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Experimental Investigation on Microcontroller based Elevator Positioning Control System Using Fuzzy-Logic

Rajesh Kumar Patjoshi, Rakhee Panigrahi

Abstract*: This paper represents an implementation for microcontroller based elevator positioning-control method (PCM) on a microcontroller (MC) family of HCS-12 (MC9s12dp256b) employing fuzzy logic. This proposed approach is comprised of MC unit, DC-motor driver unit, display component and key segment. Mamdani based Fuzzy logic control (FLC) algorithm is incorporated with MC, which controls the direction and speed of DC-motor by injecting appropriate pulse width modulation (PWM) signal to its driver circuit of DC-motor. An upward or downward movement of the elevator can be achieved through the signal generated by the FLC unit, which is incorporated with MC unit. Moreover, the display modules are utilized for spotting the elevator- car in a specific floor and also for closing and opening the elevator door. The proposed control algorithm has been validated with a small prototype experimental setup developed in our laboratory and the performance of the prototype is verified through different traffic flow environments.

Index Terms*: Positioning control system (PCS), HCS-12, Fuzzy logic, Pulse width modulation (PWM).

I. INTRODUCTION

The basic purpose of an elevator group control arrangement is to select the appropriate car to be dispatched with a reaction to a recorded hall-call and at the same time confirming that all cars in the elevator group function collectively with reference to whole group's call. Therefore, the job is not at ease, as the evidence regarding dispatching outcome is inadequate. Correspondingly, passenger's comings and targets are dynamic in nature, which leads to a complicated environment. Furthermore, the elevator control systems have been applied upon promising technologies such as artificial intelligence (AI) and computational intelligence (CI). Also, MC based FLC for elevator group control has been found to be more appropriate in control engineering study and design, as it deals with a compromise between AI and CI. Many researchers have reported about MC based elevator control system [1, 2]. They described the elevator control system built on AT89s52 MC. However, these modules are consisted of only DC motor, display module, key module and infrared detection module. In addition, this model is used for research and development of low level elevator control system

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An FPGA based elevator control system has been developed, in which a point to point wiring system is replaced with different control card for smooth running of elevator system [3, 4]. This approach does not provide any benefit to the passenger; however the cost of wiring system is reduced.

In the present investigation, we consider a HCS-12 (MC9S12DP256B) [5] MC based four floor elevator positioning control system. In this approach, two switches are applied in each floor, one switch for progressing the elevator car in ascending path and other switch for descending path. Moreover, each floor employs two sensors, one sensor for giving pause to the elevator car and another sensor for both opening and closing of the elevator door. This approach is implemented with FLC [6, 7, 8] for imparting intelligence to the elevator car in dissimilar traffic conditions for efficient functioning of elevator. However, the speed and path of the DC motor are regulated by MCS through injection of appropriate PWM signals to the H-bridge drive system. As a consequence, the proposed approach reduces the design development cycle and hardware cost, resulting towards an improvement in the control operation.

II. ELEVATOR POSITIONING CONTROL SYSTEM

The major construction of the elevator positioning control model is presented in Fig.1. The elevator system consists of MCS unit, DC-motor driver unit, infrared recognition unit, display unit and also key interfacing unit. These key modules are directly interfaced with input port of MCS unit, which provides a running path to the elevator.
Similarly, the real time running data of the elevator is identified through infrared recognition sensors, which provides a feedback signal to the MCS unit. Therefore, the display unit can exhibit the proper location of elevator. Furthermore, the speed and path of the DC motor are regulated by fuzzy logic control algorithm, which is incorporated in MCS unit. Based upon suitable control signal, MCS unit can generate appropriate gate pulse signals to the H-bridge drive circuits

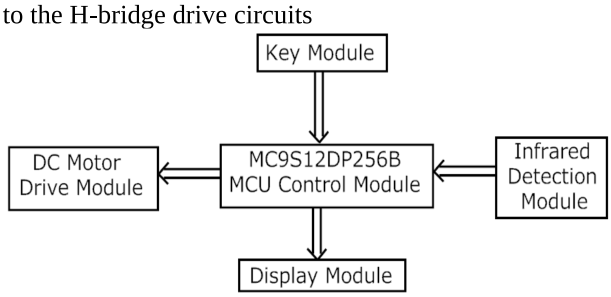

Fig.1. Elevator system model structure

III. SYSTEM HARDWARE DESIGN

A. DC-motor drive module design

DC-motor driver structure is revealed through Fig.2. The switching pulses applied as input to the DC-motor driver unit are associated with the output port of PWM channel of MC and other two ports of DC-motor driver unit are associated with the MCS output port, which gives rise to rotation of the DC-motor rotating either forward or reverse direction. The rotating speed of DC-motor is direct-proportionate with the frequency of PWM pulse.

In the driver circuit, gate of transistors Q1 and Q3 as well as Q2 and Q4 are connected together. As a result, their conduction time will depend upon polarity of input voltage. To regulate the speed of DC-motor, PWM signal is applied to input of AND gate 3, which is further connected to the transistor Q8 for driving the NMOS transistor Q7. However, the driver circuit is designed in such a way that, the gate pulse signals are only be directed upon the N-Channel MOSFET (i.e transistor Q7) as the NMOS transistor is associated with smaller gate capacitance. Therefore, in CMOS circuit, NMOS delivers high speed operation. Consecutively, it is quite effective to consider one transistor in active mode, while changing over other transistor through PWM signal.

Conversely, a fixed steady high input is applied to AND GATE 3 to operate the DC-motor in considerable speed. Additionally, a super-fast speed based AND gate such as 74F08 is desired to accomplish all the aforesaid operation. Thus, the speed control of DC-motor can be realized through fixing gate of Q1 with gate of Q3 and gate of Q2 with gate of Q4 straightly. Based upon the input signals applied to input A and B of AND GATE 1 and 2, the motor either rotates in forward or reverse direction. If both the inputs are high-level or low-level simultaneously, then the motor will brake. Therefore, the input port B is connected to A through an inverter to avoid the active braking in the circuit. As a result, input B is always opposite to input A. Hence, signal needs to be applied only at port A for direction control and the PWM signal is applied at PWM port for speed control. It is better to ramp the speed of motor since instantaneous change of speed causes a lot of back EMFs and noises. However, ramp is utilized for slowly increasing the speed of motor by gradually varying the duty-cycle of the PWM signal.

B. Switch interfacing module

Fig.3. displays the interfacing block for the HCS12 (MC9S12DP256B) MC and key module. The algorithms utilized for interfacing of key are as below:

1. AD-port receives an 8 bit arrangement through DIP switches.
2. HCS-12 reads the amount from AD-port and stores it inside memory.
3. HCS-12 performs a pair bit twiddling processes on the reading amount.
4. Results from bit twiddling shall be directed to T-port.
5. T-port shall forward the amount to the DC-motor driver circuit.

Based on the programming guidelines, program port T is registered as output port and PORT AD as input port. Therefore, all the switches are connected to PORT AD and the corresponding signal is appeared in AD port. These ports are directly linked with analog-digital (A/D) converter for further processing. Additionally, register DDRT is an 8-bit data register for T-port and every bit of this register is defined as data direction line. This means that if a particular bit is configured as one then the port behaves like an output-port and if the bit is configured as zero then the port acts like an input-port.

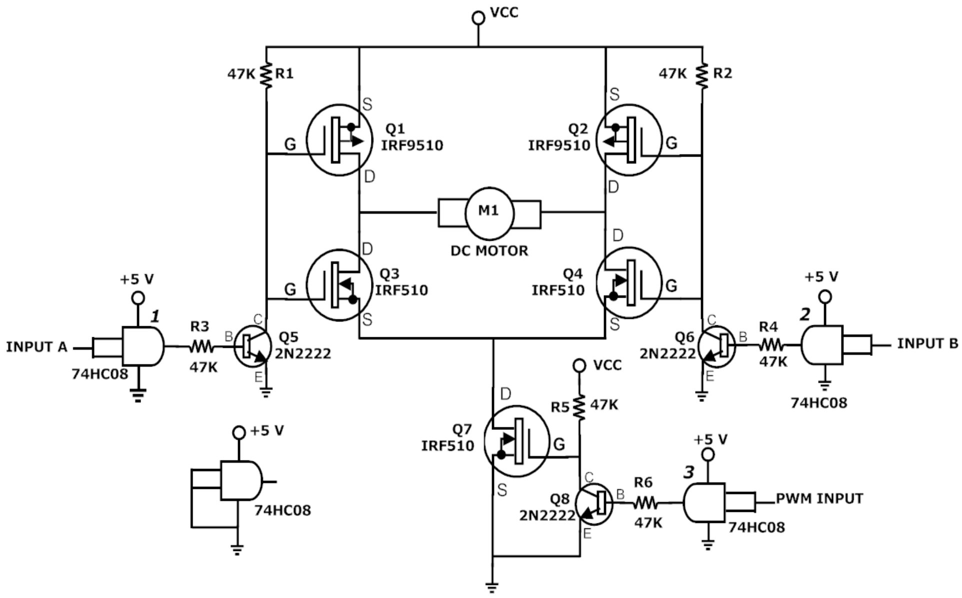

Fig.2. DC-motor driver circuit

Thus, we want to organize T-port as 8-bit output-port by assigning 1s to whole bits of DDRT. Correspondingly, port T data register PTT is 8 bit transmit register, which is utilized for sending the data to DC-motor driver circuit.

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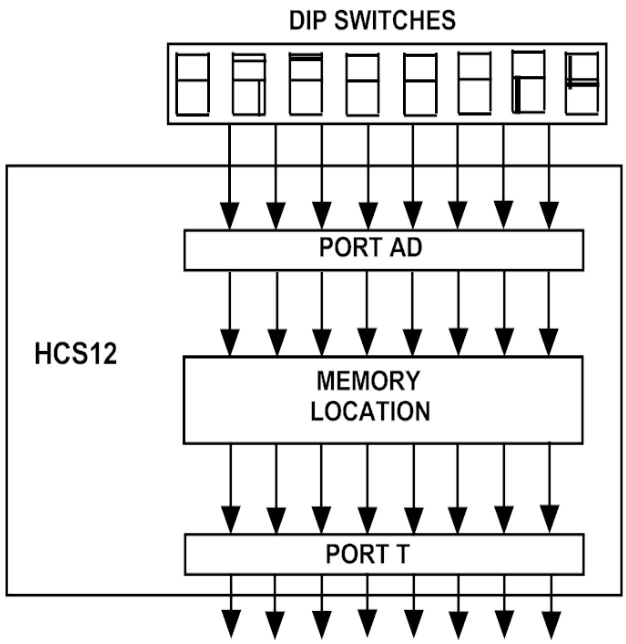


Fig.3. General interfacing block diagram of the key module and HCS12.

C. Infrared detection module design

Fig.4 shows the GP2d120xf77 IR sensor, which is a general purpose IR sensor. IR signal is used to calculate object space from 10-80 cm with analog output. Hence it needs analog-digital converter (ADC) to interface with HCS-12 MC. This sensor is used in elevator control system for identifying the elevator car in respective floor. Similarly, this sensor is also utilized for opening as well as closing the door of elevator system in the respective floor.

Fig. 4. The Infrared-Sensor (IR) GP2d120xf77

IV. CLOSING AND OPENING FOR ELEVATOR-DOOR SYSTEM

The automatic door system at office buildings and market complex are mainly utilized for convenience. Conversely, the automatic door in elevator systems is absolutely essential. Elevator systems employ two dissimilar sets of doors: one above the cars and another opening through the elevator shaft. The doors on the cars are functioned by an electric motor that is hooked up towards the elevator computer. As observed through Fig.5, the electric-motor rotates a wheel associated with a long metal arm and the metal arm is connected to another arm that is fixed to the door. Also, the door can slide backward and forward over a metal rail.

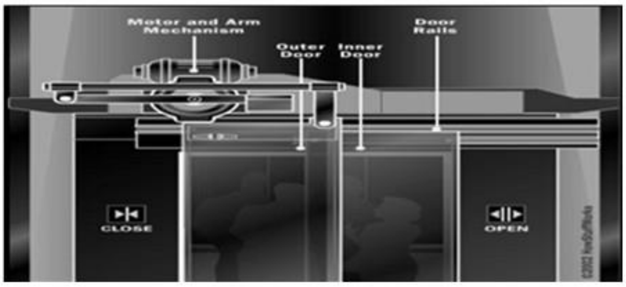


Fig. 5 Closing and opening for elevator-door system.

When the motor turns the wheel, it rotates the first metal arm and accordingly the second metal arm along with an attached door is pulled to the left. The door is made of two panels that close in on each other when the door opens and extend out when the door closes. The fuzzy based MC system can turn the motor to open the doors when the car arrives at a floor and close the doors before the car starts moving again. Fig.6 (a) displays the result for opening of the door and Fig.6 (b) shows the result for closing of the door with movement of DC-motor in both reverse and forward direction.

V. FUZZY LOGIC CONTROLLER SYSTEM FOR ELEVATOR SYSTEM

The speed control of the DC motors for elevator system is very complicated with common control methods, since it necessitates a composite mathematical model. However, Fuzzy logic [9] eradicates the necessity of mathematical modeling and permits simple completion of an elevator control system. Moreover, Fuzzy logic explains specific rules that decide the performance of the system employing word explanations instead of mathematical representation. The algorithm comprises three stages:

1. Fuzzification
2. Fuzzy-Inference
3. Defuzzification

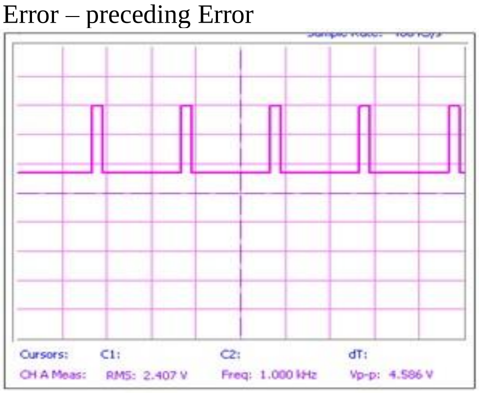
Fuzzification is the method which decides the membership degree of the input quantities towards specified fuzzy sets (linguistic variables). Thus, for the speed control of elevator system, the corresponding input quantities are:

1. Absolute error for the rotation speed:

Error = Fixed Speed – Current Speed

2. Differential rotation speed error (dError). This value is attained by deducting the preceding error quantity from the current error quantity:

dError = Error – preceding Error



(a)

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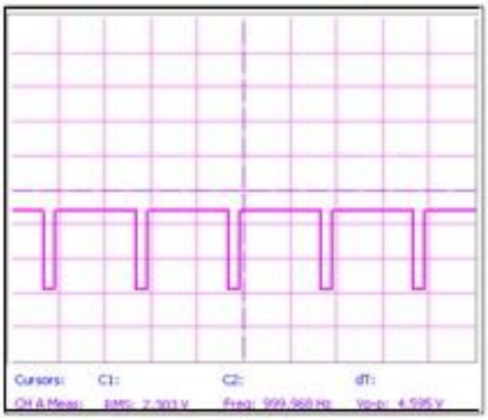

(b)

Fig. 6 Experimental result of (a) opening of elevator door system, (b) closing of elevator door system.

In this purpose five fuzzy membership functions are demarcated for the Error and dError as follows.

1. NM: negative-medium
2. NS: negative-small
3. ZE: zero-equal
4. PS: positive-small
5. PM: positive-medium

The membership function of a fuzzy-logic is a summary of the indicator job in classical sets. It implies the degree of truth as an addition of estimated values. Fuzzy logic [10] uses different types of membership functions [11], out of which triangular membership function is popular and easy to implement. Hence, we consider triangular-shaped membership function, which is revealed in Fig.7. Based on the observable data, y-axis is scaled up to 400h and x-axis is scaled from –C00h to C00h.

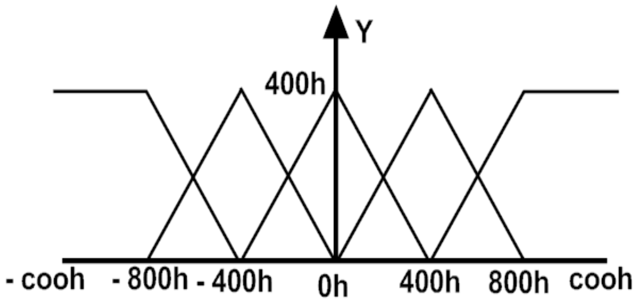

Fig.7. Input membership-function

The outcome of the fuzzification of an input quantity is a vector comprising five components, because there are five fuzzy sets and the value of every member describes the membership degree of the input quantity to a specific fuzzy set of y-axis. The vectors used for the absolute and differential errors are signified as X1 and X2. Fuzzy Inference system considers Mamdani min-max [12] relationships and it infers fuzzy quantity from the fuzzification unit as shown in Table 1. The result of the defuzzification has to provide a numeric value, which decides the duty cycle of the PWM signal utilized to operate the DC motor of elevator system. The defuzzification is obtained by finding the centroid point of the function by multiplying the output membership function and output vector Y. Equation 1 provides the information regarding general mathematical formulation, which is employed to attain the centroid point. Moreover, Fig.8 shows the coefficients [-10h, -8h, 0h, 8h, 10h] for output membership function.

Table 1. Fuzzy Inference Rule Table

Error(X1) / dError(X2)	NM	NS	ZE	PS	PM
NM	PM	PM	PM	PS	ZE
NS	PM	PM	PS	ZE	NS
ZE	PM	PS	ZE	NS	NM
PS	PS	ZE	NS	NM	NM
PM	ZE	NS	NM	NM	NM

$$\mathrm{Defz} = \frac{\sum_{i=1}^{5} Y(i)Xml}{\sum_{i=1}^{5} Y(i)} \qquad (1)$$

The differential and absolute control error dError and Error are considered for desired speed (variable set speed), existing speed (variable existing speed) and the preceding error quantity (variable last-error). These error quantities are then converted to fuzzy-vectors X1 and X2 employing function fuzzification. Afterward, the fuzzy inference instructions are concerned and the fuzzy output vector Y is produced through fuzzy inference function. This output vector is converted back into a solitary control loop output through Defuzzification and it is further included for current PWM duty cycle.

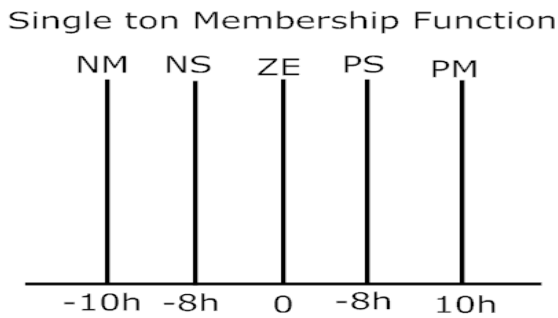

Fig.8. output membership function

VI. EXPERIMENTAL RESULT AND ANALYSIS

Fig.9 shows the experimental setup of elevator control scheme. This arrangement contains dissimilar units such as DC-motor driver unit, key segment, Infrared unit, display component and opening and closing of elevator door system. The major control unit is MC9S12DP256B. The elevator's running pathway is dependent on keys pressed and its running location is sensed through the infrared sensors. MC regulates the speed and direction of the elevator system by injecting PWM signals to DC motor drive circuit. Alternatively, the display module displays the running status of the elevator and depending upon the switch pushed in a particular floor, the elevator is moved either in upward or downward direction.

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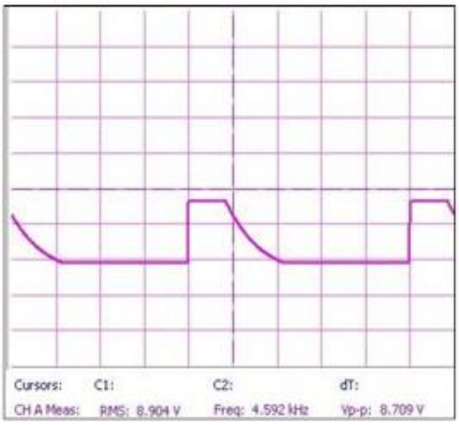
Two infrared sensors are engaged, one sensor for identifying the elevator car in a specific floor and another sensor for opening and closing the elevator door. Fig.10 displays the result for up and down movement of elevator car.

The result is also analyzed for speed control of the elevator system in different traffic conditions. Speed of the elevator system is maintained to be constant by changing the duty cycle of the PWM signal and also, this variation of duty cycle is injecting upon the driver circuit of DC motor. The variation of traffic condition is suddenly detected by fuzzy controller and accordingly, the duty cycle of PWM signal is varied. For investigating the traffic flow condition in different situations, we have considered different load conditions. Fig.11 shows the different load conditions and its corresponding duty cycle variation of PWM signal is shown in Fig.12. Table 2 displays the comparative outcome of speed alteration and duty cycle alteration of PWM signal through dissimilar load conditions.

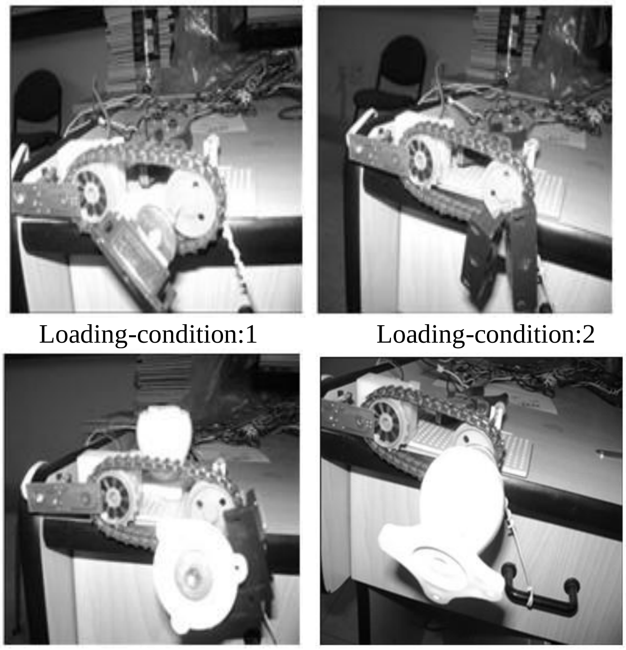
Fig.9. Experimental setup of elevator control system

(a)



(b)

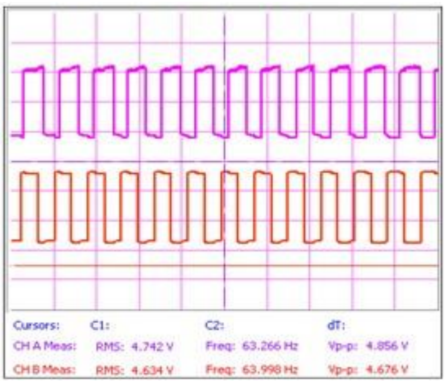
Fig.10. Experimental result for upward and downward directional flow, (a) upward direction, (b) downward direction.



Loading-condition:1 Loading-condition:2

Loading-condition:3 Loading-condition:4

Fig.11. Testing during dissimilar load conditions



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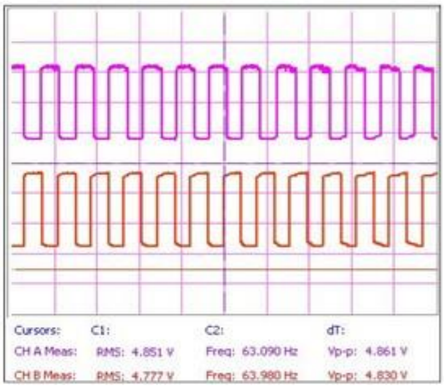

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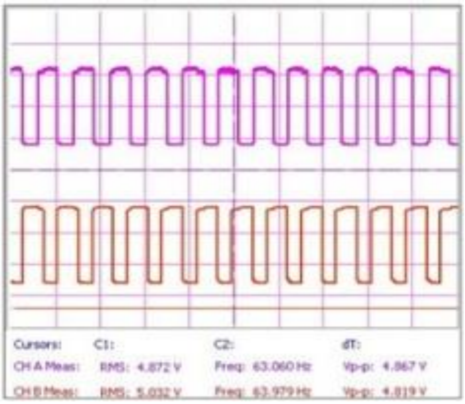

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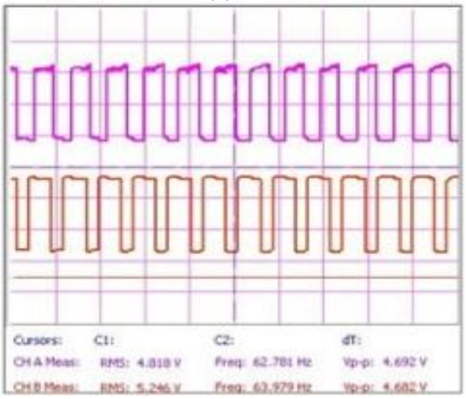

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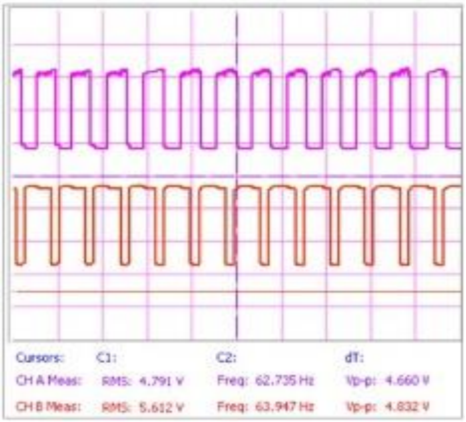

(e)

Fig.12. Duty-cycle alteration for PWM signal during, (a) No-loading condition, (b) Loading-condition:1, (c) Loading-condition: 2, (d) Loading-condition:3, (e) Loading-condition: 4.

Table 2 Comparison of speed Vs. duty cycle alteration in dissimilar loading conditions

Different load	Speed-measurement through the optical-encoder in second	PWM duty-cycle (ON time) alteration in second
With no loading state	18 ms	8 ms
Load -1	18.2 ms	10 ms
Load -2	18.4 ms	12 ms
Load -3	18.4 ms	13 ms
Load -4	18.6 ms	15 ms

VII. CONCLUSIONS

In this paper, an embedded based elevator positioning control system is designed and investigated using MC9S12DP256B with fuzzy logic based intelligent control system. The proposed technique of elevator system is designed in the laboratory with prototype experimental setup and investigated with different traffic flow conditions. To design the elevator fully comfortable, fuzzy logic controller is employed through MCS unit, which varies duty cycle of PWM signal with varying traffic conditions and maintains a steady speed of the DC-motor for efficient functioning of the elevator. Moreover, the elevator cars move either up or down depending on the key pushed and the infrared sensors are utilized for perceiving the location of the elevator cars. Correspondingly, display modules are utilized to provide real time information of elevator system. The experimental result demonstrates that our proposed elevator position control system provides excellent performance with variation of the duty cycle of PWM signal in different traffic flow conditions.

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