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Wireless Control of Prototype of PMDC Motor Using PI and Fuzzy Logic

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***Abstract*—Wireless technology is widely used to control industrial application nowadays mainly because of the safety it can offer to the workers there. The control system generally uses wireless communication to transmit commands between the control station and the controlled object or process.**

A prototype of PMDC motor which adopts a chopper based drive is used in this paper. This particular system will control the status of a PMDC motor, speed and direction of rotation (enabled by an external switch). The speed control technique is done by the PWM technique involving duty ratio control. The duty ratios can be chosen according to the user requirements, which are generated by the microcontroller, according to the required speed. The proposed design communicates with a remote control unit using Bluetooth. The logic drive is implemented using ARM7 microcontroller unit. The ARM processor houses a Bluetooth module, acting as a slave. A handheld device serves the purpose of a master. A Proportional & Integral and Fuzzy Logic Controller are made to drive the PMDC motor individually. It provides a feedback to the motor to reduce settling time. The simulation results are intended to show small ripple in rotational speed and fast response to change.

***IndexTerms*—Wireless, PMDC, PI Controller, Fuzzy Controller, MATLAB, Bluetooth, ARM 7, PWM**

A.INTRODUCTION

Microprocessor based power electronic drives have been a simulating area of research since the advent of microchip fabrication technology. It is a very practical idea as wireless technology is becoming increasingly more available. In this project, a wireless DC motor drive is proposed in order to provide a cost effective and remote control of Permanent Magnet DC (PMDC) motor for home and industrial applications.

In the proposed system, the parameters such as average value of voltage waveform and hence the speed of the motor is controlled by Microcontroller Unit (MCU). The design consists of a commanding and a control mechanism where communication between the commanding and control unit is made possible through a blue tooth module.

The idea of this project involves around both power loss reduction and wireless control. The idea of using blue tooth as the wireless medium was also a big motivation for this project as this technology is ubiquitous. A comprehensive understanding of how it works has also been done simultaneously. The space was facilitated to us by VI Microsystems, Chennai.

The PI Controller and Fuzzy Controllers used here are utilized individually instead of a hybrid controller [1].

B.OVERVIEW OF PMDC MOTOR

The PMDC motor used here uses a 24 v supply. These motors are used where high starting/acceleration torque is needed[2]. The speed control and variation in these types of motors are done by varying the armature voltage since the flux in the motor remains constant. So these motors are used in the system where the control is required only below the base speed.

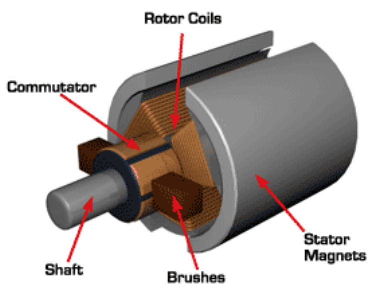


Fig 1.PMDC Motor.

The field poles of this motor are essentially made of permanent magnet. A PMDC motor mainly consists of two parts - stator and rotor. Here the stator is a steel cylinder. The magnets are mounted in the inner periphery of this cylinder. The permanent magnets are mounted in such a way that the N – pole and S – pole of each magnet are alternatively faced towards armature as shown in the figure. In addition to holding the magnets on its inner periphery, the steel cylindrical stator also serves as low reluctance return path for the magnetic flux. Generally, rare earth hard magnetic materials are used for these permanent magnets.The rotor of PMDC motor is similar to other DC motors. The rotor or armature of permanent magnet dc motor also consists of core, windings and commutator. Armature core is made of number of varnish insulated, slotted circular lamination of steel sheets. By fixing these circular steel sheets one by one, a cylindrical shaped slotted armature core is formed. The varnish insulated laminated steel sheets are used to reduce eddy current loss in armature of permanent magnet dc motor. These slots on the outer periphery of the armature core are used for housing armature conductors in them. The armature conductors are connected in a suitable manner which gives rise to armature winding. The end terminals of the winding are connected to the commutator segments placed on the motor shaft. Like other dc motors, carbon or graphite brushes are placed with spring pressure on the commutator segments to supply current to the armature.

Open loop control

In the open loop control once when the input is applied the motor, it rotates at a speed less than or greater than the rated value. Time taken for the motor to achieve set speed condition is equal to the motor actual speed, is large which increases the settling time for the motor. Hence, closed loop control is adopted where less erroneous value as well as faster settling time is achieved.

Closed loop control

Speed is controlled by varying the voltage applied to the armature. Feedback devices sense the motor speed and send this information to the controller (either PI or Fuzzy logic controller) to vary its output voltage up or down to keep speed at or near the set value. Feedback technique employed here is MOC sensor which senses the speed of motor

At the no load, the speed is maximum and at the point where the torque is maximum the motor stops rotating and it draws maximum current. This current is called stalling current.

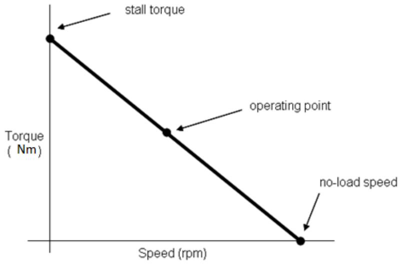


Fig 2 Speed – Torque characteristics

Applications

- Battery powered devices like wheel chairs and cordless power tools
- Conveyers
- Door openers
- Welding equipment
- X-ray and tomographic systems

C. BLOCK DIAGRAM

The block diagram consists of multi output power supply unit, the microcontroller, the driver circuit and an MOC sensor setup with a PMDC motor. The microcontroller facilitates wireless communication by an attachable Bluetooth module acting as a slave. The Bluetooth enabled motor speed commanding device acts as a Master.

Components

The Multi Output Power Supply block consists of 2 step down transformers with multiple taps, 18 V and 9V output respectively, followed by a bridge rectifier section along with capacitive filters and regulators. Voltage regulators 7805 and 7812 maintain a 5V and 12 V DC outputs respectively.

The driver circuit connecting the microcontroller output to the MOSFET has three main components – the opto coupler,

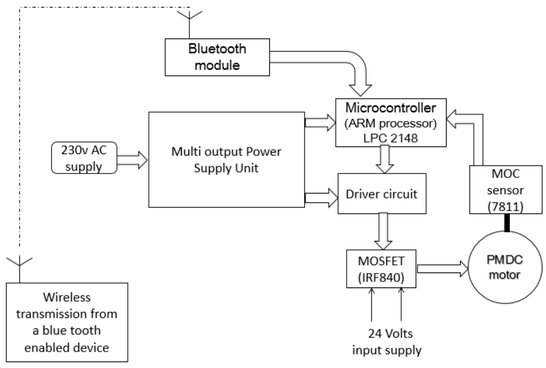


Fig 3Overall Block Diagram

the inverter and the driver IC. The opto coupler (6N137) is used to isolate the power circuit of the MOSFET and the microcontroller unit hence ensuring safety from spikes. This

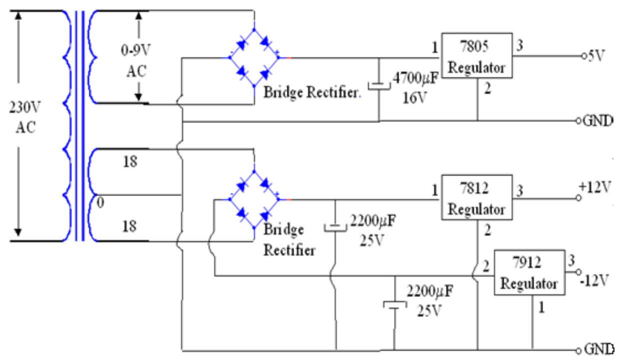


Fig 4 Power Supply Circuit

results in an inverted output, calling for an inverter. These are then driven (or amplified) by the driver IC (IR2110). All these signals travelling are pulse width modulated waves which are finally given to the MOSFET[5] switch which runs the motor.

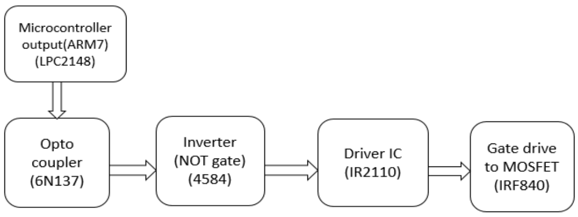


Fig 5.Driver block diagram

Pulse Width Modulation

Speed control for this motor can be easily done by the armature control method where the supply voltage is varied by a rheostat. But this leads to power loss in the form of heat from a rheostat. Hence, we go for the PWM control which reduces this loss by using a power electronic switch.

Pulse width modulation speed control works by driving the motor with a series of “ON-OFF” pulses and varying the duty cycle, the fraction of time that the output voltage is “ON” compared to when it is “OFF”, of the pulses while keeping the frequency constant.

The power applied to the motor can be controlled by varying the width of these applied pulses and thereby varying the average DC voltage applied to the motors terminals. By changing or modulating the timing of these pulses the speed of the motor can be controlled, i.e., the longer the pulse is "ON", the faster the motor will rotate and vice versa.

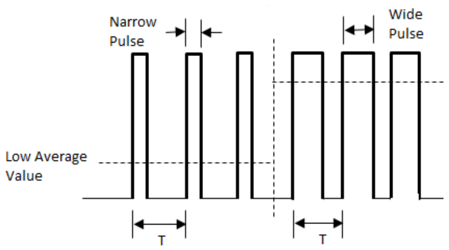


Fig 6.PWM Representation

Here, T represents total time period. The narrow and wide pulses (T_{on}) determine the duty cycle.

Duty cycle = T_{on} / T

The use of pulse width modulation to control a small motor has the following advantage: the power loss in the switching transistor is small because the transistor is either fully "ON" or fully "OFF". As a result the switching transistor has a much reduced power dissipation giving it a linear type of control resulting in better speed stability. Also the amplitude of the motor voltage remains constant.

To produce a PWM pulse train, the signal is compared with the carrier wave (sawtooth waveform here). When the latter is less than the former, the PWM signal is in high state (1); otherwise, it is in low state (0).

D. HARDWARE DESCRIPTION

LPC2148

The LPC 2148 microcontroller is based on a 32-bit ARM7TDMI-S CPU with real time emulation and embedded trace support. To enable maximum clock rate, it is designed with a 128 bit wide memory interface and unique accelerator architecture.

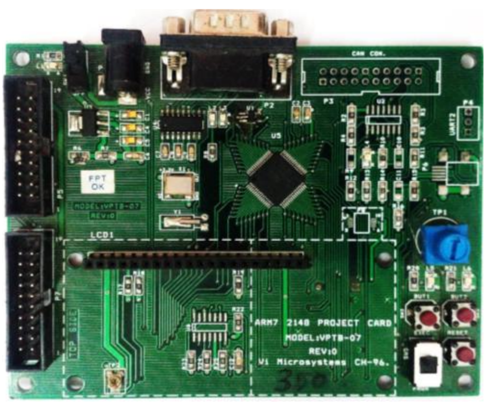


Fig 8.LPC 2148 Embedded Board

LPC 2148 has a 3 stage instruction pipeline with a Von-Neumann Architecture. The average instruction cycle time is approximately 32 ns with a 60 MHz operation.

Due to its portable size and low power consumption, it is

Input	Enable	Output
H	H	L
L	H	H
H	L	H
L	L	H

Fig 10.OptocouplerTruth Table

ideal where miniaturization is the key requirement such as access control and point of scale. Serial communication ranges from USB 2.0, multiple UARTs, SPI, SSI to i2C-bus and on chip SRAM of 40kB. Various 32-bit timers, single or dual 10-bit ADCs, 10-bit DAC, PWM channels and 45 fast GPIO lines with 9 edge or level sensitive external interrupt pins are present.

The General Purpose Parallel (GPIO) registers, when enabled, are relocated to the local ARM bus to provide the fastest possible I/O timing. These registers are byte addressable. The ADC is of 10-bit successive approximation type capable of performing more than 400000 10-bit samples

Fig 9.Optocoupler Pin Configuration

per second. ADC0 has six channels and ADC1 has eight channels. The DAC is also 10 bit with a buffered output.

The applications range from communication gateways, soft modems, voice recognition to medical systems

Optocoupler(6N137)

An opto coupler is essentially an optical transmitter and an optical receiver connected by a nonconductive barrier. It uses a beam of light to transfer energy from one circuit element to another. Optocouplers are most often used to separate two circuit elements that are operating on extremely different voltages. This prevents damage to the part working at a lower voltage. They also work to keep the two elements from being damaged by reverse voltage or power surges because of this trait, opto couplers are best utilized in associated with on off switches and the transfer of digital data. They are commonly ground between a transmitter and a receiver in an electric circuit. 6N137 contains high emitting diode and a one chip photo IC. It is packaged in an 8 pin DIP and is TTL compatible.

As indicated in the truth table, it not only isolates the system by also inverts the output obtained. The default state is high (since the input '0' is assumed as default) and stays high if the enable is low. When the input is high, the LED glows emitting rays which will ground the receiving circuit. Hence, the output is low. When the output is low, there is no current flow from Vin to ground and hence the input voltage is obtained at the output. The main duty is for input, output isolation for the microcontroller units. Noise suppression in the switching circuits is also seen while using this.

Inverter

The NOT gate does logical negation on the digital bits. The NOT gate here is used in the driver. The Opto Coupler transmits the signals in an inverted form as discussed above. Hence, to re-invert the signals, the NOT gate is used.

Driver IC

The driver IC translates TTL or CMOS logical signals, to a higher voltage and higher current, with the goal of rapidly and completely switching the gate of a MOSFET. Essentially, it is a voltage level shifter with an amplifier. This driver receives its signal from the NOT gate which negates the inversion done by the optocoupler.

The IR2110/IR2113 are high voltage, high speed power MOSFET and IGBT drivers with independent high and low side referenced output channels.

Logic inputs are compatible with standard CMOS or LSTTL output, down to 3.3V logic. The output drivers feature a high pulse current buffer stage designed for minimum driver cross-conduction. Propagation delays are matched to simplify use in high frequency applications. The floating channel can be used to drive an N-channel power MOSFET or IGBT in the high side configuration which operates up to 500 or 600 volts.

MOSFET

The metal–oxide–semiconductor field-effect transistor (MOSFET, MOS-FET, or MOS FET) is a type of transistor used for amplifying or switching electronic signals. The main advantage of a MOSFET transistor over a regular transistor is that it requires very little current to turn on (less than 1mA), while delivering a much higher current to a load (10 to 50A or more). However, the MOSFET requires a higher gate voltage (3-4V) to turn on.

Applications

- Switching regulators
- Relay drivers
- Variable Frequency Drives
- SMPS

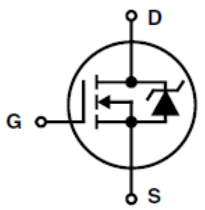


Fig 11.MOSFET Internal Diagram

MOC Sensor

MOC7811 sensor is used to count the number of rotations of the aluminium disc connected to the motor shaft. It consists of IR LED and Photodiode mounted facing each other enclosed in plastic body. This is normally used as positional sensor switch (limit switch). It has four legs: 2 legs for diode and 2 for transistor. Both are inbuilt, no external connection required. When light emitted by the IR LED is blocked because of alternating slots of the encoder disc logic level of the photo diode changes. This change in the logic level can be sensed by the microcontroller or by discrete hardware. Current limiting resistance is required.

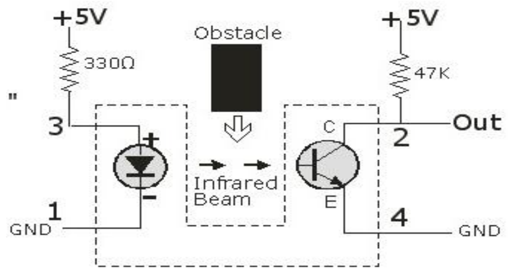


Fig 12.MOC Sensor Working

The above is the internal diagram of the MOC Sensor. The IR Led here is always ON. Hence, it acts as a base signal for the photo transistor and it conducts giving an output of 0. When it is cut by an obstacle, the IR signal is cut and the transistor fails to conduct. The input voltage of 5 V would be available at the Output pin. The transistor output voltage can be 30 V (maximum).

Applications

- DC motor position / velocity control
- Position and velocity servomechanisms
- Factory automation robots
- Numerically controlled machinery
- Computer printers and plotters

Bluetooth Module

Bluetooth is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves from 2.4 to 2.485 GHz) from fixed and mobile devices and building personal area networks (PANs).

Bluetooth is a packet-based protocol with a master-slave structure. One master may communicate with up to seven slaves in a piconet. All devices share the master's clock. Packet exchange is based on the basic clock, defined by the master, which ticks at 312.5 µs intervals. Two clock ticks make up a slot of 625 µs, and two slots make up a slot pair of 1250 µs. In the simple case of single-slot packets the master transmits in even slots and receives in odd slots. The slave, conversely, receives in even slots and transmits in odd slots. Packets may be 1, 3 or 5 slots long, but in all cases the master's transmission begins in even slots and the slave's in odd slots.

The Bluetooth module consists of a Bluetooth Serial Interface (HC-05) and a Bluetooth adapter (HC – M6). Bluetooth serial module is used for converting serial port to Bluetooth. It has two modes: master mode and slaver device. This even number named device is defined as the master or the slaver as a part of the factory setting and cannot be changed.

The main function of Bluetooth serial module is replacing the serial port line, like:

1. There are two MCUs want to communicate with each other. One connects to Bluetooth master device while the other one connects to slave device. Their connection can be built once the pair is made.

This Bluetooth connection is equivalently linked to a serial port line connection including RXD, TXD signals. And they can use the Bluetooth serial module to communicate with each other.

2. When MCU has Bluetooth slave module, it can communicate with Bluetooth adapter of computers and smart phones. Then there is a virtual communicable serial port line between MCU and computer or smart phone.

Communication between two Bluetooth modules requires at least two conditions:

(1) The communication must be between master and slave.

(2) The password must be correct.

This acts as the slave device and the Bluetooth enabled phone or PC will be the master device. Once the password is verified with the slave, the master can start sending messages regarding the speed of the motor which is to be set as the reference. Hence, the reference is effectively communicated to the microcontroller.

E. SOFTWARE TOOLS

Introduction to PI and Fuzzy Logic

PI Controller

The Proportional control generates the output proportional to the given input. The integral control is used to eliminate small errors. The Proportional-Integral-Derivative (PID) controller provides accurate output but the settling time taken to achieve the ideal condition is large. Hence the Proportional-Integral (PI) controller is used where the settling time is comparatively small. The PI controller[3] is essentially a low pass filter.

The process variable is the current speed of motor, the set point is the speed defined by the user as reference speed and the control variable is the output from the PI controller.

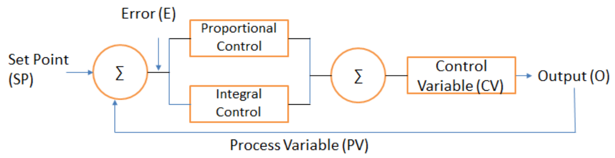


Fig 13.Schematic of PI controller

The equations describing the controller:

- E = SP – PV
- Integral = Integral + E
- Control Variable = (Kp * E) + (Ki * I)

Where, Kp = Proportional Constant and Ki = Integral Constant

Generally 0.1<Ki<1 and 0.01<Kp<1.

The advantages and disadvantages of a properly designed PI controller are as follows:

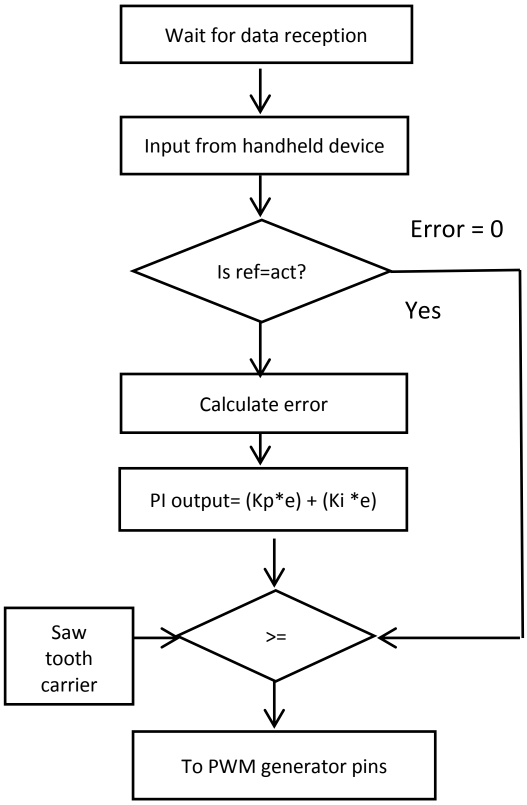
- Improves damping and reduces maximum overshoot.
- Increases rise time.
- Decreases bandwidth.
- Improves gain margin and phase margin.
- Filters out high frequency noise.

The actual setup in the simulation of controlling of PMDC motor using PI controller consists of the PMDC motor whose speed is directly controlled by the MOSFET. Initially the supply voltage is applied across the motor through the MOSFET. Whenever the MOSFET receives the gate pulse the motor rotates.

In the simulations, the speed obtained from the motor is in rps (rotation per second). Hence to convert it to the actual rpm (rotation per minute) value, the rps value is multiplied with the constant 30/pi.

The rpm is then compared with the set speed and the output is fed to the PI controller. The PI controller on receiving the input provides the reference output which is compared with the saw tooth carrier wave and the output is given as the gate drive to the MOSFET.(K_p=0.1 and K_i=1here).

Flowchart for PI Controller



Fuzzy Logic Controller

In recent years, the number and variety of applications of fuzzy logic have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection. Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multi valued logic. However, in a wider sense fuzzy logic (FL) is almost synonymous with the

	NB	NM	NS	ZE	PS	PM	PB
NB	VB	VB	VB	B	SB	S	ZE
NM	VB	VB	B	B	MB	S	VS
NS	VB	MB	B	VB	VS	S	VS
ZE	S	SB	MB	ZE	MB	SB	S
PS	VS	S	VS	VB	B	MB	VB
PM	VS	S	MB	B	B	VB	VB
PB	ZE	S	SB	B	VB	VB	VB

Fig 14. General Rule Base

theory of fuzzy sets, a theory which relates to classes of objects with unsharp boundaries in which membership is a matter of degree. Even in its more narrow definition, fuzzy logic differs both in concept and substance from traditional multi valued logical systems. In effect, much of FL may be viewed as a methodology for computing with words rather than numbers. Although words are inherently less precise than numbers, their use is closer to human intuition. Furthermore, computing with words exploits the tolerance for imprecision and thereby lowers the cost of solution. Another basic concept in FL, which plays a central role in most of its applications, is that of a fuzzy if-then rule or, simply, fuzzy rule.

When the exact analytical model of the controlled system is uncertain or difficult to be characterized, intelligent control techniques such as fuzzy logic control (FLC), neural network control, or genetic algorithm may allow better performance.

Intelligent control approaches try to imitate and learn the experience of the human expert to get satisfactory performance for the controlled plant. The FLC has been found particularly suitable for controller design when the plant is difficult to model mathematically due to its complexity, nonlinearity, and/or imprecision. Hence, the FLC is widely applied in a considerable variety of engineering fields today because of its adaptability and effectiveness.

The FLC architecture approximates the way of expert operation intuitiveness; this makes it attractive and easy to incorporate heuristic rules that reflect the experience of human experts into the controller. Recently, fuzzy control theory has been widely studied, and various types of fuzzy controllers have also been proposed in the base paper to improve the drive performance further. In these research works, the main techniques utilized to enhance the self-adaptability and performance of the FLC are scaling factor (SF) tuning, rule base modification, inference mechanism improvement, and membership function redefinition and shifting. Among these techniques, SF tuning is the most used approach, and it has a significant impact on the performance of an FLC.

Today, home appliance applications require more and more features such as motor speed adaptations to multipurpose accessories, user friendly interfaces, and security features. Such new requirements can be achieved through a low-end microcontroller-based electronic control using the fuzzy logic approach. Nowadays, most of fuzzy logic-based controls are only limited to a complicated ranking management of user interfaces, sensors, and actuators, corresponding to a slow software speed operation. This paper proposes a totally different use of fuzzy logic. In this case, fuzzy logic is implemented in a standard microcontroller to regulate the speed of a PMDC motor by a real time adjustment of the motor speed. This microcontroller directly tunes the motor current by means of a chopper converter. Starting from a basic food-processor application, the paper practically shows how a fuzzy logic approach can be applied to build a closed speed regulation loop from a very low cost tacho-generator. The paper gives the practical procedure to define the input parameters and to build fuzzy logic rules when using the fuzzy logic development tool. Finally, the major benefits of this project lie in an original approach where fuzzy logic is applied to fast "real-time" regulation loop without requiring any specific expertise in conventional methods of regulation. Benefits are discussed and concrete results are given.

So far in this project:

This project consists of a fuzzy logic control to vary the speed of the motor. The membership functions which are seven in number vary from the largest value in negative to the largest value in positive. The output is a fuzzified result of the two input functions, namely, error in speed and change in error. They can be explained as follows:

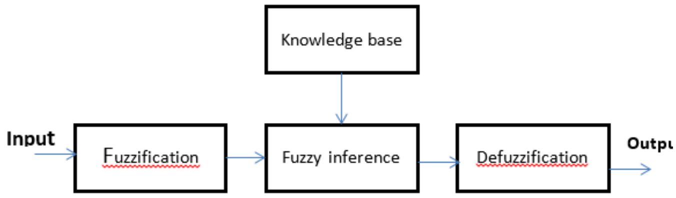


Fig 16.Schematic of FLC

Error: The difference of the current speed of the motor to the reference speed, i.e the set speed is the error. This is calculated by:

$e(k) = r(k) - y(k)$

e(k)= error in speed

r(k)=required speed

y(k)= existing speed

This speed input is given by means of a closed loop.

Change in error: The change in error, del E is the ratio of the change in speeds to the change in the selected speed slab. This is calculated by the formula:

$\Delta e(k) = e(k) - e(k-1) = y(k-1) - y(k),$

if $r(k) = r(k-1)$

Δ e(k) = change in error

k is the instant of occurrence

Label & Membership functions	Description (Based on Speed)	Speed output range (defining constants)
NB-Trapezoidal	Negative big	[2208 -1802 -1320 -869.8]
NM-Triangular	Negative medium	[-1320 -759.5 -198.7]
NS-Triangular	Negative small	[-870.6 -193.8 2.19]
ZE-Triangular	Zero	[-192.9 3.143 199.1]
PS-Triangular	Positive small	[2.19 198.6 840.2]
PM-Triangular	Positive medium	[199.6 760.4 1321]

The PI-like fuzzy controller (PIFC) is driven by a set of control rules rather than constant proportional and integral gains. The main difference between both controllers is that the STFC includes another control rule base for the gain updating factor α. Adaptability is necessary for fuzzy controllers to ensure acceptable control performance over a wide range of load variations regardless of inaccurate operating knowledge or plant dynamic behaviour.

Here, a discrete-time controller with two inputs and a single output is considered.

From Fig., the error e and change of error Δe are used as the input variables, which are defined as

$e(k) = r(k) - y(k)$

$\Delta e(k) = e(k) - e(k-1)$

$= y(k-1) - y(k)$, if $r(k) = r(k-1)$

where r and y denote the reference command and plant output, respectively. Indices k and k − 1 represent the current and previous states of the system, respectively. The controller output is the incremental change of the control signal Δu(k). The control signal can be obtained by

$u(k) = u(k-1) + \Delta u(k)$.

The linguistic values ZE, VS, S, SB, MB, B, and VB represent zero, very small, small, small big, medium big, big, and very big, respectively.

$\Delta\omega_{err}$ \ ω_{err} (Δi^*_{α})	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NS	NVS	NVS	ZE
NM	NB	NM	NS	NS	NVS	ZE	PVS
NS	NB	NS	NVS	NVS	ZE	PS	PS
ZE	NS	NS	NVS	ZE	PVS	PS	PS
PS	NS	NS	ZE	PVS	PVS	PS	PB
PM	NVS	ZE	PVS	PS	PS	PM	PB
PB	ZE	PVS	PVS	PS	PB	PB	PB

Fig 15.Combined Rule Base for Output MP

Here, except for the two fuzzy sets at the outmost ends (trapezoidal MFs are considered), symmetric triangles with equal bases and 50% overlap withadjacent MFs are chosen.

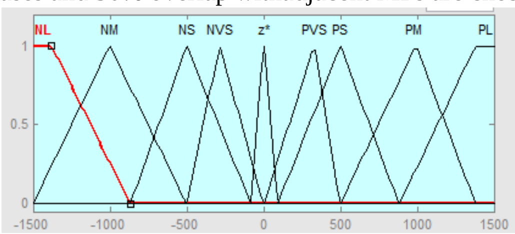


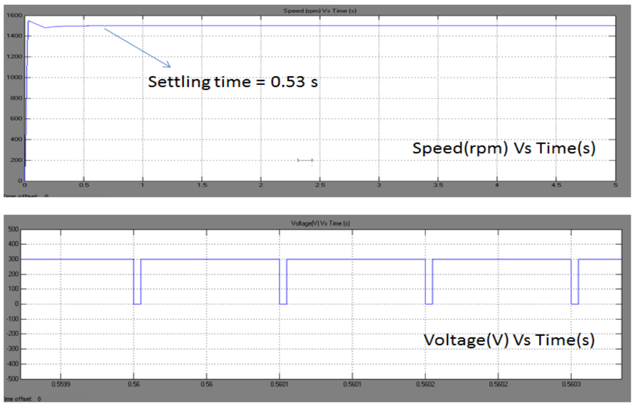
Fig 16a. General Membership Functions

Simulations

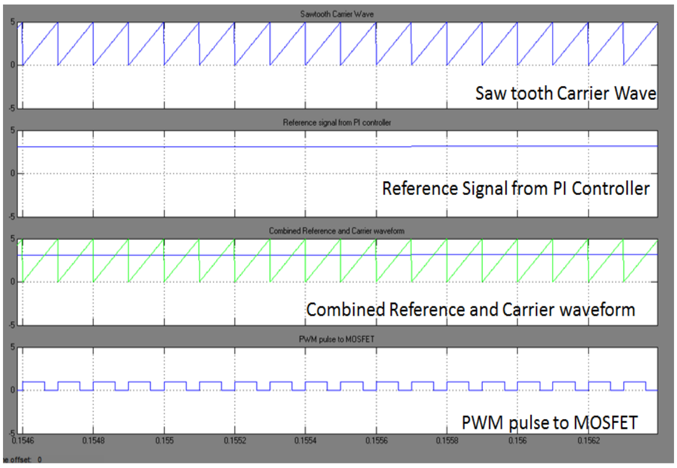
Simulink, developed by MathWorks, is a data flow graphical programming language tool for modeling, simulating and analyzing multi domain dynamic systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment and can either drive MATLAB or be scripted from it.

SPEED AND VOLTAGE WAVEFORMS DURING SIMULATION

1500 RPM



REFERENCE AND CARRIER WAVEFORMS



FOR FLC

1500 RPM

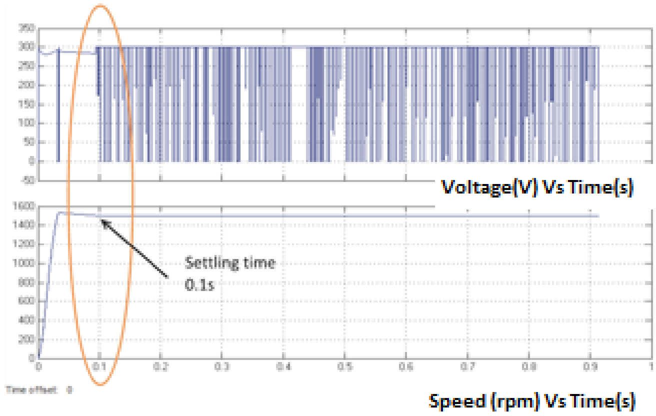


Fig.17 Settling time in FLC

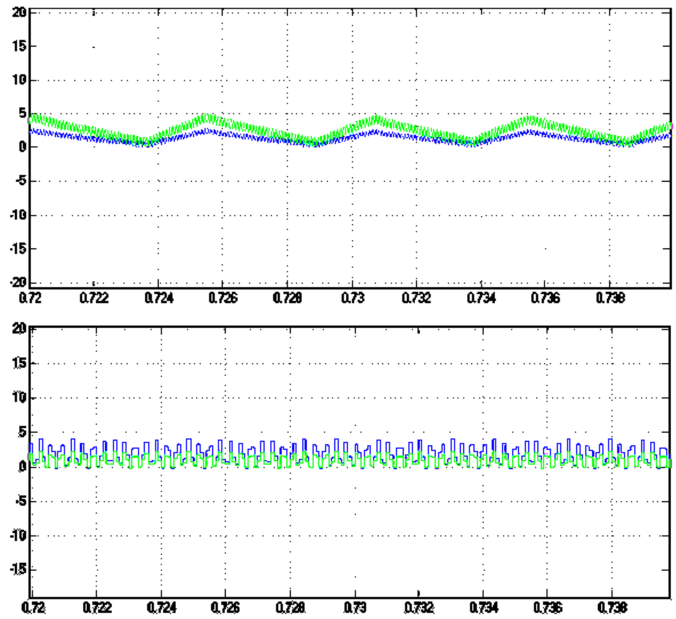
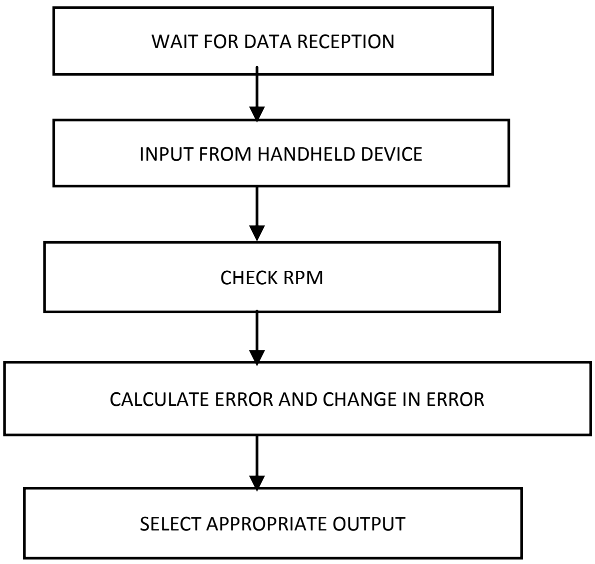


Fig 17.a Current and torque waveforms of PMDC motor via FLC based feedback

Flowchart for FLC system



F.IMPLEMENTATION AND TESTING

Flowchart for the Embedded C Program

The entire set of controllers were programmed in Embedded C and uploaded into the LPC2148 Board. The two select pins are two button switches present in the board. One button is programmed for PI controller and the other for fuzzy controller.

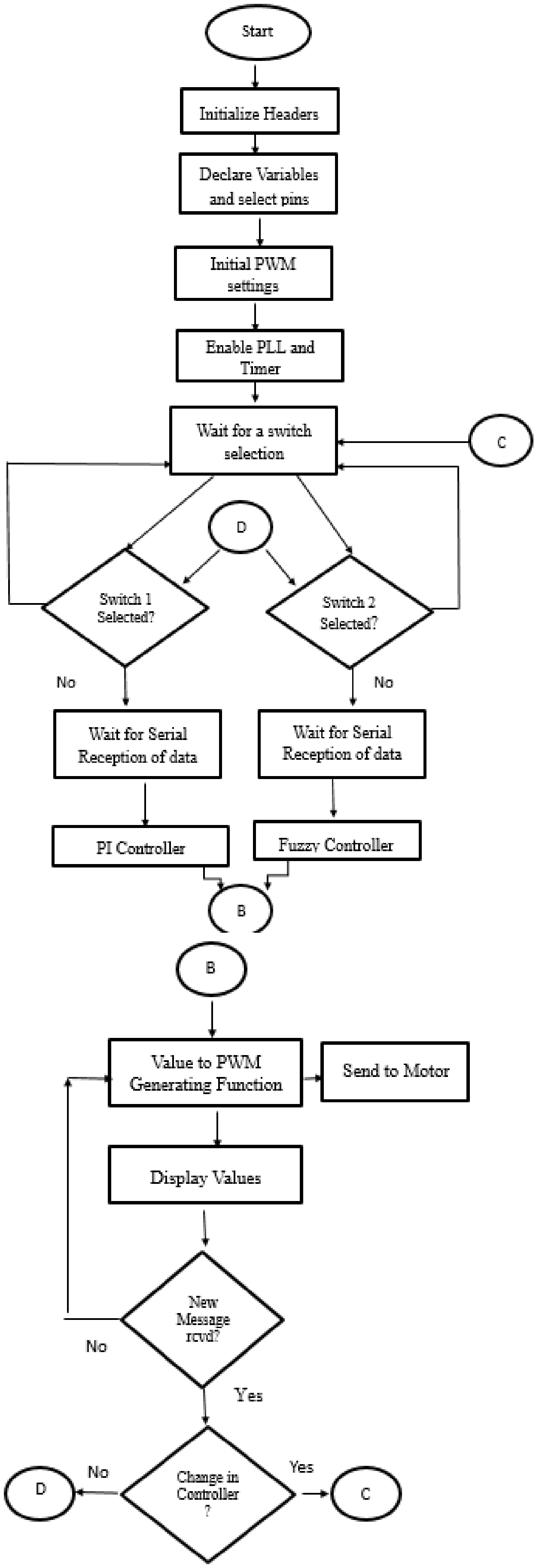


Fig 19. Overall Flow Chart

Hardware Implementation

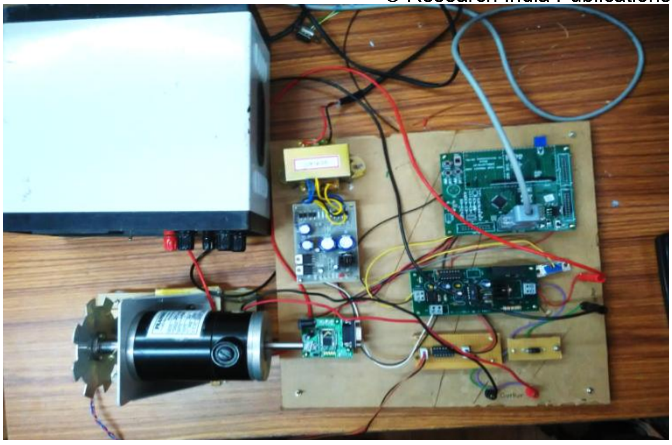


Fig. 18. Hardware

Android Application

Here android application is used to send speed to the motor. First the blue tooth enabled device is paired with the Bluetooth module in the hardware setup using password. Once the pairing is done, the current speed of the motor is displayed in the display screen. The speed at which the motor is to be operated is set by the user as set speed and the change in speeds are observed.

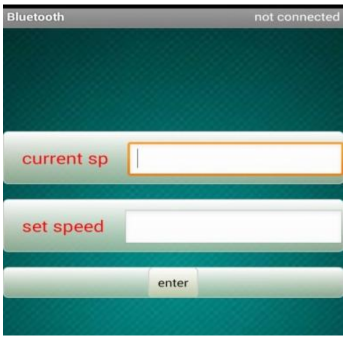


Fig 20.Speed transfer via blue tooth

Testing

The real time comparison of PI and Fuzzy is done using lab view and the results thus obtained are similar to that of simulation results.

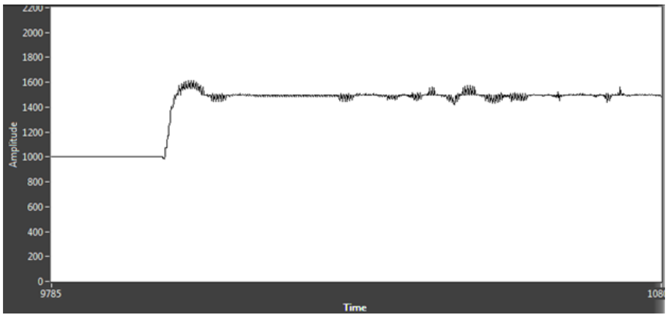


Fig 21.PI controller - 1500 rpm

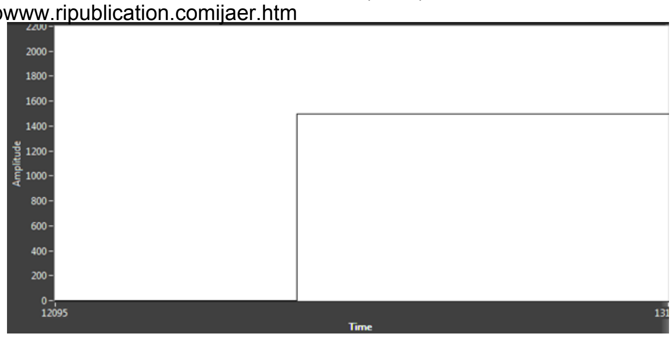


Fig 22. Fuzzy controller - 1500 rpm

H.CONCLUSION

A closed loop control system was implemented based on PI and Fuzzy Logic Controllers. The motor was able to run at the various speed set by the user. In the simulation and the actual implementation, fuzzy logic controller was found to have a better settling time and a higher initial torque than the PI controller. The motor was given the speed command from a distance not more than 10 metres from a phone and was observed to perform efficiently, more so, with the FLC.

The future scope is as follows. This same idea can be applied on multiple drives to make them run at same or different speeds. The fuzzy settling times can be reduced by adding more membership functions and reducing their widths.This can also be extended to different types of motors in the industry so as to help them achieve complete automation.

H.ACKNOWLEDGMENT

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