PERFORMANCE INVESTIGATION OF FUZZY LOGIC CONTROL OF PHASE CONTROLLED CONVERTER FED DC MOTOR DRIVE

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

ELECTRICAL ENGINEERING

(With Specialization in Power Apparatus and Electric Drives)

By

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CANDIDATE'S DECLARATION

I here by declare that the work is being presented in the dissertation report entitled "PERFORMANCE INVESTIGATION OF FUZZY LOGIC CONTROL OF PHASE CONTROLLED CONVERTER FED DC MOTOR DRIVE" submitted in partial fulfillment of the requirements for the award of the degree of MASTER OF TECHNOLOGY with specialization "POWER APPARATUS AND ELECTRICAL DRIVES" to the department of ELECTRICAL ENGINEERING IIT ROORKEE is an authentic record of my own work carried out under the guidance of DR. PRAMOD AGRAWAL ,PROFESSOR ,department of ELECTRICAL ENGINEERING.

The matter embodied in this dissertation report has not been submitted by me for the award of any other degree.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

Fuzzy logic is given grater emphasis in industrial control applications. This scheme proposed “performance investigation of fuzzy logic control of phase controlled converter fed DC motor” it is PC based with C programming and the designed controller has two loops with inner current control loop and outer speed control with fuzzy compensation used to linearize the converter transfer characteristics in discontinuous mode. The fuzzy controller designed and evaluated by MATLAB simulation. The fuzzy controller used to generate the change in control voltage for thyristor converter .which in turn changes the armature voltage of converter the simulated results are compared with experimental results.

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CHAPTER 1

INTRODUCTION

During the past several years, fuzzy control has emerged as one of the most active and fruitful areas for research in the applications of fuzzy set theory, especially in the realm of industrial processes, which do not lend themselves to control by conventional methods because of a lack of quantitative data regarding the input-output relations. Fuzzy control is based on fuzzy logic-a logical system which is much closer in spirit to human thinking and natural language than traditional logical systems. The fuzzy logic controller (FLC) based on fuzzy logic provides a means of converting a linguistic control strategy based on expert knowledge into an automatic control strategy.

Fuzzy logic is recently finding wide popularity in various applications that include management, economics, and Medicine and process control systems. A fuzzy control Algorithm for a process control system embeds the intuition and experience of an operator, designer and researcher. The control does not need accurate mathematical model of a plant, and therefore, it suits well to a process where the model is unknown or ill-defined.

The fuzzy control also works well for complex nonlinear multi-dimensional system, system with parameter variation problem, or where the sensor signals are not precise. Fuzzy controllers have been applied to many industrial applications. The main feature of a fuzzy controller is that it can convert the linguistic control rules based on expert knowledge into automatic control strategy. Fuzzy-based methods are useful when precise Mathematical formulations are not feasible. Moreover, fuzzy logic controllers often yield superior results compared to conventional control approaches. Fuzzy logic extensively used to improve or to replace conventional control techniques because these techniques do not require a precise model.

Fuzzy logic is being increasingly used to design and implement complex control systems. Classical controllers are designed by various techniques for a variety of control systems applications, and are modeled on the systems or process being controlled. Fuzzy control is based on the human operator's behavior.

1.1: FUZZY LOGIC IN POWER ELECTRONICS AND DRIVES

A power electronics system, in general, has complex nonlinear model with parameter variation problem, the fuzzy control linearizes the transfer characteristics of the converter in discontinuous conduction mode and controls the feedback current and speed loops as well. And the control needs to be very fast.

Major problems in applying a conventional control algorithm in a speed controller are the effects of nonlinearity in a DC motor. The nonlinear characteristics of a DC motor such as saturation and friction could degrade the performance of conventional controllers. Many advanced model-based control methods such as variable-structure control and model reference adaptive control have been developed to reduce these effects. However, the performance of these methods depends on the accuracy of system models and parameters. Generally, an accurate non-linear model of an actual DC motor is difficult to find, and parameter values obtained from system identification may be only approximated values.

DC motor drives are used in speed control applications because of their low initial cost, excellent drive performance and low maintenance requirement. In many adjustable speed drives, especially in large power rating applications, three phase filly controlled converters are preferred because of their low ripple content in the output voltage and absence of commutating circuits. The transfer characteristic of this converter fed motor is non-linear in nature. A PI controller is not suitable for non-linear operating conditions. Hence a non-linear controller such as fuzzy controller is desirable for the speed control of these converters fed drives.

A FLC has been implemented on many platforms such as digital signal processor (DSP) or off-the shelf microcontroller. These platforms have different advantages and disadvantages. The FLC developed on DSP or PC can quickly process fuzzy computation to generate control efforts, but the physical size of the system may too big and quite expensive for a small DC motor application.

1.2 SPEED CONTROL OF DC MOTOR:

Fig 1.1 shows the separately excited DC MOTOR

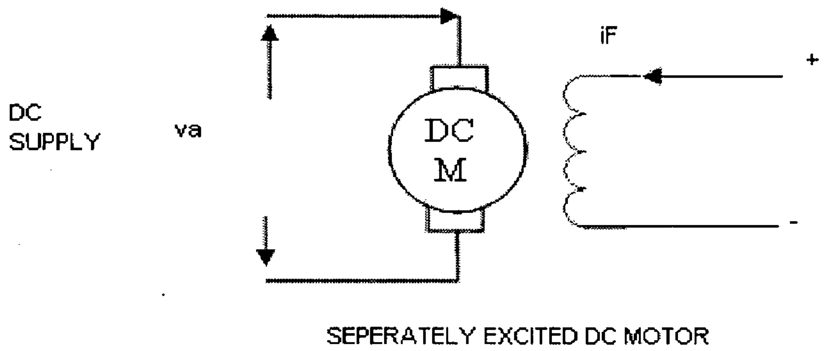


FIG 1.1

SPEED CONTROL METHODS:

1. armature voltage control
2. field control method

ARMATURE VOLTAGE CONTROL:

This method is mainly used to control the speed of machine below the rated speed .by changing the voltage applied to motor the back emf changes and speed changes.
If V_a is the armature voltage and I_a is the armature current then

$$V_a = I_a R_a + E_b$$

Where R_a = armature resistance

E_b =back emf (counter emf)

If the speed at rated back emf E_b is N_b and at any back emf E speed is N_b

$$\frac{N}{N_b} = \frac{E}{E_b}\ (I_f const) \ldots\ldots\ldots\ldots\ldots\ldots (1.1)$$

FIELD CONTRL:

This method is mainly used to control the speed above rated speed of machine by changing the field current and applying the voltage.

In field control the speed ratio is

$$\frac{N}{N_r} = \frac{I_{f1}}{I_{f2}} \text{(Keeping the } E_b \text{ const)}\dots\dots\dots\dots (1.2)$$

1.3 LITERRATURE RIVEW:

Fuzzy logic or fuzzy set theory is recently getting Increasing emphasis in process control applications. A general fuzzy set theory based control of converter fed DC motor has been suggested in [1]. An application of fuzzy logic in a speed control system that uses a phase-controlled bridge converter and a separately excited Dc machine. The fuzzy control is then extended to the current and speed control loops, replacing the conventional proportional-integral (PI) control method. The compensation and control algorithms have been developed in detail and verified by digital simulation of a drive system. In [2] fuzzy logic has been implemented using microcontroller with only speed controller and compensation but this scheme the transient response of the drive is not so good .because there is no inner current controller for improving the current response and the sampling speed is also low with micro controller.

In [3] proposed new control method of a separately excited dc traction motor using fuzzy logic. The design of a fuzzy logic controller for a traction DC motor drive has been implemented with computer interfaced for chopper fed dc motor but with chopper the ripple in the output voltage is large. An alternative method has been suggested in [4] using fuzzy chips for programming like commercial microcontroller for controller DC motor. The main feature of this chip is its capability in hardware level to execute fuzzy computation. Fuzzy rules and membership functions are defined and stored in RAM or ROM.

In [5] fuzzy logic has been applied for a universal motor a real time adjustment (every 30 millisecond) of the motor current. This microcontroller directly tunes the motor current by means of a chopper converter. In [6] three unique methods of efficient dc motor speed control. A simplified real time speed control approach using ***'C'*** next an Intel 16-bit microcontroller based fuzzy controller using assembly language and finally, using Inform fuzzy tools which allows fuzzy system design with graphical development tools including simulation and code optimization. Binary Input Output Fuzzy Associative Memory (BIOFAM) is used for control. Fuzzy Associative Memories (FAM) are transformations of sets. In this also compared different control schemes with different implementation.

In this chapter introduction fuzzy control and the application fuzzy logic in power electronics and drives in industries. And also different speed controlling of dc motor drive are given. Literature survey for different controls and implantation for fuzzy speed control with chopper and converter fed Dcmotor.

CHAPPTER 2

PHASE-CONTROLLED CONVERTER FED DC MOTOR DRIVE

Fig. 2.1 shows the three phase fully controlled Converter Bridge feeding DC motor

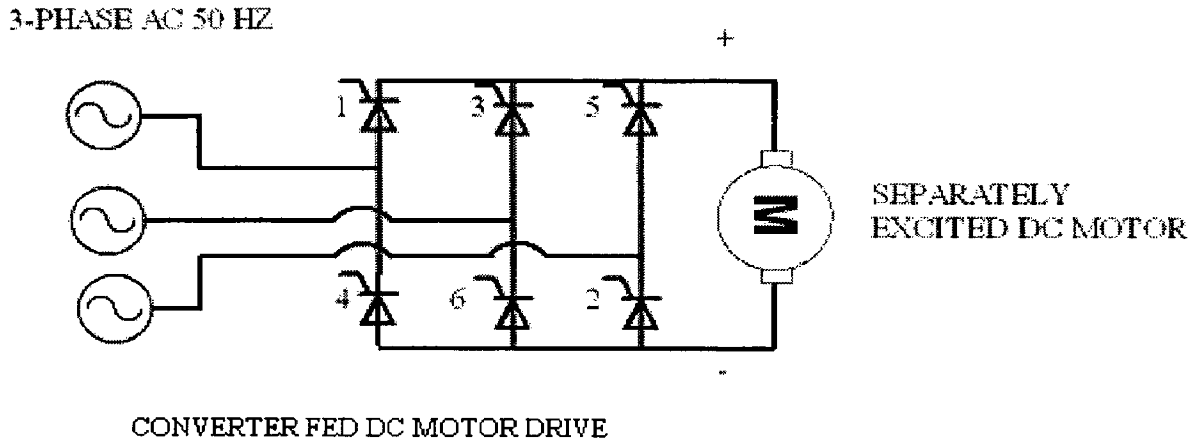


FIG: 2.1(separately excited)

The power circuit consists of a phase-controlled bridge converter that drives a separately excited DC motor. For simplicity, the converter is used in motoring mode only with fixed field excitation the converter may operate in continuous or discontinuous current conduction mode. The discontinuous conduction mode that occurs during low torque high speed conditions leads to poor speed regulation. Discontinuous mode occurs because of high value of back emf.

2.1 CONTINUOS CONDUCTION MODE:

The continuous mode occurs during the low speed/high torque because of back emf low during continuous conduction mode, the DC output voltage (V_d) remains constant irrespective of the average motor current (I_d) for a particular firing angle α.

During the continuous conduction mode the armature output voltage

$$V_a=\left(3*\frac{V_m}{\pi}\right)\cos(\alpha) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ldots. (2.1)$$

Per unit output voltage = $V_d \text{ (pu)} = \frac{3}{\pi} * \cos(\alpha)$

Per unit armature current $I_d = \frac{X}{R}\left[\cos(\alpha) - \frac{\pi E_b}{V_m}\right] \quad \ldots\ldots\ldots (2.2)$

Where I_a = armature current (average)

V_m = peak ac line voltage

X = armature reactance (ωL)

R_a = armature resistance

α = converter firing angle

E_b = armature counter emf

And V_d = converter output voltage (average)

The line voltage (V_m) can essentially be considered as constant, and therefore, V_d can be controlled linearly by V_m with cosine wave crossing technique.

2.2 DISCONTINUOUS CONDUCTION MODE:

During discontinuous state for the same value of α the DC output voltage is higher than its value in continuous conduction mode due to the reflection of back emf when the current is zero. Hence, once the motor enters into discontinuous conduction mode, the

DC output voltage no longer remains constant, but varies with the conduction angle β. The value of β in turn depends upon the load conditions and magnitude of the supply voltage.

In discontinuous conduction mode, the following armature circuit equations are valid.

$$I_a(pu) = \frac{I_a}{3V_m / \pi x} = \left[\cos(\pi/3+\alpha) - \cos(\pi/3+\alpha+\beta) - \frac{E_b\beta}{V_m}\right] \ldots\ldots\ldots\ldots\ldots (2.3)$$

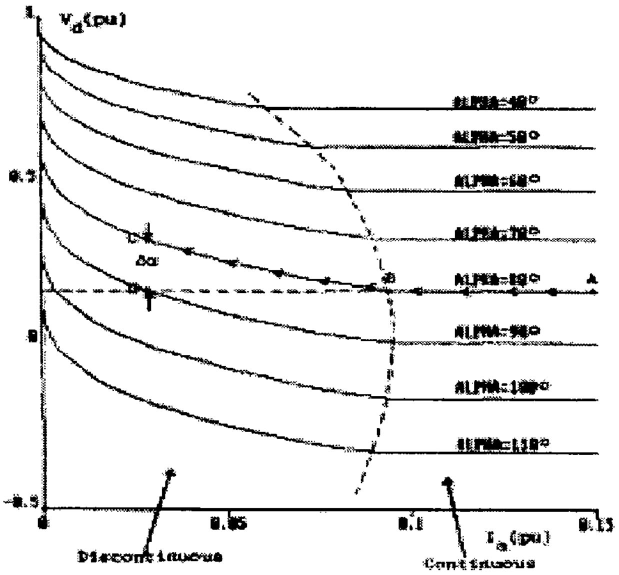
$$V_d(pu) = \frac{V_d}{V_m} = \left[\cos(\pi/3+\alpha) - \cos(\pi/3+\alpha+\beta) - \frac{E_b\beta}{V_m}\right] + \frac{E_b}{V_m} \ldots\ldots\ldots\ldots\ldots (2.4)$$

$$\frac{E_b}{V_m} = \frac{\sqrt{1+(X/R)^2}}{[1-\exp(-R\beta/X)]}\{\sin(\pi/3+\alpha+\beta-\phi) - \sin(\pi/3+\alpha)\exp(-R\beta/X)\} \ldots\ldots (2.5)$$

Where β = conduction angle of current pulse ($0 < \beta < \pi/3$)

2.3TRANSFER CHARACTERSTICS OF CONVERTER:

The $V_d(pu) - I_d(pu)$ graph is shown in fig 2.2 with different firing angles which shows the boundary between continuous and discontinuous modes.



Theoretical $V_d - I_a$ (pu) phase plot without compensation.

FIG: 2.2

For a fixed X / R parameter, the above equations are plotted in Fig: 2.2 for different α angles, which also indicate the boundary between continuous and discontinuous conduction modes. For example, at $\alpha = 80°$, the conduction is continuous at the point A. As the machine counter emf is increased, the V_d *(pu)* remains constant at decreasing I_a *(pu)* until the point B when the conduction becomes discontinuous.

Further increase of counter emf will cause increase of V_d *(pu)* until it reaches the point at Which I_a *(pu)* = *0*. The nonlinear V_d *(pu)* - I_a *((pu)* relation adversely affects the gain characteristics of the current control loop. If, for example, the loop gain is made optimum at continuous conduction mode, the lower gain at discontinuous conduction will make the loop response sluggish. On the other hand, if the gain is optimized for discontinuous mode at a certain operating point, the loop will tend to be unstable at continuous conduction.

Among the number of methods suggested to linearize the converter transfer characteristics at discontinuous conduction mode, the look-up table method appears to be very attractive. In this method, an auxiliary compensating $\Delta\alpha$ angle is generated as a function of main α angle and armature current I_a and then added with the α angle to generate the α_o.As a consequence, V_d *(pu)* -I_a *((pu)* relation for each a angle becomes horizontal at discontinuous mode in fig 2.2, and therefore, the gain value becomes the same as in continuous conduction. The two-dimensional relation of $\Delta\alpha$ can be precomputed for each X / R parameter and stored in the form of a look-up table for microcomputer implementation. If the Parameter X / R variation is considered, and the compensating angle is needed with good accuracy, then the look-up tables memory tends to be very large.

In this chapter different operating modes of converter fed DC motor drive, corresponding mathematical per unit output voltage (V_d) in both modes are derived and also the transfer characteristics of converter which indicates boundary of continuous and discontinuous modes discussed.

CHAPTER 3

FUZZY LOGIC

Fuzzy logic, which is the logic on which fuzzy control is based, is much closer in spirit to human thinking and natural language than the traditional logical systems. Fuzzy logic, unlike the crispy logic in Boolean theory, deals with uncertain or imprecise situations. A variable in fuzzy logic has sets of values which are characterized by linguistic expressions, such as SMALL, MEDIUM, LARGE, etc. These linguistic expressions are represented numerically by fuzzy sets (sometimes referred to as fuzzy subsets). Every fuzzy set is characterized by a membership function, which varies from 0 to 1 (unlike 0 and 1 of a Boolean set). It provides an effective means of capturing the approximate, inexact nature of the real world. Viewed in this perspective, the essential part of the fuzzy logic controller (FLC) is a set of linguistic control rules related by the dual concepts of fuzzy implication and the compositional rule of inference.

A fuzzy set has a distinct feature of allowing partial membership. In fact, a given element can be a member of a fuzzy set, with degree of membership varying from 0 (non-member) to 1 (full member), in contrast to a "crisp" or conventional set, where an element can either be or not be part of the set.

Fig. 3.1 illustrates the difference for the case of a hypothetical temperature control system. In Fig. 3.1 (b), a crisp classification is provided, such that, the temperature value T = 67°F is a member of the HOT set only. In contrast, in Fig. 3.1 (a) temperature is considered a fuzzy variable and T = 67°F is a partial member of both MILD and HOT fuzzy sets. Because language is the primary means for conveying knowledge, fuzzy variables are usually referred to as linguistic variables, and the fuzzy sets are viewed as the mathematical representation of their linguistic values (e.g., COLD, MILD, and HOT in Fig. 1). The numerical interval, that is relevant for the description of a fuzzy variable, is commonly named Universe of Discourse.

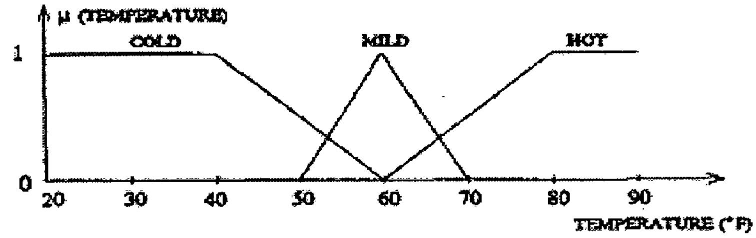


FIG:3.1(a)

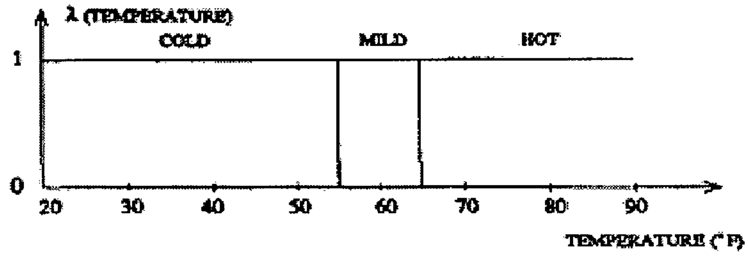


FIG: 3.1(b)

FIG 3.1

3.1 FUZZY SETS:

Let U be a collection of objects denoted generically by {U}, which could be discrete or continuous. U is called the universe of discourse and U represents the generic element Of U

Fuzzy set:

A fuzzy set F in a universe of discourse U is characterized by a membership function μ_F Which takes values in the interval [0,1] namely, $\mu_F : U \rightarrow [0,1]$. A fuzzy set may be viewed as a generalization of the concept of an ordinary set whose membership function only takes two values (0,l). Thus a fuzzy set F in U may be represented as a set of ordered pairs of a generic element u and its grade of membership function:

$$F = ((u,\ \mu_F(u))/u \in U).$$

When U is continuous, a fuzzy set F can be written concisely as

$$F = \int_U \mu_F(u)/u \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

When U is discrete, a fuzzy set F is represented as

$$F = \sum_{i=1}^{n} \mu_F(u_i)/u_i \quad \text{.................................} \quad (3.2)$$

3.1.1 OPERATIONS ON FUZZY SETS

A few operations of Boolean theory are also valid in fuzzy set theory.

Union: Given two fuzzy sets A and B, defined on a universe of discourse X, the union (A $\cup$ B) is also a fuzzy set of X, with membership function given as

$$\mu(A \cup B)(x) = MAX[\mu A(X), \mu B(X)] \quad \text{....................} \quad (3.3)$$

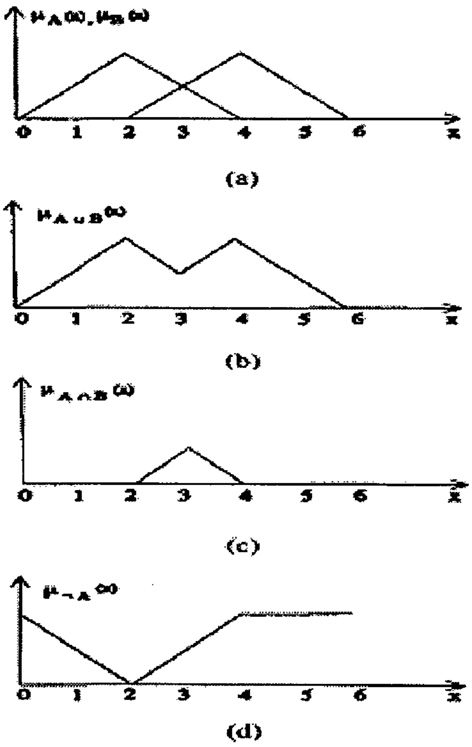
Where x is any element of X.

Intersection: The intersection of two fuzzy sets A and B of the universe of discourse X, denoted by A $\cap$ B, has the membership function given by

$$\mu(A \cap B)(x) = MIN[\mu A(X), \mu B(X)] \quad \text{.....................} \quad .(3.4)$$

Compliment: The compliment of a given set A of the universe of discourse X is denoted by $\neg A$, and has the membership function

$$\mu \neg A = 1 - \mu A(X) \quad \text{..} \quad (3.5)$$



Basic operations involving fuzzy sets. (a) Original fuzzy sets defined on x. (b) Union. (c) Intersection. (d) Negation.

FIG 3.2

A fuzzy rule typically has an IF-THEN format as follows:

IF *(x* is A AND *x* is B) THEN *(z* is C) where *x,* y and *z* are fuzzy variables and A, B and C are fuzzy subsets in the universe of discourses X, Y and Z, respectively. If the conditions expressed in the antecedent (IF portion) are met, then the action(s) specified in the consequent (THEN portion) are taken.

In order to design a fuzzy controller, a fuzzy rule base consisting of several rules must be constructed. For example, consider an hypothetical fuzzy speed control system for a dc motor, where the speed error (E) and change in error (CE) are used to determine changes in the control signal (DU), that in this case is the command armature current I^*_a

A part of the rule base would be:

Rule **1:** IF E is Zero AND CE is Zero THEN DU is Zero;

Rule 2: IF E is Zero AND CE is Negative Small THEN
DU is Negative Small;

Rule 3: IF E is Positive Small AND CE is Negative Small
THEN DU is Zero;

Here, error (E), change in error (CE) and change in control (DU) are considered fuzzy variables, with possible values given by fuzzy sets such as Positive Small, Negative Small, and so on. As illustrated in Fig. 1. A given numerical value can be a member of more than one fuzzy set. This means that, for a particular input pair of values (E and CE), more than one rule could be activated or "fired". Therefore, there must be a way to combine the individual control actions of the fired rules, such that a single, meaningful action is taken.

Composition:

In fuzzy logic terms, the composition operation is the mechanism by which such task can be performed. Although several composition principles have been proposed in the literature, the most common one is the SUP-MIN (SUPremum- MINimum) composition. In a simplistic way, given a rule base, it is possible to construct a n-dimensional fuzzy relation R (let's consider it as a function of n variables).

The simplest case is a single input (x), single output (u) system, resulting in a 2-dimensional fuzzy relation, represented by a membership function $\mu R(x,u)$ for this case; the composition operation can be expressed as:

$$\mu B(u) = SUPx(MIN(\mu A(x), \mu R(x,u))) \qquad (3.6)$$

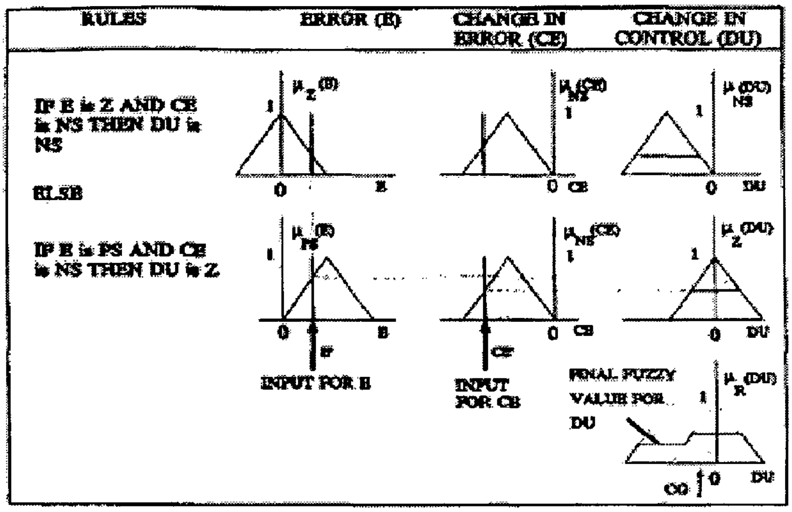


FIG 3.3

3.2 FUZZIFICATION STRATEGIES

Fuzzification is related to the vagueness and imprecision in a natural language. It is a subjective valuation which transforms a measurement into a valuation of a subjective value, and hence it could be defined as a mapping from an observed input space to fuzzy sets in certain input universes of discourse. Fuzzification plays an important role in dealing with uncertain information which might be objective or subjective in nature. In fuzzy control applications, the observed data are usually crisp. Since the data manipulation in an FLC is based on fuzzy set theory, fuzzification is necessary during an earlier stage. Experience with the design of an FLC suggests the following principal ways of dealing with fuzzification

1. A fuzzification operator "conceptually" converts a crisp value into a fuzzy singleton within a certain universe of discourse. Basically, a fuzzy singleton is a precise value and hence no fuzziness is introduced by fuzzification in this case. This strategy has been widely used in fuzzy control applications since it is natural and easy to implement. It interprets an input ***xo*** as a fuzzy set A with the membership μ_A *(x)* equal to zero except at the point (x_o), at which μ_A ***(xo)*** equals one.

2. Observed data are disturbed by random noise. In this case, a fuzzification operator should convert the probabilistic data into fuzzy numbers, i.e., fuzzy (possibilistic) data. In this way, computational efficiency is enhanced since fuzzy numbers are much easier to manipulate than random variables. An isosceles triangle was chosen to be the fuzzification function. The vertex of this triangle corresponds to the mean value of a data set, while the base is twice the standard deviation of the data set.

FUZZY INFERENCE:

The inference mechanisms employed in an FLC are generally much simpler than those used in a typical expert system, since in an FLC the consequent of a rule is not applied to the antecedent of another. In other words, in FLC we do not employ the chaining inference mechanism, since the control actions are based on one-level forward data-driven inference.

3.3 DEFUZZIFICA TION:

Basically, defuzzification is a mapping from a space of fuzzy control actions defined over an output universe of discourse into a space of non fuzzy (crisp) control actions. It is employed because in many practical applications a crisp control action is required. At present, the commonly used strategies may be described as the max criterion, the mean of maximum, and the center of area.

A. The mar criterion method

The max criterion produces the point at which the possibility distribution of the control action reaches a maximum value.

B. ***The Mean*** of ***Maximum Method (MOM)***

The MOM strategy generates a control action which represents the mean value of all local control actions whose membership functions reach the maximum. More specifically, in the case of a discrete universe, the control action may be expressed as

$$Z_o = \sum_{j=1}^{l} \frac{W_j}{l} \qquad \text{.........................} (3.7)$$

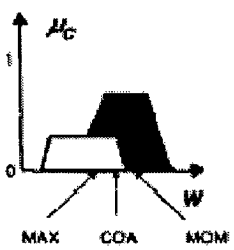
Where W_j is the support value at which the membership function reaches the maximum value $\mu_z(w_{j)}$ and l is the number of such support values.

C. The Center* of *Area Method (COA)

The widely used COA strategy generates the center of gravity of the possibility distribution of a control action. In the case of a discrete universe, this method yields

$$Z_O = \sum_{j=1}^{n} \mu_z(W_{j)}.W_j) / \sum_{j=1}^{n} \mu_z(W_{j)} \qquad \text{..............} (3.8)$$

Fig. 3.4 shows a graphical interpretation of various defuzzification strategies. That the COA strategy yields superior results However, the MOM strategy yields a better transient performance while the COA strategy yields a better steady-state performance.



Different defuzzification mothods

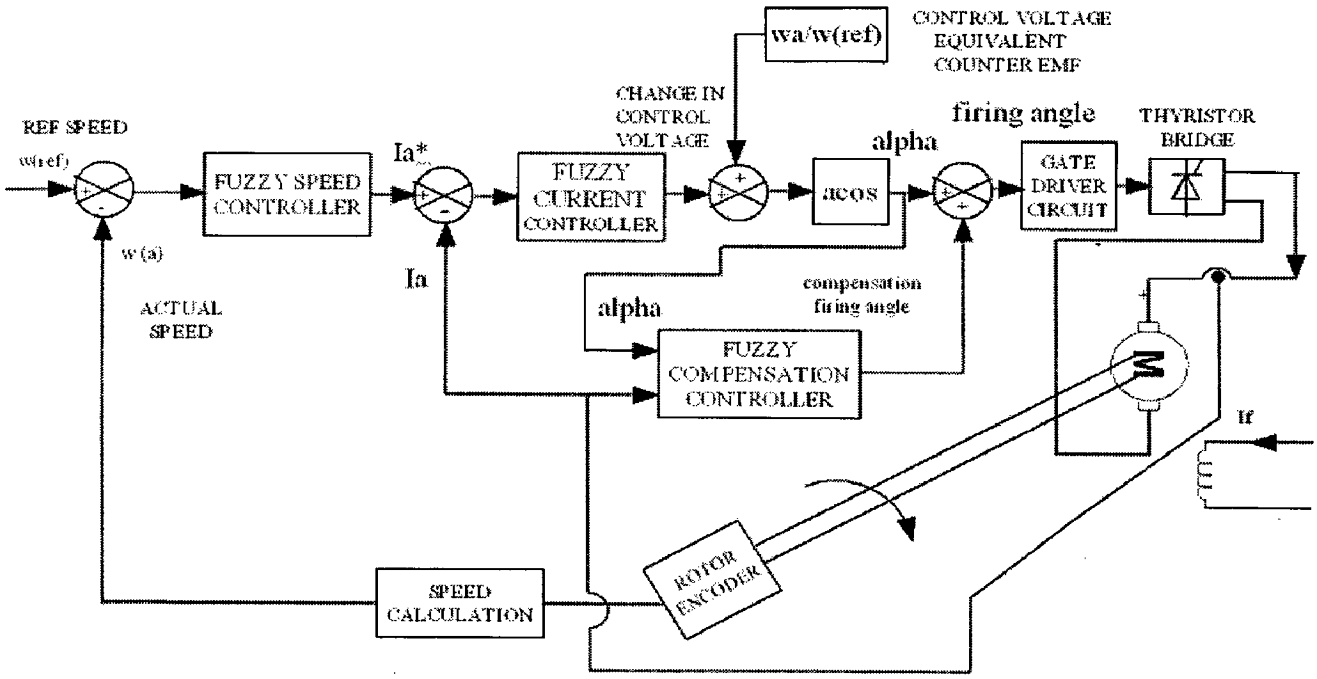
FIG 3.4

CHAPTER 4

FUZZY LOGIC CONTROLLED CONVERTER FED DC MOTOR DRIVE

4.1 CLOSED LOOP FUZZY CONTROLLED DC MOTOR:

The complete closed loop block diagram of phase controlled converter fed DC MOTOR drive is shown in fig: 4.1



CLOSED LOOP FUUZZY PHASE CONTROLLED CONVERTER FED
DC MOTOR DRIVE

FIG: 4.1

The closed loop uses three fuzzy controllers as shown above.

1. Fuzzy speed controller
2. Fuzzy current controller
3. Fuzzy compensation controller

4.1.1Fuzzy speed controller:

Fuzzy speed controller takes the speed error (E) and change in speed error (CE) as inputs and generates reference armature current for fuzzy current controller in pu.The speed is sampled at certain frequency (1k to 100k)

***4.1.2Fuzzy current controller**:*

Fuzzy current generates the control voltage of thyristor converter which decides the Delay firing angle for triggering by taking the current error (E) and change in current error (CE) as parameters.

4.1.3 Fuzzy compensation controller:

Fuzzy compensation controller is used to linearize the converter transfer characteristics at discontinuous mode to make the linear.

4.2 DESIGN OF FLC:

4.2.1 *Design parameters of FLC:*

1) Fuzzification strategies and the interpretation of a fuzzification operator (fuzzifier),

2) Data base:

a) discretization/normalization of universes of Discourse,

b) Fuzzy partition of the input and output spaces,

c) Completeness,

d) Choice of the membership function of a primary Fuzzy set

3) Rule base:

a) Choice of process state (input) variables and control (output) variables of fuzzy control rules

b) Source and derivation of fuzzy control rules,

c) Types of fuzzy control rules,

d) Consistency, interactivity, completeness of fuzzy Control rules.

4) Decision making logic

a) Definition of a fuzzy implication,

b) Interpretation of the sentence connective *and,*

c) Interpretation of the sentence connective *also,*

d) Definitions of a compositional operator,

e) Inference mechanism;

f) Defuzzification strategies and the interpretation of a defuzzification operator (defuzzifier).

While conventional controllers depends on the accuracy of the system model and parameters .FLC based on heuristic knowledge and linguistic description to perform a task all the effects of inaccurate parameters are reduced. But FLC requires enough knowledge for the system.

Initially the system is simulated with PI controller for finding the complete behavior, knowledge of the system.

4.2.2 ***Design steps:***

STEP1: DEFINING INPUTS, OUTPUTS AND UNIVERSE OF DISCOURSE

Defining inputs, outputs and universe of discourse (UOD) to apply heuristic knowledge in the FLC first inputs, outputs and UOD are defined.

(A): SPEED CONTROLLER:

Input speed error (E) and change in speed error (CE) and the output is reference armature current for current controller (I_r)

Considering the forward motoring of the system the maximum possible speed is rated speed of the system.

***Error* (E) *and Change in error (*CE):**

$$E(K) = \omega_r - \omega_a$$

$$CE(k) = E(k) - E(k-1)$$

Where ω_r = reference speed for machine

ω_a = actual speed of machine sensed using rotor encoder

At starting the maximum possible error is the rated speed of the motor.

The UOD for error is [-2900, 2900]

The change in error is also CE (UOD) [-2900, 2900]

Taking the rated speed of machine as scaling parameter then the UOD for both error ,change in error are [-1,1]

Output (I_r):

UOC for armature current is [-1, 1]

Taking the rated current as scaling parameter

(B): CURRENT CONTROLLER:

For current controller the inputs are armature current and change in armature current error.

$$\text{Current error} \quad E(k) = I_r - I_a$$

$$\text{Change in current error} \; CE(k) = E(k) - E(k-1)$$

Where I_r = the armature reference current generated by fuzzy speed controller

I_a = the actual armature current from current sensor (A/D converter)

Similarly the UOD for current error and change in current error are defined and taking the rated current of machine as scaling parameter

***Error* (E) *and Change in error* (CE):**

Considering the forward motoring of the armature current is always positive taking general limits -1,1(actual 0,1)

UOD: current error (CE) [-1, 1]

Change in current error [-1, 1]

***Output* (CU) (control voltage for converter):**

The output of current controller is the change in control voltage for thyristor converter which decides the change in armature voltage for DC MOTOR

Out put voltage of converter $V_a = (\frac{3 * V_m}{\pi})*\cos(\alpha)$

Per unit output voltage $V_{pu} = \cos(\alpha)$

The per unit output voltage for converter limits are -1 to +1

UOD for change in control voltage is [-1, 1]

(C): COMPENSATION CONTROLLER

A. *Fuzzy Linearization of Converter at Discontinuous Conduction*

It was mentioned before that fuzzy control is well-suited in a non-linear system, especially where parameter variation problem exists. Therefore, here fuzzy method of $\Delta\alpha$ angle compensation, in order to linearize the converter transfer characteristics in discontinuous conduction mode. The special feature in fuzzy control is that the $\Delta\alpha$ angle is expressed as a fuzzy relation of the variables I_a and α angle. The set of rules for fuzzy compensation is given in the matrix form in Table 4.1

α /Ia	NB	NM	ZE	PM	PB
NVB	NVB	PB	PB	PB	PB
NB	NVB	Z	Z	Z	Z
NM	NVB	NS	NVS	NVS	NVS
NS	NVB	NM	NS	NS	NS
ZE	NVB	NB	NM	NM	NS
PS	NVB	NVB	NB	NM	NM
PM	NVB	NVB	NB	NB	NB
PB	NVB	NVB	NVB	NB	NB
PVB	NVB	NVB	NVB	NVB	NB

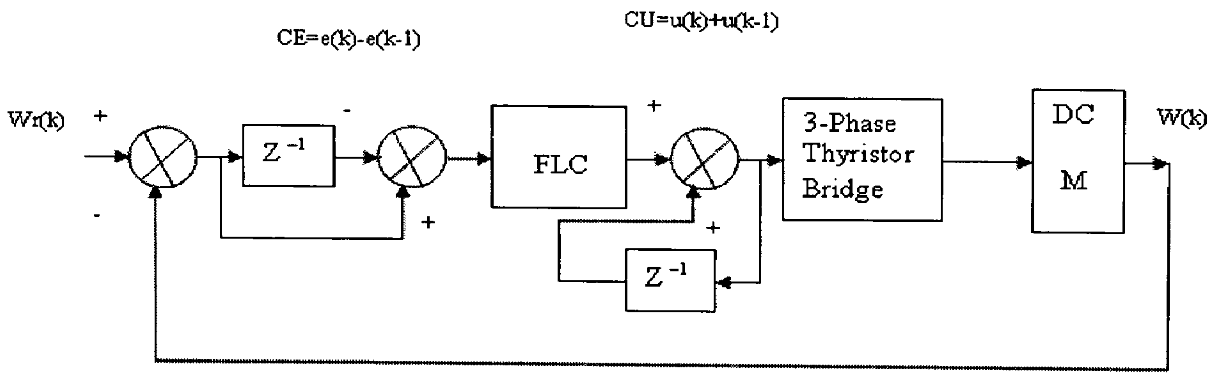
TABLE: 4.1

A typical rule has the following structure:
If I, is small negative (NS) AND α is small positive (PS) THEN $\Delta\alpha$ is small negative (NS)

The current $I_a(pu)$, is treated as normalized value. The universe of discourse of the variables cover the whole discontinuous conduction region. The sensitivity of a variable determines the number of fuzzy subsets. The universe of discourse of α is described by five fuzzy subsets, whereas $I_a(pu)$ and $\Delta\alpha$ are described by nine and eleven subsets, respectively. The linguistic terms used for the subsets are for convenience.

Block diagram for FLC:

FLC mathematical block diagram is shown is fig 4.2



FLC FOR CONVERTER FED DC MOTOR

FIG: 4.2

STEP 2: DEFINING FUZZY MEMBERSHIPFUNCTIONS AND RULES

To perform fuzzy computation the inputs and outputs mustbe converted from numerical or crisp value into linguistic forms the terms such as “small”,” big” are used to quantize the inputs and outputs values into linguistic values .

The linguistic terms are shown in table4.2

LINGUISTIC VARIABLE	MEANING
NVB	Negative very Big
NB	Negative Big
NM	Negative Medium
NS	Negative Small
ZE	Zero
PS	Positive Small
PM	Positive Medium
PB	Positive Big
PVB	Positive very Big

TABLE 4.2

Fuzzy membership functions are used to convert fuzzy crisp values into linguistic terms. A fuzzy membership function can contain several fuzzy sets depends on how many linguistic terms are used. Each fuzzy set represents one linguistic term. Several fuzzy sets are obtained using several linguistic terms. The number for indicating how much a crisp value can be a member in each fuzzy set is called degreed of membership. One crisp valued may be converted in to partly in many fuzzy sets but the membership degree in each set may different.

STEP 3: SELECTION OF FUZZY MEMBERSHIP FUNCTIONS

The control output of fuzzy controller not only depends on the defuzzification but also depends on the type of membership functions selected There are different membership function shapes based on their performance and experience. The popular shapes are triangular, trapezoidal because these shape easy to represent and require less computation time and easy implementing in programming. Using simple mathematical equations. Which in turn reduces the time for crisp output calculation in defuzzification.

***Rule table fuzzy speed and current controller*:**

The rule table of fuzzy speed and current controller with 49 rules is shown Table 4.3

E / CE	NB	NM	NS	ZE	PS	PM	PB
NB	NVB	NVB	NVB	NB	NM	NS	ZE
NM	NVB	NVB	NB	NM	NS	ZE	PS
NS	NVB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PVB
PM	NS	ZE	PS	PM	PB	PVB	PVB
PB	ZE	PS	PM	PB	PVB	PVB	PVB

TABLE 4.3

CHAPTER 5

SIMULATION STUDY

Before implementing the hardware the fuzzy control algorithm is first verified by computer simulation in MATLAB 7.01 time domain.

The parameters of the DC MOTOR drive is shown in table 5.1

PARAMETER	VALUE
H.P	0.5
RATED SPEED	2900
RATED CURRENT	2.2A
VOLT	220V
Armature resistance	12.75
Armature inductance	0.2166
Field resistance	1115
Field inductance	3.1338

TABLE 5.1

5.1 SIMULINK MODEL:

MATLAB simulink model is shown in fig: 5.1

5.1.1 Modeling equations:

Speed controller:

For speed control ω_r = ref speed

ω_a = actual speed

Speed error $E(k) = \omega_r - \omega_a$

Change in speed error $CE(k) = E(k) - E(k-1)$

The output of speed controller is the ref current for current controller

$$CU(k) = I_r$$

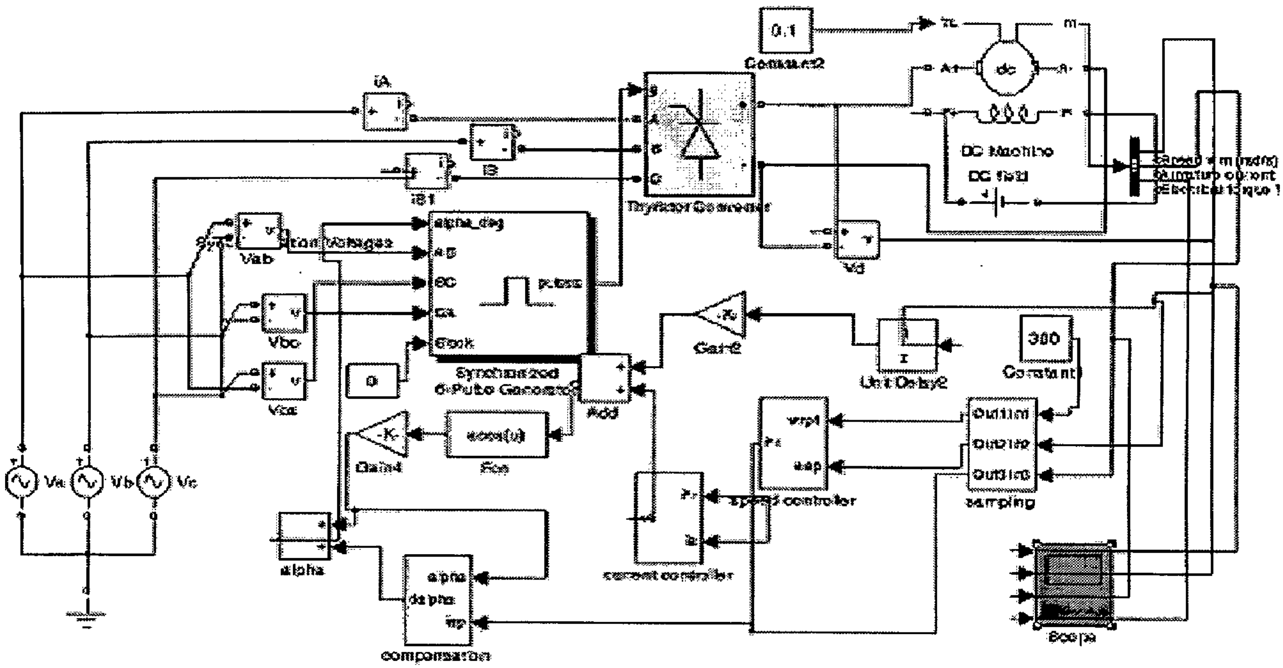


FIG 5.1

Table 4.2 shows the simulation sampling times used for current and speed

Parameter	Sampling time
speed	10KHZ
current	1KHZ

TABLE: 5.2

Current controller:

Current error $E(k) = I_r - I_a$

Change in current error $CE(k) = E(k) - E(k-1)$

Control output of fuzzy current controller is the change in control voltage for thyristor converter

$$CU(k) = \Delta V_c$$

If speed of machine at back emf E_b is N_r and at any back emf E speed is N

Then control voltage corresponding to present speed or back emf

$$V_c(k-1) = \frac{N}{N_r} = \frac{E}{E_r}$$

Total control voltage $V_c(k) = V_c(k-1) + \Delta V_c$

Firing angle $\alpha = \cos^{-1}(V_c)$

Compensation firing angle obtained from compensation controller is $\Delta\alpha$

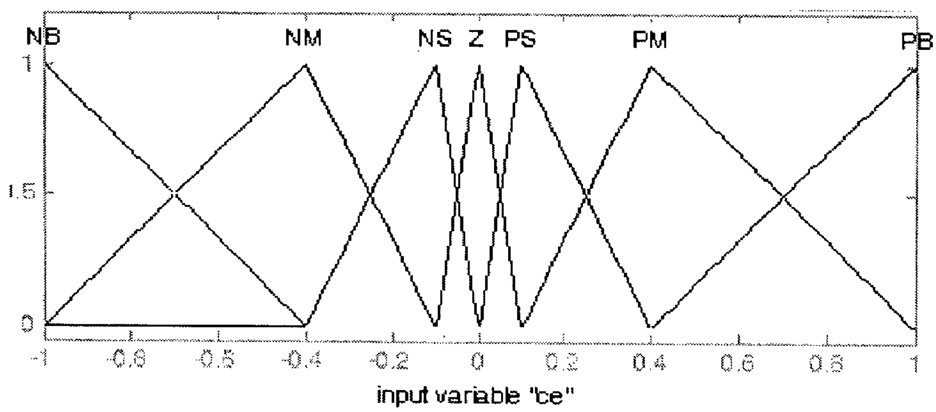
Converter firing angle is $\alpha_c = \alpha + \Delta\alpha$

Where k=sampling interval

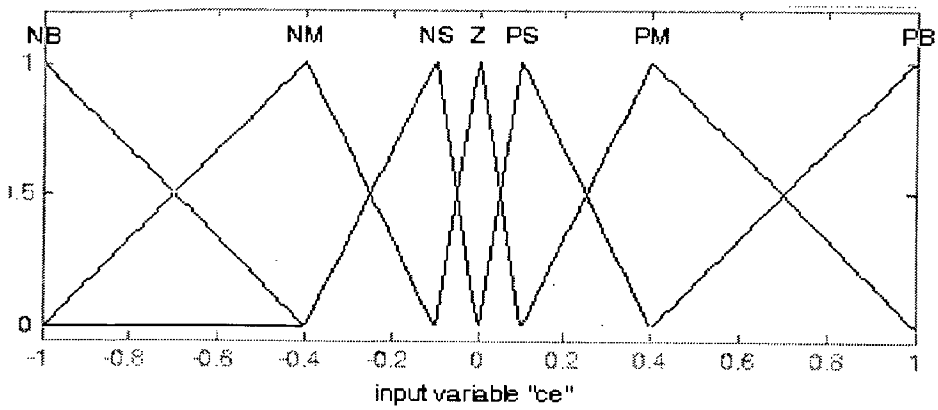
5.2 OPTIMIZED FUZZY SETS AND MEMBERSHIP FUNCTIONS:

5.2.1 Fuzzy speed and current controllers:

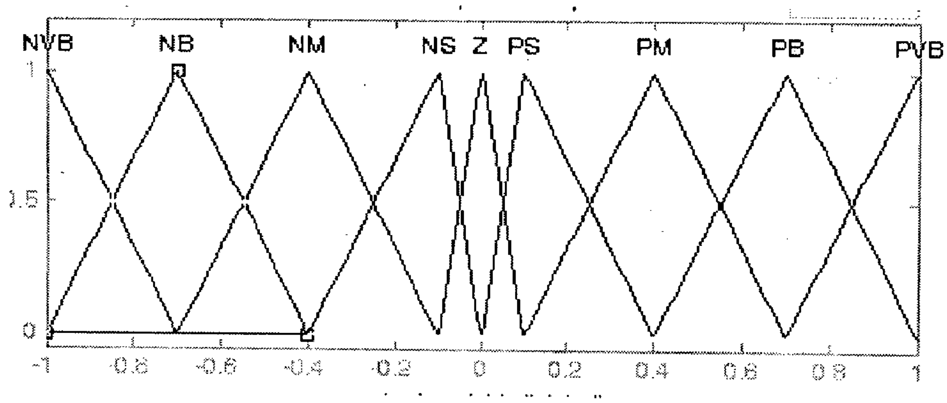
The membership functions are shown in fig 5.2



Speed error (E) 5.2(a)



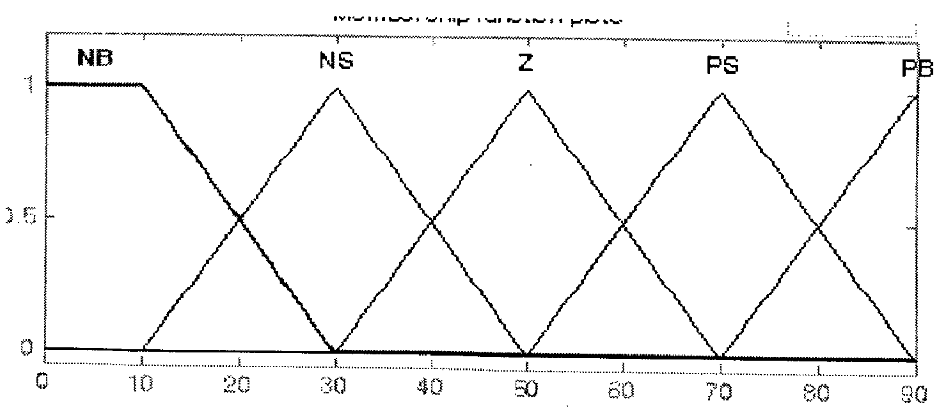
Change in speed error CE 5.2(b)



Chang in control voltage (ΔV_c) 5.2(c)

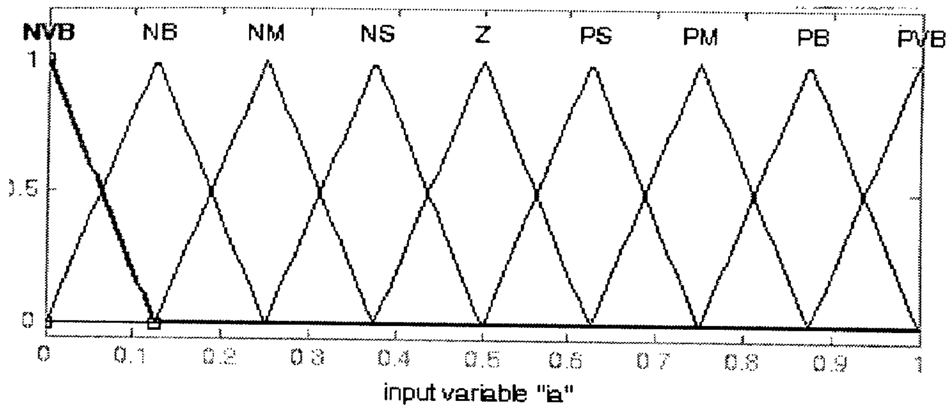
5.2.2 Fuzzy compensation controller:

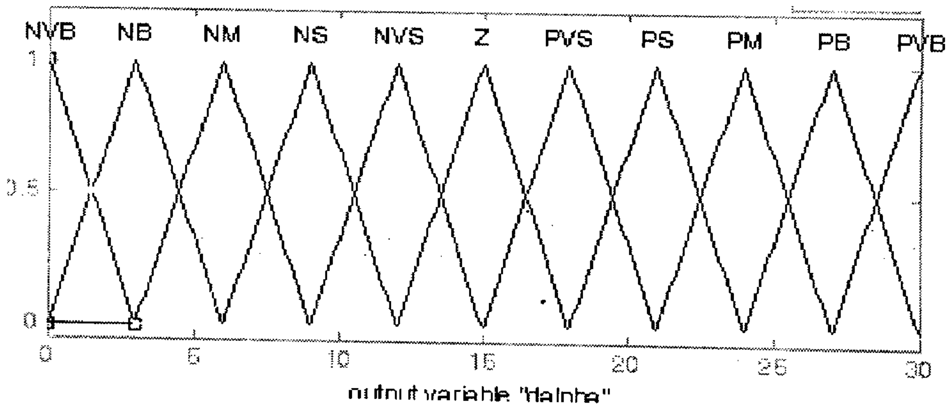
Membership functions for compensation controller ar e shown in fig 5.3



Firing angle (α) 5.3(a)

Armature current 5.3 (b)





Fuzzy compensating firing angle ($\Delta\alpha$) 5.3 :(c)

5.2.3 Precision control and sensitivity:

Fuzzy subsets for each variable have asymmetrical shape causing the more crowding near the zero point this permits the precision control near steady state operating point of speed. Considering the sensitivity of the control variable a finer partition is done for fuzzy sets as shown in fig 5.3, 5.4

5.2.4: designing (Rule base) control output:

As fuzzy control output depends on the intuition and experience instead of system model

1. If both *e(pu)* and *ce(pu)* are zero, then maintain the present control setting *U(K)* (i.e., *du(pu)* = 0)

2. If *e(pu)* is not zero, but is approaching this value at satisfactory rate, then maintain the present control setting $U(k)$

3.If e(pu) is growing, then change in the control signal *du(pu)* is not zero and its value depends on the magnitude and sign of *e(pu)* and *ce(pu)*

Control procedure:

1. Sample ω_r and ω_a
2. Compute error (E), change in error (CE) and their per unit values
3. Fuzzification of error (E) and change in error (CE)
4. Identify the four valid rules and calculate the degree of membership using MIN operator.
5. Retrieve *dui* for each rule
6. Calculate resultant crispy value of *du(pu)* by center of gravity Defuzzification method.

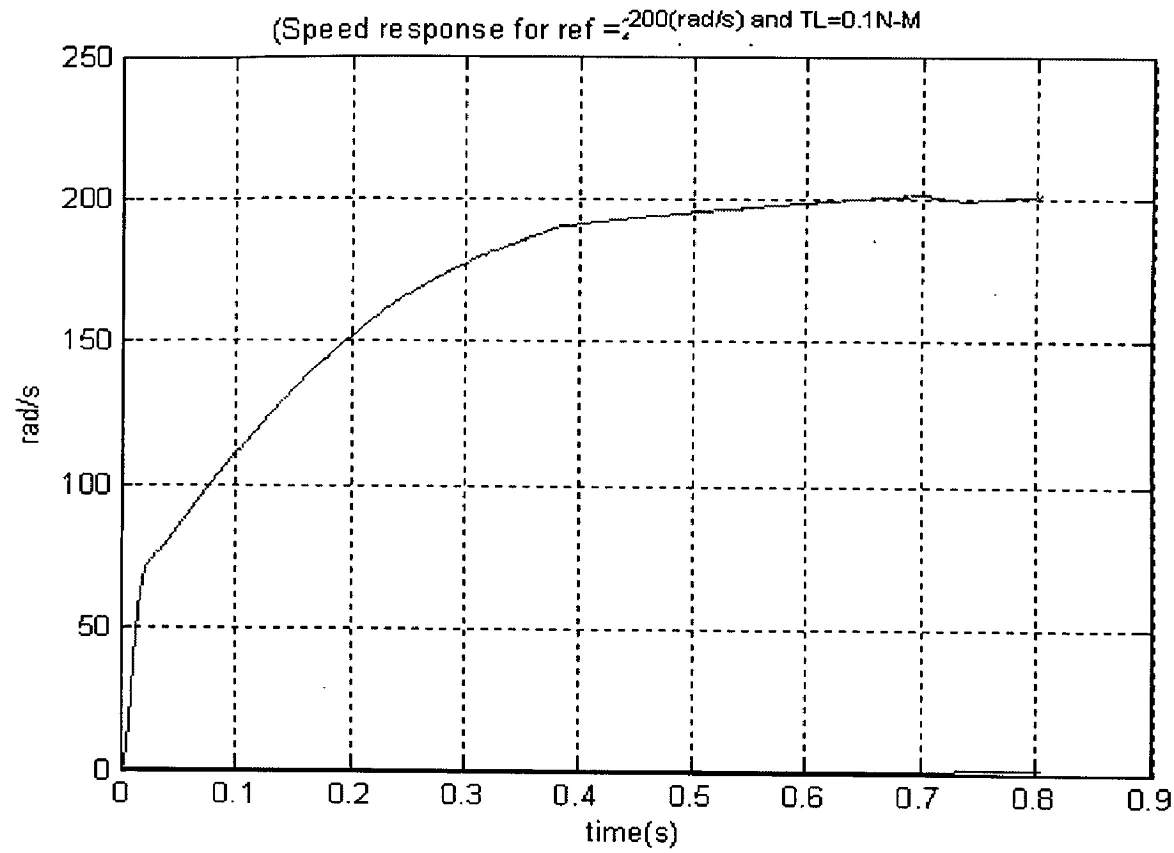
5.3 SIMULATION RESULTS:

5.3.1 with constant load:

Keeping load torque constant the response is as shown in fig 5.4

Speed:

parameter	Value
Over shoot	0.0
Steady state error	0.1%
Rise time	0.6sec
Settling time	0.6sec

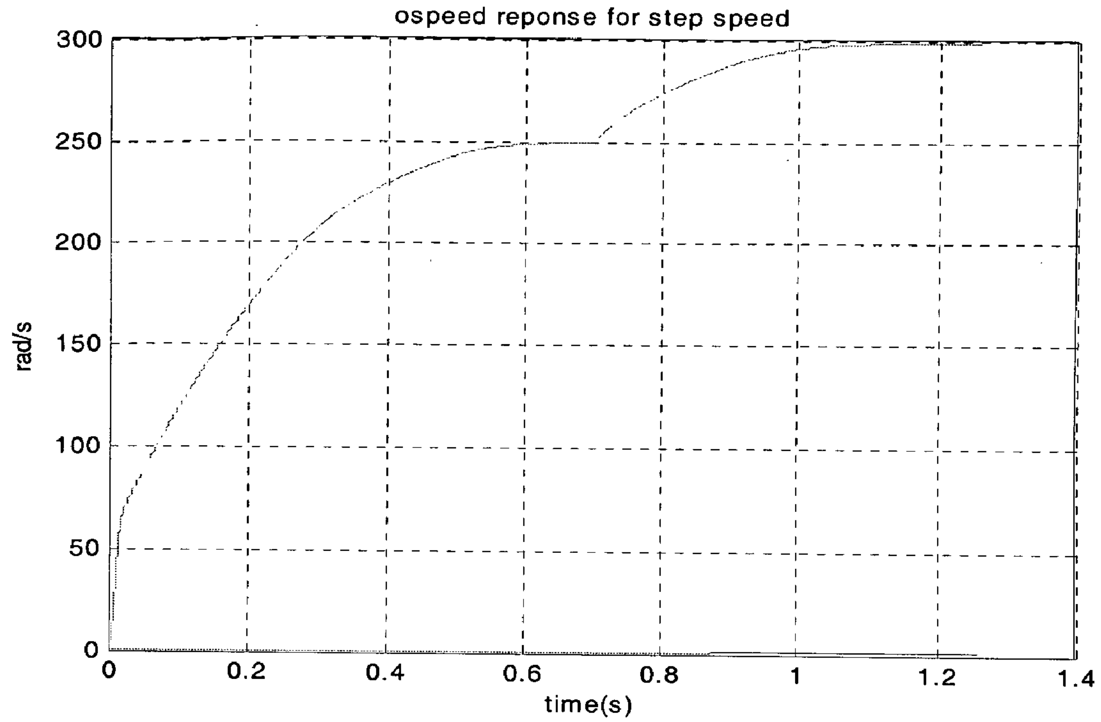


Speed plot 5.4

5.3.2 Step speed:

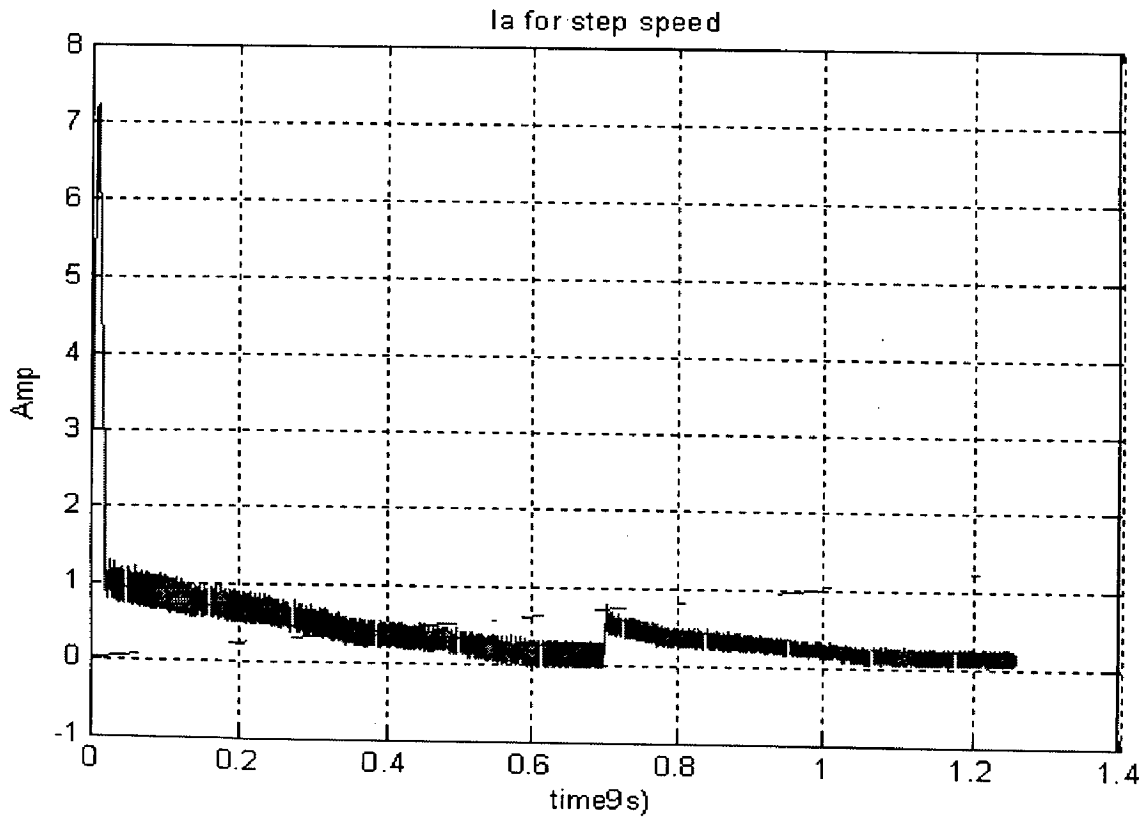
Step response of the drive from 250 to 300(rad/s) is shown in fig 5.5

Speed:
Speed response is shown in fig 5.5(a)



ospeed reponse for step speed
rad/s
time(s)
300
250
200
150
100
50
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4

FIG: 5.5(a), 5.5(b)



Ia for step speed
Amp
time9s)
8
7
6
5
4
3
2
1
0
-1
0
0.2
0.4
0.6
0.8
1
1.2
1.4

Armature voltage:

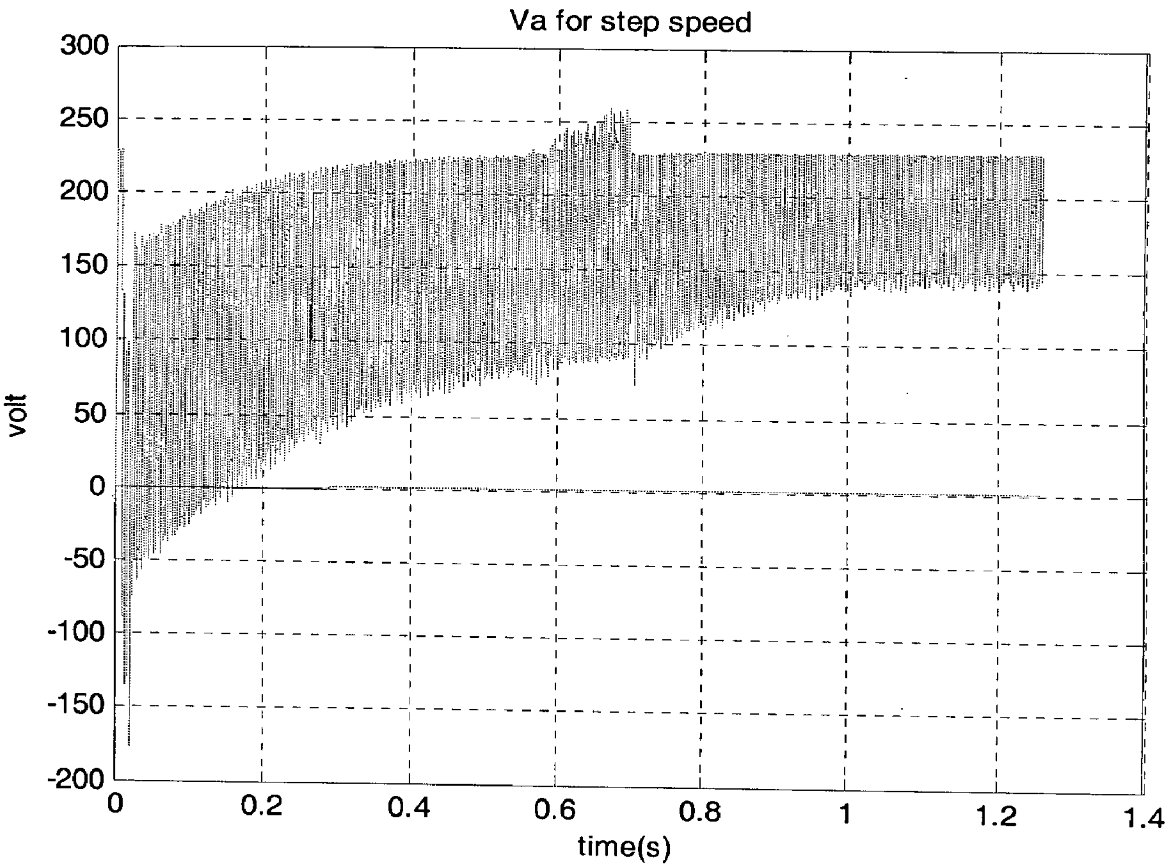


FIG: 5.5(C)

5.3.3 ***Applying sudden load (step load):***

By applying the sudden load applied at t= 0.8s after the machine has reached steady state speed then speed fall is noted and the corresponding plots are shown in fig 5.6

Drop in speed obtained is 2.66 %(8 rad/s) percentage of steady state speed

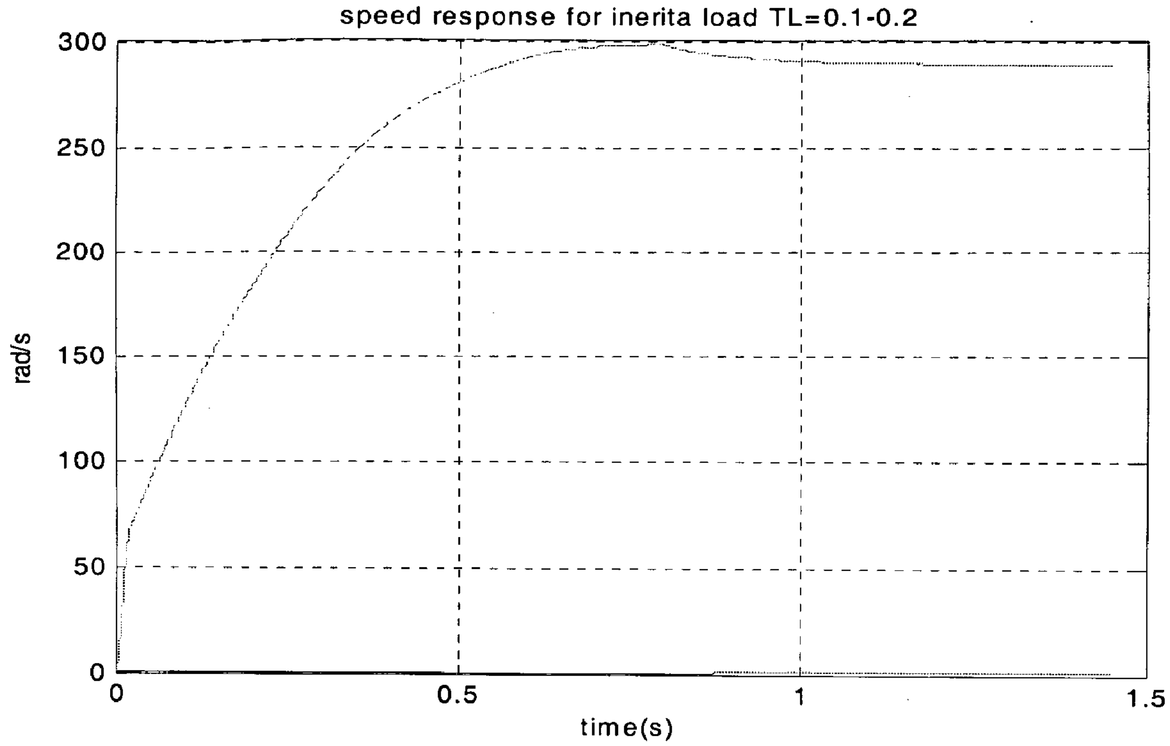
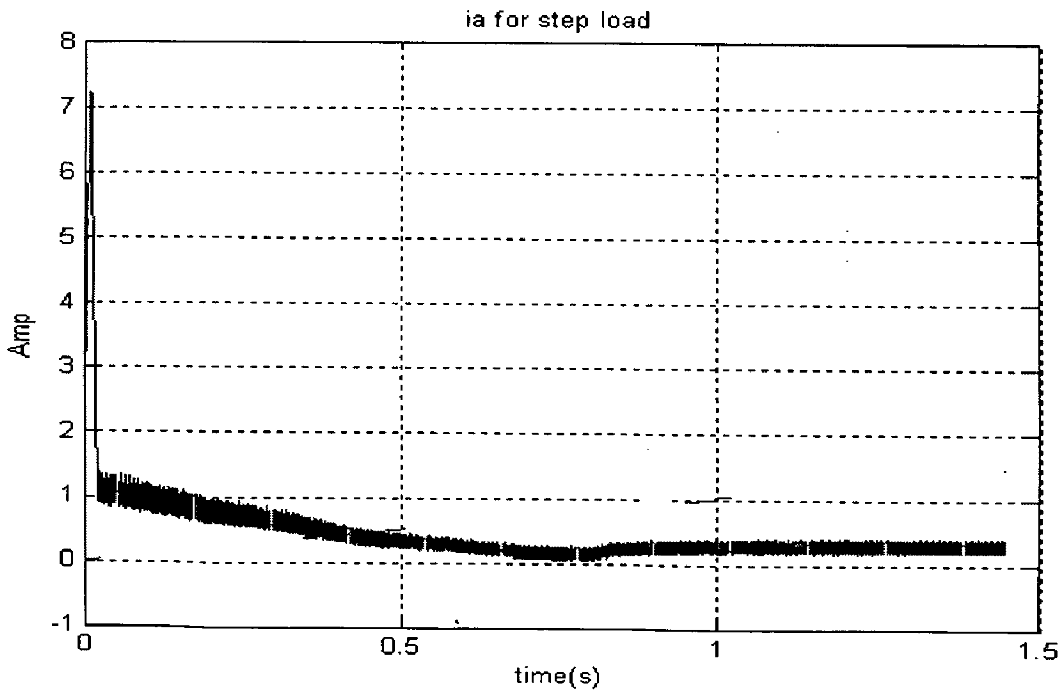


FIG 5.6(a)

Armature current:

FIG 5.6(b)



Armature voltage:

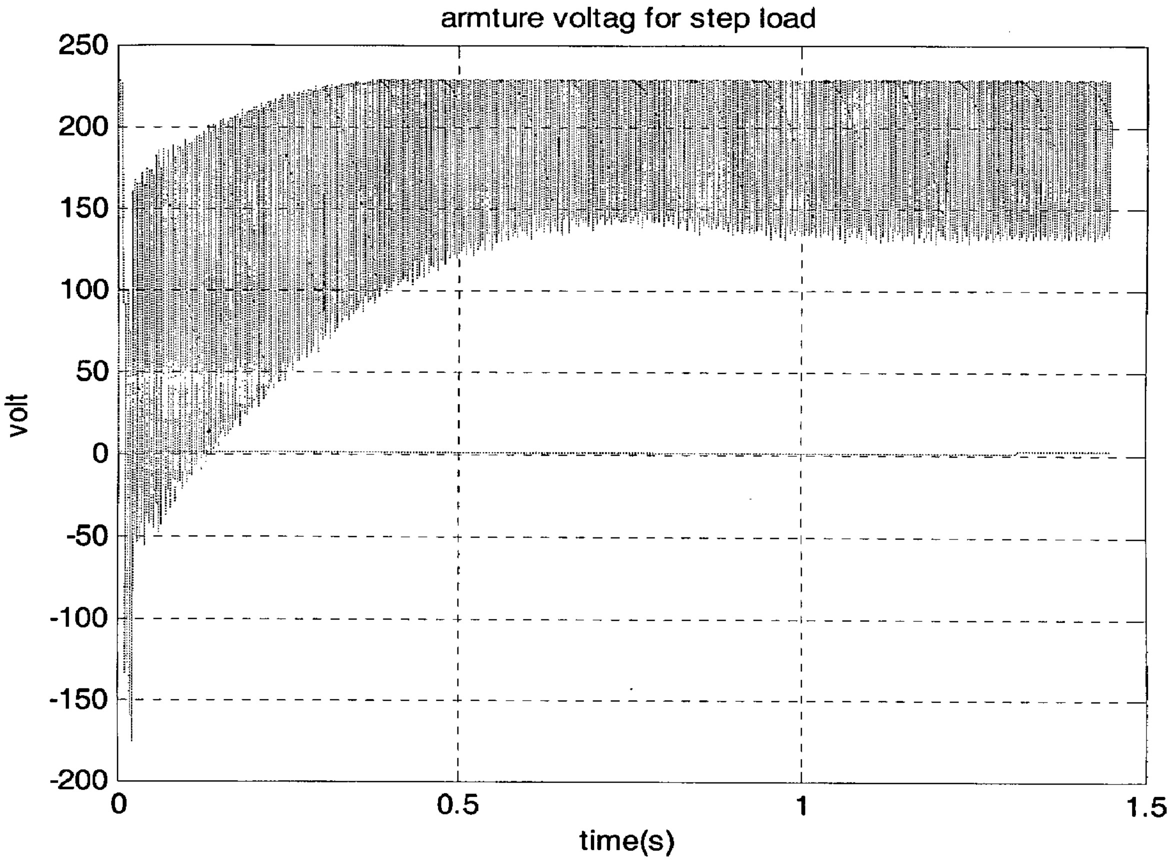


FIG 5.6(c)

In this chapter the fuzzy fed dc motor simulation studied and results are taken for different loading conditions of the machine with constant load, step response sudden load And performance observed. fuzzy results are with best performance.

CHAPTER 6

SYSTEM DEVELOPMENT

The computer based firing scheme used for generating firing pulses for the phase controlled converter fed DC MOTOR drive and the complete interfacing is shown in fig 6.1

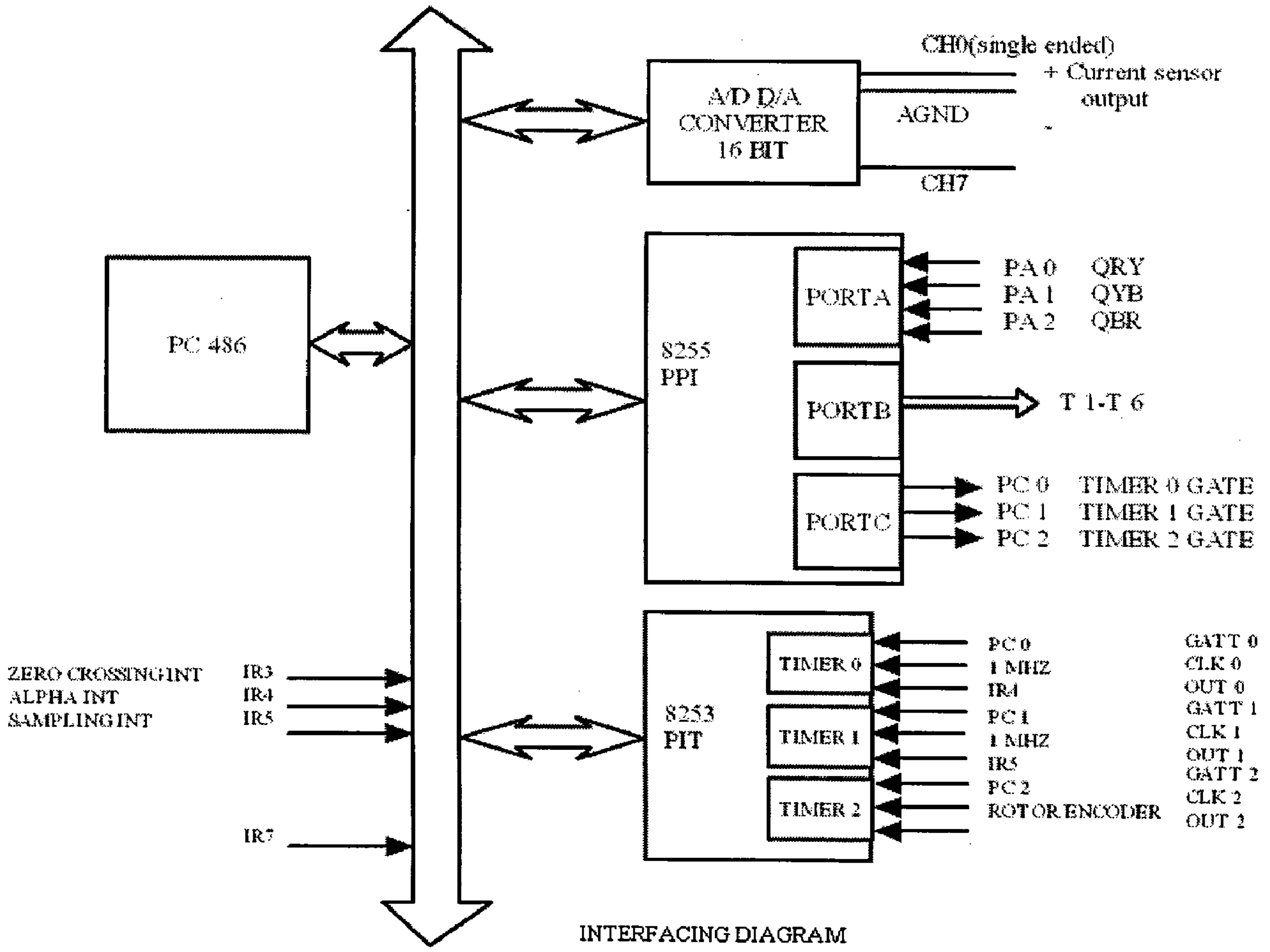


FIG 6.1

INTERFACING DIAGRAM SHOWING ALL CARDS

It uses two cards

1. INPUT/OUTPUT card
2. A/D converter card

Advantages of using computer interfacing:

Using computer interfacing

1. computation time required for calculation can be fast comparatively to a microcontroller
2. higher sampling frequencies can also be used for sampling current and speed signals
3. As the number of interrupts increases the complexity also reduces.

6.1 SYSTEM HARDWARE:

6.1.1 Synchronizing circuit:

The circuit shown in fig 6.2 is used for synchronization of the zero crossing of the 3-phase AC supply. The line-line voltages are stepped down to 12V using 440/12V step down transformer. The zero crossing the detector of three phase supply is used for interrupting the processor at every 60deg or 3.3ms and this is connected to IR3 interrupt pin of the interrupt controller.

Quantizer (QRY, QYB, QBR) signals are taken out from the converter gate are used for indicating forward biased condition of the thyristor at any instant with this the the pair of thyristor to be triggered can known.

The interrupt is taken from the NAND gate is of noise free which causes the unwanted interrupting of the processor. The quantizer signals are connected to the PORT A of the 8225 of the I/O card.

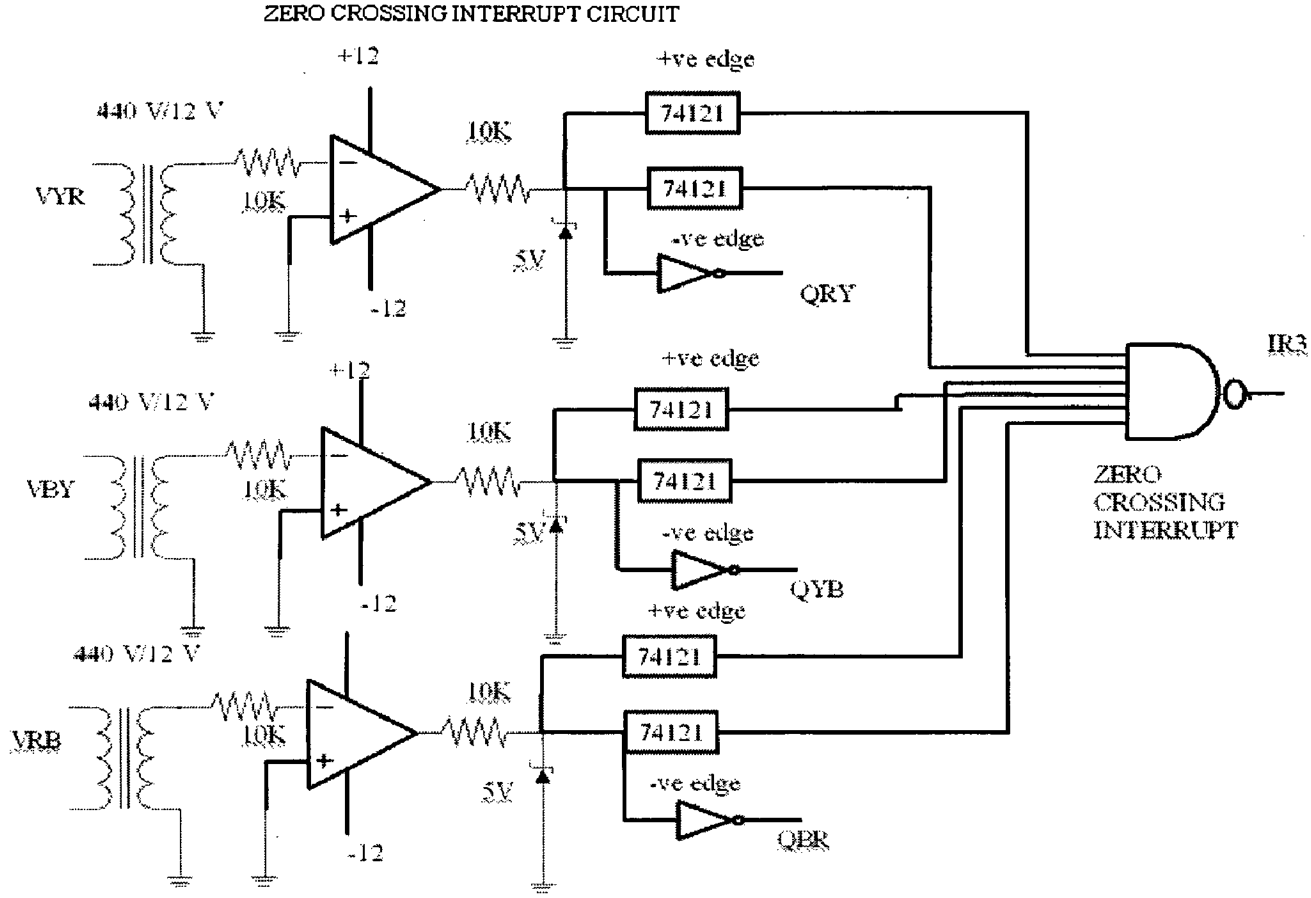


FIG 6.2

The quantizer signals (QRY, QYB, and QBR) and the zero crossing interrupt are shown in fig 6.3

6.1.2 Complete interfacing:

(a): Interrupts:

1. As shown in fig 6.1 the external hardware interrupt used for interrupting the system is connected to higher priority interrupt pin of system.
2. The delay or alpha interrupt IR4 form TIMER 0 of timer card is connected to the next priority interrupt pin of interrupt controller
3. Sampling interrupt generating from the TIMER 1 of 8253 (used for sampling the current and speed) is connected to IR5 of the system.

IR3	ZERO CROSSING INTERRUPT
IR4	ALPHA INTERRPT
IR5	SAMPLING INTERRUPT

TABLE 6.1

(b): A/D *converter and current sensor:*

The 16 bit A/D converter card shown in fig 6.1 connected to another ISA slot of 486 computers.

The A/D converter is used in single ended mode by selecting only one channel(CHANNEL 0) for digitizing the analog signal of the armature current of DC MOTOR from the current sensor as shown in fig 6.4 output of current sensor is proportionate voltage .Initially the current sensor is calibrated with 1k,10k variable resistors.

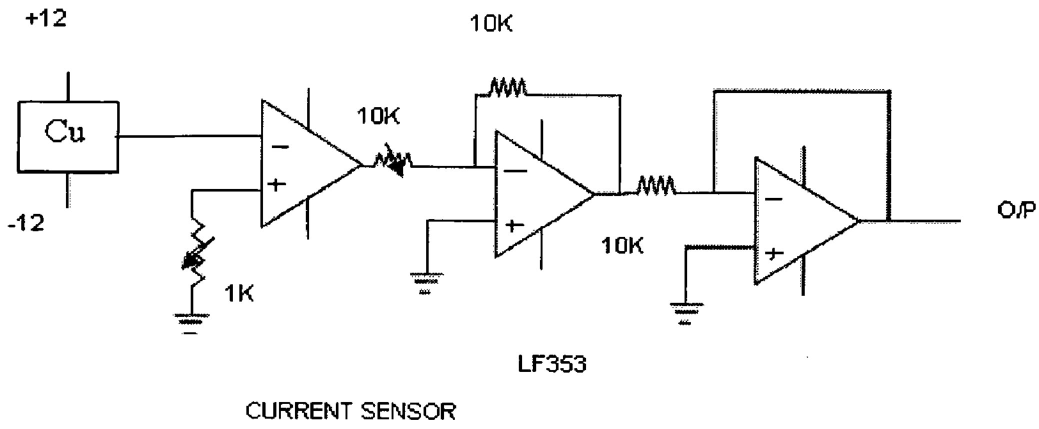

+12
10K
Cu
10K
-12
10K
1K
O/P
LF353
CURRENT SENSOR

FIG 6.4

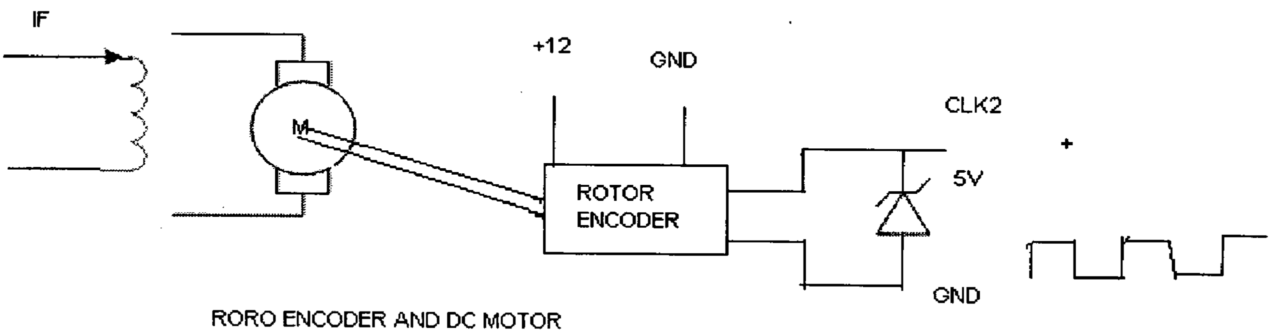

IF
+12
GND
CLK2
M
ROTOR
ENCODER
+
5V
GND
RORO ENCODER AND DC MOTOR

FIG 6.5

Rotor encoder which is coupled to motor will generate pulses of varying clock frequency depending on the speed of the machine .the sensor requires +12 volts power supply and the output at sensor terminals is 0-12V using the zener diode limited 5V this signal is connected to the CLK of TIMER 2 as shown in fig 6.1

(d): Generating firing pulses:

The 8255 peripheral interface chip is having three ports:

PORT A is used for reading the quantizer signals of the zero crossing circuit and PORT B is used for generating firing pulses for thyristors T1-T6 ,PORT C is used for triggering the timers of 8253 chips.

8255 PORTS

PORT A(PA0-PA2)	QRY,QYB,QBR
PORT B(PB0-PB5)	T1-T6
PORT C(PC0-PC2)	GATE 0-GATE2

8253 TIMERS

TIMER 0	Alpha counting
Timer 1	Sampling interrupt
TIMER 2	Counting pulses

TABLE 6.2

(e): Snubber protection:

The series R-C snubber circuit used for protection of thyristor against over voltages is shown in fig 6.6

R= 50OHM

C= 0.1 UF 1000V

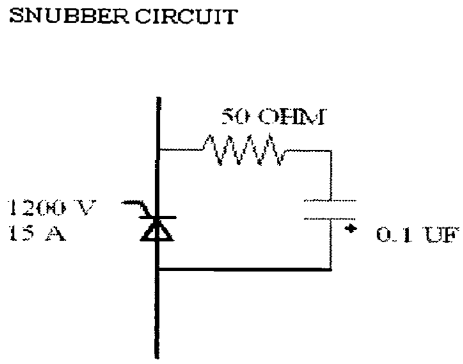


FIG 6.6

(f): Power supply:

5V,+12 and -12v dc power supply is obtained from the circuit shown in fig 6.7.through regulator.

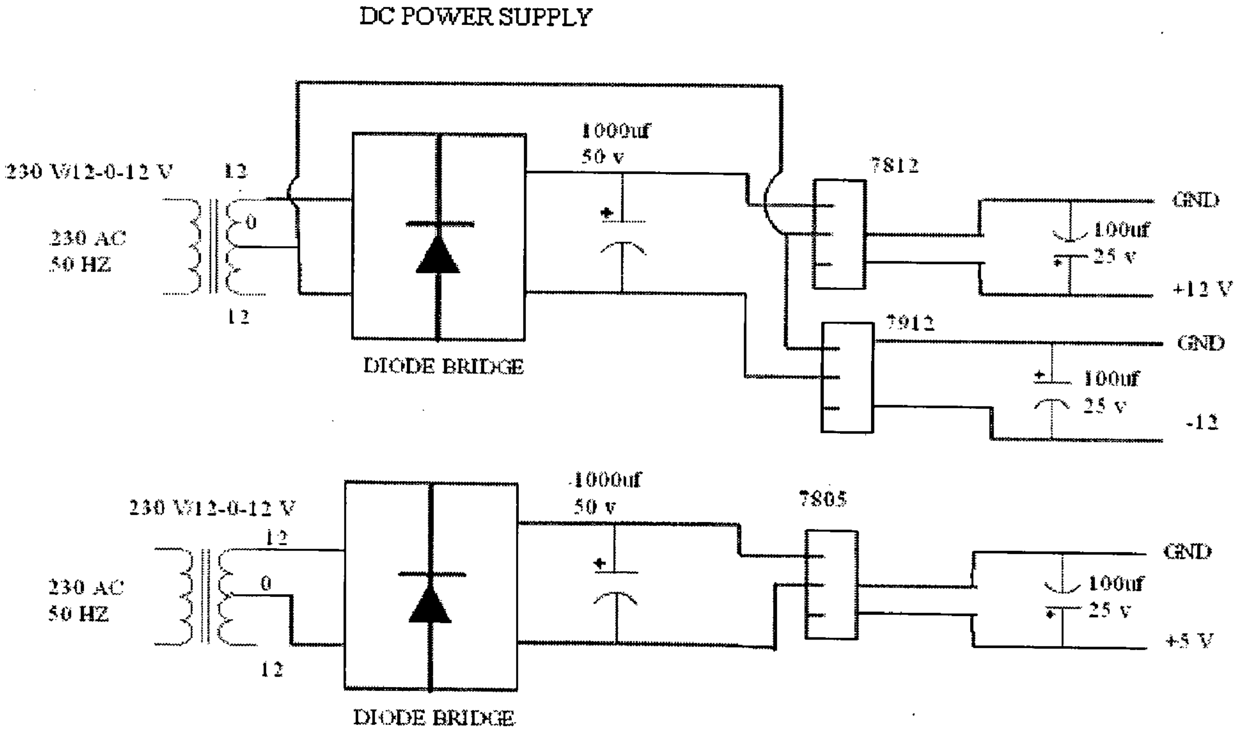


FIG 6.7

6.2 SYSTEM SOFTWARE:

The firing angle control from 0 to 180deg is divided into three zones zone 0, zone 1, and zoze 2 as shown in table 6.3 with this zone index the firing command to issued changes. And firing command look up table is shown in TABLE 6.4

ZONE TABLE

Firing angle	Zone
$\alpha >= 0 \&\& \alpha < 60$	Zone 0
$\alpha >= 60 \&\& \alpha < 120$	Zone 1
$\alpha >= 120 \&\& \alpha < 128$	Zone 2

TABLE 6.3

FIRING COMMAND TABLE

QRY QYB QBR	ZONE 0	ZONE 1	ZONE 2
1 0 1	0x30(5,6)	0x18(4.5)	0x0C(3.4)
1 0 0	0x21(6,1)	0x30(5,6)	0x18(4.5)
1 1 0	0x03(1,2)	0x21(6,1)	0x30(5,6)
0 1 0	0x06(2,3)	0x03(1,2)	0x21(6,1)
0 1 1	0x0C(3.4)	0x06(2,3)	0x03(1,2)
0 0 1	0x18(4.5)	0x0C(3.4)	0x06(2,3)

TABLE 6.4

(a): Programming modes of 8253, 8253:

The 8255 PORT A is programmed in input mode for reading the quantizer signals QRY,QYB,QBR PORT B is programmed in output mode for issuing firing commands to thyristors and PORT C IS programming in output mode for gate triggering of three timers. 8253 TIMER 0 IS Programmed in MODE 0 for generating firing angle delay interrupt and is triggered by pc0 bit of PORT C, TIMER 1: is programming for generating the sampling interrupt is programming in MODE 3 is loaded with sampling count and is triggered by pc1 of PORT and TIMER 2 is used for latching count for latching count for counting speed encoder pulses and triggered by PORT C it is loaded with ffff count at starting.

(b): A/D converter modes:

The A/D converter CHANNEL 0 is selected and connected in single ended mode with software trigger and software transfer. And three gains is selected as 1

(c): Issuing firing commands:

The ref speed is read from the key board and actual speed is calculated from speed encoder is compared and *ERROR*(*E*) and change in error *CHANGE* IN ERROR (*CE*) re calculated then fuzzy speed controller is called for generating the ref armature current in pu this per unit value of armature current is compared with actual current then current *ERROR*(*E*) and *CHANGE IN ERRO (CE)* are passed to fuzzy current controller to generate the CHANG IN ERROR VOLTAG(CU) for thyristor for and the total control voltage is brained from back emf .firing angle is calculated with cosine firing scheme then the converter firing angle is calculated by adding the compensation firing angle from FUZZY COMPENASATON CONTROLLER. When the zero crossing interrupt comes count load value is loaded in TIMER 0 and triggered and system is waiting for interrupt to come when alpha interrupt comes the status of QRY, QYB, QBR are read through PORT A and the firing command is issued from the look table.

Gate drover:

The firing pulses obtained from the 8255 are given to the gate driver circuit of converter which is used to generate short duration pulses the driver circuit is show in fig 6.8

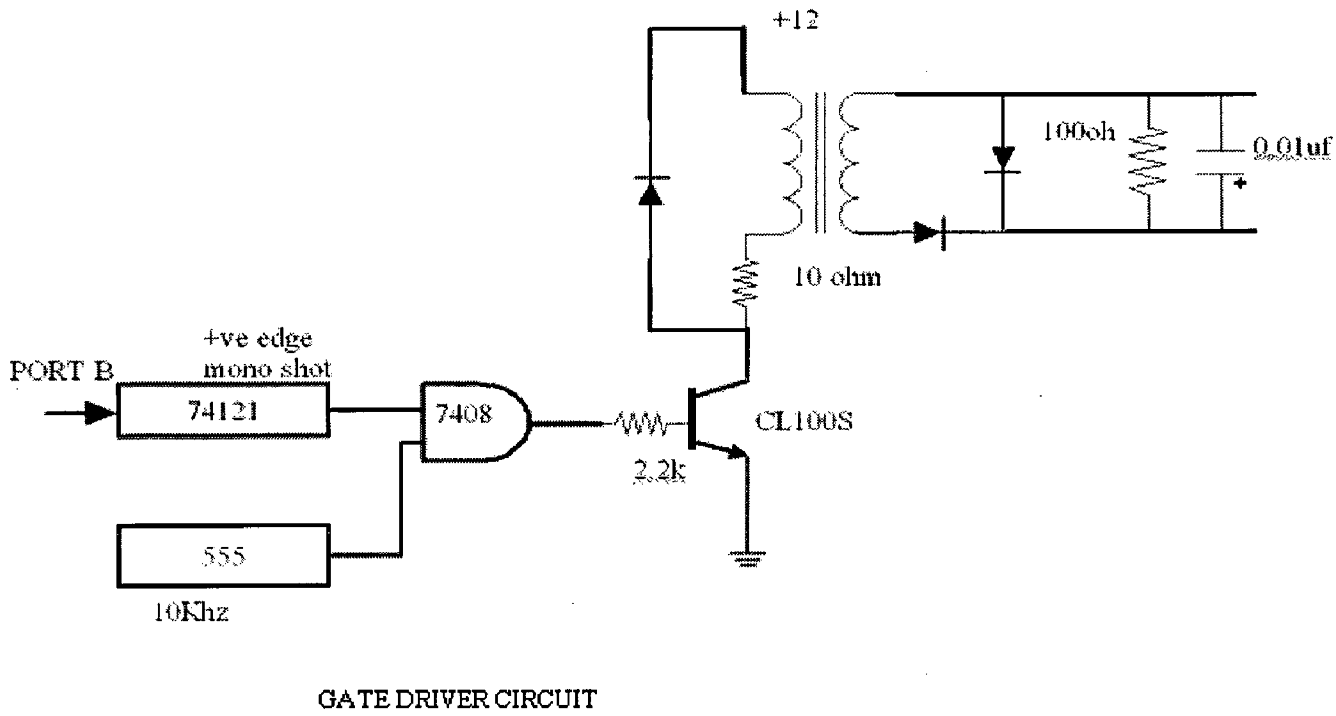


FIG 6.8

6.2.1: OPEN LOOP

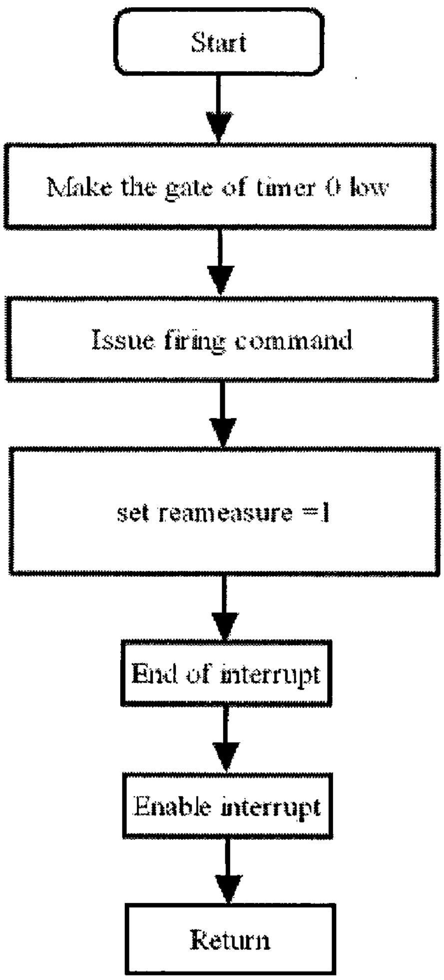
For open loop the fowling the flowcharts are required

1. Main flowchart
2. zero crossing interrupt subroutine
3. alpha interrupt subroutine
4. zone subroutine

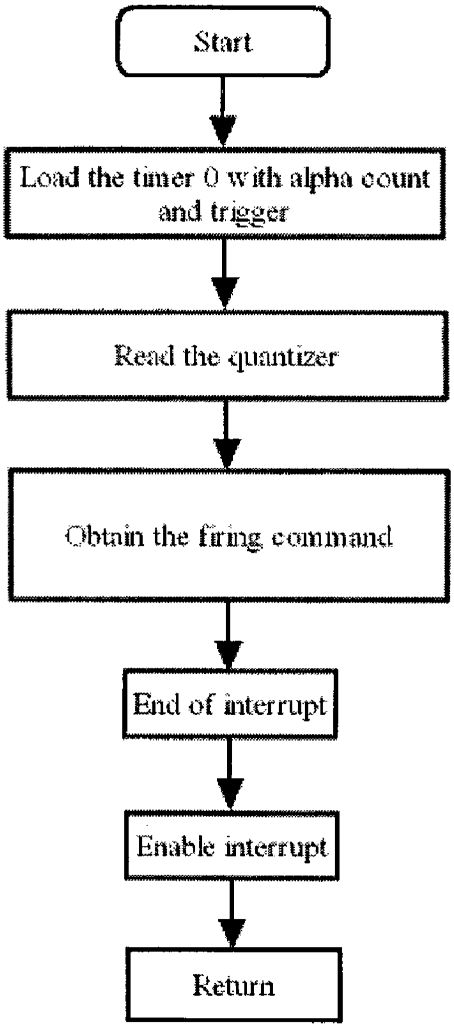
in this firing angle input is read from the key board and machine is started with soft start routine and every timer when the alpha interrupt comes firing commands are issued the main programming the looping by reading stop key if stop key is pressed then machine wil stop in this firing angle can be changed at any time from key board.

FLOWCHARTS (Open loop):

ALPHA SUBROUTINE

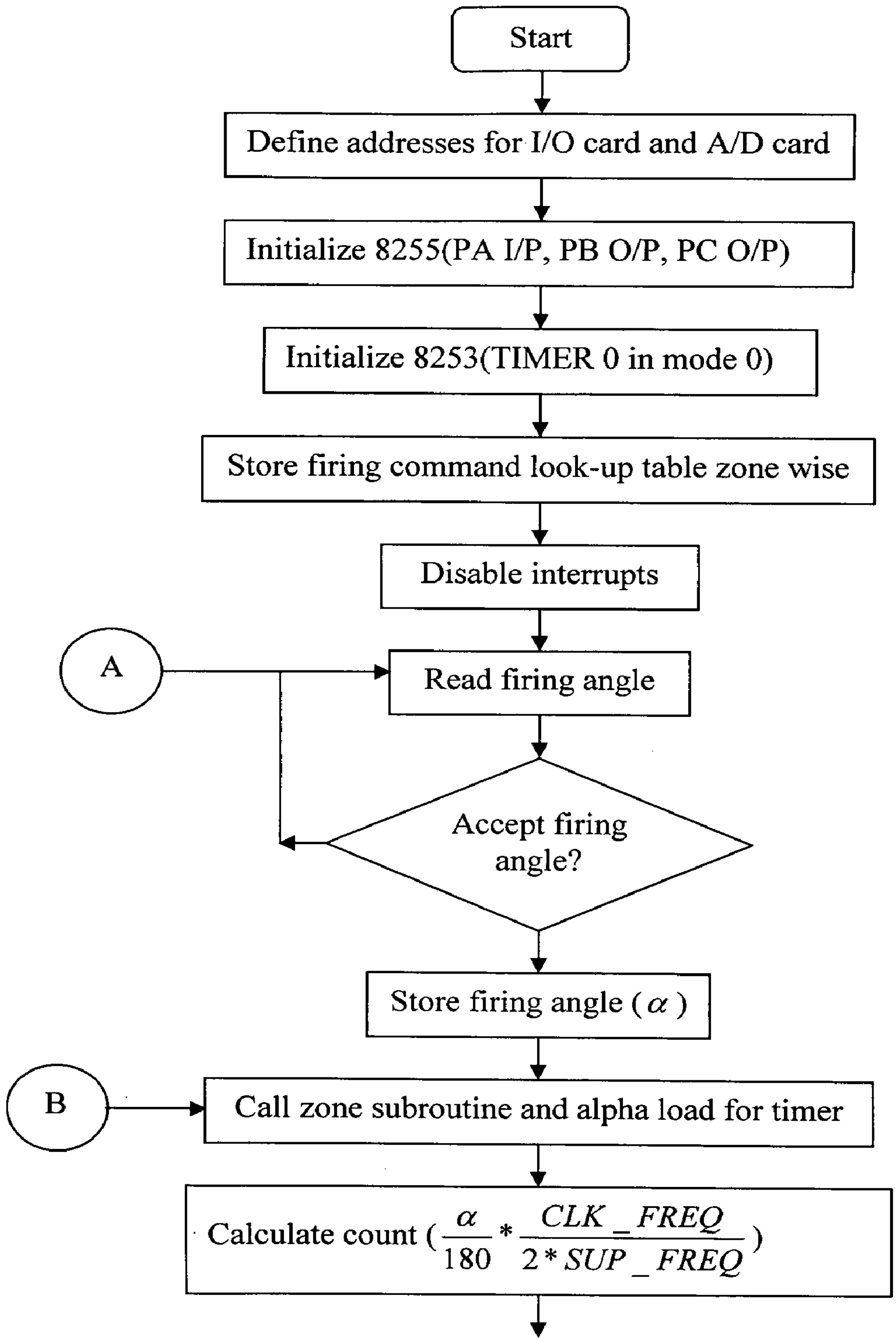


Flowchart: 2

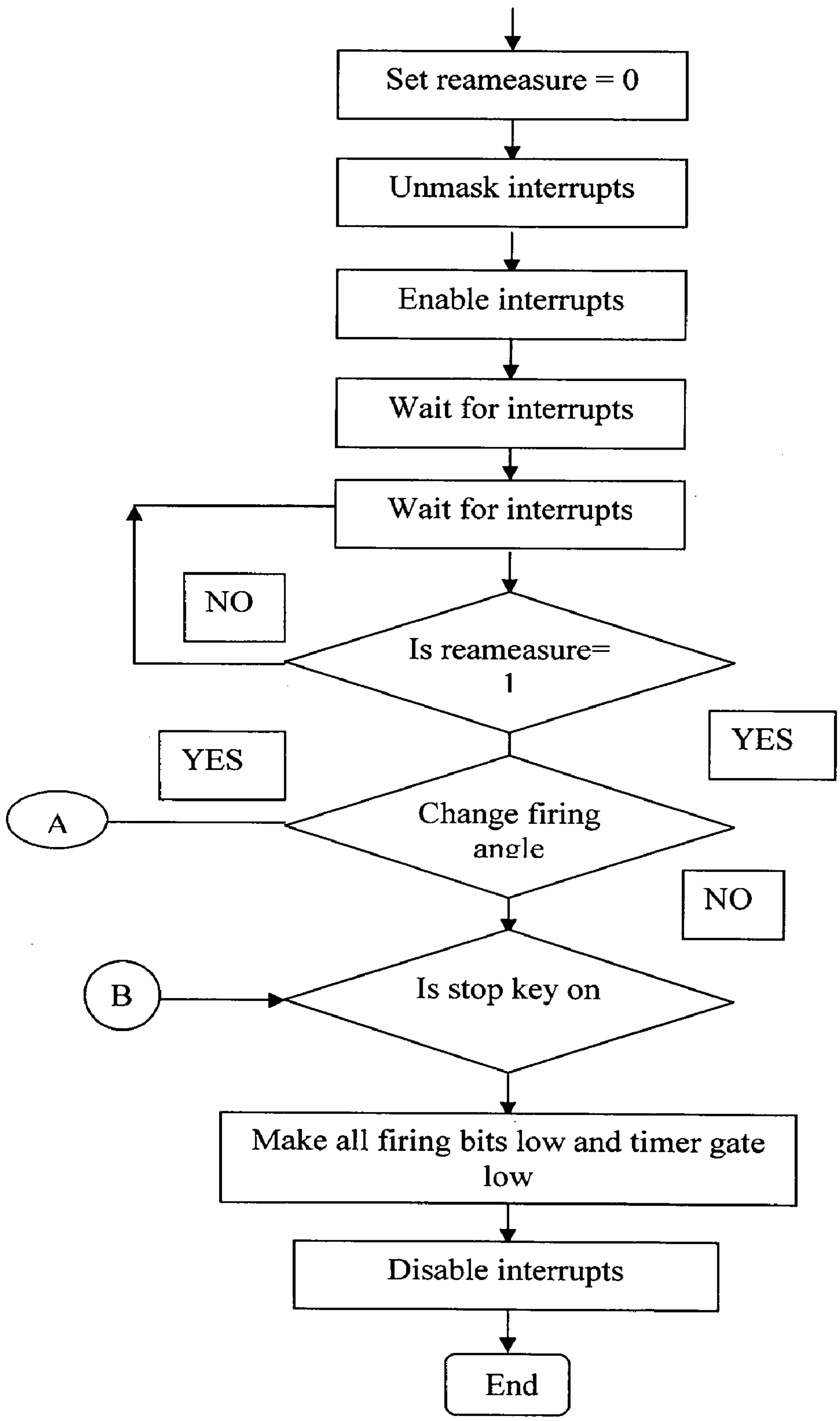


ZERO CROSSING INTERRUPT SUBROUTINE

Flowcharts: 3



MAIN FLOWCHART: 1(A) OPEN LOOP



MAIN FLOWCHART 1(B)

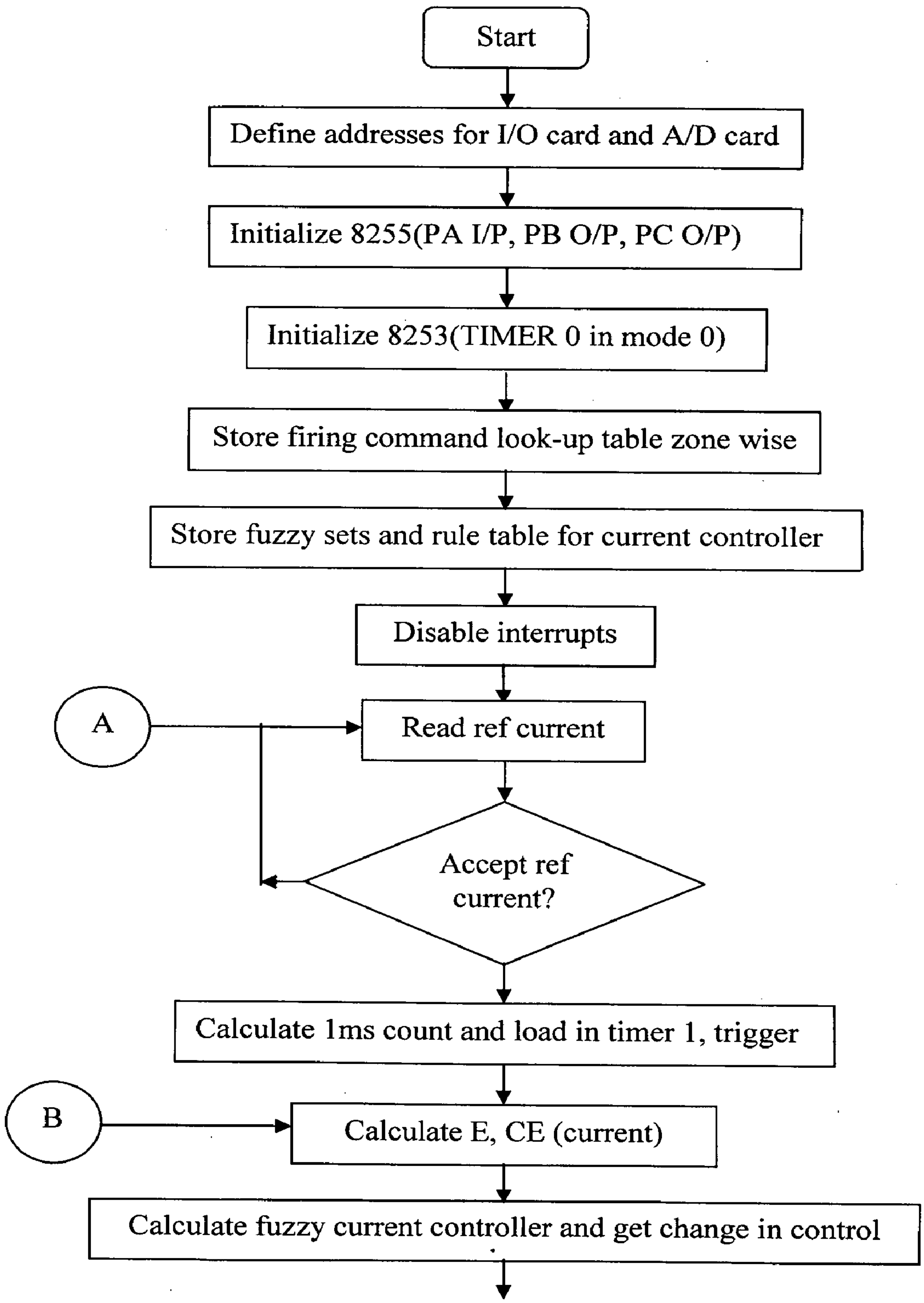
6.2.2Closed loop (with inner current loop):

1. main flowchart
2. interrupt subroutines
   - (a): alpha subroutine
   - (b): Zero crossing subroutine
   - (c): sampling subroutine
3. Zone subroutine
4. A/D current sensor subroutine
5. Fuzzy current controller subroutine

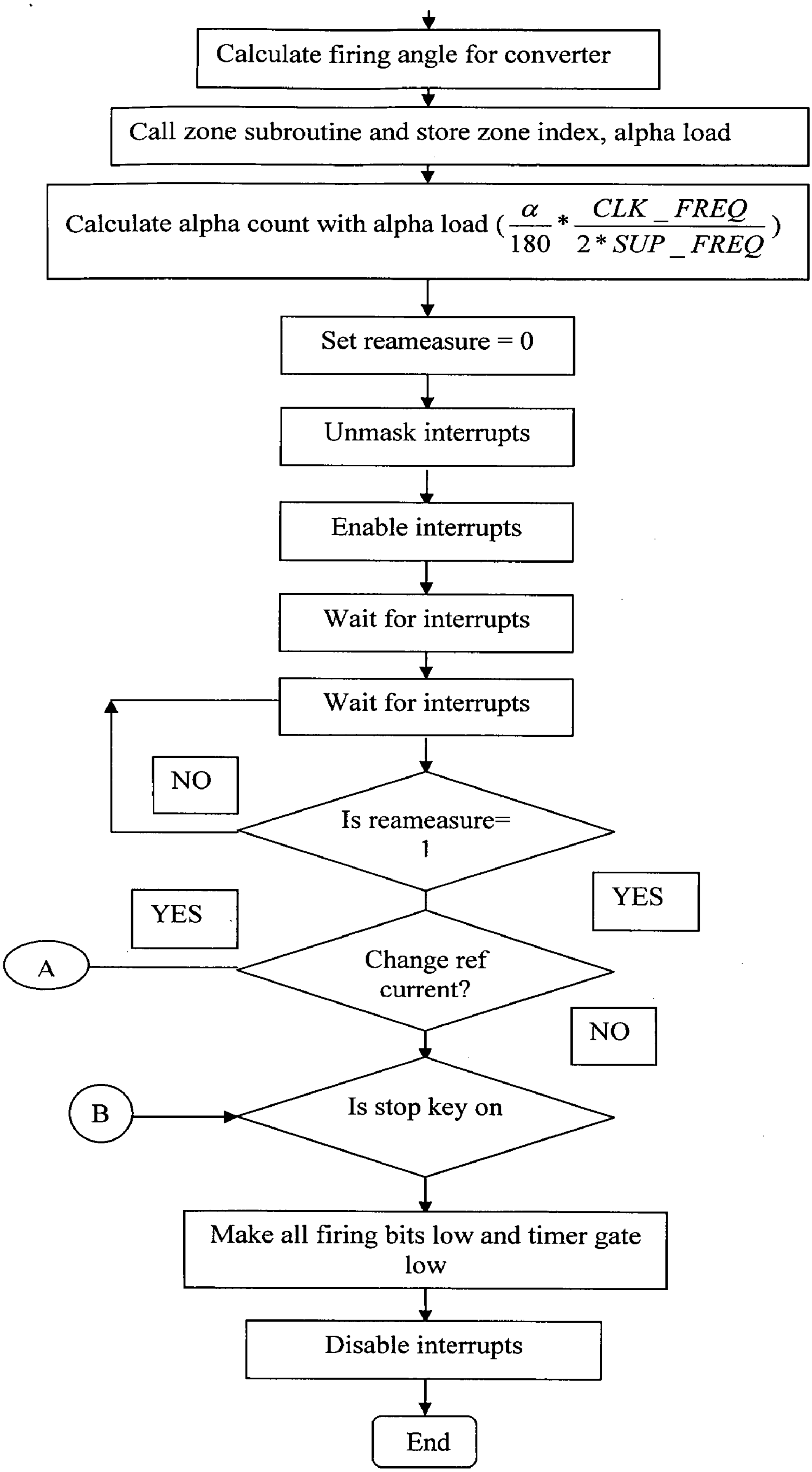
With inner current loop the reference armature current (ref_torque) is read from the input and the actual current is sampled from the sampling subroutine (interrupt) and stored in global variable, convert into pu value.

The inputs for the fuzzy current controller are error(ref-actual) and change in error every time the present value of error is assigned to previous value of error for calculating the change in error(CE) fuzzy current controller returns the change in control voltage for converter .total control voltage($CU(k)+CU(k-1)$) is calculated and firing angle for thyristor converter is obtained from cosine firing scheme with which zone index and alpha loading are obtained then firing command is issued when alpha interrupt comes.

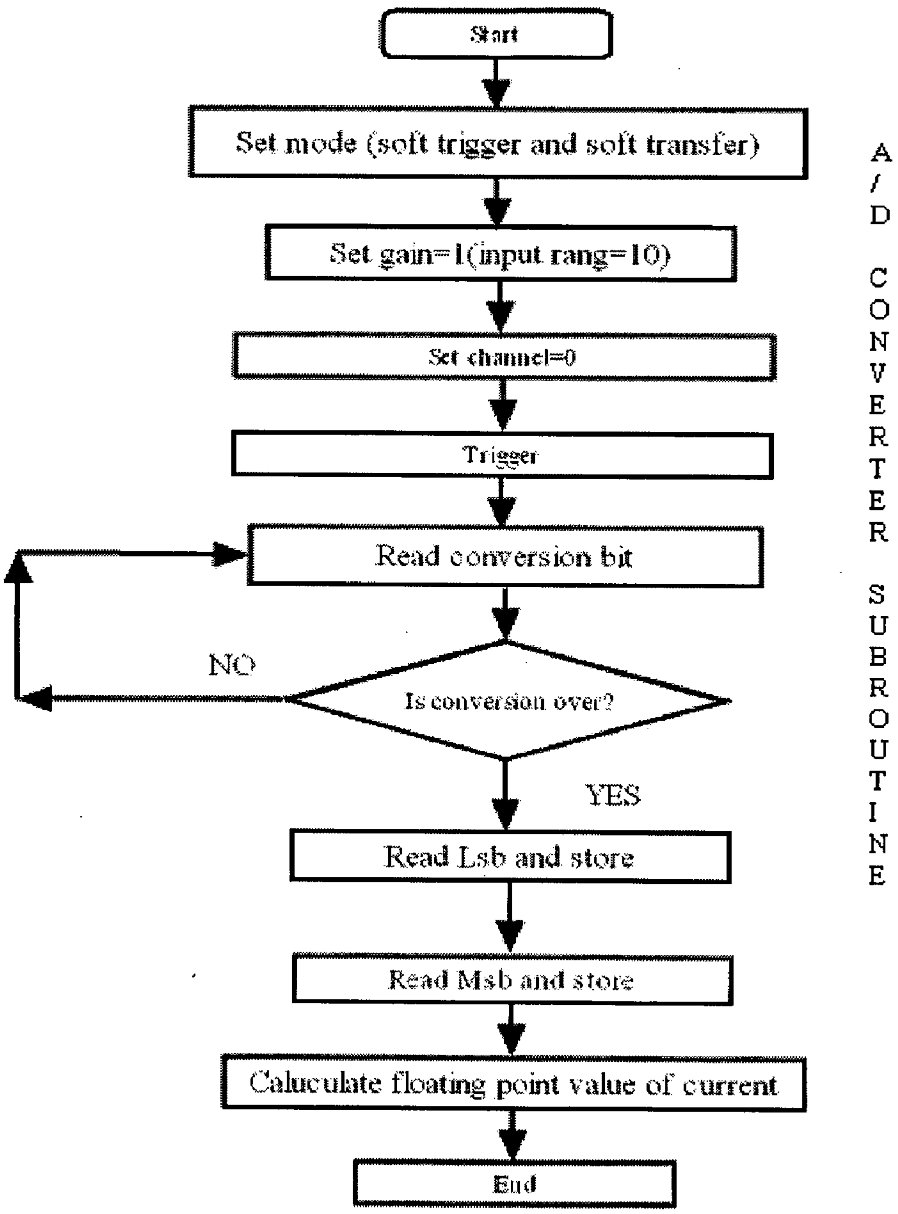
Flowcharts for closed loop (with inner current loop):



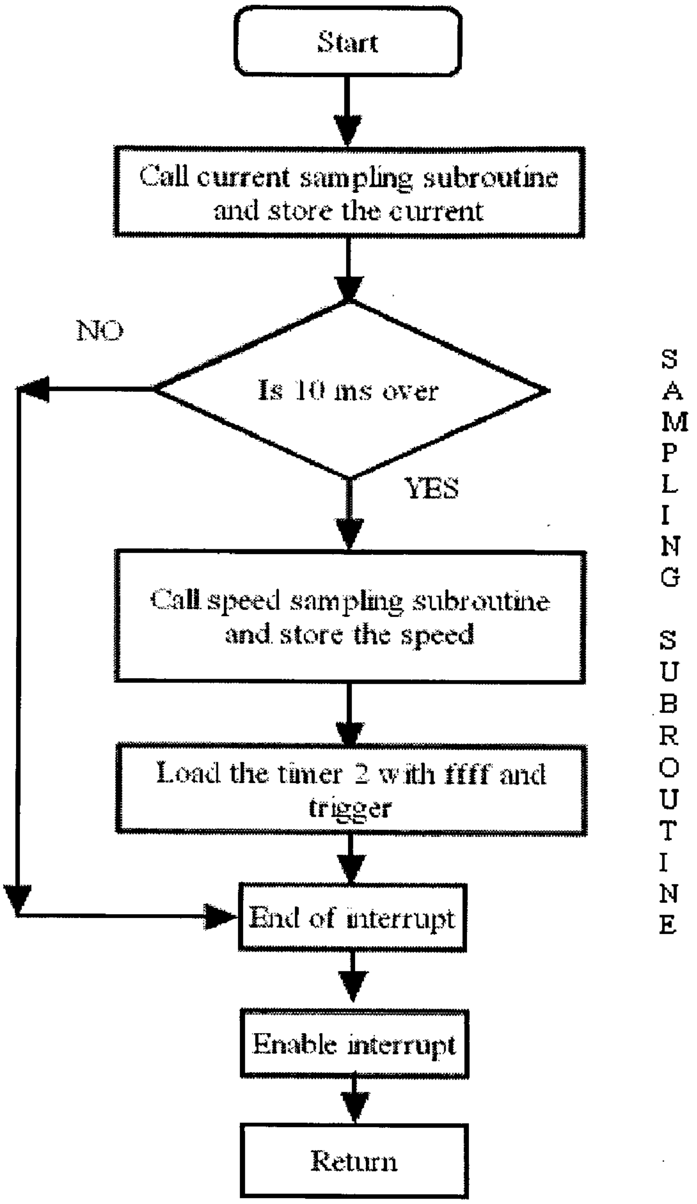
Mail flowchart 3(A)


Calculate firing angle for converter
Call zone subroutine and store zone index, alpha load
Calculate alpha count with alpha load ($\frac{\alpha}{180} * \frac{CLK\_FREQ}{2 * SUP\_FREQ}$)
Set reameasure = 0
Unmask interrupts
Enable interrupts
Wait for interrupts
Wait for interrupts
NO
Is reameasure= 1
YES
YES
A
Change ref current?
NO
B
Is stop key on
Make all firing bits low and timer gate low
Disable interrupts
End

Main flowchart 3(B)



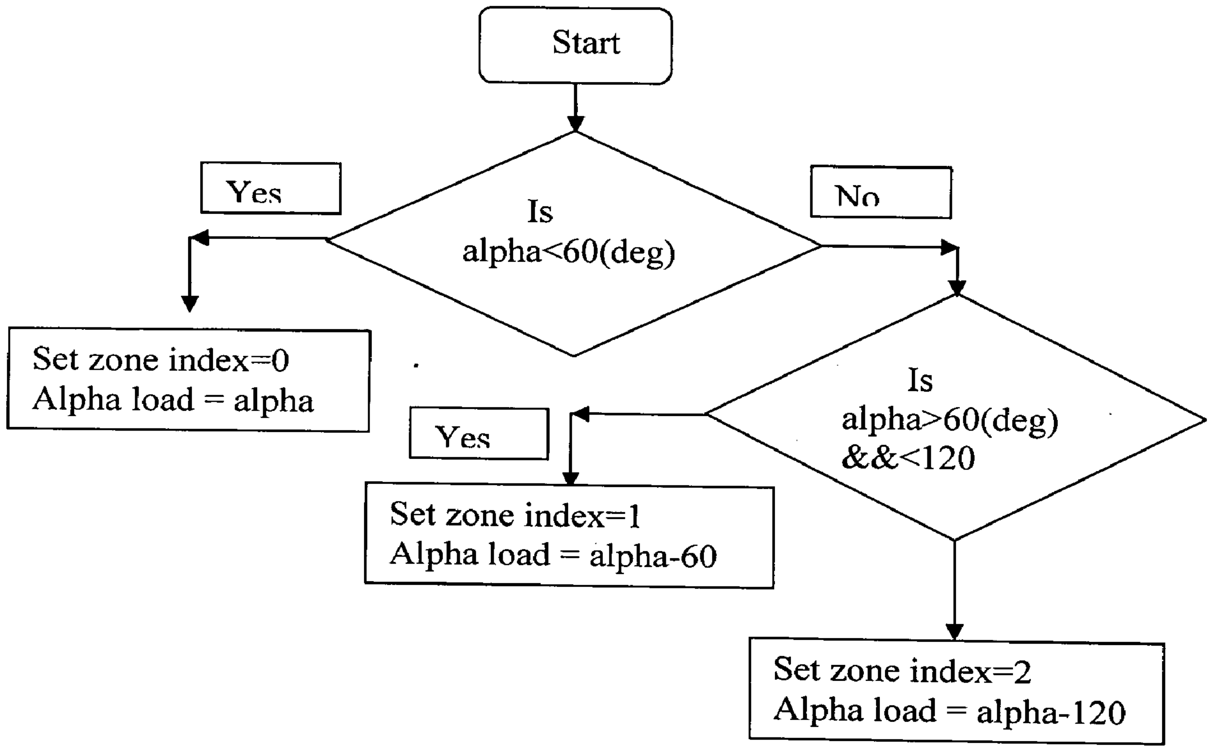
Flowchart: 4


Start
Call current sampling subroutine and store the current
NO
Is 10 ms over
YES
Call speed sampling subroutine and store the speed
Load the timer 2 with ffff and trigger
End of interrupt
Enable interrupt
Return
SAMPLING SUBROUTINE

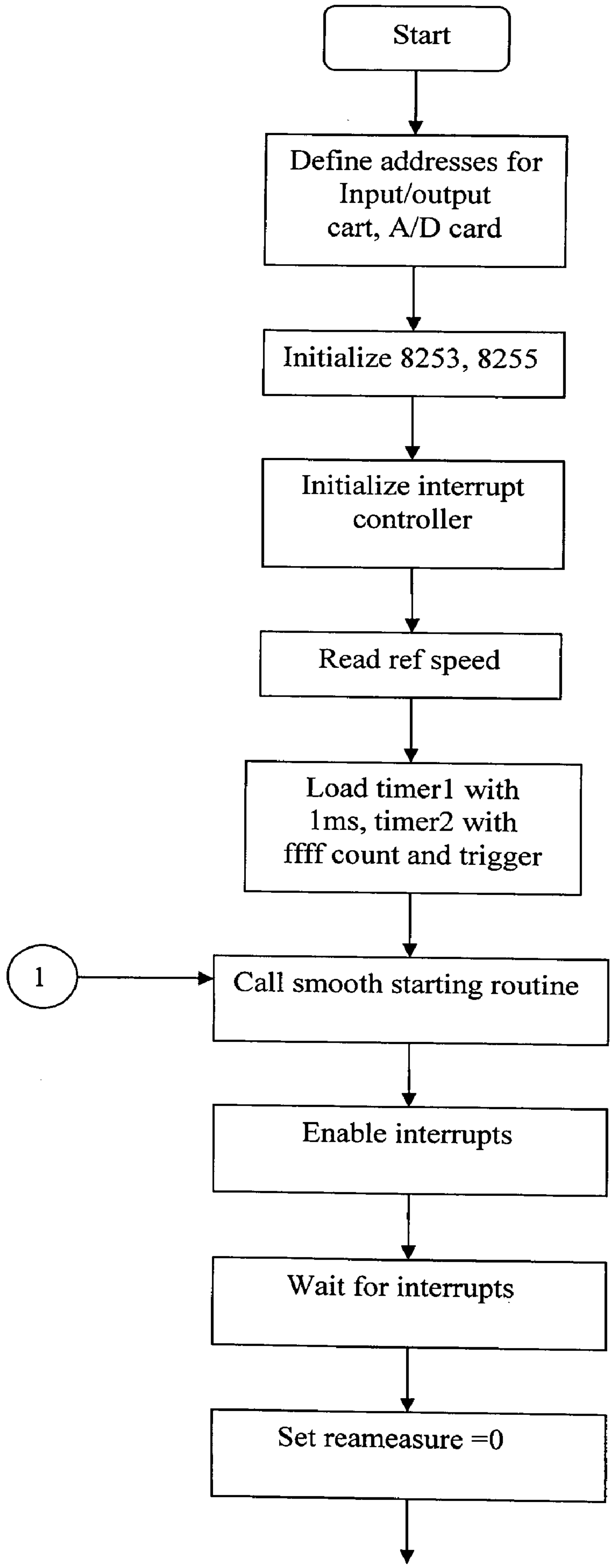
Flowchart: 5

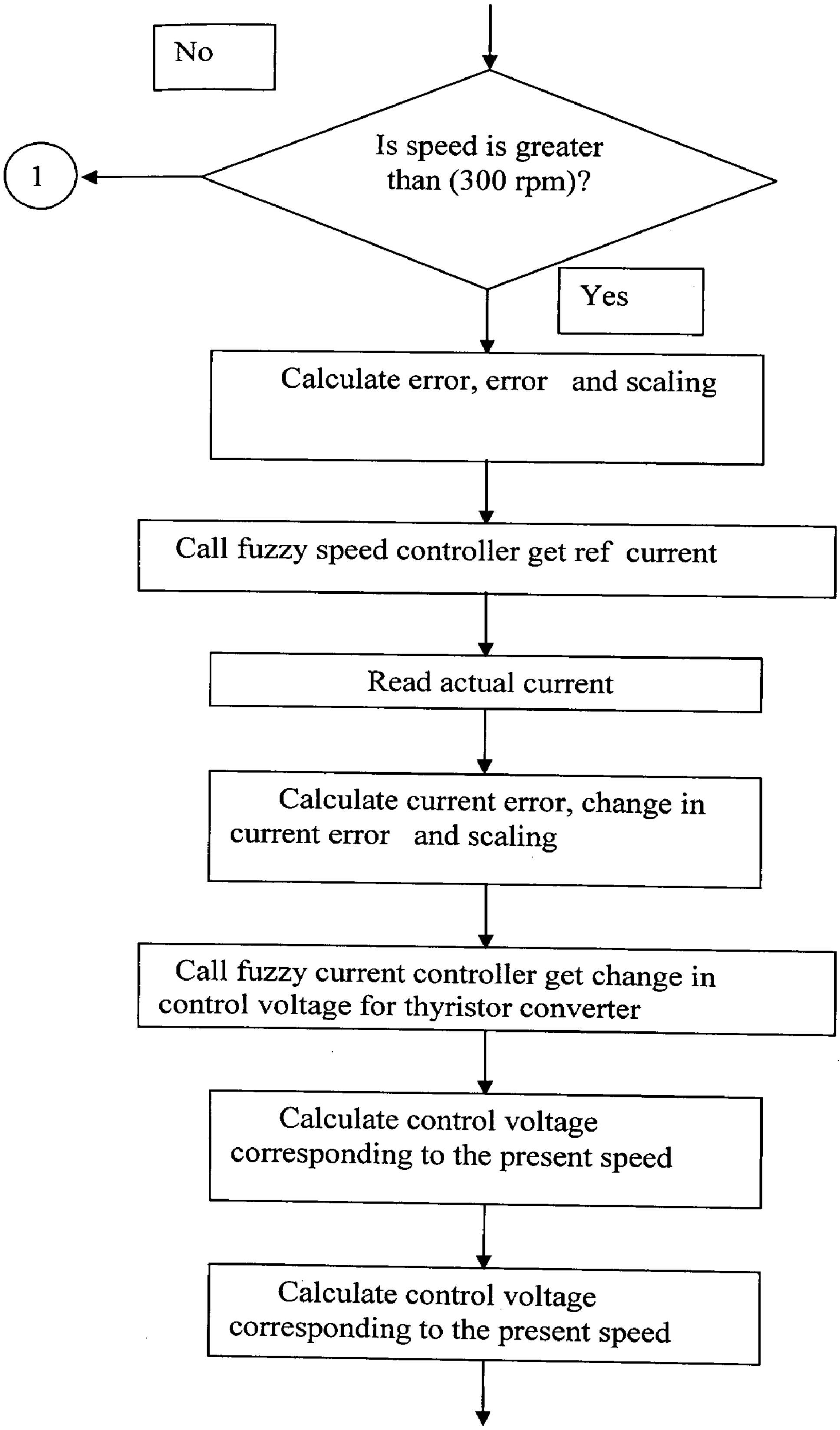
6.2.3 closed loop:

Inclsosed loop when sampling interrupt comes the current is sampled and stored in global variable and every time speed measured over index is incremented by on e and checked if it 10 then sample the sped and store it ,timer is reloaded with FFFF and triggered. Variable is set to zero.

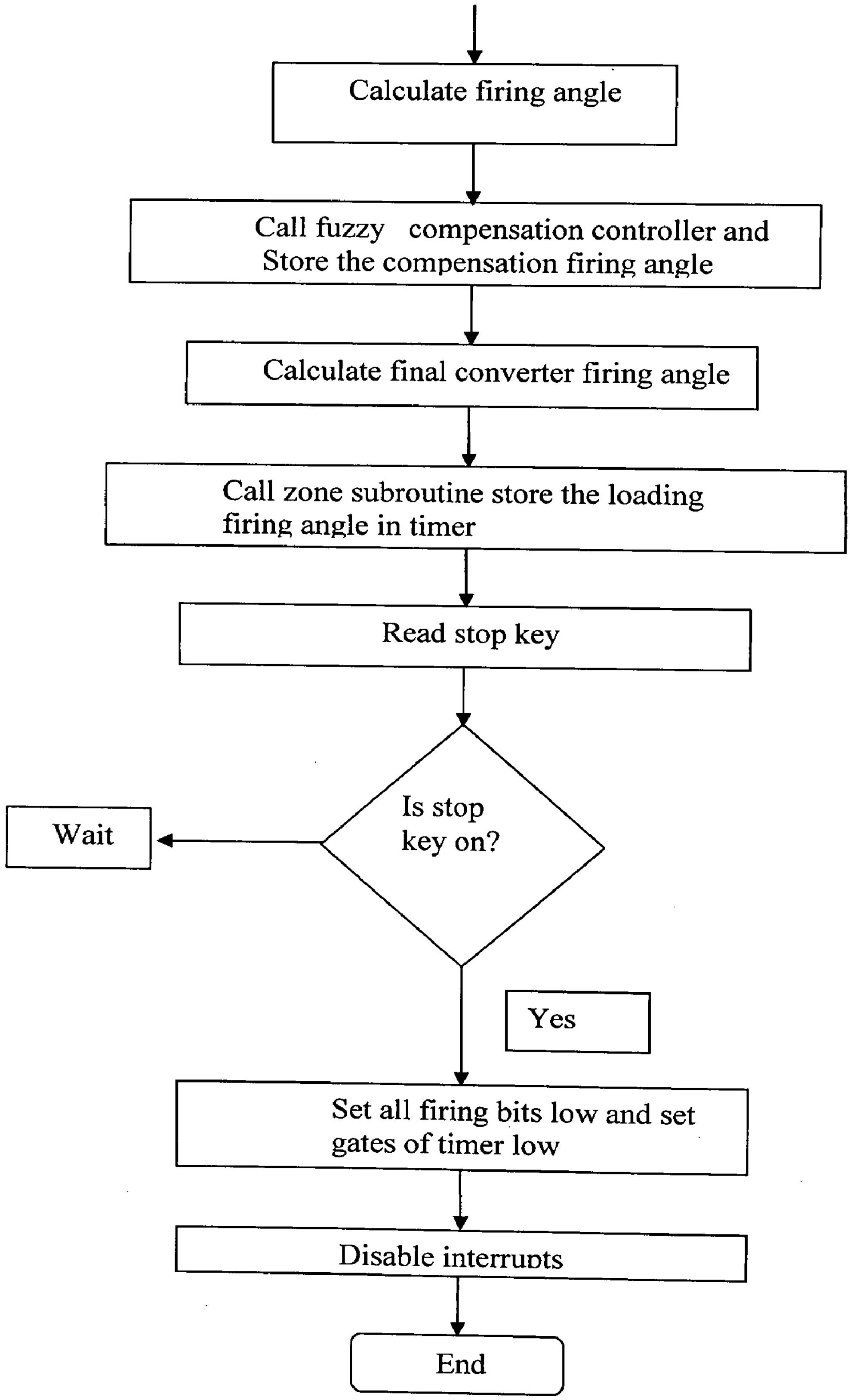


Zone subroutine
Flowchart: 6


Start
Define addresses for Input/output cart, A/D card
Initialize 8253, 8255
Initialize interrupt controller
Read ref speed
Load timer1 with 1ms, timer2 with ffff count and trigger
1
Call smooth starting routine
Enable interrupts
Wait for interrupts
Set reameasure =0


No
Is speed is greater than (300 rpm)?
1
Yes
Calculate error, error and scaling
Call fuzzy speed controller get ref current
Read actual current
Calculate current error, change in current error and scaling
Call fuzzy current controller get change in control voltage for thyristor converter
Calculate control voltage corresponding to the present speed
Calculate control voltage corresponding to the present speed

FLOWCHART :7


Calculate firing angle
Call fuzzy compensation controller and Store the compensation firing angle
Calculate final converter firing angle
Call zone subroutine store the loading firing angle in timer
Read stop key
Is stop key on?
Wait
Yes
Set all firing bits low and set gates of timer low
Disable interrupts
End

CHAPTER 7

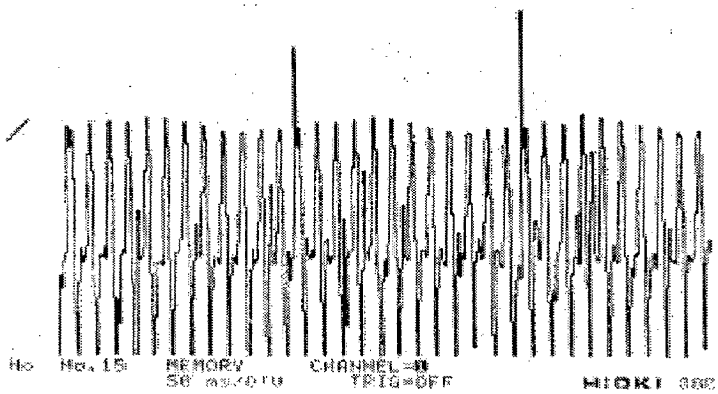
PERFORMANCE INVESTIGAION OF FUZZY AND CONVENTIONAL CONTROLLERS

7.1 EXPERIEMENTAL RESULTS:

7.1.1 OPENLOOP:

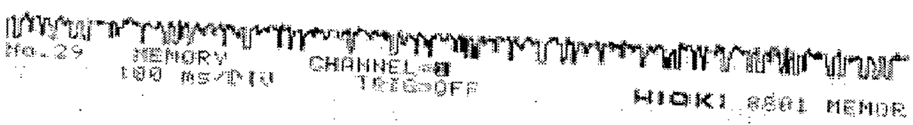
1. **for alpha =30deg**

(a):armature voltage(alpha=30deg)



ARMATURE voltage for alpha =30deg

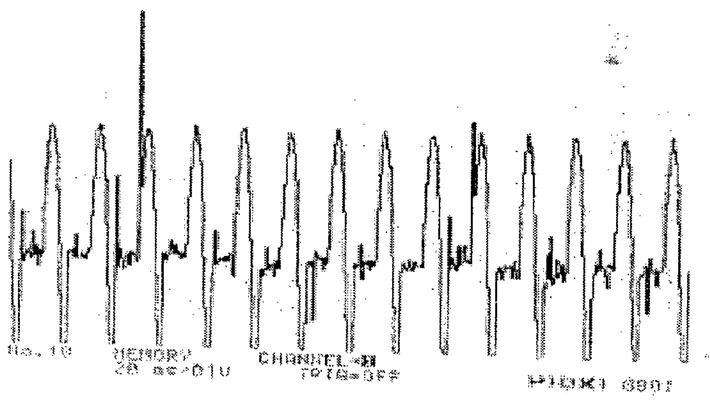
(b) armature current:



armature current for alpha =30 deg

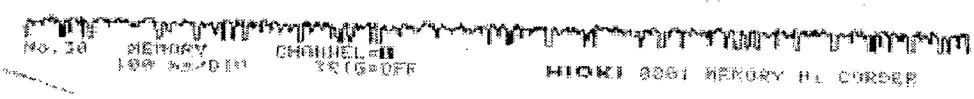
2. for alpha =45deg

(a):armature voltage:



armatrue voltage for alpha =45deg

(b) Armature current:

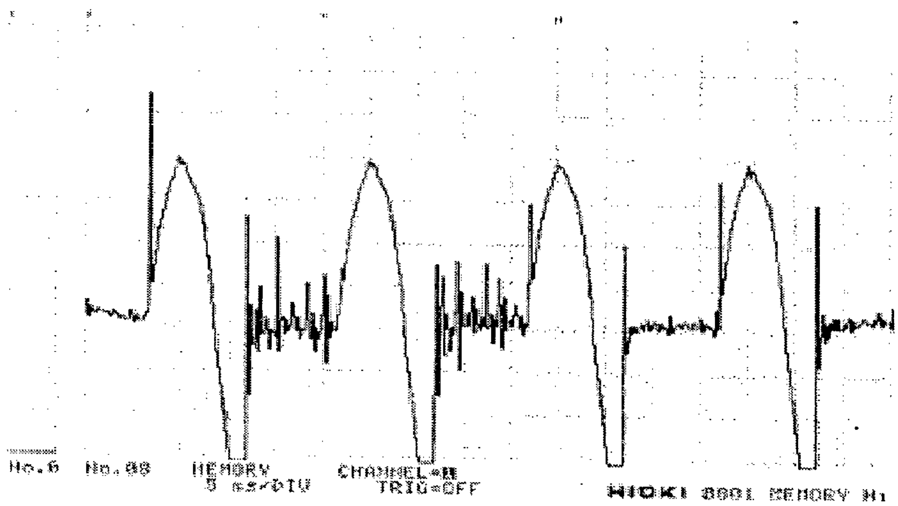


aramtaure current for alpha = 45deg

7.1.2 Closed loop (current loop):

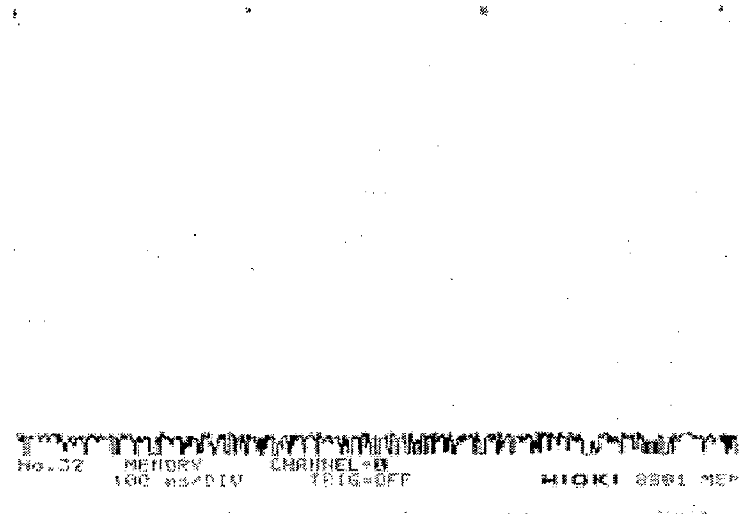
Input ref =0.3pu currnt

(a) armature voltage:



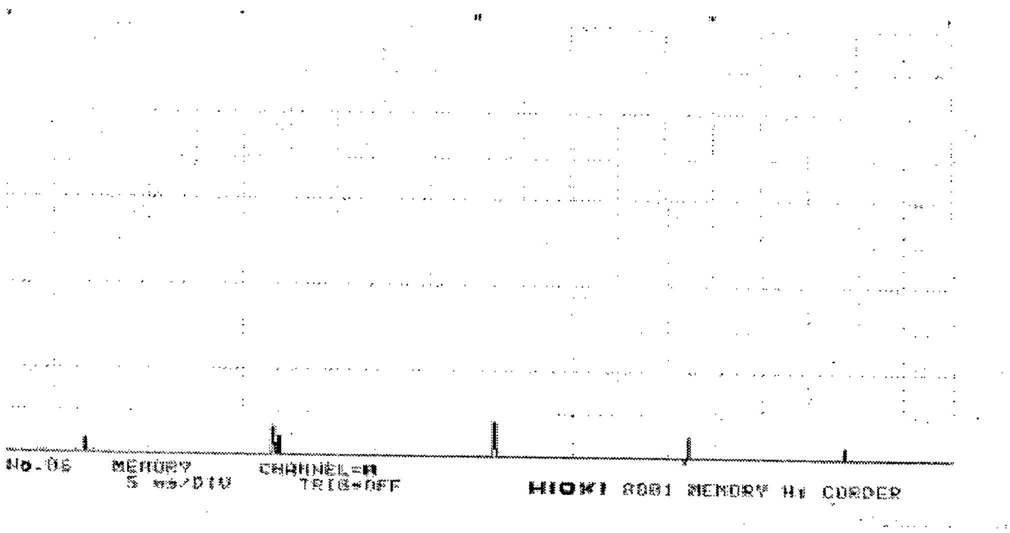
Armature voltage for ref=0.3pu

(a) armature current:

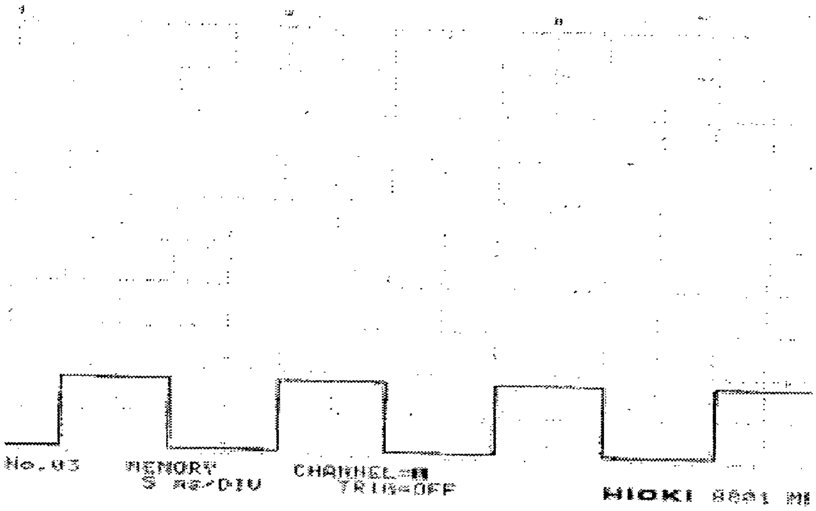


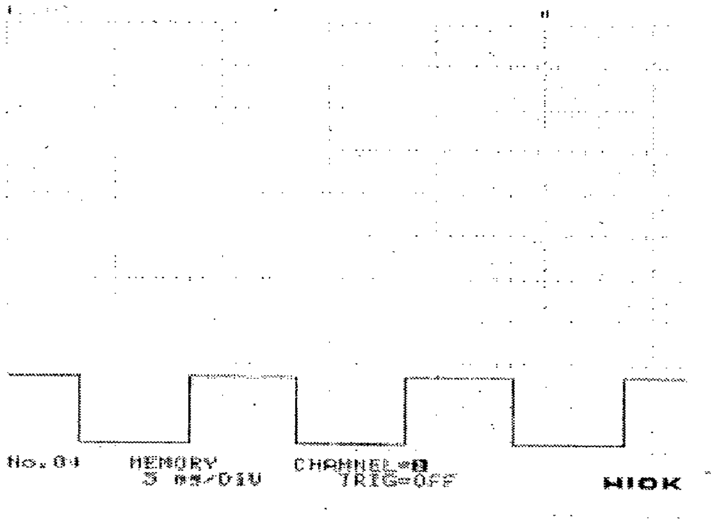
armature current for ref 0.3 pu

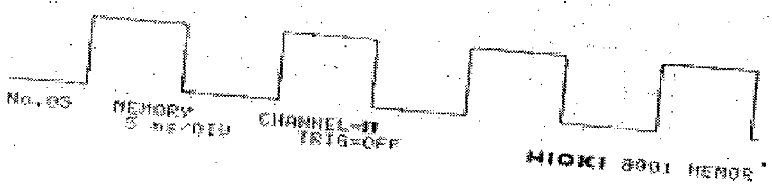
Pulses and quantizes:



pulses from pulse transformer


No.03 MEMORY 5 ms/DIV CHANNEL= TRIG=OFF
HIOKI


No.04 MEMORY 5 ms/DIV CHANNEL= TRIG=OFF
HIOK



The nonlinear characteristic adversely affects the gain characteristics of the conventional **PI** controllers used for DC drives. If the controller gain is made optimum at continuous conduction mode, the lower gain at discontinuous conduction mode will make the response sluggish. On the other hand. If the gain optimized for discontinuous conduction mode, the loop will tend to be unstable at continuous conduction mode. Since fuzzy controller is inherently adaptive in nature, it is well suited for this condition.

If the machine is controlled with **PI** controller the for running the converter in continuous mode a series inductance must be added to ensure continuous conduction which in turn increases the cost of the system. But with fuzzy a compensation controller can be used to maintain the continuous conduction by making transfer characteristics of converter linear which is simply a fuzzy rule table

ADVANTAGES OF FUZZY CONTROLLER:

1. no inductance is required in series with armature of DC motor
2. performance characteristics
   - 2.1 Steady state error is minimum
   - 2.2 No over shoot
   - 2.3 Rise time low
   - 2.4 Settling time very low
   - 2.5 Drop in speed with load is minimum

7.2 SIMULATION PERFORMANCE INVESTIGATION:

The performance parameters fuzzy controller of DC motor obtained from simulation results and hard ware results are compared

1. **Over shoot:**

   In fuzzy logic controller the overshoot disappears no overshoot the command speed exactly follows the reference speed.
2. **Steady state error:**

   The steady state error obtained from fuzzy controller is relatively small compared to conventional (PI, PID) it is in the order of 0.1 to 0.2 percentage of rated speed.
3. **Rise time:**

   Fuzzy controller has fast(less time) rise time to the steady state it is in the order sec form 0.4 to 0.6
4. **Settling time:**

   Because of no overshoot the settling time is almost equal to rise time with no oscillations
5. **Drop of speed with load:**

   As the load on the machine increases for the same value of ref speed the drop in speed in case is relatively large but with fuzzy it is also small

6. **Step applying of inertia load:**

   Once the step load is applied to the machine the speed falls suddenly to certain value but the stability of system is also good

PERFORMANCE TABLE:

The performance parameters obtained from simulation are shown in table: .2

PARAMETER	FUZZY	PI	PID
OVERSHOOT	0.0	5%	4%
RISE TIME	0.6s	0.9s	1s
STEADY STATE EROR	0.1%	0.1	0.1
DROP OF SPEED WITH LOAD	8rad/s	25rad/s	25rad/s
SETTLING TIME	0.6	1.3s	1.4s

TABLE: 7.1

REFERENCES

[1]. **A Fuzzy Set Theory Based Control of a Phase-Controlled Converter DC Machine Drive**
Sousa, G.C.D.; Bose, B.K.; Industry Applications, IEEE Transactions on Volume 30, Issue 1, Jan.-Feb. 1994 Page(s):34 - 44 Digital Object Identifiers 10.1109/28.273619

[2]. **Design and implementation of fuzzy logic control speed control system for a converter fed DC drive using 8097 microcontroller**
Chellamuthu, C. Industrial Electronics, 2000. ISIE 2000. Proceedings of the 2000 IEEE International Symposium on Volume 2, 4-8 Dec. 2000 Page(s):735 - 740 vol.2 Digital Object Identifier 10.1109/ISIE.2000.930390

[3]. **DC Motor Control by Using Computer Based Fuzzy Technique**
Cakir, B.; Yildiz, A.B.; Abut, N.; Inanc, N.; Applied Power Electronics Conference and Exposition, 1999. APEC '99. Fourteenth Annual Volume 1, 14-18 March 1999 Page(s):391 - 395 vol.1 Digital Object Identifier 10.1109/APEC.1999.749701

[4]. Fuzzy logic micro controller implementation for Dc motor speed control
Tipswan, Y.; Mo-Yuen Chow; Industrial Electronics Society, 1999. IECON 99 proceedings. The 25th Annual Conference of the IEEE Volume 3, 29 Nov.-3 Dec. 1999 Page(s):1271 - 1276 vol.3 Digital Object Identifier 10.1109/IECON.1999.819394

[5]. Fuzzy Logic Applied to Motor Control
Guillemin, P.; Industry Applications, IEEE Transactions on Volume 32, Issue 1, Jan.-Feb. 1996 Page(s):51 - 56 Digital Object Identifier 10.1109/28.485812

[6]. **Real time fuzzy logic speed control using conventional assembly and simulation methods for industrial Dc motor**
Hasan, A.R.; Industrial Automation and Control, 1995 (I A & C'95), IEEE/IAS International Conference on (Cat. No.95TH8005) 5-7 Jan. 1995 Page(s):203 - 208 Digital Object Identifier 10.1109/IACC.1995.465842

[7]. **Fuzzy Logic in Control Systems: Fuzzy Logic Controller-Part I**

Lee, C.C.; Systems, Man and Cybernetics, IEEE Transactions on Volume 20, Issue 2, March-April 1990 Page(s):404 - 418 Digital Object Identifier 10.1109/21.52551

[8]. Fuzzy Logic in Control Systems: Fuzzy Logic Controller-Part II Lee, C.C.

[9]. Power converters application and design N.Mohan, Undeland, and Robbins

[10]. Intel manuals for 8253, 8255 and datasheets

APPENDIX I

Abbreviations:

FLC	Fuzzy logic controller
PU	Per unit
UOD	Universe of discourse
REF	Reference
E	Error
CE	Change in error

APPENDIX II

Datasheets

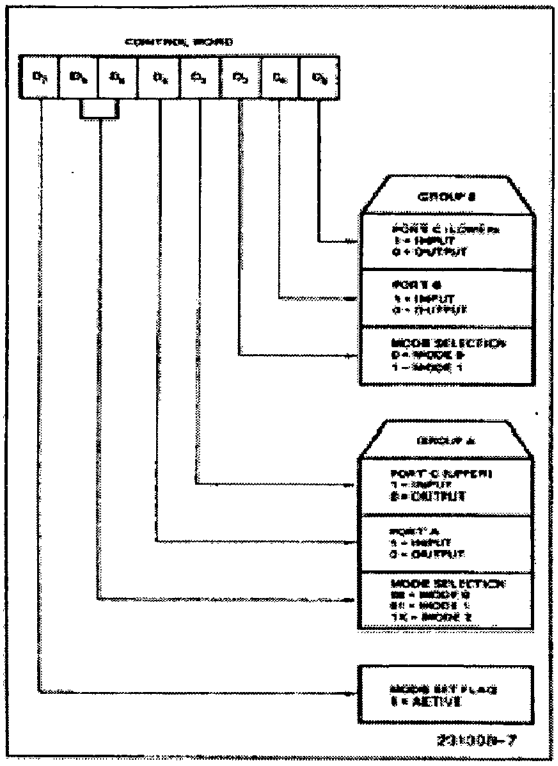
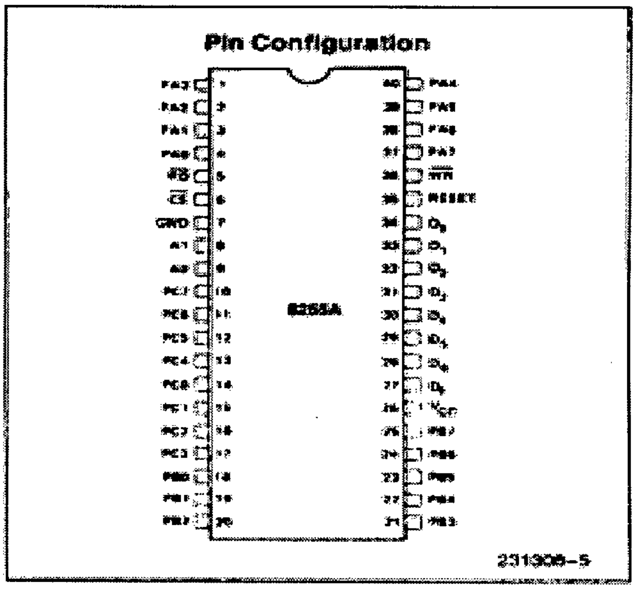


Figure 6. Mode Definition Format



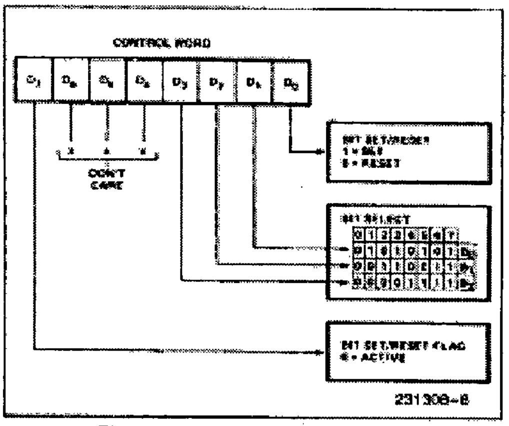
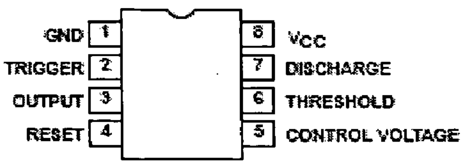
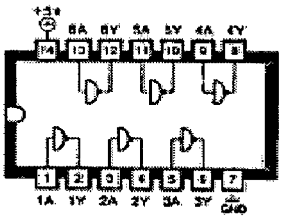


Figure 7. Bit Set/Reset Format

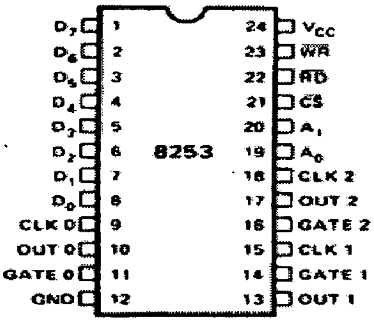
8255 Control word and pin diagram





7404 inverter

555 timer

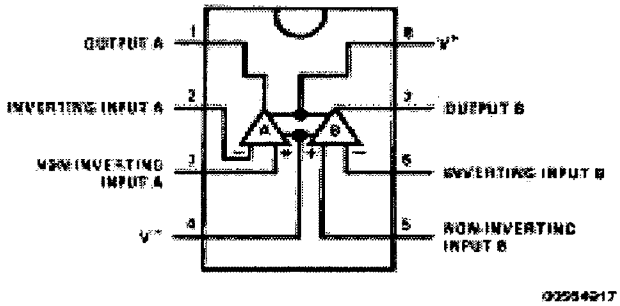


231306–2

Figure 2. Pin Configuration

Connection Diagram

Dual-In-Line Package



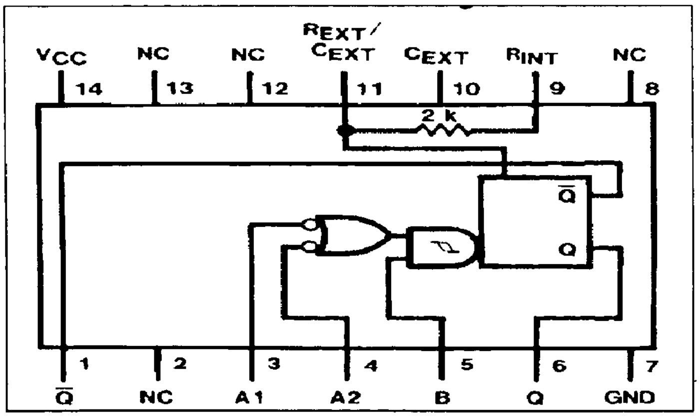
Top View

Order Number LF353M, LF353MX or LF353N

See NS Package Number M08A or N08E

8253

LF353



Function Table

Inputs			Outputs	
A1	A2	B	Q	Q̄
L	X	H	L	H
X	L	H	L	H
X	X	L	L	H
H	H	X	L	H
H	↓	H	⊓	⊔
↓	H	H	⊓	⊔
↓	↓	H	⊓	⊔
L	X	↑	⊓	⊔
X	L	↑	⊓	⊔

H = HIGH Logic Level
L = LOW Logic Level
X = Can Be Either LOW or HIGH
⊓ = A Positive Pulse
⊔ = A Negative Pulse
↑ = Positive Going Transition
↓ = Negative Going Transition

74121 and its truth table