces time delay. In this paper, measurement of speed of a DC motor has been implemented with the photoelectric method and control has been done with the PWM method by LABView FPGA.***

Key Words: *DC motor, PID, fuzzy logic, FPGA, LABView compactRIO.*

1. INTRODUCTION

DC motors are being used as an actuators in the process control applications and also extensively used in industry for applications such as robot arm drives, machine tools, rolling mills, and aircraft control [1], [2].This paper presents the implementation of a control algorithm, mostly used in real-time control applications, a classical PI controller and a rule based Fuzzy Logic controller to control the speed of a DC motor. Design of a PID controller needs a mathematical model. However, exact modeling becomes complicated when the control algorithm is to be designed for a non-linear system. Due to the linear nature of the controller, even if a superlative control design is achieved, the efficiency of the algorithm will be reduced. In order to eliminate these concerns, the concept of non-linear Fuzzy Logic controller (FLC) is being used. The FLC's are used in processes where the exact mathematical modeling and transfer functions are not known for both linear and non-linear applications. Although an accurate understanding of the inputs and outputs is required, a precise mathematical correlation between the system characteristics is not necessary. The relationship between inputs and outputs of the system are specified by the user through a rule-based approach. This paper discuss about the comparative Time response analysis of both PI and Fuzzy Logic controller for the speed control of DC motor.

2. FUZZY LOGIC

The term "Fuzzy Logic" was introduced by Lofti A. Zadeh in the year 1965. Fuzzy Logic is a many valued logic relative to binary logic. Binary logic mainly deals with only two values i.e. 0's and 1's whereas the Fuzzy Logic is concerned about the intermediate values also i.e. between 0's and 1's. Fuzzy Logic is a rule based algorithm is used where the exact mathematical model of the system is not known. It converts the rules which are in the form of human languages into mathematical equivalents. The beauty of the Fuzzy Logic is that it mimics human thinking, and adds a common sense element to the control strategy [9]. Figure 1 shows a generalized Fuzzy Logic controller consists of 1. Fuzzification module (Fuzzifier) 2. Rule base and Inference engine (Database) 3. Defuzzification module (Defuzzifier)

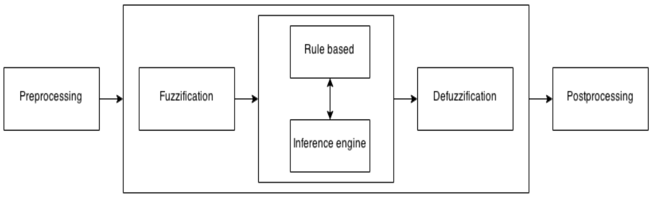


Fig -1: Block diagram of a Fuzzy controller

Fuzzification is the process of assigning suitable linguistic variables for the crisp input data, consists of membership functions that are obtained from the inputs and outputs of the system. The knowledge-base consists of a collection of rules that describe the control strategy. These rules are evaluated by an inference mechanism.[4] The rules commonly used are the IF- THEN rules. The defuzzification is the process of aggregation of the linguistic information as well as an inference process to convert output linguistic variables to crisp output by various methods such as center of area, max of means etc. Two popular models available to develop fuzzy control are 1. Mamdani model 2. Takaki-Suguno model[5].

3. THE DC MOTOR MODEL

An electric motor converts electric energy to mechanical energy by using interacting magnetic fields. The generalized equations governing the dynamic behavior of the DC motor based on the schematic diagram on Fig 2 are given by the following equations[3].

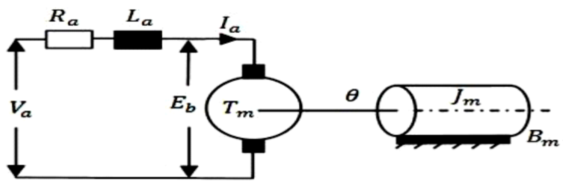


Fig -2: The schematic diagram of a DC motor

$$V_a = R_a . i_a(t) + L_a . \frac{d\,i_a(t)}{dt} + e_b(t) \quad \text{---- (1)}$$

$$e_{b(t)} = K_b . w(t) \quad \text{---- (2)}$$

$$T_{m(t)} = K_T . i_a(t) \quad \text{---(3)}$$

$$T_m = J_m . \frac{dw(t)}{dt} + B_m . w(t) \quad \text{-- (4)}$$

$$T_m = J_m . \frac{d\theta^2(t)}{dt} + B_m . \frac{d\theta(t)}{dt} \quad \text{--(5)}$$

a

$R_a J + B L_{¿}$

¿

$J L_a S^3 + ¿$ -- (6)

$\frac{\theta(s)}{V(s)} = \frac{K_b}{¿}$

Where V_a = armature voltage (V), R_a = armature resistance (Ω), L_a = armature inductance (H), i_a = armature current (A), e_b = back emf (V), w = angular speed (rad/s), $T_m = ¿$ motor torque (Nm), θ= angular position of rotor shaft (rad), J_m = rotor inertia (kg), B_m = viscous friction coefficient (Nms/rad), K_T = torque constant (Nm/A) , K_b = back emf constant (Vs/rad).

4. HARDWARE DESIGN DETAILS

The Fig 3 shows the block diagram of the speed control of a DC motor. The DC motor is attached with a disc consists of 8 Teethes. The speed of the DC motor is measured with the Opto coupler which contains of a photo diode and a photo transistor is placed between the teeth. When the rotor of the DC motor is made to rotate in between the photo diode and transistor, the light is obstructed by the teeth of the rotor which produces a pulse. 8 pulses are obtained for every revolution which is measured with the LABView compactRIO and control is done by the PWM Technique.

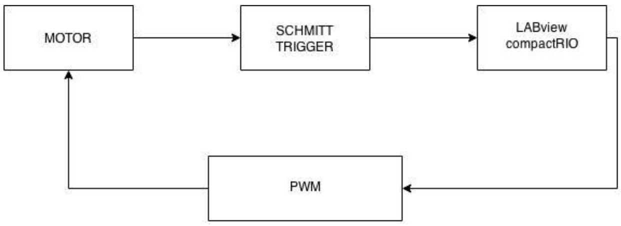


Fig -3: Block diagram of a DC motor speed control

An Opto coupler MOC3011 has been used to measure the speed which gives the output voltage of 0.2V when the tooth is present and 4.7V in the absence of the teeth. The LABView compactRIO can measure pulses only in the range of 6V-24V; hence the output of the Opto coupler is given to the Schmitt trigger designed by LM358 to shift the voltage levels from 4.8V when the teeth is present and 10V when the teeth is absence. This output is interfaced to CompactRIO Digital input (DI0).The TIP122 darlingtonpair transistor has been used to control the motor using PWM. The Fig 4 shows the detailed circuit diagram of the developed system.

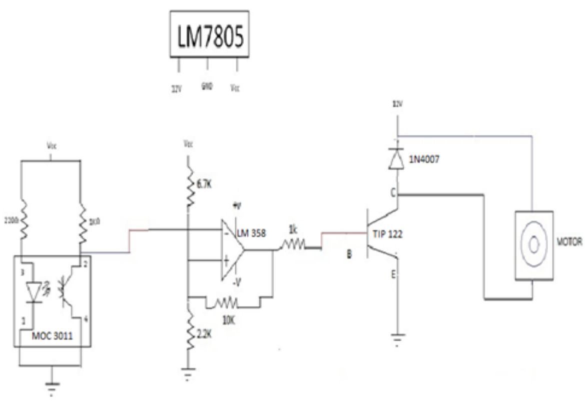


Fig -4: circuit diagram

5. IMPLEMENTATION OF FUZZY LOGIC CONTROL ALGORITHM ON COMPACTRIO

The National Instruments CompactRIO is a real time embedded controller combines an open embedded architecture with small size, and hot swappable industrial I/O modules. CompactRIO is a rugged, reconfigurable embedded system containing three components a real time controller, a reconfigurable field programmable gate array (FPGA) and industrial I/O modules to make control applications easier to design. LABView software has built-in tools to implement a PID and Fuzzy Logic algorithms. Implementation of any control algorithm using LABView CompactRIO requires two VI programs 1.Host VI 2.FPGA VI.

The Block diagram and Front panel FPGA VI of the Fuzzy Logic control of DC motor is shown in the Figure 5 and Figure 6. Measurement of speed is done with the Digital Input (DI0) of CompactRIO for every 1sec and PWM signal is generated from the Digital Output (DO1). The Block diagram and Front panel Host VI is shown in the Figure 7 and Figure 8 reads the speed after every second in rpm and error is calculated by comparing its value with the set point. The Fuzzy Controller generates the PWM ticks corresponding to the error. The Host VI transfers this PWM ticks to the FPGA VI that controls the speed of the DC motor.

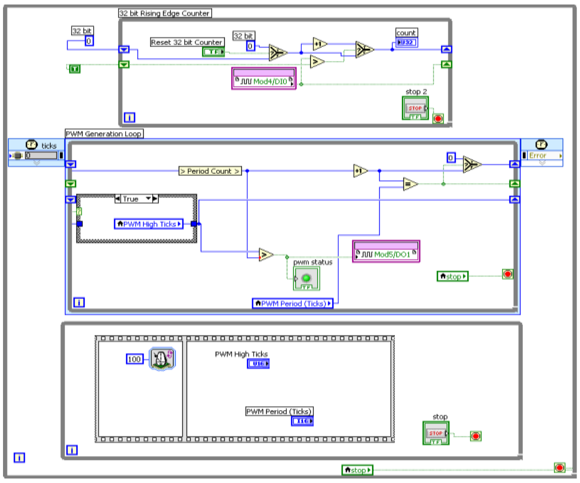


Fig -5: Block Diagram of FPGA VI of Fuzzy Logic Controller

16000 clock ticks are required to generate a 10 KHz PWM frequency from CompactRIO which has an on board clock of 40 MHz.

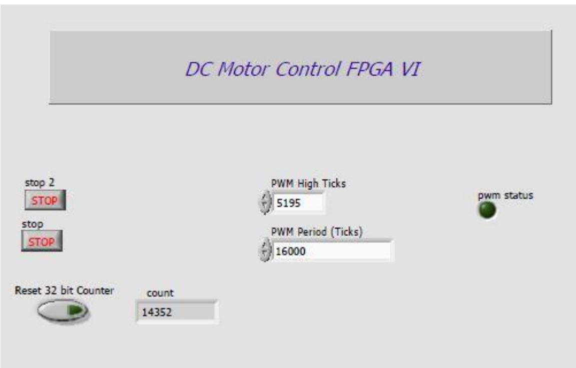


Fig- 6 Front Panel of FPGA VI of Fuzzy Logic Controller

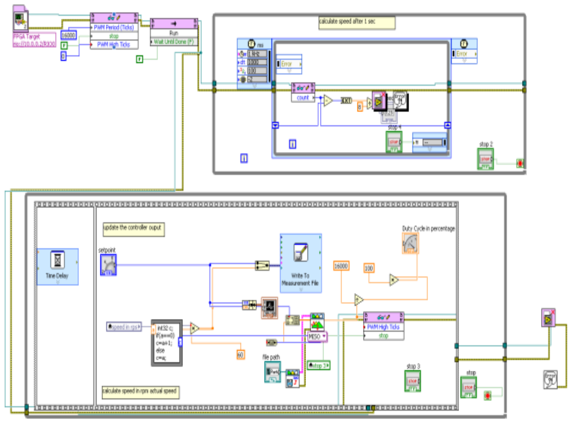


Fig-7 Block Diagram of Host VI of Fuzzy Logic Controller

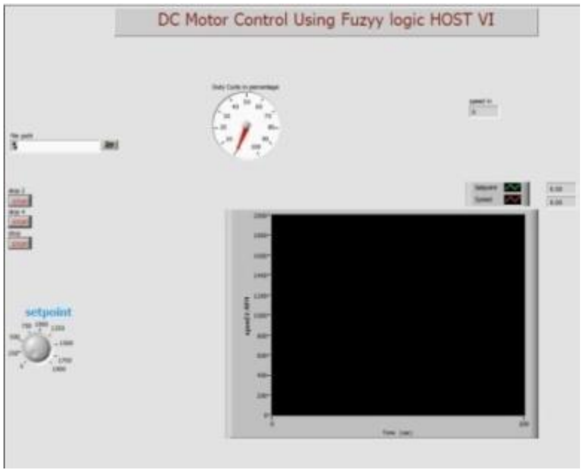
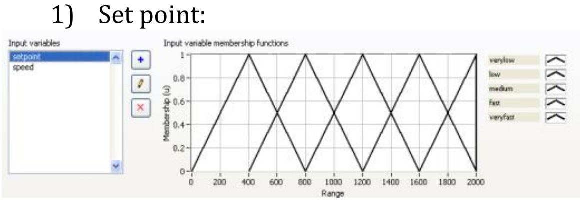


Fig- 8 Front Panel of HOST VI of Fuzzy Logic Controller

The PWM frequency of 10 KHz has been selected based on the trial and error. The Figure 9 shows the Fuzzy Logic implemented in the LABView Fuzzy tool box. The membership functions in the Fuzzy Logic have selected based on the calibration data. obtained from the experiment. The data obtained experimentally varies linearly with the PWM duty cycle vs. speed of the motor. 25 rules were prepared from the input membership functions.

Input Membership Functions

1) Set point:



2) Speed:

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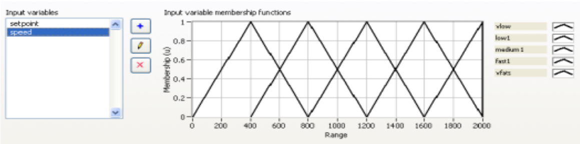
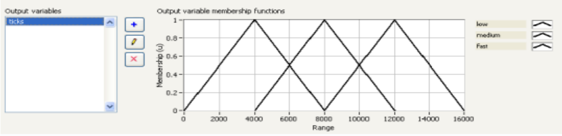


Output Membership function:

1) PWM Ticks:



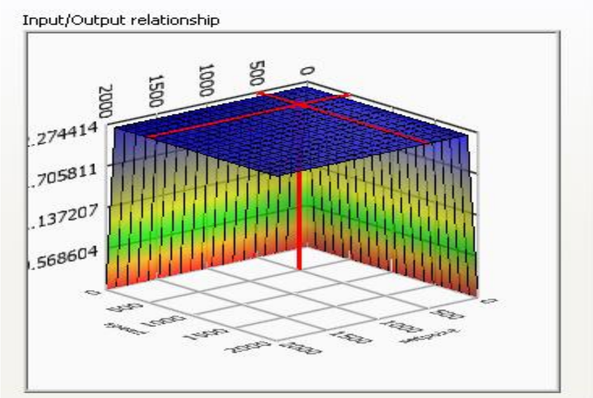


Fig-9 Fuzzy Logic in LABView

6. IMPLEMENTATION OF PI CONTROLLER ON COMPACTRIO

The Fig numbers 10, 11, 12, and 13 shows the Block diagram and Front panel controls of FPGA VI and Host VI of PI controller of the DC motor.

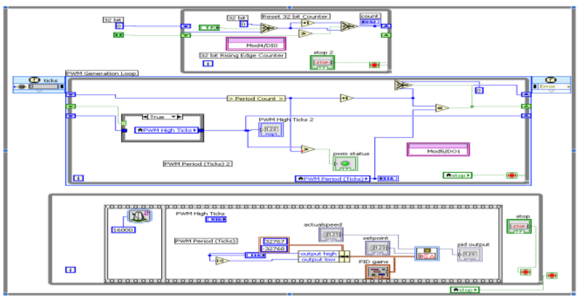


Fig10 Block diagram of FPGA VI of PI Controller

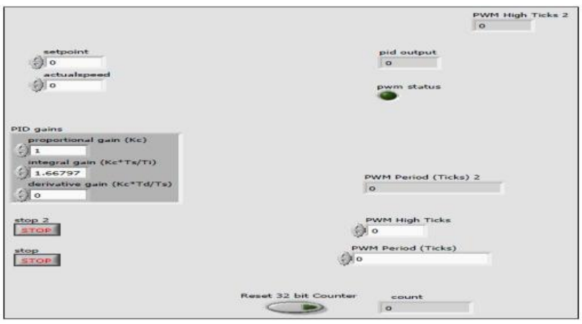


Fig- 11 Front Panel of FPGA VI of PI Controller

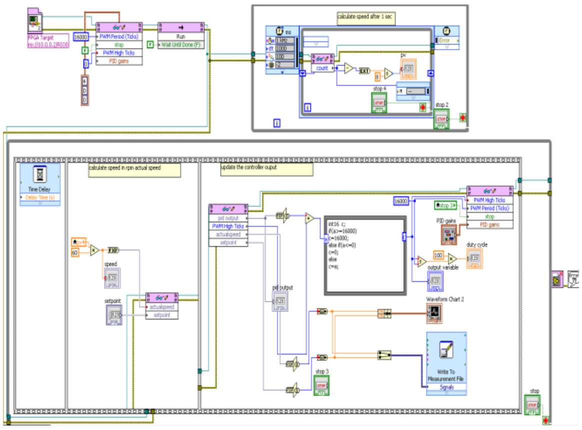


Fig-12 Block diagram of Host VI of PI Controller

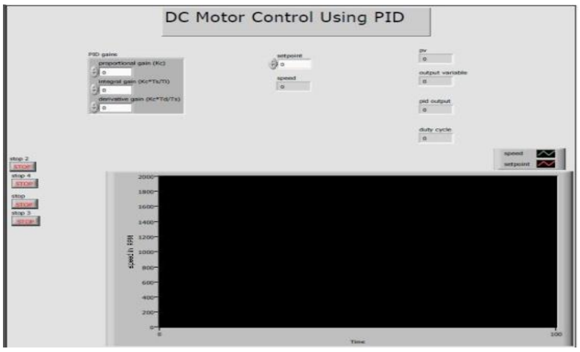


Fig- 13 Block diagram of FPGA VI of PI Controller

The only difference between Fuzzy Logic controller and PI controller is that a FPGA PID is available in the compact RIO has been used to generate the PWM signal corresponding to the error. The gain constant of proportional K_p is 4 and KI is 0.05 Sec is obtained by tuning. The Figure 14 shows the Experimental setup.

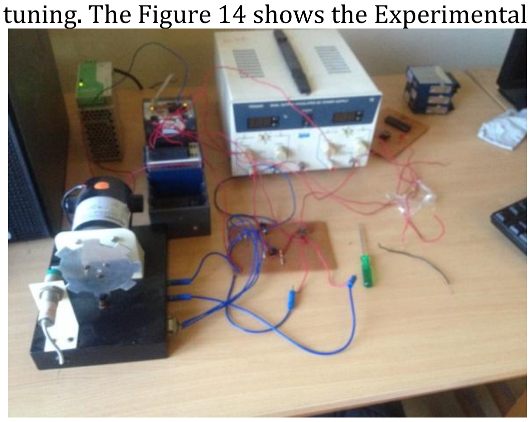


Fig-14 Experimental setup

7. RESULTS AND CONCLUSIONS

The results of the Time response parameters of DC motor speed control are calculated using LABView Control system tool box are depicted in Table1. The results shows that speed control of the DC motor using PI controller takes more rising time and oscillations for a step input, where as Fuzzy Logic control provides the smooth control. Figures 15, 16 show the response of fuzzy and PI control.

	PI Controller	Fuzzy Logic
Overshoot	28%	1%
Rise Time	1.785 Sec	1.1 Sec
Settling Time	9.45 Sec	3.6 Sec

Table 1

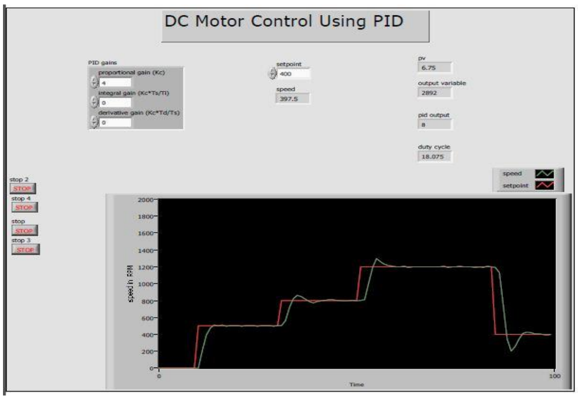


Fig-15 PI Response for Step Input

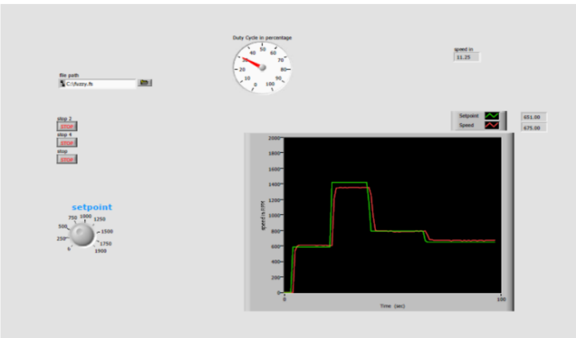


Fig- 16 Fuzzy Logic Response for Step Input

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