VOICE RECOGNITION BASED ROBOT

A Project Report

Submitted by

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"Gratitude is the memory of our hearts."

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ABSTRACT

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Robotic systems have advanced dramatically over the past few years. The automated systems were initially developed to reduce labor requirements, shorten working time reduce costs and improve quality. The current benefits such as placing or keeping workers out of the dangerous work area have improved the working environment and their morale.

In particular, we are using voice signals to operate a robot to perform a task in inhuman environment, which allow human to control the robot through the voice signals. This is a electromechanical device which uses stepper motor as the driving unit. The main objective of the project is to synchronize voice signals with the robo's action.

It deals with the recognizing voice commands interpreting them and visualizing with the help of a robot. The methodology employed here is to sample the human voice signals and to transform into digitally readable form. Then the system compares the signal with the look up table and identifies the corresponding command. According to the interpretation, the robot is stimulated to perform the operation as desired. This is an endeavor to demonstrate with the working model intricacies involved in integrating with the voice with robotics and thus make both ends meet.

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ACRONYMS

PIC -- Peripheral Interface Controller

ALU – Arithmetic Logic Unit

A/D – Analog to Digital converter

dB – Decibel

LED – Light Emitting Diode

LDR – Light Depending Resistor

IC – Integrated Circuit

DC – Direct Current

AC – Alternating Current

O/P – Output

I/P - Input

SFR -- Special Function Register

RAM – Random Access Memory

PC – Program Counter

GPR – General Purpose Register

INTRODUCTION

1. INTRODUCTION

Webster's Dictionary defines a robot as "An automatic apparatus or device that performs function ordinarily ascribed to human beings".

The word 'Robot' seems to have first become popular when Czech playwright Kovel Capak's play entitled R.U.R (Rossons Universal Robots) was first performed in Paris in the 1920s. In that play small artificial and anthropomorphic creature strictly obeyed their master's orders. These creatures were called 'Robotic' from Robota, which is the Czech and Russian word for 'drudgery' and 'hard work'

1.1 NEED FOR THE PROJECT

Technology keeps developing day by day. Everyday, we have a new technology coming up. As per Darwin's theory of the survival of the fittest, we should keep in pace with the recent developments. This calls for a means to develop an innovative system, which can perform complex takes in demand. An obvious choice would be a robot.

In conventional systems, the programs are fed into the memory and the robot executes them as designed. But when it comes to real time manipulation, the commands have to be given when and where necessary. These were accomplished through manual switches, which required some time. So for efficient execution, we propose another means to provide input. In our project, we have used human voice – a natural form of input.

Also in places where the temperatures are very much higher or in hazardous environment, a robot can accomplish the task easily. Here too, the robot has to be controlled according to the various situations that may arise.

As these studies indicate, a robot that can be directed according to the user's state of mind is surely a welcome approach to the world of automated industries.

1.2 OBJECTIVE OF THE PROJECT

The main objective of the project is to design Voice Recognition based Robot which synchronizes voice signals with the robo's action. It deals with recognizing voice signals from the microphone and visualizing the action specified with the help of a robot. The main process carried out here is to sample the voice signals and transform into readable form. This digital readable form is then compared with the look up table and identifies the corresponding commands.

To achieve this objective, we have used various components such as voice processor, microcontroller, driver circuit and stepper motor .Voice processor has two modes of operation, recording and recognizing speech. Microcontroller (PIC 16F72) used in this project has all inbuilt peripherals required for this project. Tools used in this project are MPLAB, HITECH-C, PROPIC.

1.3 OUTLINE OF THE THESIS

The thumbnail that has been discussed in this work has been enumerated below.

Chapter 1 gives a brief introduction, need and the objective of our project.

Chapter 2 deals with the human voice patterns and it also describes about the voice processor AP7003.

Chapter 3 highlights the core of the project - PIC microcontroller.

Chapter 4 explains the driver circuit ULN 2003.

Chapter 5 discusses the basic driving unit of the robot – the stepper motor.

Chapter 6 explains the overall block diagram of the project and each block in detail along with the circuit diagram.

Chapter 7 elaborates the software tools used in this project.

Chapter 8 gives an idea about how we implemented the project through flowchart. algorithm and programming.

Chapter 9 paves way for the further improvement of the project in the near future.

Chapter 10 provides the conclusion of the project.

VOICE

2. VOICE

2.1 VOICE MECHANISM

Sound is a wave phenomenon each particle of air vibrates in some fashion and passes on the disturbance to its neighbor. While this disturbance carries both information and energy to distant places, each bit of air remains always in the vicinity of the original position. Sound, whose frequency lies between 20Hz to 20,000Hz, is audible to human ears.

Voice signals include the vowels of ordinary speech as well as tones and characteristics of the singing voice. The action of vocal chords produces a sawtooth type of variation in the velocity and the corresponding pressure in the modulated stream of air. In gas or liquid, the vocal vibrations are always parallel to the direction of wave travel and hence, sound waves are classified as longitudinal waves.

2.2 HUMAN VOICE

Sound produced by human beings is due to the vibrations of the air from the lungs. The fundamental tone or frequency of the sound produced is controlled by the vocal chords. There are also present various overtones represented by vibrations having a frequency higher than the fundamental. These overtones determine the quality of voice.

In speech, movements of throat, tongue, mouth and lips modify the vibrations in the air passing through the throat and mouth. Each vowel and consonant requires a characteristic position of various organs. The combined result is to produce highly complex sequences of vibrations of rapidly varying frequency and amplitude. For speech to be transmitted electrically, the current must vary in the same way as the sound waves in the vicinity of a person speaking.

Most sound waves are not sinusoidal. Some, like a steady note played on a flute or sung vowel, are periodic signals. An oscilloscope display will show the same unit being repeated over and over. After a specified period of time, the disturbances occur again; so, period and frequency is still well defined for such a sound. A non-periodic signal has no single well defined period or frequency, but should be thought of as a mixture of many sounds covering a whole range of frequencies.

The average speech power emitted by a person at conversational level is about 10μW, when the power is averaged over a long time interval i.e., from 2 to 4 seconds. When one talks as loud as possible without straining the vocal chords, this average speech power rises to about 200μW and upon shouting to 1000μW. By contrast, the speech power associated with whispering is about 0.001μW.

2.4 VOICE PROCESSOR

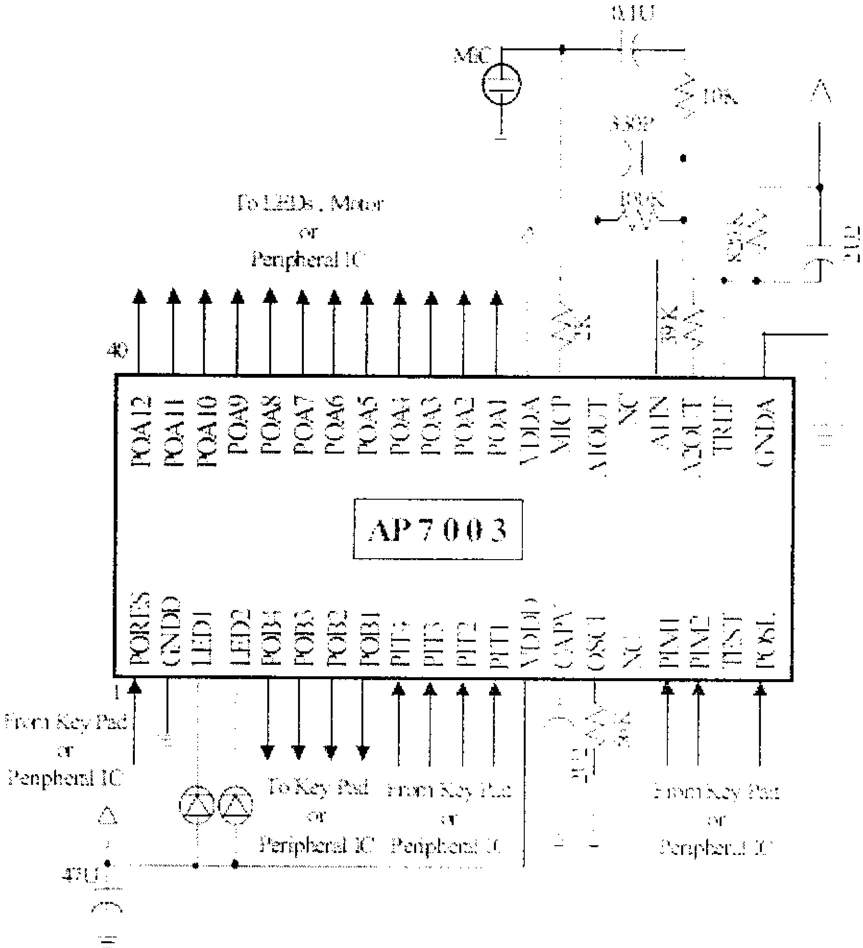

Fig.2.3 Pin Diagram of AP7003

2.5 GENERAL DESCRIPTION

AP7003 is a monolithic user dependence speech recognition IC designed for Toy Application. AP7003 consist of Microphone Amplifier, A/D Converter, Speech Processer, and I/O Controller. After pre-recording, AP7003 can recognize up to 12 different words sentences with 1.5 sec long. With highly I/O programmability, AP7003 can be adapted in a wide range application for toy products.

2.6 FEATURES

- Built in Microphone Amplifier
- Built in A/D Converter
- Twelve 1.5 sec long word sentences
- Versatile I/O Ports: 2 general inputs, 4 trigger inputs, 2 output ports of 4 outputs and 12 outputs, 2 LED drivers.
- Code option available for customs application
- 2.4V~4.5V operation voltage
- Low power consumption

2.7 FUNCTIONAL DESCRIPTION

There are two major operation modes in AP7003. The first operation is words recording modes. The second operation is words recognition modes. Beside these operations, AP7003 can detect key in signal and make output signals. All these operation are conducted by the internal program of AP7003, which is code option and can be customized.

Before you can make AP7003 operate words recognition, the target words must be recorded in AP7003 previously. There are 12 banks of memory in AP7003 for storing the features of differential target words. Each memory bank can store up to 1.5 sec long of word sentence. You can select the memory bank by key pad or just follow of words controlled by internal program of AP7003 to record the target words.

The voice of words can input to AP7003 through external microphone or other median. After properly amplified by internal microphone Amplifier, the voice signals are digitized by built in A/D Converter of AP7003. The Speech Processer of AP7003 receives the digitized voice signal and extracts the features of words.

After the target words can have been recorded in AP7003, now you can switch the operation of AP7003 into words recognition modes. The features of inputs words extracted by Speech Processer are comparing with the features of target words stored in memory. The must likely matching of words is selected as recognized target words. The results then can be output to Output Port A or other outputs pin of AP7003.

In some condition AP7003 can be programmed into shut down mode for power consumption saving and can be waked up by key in signals.

2.8 FUNCTIONAL BLOCK OF AP7003

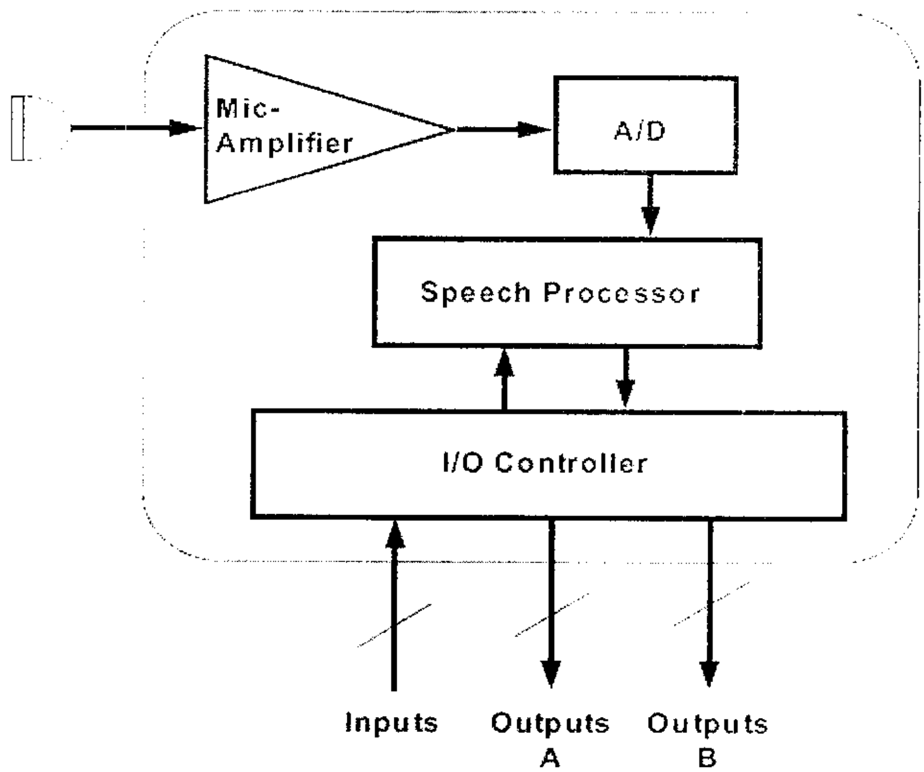

Fig.2.4 Functional Block of AP7003

2.9 APPLICATION NOTE FOR AP7003-02

AP7003-02 is programmed as a dedicated voice recognition IC. It is suitable for standalone application without micro-controller.

The operation of AP7003-02 is controlled directly through keypads. There are two kinds of keypad mode as listed in Table2. Functions of each key are described in Table3.

After power on, the output level of POB1~POB4 are all set low state. When there is any key been pushed down, the keypad scan signal are sent out from POB1 first, then POB2, POB3, and POB4 sequentially. The scan signal is 16-msec low pulse with 64-msec period. The keypad matrix is shown in Table1. Key in signal is detected through PIT1~PIT4.

The 12 word memory bank must be cleared after power on before store word. At the begin of store word mode LED1 and one of POA1~POA12 which is corresponded to selected word bank are active. AP7003-02 will go to recognition mode after input voice is stored into word bank.

At the initial state of recognition mode only LED1 is active. If there is no match word occurs at the end of recognition, LED1 will flash for 3 sec and go to back to the initial state of the recognition mode. If there is match word LED2 is active and the corresponding POA is active. LED2 and POA will be cleared 3 minutes later if auto mode is active (PIM2=0), then go back to initial state of recognition mode. AP7003-02 will go into shut down mode if there is no voice input for over 8 minutes when PIM2 is at low state.

After the target words can have been recorded in AP7003, now you can switch the operation of AP7003 into words recognition modes. The features of inputs words extracted by Speech Processer are comparing with the features of target words stored in memory. The must likely matching of words is selected as recognized target words. The results then can be output to Output Port A or other outputs pin of AP7003.

TABLE 3 KEY PAD DESCRIPTION OF AP 7003

Key Name	Description
Clear WORD	Clear12 word memory banks and go to Store WORD1
Store WORD	Select current word bank for storing input voice
Store WORD1 ~ Store Word8	Select one of word bank from first to eighth for storing input voice
WORD Up	Select upper word bank for storing input voice; The upper word bank of 12th bank is first bank
WORD Down	Select lower word bank for storing input voice; The lower word bank of first bank is first bank
Set R_Level 1 ~ Set R_Level 3	Set recognition threshold level and go to initial state of recognition mode
Clear Output	Clear POA1 ~ POA12 and LED2 then go to initial state of Recognition mode
Shut Down	Set AP7003 into shut down mode

Table 2.3 Key Pad Descriptions

PIC MICROCONTROLLER

3. PIC MICROCONTROLLER

3.1 OVERVIEW OF PERIPHERAL INTERFACE CONTROLLER (16F72)

PIC has Harvard architecture in which the data memory and program memory have separate blocks. The bus width of the program memory is 14-bit and that of data memory is 8-bit. It is a RISC controller with 35 instructions.

In this project PIC 16F72 microcontroller is used which has the peripherals like 2k ROM, 192 Bytes RAM, timers, PWM, A/D etc. A/D is used to convert analog signal into digital. PWM is used for speed control and Timer0 is used to calculate the speed. These are the basic requirements of this project.

3.2 OVERVIEW OF LCD DISPLAY

The present values of parameters like voltage, temperature and speed are displayed in LCD one by one.

3.3 OVERVIEW OF SENSORS/TRANSDUCER

Transducer is a device, which converts one form of energy into another form. In this project sensors like potential transformer and Opto Interruptor are used to sense the parameters like voltage and speed. Thermistor is a transducer, which is used to sense temperature.

3.4 INTRODUCTION TO PERIPHERAL INTERFACE CONTROLLER

A Single chip microcontroller is obtained by integrating all the components of a microcomputer in one IC package. Hence apart from CPU such a single chip microcomputer will therefore contain its own clock generator and some amount of ROM or EPROM, RAM and I/O ports on the same chip. It may also have other features like timer/counter, PWM, A/D etc., on the chip.

3.5 ARCHITECTURE OF PIC MICROCONTROLLER

Microcontroller is a tiny chip. It has inbuilt memory, timer, ports and other additional features. There are several companies manufacturing the micro controllers like Intel, Motorola and Microchip. PIC is the product of microchip. The following are the special characteristics of PIC. The architecture of PIC microcontroller is shown in the figure 3.1.

3.6 FEATURES OF PIC

- Long Word Instructions
- Single Word Instructions
- Instruction Pipeline
- Single Cycle Instruction
- Reduced Instruction Set
- Register File Architecture
- Orthogonal (Symmetric) Instructions
- Instruction Flow/Pipelining

After the target words can have been recorded in AP7003, now you can switch the operation of AP7003 into words recognition modes. The features of inputs words extracted by Speech Processer are comparing with the features of target words stored in memory. The must likely matching of words is selected as recognized target words. The results then can be output to Output Port A or other outputs pin of AP7003.

In this project PIC 16F72 microcontroller is used which has the peripherals like 2k ROM, 192 Bytes RAM, timers, PWM, A/D etc. A/D is used to convert analog signal into digital. PWM is used for speed control and Timer0 is used to calculate the speed. These are the basic requirements of this project.

3.7 ARCHITECTURE OF PIC 16F72

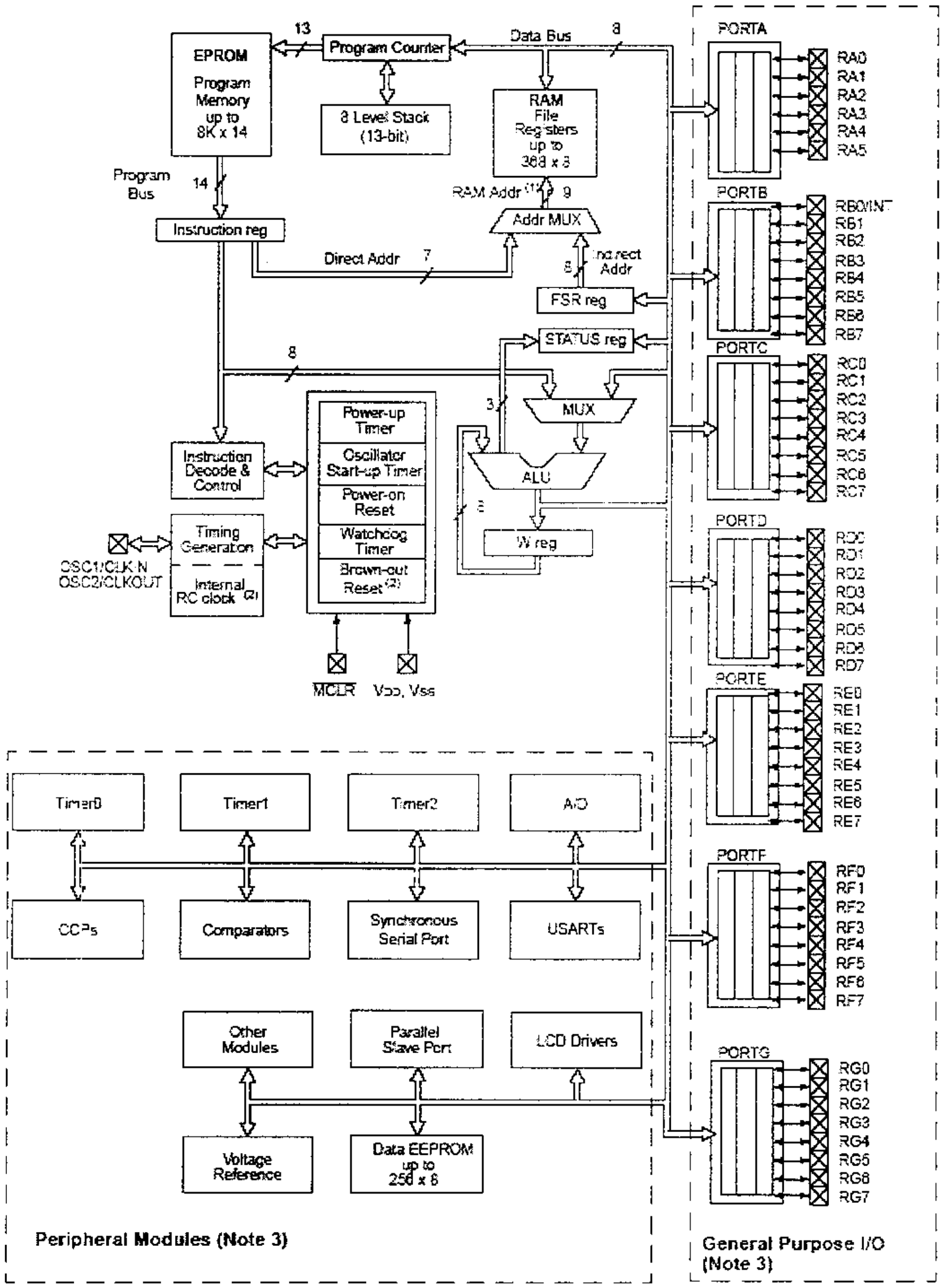

Fig.3.1 Architecture of PIC

3.8 ARITHMETIC LOGICAL UNIT (ALU)

PIC Micro controllers contain an 8-bit ALU and an 8-bit working register. The ALU is a general-purpose arithmetic and logical unit. It performs arithmetic and Boolean functions between the data in the working register and any register file.

The ALU is 8-bits wide and is capable of addition, subtraction, shift and logical operations. Unless otherwise mentioned, arithmetic operations are two's complement in nature. In two-operand instructions, typically one operand is the working register ('W' register). The other operand is a file register or an immediate constant. In single operand instructions, the operand is either the 'W' register or a file register. The 'W' register is an 8-bit working Register used for ALU operations. It is not an addressable register. Fig 3.2 shows the block diagram of ALU.

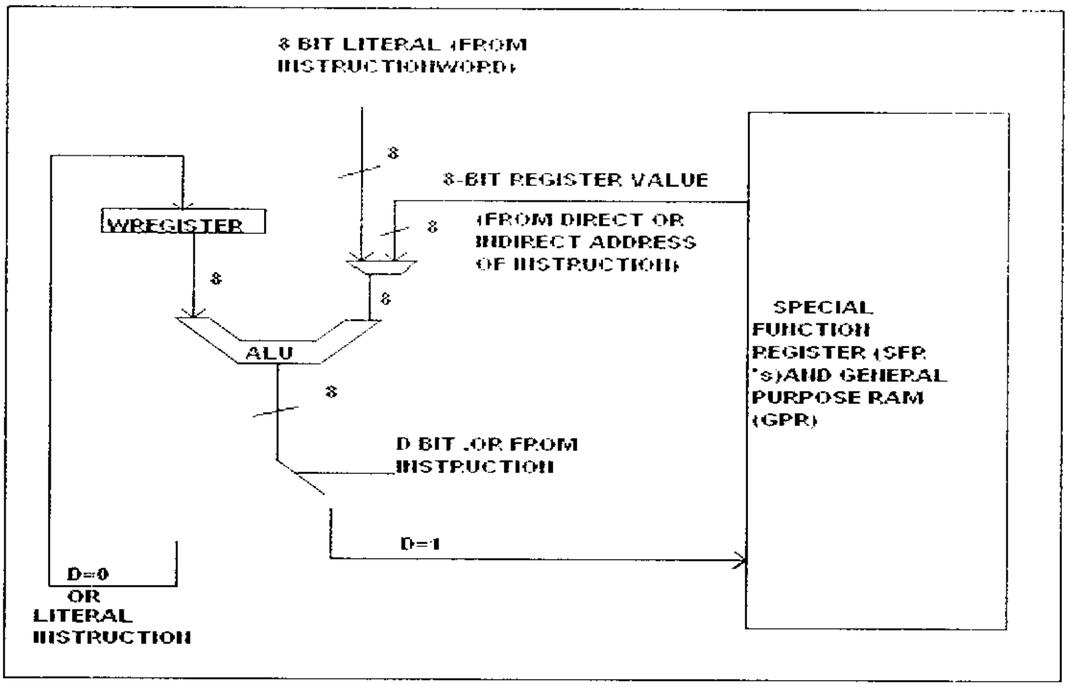

Fig. 3.2 Block diagram of ALU

3.9 STATUS REGISTER

The STATUS register contains the arithmetic status of the ALU, the RESET status and the bank select bits for data memory. Since this register controls the selection of the Data Memory banks, it is required to be present in every bank. Also, this register is in the same relative position (offset) in each bank.

The STATUS register can be the destination for any instruction, as with any other register. If the STATUS register is the destination for an instruction that affects the Z, DC or C bits, then the write to these three bits is disabled. These bits are set or cleared according to the device logic. Furthermore, the TO and PD bits are not writable. Therefore, the result of an instruction with the STATUS registers, as destination may be different than intended. For example, CLRF STATUS will clear the upper-three bits and set the Z bit. This leaves the STATUS register as 000u u1uu (where u=unchanged).

It is recommended therefore, that only BCF, BSF, SWAPF and MOVWF instructions be used to alter the STATUS register because these instructions do not affect the Z, C or DC bits from the STATUS register.

IRP	RP1	RP0	TO	PD	Z	DC	C

Bit 7 Bit 0

BIT 7

IRP: Register Bank Select bit (used for indirect addressing)

1 = Bank 2, 3 (100h - 1FFh)

0 = Bank 0, 1 (00h - FFh)

For devices with only Bank0 and Bank1 the IRP bit is reserved, always maintain this bit clear.

BIT 1

DC: Digit carry/borrow bit (ADDWF, ADDLW, SUBLW, SUBWF instructions) (for borrow the polarity is reversed)

1 = A carry-out from the 4th low order bit of the result occurred

0 = No carry-out from the 4th low order bit of the result

BIT 0

C: Carry/borrow bit (ADDWF, ADDLW, SUBLW, SUBWF instructions)

1 = A carry-out from the most significant bit of the result occurred

0 = No carry-out from the most significant bit of the result occurred.

3.10 MEMORY ORGANIZATION

There are two-memory blocks

1. Program memory
2. Data memory.

Each block has its own bus, so that access to each block can occur during the same oscillator cycle. The data memory can further be broken down into

- General Purpose RAM
- Special Function Register (SFRs)

It is recommended therefore, that only BCF, BSF, SWAPF and MOVWF instructions be used to alter the STATUS register because these instructions do not affect the Z, C or DC bits from the STATUS register.

3.11 PROGRAM MEMORY ORGANIZATION

Mid-Range MCU devices have a 13-bit program counter capable of addressing an 8K x 14 program memory space. The width of the program memory bus (instruction word) is 14-bits. Since all instructions are a single word, a device with an 8K x 14 program memory has space for 8K of instructions. This makes it much easier to determine if a device has sufficient program memory for a desired application.

3.12 PROGRAM COUNTER (PC)

The program counter (PC) specifies the address of the instruction to fetch for execution. The PC is 13-bits wide. The low byte is called the PCL register. This register is readable and writable. The high byte is called the PCH register. This register contains the PC<12:8> bits and is not directly readable or writable. All updates to the PCH register go through the PCLATH register.

3.13 STACK

The stack allows a combination of up to 8 program calls and interrupts to occur. The stack contains the return address from this branch in program execution. Mid-Range MCU devices have an 8-level deep x 13-bit wide hardware stack. The stack space is not part of either program or data space and the stack pointer is not readable or writable. The PC is PUSH onto the stack when a CALL instruction is executed or an interrupt causes a branch. The stack is POP in the event of a RETURN, RETLW or a RETFIE instruction execution. PCLATH is not modified when the stack is PUSH or POP.

It is recommended therefore, that only BCF, BSF, SWAPF and MOVWF instructions be used to alter the STATUS register because these instructions do not affect the Z, C or DC bits from the STATUS register.

3.14 DATA MEMORY ORGANIZATION

Data memory is made up of the Special Function Registers (SFR) area, and the General Purpose Registers (GPR) area. The SFRs control the operation of the device, while GPRs are the general area for data storage and scratch pad operations. The data memory is banked for both the GPR and SFR areas. The GPR area is banked to allow greater than 96 bytes of general purpose RAM to be addressed. SFRs are for the registers that control the peripheral and core functions.

Banking requires the use of control bits for bank selection. These control bits are located in the STATUS Register (STATUS<7:5>). To move values from one register to another register, the value must pass through the W register. This means that for all register-to-register moves, two instruction cycles are required. The entire data memory can be accessed either directly or indirectly. Direct addressing may require the use of the RP1:RP0 bits. Indirect addressing requires the use of the File Select Register (FSR).

Indirect addressing uses the Indirect Register Pointer (IRP) bit of the STATUS register for accesses into the Bank0 / Bank1 or the Bank2 / Bank3 areas of data memory.

3.15 SPECIAL FUNCTION REGISTERS (SFR)

The CPU and Peripheral Modules use the SFRs for controlling the desired operation of the device. These registers are implemented as static RAM. The SFRs can be classified into two sets, those associated with the "core" function and those related to the peripheral functions. Switching between these banks requires the RP0 and RP1 bits in the STATUS register to be configured for the desired bank. A Power-on Reset and other resets initialize some SFRs, while other SFRs are unaffected.

It is recommended therefore, that only BCF, BSF, SWAPF and MOVWF instructions be used to alter the STATUS register because these instructions do not affect the Z, C or DC bits from the STATUS register.

3.16 OSCILLATOR

The internal oscillator circuit is used to generate the device clock. The device clock is required for the device to execute instructions and for the peripherals to function. Four clock periods generate one internal instruction clock (TCY) cycle. There are up to eight different modes, which the oscillator may have. There are two mode which allow the selection of the internal RC oscillator clock out (CLKOUT) to be driven on an I/O pin, or allow that I/O pin to be used for general purpose function the device configuration bits select the oscillator mode .The device configuration bits are non volatile memory location and the operating mode is determined by the value written during device programming the RC oscillator option saves system cost while the LP crystal option saves power. Configuration bits are use to select the various option.

3.17 PORT CONTROL REGISTERS

3.17.1 PORTA AND TRISA REGISTER

The RA4 pin is a Schmitt Trigger input and an open drain output. All other port pins have TTL input levels and full CMOS output drivers. All pins have data direction bits (TRIS registers), which can configure these pins as output or input.

Setting a TRISA register bit puts the corresponding output driver in a hi-impedance mode. Clearing a bit in the TRISA register puts the contents of the output latch on the selected pin(s).

3.17.2 PORTB AND TRISB REGISTER

PORTB is an 8-bit wide bi-directional port. The corresponding data direction register is TRISB. Setting a bit in the TRISB register puts the corresponding output driver in a high-impedance input mode. Clearing a bit in the TRISB register puts the contents of the output latch on the selected pin(s).

3.17.3 PORTC AND TRISC REGISTER

PORTC is an 8-bit bi-directional port. Each pin is individually configurable as an input or output through the TRISC register. PORTC pins have Schmitt Trigger input buffers. When enabling peripheral functions, care should be taken in defining TRIS bits for each PORTC pin. Some peripherals override the TRIS bit to make a pin an output, while other peripherals override.

The CPU and Peripheral Modules use the SFRs for controlling the desired operation of the device. These registers are implemented as static RAM. The SFRs can be classified into two sets, those associated with the "core" function and those related to the peripheral functions. Switching between these banks requires the RP0 and RP1 bits in the STATUS register to be configured for the desired bank. A Power-on Reset and other resets initialize some SFRs, while other SFRs are unaffected.

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DRIVER CIRCUIT

4. DRIVER CIRCUIT

4.1 STEPPER MOTOR DRIVER

The control signal from the micro controller is 5v but stepper motor requires twelve volts. So ULN2803 is used. The ULN2803 Integrated Circuit (IC) is a "Eight-way Line Driver". The IC takes small current at its 8 input pins (pins 1 to 8) and allows much larger current (up to one amp) to flow via its output lines. The output of the ULN2803 is "**inverted**". This means that a HIGH at the input becomes a LOW at the corresponding output line. It consists of 8 Darlington's to amplify current. A total of two unipolar stepper motors can be controlled with this stepper motor driver. Eight bit or four bit Data from the micro controller reaches the inputs from where it is amplified to the outputs.

4.2 PIN CONNECTION

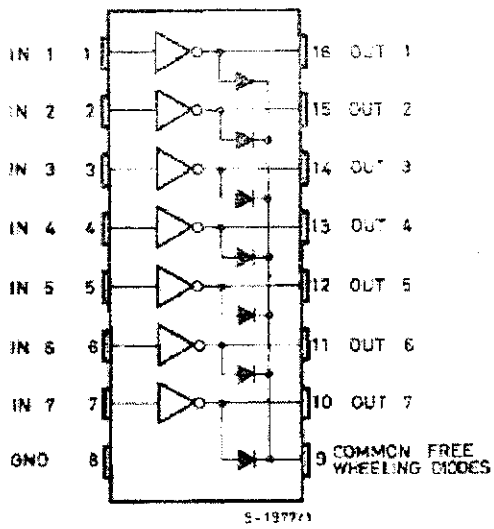


Fig. 4.1 Pin Connection of ULN 2003

4.3 STEPPER MOTOR CONTROLLER

The function of the stepper motor controller is to supply the motor logic signals, in order to implement stepping in the desired direction. The controller receives a series of pulses. The number of pulses determines the extent of revolution of the motor and their frequency determines the rate of revolution. The controller defines the strength of the pulses to enable them to turn the motor and addresses the signals to the motor coils in accordance with the desired direction of revolution. Table 4.1 lists the order of excitation of the coils which will cause a four phase stepping motor to turn clockwise and counterclockwise.

CLOCKWISE ORDER	SW1	SW2	SW3	SW4	COUNTERCLOCKWISE ORDER
HALF-STEP 1	ON	OFF	ON	OFF	HALF-STEP 1
HALF-STEP 2	ON	OFF	OFF	OFF	HALF-STEP 8
HALF-STEP 3	ON	OFF	OFF	ON	HALF-STEP 7
HALF-STEP 4	OFF	OFF	OFF	ON	HALF-STEP 6
HALF-STEP 5	OFF	ON	OFF	ON	HALF-STEP 5
HALF-STEP 6	OFF	ON	OFF	OFF	HALF-STEP 4
HALF-STEP 7	OFF	ON	ON	OFF	HALF-STEP 3
HALF-STEP 8	OFF	OFF	ON	OFF	HALF-STEP 2
HALF-STEP 1	ON	OFF	ON	OFF	HALF-STEP 1

Table 4.1 The Order of Signals in a Four Phase Stepper Motor

The stepper motor controller includes a series of electronic switches responsible for switching the voltage of the stator coils, which constitute the stator phases.

The signals sent to each of the four stator coils to create the direction of motor revolution are listed in Table 4.1. The motor for which the table was compiled is a half step motor, in which two half step advances constitute an advance of a single step.

As shown in the table, the rotor must pass through the eight positions listed, reading the table from top to bottom, in order to perform a single clockwise revolution. To create a counterclockwise revolution, the signals must be transmitted in the order listed in the table from bottom to top. Repeating either cycle of 8 motions again will create continuous revolution.

The table shows that this motor makes a full step by proceeding from any odd numbered step, two coils are ON and the other two are OFF. To proceed from one full step to the next, it is necessary to turn OFF one of the two ON coils and to turn ON one of the two OFF coils that characterized the previous step.

By skipping the even numbered steps in the table and executing only the odd numbered steps, the four phase motor for which the table was drawn up can be made to accomplish its cycle in full steps instead of half steps (meaning a four step cycle instead of an eight half step one).

The controller receives a series of pulses. The number of pulses determines the extent of revolution of the motor and their frequency determines the rate of revolution. The controller defines the strength of the pulses to enable them to turn the motor and addresses the signals to the motor coils in accordance with the desired direction of revolution. Table 4.1 lists the order of excitation of the coils which will cause a four phase stepping motor to turn clockwise and counterclockwise.

STEPPER MOTOR

5. STEPPER MOTOR

5.1 FEATURES OF STEPPER MOTOR

- Small step angle
- High positioning

5.2 STEPPER MOTOR

A stepper motor's shaft has permanent magnets attached to it, together called the rotor. Around the body of the motor is a series of coils that create a magnetic field that interacts with the permanent magnets. When these coils are turned on and off the magnetic field cause the rotor to move. As the coils are turned on and off in a certain sequence the motor will rotate forward or reverse. This is called the phase pattern.

There are several types that will cause the motor to turn. Common types are full-double phase, full-single phase, and half step. To make a stepper motor rotate, the coils must be made to constantly turn on and off.

If simply one coil is energized. the motor will just jump to that position and stay there resisting change. This energized coil pulls full current even though the motor is not turning. This is the main way steppers generate heat, when at standstill. This ability to stay at one position rigidly is often an advantage of stepper motors.

The torque at standstill is called the holding torque. Because steppers can be controlled by turning on and off coils, they are easy to control using digital computers.

There are several types that will cause the motor to turn. Common types are full-double phase, full-single phase, and half step. To make a stepper motor rotate, the coils must be made to constantly turn on and off.

5.3 STEP ANGLE

The angle through which the motor shaft rotates for each command pulse is called the step angle. Smaller the step angle, greater the number of steps per revolution and higher the resolution and higher the resolution or accuracy of positioning obtained.

- Accuracy
- High torque to inertia ratio
- Stepping rate and accuracy

5.4 TYPES OF STEPPER MOTORS

There are three types of stepper motors namely

- Permanent Magnet stepper motor
- Variable reluctance stepper motor
- Hybrid stepper motor

There are two different wiring configurations unipolar and bipolar. The stepper motor used in this project is permanent magnet unipolar motor. PM steppers have a permanent magnet in them in the form of a rotor magnetized in alternate polarity "stripes" parallel to the rotor shaft.

The angle through which the motor shaft rotates for each command pulse is called the step angle. Smaller the step angle, greater the number of steps per revolution and higher the resolution and higher the resolution or accuracy of positioning obtained.

There are two different wiring configurations unipolar and bipolar. The stepper motor used in this project is permanent magnet unipolar motor. PM steppers have a permanent magnet in them in the form of a rotor magnetized in alternate polarity "stripes" parallel to the rotor shaft.

5.5 STEPPER MOTOR CONTROL CIRCUITRY

Stepper motors coils are to be energized in a particular sequence for its rotation. A control circuitry is need for the production of the energizing sequence. Here in this project it is nothing but PIC micro controller. The control may be obtained by two methods

- Software controlled method.
- Hardware controlled method.

5.6 SOFTWARE CONTROLLED METHOD

To make the shaft to rotate for one-step angle in forward or in reverse direction, the consecutive coils are energized in clockwise or in reverse direction respectively. In this project four windings of each stepper motors are connected to port B of the micro controller using a interfacing circuitry.

As the port of the micro controller can be accessed in a bit wise manner. any coil can be energized by simply sending high bit to the particular position. As the energizing sequence is created by this software approach is called as software control method

Port B	RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0
	W4	W3	W2	W1	w4	w3	w2	w1

W4, W3, W2, W1-windings of the first stepper motor

w4, w3, w2, w1- windings of the second stepper motor.

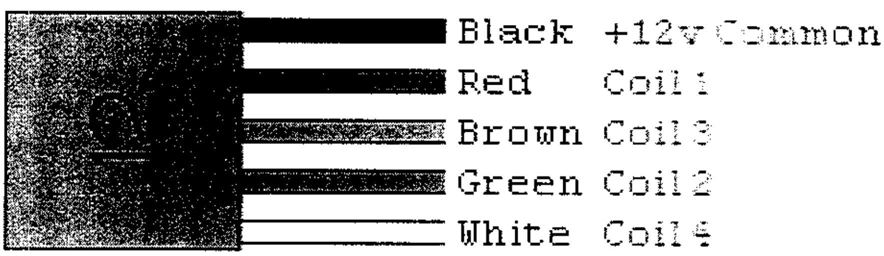


Fig. 5.1 Stepper Motor Connection Diagram

BLOCK DIAGRAM

6. BLOCK DIAGRAM

The overall block diagram of the project is presented here. The voice is given as input and the impact being the operation performed by the robot. The voice commands are given as input to the voice processor through the microphone. It converts the voice signals into corresponding electric signals. The electrical signals are in an incompatible form for the microcontroller. Hence, it is given to the signal conditioning unit and converted into a compatible form. The unit consists of amplifiers, zero crossing detectors and switching transistor. The supply to the switching transistor being 5V, the output will be pulses with amplitude of 5V and with a time period equal to the pulses corresponding to a particular voice command. The pulses are taken to the microcontroller through one of the ports of its own in-built PPI.

The microcontroller is programmed to count the pulses and compare the number of pulses with the templates already stored in the memory. If the count of the command currently produced matches with that of the template, the controller drives the stepper motor through the driving circuit. A display unit is interfaced with the microcontroller to display the pulse count. A stepper card is employed to energize the stepper motor coils in the desired sequence.

The various voice commands are differentiated using a factor called **pulse count.** Each command will have different pulse counts. Based on the count, the microcontroller identifies the command and issues the corresponding control signal, the consequence being the robot exhibiting the apt behavior.

By virtue of the stepper motor, the control system tends to be an open loop system. This makes the system more economical.

6.1 BLOCK DIAGRAM

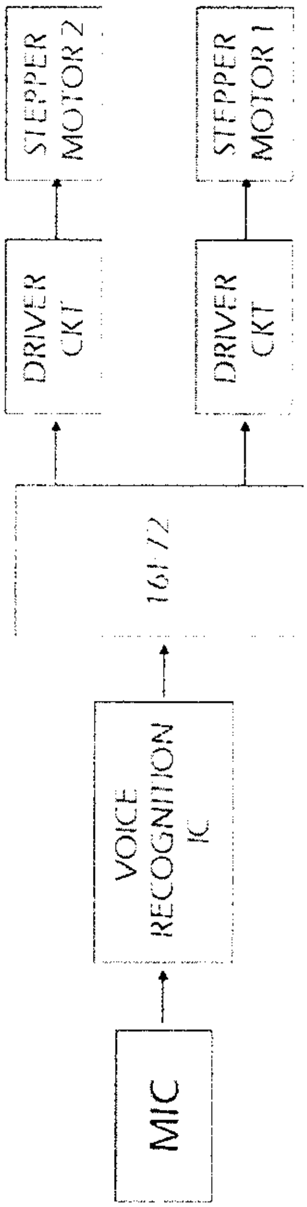


Fig. 6.1 Block Diagram of Voice Recognition Based Robot

6.1.1 POWER SUPPLY

Since all electronic circuits work only with low DC voltage, a power supply unit is needed to provide the appropriate voltage supply. This unit consists of transformer, rectifier, filter and regulator. AC voltage typically 230V is connected to a step down transformer. The output of transformer is given to the bridge rectifier and then a simple capacitor filter to produce a DC voltage initially filters it. This DC voltage is given to regulator, which gives a constant DC voltage. The Power supply unit and the Circuit diagram of GSM based process control system is shown in Figure 6.2.

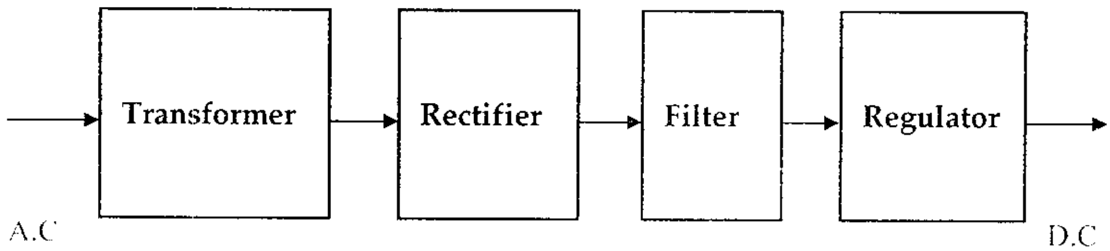


Fig. 6.2 Power supply unit

6.1.2 TRANSFORMER

A transformer is a static piece of which electric power in one circuit is transformed into electric power of same frequency in another circuit. It can raise or lower the voltage in a circuit but with corresponding decrease or increase in current. Step down transformer have been used for providing a necessary supply for the electronic circuits. In this project 230/12V transformer is used.

The various voice commands are differentiated using a factor called pulse count. Each command will have different pulse counts. Based on the count, the microcontroller identifies the command and issues the corresponding control signal, the consequence being the robot exhibiting the apt behavior.

6.1.3 RECTIFIER

The DC level obtained from a sinusoidal input can be improved 100% using a process called full wave rectification. It uses four diodes in a bridge configuration. From the bridge configuration two diodes (D2 & D3) are conducting when the other two diodes (D1 & D4) are in off state. Accordingly for the negative of the input the conducting diodes are D1 & D4. Thus the polarity across the load is the same.

6.1.4 FILTER

The filter circuit used here is capacitive filter circuit. This is connected at the rectifier output and the DC is obtained across it. The filtered waveform is essentially a DC voltage with negligible ripples.

6.1.5 REGULATOR

Regulator IC units contain the circuitry for reference source. comparator amplifier, control device and over load protection in a single IC. Although the internal construction of the IC is somewhat different from that described for discrete voltage regulator circuits, the external operation is the same. IC units provide regulation of either a fixed positive voltage, a fixed negative voltage, are an adjustably set voltage.

A power supply can be built using a transformer connected to the AC supply line to step the AC voltage to the desired amplitude. It is then rectified, filtered with the capacitor and finally regulating the dc voltage using an IC regulator. The regulators can be selected for operation with load currents from hundreds of milliamperes to tens of amperes, corresponding to power ratings from milliwatts to tens of watts.

The various voice commands are differentiated using a factor called pulse count. Each command will have different pulse counts. Based on the count, the microcontroller identifies the command and issues the corresponding control signal, the consequence being the robot exhibiting the apt behavior.

Stepper motors are connected to PORTC pins in the microcontroller. APR7003-02's o/p pins are connected to PORTA pins. Recording keys and its control o/p to the multiplexer are connected to PORTB pins. The obstacle sensor o/p is connected to RA0 pin in microcontroller. For recording the voice one of the keys has to be pressed after that the command has to be recorded. When the same pattern of voice is repeated the voice IC activates its corresponding o/p pin which is connected to microcontroller. Depending upon the input the vehicle moves forward, reverse, left and right. When a obstacle is detected the reflected light rays fall on the LDR its resistance varies and in turn o/p voltage of the circuit also varies, this o/p is fed to the analog channel-0 of the microcontroller where this signal is converted in to digital data if the acquired data is above the set level the vehicle is stopped until the obstacle is removed from its path.

6.1.6 MICROPHONE

A microphone is a special type of pressure transducer converting acoustic energy pressure waves into electrical energy for measurement. When operating in air, such transducers are called microphones and when operating in water, hydrophones. Invariably, the element is a diaphragm. A variety of transduction elements are available.

Microphones serve two principal purposes:

- They are used for converting music or speech into electrical signals, which are transmitted or processed in some manner and then reproduced.
- They serve as measuring instruments, converting acoustic signals into electrical currents, which actuate indicating meters.

The range of pressure to be measured is normally small compared with ambient pressure, even for the most intense sounds. Desirable characteristics include linearity over a wide range of amplitudes and frequencies. Sound pressure levels are commonly expressed in dB. The sensitivity of a microphone is a measure of the voltage developed per unit sound pressure.

Sensitivity (dB) = 20 $\log_{10}$ (voltage output) + 74dB (applied sound pressure in dB)

Thus, a sensitivity of -20dB means that a voltage of 0.1V will be developed by a sound signal of pressure level 74dB, which is the reference condition of sensitivity.

6.1.6.1 TYPES OF MICROPHONE

- Carbon Microphones
- Capacitive Microphones
- Dynamic Microphones
- Inductive Microphones
- Piezoelectric Microphones

6.2 CIRCUIT DESCRIPTION

The stepper motor controller circuit uses a buffer to pass the input from the microcontroller to the stepper motor controller circuit. The buffer is used to retrieve the pulses without any distortion or loss. A buffer is of great use incase of long distance transmission for retrieving the signals effectively. Such a stepper motor controller circuit is shown in Fig. 6.3. The buffer output is fed to the Darlington pair transistor whose output is used to energize the stepper motor coils. A freewheeling diode and a series resistance are connected across the stepper motor coil to provide path for current flow in the inductive load when the coil is de-energized. The current decays exponentially in the form of heat dissipation.

The microcontroller is programmed to count the pulses and compare the number of pulses with the templates already stored in the memory. If the count of the command currently produced matches with that of the template, the controller drives the stepper motor through the driving circuit. A display unit is interfaced with the microcontroller to display the pulse count. A stepper card is employed to energize the stepper motor coils in the desired sequence.

6.3 CIRCUIT DIAGRAM

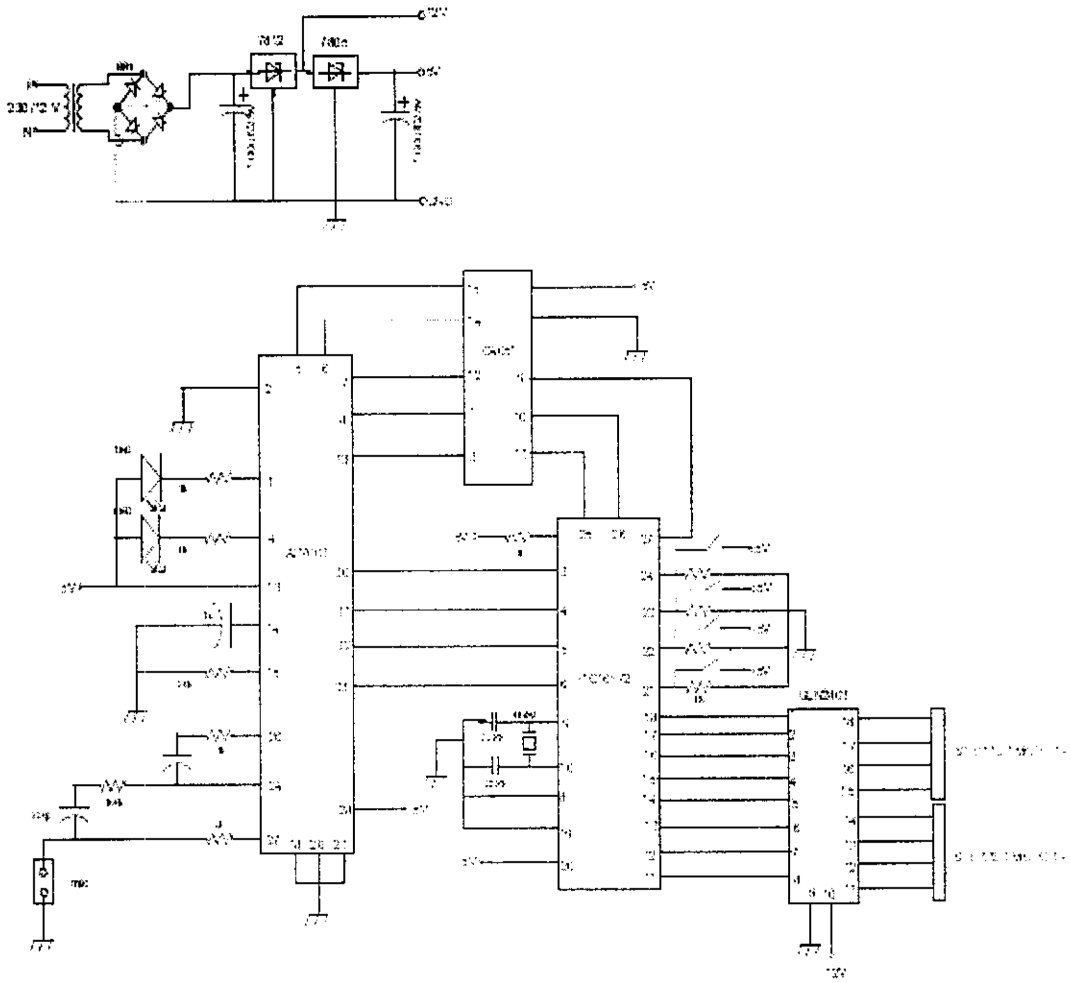


Fig. 6.3 Circuit Diagram of Voice Recognition Based Robot

SOFTWARE DEVELOPMENT TOOLS USED

7. SOFTWARE DEVELOPMENT TOOLS USED FOR VOICE RECOGNITION BASED ROBOT

7.1 SOFTWARE TOOLS USED

❖ MPLAB	- IDE (Integrated Development Environment).
❖ HITECH-C	- Cross compiler.
❖ PROPIC	- PIC Programmer.
❖ PROTEL	- PCB Designing software

7.1.1 MPLAB

To make working with the PIC microcontroller even easier, Microchip provides an excellent group of software it is called MPLAB IDE. MPLAB IDE is a software program that runs on a PC to develop applications for Microchip microcontrollers. It is called an Integrated Development Environment, or IDE, because it provides a single integrated "environment" to develop code for embedded microcontrollers. MPLAB IDE contains a text editor, assembler (MPASM assembler) and simulator (MPSIM) and this stuff will run under DOS or WINDOWS. With MPLAB IDE in hand we can write the program using the included text editor, and then assemble it with the MPASM assembler program. The MPASM assembler will develop the code format (HEX) that the PIC Microcontroller wants that code can then be burned into a PIC with the programmer.

The stepper motor controller circuit uses a buffer to pass the input from the microcontroller to the stepper motor controller circuit. The buffer is used to retrieve the pulses without any distortion or loss. A buffer is of great use incase of long distance transmission for retrieving the signals effectively. Such a stepper motor controller circuit is shown. The buffer output is fed to the Darlington pair transistor whose output is used to energize the stepper motor coils. A freewheeling diode and a series resistance are connected across the stepper motor coil to provide path for current flow in the inductive load when the coil is de-energized. The current decays exponentially in the form of heat dissipation.

7.1.2 ANALOG TO DIGITAL CONVERSION (A/D)

The analog-to-digital (A/D) converter module has up to eight analog inputs. The A/D allows conversion of an analog input signal to a corresponding 8-bit digital number. The output of the sample and hold is the input into the converter, which generates the result via successive approximation. The analog reference voltage is software selectable to either the device's positive supply voltage (VDD) or the voltage level on the VREF pin. The A/D converter has a unique feature of being able to operate while the device is in SLEEP mode. The A/D module has three registers. These registers are

- A/D Result Register (ADRES)
- A/D Control Register0 (ADCON0)
- A/D Control Register1 (ADCON1)

The ADCON0 register controls the operation of the A/D module. The ADCON1 register configures the functions of the port pins. The I/O pins can be configured as analog inputs (one I/O can also be a voltage reference) or as digital I/O.Fig.8.1 shows the A/D block diagram.

The A/D allows conversion of an analog input signal to a corresponding 8-bit digital number. The output of the sample and hold is the input into the converter, which generates the result via successive approximation. The analog reference voltage is software selectable to either the device's positive supply voltage (VDD) or the voltage level on the VREF pin. The A/D converter has a unique feature of being able to operate while the device is in SLEEP mode.

The output of the sample and hold is the input into the converter, which generates the result via successive approximation. The analog reference voltage is software selectable to either the device's positive supply voltage (VDD) or the voltage level on the VREF pin.

7.1.2.1 BLOCK DIAGRAM OF A/D

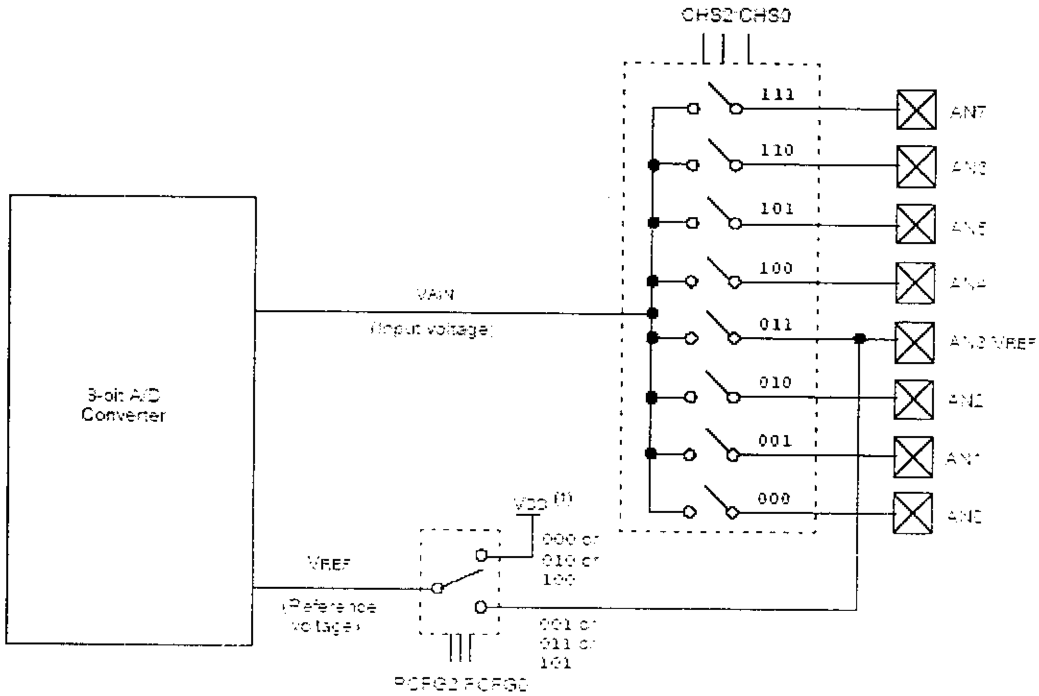


Fig. 8.1 Block Diagram of A/D

7.1.2.2 CONTROL REGISTERS

ADCON0 Register

ADCS1	ADCS0	CHS2	CHS1	CHS0	GO/DONE	Resv	ADON

Bit 7 Bit 0

BIT 7:6

ADCS1:ADCS0: A/D Conversion Clock Select bits

00= FOSC/2

01= FOSC/8

10= FOSC/32

11= FRC (clock derived from the internal A/D RC oscillator)

BIT 5:3

CHS2:CHS0: Analog Channel Select bits

000= channel 0, (AN0)

001= channel 1, (AN1)

010= channel 2, (AN2)

011= channel 3, (AN3)

100= channel 4, (AN4)

101= channel 5, (AN5)

110= channel 6, (AN6)

111= channel 7, (AN7)

NOTE

For devices that do not implement the full 8 A/D channels, the unimplemented selections are reserved. Do not select any unimplemented Channels.

BIT 2

GO/DONE: A/D Conversion Status bit

When ADON = 1

1 = A/D conversion in progress

(Setting this bit starts the A/D conversion. This bit is automatically cleared by hardware when the A/D conversion is complete)

0 = A/D conversion not in progress

BIT 1

Reserved: Always maintain this bit cleared.

BIT 0

ADON: A/D On bit

1 = A/D converter module is operating

0 = A/D converter module is shutoff and consumes no operating current

ADCON1 REGISTER

--	--	--	--	--	PCFG2	PCFG1	PCFG0
Bit 7							Bit 0

BIT 7:3

Unimplemented: Read as '0'

BIT 2:0

PCFG2:PCFG0: A/D Port Configuration Control bits are shown in the table no. 8.1

PCFG2:PCFG0	AN7	AN6	AN5	AN4	AN3	AN2	AN1	AN0
000	A	A	A	A	A	A	A	A
001	A	A	A	A	VREF	A	A	A
010	D	D	D	A	A	A	A	A
011	D	D	A	A	VREF	A	A	A
100	D	D	D	D	A	D	A	A
101	D	D	D	D	VREF	D	A	A
11x	D	D	D	D	D	D	D	D

A = Analog input D = Digital I/O

Table 8.1 A/D Port Configuration Control Bits

7.1.2.3 PROCEDURE FOR A/D

- RA0 is set to one to make it as input.
- Sending the data 0x80 to this register configures ADCON1 in this register the bit ADFM is set.
- Sending the data 0x81 to this register configures ADCON 0, in this register ADON bit is set to enable conversion and also ADCS1 is set to select the frequency of conversion.
- Delay subroutine is called (10micro sec).
- ADGO bit is set to one.
- ADGO bit is checked to know either the A TO D conversion is completed or not
- ADGO is zero --- Conversion is completed
- ADGO is one --- Conversion is not completed.

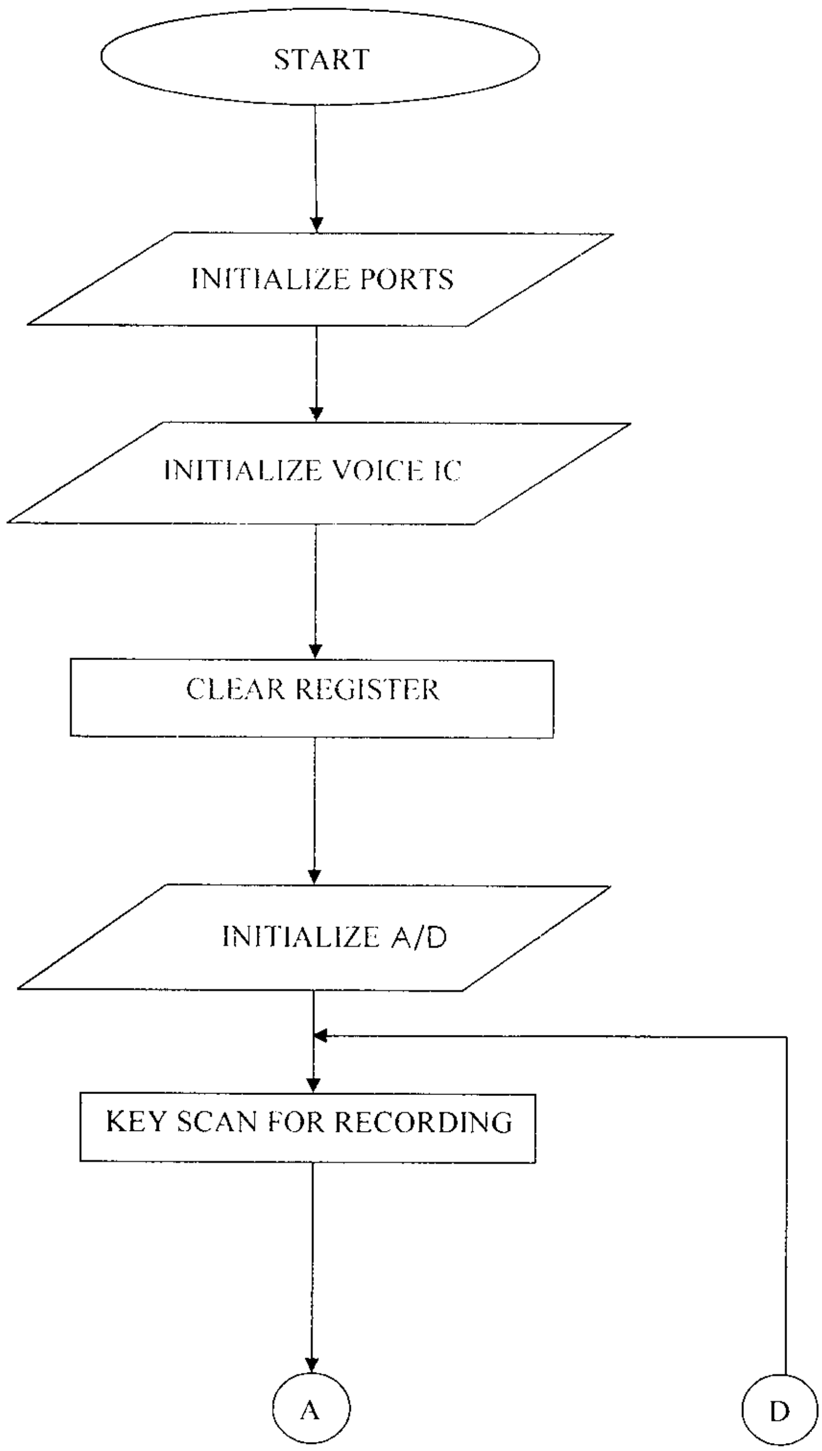
The A/D allows conversion of an analog input signal to a corresponding 8-bit digital number. The output of the sample and hold is the input into the converter, which generates the result via successive approximation. The analog reference voltage is software selectable to either the device's positive supply voltage (VDD) or the voltage level on the VREF pin. The A/D converter has a unique feature of being able to operate while the device is in SLEEP mode.

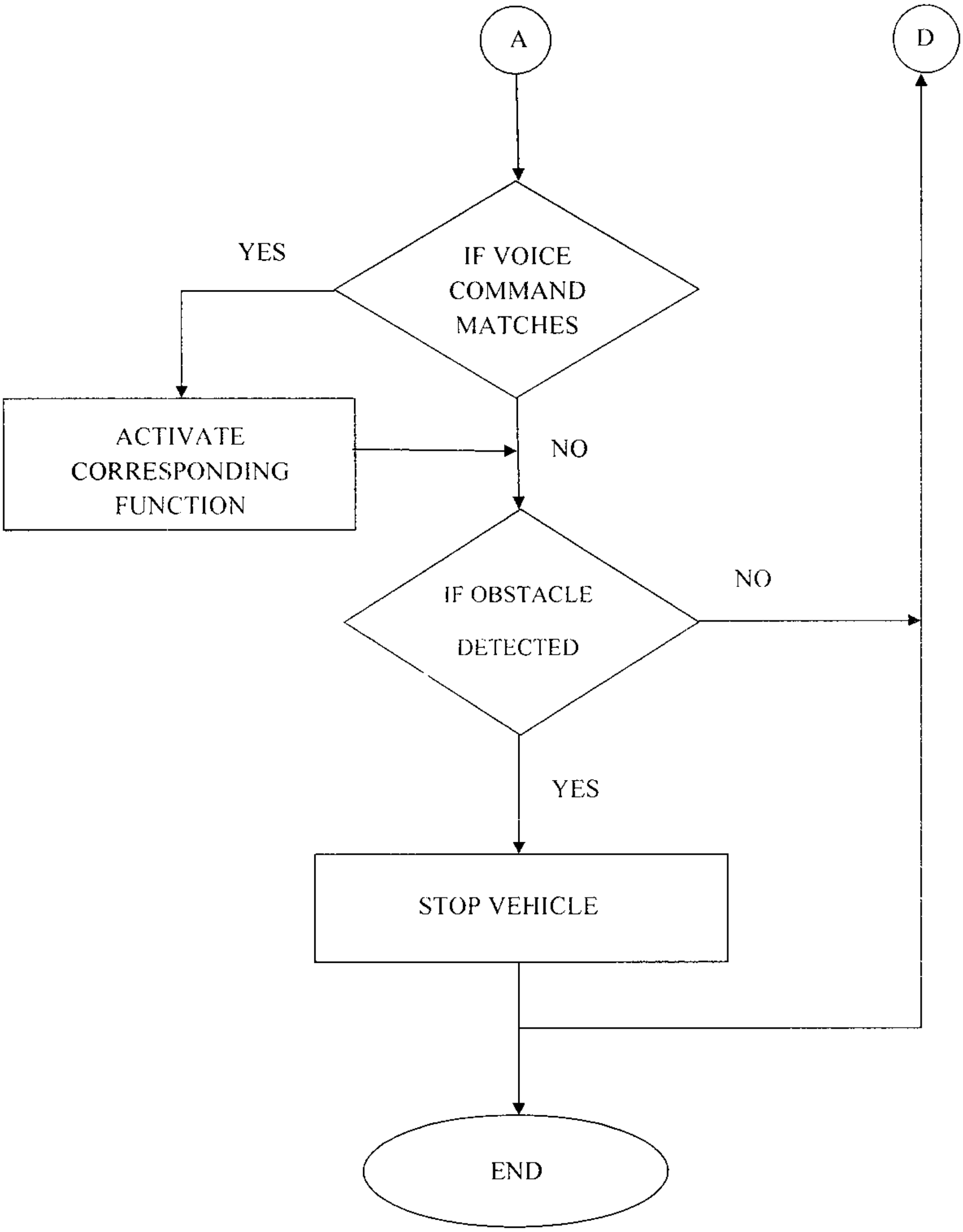
The buffer is used to retrieve the pulses without any distortion or loss. A buffer is of great use incase of long distance transmission for retrieving the signals effectively. Such a stepper motor controller circuit is shown. The buffer output is fed to the Darlington pair transistor whose output is used to energize the stepper motor coils. A freewheeling diode and a series resistance are connected across the stepper motor coil to provide path for current flow in the inductive load when the coil is de-energized. The current decays exponentially in the form of heat dissipation.

IMPLEMENTATION

8. IMPLEMENTATION

8.1 FLOWCHART




A
D
IF VOICE COMMAND MATCHES
YES
ACTIVATE CORRESPONDING FUNCTION
NO
IF OBSTACLE DETECTED
NO
YES
STOP VEHICLE
END

8.2 PROGRAM

```
/*-----------------------------------------------------------------------------------------------

SPEECH RECOGNITION BASED SECURITY SYSTEM

-------------------------------------------------------------------------------------------------
*/

#include<pic.h>

/*-----------------------------------------------------------------------------------------------

SPEECH RECOGNITION BASED HOME AUTOMATION

-------------------------------------------------------------------------------------------------
*/

unsigned char
i,times,rela1=0,rela2=0,rela3,rela4,came1,came2,came3,came4=0,s=0,result=0;

unsigned int tim1=0,tim2=0,j=0;

/*-----------------------------------------------------------------------------------------------

MAIN ROUTINE

-------------------------------------------------------------------------------------------------
*/

main()

{

TRISC=0X00;

TRISA=0X3F;

TRISA1=0;

TRISB=0X0f;

ADCON1=0X07;
```

```
PORTA=0;
PORTB=0;
PORTC=0;
RA1=0;
OPTION=0X80;
delay();
delay();
delay();
delay();
delay();
delay();
RA1=1;
delay();
delay();
delay();
while(RA5)
delay();
came1=0;
while(1)
{
record();
scan();
if(came1==1)
```

```
forward();
if(came1==2)
reverse();
if(came1==3)
left();
if(came1==4)
right();
}
}
/*-------------------------------------------------------------------------------------------------
SPEECH RECORD ACTIVATE ROUTINE
-------------------------------------------------------------------------------------------------
*/
scan()
{
if(RA5==1&&RB0==0)
{
came1=1;
RB7=1;
delay();
RB7=0;
}
```

```
if(RA4==1&&RB1==0)
{
came1=2;
RB7=1;
delay();
RB7=0;
}

if(RA3==1&&RB2==0)
{
came1=3;
RB7=1;
delay();
RB7=0;
}
if(RA2==1&&RB3==0)
{
came1=4;
RB7=1;
delay();
RB7=0;
}
}
```

```
/*------------------------------------------------------------------------------------------
                    SPEECH RECORD ACTIVATE ROUTINE
------------------------------------------------------------------------------------------
*/
record()
{
if(RB0==1)
{
delay();
while(RB0==1)
{
PORTC=0;
came1=0;
RB6=1;
RB5=0;
RB4=0;
}
delay();
delay();
delay();
delay();
RB6=0;
RB5=0;
```

```
RB4=0;
delay();
delay();
delay();
delay();
while(RA5)
delay();
}
if(RB1==1)
{
delay();
while(RB1==1)
{
camel=0;
PORTC=0;
RB6=0;
RB5=1;
RB4=1;
}
delay();
delay();
delay();
delay();
```

```
RB5=0;
RB4=0;
RB6=0;
delay();
delay();
while(RA4)
delay();
}
if(RB2==1)
{
delay();
while(RB2==1)
{
came1=0;
PORTC=0;
RB6=0;
RB5=0;
RB4=1;
}
delay();
delay();
delay();
delay();
```

```
RB5=0;
RB4=0;
delay();
delay();
while(RA3)
delay();
}
if(RB3==1)
{
delay();
while(RB3==1)
{
came1=0;
PORTC=0;
RB6=0;
RB5=1;
RB4=0;
}
delay();
delay();
delay();
delay();
RB5=0;
```

```
RB4=0;
delay();
delay();
while(RA2)
delay();
}
if(RB0==0&&RB1==0&&RB2==0&&RB3==0)
{
RB4=0;
RB5=0;
RB6=0;
}
}
/*----------------------------------------------------------------------------------------------------------
                              DELAY ROUTINE
-----------------------------------------------------------------------------------------------------------
*/
delay()
{
for(i=0;i<40;i++)
{
OPTION=0X87;
TMR0=0XD9;
```

```
TOIF=0;
while(!TOIF);
}
}
/*---------------------------------------------------------------------------------------------------------
SPEECH RECORD ACTIVATE ROUTINE
---------------------------------------------------------------------------------------------------------
*/
delay1()
{
OPTION=0X87;
TMR0=0XD9;
TOIF=0;
while(!TOIF);
result=0;
while(result<162)
{
ADCON1=0;
ADCON0=0X81;
for(s=0;s<100;s++);
ADGO=1;
while(ADGO);
result=ADRES;
```

```
}
ADCON1=0X07;
for(s=0;s<100;s++);
}
/*-----------------------------------------------------------------------------------------------
                    SPEECH RECORD ACTIVATE ROUTINE
-----------------------------------------------------------------------------------------------
*/
forward()
{
for(times=0;times<100;times++)
{
PORTC=0X81;
delay1();
PORTC=0X42;
delay1();
PORTC=0X24;
delay1();
PORTC=0X18;
delay1();
}
came1=0;
PORTC=0;
```

```
}
/*-------------------------------------------------------------------------------------------
                    SPEECH RECORD ACTIVATE ROUTINE
---------------------------------------------------------------------------------------------
*/
reverse()
{
for(times=0;times<100;times++)
{
PORTC=0X18;
delay1();
PORTC=0X24;
delay1();
PORTC=0X42;
delay1();
PORTC=0X81;
delay1();
}
came1=0;
PORTC=0;
}
```

```
/*-----------------------------------------------------------------------------------------------
SPEECH RECORD ACTIVATE ROUTINE
-----------------------------------------------------------------------------------------------
*/
left()
{
for(times=0;times<75;times++)
{
PORTC=0;
PORTC=0X10;
delay1();
PORTC=0X20;
delay1();
PORTC=0X40;
delay1();
PORTC=0X80;
delay1();
}
came1=0;
PORTC=0;
}
```

```
/*----------------------------------------------------------------------------------------------------------
SPEECH RECORD ACTIVATE ROUTINE
----------------------------------------------------------------------------------------------------------
*/
right()
{
for(times=0;times<75;times++)
{
PORTC=0X01;
delay1();
PORTC=0X02;
delay1();
PORTC=0X04;
delay1();
PORTC=0X08;
delay1();
}
camel=0;
PORTC=0;
}
```

FURTHER DEVELOPMENT

9. FURTHER DEVELOPMENT

Although any number of commands can be employed to control the robot, it depends on the user's ability to handle the class of pulses firmly established to gratify his stipulations. DSP processor can be used to store a particular persons voice for their personal use or this technique can be implemented in highly secured military operations.

High end voice IC's is used in mere future to store number of voice commands. This technique can be extended by use of Fuzzy Logic so that the robot will take decisions and act accordingly.

Stepper motor is the prominent driving unit used for any robotic application. Depending on the rating of the stepper motor, the robotic application can vary from being employed in a tiny wristwatch to high power industrial applications.

The usage of filters would reduce noise to a significant level leading to better accuracy. In future, voice synthesizers can also be used to extract every syllable and recognize the given command modulated in any form.

The robot has overcome the handicap of being "deaf". More sensors could be used, thereby helping the robot to overcome all of its shortcomings and be more humane.

CONCLUSION

10. CONCLUSION

The principle of development of science is that "Nothing is impossible". Voice adaptive robotic system looks forward to s bright and sophisticated robotic world. Much of the thesis has been devoted to develop the conceptual frameworks for integrating voice with a robot.

This project aims at making the robot respond to different commands. Even though it appears complex system, the cost involved is less, making it more economical and it is language independent. The lone requirement of the project is the voice, which needs to be given at a constant pace.

In this project, a user dependent voice adaptive system was developed. The efficacy of the entire system can be improved further and the system can be used for more number of commands if during the training of the system, the noise conditions are improved.

"Fashions fade – but style is eternal.

Technology changes – but nature is eternal."

BIBLIOGRAPHY

BIBLIOGRAPHY

[1] PIC Microchip reference manual. Microchip technology Inc., 2004.

[2] A.K.Sawhney, "A course in Electronic Measurements and Instrumentation", Dhanpat Rai & co, seventeen edition. Delhi. 2002.

[3] Myke Predko. "Programming and Customizing the PIC Microcontroller". McGraw Hill, second edition, 1998.

[4] www.microchip.com

[5] www.sensors.com

[6] www.maxim-ic.com

APPENDIX

APLUS INTEGRATED CIRCUITS INC.

AP7003-01

(Voice Recognition IC)

APPLICATION NOTE

==

APLUS INTEGRATED CIRCUITS INC.
6F-3 NO.7.LANE 75,TA-AN ROAD, SEC.1,TAIPEI,
TAIWAN, R.O.C
Tel: 886-2-2781-8277 Fax: 886-2-2781-5779

● ABSOLUTE MAXIMUM RATING

Supply Voltage (VDD to GND) ------------------------ 5V

Input Voltage Range---------------------------------------(GND- 0.3V) to (VDD + 0.3V)

Operating Temperature Range------------------------ 0℃ to +60℃

● ELECTRICAL CHARACTERISTICS

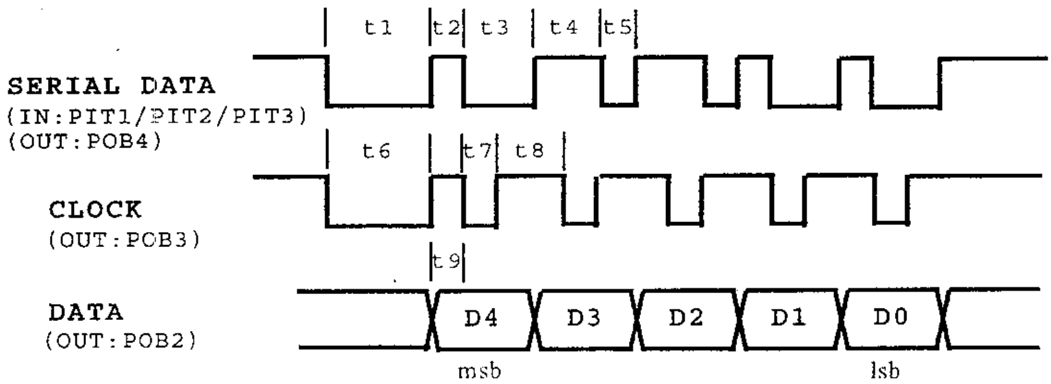
(VDD=3V , GND=0V ,Ta=+25℃, unless otherwise noted)

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Standby Current	Shut down		1	10	uA
Operating Current	Outputs no load		2		mA
Input low voltage	VDD=3V			0.8	V
	VDD=4.5V			1.2	V
Input high voltage	VDD=3V	2.2			V
	VDD=4.5V	3.5			V
Output low voltage	Iout = -0.5mA			0.5	V
	Iout = -1mA , VDD=4.5V			0.8	V
Output high voltage	Iout = 0.5mA	2.5			V
	Iout = 1mA , VDD=4.5V	3.6			V

- **PIN Description :**

Pin Name	Description
GNDD	Digital Ground pin
LED1	Low active LED driver pin, can be programmed to indicate voice input phase for standard application.
LED2	Low active LED driver pin, can be programmed to indicate the recognized result of input voice for standard application.
POB1 ~ POB4	Output Port B, can be programmed as key pad scan drivers for standard application.
PIT1 ~ PIT4	Low active Trigger Input Port, with built in pull high resistor, can be programmed as key in detector for standard application .
VDDD	Digital VDD pin
CAPV	Decoupling capacitor must be connected between this pin and ground for internal voltage regulator.
OSCI	Oscillator frequency control pin, a 56K ohm resistor must be connected between this pin and ground.
PIM1 ~ PIM2	General input pins can be programmed as mode control inputs for standard application.
TEST	TEST control pin for manufacture
POSL	Output mode selector for Output Port A, Output Port A is high active when POSL is pull high and is low active when POSL is pull low.
GNDA	Analog Ground pin
TREF	Threshold control pin for voice input
A2OUT	Output of second amplifier
A1IN	Negative input of first amplifier
A1OUT	Output of first amplifier
MICP	Positive power supply for electric microphone
VDDA	Analog VDD pin
POA1 ~ POA12	Output Port A, can be programmed as bank indicator for words recording and/or recorgnized target words.
PORES	High active input pin for clearing the status of Output Port A

● Table1: Data I/O Format for AP7003-01 :



t1(Start)	:	12 ms	t6(Start)	:	12 ms
t2(Data Low Front-end)	:	4 ms	t7(Clock Low)	:	4 ms
t3(Data Low Back-end)	:	8 ms	t8(Clock High)	:	8 ms
t4(Data High Front-end)	:	8 ms	t9(Data Ready)	:	4 ms
t5(Data High Back-end)	:	4 ms			

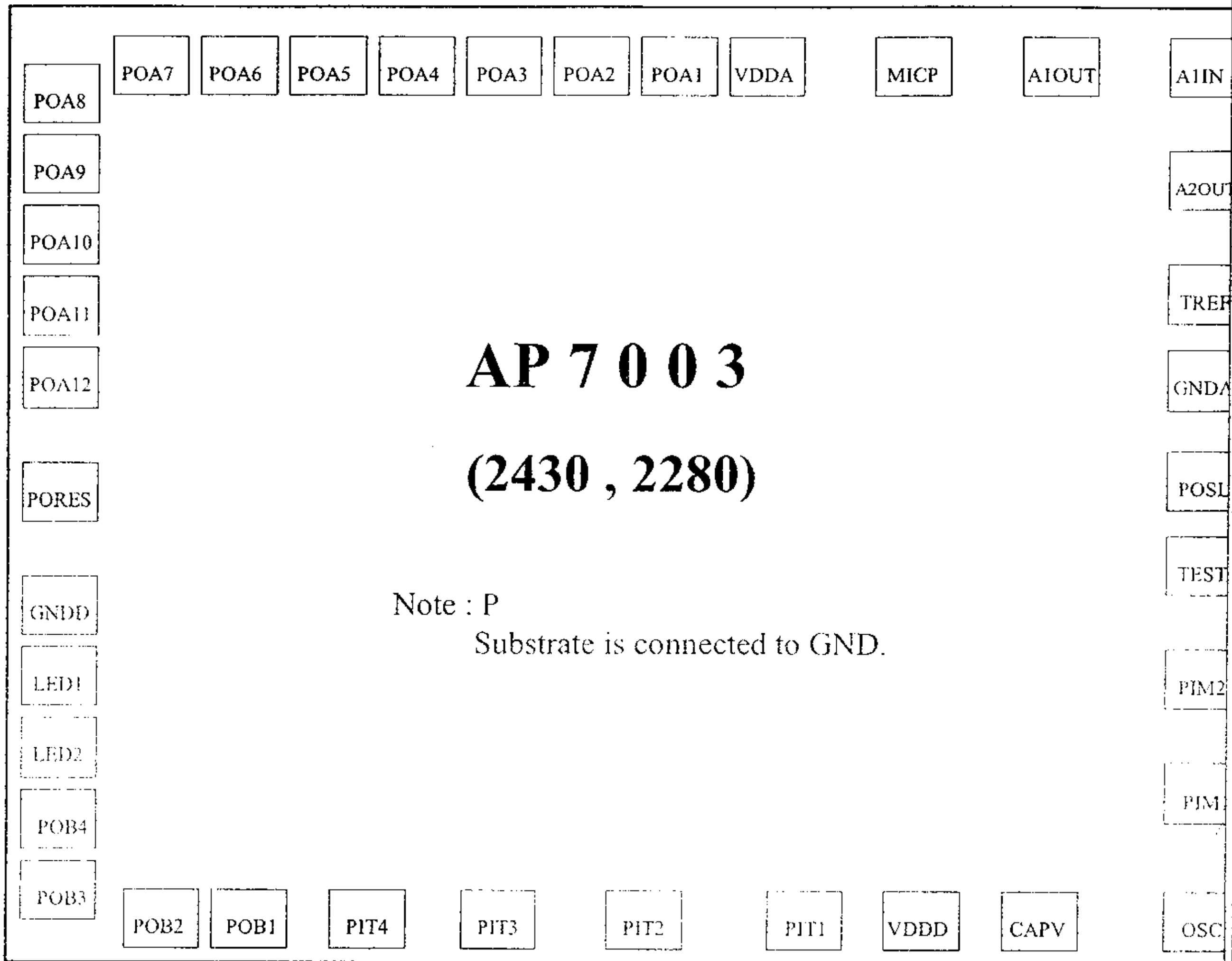
Note : Timing listed above are typical value

Code of Input DATA	
INSTRUCTION	CODE
Store WORD1	01H
Store WORD2	02H
Store WORD3	03H
Store WORD4	04H
Store WORD5	05H
Store WORD6	06H
Store WORD7	07H
Store WORD8	08H
Store WORD9	09H
Store WORD10	0AH
Store WORD11	0BH
Store WORD12	0CH
Store Flag	0DH
Clear WORD	10H
Set R_Level1	11H
Set R_Level2	12H
Set R_Level3	13H
Set R_Level4	14H
Set R_Mode1	15H
Set R_Mode2	16H
Clear Outputs	17H
Shutdown	18H

Code of Output DATA	
INSTRUCTION	CODE
Match WORD1	01H
Match WORD2	02H
Match WORD3	03H
Match WORD4	04H
Match WORD5	05H
Match WORD6	06H
Match WORD7	07H
Match WORD8	08H
Match WORD9	09H
Match WORD10	0AH
Match WORD11	0BH
Match WORD12	0CH
Done	11H
No Match WORD	12H
Data In Error	13H

MODE
PIM1 : Recog. Enable PIM2 : PORT A Enable (Both High Active)

● BONDING PAD DIAGRAM



PAD	X,Y Unite : um	PAD	X,Y Unite : um
GNDD	(150 , 938)	TREF	(2280 , 1608)
LED1	(150 , 757)	A2OUT	(2280 , 1887)
LED2	(150 , 576)	A1IN	(2280 , 2130)
POB4	(150 , 396)	A1OUT	(2001 , 2130)
POB3	(150 , 215)	MICP	(1799 , 2130)
POB2	(345 , 150)	VDDA	(1573 , 2130)
POB1	(526 , 150)	POA1	(1404 , 2130)
PIT4	(752 , 150)	POA2	(1225 , 2130)
PIT3	(1031 , 150)	POA3	(1045 , 2130)
PIT2	(1274 , 150)	POA4	(666 , 2130)
PIT1	(1553 , 150)	POA5	(667 , 2130)
VDDD	(1765 , 150)	POA6	(506 , 2130)
CAPV	(2001 , 150)	POA7	(326 , 2130)
OSCI	(2280 , 150)	POA8	(150 , 2107)
PIM1	(2280 , 393)	POA9	(150 , 1927)
PIM2	(2280 , 672)	POA10	(150 , 1746)
TEST	(2280 , 914)	POA11	(150 , 1569)
POSL	(2280 , 1193)	POA12	(150 , 1390)
GNDA	(2280 , 1396)	PORES	(150 , 1172)

MICROCHIP

PIC16F7X Data Sheet

28/40-pin, 8-bit CMOS FLASH Microcontrollers

Note the following details of the code protection feature on PICmicro® MCUs.

- The PICmicro family meets the specifications contained in the Microchip Data Sheet.
- Microchip believes that its family of PICmicro microcontrollers is one of the most secure products of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the PICmicro microcontroller in a manner outside the operating specifications contained in the data sheet. The person doing so may be engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable".
- Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our product.

If you have any further questions about this matter, please contact the local sales office nearest to you.

DNV Certification, Inc. USA

DNV MSC The Netherlands Accredited by the RvA

ISO 9001 / QS-9000 REGISTERED FIRM

Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999. The Company's quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs and microperipheral products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001 certified.

PIC16F7X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

Devices Included in this Data Sheet:

- PIC16F73
- PIC16F74
- PIC16F76
- PIC16F77

High Performance RISC CPU:

- High performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two-cycle
- Operating speed: DC - 20 MHz clock input
DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory, Up to 368 x 8 bytes of Data Memory (RAM)
- Pinout compatible to the PIC16C73B/74B/76/77
- Pinout compatible to the PIC16F873/874/876/877
- Interrupt capability (up to 12 sources)
- Eight level deep hardware stack
- Direct, Indirect and Relative Addressing modes
- Processor read access to program memory

Special Microcontroller Features:

- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- In-Circuit Serial Programming™ (ICSP™) via two pins

Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 8-bit, up to 8-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I²C™ (Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI)
- Parallel Slave Port (PSP), 8-bits wide with external RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

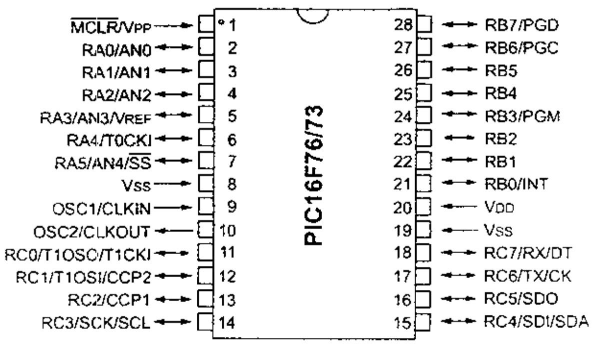
CMOS Technology:

- Low power, high speed CMOS FLASH technology
- Fully static design
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Industrial temperature range
- Low power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

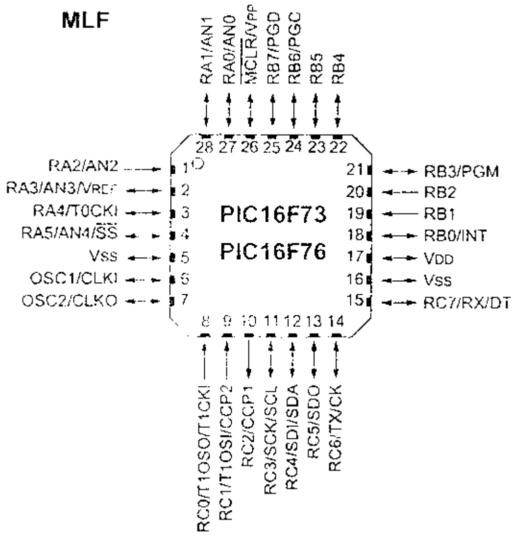
Device	Program Memory (# Single Word Instructions)	Data SRAM (Bytes)	I/O	Interrupts	8-bit A/D (ch)	CCP (PWM)	SSP		USART	Timers 8/16-bit
							SPI (Master)	I²C (Slave)		
PIC16F73	4096	192	22	11	5	2	Yes	Yes	Yes	2 / 1
PIC16F74	4096	192	33	12	8	2	Yes	Yes	Yes	2 / 1
PIC16F76	8192	368	22	11	5	2	Yes	Yes	Yes	2 / 1
PIC16F77	8192	368	33	12	8	2	Yes	Yes	Yes	2 / 1

Pin Diagrams

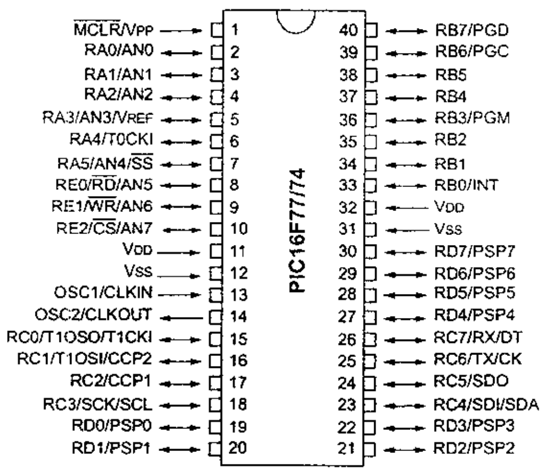
DIP, SOIC, SSOP



MLF

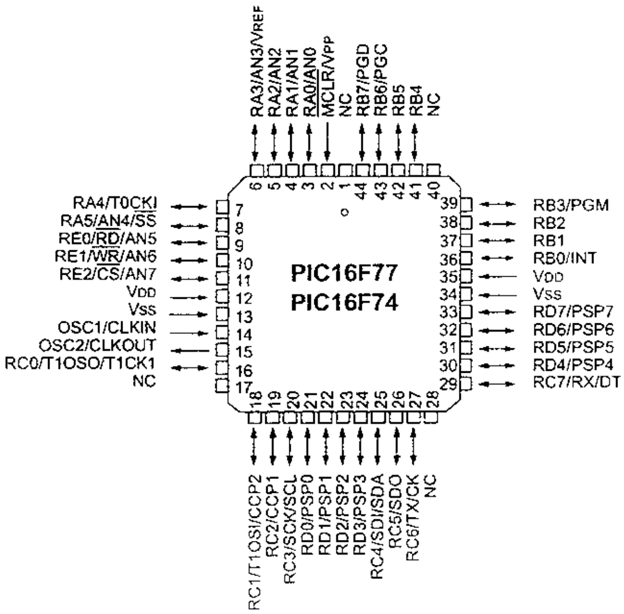


PDIP

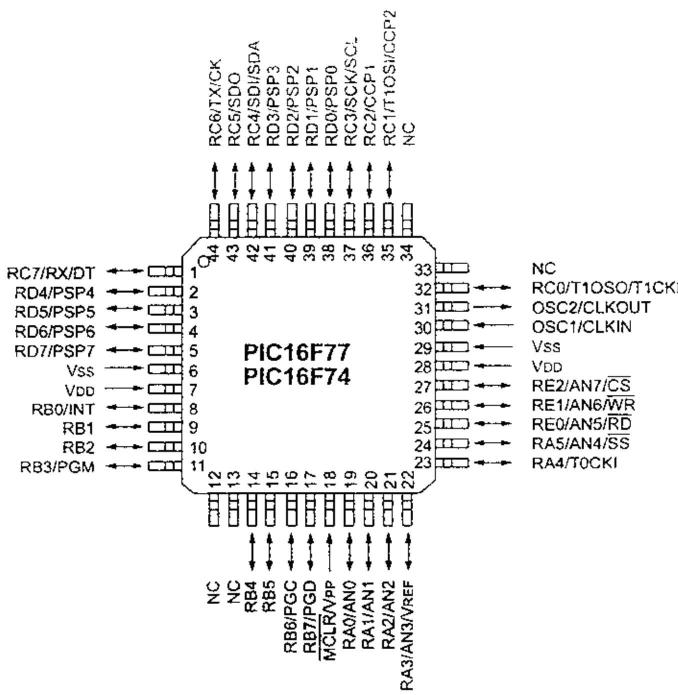


Pin Diagrams (Continued)

PLCC



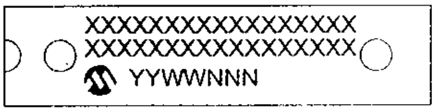
QFP



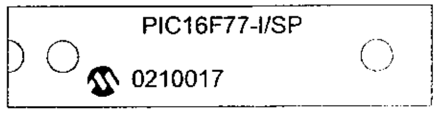
17.0 PACKAGING INFORMATION

17.1 Package Marking Information

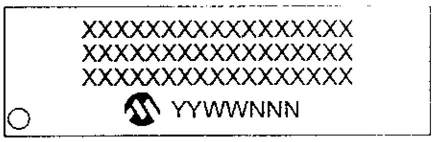
28-Lead PDIP (Skinny DIP)



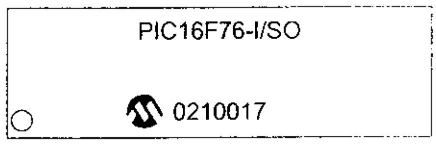
Example



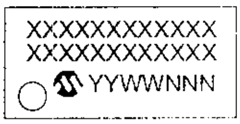
28-Lead SOIC



Example



28-Lead SSOP



Example

28-Lead MLF

Example

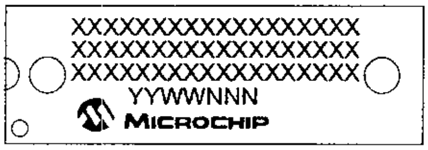
Legend:	XX...X	Customer specific information*
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line thus limiting the number of available characters for customer specific information.

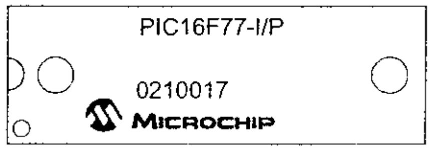
* Standard PICmicro device marking consists of Microchip part number, year code, week code, and traceability code. For PICmicro device marking beyond this, certain price adders apply. Please check with your Microchip Sales Office. For QTP devices, any special marking adders are included in QTP price.

Package Marking Information (Cont'd)

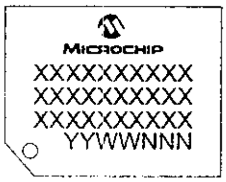
40-Lead PDIP



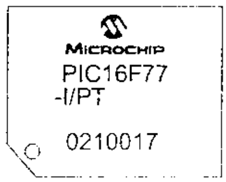
Example



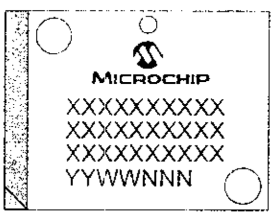
44-Lead TQFP



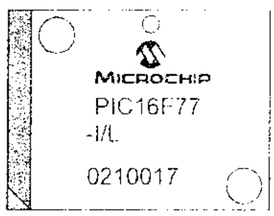
Example



44-Lead PLCC



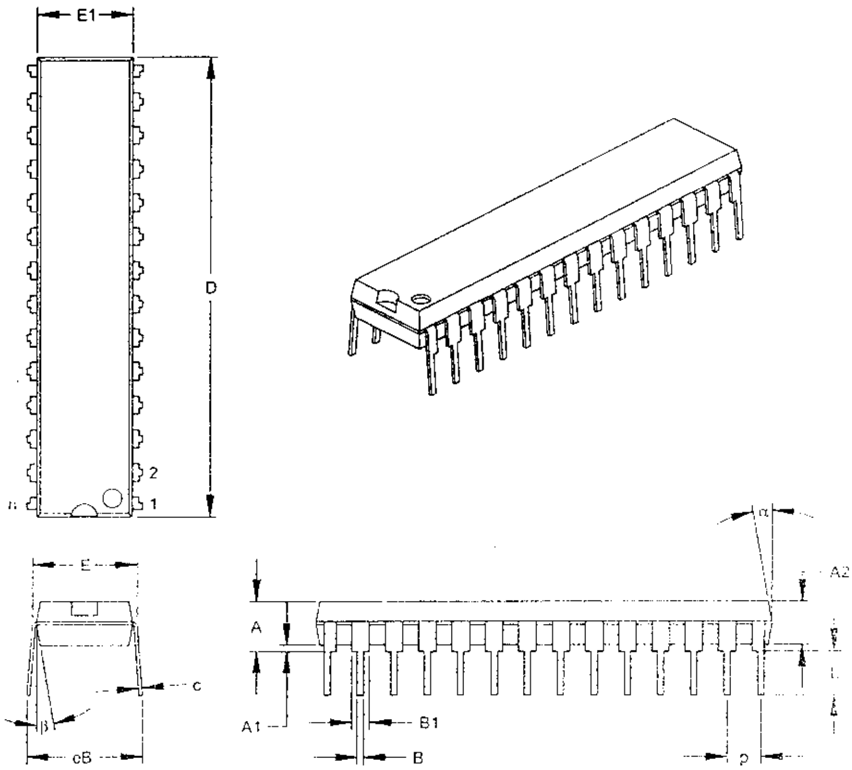
Example



17.2 Package Details

The following sections give the technical details of the packages.

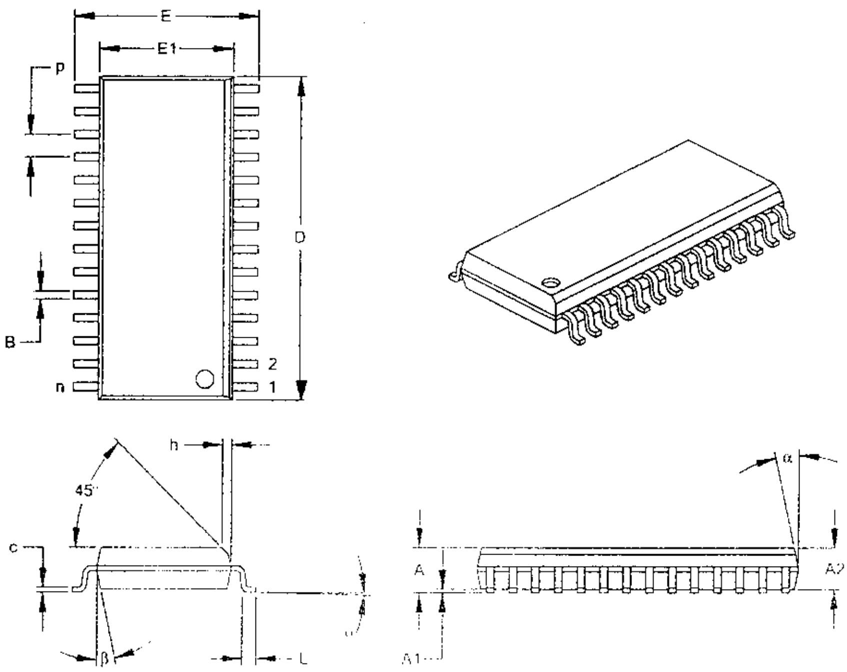
28-Lead Skinny Plastic Dual In-line (SP) – 300 mil (PDIP)



Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		28			28	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.140	.150	.160	3.56	3.81	4.06
Molded Package Thickness	A2	.125	.130	.135	3.18	3.30	3.43
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.300	.310	.325	7.62	7.87	8.26
Molded Package Width	E1	.275	.285	.295	6.99	7.24	7.49
Overall Length	D	1.345	1.365	1.385	34.16	34.67	35.18
Tip to Seating Plane	L	.125	.130	.135	3.18	3.30	3.43
Lead Thickness	c	.008	.012	.015	0.20	0.29	0.38
Upper Lead Width	B1	.040	.053	.065	1.02	1.33	1.65
Lower Lead Width	B	.016	.019	.022	0.41	0.48	0.56
Overall Row Spacing §	eB	.320	.350	.430	8.13	8.89	10.92
Mold Draft Angle Top	α	5	10	15	5	10	15
Mold Draft Angle Bottom	β	5	10	15	5	10	15

* Controlling Parameter
§ Significant Characteristic
Notes:
Dimension D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.
JEDEC Equivalent: MO-095
Drawing No. C04-070

28-Lead Plastic Small Outline (SO) – Wide, 300 mil (SOIC)

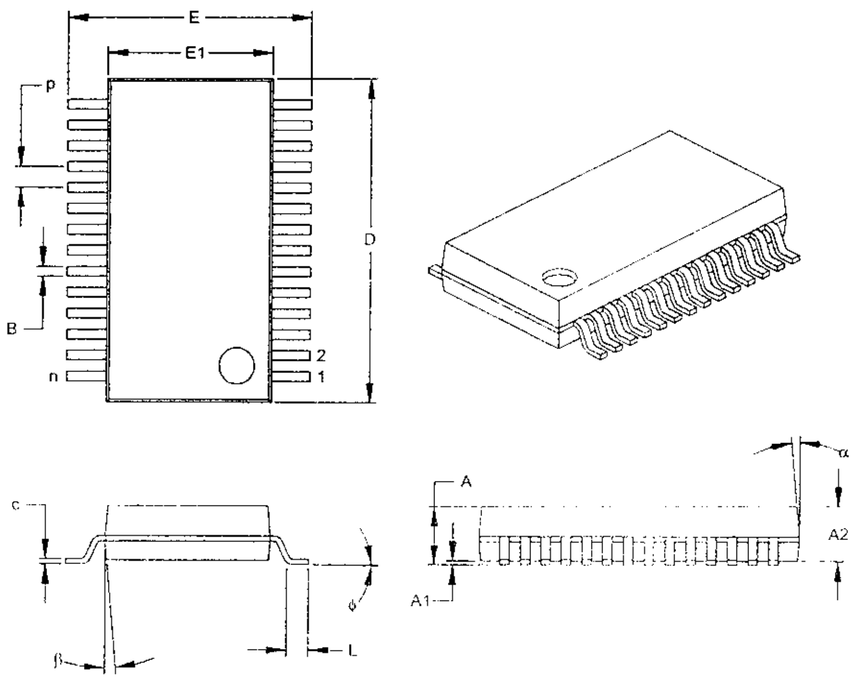


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		28			28	
Pitch	p		.050			1.27	
Overall Height	A	.093	.099	.104	2.36	2.50	2.64
Molded Package Thickness	A2	.088	.091	.094	2.24	2.31	2.39
Standoff §	A1	.004	.008	.012	0.10	0.20	0.30
Overall Width	E	.394	.407	.420	10.01	10.34	10.67
Molded Package Width	E1	.288	.295	.299	7.32	7.49	7.59
Overall Length	D	.695	.704	.712	17.65	17.87	18.08
Chamfer Distance	h	.010	.020	.029	0.25	0.50	0.74
Foot Length	L	.016	.033	.050	0.41	0.84	1.27
Foot Angle Top	φ	0	4	8	0	4	8
Lead Thickness	c	.009	.011	.013	0.23	0.28	0.33
Lead Width	B	.014	.017	.020	0.36	0.42	0.51
Mold Draft Angle Top	α	0	12	15	0	12	15
Mold Draft Angle Bottom	β	0	12	15	0	12	15

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.
JEDEC Equivalent: MS-013
Drawing No. C04-052

28-Lead Plastic Shrink Small Outline (SS) – 209 mil, 5.30 mm (SSOP)

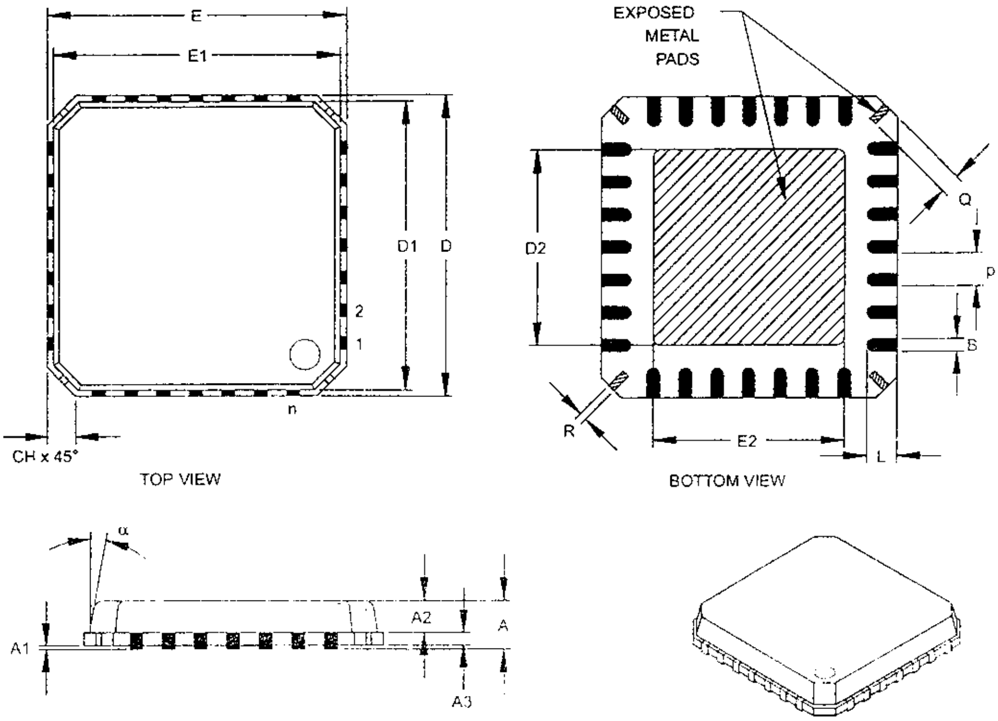


Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		28			28	
Pitch	p		.026			0.65	
Overall Height	A	.068	.073	.078	1.73	1.85	1.98
Molded Package Thickness	A2	.064	.068	.072	1.63	1.73	1.83
Standoff §	A1	.002	.006	.010	0.05	0.15	0.25
Overall Width	E	.299	.309	.319	7.59	7.85	8.10
Molded Package Width	E1	.201	.207	.212	5.11	5.25	5.38
Overall Length	D	.396	.402	.407	10.06	10.20	10.34
Foot Length	L	.022	.030	.037	0.56	0.75	0.94
Lead Thickness	c	.004	.007	.010	0.10	0.18	0.25
Foot Angle	φ	0	4	8	0.00	101.60	203.20
Lead Width	B	.010	.013	.015	0.25	0.32	0.38
Mold Draft Angle Top	α	0	5	10	0	5	10
Mold Draft Angle Bottom	β	0	5	10	0	5	10

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.
JEDEC Equivalent: MS-150
Drawing No. C04-073

28-Lead Plastic Micro Leadframe Package (MF) 6x6 mm Body (MLF)



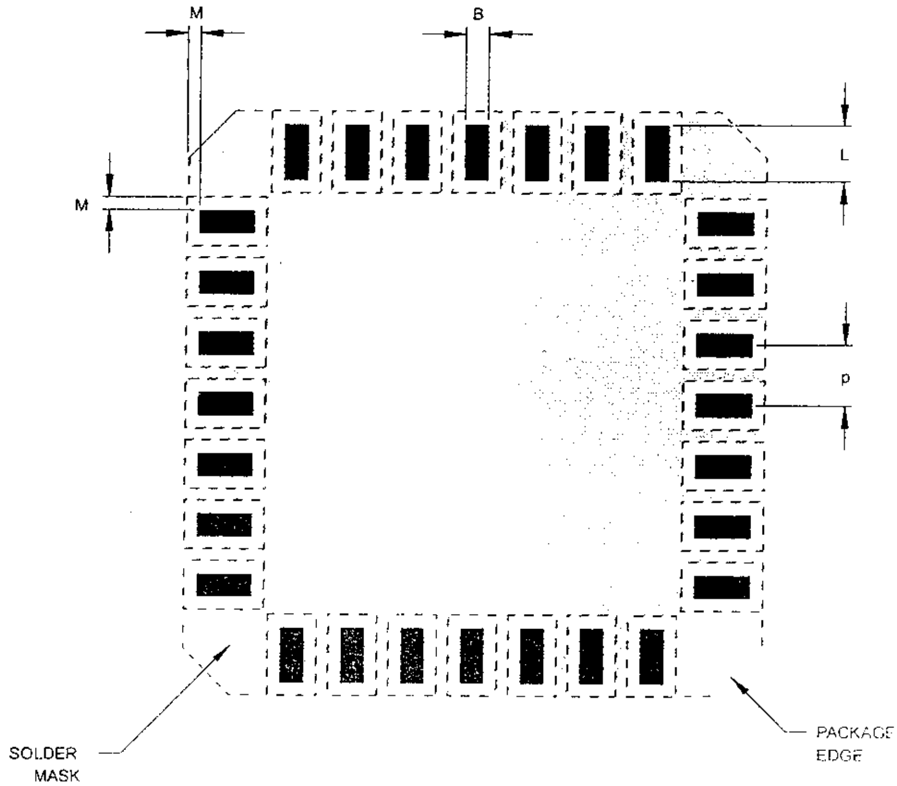
Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		28			28	
Pitch	p		.026 BSC			0.65 BSC	
Overall Height	A		.033	.039		0.85	1.00
Molded Package Thickness	A2		.026	.031		0.65	0.80
Standoff	A1	.000	.0004	.002	0.00	0.01	0.05
Base Thickness	A3		.008 REF.			0.20 REF.	
Overall Width	E		.236 BSC			6.00 BSC	
Molded Package Width	E1		.226 BSC			5.75 BSC	
Exposed Pad Width	E2	.140	.146	.152	3.55	3.70	3.85
Overall Length	D		.236 BSC			6.00 BSC	
Molded Package Length	D1		.226 BSC			5.75 BSC	
Exposed Pad Length	D2	.140	.146	.152	3.55	3.70	3.85
Lead Width	B	.009	.011	.014	0.23	0.28	0.35
Lead Length	L	.020	.024	.030	0.50	0.60	0.75
Tie Bar Width	R	.005	.007	.010	0.13	0.17	0.23
Tie Bar Length	Q	.012	.016	.026	0.30	0.40	0.65
Chamfer	CH	.009	.017	.024	0.24	0.42	0.60
Mold Draft Angle Top	α			12°			12°

*Controlling Parameter

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.
JEDEC equivalent: pending

Drawing No. C04-114

28-Lead Plastic Micro Leadframe Package (MF) 6x6 mm Body (MLF) (Continued)

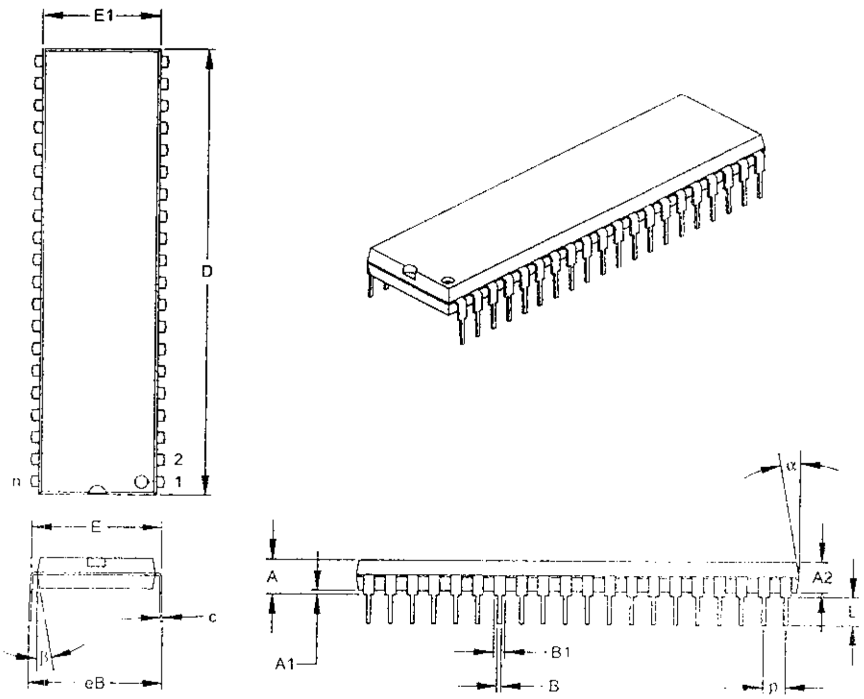


Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Pitch	p		.026 BSC			0.65 BSC	
Pad Width	B	.009	.011	.014	0.23	0.28	0.35
Pad Length	L	.020	.024	.030	0.50	0.60	0.75
Pad to Solder Mask	M	.005		.006	0.13		0.15

*Controlling Parameter

Drawing No. C04-2114

40-Lead Plastic Dual In-line (P) – 600 mil (PDIP)

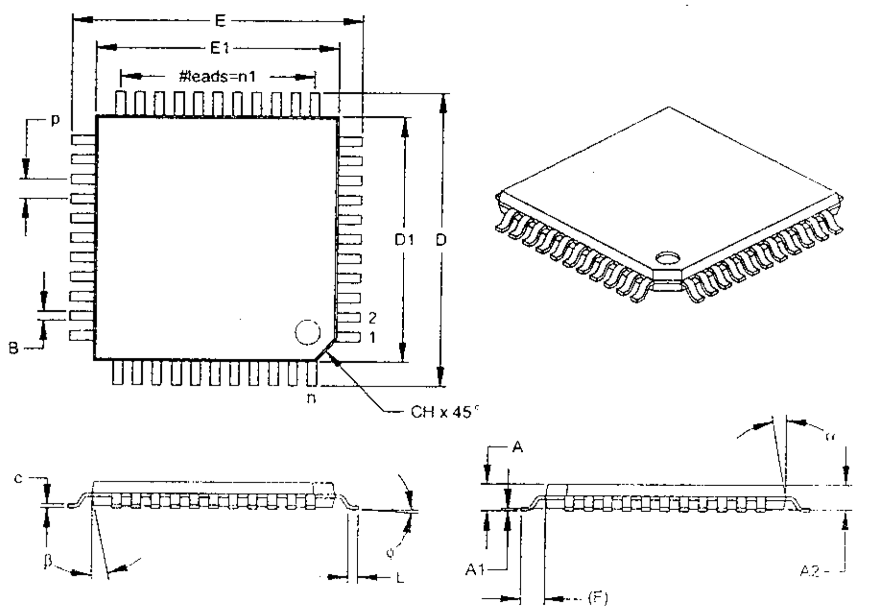


Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		40			40	
Pitch	p		.100			2.54	
Top to Seating Plane	A	.160	.175	.190	4.06	4.45	4.83
Molded Package Thickness	A2	.140	.150	.160	3.56	3.81	4.06
Base to Seating Plane	A1	.015			0.38		
Shoulder to Shoulder Width	E	.595	.600	.625	15.11	15.24	15.88
Molded Package Width	E1	.530	.545	.560	13.46	13.84	14.22
Overall Length	D	2.045	2.058	2.065	51.94	52.26	52.45
Tip to Seating Plane	L	.120	.130	.135	3.05	3.30	3.43
Lead Thickness	c	.008	.012	.015	0.20	0.29	0.38
Upper Lead Width	B1	.030	.050	.070	0.76	1.27	1.78
Lower Lead Width	B	.014	.018	.022	0.36	0.46	0.56
Overall Row Spacing §	eB	.620	.650	.680	15.75	16.51	17.27
Mold Draft Angle Top	α	5	10	15	5	10	15
Mold Draft Angle Bottom	β	5	10	15	5	10	15

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.
JEDEC Equivalent: MO-011
Drawing No. C04-016

44-Lead Plastic Thin Quad Flatpack (PT) 10x10x1 mm Body, 1.0/0.10 mm Lead Form (TQFP)

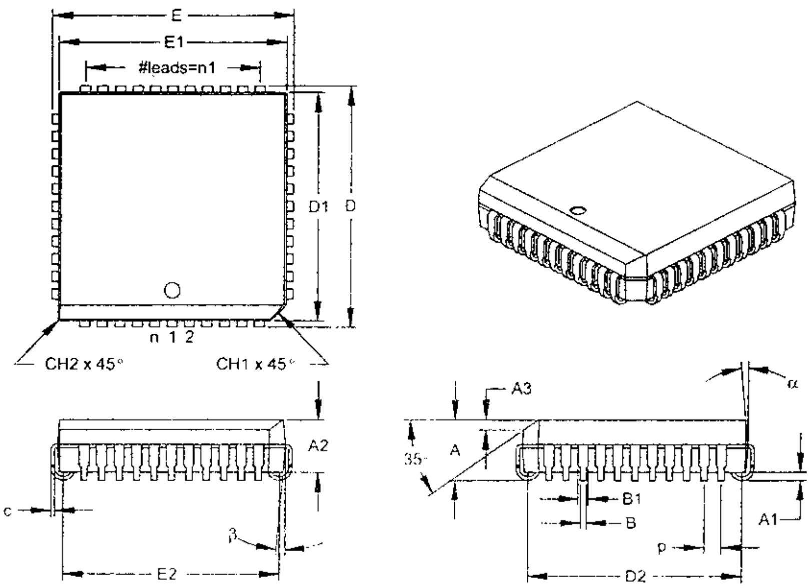


	Units	INCHES			MILLIMETERS*		
	Dimension Limits	MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		44			44	
Pitch	p		.031			0.80	
Pins per Side	n1		11			11	
Overall Height	A	.039	.043	.047	1.00	1.10	1.20
Molded Package Thickness	A2	.037	.039	.041	0.95	1.00	1.05
Standoff §	A1	.002	.004	.006	0.05	0.10	0.15
Foot Length	L	.018	.024	.030	0.45	0.60	0.75
Footprint (Reference)	(F)		.039		1.00		
Foot Angle	φ	0	3.5	7	0	3.5	7
Overall Width	E	.463	.472	.482	11.75	12.00	12.25
Overall Length	D	.463	.472	.482	11.75	12.00	12.25
Molded Package Width	E1	.390	.394	.398	9.90	10.00	10.10
Molded Package Length	D1	.390	.394	.398	9.90	10.00	10.10
Lead Thickness	c	.004	.006	.008	0.09	0.15	0.20
Lead Width	B	.012	.015	.017	0.30	0.38	0.44
Pin 1 Corner Chamfer	CH	.025	.035	.045	0.64	0.89	1.14
Mold Draft Angle Top	α	5	10	15	5	10	15
Mold Draft Angle Bottom	β	5	10	15	5	10	15

* Controlling Parameter
§ Significant Characteristic

Notes:
Dimensions D1 and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.
JEDEC Equivalent: MS-026
Drawing No. C04-076

44-Lead Plastic Leaded Chip Carrier (L) – Square (PLCC)



Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		44			44	
Pitch	p		.050			1.27	
Pins per Side	n1		11			11	
Overall Height	A	.165	.173	.180	4.19	4.39	4.57
Molded Package Thickness	A2	.145	.153	.160	3.68	3.87	4.06
Standoff §	A1	.020	.028	.035	0.51	0.71	0.89
Side 1 Chamfer Height	A3	.024	.029	.034	0.61	0.74	0.86
Corner Chamfer 1	CH1	.040	.045	.050	1.02	1.14	1.27
Corner Chamfer (others)	CH2	.000	.005	.010	0.00	0.13	0.25
Overall Width	E	.685	.690	.695	17.40	17.53	17.65
Overall Length	D	.685	.690	.695	17.40	17.53	17.65
Molded Package Width	E1	.650	.653	.656	16.51	16.59	16.66
Molded Package Length	D1	.650	.653	.656	16.51	16.59	16.66
Footprint Width	E2	.590	.620	.630	14.99	15.75	16.00
Footprint Length	D2	.590	.620	.630	14.99	15.75	16.00
Lead Thickness	c	.008	.011	.013	0.20	0.27	0.33
Upper Lead Width	B1	.026	.029	.032	0.66	0.74	0.81
Lower Lead Width	B	.013	.020	.021	0.33	0.51	0.53
Mold Draft Angle Top	α	0	5	10	0	5	10
Mold Draft Angle Bottom	β	0	5	10	0	5	10

* Controlling Parameter
§ Significant Characteristic
Notes:
Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.
JEDEC Equivalent: MO-047
Drawing No. C04-048

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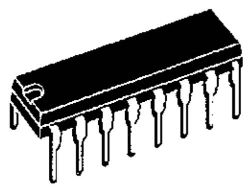
01/18/02

ULN2001A-ULN2002A
ULN2003A-ULN2004A

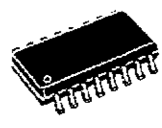
SEVEN DARLINGTON ARRAYS

- SEVEN DARLINGTONS PER PACKAGE
- OUTPUT CURRENT 500mA PER DRIVER (600mA PEAK)
- OUTPUT VOLTAGE 50V
- INTEGRATED SUPPRESSION DIODES FOR INDUCTIVE LOADS
- OUTPUTS CAN BE PARALLELED FOR HIGHER CURRENT
- TTL/CMOS/PMOS/DTL COMPATIBLE INPUTS
- INPUTS PINNED OPPOSITE OUTPUTS TO SIMPLIFY LAYOUT



DIP16

ORDERING NUMBERS: ULN2001A/2A/3A/4A



SO16

ORDERING NUMBERS: ULN2001D/2D/3D/4D

DESCRIPTION

The ULN2001A, ULN2002A, ULN2003 and ULN2004A are high voltage, high current darlington arrays each containing seven open collector darlington pairs with common emitters. Each channel rated at 500mA and can withstand peak currents of 600mA. Suppression diodes are included for inductive load driving and the inputs are pinned opposite the outputs to simplify board layout.

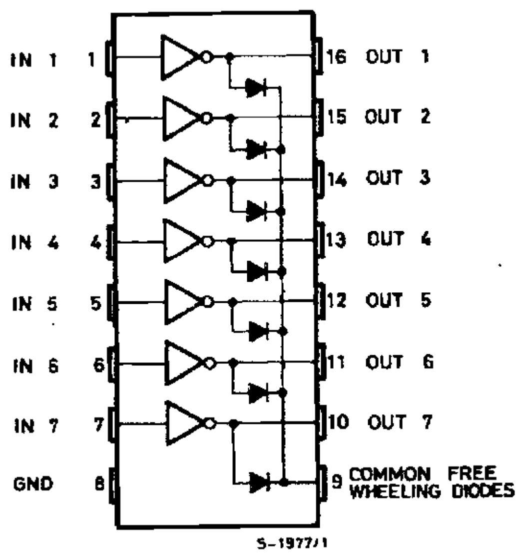
The four versions interface to all common logic families :

ULN2001A	General Purpose, DTL, TTL, PMOS, CMOS
ULN2002A	14-25V PMOS
ULN2003A	5V TTL, CMOS
ULN2004A	6–15V CMOS, PMOS

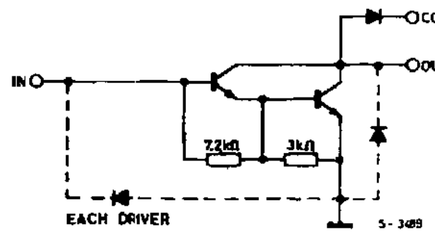
These versatile devices are useful for driving a wide range of loads including solenoids, relays DC motors, LED displays filament lamps, thermal printheads and high power buffers.

The ULN2001A/2002A/2003A and 2004A are supplied in 16 pin plastic DIP packages with a copper leadframe to reduce thermal resistance. They are available also in small outline package (SO-16) as ULN2001D/2002D/2003D/2004D.

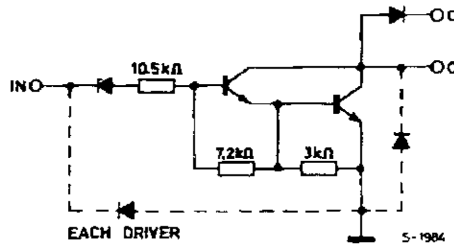
PIN CONNECTION



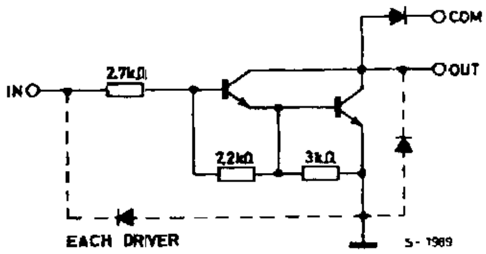
SCHEMATIC DIAGRAM



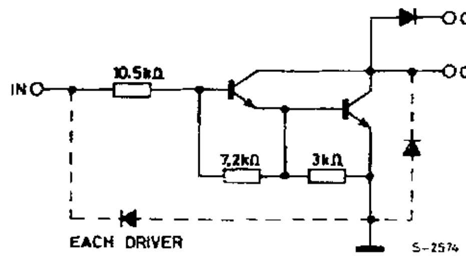
Series ULN-2001A
(each driver)



Series ULN-2002A
(each driver)



Series ULN-2003A
(each driver)



Series ULN-2004A
(each driver)

ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
V_o	Output Voltage	50	V
V_{in}	Input Voltage (for ULN2002A/D - 2003A/D - 2004A/D)	30	V
I_c	Continuous Collector Current	500	mA
I_b	Continuous Base Current	25	mA
T_{amb}	Operating Ambient Temperature Range	– 20 to 85	°C
T_{stg}	Storage Temperature Range	– 55 to 150	°C
T_j	Junction Temperature	150	°C

THERMAL DATA

Symbol	Parameter		DIP16	SO16	Unit
$R_{th\ j\text{-}amb}$	Thermal Resistance Junction-ambient	Max.	70	100	°C/W

ELECTRICAL CHARACTERISTICS (T_{amb} = 25°C unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit	Fig.
I_{CEX}	Output Leakage Current	V_{CE} = 50V T_{amb} = 70°C, V_{CE} = 50V T_{amb} = 70°C for ULN2002A V_{CE} = 50V, V_i = 6V for ULN2004A V_{CE} = 50V, V_i = 1V			50 100 500 500	μA μA μA μA	1a 1a 1b 1b
$V_{CE(sat)}$	Collector-emitter Saturation Voltage	I_C = 100mA, I_B = 250μA I_C = 200 mA, I_B = 350μA I_C = 350mA, I_B = 500μA		0.9 1.1 1.3	1.1 1.3 1.6	V V V	2 2 2
$I_{i(on)}$	Input Current	for ULN2002A, V_i = 17V for ULN2003A, V_i = 3.85V for ULN2004A, V_i = 5V V_i = 12V		0.82 0.93 0.35 1	1.25 1.35 0.5 1.45	mA mA mA mA	3 3 3 3
$I_{i(off)}$	Input Current	T_{amb} = 70°C, I_C = 500μA	50	65		μA	4
$V_{i(on)}$	Input Voltage	V_{CE} = 2V for ULN2002A I_C = 300mA for ULN2003A I_C = 200mA I_C = 250mA I_C = 300mA for ULN2004A I_C = 125mA I_C = 200mA I_C = 275mA I_C = 350mA			 13 2.4 2.7 3 5 6 7 8	V	5
h_{FE}	DC Forward Current Gain	for ULN2001A V_{CE} = 2V, I_C = 350mA	1000				2
C_i	Input Capacitance			15	25	pF	
t_{PLH}	Turn-on Delay Time	0.5 V_i to 0.5 V_o		0.25	1	μs	
t_{PHL}	Turn-off Delay Time	0.5 V_i to 0.5 V_o		0.25	1	μs	
I_R	Clamp Diode Leakage Current	V_R = 50V T_{amb} = 70°C, V_R = 50V			50 100	μA μA	6 6
V_F	Clamp Diode Forward Voltage	I_F = 350mA		1.7	2	V	7

TEST CIRCUITS

Figure 1a.

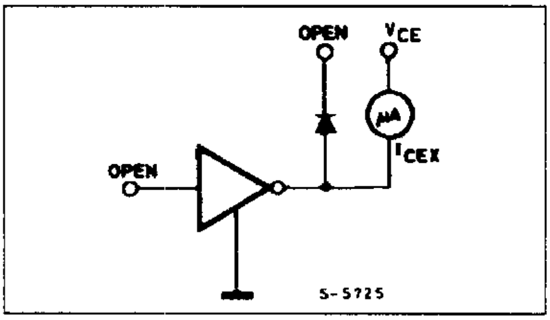


Figure 1b.

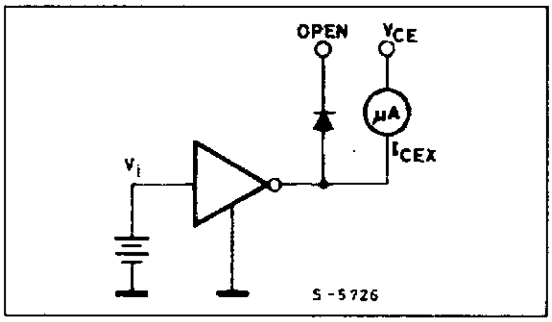


Figure 2.

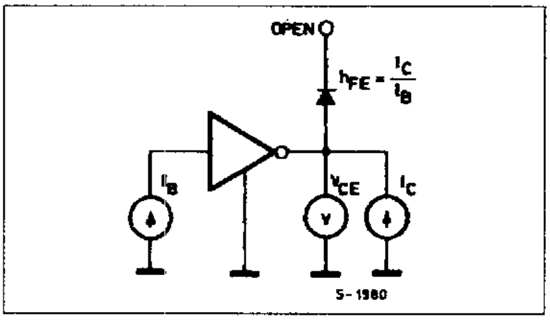


Figure 3.

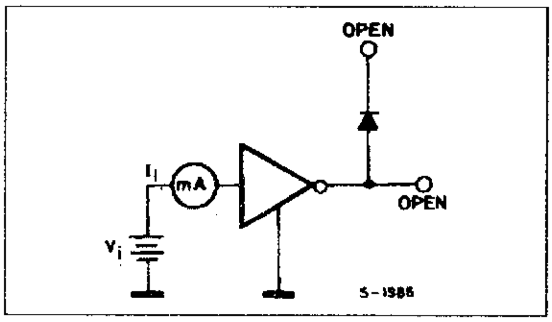


Figure 4.

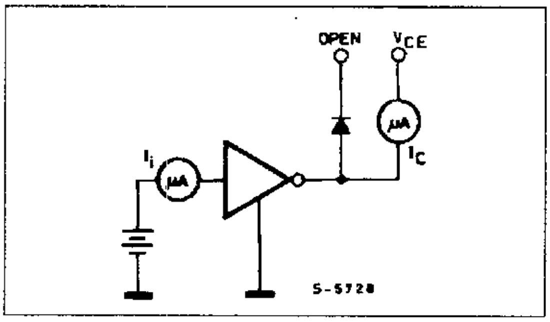


Figure 5.

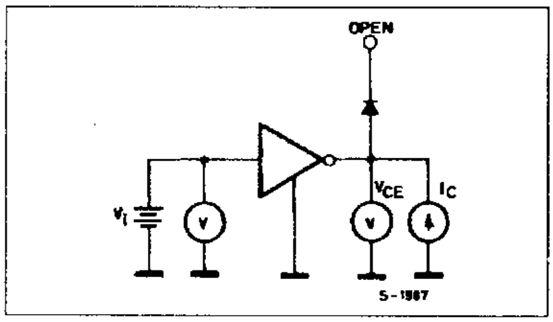


Figure 6.

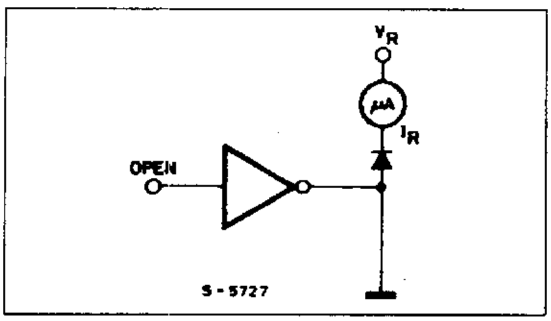


Figure 7.

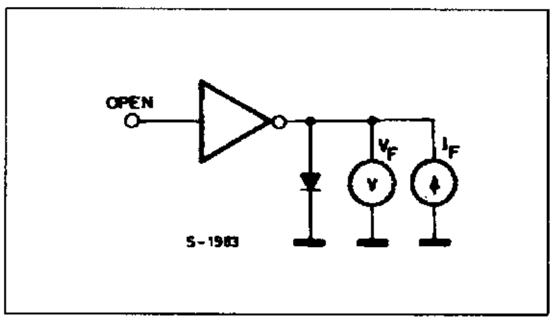


Figure 8: Collector Current versus Input Current

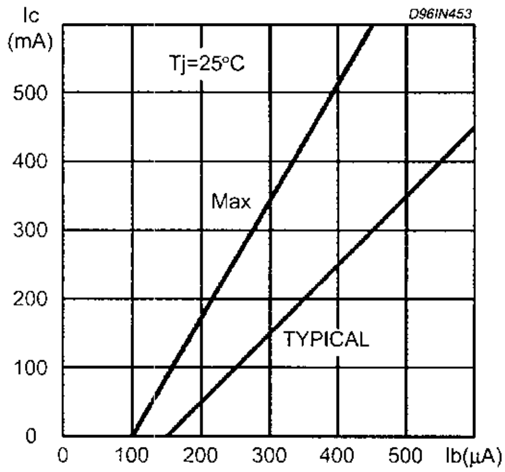


Figure 9: Collector Current versus Saturation Voltage

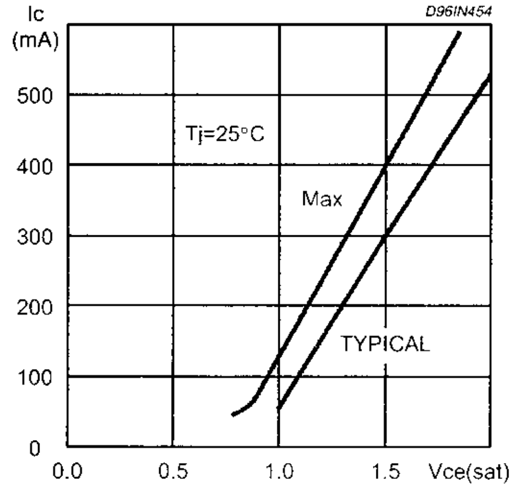


Figure 10: Peak Collector Current versus Duty Cycle

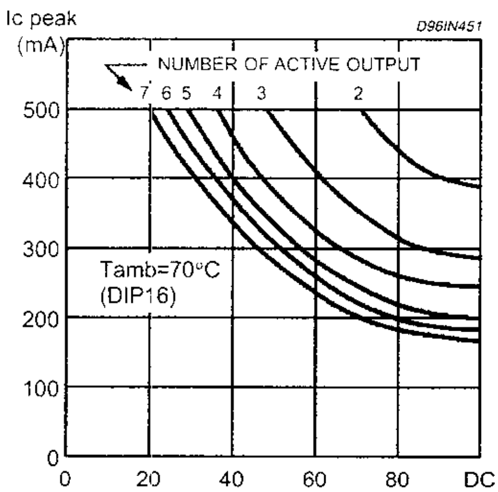
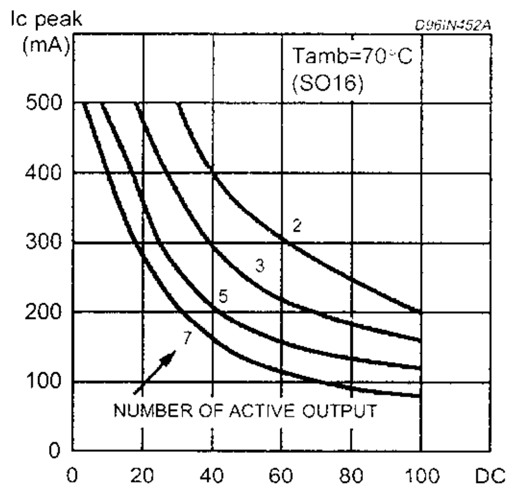
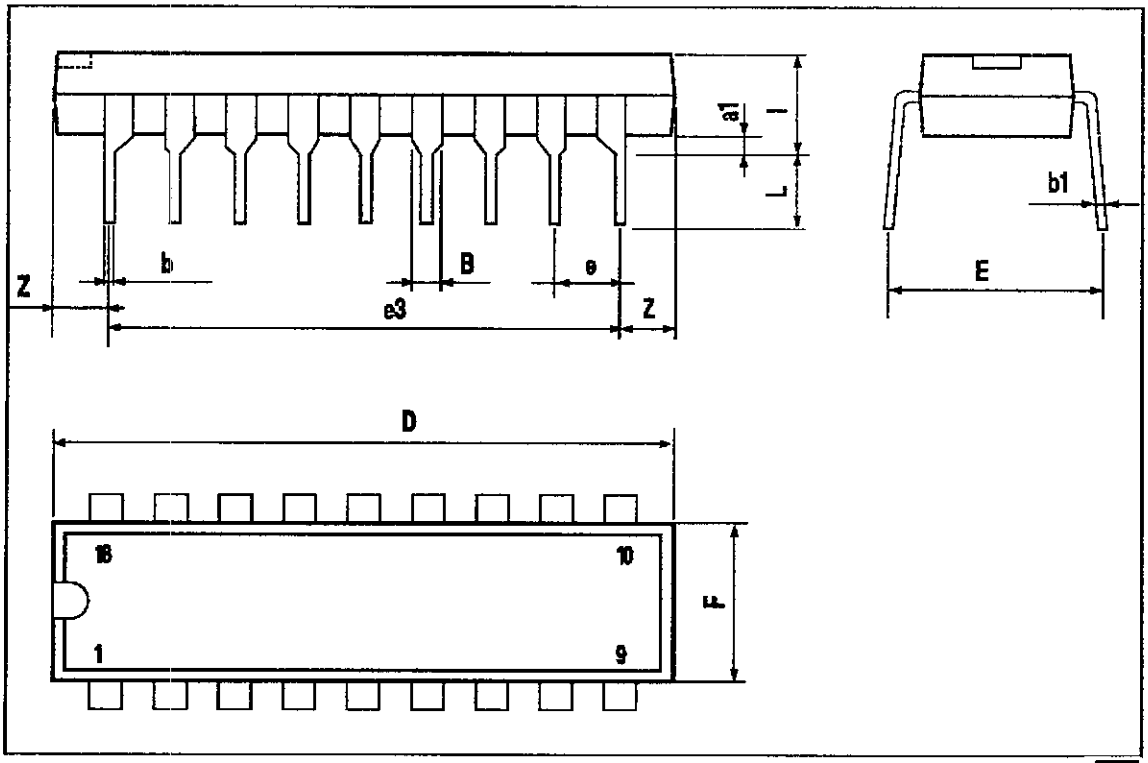


Figure 11: Peak Collector Current versus Duty Cycle



DIP16 PACKAGE MECHANICAL DATA

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
a1	0.51			0.020		
B	0.77		1.65	0.030		0.065
b		0.5			0.020	
b1		0.25			0.010	
D			20			0.787
E		8.5			0.335	
e		2.54			0.100	
e3		17.78			0.700	
F			7.1			0.280
I			5.1			0.201
L		3.3			0.130	
Z			1.27			0.050



SO16 PACKAGE MECHANICAL DATA

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A			1.75			0.069
a1	0.1		0.25	0.004		0.009
a2			1.6			0.063
b	0.35		0.46	0.014		0.018
b1	0.19		0.25	0.007		0.010
C		0.5			0.020	
c1	45 (typ.)					
D	9.8		10	0.386		0.394
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		8.89			0.350	
F	3.8		4.0	0.150		0.157
L	0.4		1.27	0.016		0.050
M			0.62			0.024
S	8 (max.)