A Thesis Report On

DEVELOPMENT OF VISUAL INTERFACE AND HARDWARE LOGIC FOR OPEN ARCHITECTURE NC CONTROLLER FOR 3-AXIS SIMULTANEOUS INTERPOLATION

Submitted

In partial fulfilment of the requirement for the award of degree of

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Submitted by

RAHUL KUMAR
ROLL NO: 801081021

Under the guidance of

Mr. Ravinder K. Duvedi
Assistant Professor
Mechanical Engineering Department

Mr. Ankush Kansal
Assistant Professor
Electronics and Communication Engg. Department

MECHANICAL ENGINEERING DEPARTMENT
THAPAR UNIVERSITY
PATIALA-147004, INDIA
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CERTIFICATE

This is to certify that the thesis titled, **"DEVELOPMENT OF VISUAL INTERFACE AND HARDWARE LOGIC FOR OPEN ARCHITECTURE NC CONTROLLER FOR 3-AXIS SIMULTANEOUS INTERPOLATION"** being submitted by **RAHUL KUMAR REGISTRATION NO. 801081021**, in partial fulfilment of the requirements for the award of degree of MASTER OF ENGINEERING in CAD/CAM & ROBOTICS ENGINEERING at THAPAR UNIVERSITY, PATIALA is a bonafide work carried out by him under our guidance and supervision and that no part of this thesis work has been submitted before for the award of any degree at any other place.

Mr. R.K. Duvedi
Assistant Professor
Mechanical Engineering Department

Mr. Ankush Kansal
Assistant Professor
Electronics and Communication Engg. Department

Dr. Ajay Batish
Professor and Head, MED
Thapar University, Patiala

Dr. S. K. Mohapatra
Dean of Academic Affairs
Thapar University, Patiala

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RAHUL KUAMR

Roll No.: 801081021

ABSTRACT

The trends in the NC machine tool development are towards open architecture control and Direct Model to Part machining strategies. The NC machine requirement of better simplicity, portability, interoperability, adaptability and low cost necessitates the improvement and simplification of conventional NC machining procedures. One major issue with the conventional NC technology is that the motion control in NC machining operations cannot be efficiently automated with the restrictive (ISO 6983) G and M codes. G and M code were designed in the era when paper tapes were used for program input in NC. Nowadays the G-code programs are generated by the computer aided manufacturing (CAM) tools, using the geometrical data from computer aided design (CAD) tools as input. However, CNCs of different vendors implement different versions of G-code which lacks portability and leads to proprietary CAD–CAM–CNC integrated modules/software. An open architecture control machine tools can be directly controlled from a computer, rather than a dedicated NC controller. This is possible by virtue of high processing speed and low cost of a modern computer. An open architecture NC tool paths is free from conventional ISO G and M based NC tool paths, rather use a file containing the pre-calculated locations of the relative position of the cutter with respect to the work piece in a logical sequence.

In the present work a PC based interactive interface and CNC drive control system capable of three axis simultaneous interpolations for sculptured surface machining has been developed. The GUI and NC interface hardware has been developed for a PC controlled 3-axis vertical milling machine which finds its tremendous applications in machining of sculptured surfaces. Some dedicated CNC machines are available for machining sculptured surfaces but because of heavy cost these are not affordable for small scale production work. The development of GUI and the NC hardware along with the logics followed has been explained in the chapter 3 and 4 of this thesis report. The testing and validation of the GUI interface and NC interface hardware has been done using a specially developed electronic hardware using stepper motors. This work is aimed at providing a low cost NC machine interface from PC (GUI) and hardware interface for machine drive control so that the dependency of commercially available NC controllers can be avoided. This is a step towards customised CAD/CAM integration to enable NC machine tool with new control strategies, sensors and interfaces. Also the open architecture based NC system will be better affordable than the commercial NC system for sculptured surface machining.

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CHAPTER: 1

INTRODUCTION

The numerical control is widely used in the modern manufacture system industries. Numerical control (NC) is the technology concerned with operation of a machine tool by using a series of coded instructions consisting of numbers, letters of the alphabet, and symbols that the machine control unit (MCU) can understand. A category of automated machine tools, such as drills and lathes, can be operated from instructions in a program. Numerical control (NC) machines are used in manufacturing tasks, such as milling, turning, punching and drilling. Both NC and CNC (computer Numerical Control) are used to describe this category. CNC machine tools are the main components in any state of the art manufacturing system. There are demands and new opportunities to empower the current CNC machines based on personal computer (PC) with the much needed features such as amazing speed, accuracy, efficiency and repeatability, agility and re-configurability [1].

The first NC machines were built in the 1940s and 1950 by John T. Parsons in collaboration with MIT (Massachusetts Institute of Technology) based on existing tools that were modified with motors that moved the feed drive/controls to follow instruction fed in to the control system through punched tape. These early servomechanisms were rapidly augmented with analog and digital computers, creating the modern computer numerical control (CNC) machine tools that have revolutionized the machining processes.

By the mid-1960s, NC technology was playing a dominant role in the industry. NC machines were being installed in metal working production environments all over the United States. Most machine programs were recorded on a punched paper or aluminium30 tape until about 1980. In the 1970s and 80s, the growth of microprocessor technology made it possible for computers to be used for control of NC machines, hence the term CNC came into existence. The instructions coded in to a NC program are changed into electrical pulses using machine control unit (MCU) to actuate drive motors to carry out manufacturing operations on a work piece. The numbers, letters, and symbols are coded instructions that refer to specific distances, positions, functions, or motions, that the machine tool can understand as it machines the work piece.

1.1 CNC MACHINE COMPONENTS

The CNC machines are generally has three main components which are: NC Part Program, Machine Control Unit (MCU), and Machine tool. These three main components have been explained below:

1.1.1 Part Program: The part programs are generally generated manually or with Computer Aided Manufacturing (CAM) software packages by using the cutting parameters and the part's Computer Aided Design (CAD) model data. This part program contains the machine movement instructions usually in a standard machine tool language, such as by using ISO G and M codes. The NC program has systematic information about motion commands to actuate machine drive motors to move the cutting tool relative to work piece. In addition NC part program also contain information about feed, speed, and other parameters for special machining cycles and other auxiliary function to be actuated on machine tool

1.1.2 Machine Control Unit (MCU)

The machine control unit (MCU) is the backbone of CNC systems and executes the following six functions:

(i) Read coded instructions

(ii) Decode coded instructions

(iii) Implement interpolations to generate axis motion commands

(iv) Feed axis motion commands to amplifier circuits to drive axis mechanisms

(v) Receive the feedback signals of position and speed for each drive axis

(vi) Implement auxiliary control functions such as coolant ON/OFF, spindle ON/OFF, and tool change

The main constituent components of MCU are as follows.

(a) Graphical user interface: The Graphical User Interface (GUI) is the way for human interaction with computer/Machine control unit (MCU) that uses the window icon, menus and which can be manipulated by external peripheral devices like keyboard or mouse. The CNC controller console allows the operators to interact with the machines. The user interface displays the in-process machine status and received the feedback to show the front screen of GUI. It also allows the operators to edit and verify the programs prior to the actual machining process to prevent any errors in the tool path. The GUI main screen works with different modes to control the CNC machine like home mode, edit mode, jog mode, automatic mode. The different machine control modes have been discussed in detail in chapter 4.

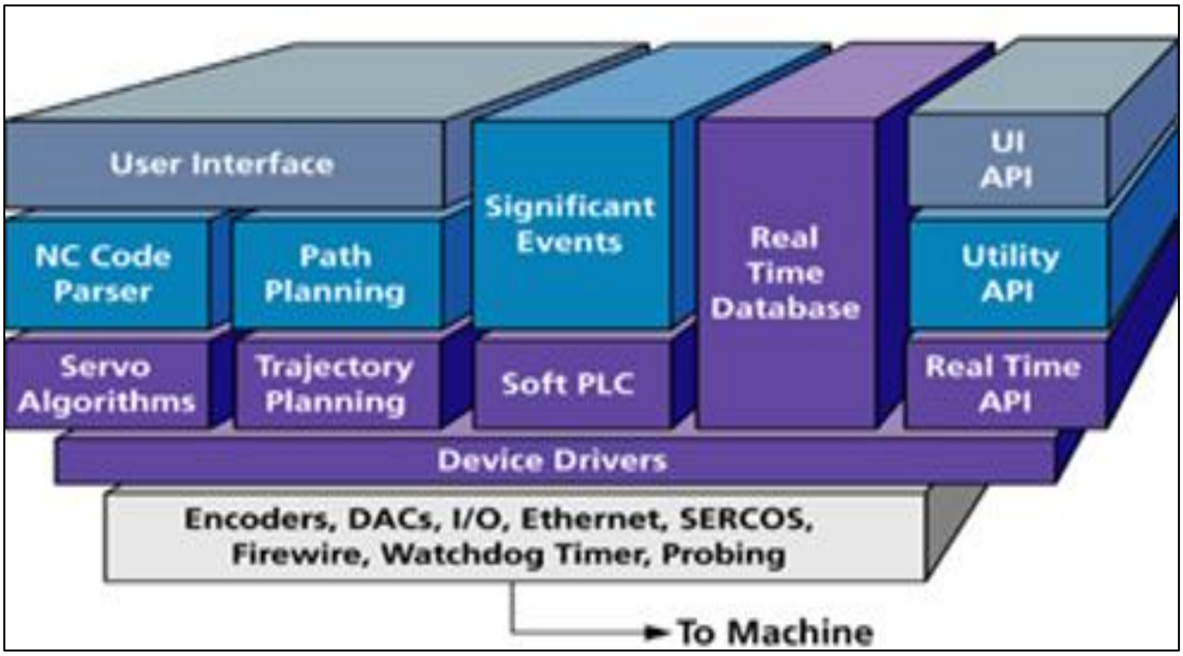


Figure 1.1: Open architecture of CNC machine [16]

(b) Machine drive units: The machine dive unit consist of two main components namely electrical motor and motor drivers. The types of electrical motors that can be used with the NC system are stepper drives, DC servo drives or induction motors. The drive motors coupled with mechanical components such as ball screw unit and LM ways help to move the machine drives axis linearly. The whole idea of a drive system is to convert controlled rotary motion to controlled linear motion with the help of CNC controller. The motor drive consists of electronic and electrical components responsible for converting the NC program data into suitable form to actuate the drive motors, so that displacement, speed and acceleration function of drive motors can be controlled to get desired linear motion along a particular drive axis of machine tool.

(c) Feedback: When the machine drives are actuated, it is desirable to receive feedback from the controller. A feedback system is also referred to as a measuring system. It uses position and speed sensors to continuously monitor the position of the cutting tool at any particular time with respect to some previously defined reference. The MCU uses the difference between reference signals and feedback signals for correcting position and speed errors. Feedback sensors like encoders (rotary/linear), linear scales, limit switches, Ferranti scales and resolvers can be used as feedback device in a CNC system.

(d) Safety alarms: It is an indicator for abnormal operation or machine setting that serves to call attention and warnings caused by the operation of the component parts and safety devices of the machine. The automatic CNC machine has been put limit exceed switch to indicate the over travel of drives and hence prevent the over travel by indicating the warning messages on CNC console or through some light indicators. The different types of program/software checks can also be used to actuate the buzzer alarms in case when user/machine operator tries to execute a wrong NC program. The power connection is the most important safeties, if the any power cable will be loose, the machine will be not started and show the error message.

1.1.3 Machine Tool

A machine tool is a machine for shaping or machining metal or other rigid materials using conventional metal removal processes like cutting, boring, grinding, shearing or other forms of deformation like press working and using non-conventional machining processes like electric discharge machining or laser cutting. All machine tools have some means of constraining the work piece and provide a guided movement of the parts of the machine. Thus the relative movement between the work piece and the cutting tool which is called the tool path is controlled or constrained by the mechanical mechanism of machine tool. The common NC system are designed to perform machining operation, wherein the machine tool consist of the worktable and spindle as well as the motors and control systems required to drive them. Its also includes the cutting tools, work fixture, and auxiliary equipment needed in the machining operation. Such NC machining systems are called machining centres, which have several timesaving features into a single of automatic production equipment. A machining centre is capable of performing a variety of different operation like drilling, tapping, reaming, milling, and boring. The best part of the machining centres is the capacity to change tools automatically. Another unique capability of the NC machining centre is work piece positioning. The machine table can orient the job so that it can be machined on several surfaces, as required. Finally, a fourth feature possessed by some machining centres is the presence of two table or pallets for work piece holding. When machining is being performed on one work part, the operator can unload the previously completed piece, and loading the next one.

1.2 MODERN DEVELOPMENT IN CNC TECHNOLOGIES

The major goal of modern CNC technology is to handle the operations in order to improve the productivity, increase the product quality and uniformity, minimize the cycle times and effort, and reduce the labour cost. In the past time the NC operations were carried out using 1 inch wide punched tape, which acted as source for data decoding for NC tape reader. NC tape readers used to interpret the NC code/ program and enter one command instruction at a time in to the NC controller/ MCU for execution of the NC part Program. In manual part programming, the punched tape is prepared directly from the part program manuscript on a typewriter device equipped with tape punching capability. In the computer assisted part programming, the computer interprets the list of part programming instruction, performs the necessary calculation to convert in to the machine tool motion commands. The NC controllers hardware in such machine tools were responsible for the executing the interpolation functions because the computational power of the computers were not so good in case we wanted to get higher feed rates for machining. In an attempt for reducing the cost for NC machine tools and improving operations using NC technology a new concept of direct numerical control (DNC) was developed in late seventies. It was after introduction of direct numerical control (DNC) that a number of NC machine tools were controlled in real time through direct connection with a large computer system. Now, instead of using tape reader which happens to be the most unreliable, the part program was transmitted to the machine tool directly from the computer memory. In principle, one large computer can be used to control more than 100 separate machine so all the aspects is very costly and needed bulk memory to store the NC part program. But DNC systems were also not so cost effective and were suited for mass or large batch sized production only.

The modern personal computers (PC) possess a great level of data processing capability along with capability to handle larger memory. Also the cost of such computer systems has reduced drastically. It has lured many NC developers to use the capability of computer system in place of a conventional NC hardware controller, and the hardware functions of a conventional NC controller can be executed using a suitable software package through the modern PC. Such an approach has not only overcome problems like inflexibility, large physical space, time and costs of up-gradation present in conventional hardware controllers; but also provide us with a better user interface and multi-programming options. The present day high speed PCs loaded with one of the popular desktop Operating Systems like Windows XP would make a good control centre for a CNC machine.

In the section below the different approaches developed for CNC system using the PC as NC controller has been presented.

1.2.1 DMAC (Direct Machining and Controlling)

Direct machining and control (DMAC) has provided a unique solution to the shortcomings of typical machine tool controllers. The DMAC controller is software-based and very flexible. The first major difference with the DMAC controller is the method of motion input. In place of the usual G and M style commands, the DMAC controller is given entity path information. This can be in the form of position target moves, line moves, arc moves, or NURBS moves. As a result, CAM packages are not required to tessellate complex curves into miniscule arcs and line segments. This results in improved path accuracy, and provides the controller with complex path planning and blending algorithm [29].

1.2.2 Open Architecture Personal Computer-Based CNC

Open architecture Computer based technology today has allowed us to integrate virtually all phases of manufacturing operations, which consist of various technical as well as managerial activities. With sophisticated software and hardware, manufacturers are now able to minimize manufacturing costs, improve product quality, reduce product development time, and maintain a competitive edge in the domestic and international marketplace. Beginning with computer graphics, the use of computers has been extended to computer-aided design and manufacturing and, ultimately, to computer integrated manufacturing (CIM) system. CIM system is a broad term describing the computerized integration of all aspects of design, planning, manufacturing, distributions, and management [17].

1.2.3 Michigan University Open Architecture Controller

It is a supervisory control / process control structure for the test bed in which adaptive control and monitoring functions has been developed on a single platform which were able to directly integrate with low level motion and input / output functions. The supervisory level was also given the responsibility to "integrate and coordinate the control modules to complete the operation [11]. Later work by Koren et al [13], related to the UMOAC test bed examined distributed control architectures and compared their requirements to that of more traditional control architectures. These systems connect a collection of self-controlled drive units using a digital network. A central processor interpolates motion. This research focused on quantifying the real time requirements for the distributed and conventional architectures. Such systems have been reported to be flexible and promote user enhancement, but must be designed carefully with respect to effective network bandwidth if real time requirements are to be satisfied.

1.3 CNC CONTROLLER REQUIREMENT FOR SCULPTURED SURFACE MACHINING

This CNC controller requirement is related to the machining of complex surfaces, ruled or sculptured, which is very common for forge and stamping dies, injection moulds and aero engine components. Difficult-to-cut materials and complex part geometry are the two factors involved. The current CNC technology used for finishing operations use high-speed milling in three axes using ball-end milling tools, or in five axes using ball or flat-end mills. Dies and moulds require precise final forms and good roughness. Modelling the milling operation helps to define optimal tool paths and cutting conditions. The challenge is to produce precise free-forms surfaces on difficult-to-cut materials, with narrow tolerances and good economical performance. The latter aspect is critical because low-wage countries are new competitors in the dies and moulds market. Several key issues must be taken into account for getting better and precise freeform surfaces which include: the use of three-axis or five-axis machines, powerful computer-aided manufacture (CAM) systems, high-tech tools and skilled programmers and machinists. The complex surface machining systems are NC tool path planning modules integrated with CAD modules & dedicated NC machining centres, which is a very complicated & costly process. The cheap and best alternative object could be a simplified integrated CAD/CAM approach for CNC machining like open architecture control, which can efficiently utilize the capabilities of modern computer [18]. The operations of such systems can be made fool proof and simple so that we do not need very skilled operators on the shop floor and the supervisory control for the machining operation can be shifted from the operator to computer control system through the CNC controller software lying in the PC based system.

1.4 ROLE OF MICROCONTROLLER FOR PC BASED NC CONTROLLER DEVELOPMENT

A microcontroller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications. Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems. Now a days cost of microcontroller IC and the programmer kits are affordable. Thus microcontroller technology coupled with the capability of modern PC can be explored for various precision drive control applications such as NC machine tools.

1.5 PRESENT WORK

The NC controller is very important part of the machine, also called heart of CNC machine. The commercial NC controllers used with contemporary CNC machines are very sophisticated and costly. The use of these NC controllers can only be effective for batch or mass production system. The cost of repair and up-gradations of commercial NC controllers is also very costly affair. Using the capability of modern PC suitable NC controller can be developed which can be upgraded through change of software rather than change of hardware components. The aim of the present is to develop a PC based interactive interface and CNC drive control system capable of three axis simultaneous interpolation for sculptured surface machining. Under the present work three main components for new PC based CNC controller has been develop, which are: a customized interactive CNC interface build on window XP operating system, customized control logic for data communication from PC based interface to the NC controller, and the hardware logic NC controller for simultaneous control of three machine drives. The drive motors used for testing the NC controller system are small stepper motors. The 3^{rd} and 4^{th} chapters of this report contain the detailed step-wise description of the three NC components developed under present work, along with results and discussion about testing of the control system in chapter 5.

CHAPTER: 2

LITERATURE REVIEW

Modern manufacturing industries need high accuracy in every type of manufacturing process at production capacity in large scale, which can be fulfilled with use of NC machines. In the present work the aim is to develop a customized NC controller for sculptured surface machining. The literature review for the purpose of present study has been explained below.

2.1 MACHINE TOOL OPEN SYSTEM ARCHITECTURE FOR INTELLIGENT CONTROL (MOSAIC)

Pritchow [24] has carried out the most established research related to open architecture machine tool control, centres around the MOSIAC system developed at New York University. The Machine Open Systems Architecture for Intelligent Control was originally developed to facilitate research related to expert planning systems and quality related sensor data. Conventional controllers at that time were unable to support the information flow required for these tasks. The MOSAIC architecture was based on a memory mapped backplane architecture (VMEbus) with specialized hardware for axis control, machine input / output, and a general purpose processor running a real time POSK compliant operating system. Access to the controller functions was provided by a library of C language routines. These routines formed part of a larger 'machine' operating system mat, being POSK compliant, was able to freely exchange information with workstation based software for expert system based process planning and part probing.

Wright [3] and Hansen [4] have describe the Later work related to the MOSAIC system focused on the development of these higher level functions. Several published works have included a wide range of applications including adaptive control strategies and an Internet based machining centre.

2.2 OPEN SYSTEMS ARCHITECTURE FOR CONTROLS WITHIN AUTOMATION SYSTEMS (OSACA)

Koren [9] has describe the OSACA (1998) architecture is a Control Open System Architecture for Automatic Systems. It appeared in Europe with the ESPRIT III Project 6379 program, being one of the largest projects involving standards for OAC (Open Architecture Control) that includes network connection and application.

Daniel [5] reported about the OSACA project, which began in 1992 in research institutes of France, Germany, Italy, Spain and Switzerland. The main goal of the OSACA project was the definition of an independent hardware and modularity, that is, to work in modules allowing the addition or removal of numeric control, robot control, Programmable Logical Controllers (PLCs), cells control, etc. To manage these modules, the OSACA phase II project 9115 was created to establish software modular systems, communication interfaces, and operation and open data base systems for new functions and for use in new digital equipment.

Altintas and Newell [10] have the objective is to exchange information between users and manufacturers, bringing benefits to both. The OSACA architecture allows the assembly of the machine tool control using a user interface, without the need to review the whole software,. To reach this goal it is necessary to know the concept of platform A platform is composed of hardware and program groups (operating system, communication system) that offer a uniform service for the functional unit (FU) control. The application-programming interface (API) with the FU is based on a well-defined task. The three main platform areas are:

(i) **Communication System:** Hardware and software are defined independently of the information exchange interface among different modules of the controller application. The OSACA communication system allows the information exchange in a transparent way between client and server applications.
(ii) **Reference Architecture:** Determines the control FU and specifies the external interface. This is done to enable the use and integration of external units through internal data in a well-defined way. FU examples are Man Machine Interface, Interlock Logical Control, and Axes Movement Control. For each identified FU, an external module using an object oriented communication for data interfacing with application modules is defined. The interface of writing and reading data access is located in the Architecture Oriented Object and this access is available with the use of a Communication Oriented Object.
(iii) **System Configuration:** Allows a controller dynamic configuration through a combination of different application modules. This does not only allow determining a specific topology of a given functionality, but also the synchronization among the distributed processes. Figure 2.1 describes the platform of the OSACA system, where a configuration request generated by a microcomputer is sent to the system. The reconfiguration uses FU (Function Unite), which works, based on object oriented programs, a class library, with variables and internal data. The OSACA application protocol uses a client/server base

mounted on the object orientation principle. All FU functionality will have external access and it is configurable by the communication platform. From the customer's viewpoint, the server can be accessed through shipping and reception of system communication messages.

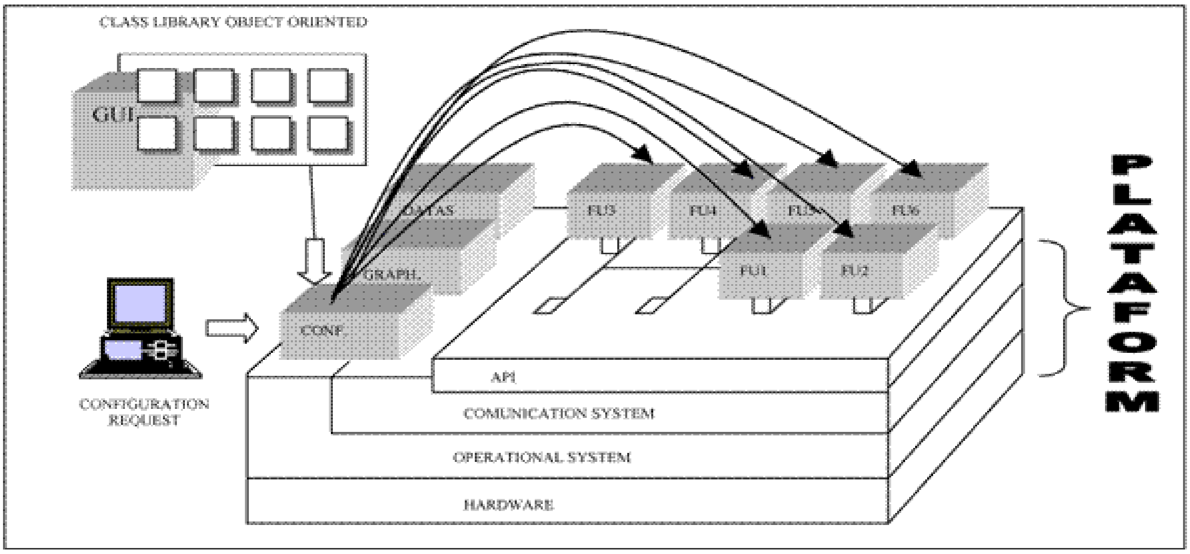


Figure 2.1: Open architecture control in automation system

2.3 THE OPEN MODULAR ARCHITECTURE CONTROLS (OMAC)

Pritschow et all [5] have studied the OMAC architecture had its beginning in December of 1994 with the publication of "Requirements of Open, Modulate Architecture Controllers for Applications in the Automotive Industry" by Chrysler, Ford and General Motors. This document served as a guide for controllers API in the North American automobile industries.

The OMAC group is composed of open architecture system users, whose objective is to work together, bringing several benefits such as:

(i) To establish a position of the open architecture controllers based on experience of the software users and machine manufacturers;

(ii) To accelerate the open control use within the industries, with the use of APIs;

(iii) To promote the development of open control among controller manufacturers;

(iv) To develop collective solutions for the development, commercialization and use of open architecture controller technology.

2.4 OPEN ARCHITECTURE MACHINE TOOL CONTROL

Open architecture machine tool control has been identified as an 'enabling' technology for the application of advanced controls in manufacturing. The desire for such systems has been in response to the frustration experienced by practitioners and researchers alike when advanced control techniques were attempted on current 'closed' architecture controllers. The term 'open ‘originates from the PC and workstation industry, where 'open systems' technologies have greatly enhanced the use and development of complex computer system [20][21][22][23].

Several commercial and academic programs that have focused on realizing some form of open architecture for machine tool controllers and manufacturing automation systems in general. Fundamentally, each approach has been concerned with one or more of the following:

(i) The integration of physical hardware devices,

(ii) Communication interfaces between devices,

(iii) Models of interaction between computing resources motion control and I/O devices.

These items provide a useful point of reference with which the different OAC systems can be compared. The following survey outlines the major accomplishments in this area

2.5 UNIVERSITY OF MICHIGAN OPEN ARCHITECTURE CONTROLLER (UMOAC)

Birla et al [11] have described an open architecture test bed developed at the University of Michigan (UMOAC) using a variety of platforms like PC based,VME bus(backplane),CAN bus(distributed).Custom software libraries allowed the development of control and monitoring systems within the environment of a real time operating system. An elaborate software hierarchy provided an object oriented application interface with abstractions of the machine functions.

2.6 HIERARCHICAL OPEN ARCHITECTURE MULTIPROCESSOR COMPUTER NUMERICAL CONTROLLER (HOAM-CNC) CONTROLLER

The HOAM-CNC architecture–Open System Architecture Hierarchical Multi-processor for CNC machines-acts mainly in the machine hardware, offering the advantages of having two buses, a CNC control bus and another bus to allow the introduction of new components which studies open architecture controller in real time for machines tools of high performance. They execute the implementation of several different types of hardware control with net communications to study the difference in machine performance depending on the adopted architecture as reported by Birla et al [11] and Koren et al [12]. They use this architecture seeking the regulating adaptive control. Modules that detect tool damage and vibration are inserted using acoustic sensors for the control execution.

Altintas et al [14] has reported about the use of a primary bus to execute the machine control process and to monitor the tasks and a secondary bus of higher performance is used to communicate with the CNC.

2.7 UNIVERSITY OF BRITISH COLUMBIA OPEN ARCHITECTURE CONTROLLER

Yellowley and Pottier [7] have presented an OAC system based on modular backplane architecture. A combination of processing modules was used to implement axis control, trajectory generation, and process monitoring and control. An interpreter, FORTH based programming interface allowed high level macros to be called from each motion program line. In this manner it was proposed that monitoring and control functions to be called from within the motion program, thus associating the process and geometry with the machine control.

2.8 PERSONAL COMPUTER BASED CONTROLLERS

Chiang and S.T [8] in his research described a PC-based CNC that can control up to eight axes, including four CNC axes, PLC axes, and a spindle. The product features a 1,000-block/sec processing time and what's described as flexible and extensive macros and dynamic look ahead contour control for high-precision high-speed molding. Also included is an intuitive Windows based GUI interface. The PC-based controllers are designed to use readily available commercial hardware components, such as motion control cards, to reduce the cost of the construction, and provide reconfiguration capability for the controller to quickly adapt to newly released technology. One PC performs all servo control, including feedback loops and NC-path generation, as well as providing a user interface, data processing, plant monitoring, network communication, and file management. This host PC runs on Windows NT, Windows 2000, Windows XP, and Windows XPE with a Venturcom RTX real-time extension to the operating system.

2.9 INTELLIGENT MACHINING SYSTEM

Balic [19] in his research the Intelligent systems are those systems which operating autonomously or semi-autonomously in uncertain environments with minimum supervision and interaction with a human operator. Such systems are driven by controls with some special characteristic, technique and method widely known as intelligent control technique.

The three basic steps of intelligent machining system (IMS) are:

(i) Sensing

(ii) Monitoring

(iii) Control

Yamazaki et al. [13] have developed an integrated CAM / monitoring system for three dimensional sculptured surface machining. The system tells us the tool path planning in real time. A CAM system was developed using surface modelling techniques and implemented as a real-time tool-path generator. Solid models of the tool and work piece were used to generate simulated cutting force to infer machining torque and surface errors. This "machining scenario" is a record of a simulation run for a particular operation and consists of:

(i) Process plan data (tool positions, NC commands, tool types)

(ii) Machining conditions (feeds and speeds)

(iii) Geometric data (tool-work piece contact faces)

(iv) Physical data (expected cutting force, torque, and machining error)

The approach demonstrated several significant benefits related to the use of artificial intelligence techniques such as the ability to handle virtually any number of constraints, process models, and sensory inputs, and the ability to include heuristic type reasoning into the overall control solution. While the work was a novel alternative to previous ACO approaches, it also introduced the idea of using "machine intelligence" as a control strategy for machining processes. Simulation studies of the decision system indicated that the technique performed better than the traditional ACO methods.

O'Hare [2] has suggested that ideas from the field of distributed AI had direct applications in manufacturing systems. In particular, the use of an agent based paradigm for the decomposition of computer integrated manufacturing systems. Under this approach, individual agents maintained certain "responsibilities" and interacted with other agents to achieve an overall goal. For the machining application the author suggested agents for:

(i) Planning and scheduling

(ii) Computer aided design

(iii) Material handling systems

(iv) Machining systems

Teltz and Elbestawi [6] have presented a hierarchical, knowledge based controller for turning. The system consisted of three distinct sub systems, implemented as independent tasks in a multi-threaded application:

(i) Adaptive force controller

(ii) Chatter detection and control system

(iii) Knowledge based supervisory system

2.10 DESIGN AND SIMULATION OF MICROCONTROLLER BASED AUTOMATIC TOOL CHANGING SYSTEM IN CNC MACHINE

Lynn [25] has presented a PIC 16F877A microcontroller is used to control the motors and interface between the user input and the driver circuit. There are some requirements for proposed system design. The first fact of microcontroller is to provide inexpensive, programmable logic control and interfacing to external devices. The second option is that there are about 32I/O pins are required for interfacing various input and output devices. PIC 16F877A is used in this research because it is compatible all these requirements

2.11 A REVIEW OF THE EVOLUTION OF MICROCONTROLLER-BASED MACHINE AND PROCESS MONITORING

Frankowiak [26] has describe in this paper reviews the evolution of intelligent, distributed, microcontroller based machine and process monitoring systems. It considers basic building blocks that support such systems through the development of fault diagnostic methods, intelligent system based approaches and sensor-based machine monitoring. It then identifies three approaches that may be utilised when designing monitoring system architecture: integrated, distributed and embedded. Current applications of these approaches, when deployed individually and in combination with each other, are then discussed. In particular, the paper considers the efficacy of microcontroller based embodiments, in both current and future monitoring activities.

2.12 MULTI AXIS LINEAR INTERPOLATOR DESIGN WITH PIC-MICROPROCESSOR

Zhou [27] suggest that presented an improve algorithm in least deviation linear interpolator, which simplify the interpolation calculator. Also in the research, it designs a platform for least deviation linear interpolation with two axis linear guides, and it realizes the linear interpolator by PIC microprocessor with MPLAB C language in PIC microprocessor in the research.

2.13 DESIGN AND REALIZATION OF ASTEP-NC COMPLIANT CNC EMBEDDED CONTROLLER

Calabrese [28] has discussed STEP-NC, which is a model for data transfer between CAD/CAM and CNC that allows specifying machining process rather that tool motion with respect to the machine axes. STEP-NC CNC controllers are a new breed of CNC controllers that allow using this high-level model for a seamless integration in the CAD/CAM-CNC chain. Various prototypes of STEP-NC CNC controllers have been developed so far, mainly based on industrial PCs. In this paper we instead show how it is possible to realize a STEP-NC CNC controller using a low cost microcontroller, embedded in the CNC machine; this goal has been obtained by accurately parallelizing the tasks involved in the machining process. More precisely, this paper presents the design and realization of an embedded system able to control a CNC machine with two degrees of freedom, to machine STEP-NC part programs and to perform also other high level activities.

2.14 CONCLUSION OF LIERATURE REVIEW

From the literature review presented above it has found that contemporary research related to NC machine tool development is directed towards open architecture control and Direct Model to Part machining strategies. One major issue with the conventional NC technology is that the motion control in NC machining operations cannot be efficiently automated with the restrictive (ISO 6983) G and M code. However, CNCs of different vendors implement different versions of G-code which lacks portability and leads one to buy the customised and costly CAD/CAM-CNC integrated modules/software. An open architecture control machine tools can be directly controlled from a computer, rather than a dedicated NC controller. It is aimed at providing a low cost NC machine interface from PC and hardware interface for machine drive control so that the dependency of commercially available NC controllers can be avoided. There are several factors that restrict the use of PC directly as NC controller as one need to develop the interface logic and data communication modules for control of drive motors through PC. The interface logic and data communication for NC motions can be executed in several ways but these protocols have not been yet standardised. There are tremendous opportunities for simplification of data communications for precise and faster NC drive motions.

CHAPTER: 3

ELEMENTS OF PC BASED NC CONTROLLER

Under present work an attempt has been made to develop a PC based NC controller. The main components required for the development of the PC based NC controller are as listed below:

1. Personal Computer (PC) with sufficient computational capability and storage capacity.
2. Graphical user interface (GUI) to interact with the machine through interface hardware.
3. PC-Drive interface hardware.
4. Selection of type of drive.

In the following sections the detailed description about the selection of standard electronic components and logic used for required hardware development have been explained.

3.1 HARDWARE COMPONENTS USED FOR PC BASED CNC CONTROLLER

The development of PC based CNC controller to need the hardware components for check the proper functioning .The hardware components should be take easily available in the market and purchase very low price. The following components listed below:

(i) PIC-microcontroller

(ii) Printed circuit board (PCB)

(iii) Transmitter receiver IC

(iv) Regulator 7805

(v) UNL2003 (power to drive motor)

(vi) Crystal to generate frequency

(vii) Transformer

(viii) Capacitor

(ix) Stepper motor

(x) Diode

3.2 SELECTION OF DRIVE MOTORS

Drive unit is having the electric power motors, routers and high precision motion convertor mechanism. Sufficient rated torque of electric drive motors, with having zero play in motion converter mechanisms. In the hardware check out and take the suitable drive motor discuss below.

3.2.1 Types of CNC drive motors

(i) DC Motors
(ii) Brushless Direct-Current Motor
(iii) Stepper Motor

(i) DC Motor: The brushed DC electric motor generates torque directly from DC power supplied to the motor by using internal commutation, stationary magnets (permanent or electromagnets), and rotating electrical magnets. The advantages of a brushed DC motor include low initial cost, high reliability, and simple control of motor speed. Disadvantages are high maintenance and low life-span for high intensity uses.

(ii) Brushless direct-current motor: Brushless DC (BLDC) motor is a rotating electric machine where the stator is a classic three-phase stator like that of an induction motor and the rotor has surface-mounted permanent magnets. Therefore, BLDC motors often incorporate either internal or external position sensors to sense the actual rotor position or the position can be detected without sensors.

(iii) Stepper Motor: The best digital actuator is stepper motor; in other words, they are either on or off. These motors are commonly used in measurement and control applications. Sample applications include ink jet printers, CNC machines and volumetric pumps. Several features common to all stepper motors make them ideally suited for these types of applications.

3.2.2 Types of Stepper motor

(i) Variable-reluctance stepper motor
(ii) Permanent-magnet stepper motor
(iii) Hybrid stepper motor

3.2.2.1 Variable-reluctance (VR)

This type of stepper motor has been around for a long time. It is probably the easiest to understand from a structural point of view.This type of motor consists of a soft iron multi-toothed rotor and a wound stator. When the stator windings are energized with DC current the poles become magnetized. Rotation occurs when the rotor teeth are attracted to the energized stator poles.

3.2.2.2 Permanent Magnet (PM)

Often referred to as a “tin can” or“canstock” motor the permanent magnet step motor is a low cost and low resolution type motor with typical tep angles of 7.5° to 15°. (48 – 24 steps/revolution) PM motors as the name implies have permanent magnets added to the motors structure. The rotor no longer has teeth as with the VR motor. Instead the rotor is magnetized with alternating north and south poles situated in a straight line parallel to the rotor shaft. These magnetized rotor poles provide an increased magnetic flux intensity and because of this the PM motor exhibits improved torque characteristics when compared with the VR type

3.2.2.3 Hybrid (HB)

The hybrid stepper motor is more expensive than the PM stepper motor but provides better performance with respect to step resolution, torque and speed. Typical step angles for the HB stepper motor range from 3.6° to 0.9° (100 – 400 steps per revolution). The hybrid stepper motor combines the best features of both the PM and VRtype stepper motors. The rotor is multi-toothed like the VR motor and contains an axially magnetized concentric magnet around its shaft. The teeth on the rotor provide an even better path which helps guide the magnetic flux to preferred locations in the air gap. This further increases the detent, holding and dynamic torque characteristics of the motor when compared with both the VR and PM types.

The information about the three motors is given in the above the paragraph, finally the available stepper motor in the market which has been shown in figure 3.1 has been selected for development of PC based CNC controller for X, Y, Z drive motor. The characteristic features of the general stepper motors are as follows.

(i) Open loop positioning: the stepper motors move in increments or steps. As long as the motor runs within its torque specification, the position of the shaft is known at all times without the need for a feedback mechanism.

(ii) Holding torque: As motor speed increases, torque decreases. Most motors exhibit maximum torque when stationary; however, the torque of a motor when stationary (holding torque) defines the ability of the motor to maintain a desired position while under external load

(iii) Load Independent: Stepper motors move at a set speed regardless of load as long as the load does not exceed the torque rating for the motor.

(iv) Excellent response: Stepper motors have very good start-up, stopping and reverse motion response.

3.2.3 Selection of Stepper Motor for Test Hardware Circuit Design

Stepper motors are electromechanical devices that convert a pattern of inputs and the rate-of-change of those inputs into precise rotational motion. The rotational angle and direction for each change (step) is determined by the construction of the motor as well as the step pattern input. The M42SP-4NP is a standard made by MITSUMI Inc. as shown in figure 3.1. Four-phase unipolar stepper motor that is easily controlled when buffered with an appropriate high-current driver (ULN2003 or similar suggested) .The parameter of stepper has been explained in table 3.1.

Figure 3.1: Stepper motor used for test hardware

Table 3.1: Parameters of stepper motor

Parameters	**Values**
Step angle	7.5^0 per step
Holding torque	49.0 N-mm
Rated voltage	DC12V
Rated current/phase	259Ma
Excitation method	2-2 phase excitation (unipolar)

3.3 MICRO CONTROLLER

Micro suggests that the device is small, and controller means that the device can be used to control objects, processes, or events. Another term to describe a microcontroller is embedded controller, because the microcontroller and its support circuits are often built into, or embedded in, the devices they control. The very common known micro controllers available in market are:

i) 8051 microcontroller
ii) 8031 microcontroller
iii) 8751 microcontroller
iv) PIC microcontroller

The above listed microcontroller except PIC micro-controller are low efficiency, speed, packaging, power consumption, less no. of I/O pins on the chip and cost effectively. The PIC microcontroller is best for to fulfil the need of our electronics part. The main component and driver circuit Micro Chip 40-Pin 8-Bit CMOS FLASH Microcontroller PIC16F877 has been used for development of the PC interface to connect to drive motors. Figure 3.2 shows Pin description of PIC microcontroller.

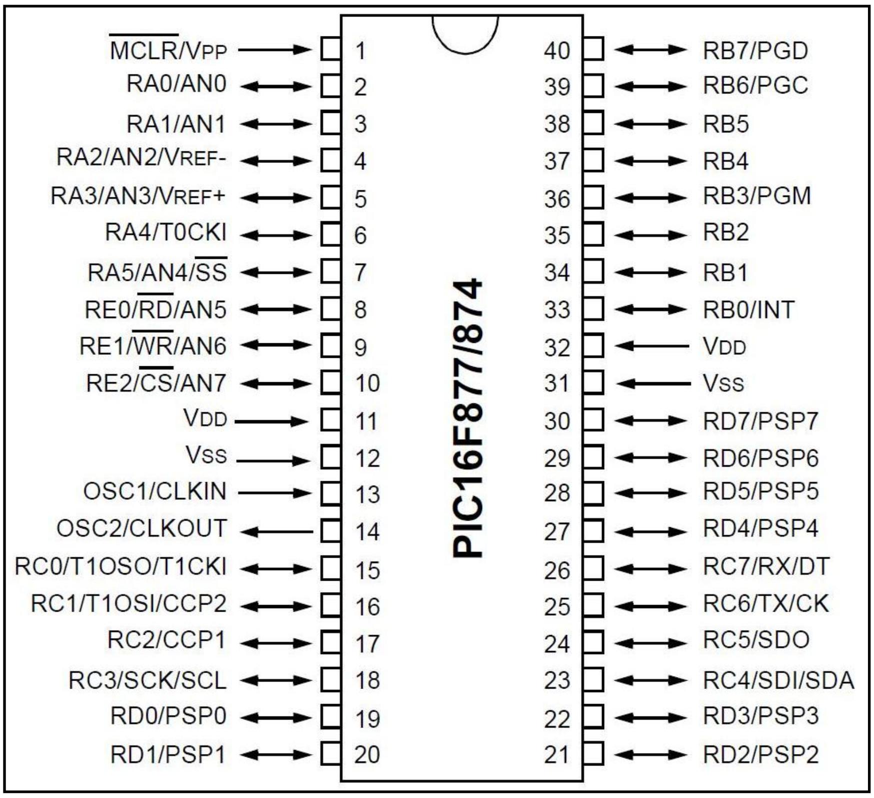


Figure 3.2: Pin Diagram of pic microcontroller.

Following are the features of PIC-16F877 microcontroller:

(i) High speed 20 MHz
(ii) Enough memory Up to 8K x 14 words of FLASH Program Memory, 368 x 8 bytes of Data Memory (RAM), 256 x 8 bytes of EEPROM Data Memory
(iii) Power-on Reset (POR).

(iv) Programmable code protection.

(v) Power saving SLEEP mode.

(vi) Low power, high speed CMOS FLASH/EEPROM technology.

(vii) In-Circuit Serial Programming (ICSP) via two pins.

(viii) In-Circuit Debugging via two pins

(ix) Processor read/write access to program memory

(x) Wide operating voltage range: 2.0V to 5.5V

(xi) Commercial, Industrial and Extended temperature ranges.

(xii) Low-power consumption: - < 0.6 mA typical @ 3V, 4 MHz

-<20 µA typical @ 3V, 32 kHz

- < 1 µA typical standby current

3.4 PCB LAYOUT DESIGN

The need of compact PCB electronic circuit is designing in OrCad. The OrCad Layout is a powerful circuit board layout tool that has all the automated functions to quickly complete in PCB.The main part is to place the components on the board. Selecting a track in layout highlights the corresponding net. In layout, set up of an environment is needed to create a new design board, e.g., selecting the units of measurement, create the board outline, defining the layer stack, setting the system grids, defining the manufacturing technology, defining pad stack, defining via and setting has to be done. Figure 3.3 has shown the PCB design of electronic controller.

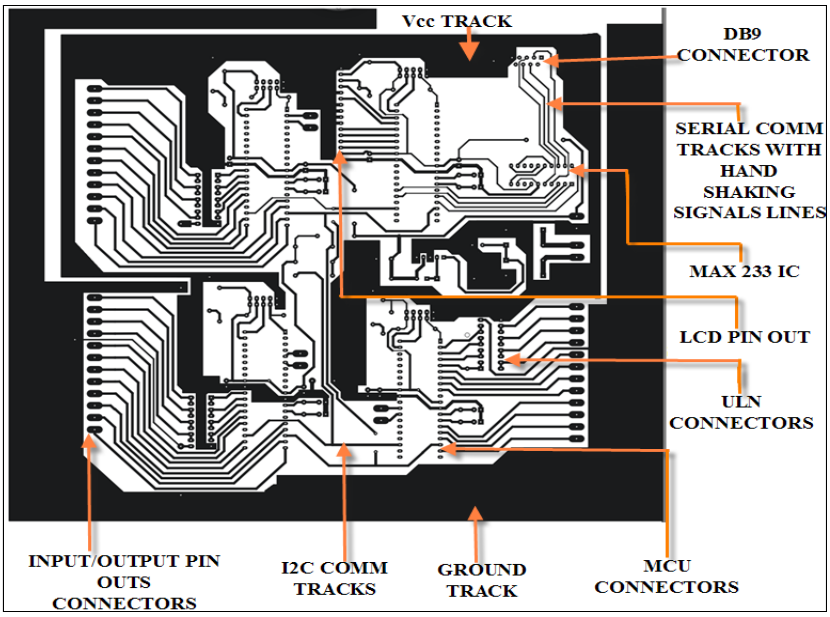


Figure 3.3: PCB layout in Orcad

3.5 DATA COMMUNICATION METHOD

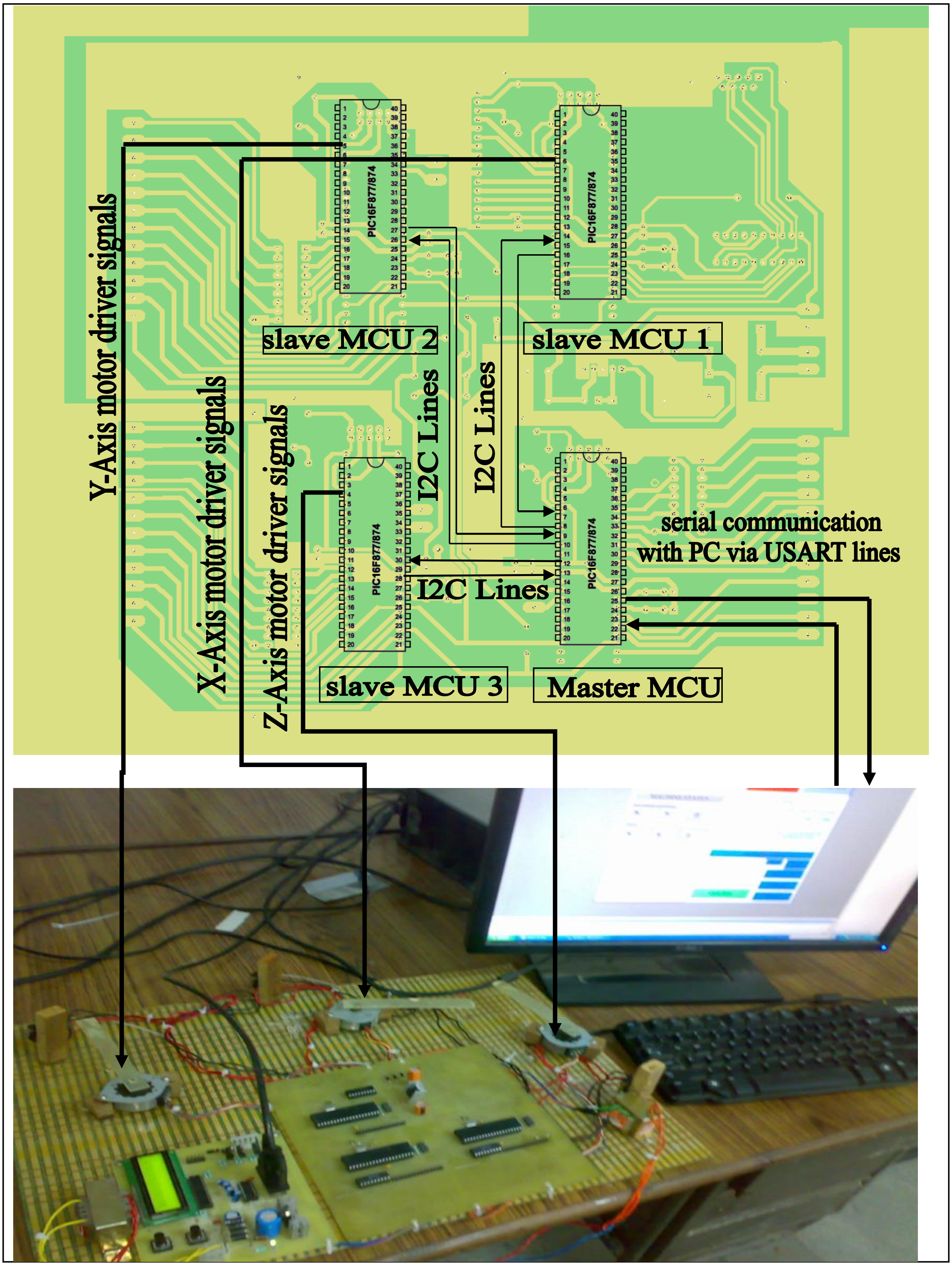


Figure 3.4: Data Communication through PC to Microcontroller

The Window XP based PC has been used communicate the data from microcontroller, all of these will help in development of more precise and accurate mechanism, PC has sufficient memory, amazing speed, accuracy, efficiency and repeatability. To receive the data from microcontroller, change the setting of PC baud rate (9600) and the rate of bits transfer (8) on PC, according to the type of microcontroller. To receive the data from PC, The master microcontroller works as arithmetic logical unit which performs all the mathematical operation then passes values to the salve microcontroller. Then the remaining calculation is performed by the slave microcontrollers, which further send signal to x, y, z drives. The communication between master and slave microcontrollers and PC takes place in several levels as listed below and shown in figure.3.4.

(i) PC to Master Microcontroller

(ii) Master Microcontroller to PC

(iii)Master Microcontroller to Slave Microcontroller

(iv)Slave Microcontroller to Master Microcontroller

(v) Slave to Drive Motor

3.6 COMMUNICATION TECHNIQUE

There are several communications techniques reported for use between OAC system modules, including:

(i) Shared memory,

(ii) Bus communications

(iii)Standard communications protocols.

The method has typically been associated with the topology of the communicating modules; the choice in any given situation largely due to the time requirements of the particular modules involved. In the case of shared memory and bus based communications, modules wishing to interface with other modules must use hardware addresses. These addresses are typically hard coded' into module source code, and if modified due to changes in hardware configuration, require at best minor source code modifications and re compilation.

Alternatively, most standard communications protocols use 'soft' addressing schemes. In this case, the underlying system resolves communication addresses at run time. Changes to hardware configuration require only modifications to addressing data bases. Application code remains unchanged.

3.6.1 Serial Communication

Although the personal computers offer various data and command transfer protocols, such as serial port, parallel port, Universal Serial Bus (USB) communication port, and others, the serial port was retained as the method of choice for communicating with the controller circuit. The simplicity and ease of programming the serial port via the computer's operating system are the main advantages of using the serial port. In parallel data transfer, often 8 or more lines (wire conductors) are used to transfer data to a device that is only a few feet away. To transfer to a device located at any distance, the serial method is used. Figure 3.5 shows the main difference in serial and parallel data transfer scheme. In serial communication, the data is sent one bit at a time. In contrast to parallel communication, in which the data is sent a byte or more at a time. The pic microcontroller has in built ready to use serial communication module. The module works independently to communicate with other devices. So the microcontroller is simultaneously controlling the machine control operations and communicates with other devices by USART.

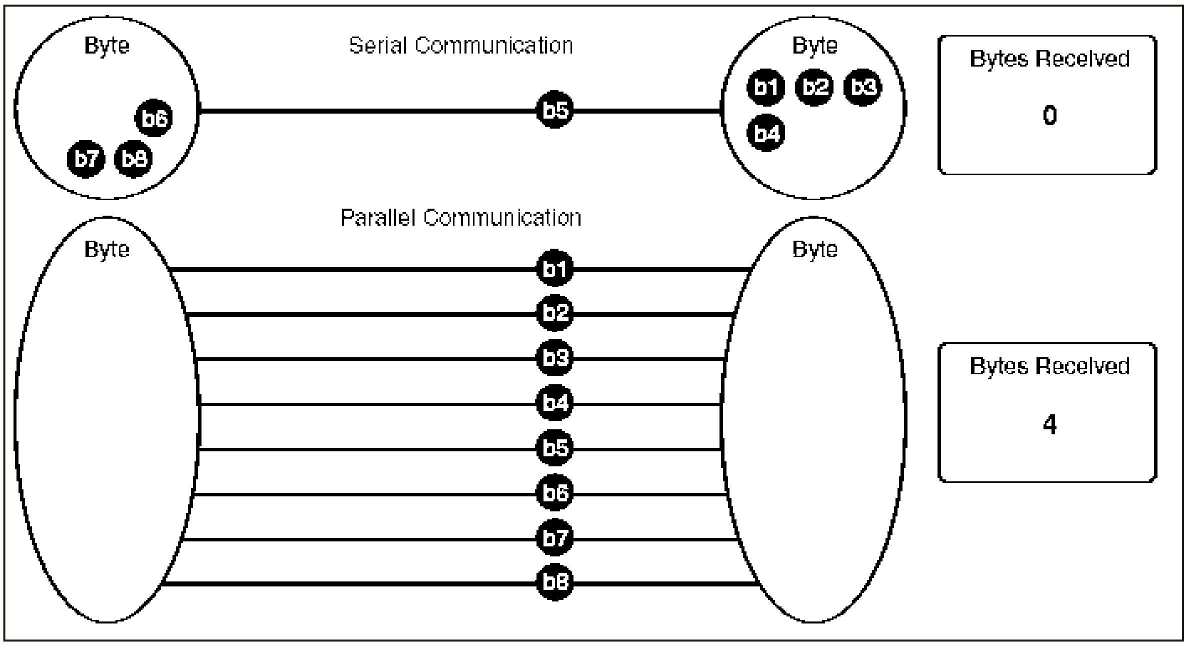


Figure 3.5: serial versus parallel data transfer.

3.6.2 Basics of Serial Communication

When a microprocessor communicates with outside world, it provides the data in byte-sized chunks. In some cases, such as printers, the information is simply grabbed from the 8-bit data bus of the printer. This can work only if the cable is not too long, since long cables diminish and even distort signals. Furthermore, an 8-bit data path is expensive. For these reasons, serial communication is used for transferring data between two systems located at distances of hundreds of feet. The fact that, in serial communication one data line for transmission and one for reception is used, (instead of the 8-bit data line in parallel communication) makes it not only much cheaper but also makes it possible for two devices at different location to communicate over the telephone line.

For serial data communication to work, the byte of data must be converted to serial bits using a parallel-in-serial-out-shift register. Then it can be transmitted over a single data line. This also needs that at the receiver end there must be a serial-in-parallel-out shift register to receive the serial data and pack them into a byte.

3.6.3 Serial data communication uses two methods

(i) Asynchronous

(ii) Synchronous

The **Synchronous** method transfers a block of data (characters) at a time while the **Asynchronous** transfers a single byte at a time it is possible to write program to use either of these methods. For this reason, there are special I.C. chips made by many manufacturers for serial data communication. These chips are commonly referred to as UART(Universal Asynchronous Receiver-Transmitter)and USART(Universal Synchronous-Asynchronous Receiver-Transmitter).

3.6.3.1 Asynchronous Serial Communication and Data Framing: The data coming in at the receiving end of the data line in a serial data transfer in binary, It is difficult to make sense of the data unless the sender and receiver agree on a fixed set of rules called protocol. Protocol is how the data is packed how many bits constitute a character, and when the data begins and ends.

3.6.3.2 Start and Stop Bits: Asynchronous serial data communication is widely used for character-oriented transmission, while Block-Oriented data transfer uses the Synchronous method. In the Asynchronous method, each character is placed in between Start and Stop bits. This is called Framing. In Data Framing, for Asynchronous communications, the data, such as ASCII characters, are packed in between a Start bit and a Stop bit. The Start bit is always one bit but a Stop bit can be 1 or 2 bits. The Start bit is always a 0(low) and stop bits is l(high).

3.6.3.3 Data Transfer Rate: The rate of data transfer in serial data communication is stated in bps (bits per second).Another widely used terminology for bps is baud rate .However, the baud and bps rates are not necessarily equal. This is due the fact that baud rate is the modem terminology and is defined as the number of signal changes per second. In modems, there are occasions when a single change of signal transfer several bits of data. As far as the conductor wire is concerned, the baud the rate and the bps are the same.

3.7 RS232 STANDARDS

RS-232 (Recommended Standard - 232) is a telecommunications standard for binary serial communications between devices. It supplies the roadmap for the way devices speak to each other using serial ports. The devices are commonly referred to as a DTE (data terminal equipment) and DCE (data communications equipment); for example, a computer and modem, respectively. The standard defines the electrical characteristics and timing of signals, the meaning of signals, and the physical size and pin out of connectors. The current version of the standard is TIA-232-F Interface between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange. An RS-232 port was once a standard feature of a personal computer for connections to modems, printers, mice, data storage, un-interruptible power supplies, and other peripheral devices. However, the limited transmission speed, relatively large voltage swing, and large standard connectors motivated development of the universal serial bus which has displaced RS-232 from most of its peripheral interface roles. To show in given figure 3.6

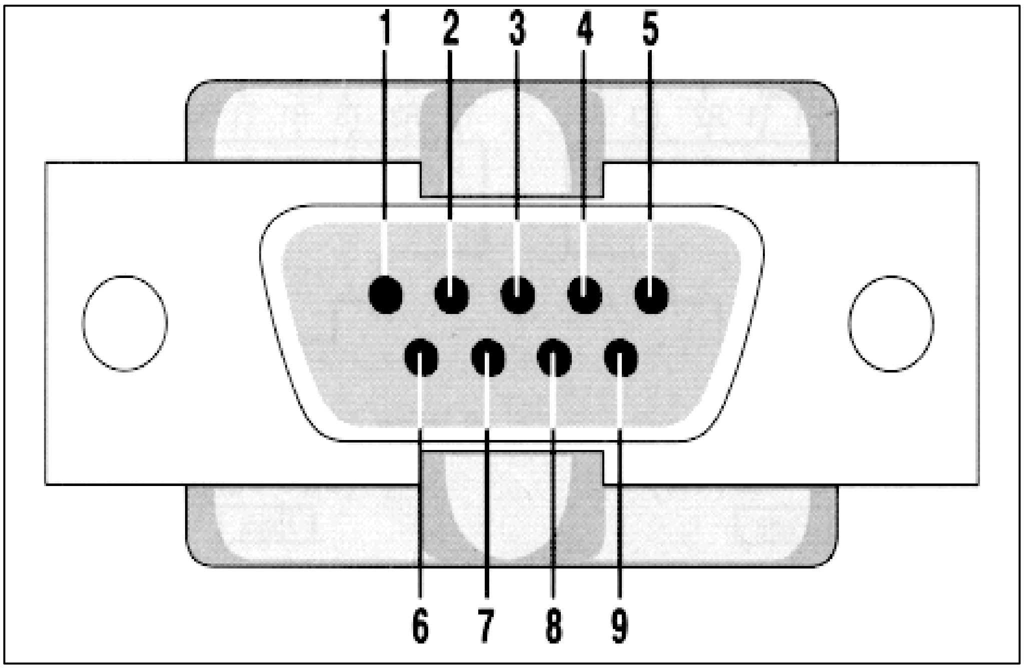


Figure 3.6: IBM PC DB-9Signal pins

Table 3.3: PIN Discription

Pin	Signal	Pin	Signal
1	Data Carrier Detect	6	Data Set Ready
2	Received Data	7	Request to Send
3	Transmitted Data	8	Clear to Send
4	Data Terminal Ready	9	Ring Indicator
5	Signal Ground		

To allow compatibility among data communication equipment made by various manufacturers, an interfacing standard called RS-232 was set by the Electronics Industries Association (EIA) in 1960. Today, RS232 is the most widely used serial input-output interfacing standard. This standard is used in PCs and numerous types of equipments. In RS-232 , a 1 is represented by -3 to -25V,while a 0 bit is +3 to +25 V, making -3 to +3 undefined. For this reason, to connect any RS-232 to microcontroller voltage a converter such as MAX232 is required to convert the TTL logic levels to RS-232 voltage level and vice-versa. Now days, RS-485, standards are also becoming popular. DB-9 Connectors are used for serial data communication at the PC end & describe in figure 3.7.

3.7.1 USART Communication with PC in PIC-168F77 Microcontroller

In the PIC 16F877, the USART is accessed through pins RB6 and RB7. It has two modes of operation, synchronous (using a separate clock signal) and asynchronous (no clock connection). The asynchronous mode is probably used more often, as other methods of synchronous transmission are available in the PIC. In asynchronous mode, RB6 acts as a data transmit (TX) output, and RB7 as data receive input (RX) (16F877 data sheet, section 3.3). Data is usually transmitted in 8-bit words (9 is an option), with the least significant bit sent first. The receiver must sample the input at the same rate as the data is sent, so standard clock (baud) rates are used. 9600 baud is used here, meaning that the bits are transmitted at about 10k bits/s. Separate transmit and receive lines are used, so it is possible for these operations to be carried out simultaneously.

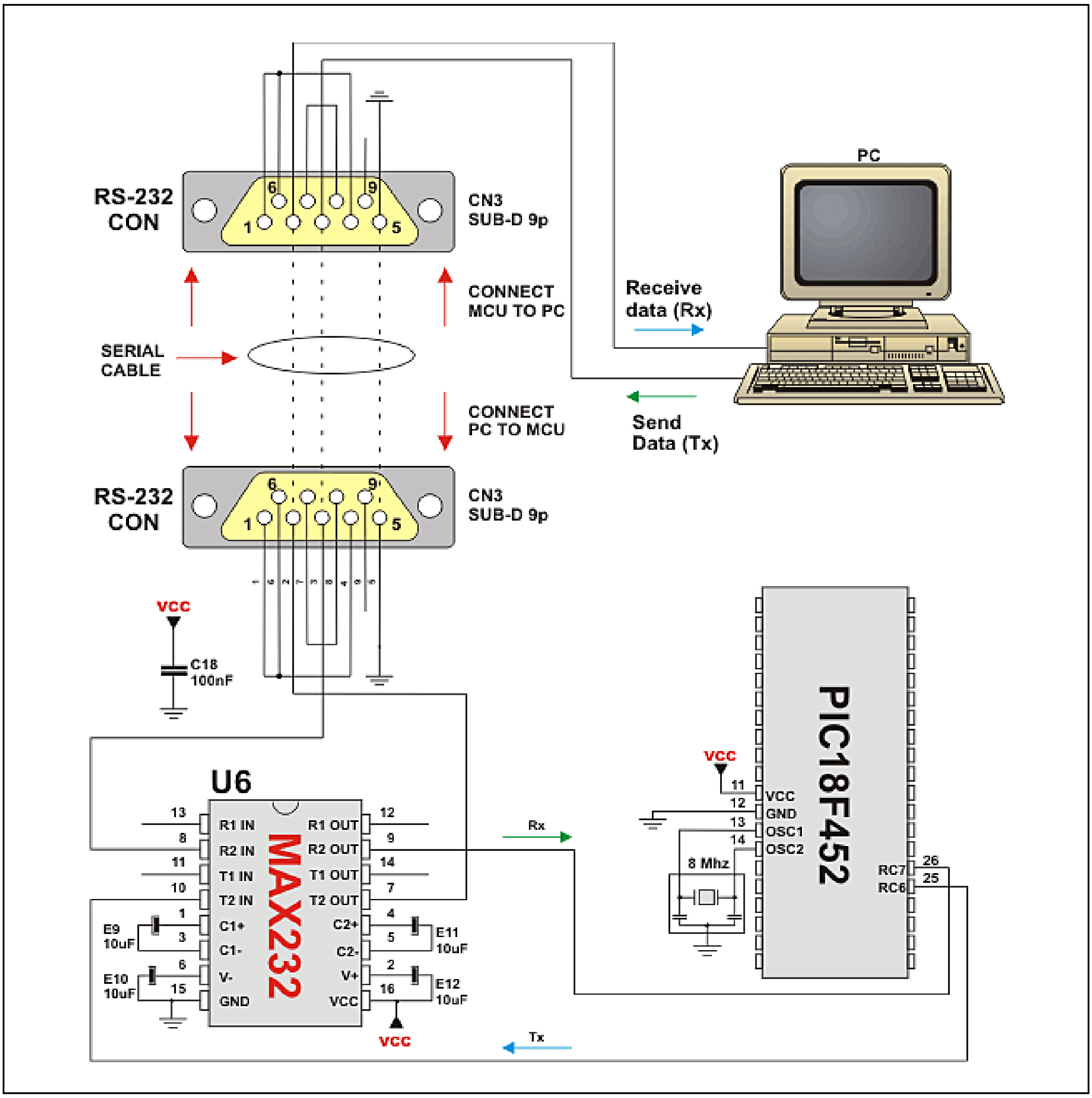


Figure 3.7: RS 232 Connections with PIC Microcontroller and PC by Using MAX 232 IC.

In the block diagram in figure 3.8 (a), the PIC is connected to a PC. The PIC USART output itself operates at TTL voltages, and needs an external serial line driver to convert its output into a higher symmetrical line voltage. This is necessary because a simple baseband data signal is attenuated down a line, due to the distributed resistance and capacitance of the cabling. The standard RS232 interface operates with a higher line voltage so that the signal can be transmitted further before being overcome by noise and interference. A typical link distance for RS232 is around 10 m with symmetrical voltages of up to +/-25V. +/- 12 V is more typical. The signal is also inverted with respect to the TTL version as shown in figure 3.8(b).

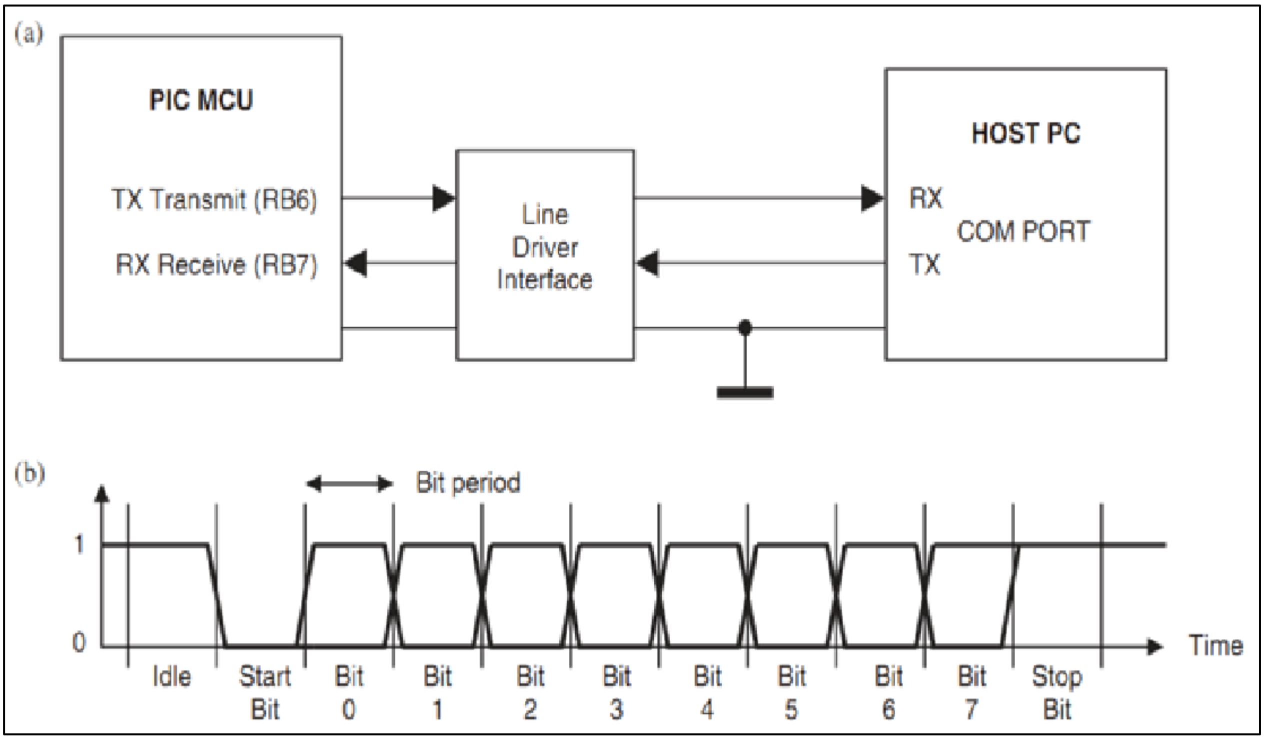


Figure 3.8: (a) Connection to PC, (b) Signal at PIC Port

It has been initially assume that the MCU is transmitting. The sender and receiver have to be initialised to use the same baud rate, number of data bits (default 8) and number of stop bits (default 1). The transmit (TX) output is high when idle (external line negative). When the serial buffer register TXREG) is written, the data is automatically sent as follows. The start of the byte transmission is signalled by the line going low for one clock period (start bit). The following 8 bits are then output from the transmit register, at intervals determined by the selected baud rate. In the figure 3.8 (b), the bits are shown as both high and low, to indicate that either is possible, depending on the particular data word. After the last data bit, the line is taken high by the transmitter for one clock period (stop bit), and that is the end of that transmission. The line is left high if there is no more data; another word can be transmitted after a delay, or immediately following. The protocol is thus about as simple as it is possible to get. The data is often ASCII coded, as the USART is frequently used to transmit character-based messages. The receiver must be initialised to read in the data at the same baud rate. At 9600 baud, the bit period is about 100 micro sec. When the falling edge of the start bit is detected, the receiver must wait for 1.5 bit periods, and then sample the line for the first data bit (LSB), read the next after a further clock cycle and so on until the set number of bits has been read in. The stop bit confirms the end of the byte, and another transmission can start. An interrupt flag is used to signal to the receiver MCU that there is data waiting. It must be read from RCREG register before the next byte arrives.

3.8 MASTER SYNCHRONOUS SERIAL PORT (MSSP) MODULE IN THE PIC-16F877A MICROCONTROLLER

The Master Synchronous Serial Port (MSSP) module is a serial interface useful for communicating with other peripheral or microcontroller devices. These peripheral devices may be serial EEPROMs, shift registers, display drivers, A/D converters, etc. The MSSP module can operate in four modes.

(i) Serial Peripheral Interface

(ii) Inter-Integrated Circuit (I^2C)

(iii) Full Master Mode

(iv) Slave mode (with general address call)

3.8.1 I^2C bus communication protocol

The I^2C interface protocol to ensure reliable transmission and reception of data. When the bus is active, one device is the Master (generates the clock and the handshaking signals), while all the other devices are Slaves. The current bus Master can both read-from and write-to any of the Slave units by addressing them individually. On a Multi-Master bus the Masters follow an arbitration scheme to ensure that the bus is not corrupted.The versatile I^2C-bus is used in various control architectures such as System Management Bus (SM Bus), Power Management Bus (PM Bus), Intelligent Platform Management Interface (IPMI), Display Data Channel (DDC) and Advanced Telecom Computing Architecture (ATCA).

3.8.2 I^2C- bus features

The following features are:

(i) Some intelligent control, usually a single-chip microcontroller.

(ii) General-purpose circuits like LCD and LED drivers, remote I/O ports, RAM.

(iii) EEPROM, real-time clocks or A/D and D/A converters.

(iv) Application-oriented circuits such as digital tuning and signal processing circuits for

(v) Radio and video systems, temperature sensors, and smart cards.

(vi) Only two bus lines are required; a serial data line (SDA) and a serial clock line (SCL)

(vii) Each device connected to the bus is software addressable by a unique address and simple master/slave relationships exits at all times & master can operates as master-transmitter or as master-receivers

(viii) It is a true multi-master bus including collision detection and arbitration to prevent data corruption if two or more masters simultaneously initiate data transfer.

(ix) Serial, 8-bit oriented, bidirectional data transfers can be made at up to 100 Kbit/s in the standard-mode, up to 400kbit/s in the fast mode, up to 1 Mbit/s in fast mode.

3.8.3 I ^{2}C Communication through master microcontroller with slaves microcontroller

If the master is receiving the data, it generates an acknowledge signal for each received byte of data except for the last byte. To signal the end of data to the slave-transmitter, the master does not generate acknowledge. The slave then releases the SDA line so the master can generate the STOP condition. The master can also generate the STOP condition during the acknowledge pulse for valid termination of data transfer .If the slave needs to delay the transmission of the next byte, holding the SCL line low will force the master in to a wait state. Data transfer continues when the slave releases the SCL line. This allows the slave to move the received data or fetch the data it needs to transfer before allowing the clock to start. This wait state technique can also be implemented at the bit level show in figure 3.9(A)

3.8.4 Transmission Control in Master/Slaves I^{2}C Communication

The clock and data lines are high when idle. The write and read sequences are initiated by a start bit sequence generated by the master controller. The transmission starts when the data line goes low; the clock then starts and an address or data bit output during the clock high period, which is latched into the slave receive shift register on the falling clock edge. After the eighth bit, the master (MCU) releases the data line, to allow the slave (EEPROM) to hold the line low to acknowledge the bits have been received. At the end of the next (ninth) clock high period, the slave releases the data line and the master can transmit the first bit of the next byte.

In the memory write sequence, when acknowledge is generated after the data byte has been received, and the master stops and both lines go high. In the memory read sequence, the master stops after the address write has been sent, and restarts in order to send a read control byte. It will then read the eight data bits returned by the memory chip, but does not generate acknowledge. The master then stops, and the lines go idle again. Figure 3.10 shows interfacing 24c02 IC to Pic via i^{2}c lines.

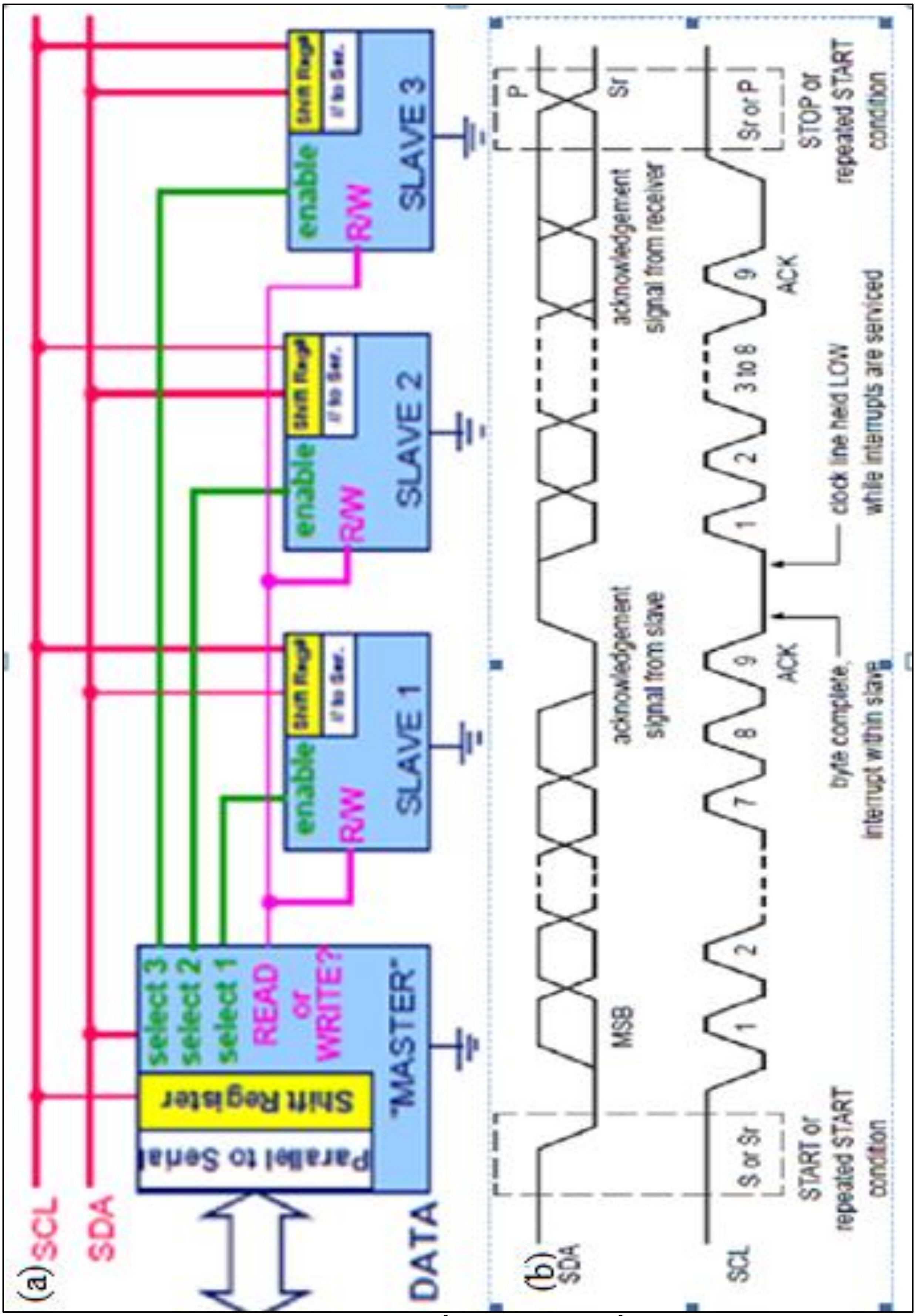


Figure 3.9 (a) :Inter- IC Bus (I^2C) connection, (b) I^2C signals.

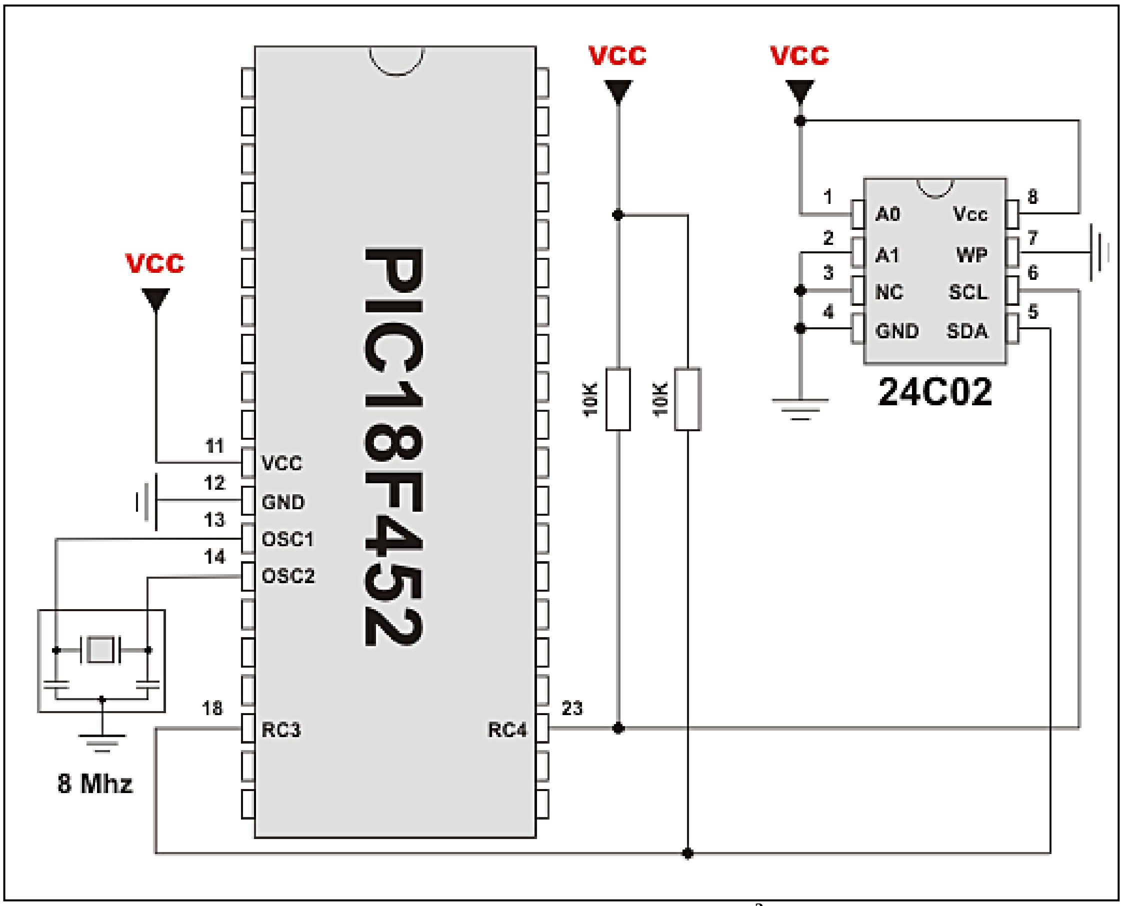


Figure 3.10: Interfacing 24c02 to PIC via I^{2}C Lines

The shift register of microcontroller used to send and receive the data bits is not directly accessible. The buffer register SSPBUF holds the data until the shift register is ready to send it (transmit mode), or receives it when the shift is finished in receive mode. The send operation is triggered by setting the Send Enable (SEN) bit, and the Buffer Full (BF) flag indicates that the data have been loaded. The interrupt flag (SSPIF) is automatically set to indicate start of transmission, and must be cleared in software if necessary. The Acknowledge Status (ACKSTAT) bit is cleared by acknowledge from the slave, to indicate that the byte has been received. SSPIF is then set again to indicate the end of the byte transmission, and the buffer can then be written with the next byte.

In the memory write sequence, when acknowledge is generated after the data byte has been received, and the master stops and both lines go high. In the memory read sequence, the master stops after the address write has been sent, and restarts in order to send a read control byte. It will then read the eight data bits returned by the memory chip, but does not generate acknowledge. The master then stops, and the lines go idle again.

CHAPTER: 4

GRAPHICAL USER INTERFACE (GUI) IN VISUAL BASIC

A graphical user interface (GUI) is a human computer interface which is a way for humans to interact with computers. Its uses windows, icons and menus which can be manipulated by a mouse, and often to a limited extent by a keyboard as well. A window is a rectangular portion of the monitor screen that can display its contents like program, icons, a text file or an image seemingly independently of the rest of the display screen. A major feature is the ability for multiple windows to be open simultaneously. Each window can display a different application, or each can display different files like text, image or spread sheet files, that have been opened or created with a single application.

4.1DEVELOPMENT OF VISUAL INTERFACE FOR PC BASED NC CONTROLLER

Visual Basic is a tool that allows you to develop Windows (Graphic User Interface - GUI) applications. The applications have a familiar appearance to the user. It is a high level programming language evolved from the earlier DOS version called BASIC. BASIC stands for Beginners' All-purpose Symbolic Instruction Code. The program codes in Visual Basic resemble the English language. Different software companies produce different versions of basic, such as Microsoft, QBASIC, QB software companies produce different versions of BASIC, such as Microsoft QBASIC,QUICKBASIC, GWBASIC, and IBM BASICA and so on. Visual Basic is event-driven, meaning code remains idle until called upon to respond to some event (button pressing, menu selection). Visual Basic is governed by an event processor. Nothing happens until an event is detected. Once an event is detected, the code corresponding to that event (event procedure) is executed. Program control is then returned to the event processor in show in fig 4.1.

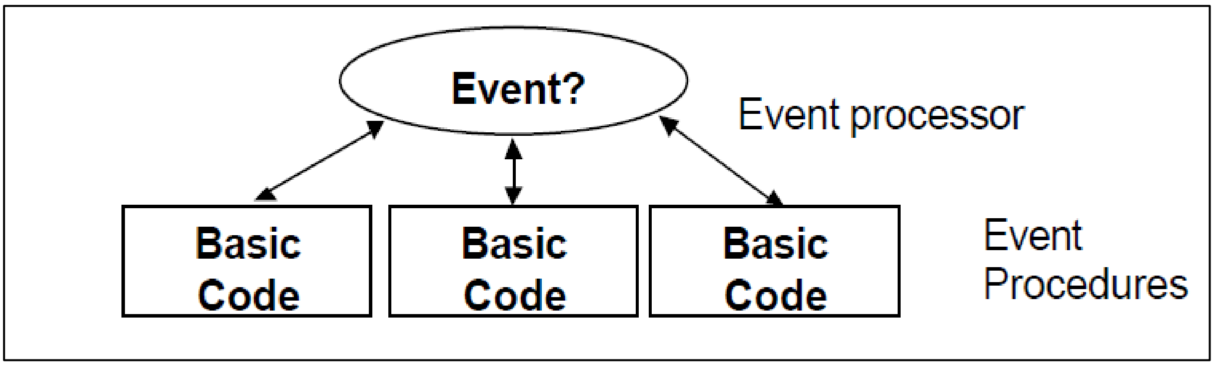


Figure 4.1: Program must be respond to events

4.2 THE VISUAL BASIC ENVIORNMENT

The Visual basic IDE shown in figure 4.2 neatly organizes a number of toolbars and information panels that assist in creating user interfaces and writing code. It manages and allows an easy access to the entire project.

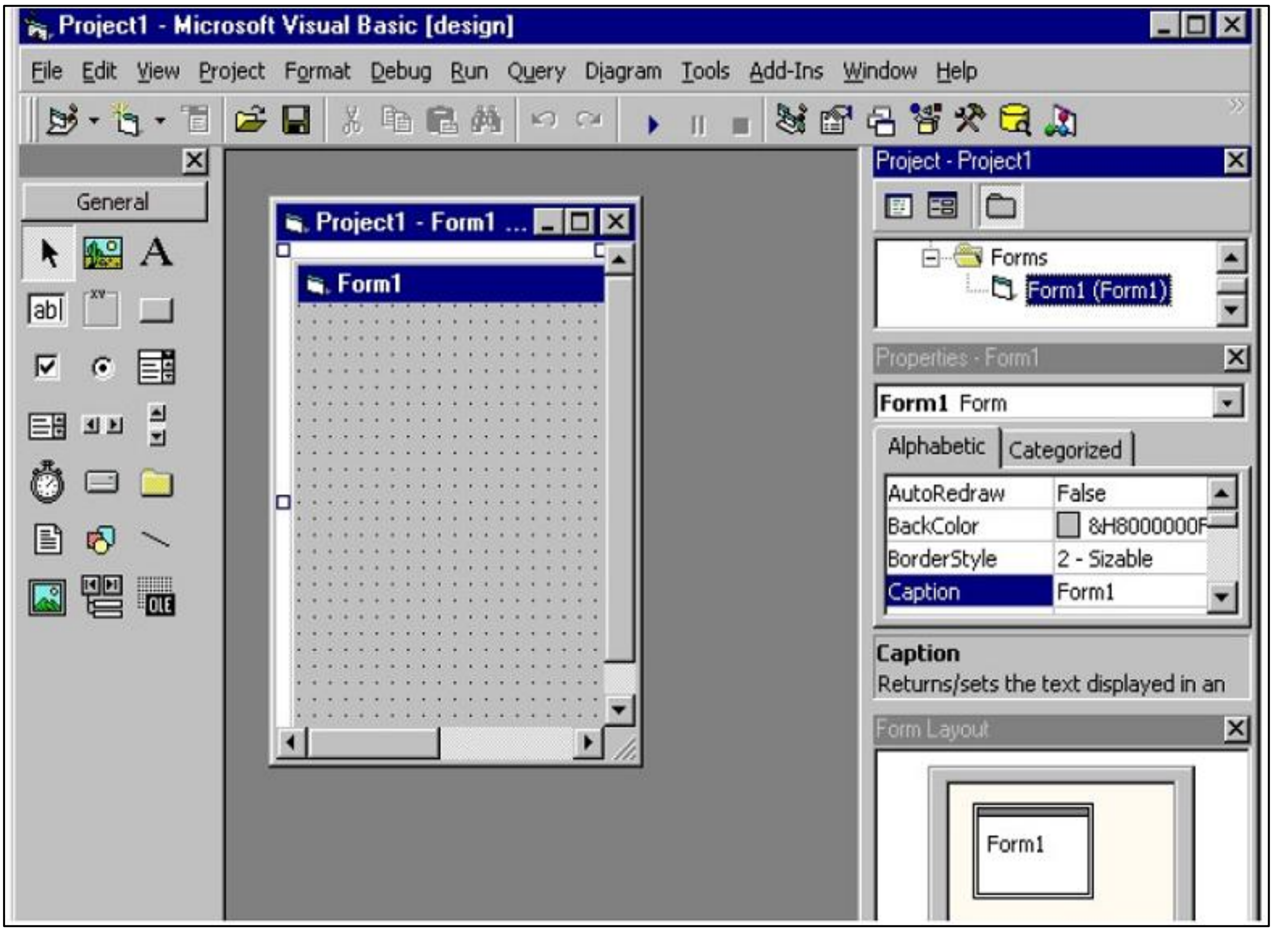


Figure 4.2: The basic visual basic environment

Development Environment in Visual Basic has several elements which has been explained below:

(i) The visual basic main window

The Main Window consists of the title bar, menu bar, and toolbar. The title bar indicates the project name, the current Visual Basic operating mode, and the current form. The menu bar has drop-down menus from which you control the operation of the Visual Basic environment. The toolbar has buttons that provide shortcuts to some of the menu options. The main window also shows the location of the current form relative to the upper left corner of the screen and the width and length of the current form in the shown in figure 4.3.

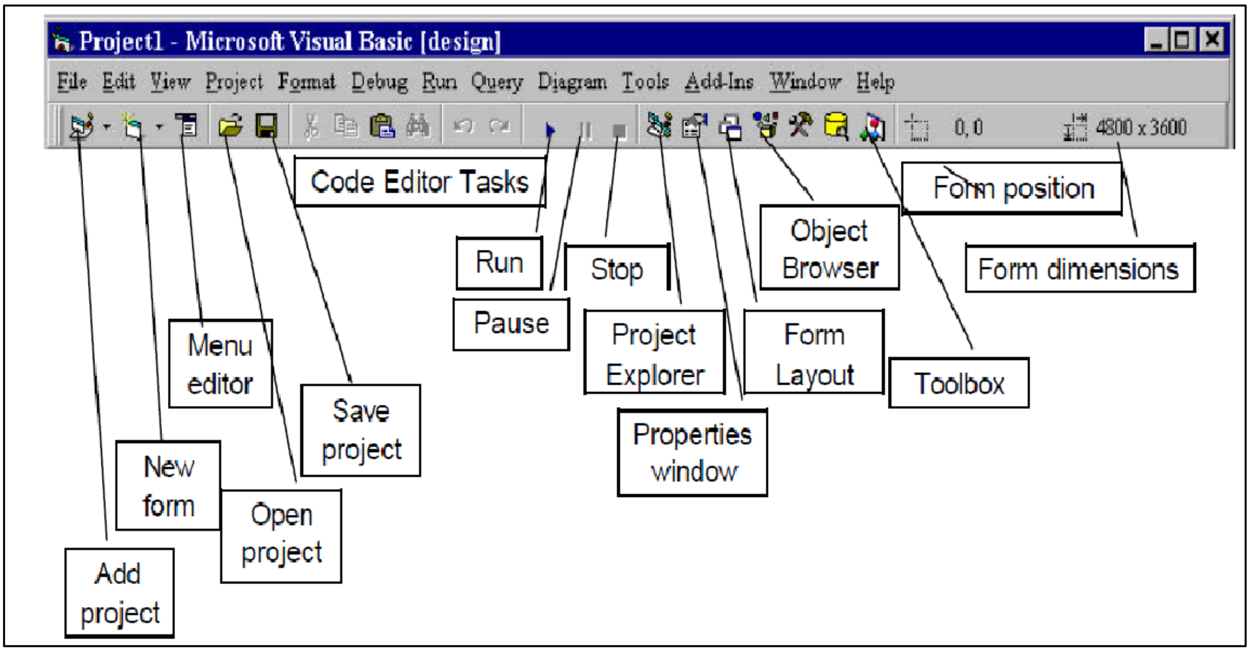


Fig 4.3: visual basic main window

(ii) The Tool Box window

The Visual Basic Toolbox contains the general objects and controls. There are forms to create the user interface of your VB applications as shown in figure 4.4

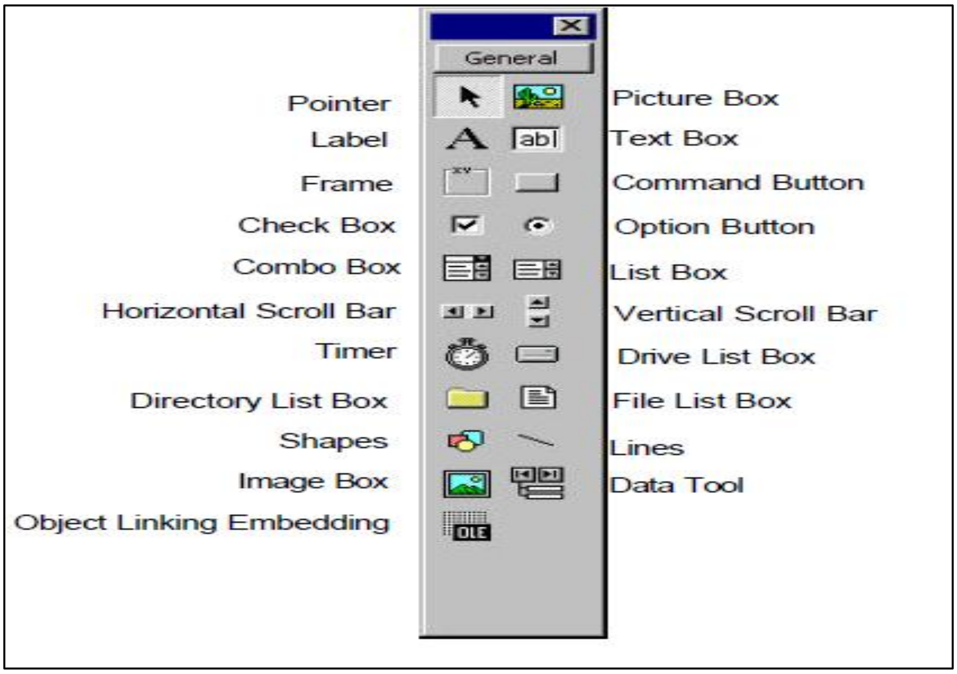


Figure 4.4: Tool box window

(iii) Project explorer window

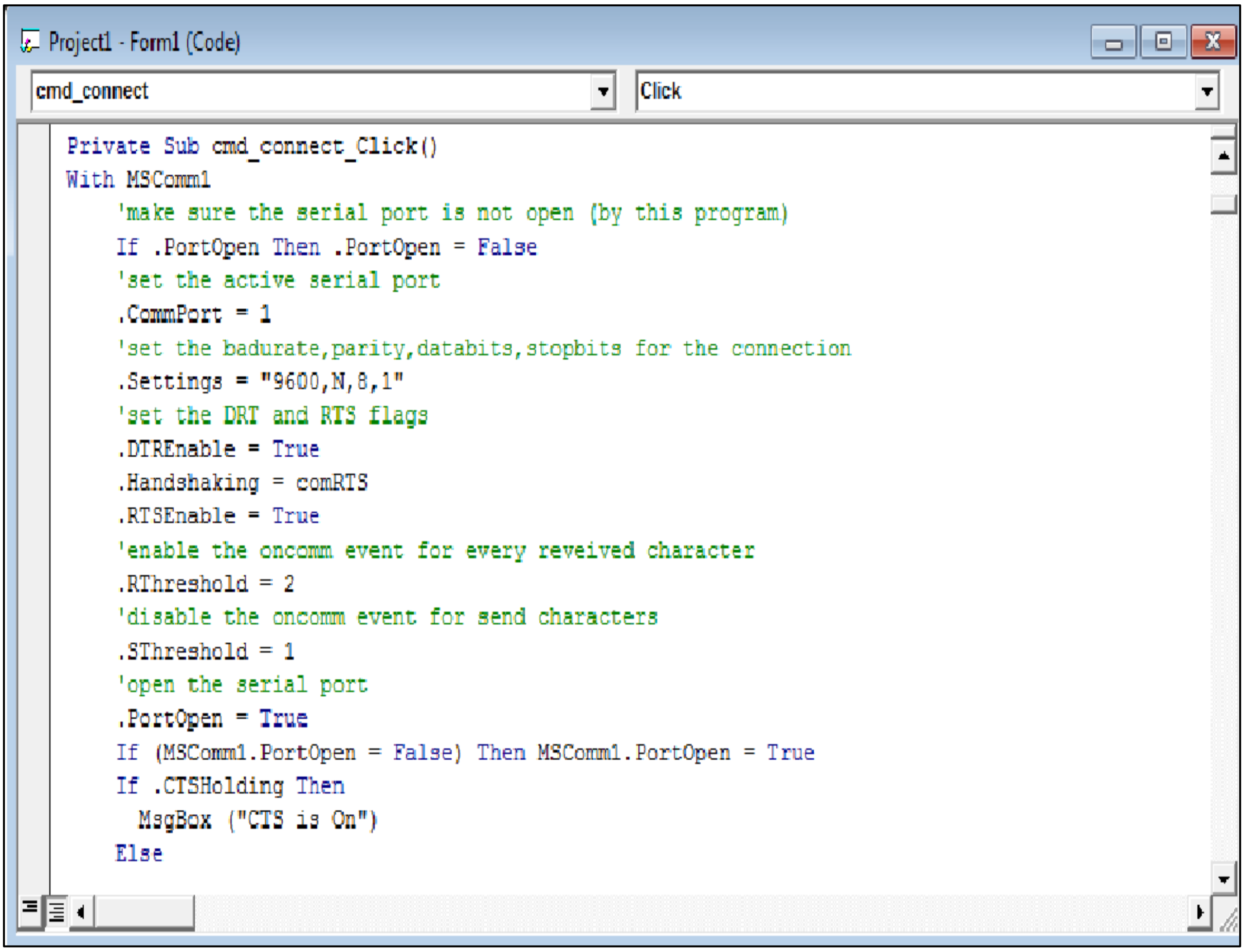
In this window all the collection of files in VB application is known as Project Explorer Window. The following extension used in VB application like VB project (with extension .vbp), Form(with extension .frm),Module (with extension .bas),Designer (with extension.dsr).

(iv) Project window

Properties of an object reflect the characteristic of the object for example Width, Height, and appearance. Each object in VB6 program has its own properties. For example properties of ***text box*** are Name, Alignment, Appearance, Locked, and Text, etc. Properties of ***label*** are Name, Alignment, Appearance, Locked and Caption font. Each property of object has a default value and with Visual Basic Properties window, the properties of the objects can be set at ***design time***. Some of properties can be changed at run time.

(v) Code window

It is very important features of visual basic programming. In this window we have write the coding part and users known as colour combination code in this widow .when use this window VB keywords comments are in green and most VB key words are in black and blue in figure 4.5.



```
Project1 - Form1 (Code)
cmd_connect                         Click

Private Sub cmd_connect_Click()
With MSComm1
    'make sure the serial port is not open (by this program)
    If .PortOpen Then .PortOpen = False
    'set the active serial port
    .CommPort = 1
    'set the badurate,parity,databits,stopbits for the connection
    .Settings = "9600,N,8,1"
    'set the DRT and RTS flags
    .DTREnable = True
    .Handshaking = comRTS
    .RTSEnable = True
    'enable the oncomm event for every reveived character
    .RThreshold = 2
    'disable the oncomm event for send characters
    .SThreshold = 1
    'open the serial port
    .PortOpen = True
    If (MSComm1.PortOpen = False) Then MSComm1.PortOpen = True
    If .CTSHolding Then
      MsgBox ("CTS is On")
    Else
```

Figure 4.5: Visual Basic Interactive Development Environment

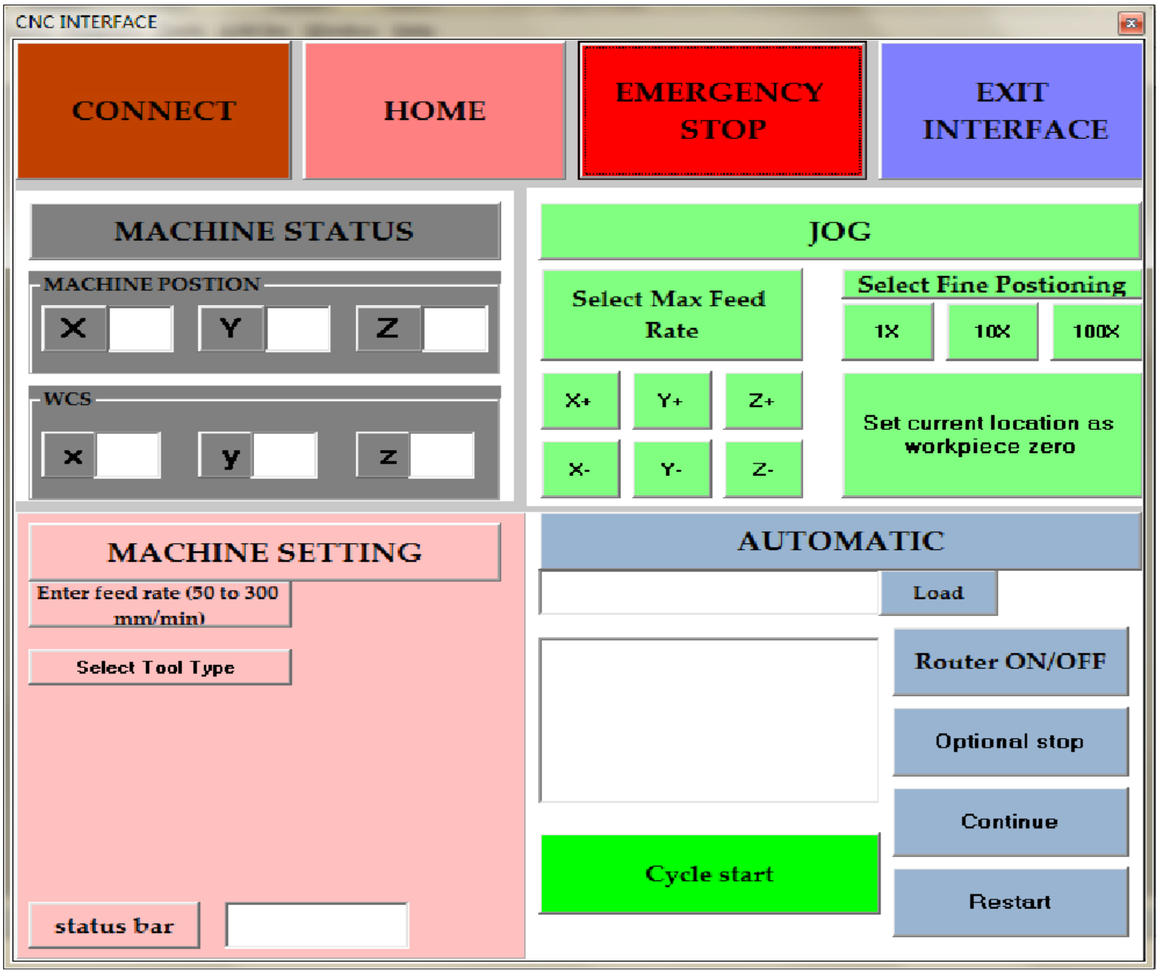


Figure 4.6: CNC main screen module

4.3 NC CONTROL GRAPHICAL USER INTERFACE (GUI)

The front end of CNC interface was developed in Visual Basic 6.0. The Graphical user interface (GUI) we have controls all the machine motion by sending the command to CNC controller and receives feedback to the controller. The current activity and status of machine is displayed in the GUI.The figure 4.6 displays the overall appearance of GUI.

4.3.1 Key features of GUI Design

The front end of GUI software has the following features.

1. Easily connect with handshake capability to the microcontroller memory.
2. Set feed rate according to material and tool selection.
3. Proper file extension filter.
4. Easily loaded tool position file.
5. Report the successful completion of task.
6. Required less memory.
7. Easy to operate interactive interface and user friendly.

8. If system crashes while running the program it can easily be handled from debugging.
9. The program execution computationally fast.

4.3.2 Modules of GUI

The development of interface in Visual basic has been done in the following module:

1. CNC interface main screen module
2. Machine setting module
3. Jog module
4. Machine status module
5. Automatic module

The detailed functioning of the above listed four GUI modules have been explained in following sub-sections

4.3.3 CNC interface main screen module

The main screen of CNC interface which helps to interact with machine. They have put following button in the interface to connect the machine and the function of these buttons work is different for example, user wants to start the machine firstly we go to clicked on connect buttons .The connect button colour will be change and display the message is connected on the screen. The clicked on home button the all drives works anywhere will be shift on home position. The clicked on emergency stop button the machine is stop immediately and user wants to exit the interface click on exit interface button. It is too easy the understand the function of these buttons mention in main screen window has been listed below with the help of flow charts. The main screen flow charts shown in figure 4.7

.

(i) Overall working of GUI: In the main screen flow chart explained with all the buttons. The firstly want to start the machine with the help of connect button and after clicked the home button, all drive reaches in home position, next to connect the jog mode. The jog module, select the maximum feed rate and fine positioning speed. The machine setting module will be help to select the tool type and choose the feed rate. In the automatic module to load the tool path file and clicked on cycle start button, select the optional stop to stop the machine in between the working position and after clicked on restart button, user wants the load new file or either start with existing file.

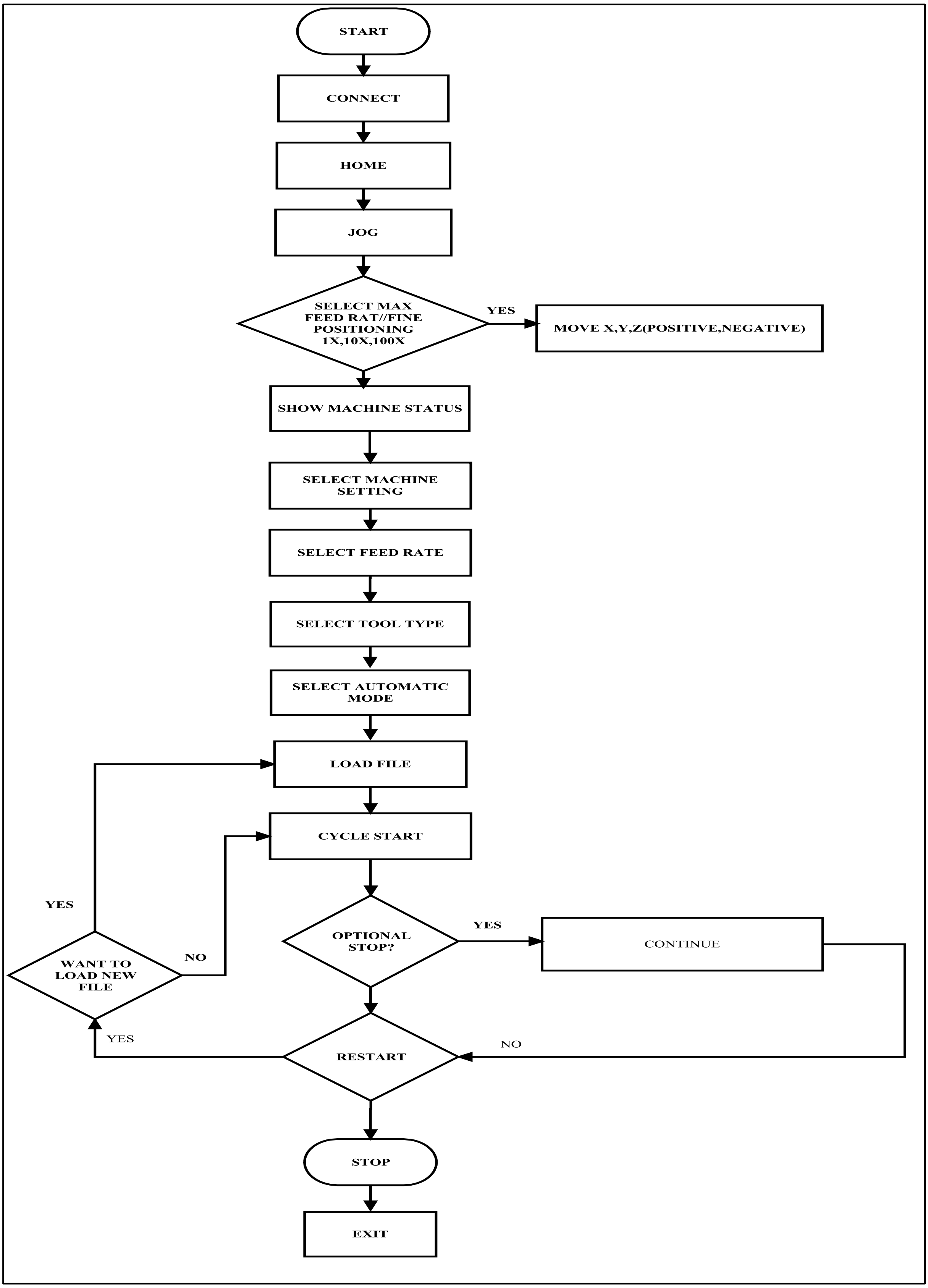


Figure 4.7: Flow chart for overall functioning of GUI

ii) Working of Connect Button Menu: In this button has been connect with PC and ready for transfer the data. When the connect clicking event by the user port will be open and show the connected message. Its easy to explain with the help of flow chart show in figure 4.8.

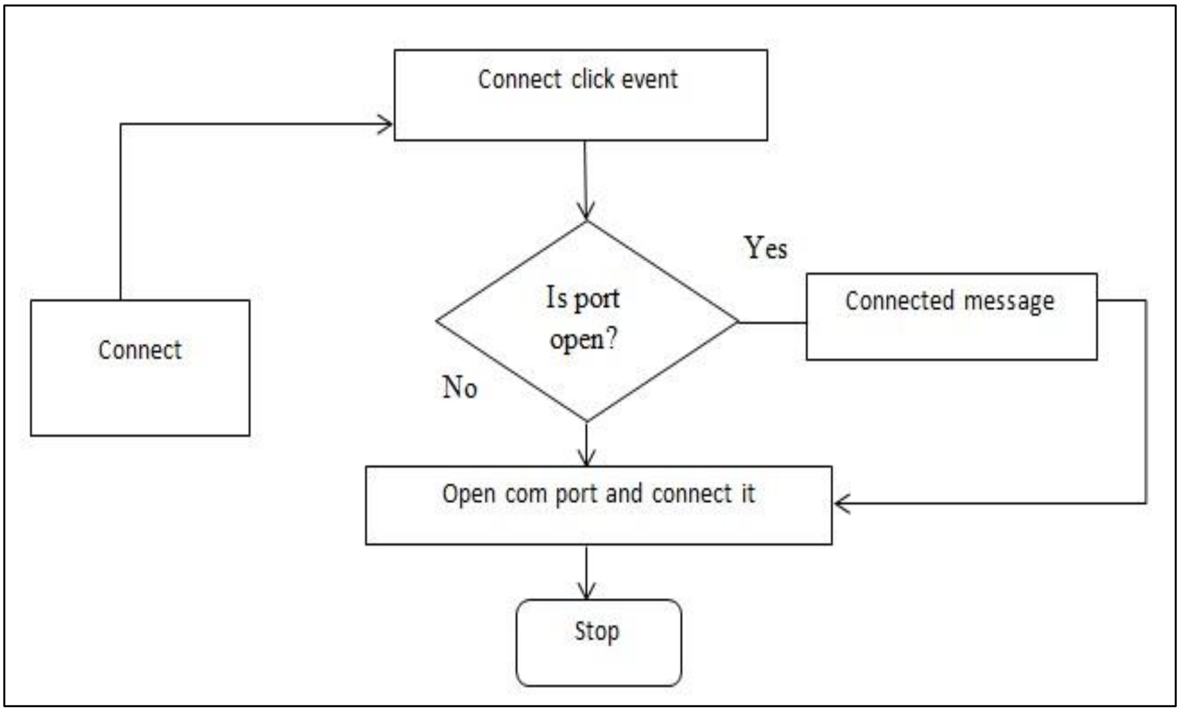


Figure 4.8: Connect click event

iii) Working of Home Button Menu: In the home button click event all the drive will set on the home position show in the flow chart figure 4.9.

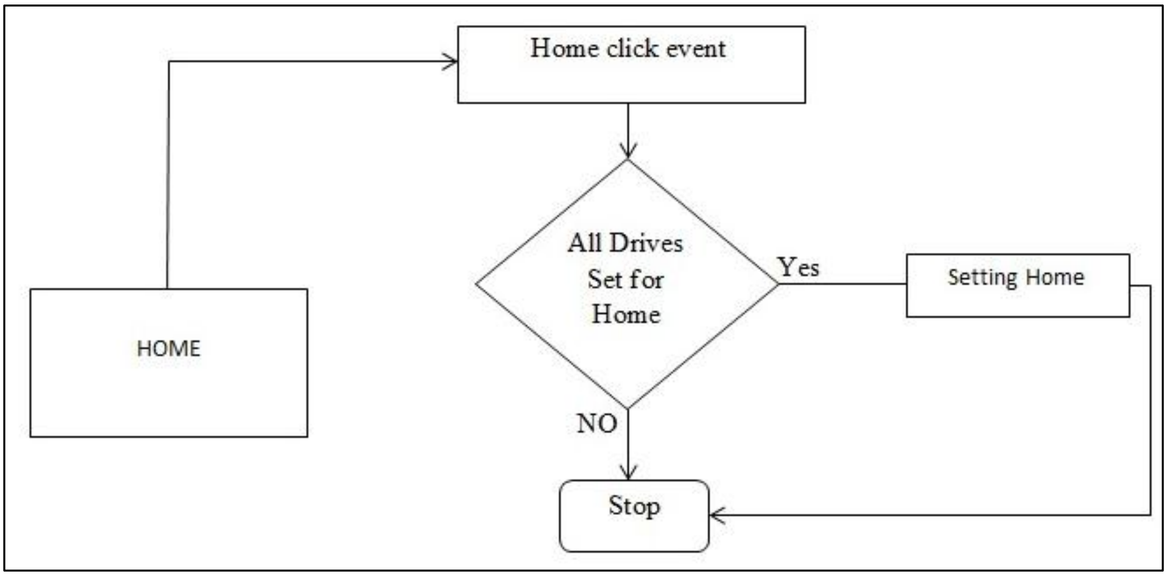


Figure 4.9: Home Button to Set All Drives.

(iii) Working of Option in Automatic Mode: In the automatic mode the load click event open the dialog box and show the no of files, the suitable tool path file picked as show in flow chart figure 4.10.

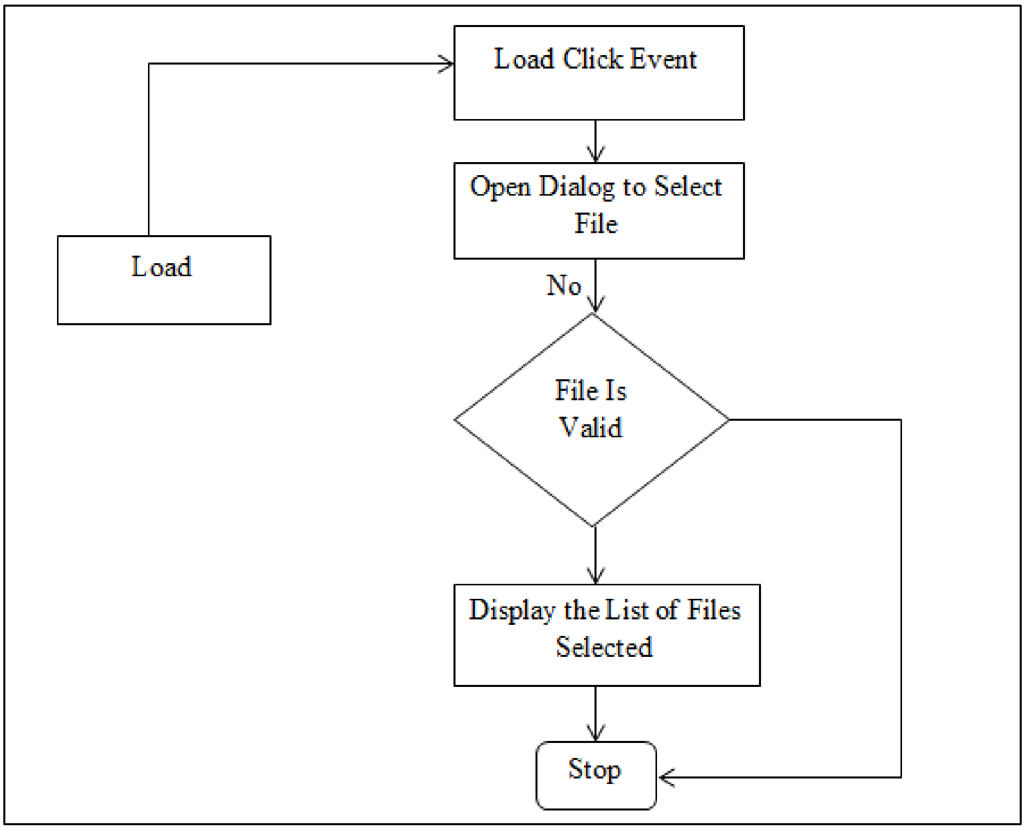


Figure 4.10: Load clicked button

(iv) Working of Cycle Start Menu: In the cycle start click event the suitable tool path file in the dialog box and transmitted the value of x,y,z to controller, after command will be transmitted file box is clear and ready to new tool path value. The flow chart is explained below in figure 4.11

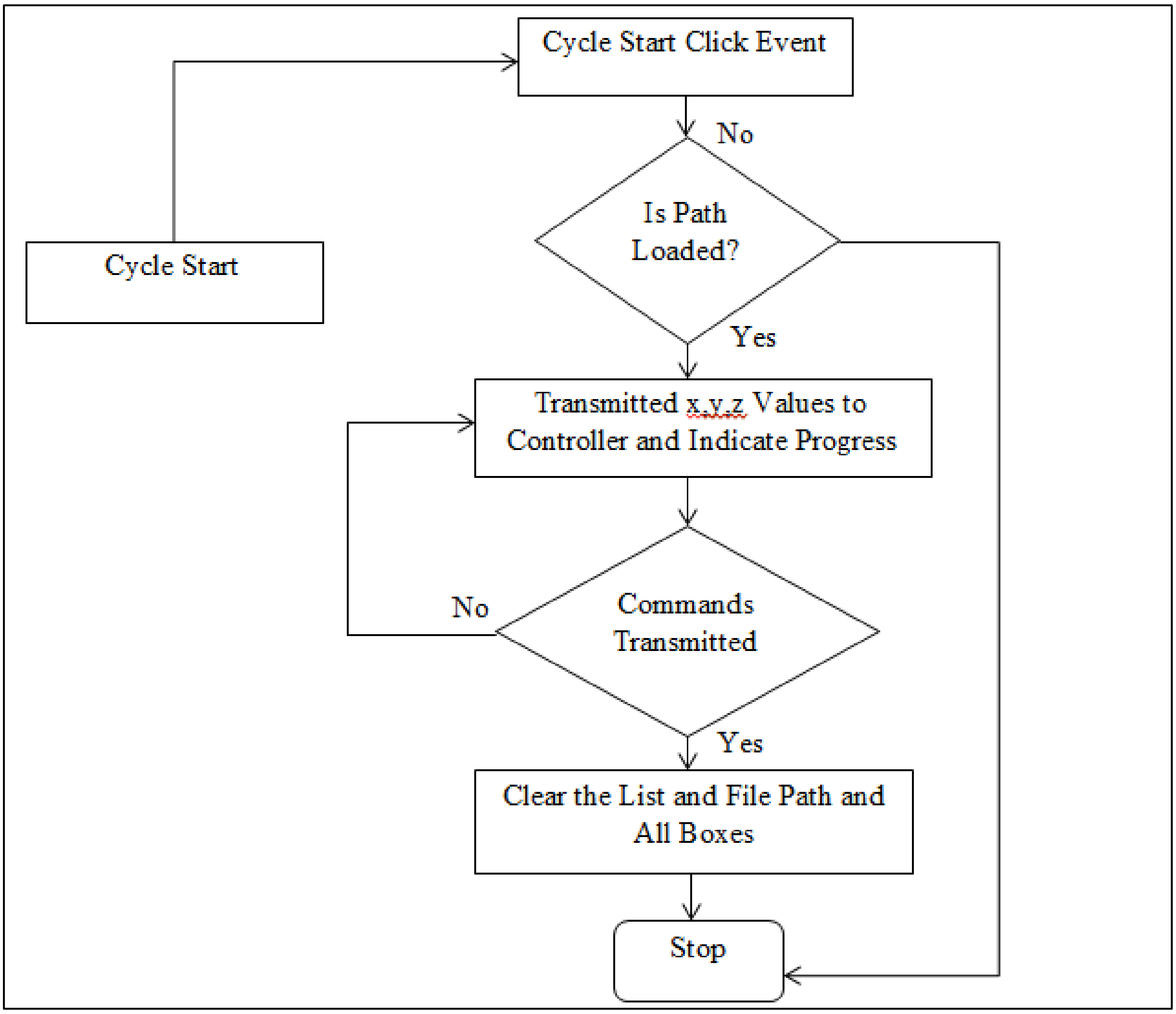


Figure 4.11: Click Cycle Button to Start Machining

4.3.4 Jog Module

If the user wants to set the jogging mode, with the help of this button x,y,z drives can be selected with respect to WCS (work coordinate system which is called floating zero) and click on select fine positioning choose the speed of drives from 1x,10x,100x buttons. The select maximum feed rate button is used to gives the maximum feed to motor drives. The jog modules screen as shown in figure 4.12.

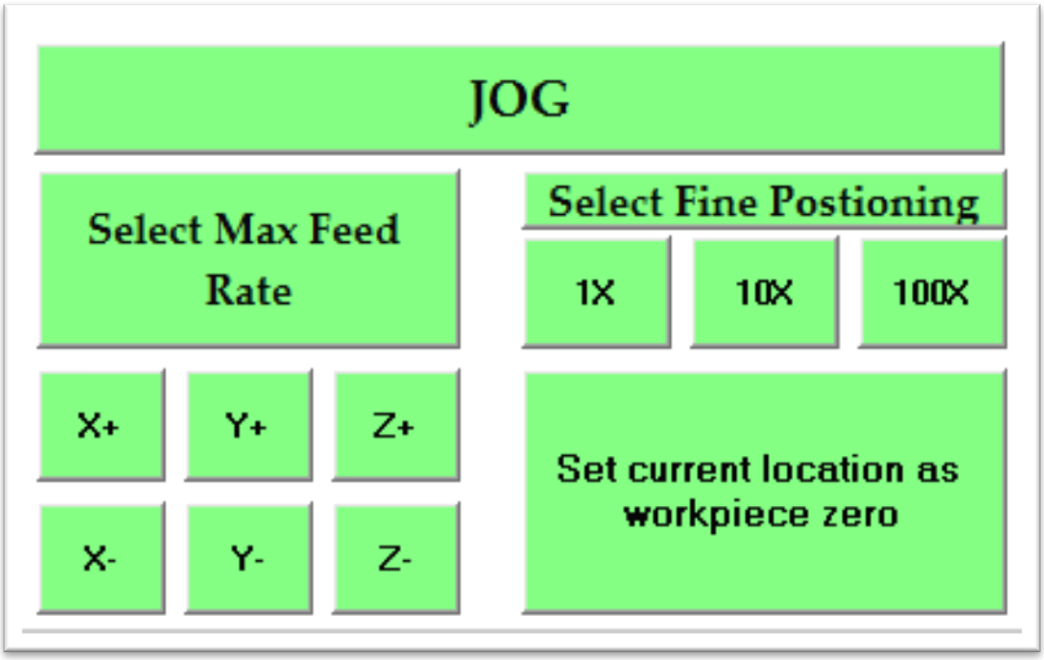


Figure 4.12: Setting the machine jog module

4.3.5 Machine setting module

To run the machine on a definite feed rate, its corresponding value should be selected and then entered accordingly 50 to 300mm/min. This is done by clicking the feed rate button which allows a pop up window to open shown in figure 4.13.

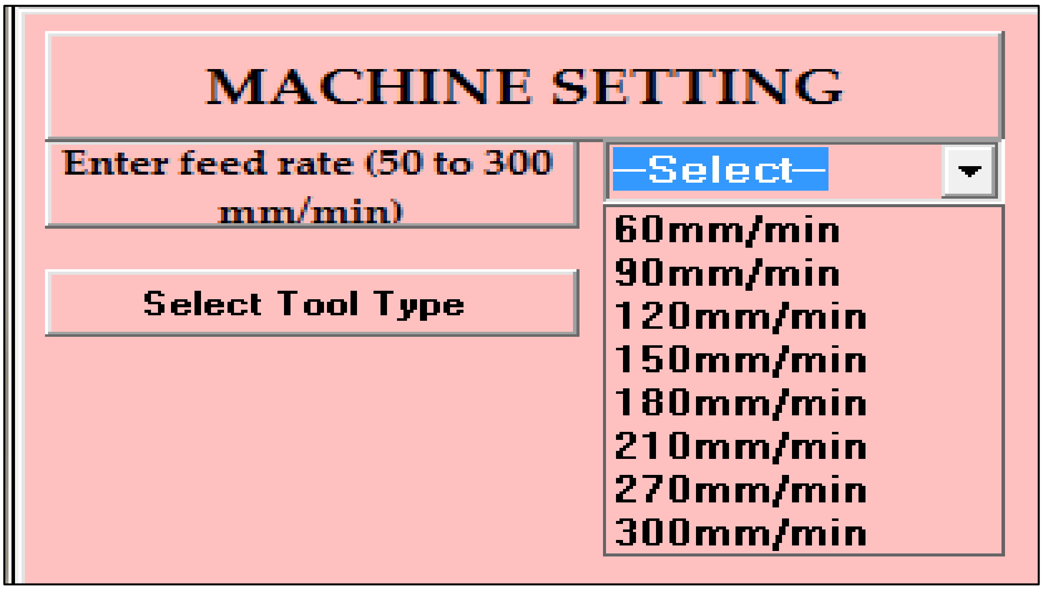


Figure 4.13: Select feed rate pop mindow

In the machine setting clicking on tool type setting button a pop window will open then select the tool ball end mill as shown in figure 4.14.

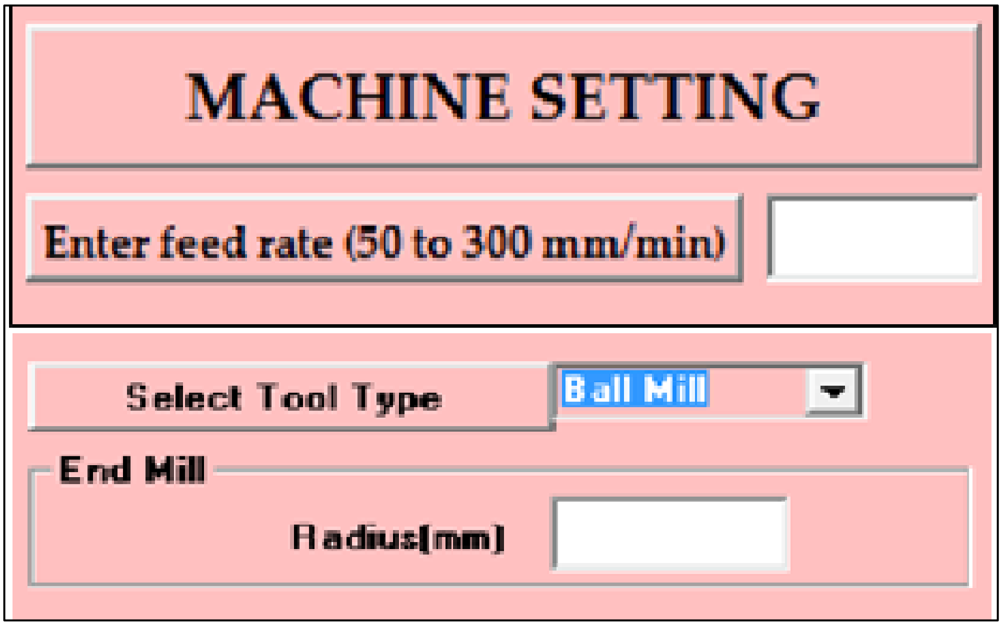


Figure 4.14: Select ball end mill tool

In the machine setting window, select the radiused end mill and enter the shaft radius, corner radius in mm as shown in figure 4.15.

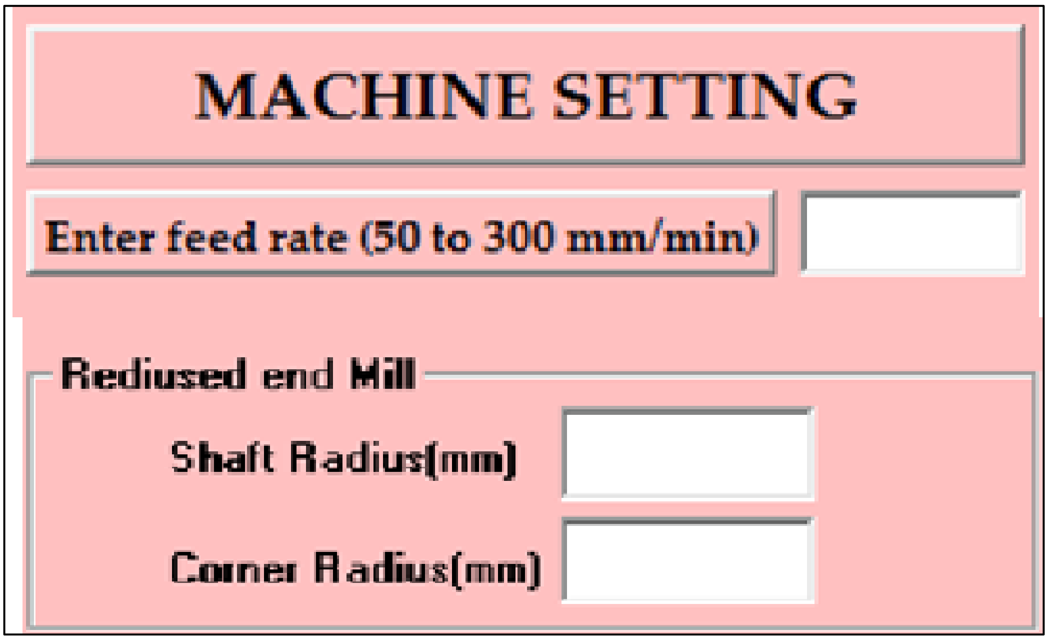


Figure 4.15: Select radiused end mill tool

4.3.6 Machine status module

When the machine is started on work mode, if the user wants to show the machine status, then the dialog box of the machine position show the x,y,z, coordinate w.r.t of WCS as shown in figure 4.16.

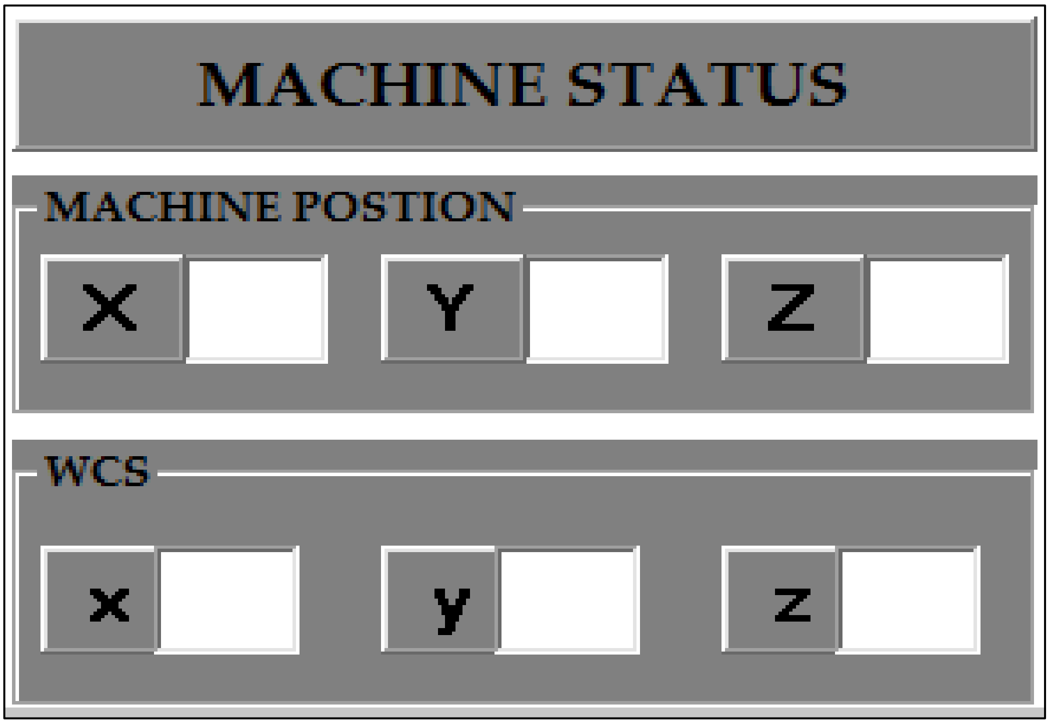


Figure4.16: Show machine status

4.3.7 Automatic module

In this module user need to give the command to CNC controller. The load command button open as 'Open' Dialog shown in figure 4.17 which is used in load the *. tp file in to the list provided. The text file contains the values to be serially transmitted to the controller for the movement of 3motors viz. X-axis, Y-axis, Z-axis motors

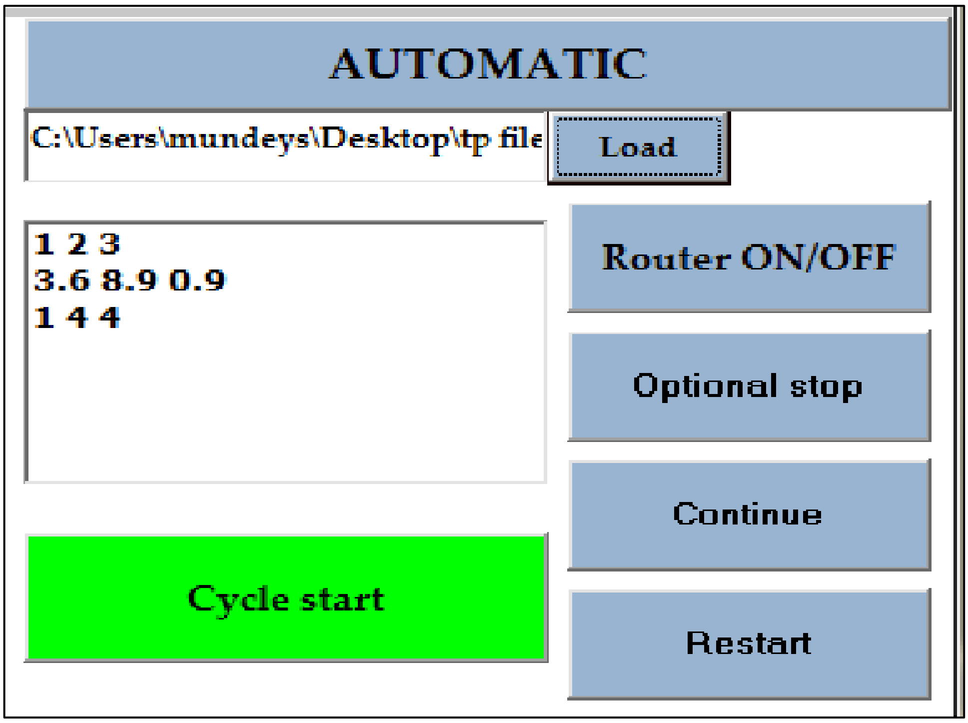


Figure 4.17: Loading the Commands from *.tp file to List Box

When the cycle start button is clicked the machine starts becomes operational according to the given .tp file value. The machine will keep on operating until the execution of .tp file is completed, if the user wants to stop the machine in between the operation using optional stop button for resuming continue button is used.

CHAPTER: 5

TEST OF GUI AND HARDWARE

The development of Graphical user interface and PC based NC controller is a very difficult task. GUI interface and NC controller hardware has been done using a specially developed electronic hardware using stepper motors. This work is aimed at providing a low cost NC machine interface from PC (GUI) and hardware interface for machine drive control so that the dependency of commercially available NC controllers can be avoided. The PC based NC controller and its proper functioning explained with flow chart in chapter 4.

The controller unit is most important parts part of the NC and CNC machines. The NC controller uses 4 microcontrollers, one acting as master others acting as slave microcontroller for simultaneous control of X, Y and Z axis. It reads and interprets the program of instructions and converts them in the mechanical actions of the machine tool. Thus the controller unit forms an important link between the program and the machine tool. The control unit operates the machines as per the set of instructions given to it.The control unit comprises of tape reader, a date buffer, signal output channels to the machine tools, feedback channel from the machine tool, and the sequence control to coordinate the overall machining operation. To test or run new tool path conventional machine are not suitable and CAM package is needed to convert new tool path into vendor controlled CNC machine code. Problem in existing NC machines are these are having controller which are vendor or manufacturer controlled. Researchers could not do modification in vendor controlled machine.

5.1 Features of Developed Open Architecture NC controller

This thesis work presents new architecture controller which is fully designed to meet new need of tool path programmers those are working on “Direct Model to Part” machining. Power of personal computer which is having great computational speed has been utilized to do complex calculation and to run decision making algorithms by taking feedback from controller.

Following are the key feature of developed open architecture NC controller for personal computer-controlled vertical 3-axis NC machine for simultaneous interpolation has been discuss below.

i. Developed controller is free for adding new algorithms and controller programs according to up gradation of existing system.
ii. Developed controller has one master and three slave controllers. Slave controllers are simultaneously controlling and real time monitoring the motion of individual axis and master controller keep on communicating with PC and slaves microcontrollers.
iii. All four microcontrollers are running in parallel. This presents the application of parallel processing which makes system faster.
iv. Controller is programmed to interpolate points in 3D space within its work volume in absolute mode.
v. Handshaking signal is enabled in serial communication between microcontroller and PC which ensures the no loss of data while transmission from PC to MCU at high speed.
vi. 3 slaves MCUs controlled by Master MCU via I2C lines. With I2C communication Master MCU can handle up to 1024 Slave MCUs which make OAC expandable.

5.2 Testing of Graphical User Interface

The test of GUI is firstly performed by connect button, these button has been connect with PC and ready for transfer the data. The home mode gives the result all drives motors moves with in limit switch when the limit is exceeded the motor drives will be stop. Load button Performed by running the tool path file. The tool path file is in x, y,z data and is in the form of absolute mode. According to the data reaches in three drives and its moving the no.of steps. In the CNC interface is tested the jog mode all the drives have moves with in maximum feed and moves to fine positioning speed 1x,10x,100x. In setting module the feed rate is tested according to user by the enter. In the automatic module the cycle start button is tested the tp file according to the enter by the user. The systematic working and back end programming of GUI is tested with NC controller which shows correct results shown in figure 5.2.

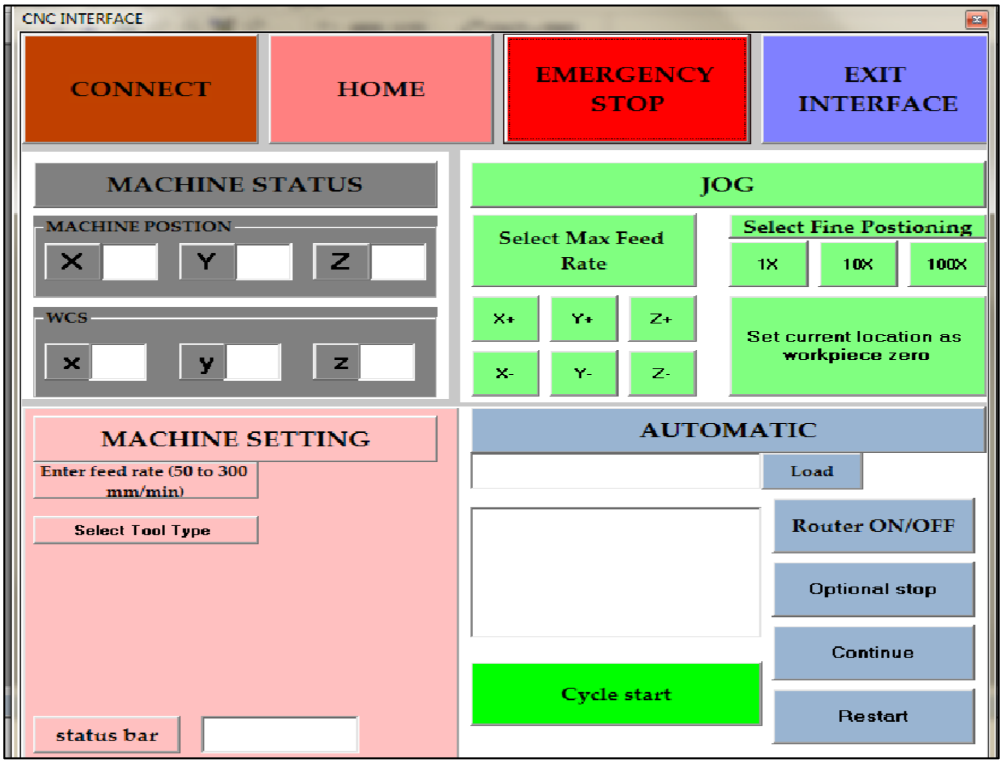


Figure 5.2: The main screen CNC interface

5.3 Testing of Hardware Circuit for NC Controller

The development of the NC controller Developed controller has capability to incorporate new sensors and machine vision system on later part to make intelligent machining system. Under this hardware check the stepper motor moving within limits of position .The check the limit position with help of hard plastic strip mount on stepper motor is moving with giving no. of steps show in figure 5.4. The drive motors is moving with the help of tool path file (tp) load in automatic mode of GUI.

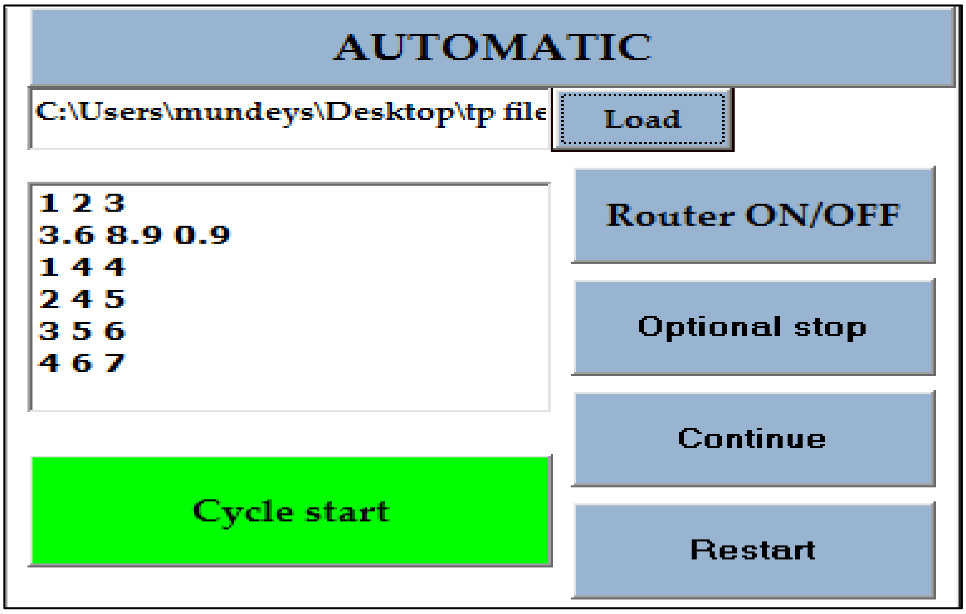


Figure 5.3: Stepper motor with limit switch

5.4 Validation Working NC Controller for Motion Control of Drive Motor

The stepper motor has minimum angle is 1.8^0 and minimum delay period of 0.005s. The available resolution of stepping drives is 200 steps per revolution. The motor drive working of this system is tested with tp file. The time duration is noted with the help of stop watch and helps to calculate the no.of steps per unit time and master controller records the complete execution time.

CHAPTER: 5

TEST OF GUI AND HARDWARE

The PC based NC controller has been developed in two different but integrated parts namely Graphical user interface and PC based NC controller. GUI interface and NC controller interface hardware has been developed using stepper motors as drive motors. This work is aimed primarily at development of a PC based NC control interface (Graphical User Interface, GUI) and hardware interface for machine drive control so that the dependency of commercially available NC controllers can be avoided. The PC based NC controller and its proper functioning explained with flow chart in chapter 4.

The controller unit is most important part of NC machines. The NC controller developed under present work uses 4 microcontrollers, one acting as master others acting as slave for simultaneous motion control of X, Y and Z axis drive motors. The drive motor actuate with the help of tool path file (tp).The tp file contains x, y, z data and this data reaches in master microcontroller, ensure that master microcontroller has received enough memory to receive the data from PC and after the master microcontroller to passes the data slave microcontroller. In the slave microcontroller set the minimum time delay period to receive the data from master microcontroller. In such case the slave microcontroller passes the data to stepper motor drives, the motor drives receive the data in form pulses and its moves the no.of steps.

The drives motor chosen for testing NC control interface and GUI are stepper motors of 259MA and DC12V and has minimum delay period of 0.005sec. The available resolution of the stepper motors is 200 steps per revolution. Thus the maximum achievable feed rate with the present NC controller is restricted to 300 mm/min if these drive motors are to be used with a ball screw of pitch 5mm for conversion of rotary motion of the stepper motors to linear motion of the machine drive.

5.1 Features of Developed Open Architecture NC controller

This thesis work presents new architecture controller which is fully designed to meet new need of tool path programmers those are working on “Direct Model to Part” machining. Power of personal computer which is having great computational speed has been utilized to do complex calculation and to run decision making algorithms by taking feedback from controller.

Following are the key feature of developed open architecture NC controller for personal computer-controlled vertical 3-axis NC machine for simultaneous interpolation has been discuss below.

i. Developed controller is free for adding new algorithms and controller programs according to up gradation of existing system.
ii. Handshaking signal is enabled in serial communication between microcontroller and PC which ensures the no loss of data while transmission from PC to MCU at high speed.
iii. Developed controller has one master and three slave controllers. Slave controllers are simultaneously controlling and real time monitoring the motion of individual axis and master controller keep on communicating with PC and slaves microcontrollers.
iv. All four microcontrollers are running in parallel. This presents the application of parallel processing which makes system faster.
v. 3 slaves MCUs controlled by Master MCU via I2C lines. With I2C communication Master MCU can handle up to 1024 Slave MCUs which make OAC expandable.
vi. Controller is programmed to interpolate points in 3D space within its work volume in absolute mode.

5.2 Testing of Graphical User Interface

The test of GUI has been performed starting with the "*Connect Button*", this button when enabled connects the NC hardware interface with PC and ensures that PC and Master micro controllers are ready for transfer of data. Until the "*Connect Button*" has ensured that the communication between master microcontroller and PC is established, till then the other functions of GUI are not enabled. After there is message in status mode stating "*Connected*", one can proceed for "*home mode".* In home mode all drives motors moves until the limit switches on the drive extreme positions are found and when the motor drives touches the limit switches these will stop and set in the microcontroller zero reading.

Next is "*Jog Mode"* setting, which has been tested for ensuring the default rotation speed of the drive motors, when the default feed rate option is selected for moving the motor drives.

Jog Mode is for setting the work-piece coordinate system at some user defined location. The precise motion of the motor drives is possible if one select fine positioning speed for all motor drives moves with 1x, 10x, 100x speed. But under fine positioning option one click of mouse will move only one step in positive or negative direction along X or Y or Z axis, one axis motor at a time. They have ensured all the parameter in jog mode is systematic working and back end programming of GUI is tested with NC controller which shows correct results.

Next is "*machine module*" setting which has been selected the feed rate 60mm/min to 300mm/min for tool path position. In the "*automatic module*" the Load button Performed by running the tool path file (tp). The tool path file contains x, y, z data and is in the form of absolute data position and after "*cycle start button*" is tested to execute the tool path file (tp) file according to the enter by the user. The drive motors is moving with the help of tool path file (tp) show in figure 5.2 (a). Under this hardware check the stepper motor moving within limits of position .The check the limit position with help of hard plastic strip mount on stepper motor is moving with giving no. of steps show in figure 5.2 (b) .The systematic working and back end programming of GUI is tested with NC controller interface shown in figure 5.2(C).

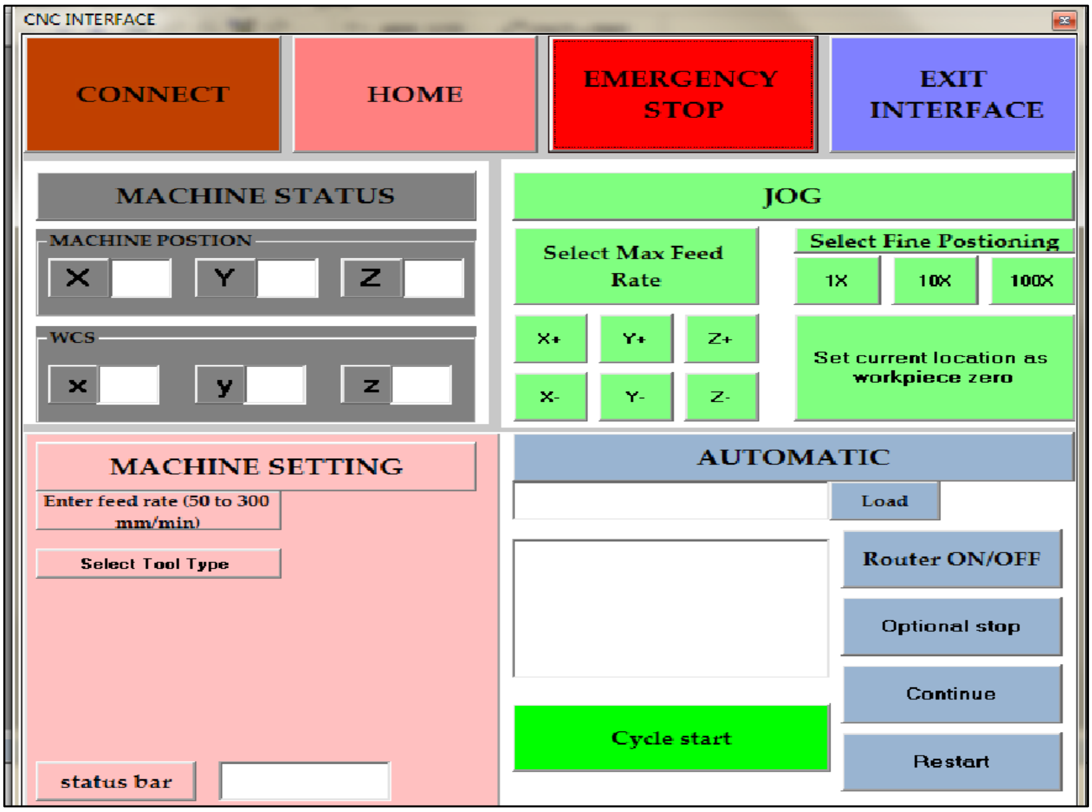


Figure 5.2(c): The main screen CNC interface

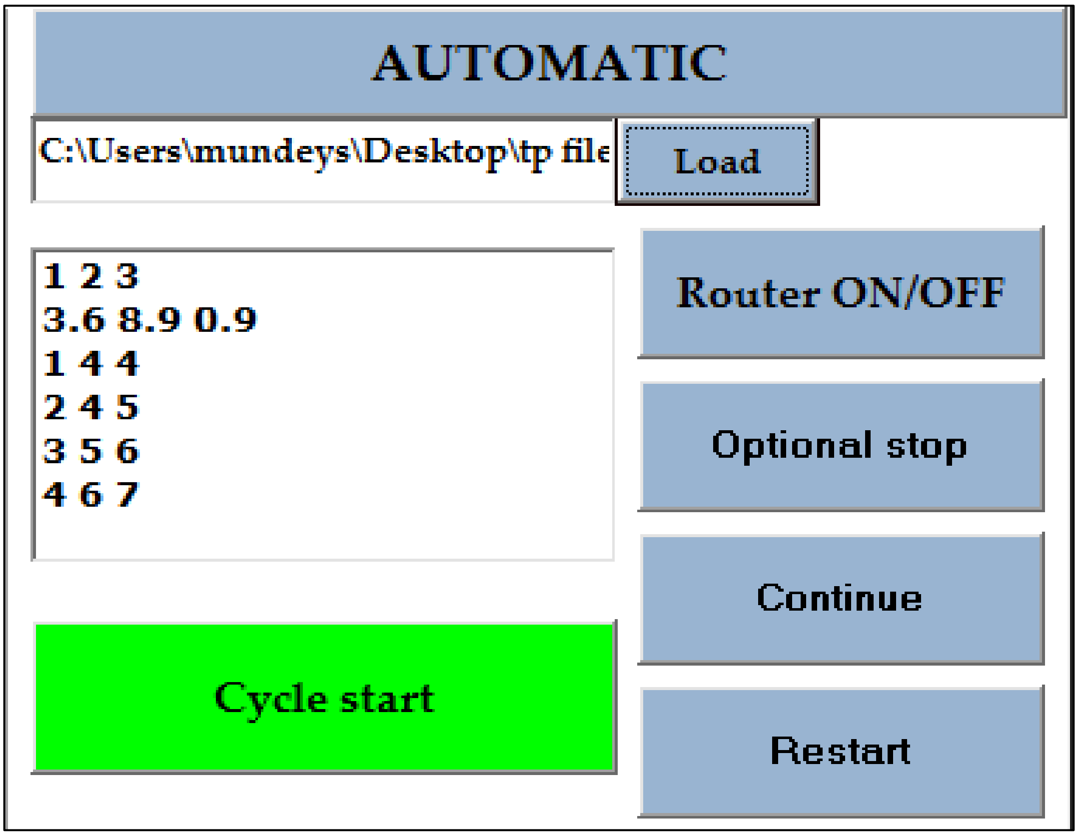


Figure 5.2(a): Load tp File

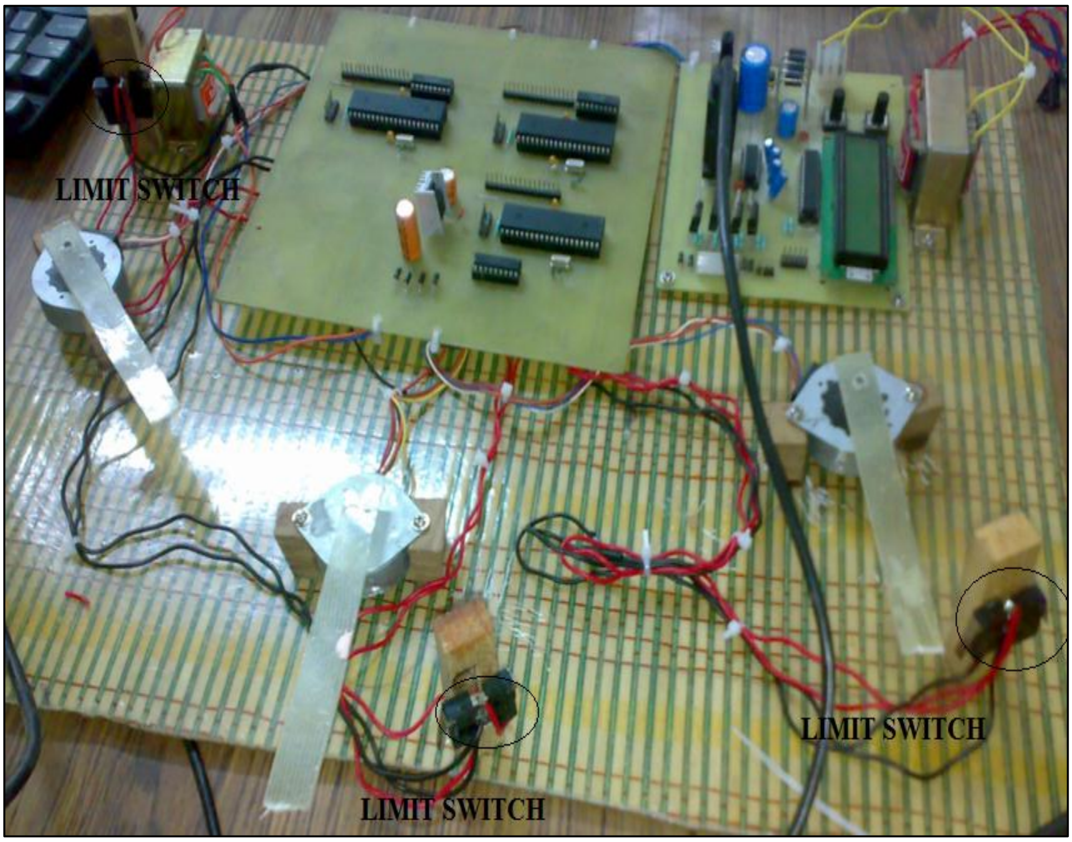


Figure 5.2(b): Stepper motor with limit switch

5.3 Validation for Working of NC Controller for Motion Control

The stepper motor has minimum angle is 1.8^0 and minimum delay period of 0.005s. The available resolution of stepping drives is 200 steps per revolution. The motor drive working of this system is tested with tp file. According to the testing of stepper motor. The motor drives are set by the home position and after the jog mode use to move the motor drive four steps and after the stop immediately. The new tp file will be loaded only contains the x position data in absolute mode like 10, 0, 0. The feed rate will be fixed is 60mm/min.This command through only x motor drives is move and after same validation for in y position data in absolute mode like 0, 10, 0 and z position data like 0, 0, 10. In this test know about the logic for NC controller for motion control in x,y,z direction is ok. Along The time to calculate the no.of steps per unit time and master controller records the complete execution time.

CHAPTER: 6

CONCLUSION AND FUTURE SCOPE OF WORK

6.1 CONCLUSION

The development of Graphical user interface and PC based NC controller is a very complicated task. Under the present thesis work, a simplified approach for GUI and NC controller has been presented. The conclusions drawn from the present work are as follows:

1. The NC controller developed has a very simple stepwise integration with the Graphical user interface which is very easy to follow.
2. The drives chosen for testing the present approach are stepper motors of Amp, V and has minimum delay period of 0.005sec. Thus the maximum achievable feed rate with the present NC controller is restricted to 300 mm/min if we choose these drive motors with a ball screw of pitch 5mm.
3. The available resolution of stepping drives is 200 steps per revolution. Thus the minimum step distance the NC controller would be able to traverse using a 5mm pitch ball screw will be 0.025mm. This precision is good for manufacturing sculptured surfaces.
4. The NC controller uses 4 microcontrollers, one acting as master others acting as slave for simultaneous control of X,Y and Z axis. The concept of resolved feed rate control has been used for accurately achieving the specified path feed rate which can be 300 mm/min maximum.
5. If a stepper drive motor with frequency responses better than 0.005 sec can be used then the feed control can be enhanced using the same hardware circuit because the maximum frequency of the PIC microcontroller is 20MHZ.

6.2 FUTURE SCOPE OF WORK

During the present work certain aspects has been observed for the design of NC controller. For the enhancement of present work following activities can be undertaken as future work:

1. The possibility of better stepper motors having response time less than 0.005 sec can be explored as this will enhance the feed rate at which the NC system will be able to work.
2. Possibility of using a DC servo drive can be explored for better and more stable NC controller design.

3. A suitable machine tool structure can be designed to test the working and accuracy of NC controller with more powerful stepper drives which is far higher than the frequency at which the present stepper drive motor can work.

4. Encoders can be integrated with slave drives to feed stepper drives to ensure the accurate working of NC controller.

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