Maze Mouse

by

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Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Electrical & Electronics Engineering Programme
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in partial fulfillment of the requirement for the
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Approved:

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UNIVERSITI TEKNOLOGI PETRONAS
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June 2004

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Nurin Naurah bt. Md. Yusof

ABSTRACT

This report is intended to provide an insight view of the Maze Mouse project. The first chapter serves as the introduction to the project, which covers the background of study, problem statement, and objectives and scope of study. The objective of this project is to produce a prototype of a mouse that can find its own way out of a maze smoothly, but not necessarily very quickly. This will be explained later in the report. This project requires strong basics in electronics, covering three important aspects of the mouse which are microcontroller, infrared sensor and stepper motor. The earlier part of the second chapter describes the details of the Sterling Mouse, an example of a maze mouse. The Sterling Mouse was created by Nick Smith as a participant in the Micromouse Competition held in the United States. The third chapter of this report presents the methodology used in completing this Maze Mouse project. This includes the purchasing and procurement of the components, circuit construction, programming and integration of the mouse's separate circuits. In the next chapter, you will be provided with the details of the project work, which focuses on how the prototype gets to work.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my deepest gratitude to Allah the Almighty, as I have managed to complete this project within the time given. I would also like to grab this opportunity to thank those who have helped me throughout the course of this project. My first thank you goes to my project supervisor, Dr. Nordin Saad, for he has indeed helped a lot in completing the project. Without his guidance and supervision, I would not be able to carry out all the project work. To my parents, Md. Yusof Jamar and Maznah Abas, thank you very much for the support given. In fact, no words can describe my gratefulness to them. My thankfulness also goes to Asmalilah and Mohd. Faiz, my friends doing the same project as me. Their vast cooperation during the ups and downs of the project work is very highly appreciated. Thank you also to Ms. Siti Hawa Tahir, the technician in charge of handling the Final Year Project students. She has certainly assisted in ensuring that our progress complies with the project schedule underlined by the committee. Lastly, I thank you all those who have been involved in ensuring my project is a success, whether directly or indirectly.

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CHAPTER 1
INTRODUCTION

1.1 Background of Study

The Maze Mouse is a subject already popular in countries such as the United States of America (USA), United Kingdom (UK), Japan and Canada. There have been a number of Maze Mouse projects done by university students from these countries. There have also been a few micromouse competition being held overseas, in which the concept is similar to my maze mouse. The competitions are held in a large-scale manner, in which they involve contestants from different institutions.

A maze mouse is actually a small robot which is designed to solve a given maze in which it is placed. However, the detailed specifications of each mouse depend on the requirement. For example, a maze mouse must have the ability to solve a maze in the shortest time in order to win a competition. As for my mouse, the requirement is different as would be described later. Development of the robot involves both the physical construction of the robot and the realization of maze solving ability by implementing some maze-solving algorithms in software.

Based on the information gathered, a maze mouse basically consists of three major parts:

i. *Mouse control*

This is the most crucial part, since it handles sensor information and motor control in pursuit of solving a given maze. Various types of controller can be used for a maze mouse. Current applications show that the type ranges from simple PLC control to more complex neuro-fuzzy technique.

ii. Sensor

There are a few types of sensors which have been used in previous maze mouse projects, such as micro switch sensor, relay sensor and infra-red sensor. These sensors are responsible to provide information (e.g. junctions or dead ends) about the path followed to the controller. It is based on these sensor inputs that the mouse controller can perform the maze solving algorithm.

iii. Motor driver

This part controls the motor speed and direction of the mouse while moving along a given maze. This part is important to ensure smoothness of the mouse's movement. The project work regarding this part requires some mechanical knowledge.

Apart from these three parts of the mouse, another important element of the mouse is the power supply part. Most of the time, the mouse gets its power supply from a 9V battery.

The software part of the mouse involves the programming of the microcontroller, RAM and/or ROM. The program plays the most important role in determining a successful operation of the mouse. It contains the predefined algorithm that the mouse should follow in order to get out of the maze safely.

Together with the prototype of the mouse, the maze is not to be left out. Usually, the mazes used in the micromouse competitions are made from wood and they follow certain standard as defined by the rules of the competition. Similarly, the maze for this project will be constructed according to a set of criteria that will be discussed in later chapters.

1.2 Problem Statement

By the end of the year, a prototype of a maze mouse is to be produced. The maze mouse must be able to find its own way out of a given maze, regardless of the time consumed and the distance traveled. The maze is to be built using black and white paints to differentiate between the walls and maze, respectively.

The project is to be carried out based on two different but highly related aspects: hardware and software. The hardware aspect requires the development of the microcontroller circuit, sensor interfacing and the mouse mechanical system. These three elements should then be integrated so as to produce a complete prototype.

The software aspect of the project will require the development of a program that controls the whole operation of the mouse. Based on the information from the sensors, the program must be able to come out with the decision for the mouse to act. Specifically, programs are to be written for the 80C31 microcontroller, the RAM IC and the EPROM IC. In order to write the program, the flow chart of the mouse's movement should first be determined. By the end of the year, the mouse prototype should be able to maneuver and find its route out of the maze.

The maze mouse, and other similar devices, is a very useful tool in the robotics and industrial automation field. It can be used to help us humans in reaching those areas in plants or factories which are either dangerous or within our arms' reach. The basic concept of the maze mouse has also been expanded to produce the Autonomous Guided Vehicle (AGV), an emerging technology at present.

The main principle of AGV, robot navigation, is defined as [1]the guiding of a mobile robot to a desired destination or along a desired path in an environment characterized by a terrain and a set of distinct objects, such as obstacles and landmarks. The autonomous navigate ability and road following precision are mainly influenced by its control strategy and real-time control performance.

By autonomous robot navigation, we mean the ability of a robot to move purposefully and without human intervention in environments that have not been specifically engineered for it. Autonomous navigation requires a number of heterogeneous capabilities, including the ability to execute elementary goal-achieving actions, like reaching a given location; to reach in real time to unexpected events, like the sudden appearance of an obstacle; to determine the robot's position; and to adapt to changes in the environment.

1.3 Objectives and Scope of Study

The completion of the project should fulfill these following objectives:

1. To understand and construct a fully operational infra-red sensor circuit. This sensor circuit should be able to detect the presence or absence of wall at the left, front or right side of the mouse.
2. To understand and construct the motor driver circuit. This circuit is responsible in determining the motor's speed and direction.
3. To understand and develop the controller circuit of the mouse, complete with its program, which is the primary element of the mouse. This controller should be able to read the information given by the sensors correctly in order to produce the decision, on which the motor should act, for the mouse to get out of the maze safely.
4. Finally, to integrate all the components of the mouse to produce a complete prototype of the maze mouse that can find its own way out of a maze.

This Maze Mouse project will in the end enables me to apply all the technical knowledge learned during the years in the university. This would especially refer to the electronics and programming stuff. Lessons acquired from subjects such as Analogue Electronics and Microprocessor I would be very useful in completing this project.

For the purpose of ensuring the feasibility of the project within the scope and time frame, focus is concentrated mainly on the hardware assembly of the mouse prototype during the first semester. Then, during the second semester, more effort is put into developing the program for the microcontroller. Shown in the Appendix is the Gantt chart of this project's scheduling for two semesters.

CHAPTER 2
LITERATURE REVIEW AND/OR THEORY

2.1 [2]Sterling Mouse by Nick Smith

The Sterling Mouse is one of the contestants for the Micromouse UK competition (Micromouse). Micromouse is an annual robotics competition in which autonomous robot 'mice' compete against each other to solve a 16 by 16 inch maze in the shortest time. Each square of the maze is 18 cm by 18 cm. The walls are 5 cm high and 1.2 cm thick.

The mice participating in the competition can be as simple as a Lego Mindstorms kit with light and touch sensors, or as complex as a vision guided chassis with DC motors controlled by a Digital Signal Processing chip.

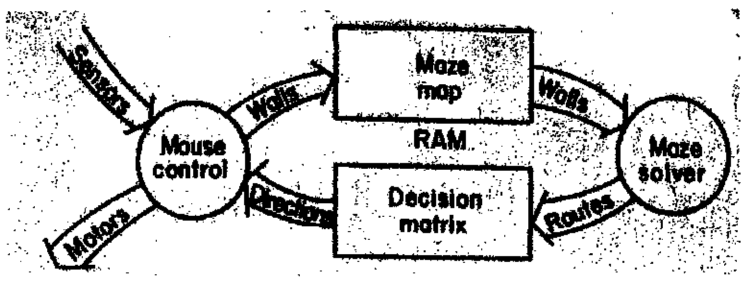


Figure 1 Overall structure of the Sterling Mouse

The overall structure of the Sterling Mouse is as illustrated above. It can be seen that there are basically two independent parts. The mouse control handles sensor information and motor control and builds up a bit map of the maze. The maze solver takes the bit map of the maze and builds a decision matrix on which the mouse acts.

2.1.1 Mouse Mechanics

Although described as circular, the mouse is actually octagonal with a driving wheel on each side. It also has a cup mounted ball bearing for stability and ease of movement at the front and back. A pair of stepper motors (one for each wheel) drives the main wheels under direct CPU control. To get a good top speed the motors are accelerated from rest using an acceleration table derived by trial and error. Direction control is achieved in a tank-like manner by accelerating and decelerating the wheels independently. Turning is accomplished by reversing one of the wheels. The mouse has eight switches to enable different speed ranges to compensate for actual conditions on the day and also variable battery power.

The position of the mouse is calculated by keeping a tally of the number of steps moved over time. To allow for cumulative errors and the possibility of the motors dropping some steps the mouse position is reset whenever a wall is encountered in front or whenever a wall disappears on either side, i.e. about half way between two squares. A maximum error of about five inches can be tolerated.

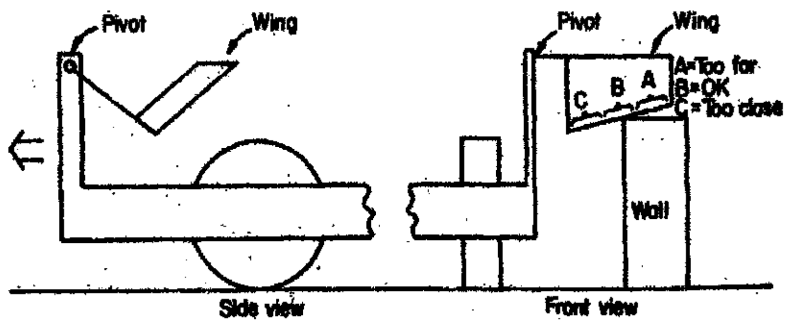


Figure 2 Mechanical diagram of the Sterling Mouse

There are seven sensors in total: one microswitch on the front and three sensors built from old relay contacts mounted on wings on each side. The wings, shown in Figure 2, essentially tell the mouse whether there is a wall present and if so whether the mouse is too close or too far from it on each side. The mouse will run down the centre of the maze, within a fixed tolerance, as long as at least one side wall is present. When there are no walls on either side the mouse travels in a straight line.

2.1.2 Computer

The brain of the mouse is made up of the six chips detailed below:

MANUFACTURER	FUNCTION NO.	DESCRIPTION
RCA CDP	1802	CPU (CMOS)
RCA CDP	1851	Programmable I/0 interface (CMOS)
RCA CDP	1859	Memory management chip (CMOS)
RCA	4069	Hex inverter (CMOS)
Mostek	4118	1 k x 8 static RAM
Hitachi	2716	2k x 8 5 V PROM

Table 1 The chips used in the brain of the Sterling Mouse

The requirement of low power consumption makes the use of CMOS chips highly desirable. Unfortunately space limitations and the need for hand wiring precluded the use of the lower density CMOS memories.

Maximum use of the 1802 CPU has enabled a powerful program to be produced using little memory. The 1802 has 16 x 16-bit internal registers and all mouse status and control information is kept in these registers. Only 1 byte of RAM is required, and is used for logic and arithmetic operations. The 16 x 16 byte map of the maze and the 16 x 16 byte decision matrix are also held in RAM. Total EPROM requirements are about 800 byte made up of 700 bytes for the main control program and 100 bytes for the maze solver.

2.2 Microcontroller

Nowadays we can find microcontroller in almost every electronic device such as VTR`s, TV`s, heating control etc. [3]By using a microcontroller in a hardware design, the workflow is completely different. Most of the time is spent in writing software but on the other hand we can reduce the hardware design to a maximum.

A typical microcontroller device is the 8051 designed by INTEL. In the last 10 years a lot of companies like Atmel, Philips, Matra Harris, OKI, Dallas, Cypress and Infineon have developed new derivates, with special features, all based on the 8051 core. The 8051 is currently the most successful microcontroller family in the world. Software resources are also available without any problems.

2.3 Infrared Sensor

The wavelength range for light in the near infrared region is about [4]700 nanometers (nm) to 1100 nm. The infrared detector, or phototransistor, can be made up fundamentally based on two configurations: common emitter amplifier and common collector amplifier.

2.3.1 Common-Emitter Amplifier Circuit

The common-emitter amplifier circuit (Figure 3) generates an output which transitions from a high state to a low state when light in the near-infrared range is detected by the phototransistor. The wavelength range for light in the near infrared region is about 700 nanometers (nm) to 1100 nm. The output is created by connecting a resistor between the voltage supply and the collector pin of the component. The output voltage is read at the terminal of the collector. It is called an amplifier circuit because the current generated in the component when light is detected is very small. However, the component has an internal amplifier (in this case a phototransistor) which magnifies this current to useful levels.

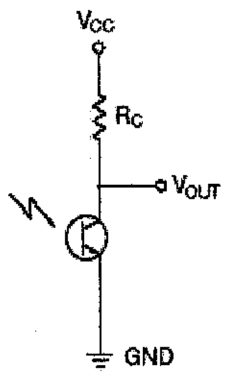


Figure 3 Common-Emitter Amplifier

2.3.2 Common-Collector Amplifier Circuit

The common-collector amplifier (Fig. 2) generates an output which transitions from a low state to a high state when IR light is detected by the phototransistor. The output is created by connecting a resistor between the emitter pin of the component and ground. The output is read at the emitter terminal.

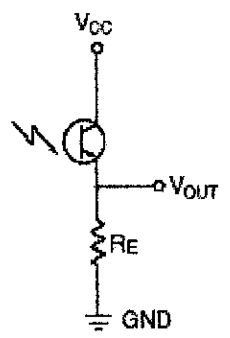


Figure 4 Common-Collector Amplifier

In both circuits the phototransistor can be used in two modes, an active mode and a switch mode. Operating in the active mode means that the phototransistor generates a response proportional to the light received by the component up to a certain light level. When the amount of light surpasses that level, the phototransistor becomes saturated and the output will not increase even as the light level increases. This mode is useful in applications where it is desired to detect two levels of inputs for comparison. Operating in the switch mode means that the phototransistor will either be "off" (cut-off) or "on" (saturated) in response to the light. This mode is useful when a digital output is required for object detection or encoder sensing.

By adjusting the load resistor in the amplifier circuit one can set the mode of operation. The correct value for the resistor can be determined by the following equations:

$$\textit{Active Mode}: V_{CC} > R_L \times I_{CC}$$

$$\textit{Switch Mode}: V_{CC} < R_L \times I_{CC}$$

Typically a resistor value of 5kΩ or higher is adequate to operate the phototransistor in the switch mode. The high level output voltage in the switching mode should equal the supply voltage. The low level output voltage in the switching mode should be less than 0.8 Volts.

The greatest distance at which an infrared solution will still work depends much on the application. [5]In most cases, by pulsing the emitter with a high drive current and using a sensitive photo sensor, such as a photo Darlington, one can expand the range:

- The range for detecting an object by reflection can be from 0 mm to 400 mm. The factors involved are the configuration and reflectivity of the reflective surface, the drive current of the emitter, and the photo sensor output. Dust, however, can impair this range.
- Object sensing by transmissivity (i.e. breaking a beam of light between two points with an object) has a range of 0 to 12 m. The factors involved are the size of the object used to break the beam, the drive current of the emitter, the output type of the photo sensor, and the electrical timing techniques used such as synchronous detection.
- For pure data transmission, the range is from 0 to 15 m. The factors are the data rate, the coding and modulation technique, and the expected signal to noise ratio or bit error rate. A high emitter drive current can improve the range of the system.

[6]Listed below are the specification definitions for an infrared:

NO.	TERM	DEFINITION
1	Aperture Width	Width of the built-in openings in front of the emitter and photo sensor that define the size of the beam.
2	$BV_{CEO>}$	Collector-Emitter Breakdown Voltage with the base open.
3	Emission Angle @ 1/2 Power	Angle of the cone where the light intensity is half that on the optical axis.
4	I_{CC} Supply Current	Current drawn from the supply at a given voltage.
5	I_{CEO}	Collector-Emitter current for radiant sensitive devices when the base is open and without radiant incidence.
6	I_F	Current flowing through a diode from anode to cathode.
7	I_{F+}	Diode forward current (I_F) required to cause the output to turn on.
8	I_{F-}	Diode forward current (I_F) required to cause the output to turn off.
9	I_R	Current flowing through a diode from cathode to anode.
10	I_R(D)	Reverse dark current for a given supply voltage.
11	Lead Spacing	Distance between the leads from the emitter side of the package to the photo sensor side.
12	Light Current	Current which flows through a device due to radiant incidence.
13	Negative Threshold	Amount of incident light at which the device turns off.
14	On-State Collector Current	Collector current at a specified radiant incidence and a specified collector voltage.
15	Operating Supply Voltage	Voltage under which the device operates.
16	Output Configuration	Output circuit and function.
17	Output Power	The radiant intensity of emitted light measured in mW/sr.
18	Positive Threshold	Amount of incident light required to turn the device on.
19	Reception Angle @ 1/2 Power	Angle of the cone where the sensitivity is half that on the optical axis.
20	V_F	Voltage between anode and cathode at a specified forward current.
21	V_R	Voltage between cathode and anode at a specified reverse current.

Table 2 Infrared Specifications Definition

[7]Infrared phototransistors are also sensitive to visible light and therefore will need to be shielded in someway to prevent the device from being swamped by the rooms lighting. This can be done by hiding the phototransistor inside a line side structure or

placing it inside a short piece of opaque tubing. If the phototransistor is mounted, the back of the transistor can be painted black to prevent room light from entering.

The next diagram shows a method of shielding the detector phototransistor from room light.

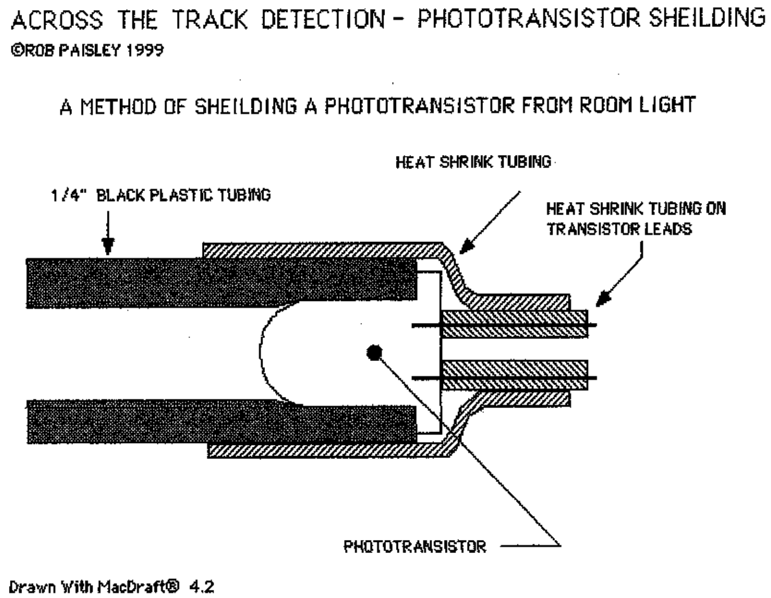


Figure 5 Detector Shielding Method

CHAPTER 3
METHODOLOGY OR PROJECT WORK

3.1 Literature Review

The project work is first conducted by performing extensive literature review on all topics related to maze mouse. The objective is to gain as much information as possible that is helpful throughout the process of completing the project. The findings are as stated in the previous chapter.

3.2 Hardware Construction

Having understood the concepts of a maze mouse, the next step is to determine the correct circuit to build it. Upon having the circuits, I began the procurement of the required components for the prototype. The list of the hardware components used is in the appendix.

Then, the project work continues with the construction of the circuitries involved to operate the maze mouse. The circuits used to realize the maze mouse are as shown in the appendix.

As stated earlier, the prototype of the maze mouse consists of the following three main circuits:

i. Microcontroller circuit

ii. Motor driver circuit

iii. Infrared sensor circuit

Among all the above circuits, the sensor circuit is identified to be the most complex. Therefore, it is first constructed on a piece of breadboard so that its functionality can be tested, independently. This is to ensure correct operation of the sensor to avoid further problems in the future.

The next section will further describe all the three circuits involved.

3.2.1 Microcontroller Circuit

The microcontroller circuit is by heart the most important component of the maze mouse. Basically, the microcontroller coordinates the task of position monitoring, movement, maze navigation and solution evaluation of the mouse. The circuit construction is carried out first before the microcontroller is programmed.

3.2.2 Motor Driver Circuit

As for the motor to be used on the maze mouse, there are two options available: stepper motor and servo motor. Stepper motors are permanent magnetic motors that 'step' one increment each time the computer gives its control electronics one pulse. They do not require position feedback if run within their limits. When stopped, they inherently hold their position.

Servo motors are standard DC or brushless motors with an encoder feedback loop. The computer reads the position of the motor and controls the power applied to the motor.

Stepper motors are generally just as accurate as servos and are simpler and more reliable and maintenance free in harsh dusty applications. The servo motor's encoder is susceptible to dirt and vibration that can cause problem.

For this maze mouse, stepper motors are chosen since they provide precise position control but little speed, whereas DC motors are the opposite. The accurate control can be very handy when trying to measure the position of the mouse. This is because the stepper motors are directed to turn a set arc, not move at a set speed. [8]Table below shows the difference in characteristics between servo motors and stepper motors:

MOTION CHARACTERISTICS	SERVO MOTORS	STEPPER MOTORS
High Torque, Low Speed	Can be considered if cost or complexity is not an issue.	Continuous duty applications requiring high torque and low speed.
High Torque and high speed (>2000 rpm)	Continuous duty applications requiring high torque and high speed. A DC servomotor can deliver greater continuous shaft power at high speeds compared to steppers. High speed up to 12000 rpm is possible. AC servo motors can handle higher current surges compared to DC servos. You can get lot stronger AC servo compared to either DC servo or DC stepper.	If speeds are less than 2000 rpm stepper may be economical. Stepper becomes bulky at high torque.
Short, Rapid Repetitive Moves	Use servo if high dynamic requirements are needed.	Stepper motor will offer more economic solution when requirements are more modest.
Positioning Applications	Servo can handle effectively when load is mostly inertia instead of friction. The ability to overdrive servo motor in intermittent duty allows a smaller motor to be used. If positioning is critical in micron level use servo.	Use stepper motor if torque is lower than 500 oz-in, less 2000 rpm, low to medium acceleration rates.
Applications in Hazardous Environments	Use brushless servo motor.	Use stepper motor.
Low Speed, High Smoothness	Use DC servo.	Use micro stepping.
Control Method	Closed loop.	Preferred to be used in open loop applications.

Table 3 Differences between servo motors and stepper motors

3.2.3 Infra Red Sensor Circuit

The infra red sensors are used to detect the existence of boundaries in front of it, to the left or to the right of it. Three sensors will be at the left and right side and another two will be at the front side. The sensor circuit is tested repeatedly for its sensitivity and reliability to prevent future problems after a full prototype is developed.

All the hardware required to realize the above circuits are listed in the appendix.

3.3 Software

The software part of this project involves the programming of the microcontroller, Random Access Memory (RAM) and Erasable Programmable Read Only Memory (EPROM) integrated circuits (IC). These IC's are used in the microcontroller circuit of the maze mouse. For the 80C31 microcontroller, the programming will be done using the assembly language.

A lot of programming languages are available for the 8x51 family. [9]Examples are such as PLM51, C51, BASIC, PASCAL or ASSEMBLER. For generating a program which can be executed by a microcontroller, regardless of which language to be used, a compiler is needed. The job of a compiler is to convert a source code, written in a high level language, into machine code. The machine code will be a format which can be executed by a microcontroller and it is possible to be written into an EPROM. The format needed for the 8x51 family will be the INTEL HEX code.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Microcontroller circuit

Shown below is the rough layout of the microcontroller circuit board of the Maze Mouse:

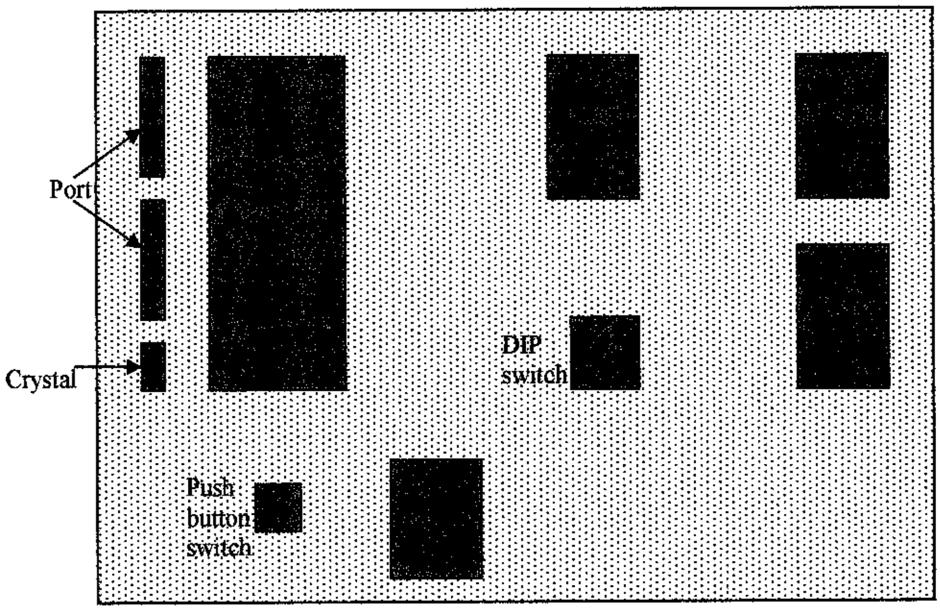


Figure 6 Microcontroller board layout

The Maze Mouse uses the 80C31 Intel microcontroller which belongs to the 8051 family. At this part of the mouse lays its brain that is fully responsible for its act.

There is basic [10]difference between a microcontroller and a CPU. With a microcontroller, the peripheral components like RAM, ROM, a serial port or an ADC or DAC are on chip. That means it is possible to realize complex system control functions with only one chip. For instance, we can use a microcontroller for the system control of a VTR or in a videotext decoder. Whatever that we intend to do with a microcontroller only depends on the software.

The 8051 was the first device that was available on the market. Designed by INTEL this chip already contains two 16 bit timer/counter, a serial port and an internal RAM. As an 87C51 the chip also contains the program memory on chip. The 80C31 is the ROMless version. Figure 7 shows a circuit diagram of an 80C31 with an external program memory.

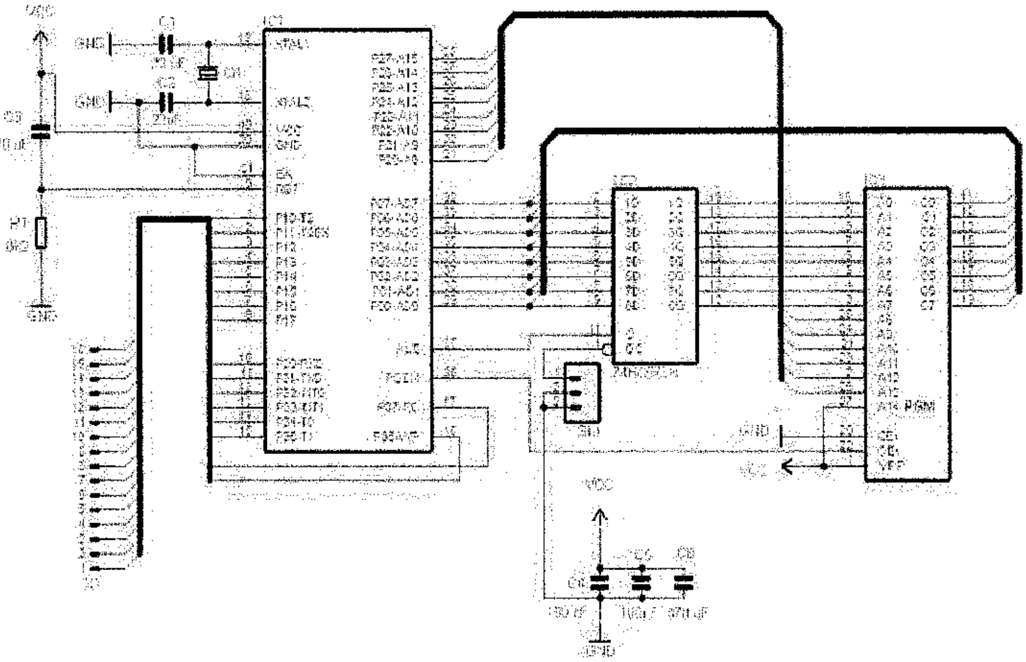


Figure 7 Circuit diagram of an 80C31 with an external program memory

Referring to the figure above, IC 1 is an 80C31. This chip contains four 8 bit ports (P0, P1, P2, and P3). In this example we are using an external memory. In that case Port 0 and 2 are used as an address/data bus. Pin 31 decides if we are to use this chip as a stand alone version or using an external program memory device. If we connect Pin 31 to ground, the 80C31 is forced to use the external memory instead of the internal one. EA stands for external access. In the first step, the microcontroller writes the address to the program memory. P0 contains the address low byte and P2 contains the address high byte. By using the ALE signal (Pin 30) the address low byte will be stored in IC2. ALE stands for address latch enable. In the second step, the microcontroller uses the PSEN signal to read the first command from the program memory. PSEN stands for program store enable. P0 reads the command and it will be executed by the microcontroller. If the program is running, this procedure will happen all the time. The clock signal will be generated by the crystal Q1, the internal circuit of the microcontroller and the capacitors C1 and C2. A typical value for the capacitors will be 33pF. The frequency of the crystal depends on the microcontroller device type. A typical value will be 12 -24 MHz. The reset signal will be generated by R1 and C3.

4.2 Infrared Sensor

Figure below shows the layout of the sensor circuit board:

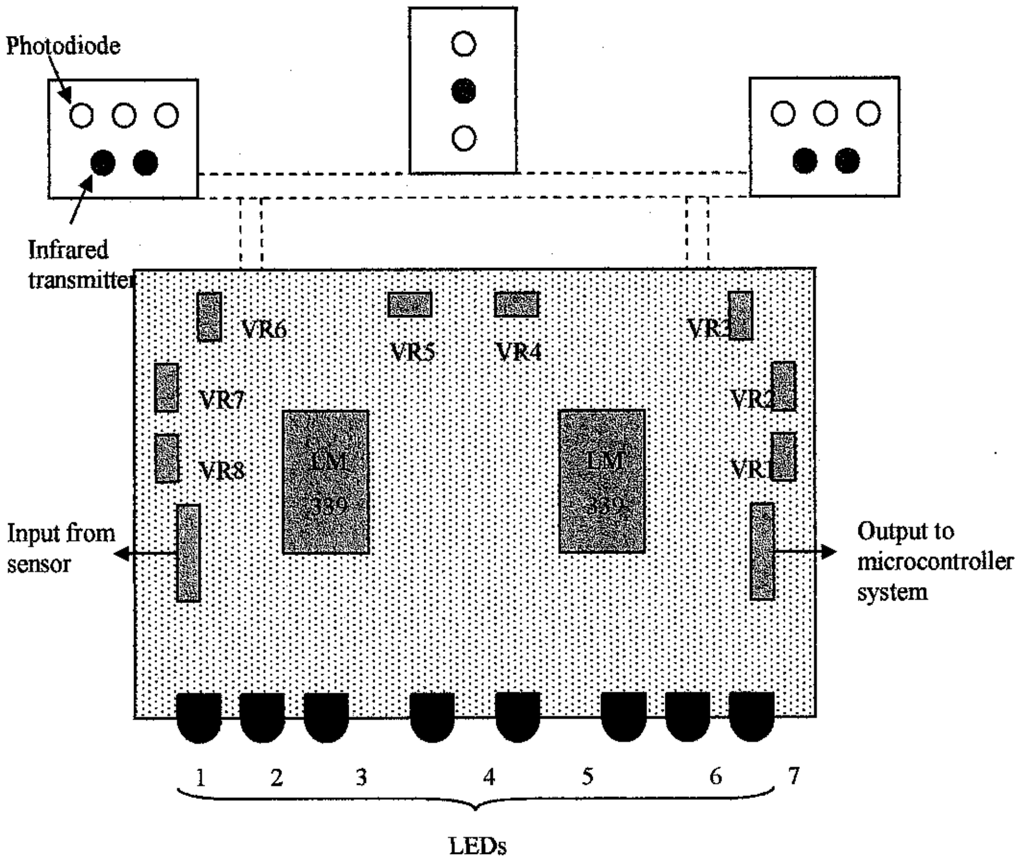


Figure 8 Infrared sensor circuit board

Referring to the above figure, the LED's will serve as the indicators to show which sensor is activated.

4.2.1 Maze Mouse Sensor Circuit

Figure below shows one particular infrared sensor circuit used by the maze mouse:

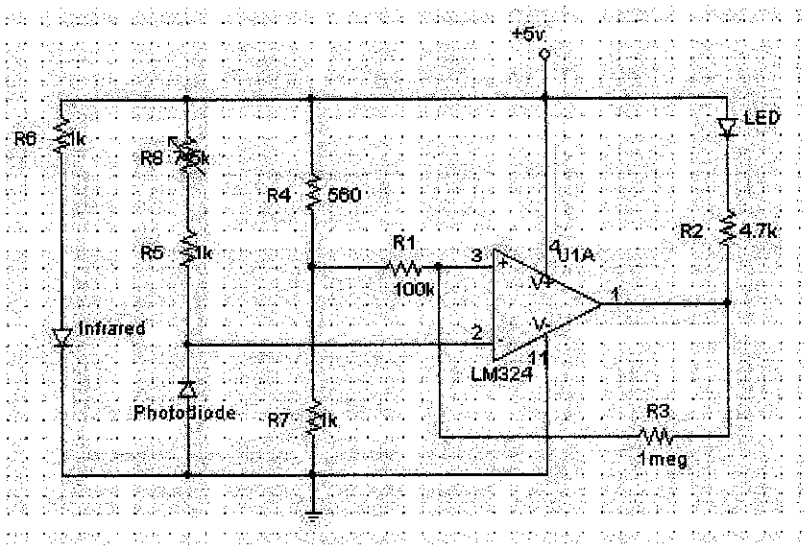


Figure 9 Sensor circuit of the Maze Mouse

Referring to the circuit above, the reference voltage is at the positive input of the comparator. The value of R6 depends on the number of sensor circuits to be combined. The complete schematic diagram in the appendix shows that 33Ω resistor is used for the combination of two circuits and 100Ω resistor is used for the combination of three circuits.

Basically, the infrared emitter produces an infrared beam which will be reflected by obstacles in front of it. This reflected signal should be detected by the photo diode. Upon detection, the respective LED's should light up. In other words, detection of infrared beam indicates the presence of obstacle and the microcontroller should react based on this input to direct the motors' movement.

In the Interim report I have produced last semester, the place of R7 in the circuit actually belongs to a 3.3V zener diode. However, it was changed to obtain a different reference voltage for the LM339 comparator. This is to improve on the sensor's performance.

4.3 Motor Driver

The layout for the motor driver circuit board is as shown below:

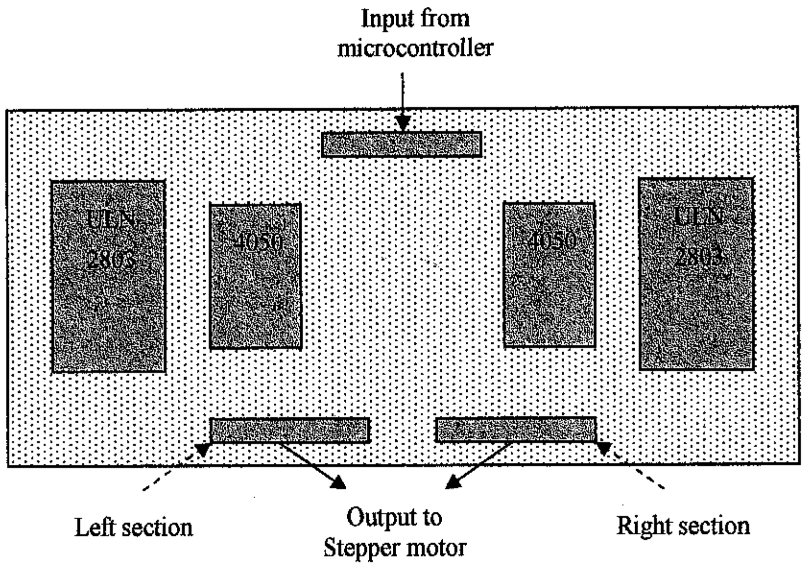


Figure 10 Motor driver circuit board layout

4.4 The Maze

The maze used in this project is a simple one. It will be built on a piece of wood (preferably plywood). The wood will be painted with two colours; black and white. The black paint represents walls and the white paint represents the path available. The white paint will reflect the infrared beam emitted by the infrared transmitter, and this reflected beam will reach the receiver. Therefore, detection of infrared beams indicates presence of a clear path.

In order for the mouse to navigate safely along the maze, the microcontroller is to be programmed with specific instructions based on the input from sensors. Up to this time, the following movements are to be followed by the mouse:

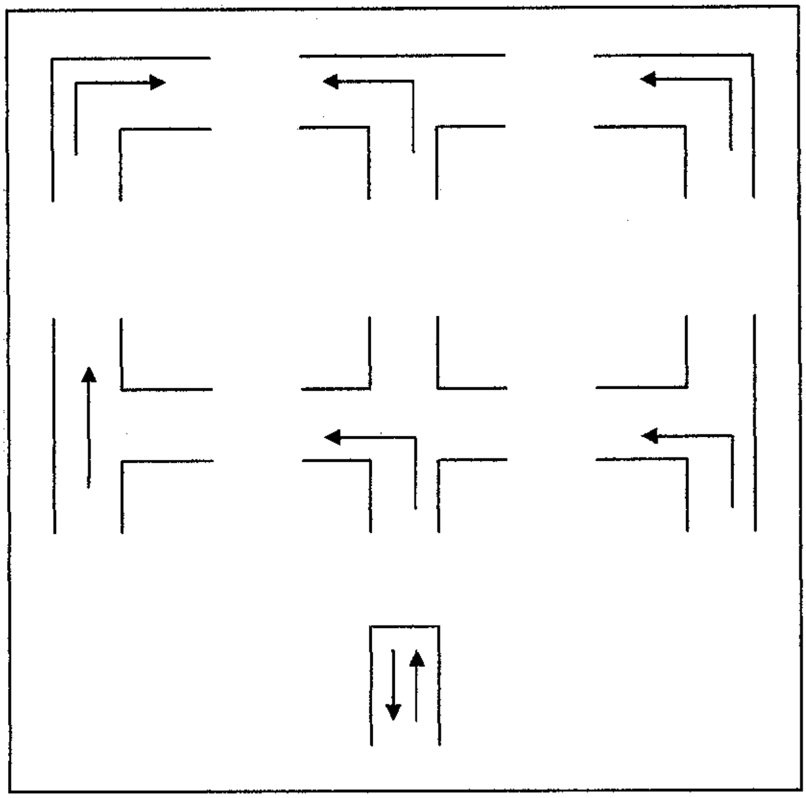


Figure 11 Movements of the mouse along the maze

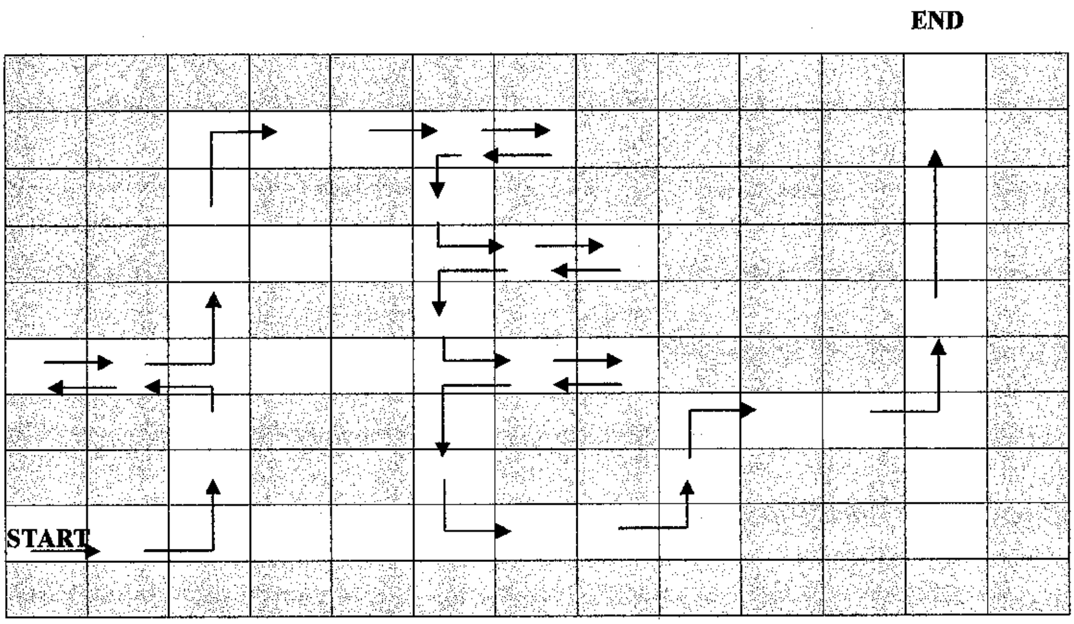


Figure 12 Example of a maze and the projected path of the mouse

4.5 Programming

To begin with the programming, we have first decided that detection of infrared beam by the receivers will be translated to logic 1 (high) and vice versa. In other words, high inputs from the sensors indicate existence of boundaries along the maze.

The table below shows the decision to be made by the microcontroller based on the inputs from the sensors:

Left Sensor	Forward sensor	Right sensor	Input to micro-c	Routing	Decision
Low	High	High	011	Left corner	Turn Left
High	High	Low	110	Right corner	Turn Right
High	Low	High	101	Straight line	Forward
Low	Low	Low	000	4 Junction	Turn Left
High	High	High	111	Dead End	Reverse
Low	Low	High	001	T Left Junction	Turn Left
High	Low	Low	100	T Right Junction	Forward
Low	High	Low	010	T Junction	Left

Table 4 Inputs from sensors and the corresponding actions

After the mouse has performed the respective action, the microcontroller will have to check that the mouse is moving in the forward direction. This will be done by checking that the inputs from the sensors equal to the value of 101. The whole operation can be described according to the following steps:

1. Inputs received from the sensors.
2. Inputs from sensors are compared with the stored bits in microcontroller register, one by one.

3. If input bits are equal to the stored bits, the microcontroller will make the corresponding decision, also in bits of three.
4. The decision bits will be sent to the motors, for them to make the right movement.
5. Microcontroller performs checking function for forward movement.

The steps above are summarized in the following flowchart:

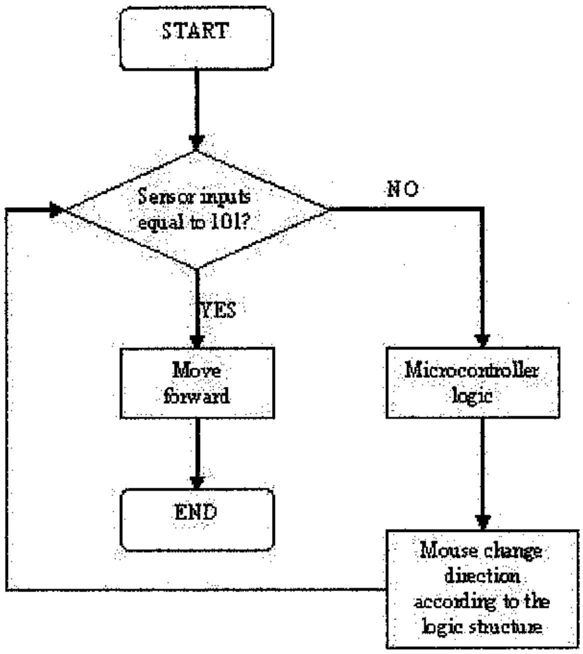


Figure 13 General flowchart of the mouse's operation

For the microcontroller program written, please refer to the appendix.

CHAPTER 5
CONCLUSION

As presented in this report, the project work has reached the objective, which is to develop a mouse that can find its own way out of a maze. The concept of a maze mouse is actually the basis of a mobile robot, which usage is getting more popular nowadays. The most important aspect is the ability of the mouse to detect obstacles awaiting it and to translate this information to determine its movement.

By integrating the microcontroller, the infra-red sensor and the motor driver components, we finally obtain a complete prototype of a maze mouse. The overall operation of the mouse is governed by a simple program written into the 80C31 microcontroller, together with the other supporting memory IC's. This particular program is the one responsible in translating the input coming from the sensors to the output, which is the motor movement. Lastly, for the mouse to be succeed in its operation, all its independent parts must first confirmed to be reliable and performing correctly as per requirement.

REFERENCES

[1] Reactive Navigation for Autonomous Guided Vehicle Using the Neuro-fuzzy Techniques; Jin Cao, Xiaoqun Liao, and Ernest Hall; Center for Robotics Research, ML 72; University of Cincinnati

[2] http://micromouse.cs.rhul.ac.uk/index.html

[3] http://reinerjansen.de/4flash/english_version/hauptteil_english_version.html#basics

[4] http://www.fairchildsemi.com/an/AN/AN-3005.pdf

[5] http://www.fairchildsemi.com/products/opto/ir/prodnote.html#faq

[6] http://www.fairchildsemi.com/products/opto/ir/infrared.html

[7] http://home.cogeco.ca/~rpaisley4/ATDetIR.html

[8] http://www.netmotion.com/htm_files/adv_motors.htm#four

[9] http://reinerjansen.de/4flash/english_version/hauptteil_english_version.html#basics

[10] http://reinerjansen.de/4flash/english_version/hauptteil_english_version.html#basics

APPENDIX A

Project Gantt Chart

GANTT CHART OF FIRST SEMESTER

NO.	ITEMS/WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Selection of project topic	▓														
2	Preliminary research work		▓	▓												
3	Submission of Preliminary Report				◆											
4	Project work				▓	▓	▓	▓								
	- Reference/Literature															
	- Hardware construction															
	- Maze construction															
5	Submission of Progress Report								◆							
6	Project work continue								▓	▓	▓	▓				
7	Submission of Interim Report final draft												◆			
8	Submission of Interim Report														◆	
9	Oral presentation															◆

GANTT CHART OF SECOND SEMESTER

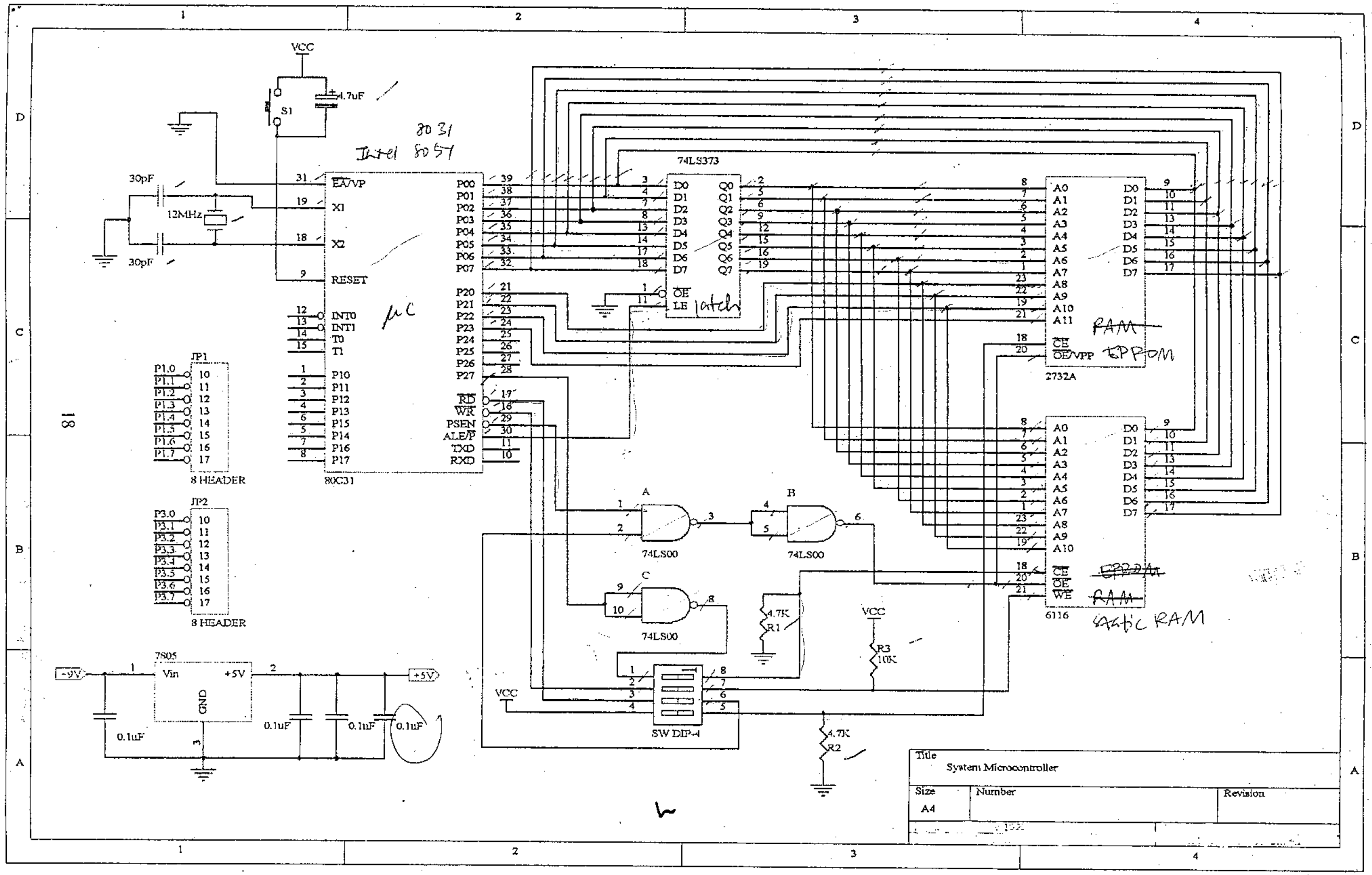
NO.	ITEMS/WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	Project work continue	■	■	■																	
2	Submission of progress report 1				◆																
3	Project work continue				■	■	■	■	■												
	- Improvement on prototype design																				
	- Development of microcontroller program																				
4	Submission of progress report 2								◆												
5	Project work continue									■	■	■	■	■							
6	Submission of Dissertation final draft													◆							
7	Oral presentation															◆					
8	Extended abstract																	◆			
9	Submission of project dissertation																				◆

APPENDIX B

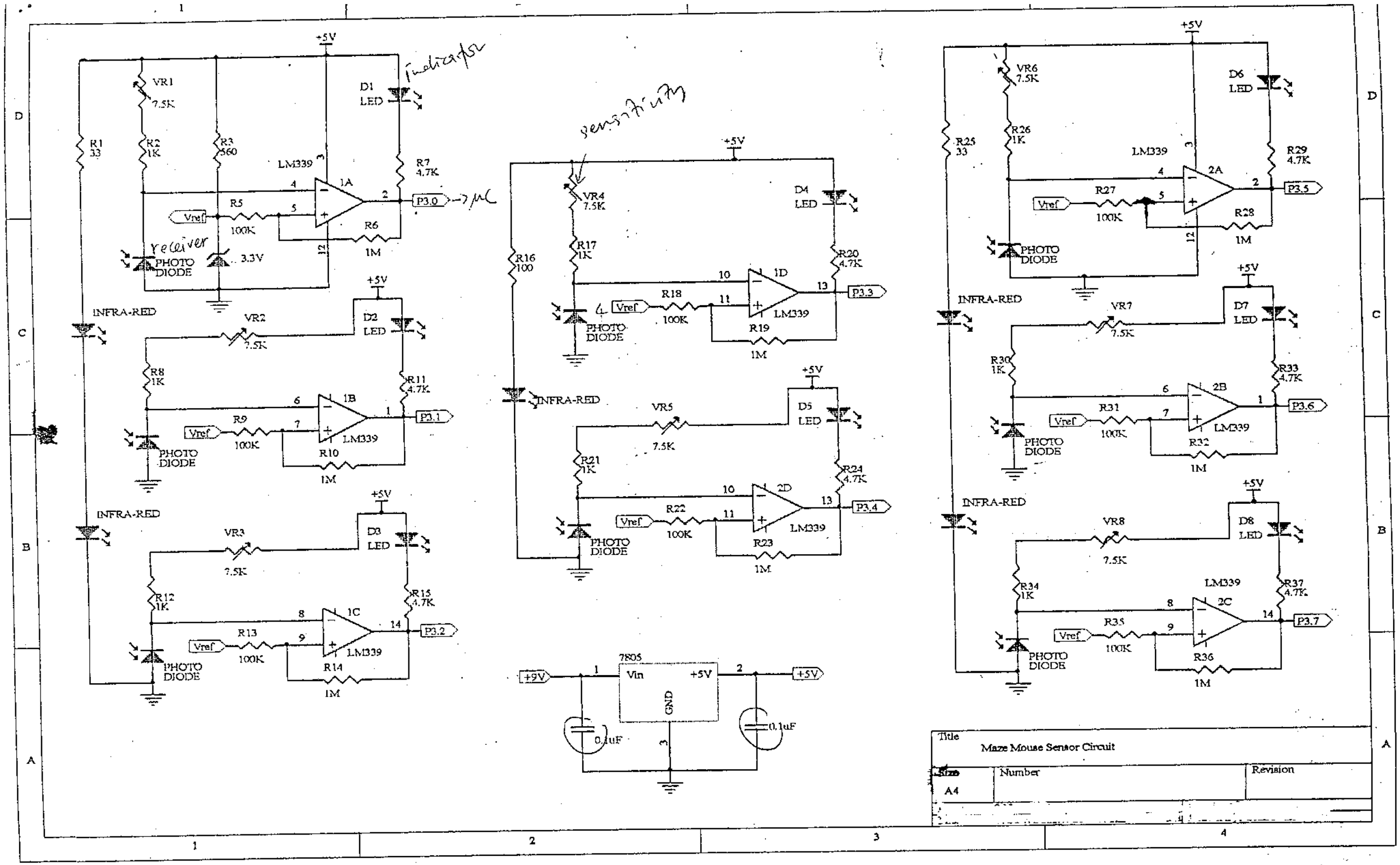
List of hardware used

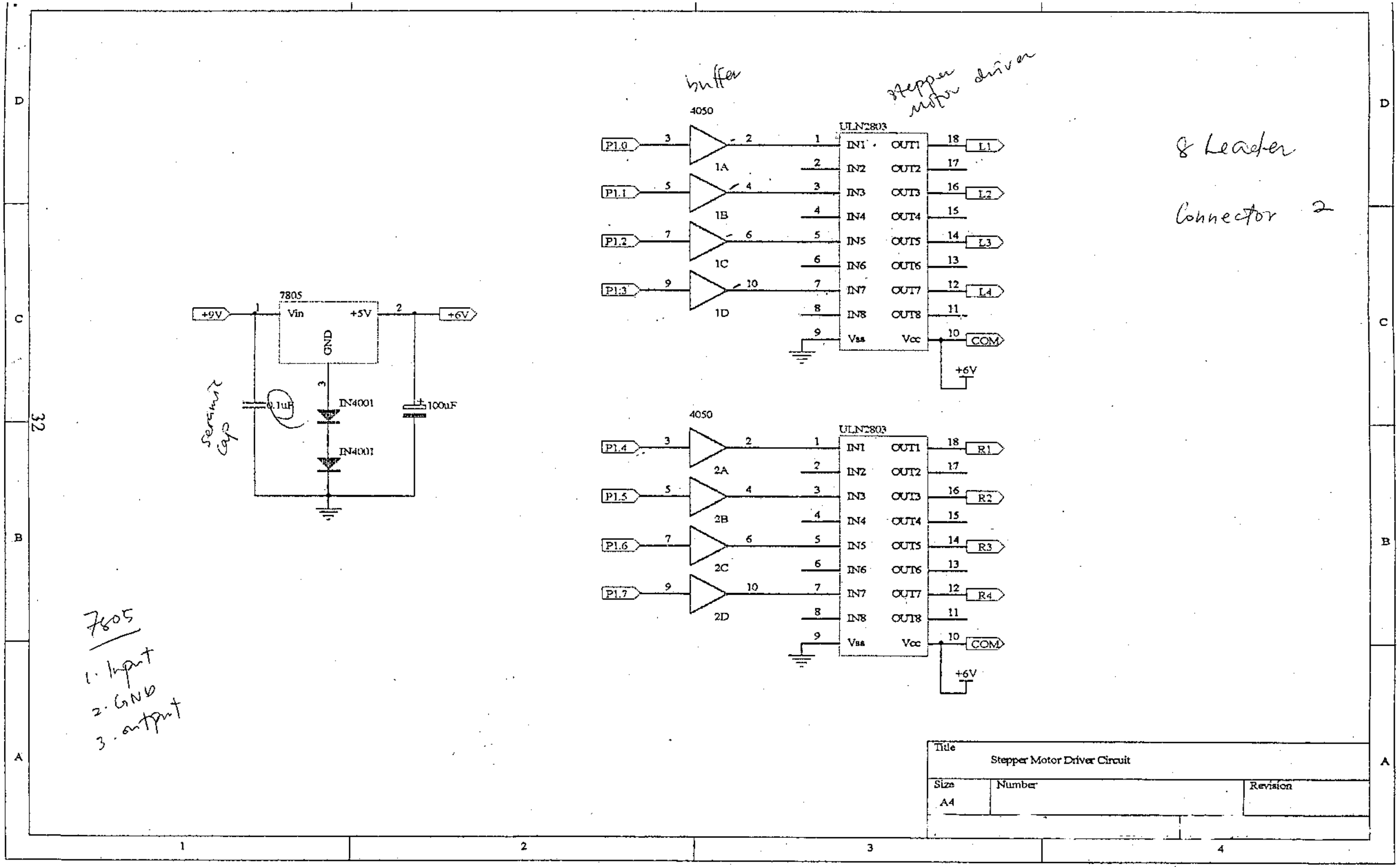
List of hardware required for the Maze Mouse project:

NO.	ITEM	DESCRIPTION
1	IC:	
	1. 7805	Voltage regulator
	2. 4050	Buffer
	3. ULN2803	Stepper motor driver
	4. 80C31	Microcontroller
	5. 74LS373	Latch
	6. 74LS00	NAND gate
	7. 2732A	RAM
	8. 6116A	EPROM
	9. LM339	Amplifier
2	Capacitor:	
	1. 100 μF	Electrolytic
	2. 4.7 μF	Electrolytic
	3. 0.1 μF	
	4. 30 pF	
3	Resistor:	
	1. 4.7 kΩ	
	2. 10 kΩ	
	3. 560 Ω	
	4. Variable resistor 10 kΩ	
4	Diode:	
	1. 1N4001	
	2. Photo diode	
	3. LED	
	4. 3.3V zener diode	
5	Others:	
	1. 12MHz crystal oscillator	
	2. 5V stepper motor	
	3. 8-pin header	
	4. Switch DIP-4	
	5. Push button switch	
	6. Infrared sensor	
	7. IC socket	
	8. Solder iron & solder lead	
	9. Vero board	
	10. Wire	
	11. Wire cutter	
	12. Rainbow wire	



VCC
S1
4.7uF
30pF
12MHz
EA/VP
X1
X2
RESET
INT0
INT1
T0
T1
P00
P01
P02
P03
P04
P05
P06
P07
P20
P21
P22
P23
P24
P25
P26
P27
RD
WR
PSEN
ALE/P
TXD
RXD
P10
P11
P12
P13
P14
P15
P16
P17
80C31
74LS373
OE
LE
2732A
A0
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
A11
CE
OE/VPP
D0
D1
D2
D3
D4
D5
D6
D7
6116
WE
JP1
P1.0
P1.1
P1.2
P1.3
P1.4
P1.5
P1.6
P1.7
8 HEADER
JP2
P3.0
P3.1
P3.2
P3.3
P3.4
P3.5
P3.6
P3.7
8 HEADER
A
B
C
74LS00
74LS00
74LS00
4.7K
R1
VCC
R3
10K
4.7K
R2
SW DIP-4
7805
Vin
+5V
GND
-9V
+5V
0.1uF
0.1uF
0.1uF
0.1uF
Title
System Microcontroller
Size
A4
Number
Revision


Maze Mouse Sensor Circuit
Title
Size A4
Number
Revision
LM339
INFRA-RED
PHOTO DIODE
LED
Vref
+5V
+9V
7805
Vin
GND
0.1uF
P3.0
P3.1
P3.2
P3.3
P3.4
P3.5
P3.6
P3.7


buffer
stepper motor driver
4050
ULN2803
P1.0
P1.1
P1.2
P1.3
P1.4
P1.5
P1.6
P1.7
1A
1B
1C
1D
2A
2B
2C
2D
IN1 IN2 IN3 IN4 IN5 IN6 IN7 IN8 Vss
OUT1 OUT2 OUT3 OUT4 OUT5 OUT6 OUT7 OUT8 Vcc
L1
L2
L3
L4
R1
R2
R3
R4
COM
+6V
8 Leader
Connector 2
7805
Vin
+5V
GND
+9V
0.1uF
100uF
IN4001
ceramic cap
7805
1. Input
2. GND
3. output
Title
Stepper Motor Driver Circuit
Size
A4
Number
Revision

APPENDIX D

Data sheets

DATA SHEET

80C51/87C51/80C31

80C51 8-bit microcontroller family

4K/128 OTP/ROM/ROMless low voltage (2.7V–5.5V), low power, high speed (33 MHz)

Product specification
Supersedes data of 1998 Oct 14
IC20 Data Handbook

1999 Apr 01

Philips Semiconductors

PHILIPS

DESCRIPTION

The Philips 8XC51/31 is a high-performance static 80C51 design fabricated with Philips high-density CMOS technology with operation from 2.7V to 5.5V.

The 8XC51/31 contains a 4k × 8 ROM, a 128 × 8 RAM, 32 I/O lines, three 16-bit counter/timers, a six-source, four-priority level nested interrupt structure, a serial I/O port for either multi-processor communications, I/O expansion or full duplex UART, and on-chip oscillator and clock circuits.

In addition, the device is a low power static design which offers a wide range of operating frequencies down to zero. Two software selectable modes of power reduction—idle mode and power-down mode are available. The idle mode freezes the CPU while allowing the RAM, timers, serial port, and interrupt system to continue functioning. The power-down mode saves the RAM contents but freezes the oscillator, causing all other chip functions to be inoperative. Since the design is static, the clock can be stopped without loss of user data and then the execution resumed from the point the clock was stopped.

SELECTION TABLE

For applications requiring more ROM and RAM, see the 8XC52/54/58/80C32, 8XC51FA/FB/FC/80C51FA, and 8XC51RA+/RB+/RC+/80C51RA+ data sheet.

ROM/EPROM Memory Size (X by 8)	RAM Size (X by 8)	Programmable Timer Counter (PCA)	Hardware Watch Dog Timer
80C31/8XC51			
0K/4K	128	No	No
80C32/8XC52/54/58			
0K/8K/16K/32K	256	No	No
80C51FA/8XC51FA/FB/FC			
0K/8K/16K/32K	256	Yes	No
80C51RA+/8XC51RA+/RB+/RC+			
0K/8K/16K/32K	512	Yes	Yes
8XC51RD+			
64K	1024	Yes	Yes

FEATURES

- 8051 Central Processing Unit
  - 4k × 8 ROM (80C51)
  - 128 × 8 RAM
  - Three 16-bit counter/timers
  - Full duplex serial channel
  - Boolean processor
  - Full static operation
  - Low voltage (2.7V to 5.5V@ 16MHz) operation
- Memory addressing capability
  - 64k ROM and 64k RAM
- Power control modes:
  - Clock can be stopped and resumed
  - Idle mode
  - Power-down mode
- CMOS and TTL compatible
- Three speed ranges at V_{CC} = 5V
  - 0 to 16MHz
  - 0 to 33MHz
- Three package styles
- Extended temperature ranges
- Dual Data Pointers
- Second DPTR register
- Security bits:
  - ROM (2 bits)
  - OTP/EPROM (3 bits)
- Encryption array—64 bytes
- 4 level priority interrupt
- 6 interrupt sources
- Four 8-bit I/O ports
- Full–duplex enhanced UART
  - Framing error detection
  - Automatic address recognition
- Programmable clock out
- Asynchronous port reset
- Low EMI (inhibit ALE)
- Wake-up from Power Down by an external interrupt (8XC51)

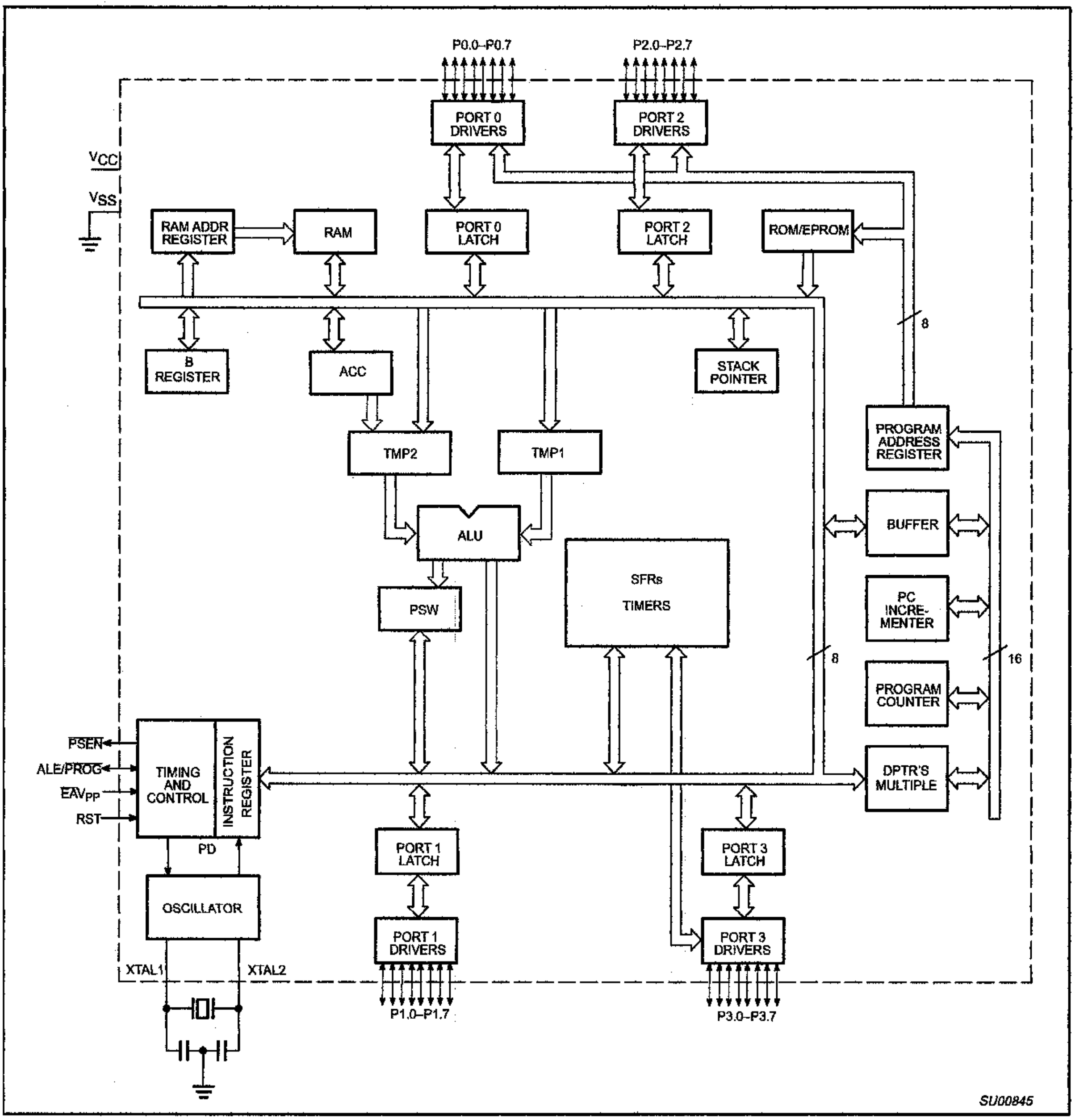
80C51/87C51 AND 80C31 ORDERING INFORMATION

	MEMORY SIZE 4K × 8	ROMless	TEMPERATURE RANGE °C AND PACKAGE	VOLTAGE RANGE	FREQ. (MHz)	DWG. #
ROM	P80C51SBPN	P80C31SBPN	0 to +70, Plastic Dual In-line Package	2.7V to 5.5V	0 to 16	SOT129-1
OTP	P87C51SBPN					
ROM	P80C51SBAA	P80C31SBAA	0 to +70, Plastic Leaded Chip Carrier	2.7V to 5.5V	0 to 16	SOT187-2
OTP	P87C51SBAA					
ROM	P80C51SBBB	P80C31SBBB	0 to +70, Plastic Quad Flat Pack	2.7V to 5.5V	0 to 16	SOT307-2
OTP	P87C51SBBB					
ROM	P80C51SFPN	P80C31SFPN	–40 to +85, Plastic Dual In-line Package	2.7V to 5.5V	0 to 16	SOT129-1
OTP	P87C51SFPN					
ROM	P80C51SFAA	P80C31SFAA	–40 to +85, Plastic Leaded Chip Carrier	2.7V to 5.5V	0 to 16	SOT187-2
OTP	P87C51SFAA					
ROM	P80C51SFBB	P80C31SFBB	–40 to +85, Plastic Quad Flat Pack	2.7V to 5.5V	0 to 16	SOT307-2
OTP	P87C51SFBB					
ROM	P80C51UBAA	P80C31UBAA	0 to +70, Plastic Leaded Chip Carrier	5V	0 to 33	SOT187-2
OTP	P87C51UBAA					
ROM	P80C51UBPN	P80C31UBPN	0 to +70, Plastic Dual In-line Package	5V	0 to 33	SOT129-1
OTP	P87C51UBPN					
ROM	P80C51UBBB	P80C31UBBB	0 to +70, Plastic Quad Flat Pack	5V	0 to 33	SOT307-2
OTP	P87C51UBBB					
ROM	P80C51UFAA	P80C31UFAA	–40 to +85, Plastic Leaded Chip Carrier	5V	0 to 33	SOT187-2
OTP	P87C51UFAA					
ROM	P80C51UFPN	P80C31UFPN	–40 to +85, Plastic Dual In-line Package	5V	0 to 33	SOT129-1
OTP	P87C51UFPN					
ROM	P80C51UFBB	P80C31UFBB	–40 to +85, Plastic Quad Flat Pack	5V	0 to 33	SOT307-2
OTP	P87C51UFBB					

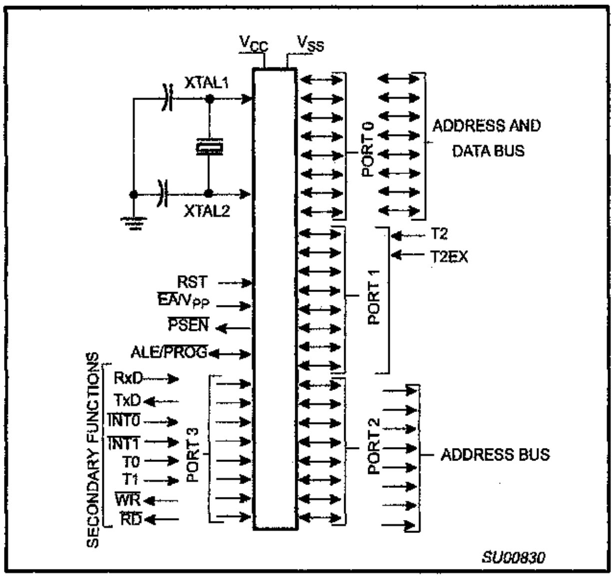
80C51/87C51 AND 80C31 ORDERING INFORMATION

DEVICE NUMBER (P87C51)	OPERATING FREQUENCY, MAX (S)	TEMPERATURE RANGE (B)	PACKAGE (AA)
P80C51 ROM	S = 16 MHz	B = 0° to +70°C	AA = PLCC
P87C51 OTP	U = 33 MHz	F = –40°C to +85°C	BB = PQFP
P80C31 ROMless			PN = PDIP

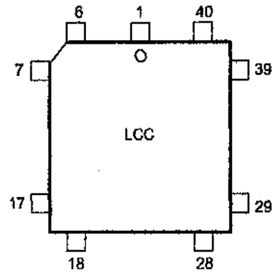
BLOCK DIAGRAM



LOGIC SYMBOL



PLASTIC LEADED CHIP CARRIER PIN FUNCTIONS

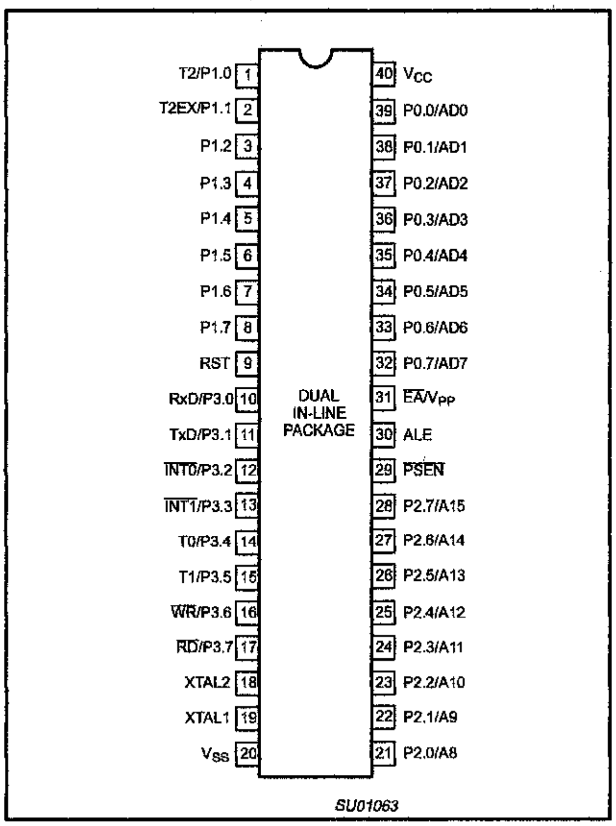


Pin	Function	Pin	Function	Pin	Function
1	NIC*	16	P3.4/T0	31	P2.7/A15
2	P1.0/T2	17	P3.5/T1	32	PSEN
3	P1.1/T2EX	18	P3.6/WR	33	ALE
4	P1.2	19	P3.7/RD	34	NIC*
5	P1.3	20	XTAL2	35	EA/V_{PP}
6	P1.4	21	XTAL1	36	P0.7/AD7
7	P1.5	22	V_{SS}	37	P0.6/AD6
8	P1.6	23	NIC*	38	P0.5/AD5
9	P1.7	24	P2.0/A8	39	P0.4/AD4
10	RST	25	P2.1/A9	40	P0.3/AD3
11	P3.0/RxD	26	P2.2/A10	41	P0.2/AD2
12	NIC*	27	P2.3/A11	42	P0.1/AD1
13	P3.1/TxD	28	P2.4/A12	43	P0.0/AD0
14	P3.2/INT0	29	P2.5/A13	44	V_{CC}
15	P3.3/INT1	30	P2.6/A14		

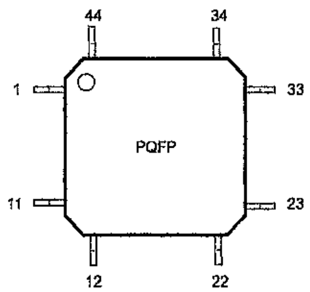
* NO INTERNAL CONNECTION

SU01062

PIN CONFIGURATIONS



PLASTIC QUAD FLAT PACK PIN FUNCTIONS



Pin	Function	Pin	Function	Pin	Function
1	P1.5	16	V_{SS}	31	P0.6/AD6
2	P1.6	17	NIC*	32	P0.5/AD5
3	P1.7	18	P2.0/A8	33	P0.4/AD4
4	RST	19	P2.1/A9	34	P0.3/AD3
5	P3.0/RxD	20	P2.2/A10	35	P0.2/AD2
6	NIC*	21	P2.3/A11	36	P0.1/AD1
7	P3.1/TxD	22	P2.4/A12	37	P0.0/AD0
8	P3.2/INT0	23	P2.5/A13	38	V_{CC}
9	P3.3/INT1	24	P2.6/A14	39	NIC*
10	P3.4/T0	25	P2.7/A15	40	P1.0/T2
11	P3.5/T1	26	PSEN	41	P1.1/T2EX
12	P3.6/WR	27	ALE	42	P1.2
13	P3.7/RD	28	NIC*	43	P1.3
14	XTAL2	29	EA/V_{PP}	44	P1.4
15	XTAL1	30	P0.7/AD7		

* NO INTERNAL CONNECTION

SU01064

Order this document by ULN2803/D

MOTOROLA

ULN2803
ULN2804

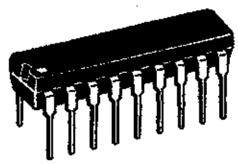
Octal High Voltage, High Current Darlington Transistor Arrays

The eight NPN Darlington connected transistors in this family of arrays are ideally suited for interfacing between low logic level digital circuitry (such as TTL, CMOS or PMOS/NMOS) and the higher current/voltage requirements of lamps, relays, printer hammers or other similar loads for a broad range of computer, industrial, and consumer applications. All devices feature open–collector outputs and free wheeling clamp diodes for transient suppression.

The ULN2803 is designed to be compatible with standard TTL families while the ULN2804 is optimized for 6 to 15 volt high level CMOS or PMOS.

OCTAL PERIPHERAL DRIVER ARRAYS

SEMICONDUCTOR TECHNICAL DATA



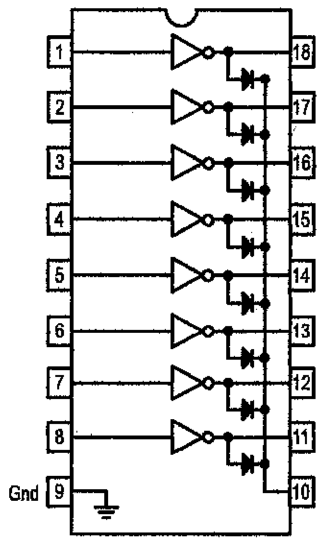
A SUFFIX
PLASTIC PACKAGE
CASE 707

MAXIMUM RATINGS (T_A = 25°C and rating apply to any one device in the package, unless otherwise noted.)

Rating	Symbol	Value	Unit
Output Voltage	V_O	50	V
Input Voltage (Except ULN2801)	V_I	30	V
Collector Current – Continuous	I_C	500	mA
Base Current – Continuous	I_B	25	mA
Operating Ambient Temperature Range	T_A	0 to +70	°C
Storage Temperature Range	T_{stg}	–55 to +150	°C
Junction Temperature	T_J	125	°C

$R_{\theta JA}$ = 55°C/W
Do not exceed maximum current limit per driver.

PIN CONNECTIONS



ORDERING INFORMATION

Device	Characteristics		
	Input Compatibility	V_{CE}(Max)/I_C(Max)	Operating Temperature Range
ULN2803A	TTL, 5.0 V CMOS	50 V/500 mA	T_A = 0 to + 70°C
ULN2804A	6 to 15 V CMOS, PMOS		

ELECTRICAL CHARACTERISTICS (T_A = 25°C, unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
Output Leakage Current (Figure 1)		I_{CEX}				µA
(V_O = 50 V, T_A = +70°C)	All Types		–	–	100	
(V_O = 50 V, T_A = +25°C)	All Types		–	–	50	
(V_O = 50 V, T_A = +70°C, V_I = 6.0 V)	ULN2802		–	–	500	
(V_O = 50 V, T_A = +70°C, V_I = 1.0 V)	ULN2804		–	–	500	
Collector–Emitter Saturation Voltage (Figure 2)		$V_{CE(sat)}$				V
(I_C = 350 mA, I_B = 500 µA)	All Types		–	1.1	1.6	
(I_C = 200 mA, I_B = 350 µA)	All Types		–	0.95	1.3	
(I_C = 100 mA, I_B = 250 µA)	All Types		–	0.85	1.1	
Input Current – On Condition (Figure 4)		$I_{I(on)}$				mA
(V_I = 17 V)	ULN2802		–	0.82	1.25	
(V_I = 3.85 V)	ULN2803		–	0.93	1.35	
(V_I = 5.0 V)	ULN2804		–	0.35	0.5	
(V_I = 12 V)	ULN2804		–	1.0	1.45	
Input Voltage – On Condition (Figure 5)		$V_{I(on)}$				V
(V_{CE} = 2.0 V, I_C = 300 mA)	ULN2802		–	–	13	
(V_{CE} = 2.0 V, I_C = 200 mA)	ULN2803		–	–	2.4	
(V_{CE} = 2.0 V, I_C = 250 mA)	ULN2803		–	–	2.7	
(V_{CE} = 2.0 V, I_C = 300 mA)	ULN2803		–	–	3.0	
(V_{CE} = 2.0 V, I_C = 125 mA)	ULN2804		–	–	5.0	
(V_{CE} = 2.0 V, I_C = 200 mA)	ULN2804		–	–	6.0	
(V_{CE} = 2.0 V, I_C = 275 mA)	ULN2804		–	–	7.0	
(V_{CE} = 2.0 V, I_C = 350 mA)	ULN2804		–	–	8.0	
Input Current – Off Condition (Figure 3) (I_C = 500 µA, T_A = +70°C)	All Types	$I_{I(off)}$	50	100	–	µA
DC Current Gain (Figure 2) (V_{CE} = 2.0 V, I_C = 350 mA)	ULN2801	h_{FE}	1000	–	–	–
Input Capacitance		C_I	–	15	25	pF
Turn–On Delay Time (50% E_I to 50% E_O)		t_{on}	–	0.25	1.0	µs
Turn–Off Delay Time (50% E_I to 50% E_O)		t_{off}	–	0.25	1.0	µs
Clamp Diode Leakage Current (Figure 6) (V_R = 50 V)	T_A = +25°C T_A = +70°C	I_R	–	–	50 100	µA
Clamp Diode Forward Voltage (Figure 7) (I_F = 350 mA)		V_F	–	1.5	2.0	V

LM2901,LM339/LM339A,LM3302 LM239/LM239A

Quad Comparator

Features

- Single or Dual Supply Operation
- Wide Range of Supply Voltage
  LM2901,LM339/LM339A,LM239/LM239A: 2 ~ 36V (or ±1 ~ ±18V)
  LM3302: 2 ~ 28V (or ±1 ~ ±14V)
- Low Supply Current Drain 800μA Typ.
- Open Collector Outputs for Wired and Connectors
- Low Input Bias Current 25nA Typ.
- Low Input Offset Current ±2.3nA Typ.
- Low Input Offset Voltage ±1.4mV Typ.
- Input Common Mode Voltage Range Includes Ground.
- Low Output Saturation Voltage
- Output Compatible With TTL, DTL and MOS Logic System

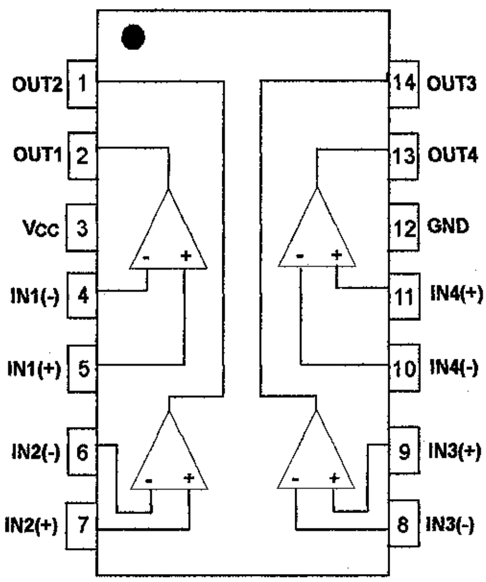
Description

The LM2901, LM339/LM339A ,LM239/LM239A, LM3302 consist of four independent voltage comparators designed to operate from single power supply over a wide voltage range.

14-DIP

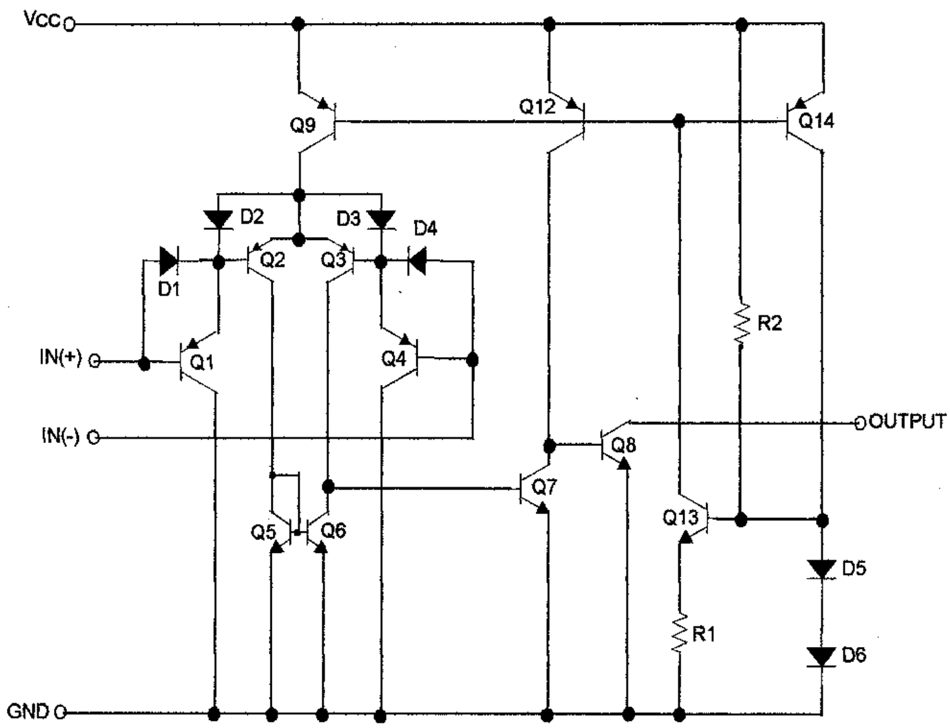
14-SOP

Internal Block Diagram



Rev. 1.0.2

Schematic Diagram



Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Supply Voltage	V_{CC}	±18 or 36	V
Supply Voltage only LM3302	V_{CC}	±14 or 28	V
Differential Input Voltage	$V_{I(DIFF)}$	36	V
Differential Input Voltage Only LM3302	$V_{I(DIFF)}$	28	V
Input Voltage	V_I	-0.3 to +36	V
Input Voltage Only LM3302	V_I	-0.3 to +28	V
Output Short Circuit to GND	-	Continuous	-
Power Dissipation	P_D	570	mW
Operating Temperature LM339/LM339A LM2901/LM3302 LM239/LM239A	T_{OPR}	 0 ~ +70 -40 ~ +85 -25 ~ +85	°C
Storage Temperature	T_{STG}	-65 ~ +150	°C

FAIRCHILD
SEMICONDUCTOR™

March 1998

DM74LS373/DM74LS374
3-STATE Octal D-Type Transparent Latches and Edge-Triggered Flip-Flops

General Description

These 8-bit registers feature totem-pole 3-STATE outputs designed specifically for driving highly-capacitive or relatively low-impedance loads. The high-impedance state and increased high-logic level drive provide these registers with the capability of being connected directly to and driving the bus lines in a bus-organized system without need for interface or pull-up components. They are particularly attractive for implementing buffer registers, I/O ports, bidirectional bus drivers, and working registers.

The eight latches of the DM54/74LS373 are transparent D-type latches meaning that while the enable (G) is high the Q outputs will follow the data (D) inputs. When the enable is taken low the output will be latched at the level of the data that was set up.

The eight flip-flops of the DM54/74LS374 are edge-triggered D-type flip flops. On the positive transition of the clock, the Q outputs will be set to the logic states that were set up at the D inputs.

A buffered output control input can be used to place the eight outputs in either a normal logic state (high or low logic levels) or a high-impedance state. In the high-impedance state the outputs neither load nor drive the bus lines significantly.

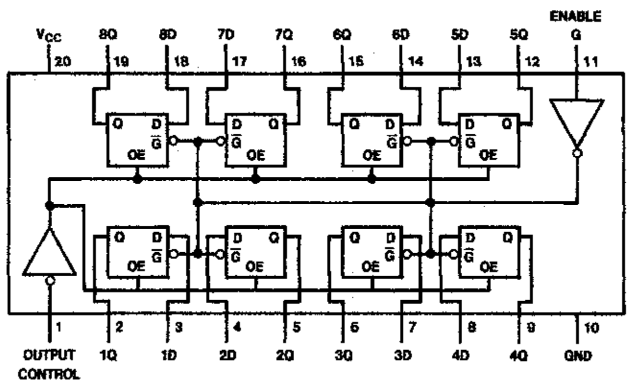
The output control does not affect the internal operation of the latches or flip-flops. That is, the old data can be retained or new data can be entered even while the outputs are off.

Features

- Choice of 8 latches or 8 D-type flip-flops in a single package
- 3-STATE bus-driving outputs
- Full parallel-access for loading
- Buffered control inputs
- P-N-P inputs reduce D-C loading on data lines

Connection Diagrams

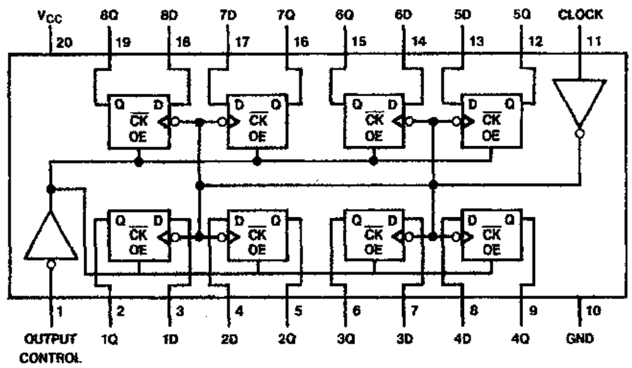
Dual-In-Line Packages
'LS373



Order Number DM54LS373J, DM54LS373W, DM74LS373N or DM74LS373WM
See Package Number J20A, M20B, N20A or W20A

Connection Diagrams (Continued)

'LS374



DS006431-2

Order Number DM54LS374J, DM54LS374W, DM74LS374WM or DM74LS374N
See Package Number J20A, M20B, N20A or W20A

Function Tables

DM54/74LS373

Output Control	Enable G	D	Output
L	H	H	H
L	H	L	L
L	L	X	Q_0
H	X	X	Z

H = High Level (Steady State), L = Low Level (Steady State), X = Don't Care
↑ = Transition from low-to-high level, Z = High Impedance State
Q_0 = The level of the output before steady-state input conditions were established.

DM54/74LS374

Output Control	Clock	D	Output
L	↑	H	H
L	↑	L	L
L	L	X	Q_0
H	X	X	Z

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March 1998

DM74LS00
Quad 2-Input NAND Gates

General Description

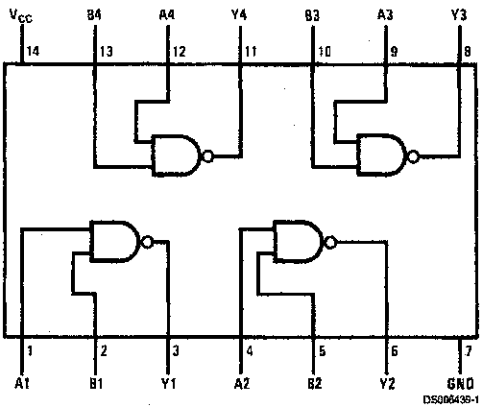
This device contains four independent gates each of which performs the logic NAND function.

Features

- Alternate Military/Aerospace device (54LS00) is available. Contact a Fairchild Semiconductor Sales Office/Distributor for specifications.

Connection Diagram

Dual-In-Line Package



Order Number 54LS00DMQB, 54LS00FMQB, 54LS00LMQB, DM54LS00J, DM54LS00W, DM74LS00M or DM74LS00N
See Package Number E20A, J14A, M14A, N14A or W14B

Function Table

$$Y = \overline{AB}$$

Inputs		Output
A	B	Y
L	L	H
L	H	H
H	L	H
H	H	L

H = High Logic Level
L = Low Logic Level

Absolute Maximum Ratings (Note 1)

Supply Voltage	7V
Input Voltage	7V
Operating Free Air Temperature Range	
DM54LS and 54LS	−55°C to +125°C
DM74LS	0°C to +70°C
Storage Temperature Range	−65°C to +150°C

Recommended Operating Conditions

Symbol	Parameter	DM54LS00			DM74LS00			Units
		Min	Nom	Max	Min	Nom	Max	
V_{CC}	Supply Voltage	4.5	5	5.5	4.75	5	5.25	V
V_{IH}	High Level Input Voltage	2			2			V
V_{IL}	Low Level Input Voltage			0.7			0.8	V
I_{OH}	High Level Output Current			−0.4			−0.4	mA
I_{OL}	Low Level Output Current			4			8	mA
T_A	Free Air Operating Temperature	−55		125	0		70	°C

Note 1: *The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The parametric values defined in the "Electrical Characteristics" table are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.*

Electrical Characteristics

over recommended operating free air temperature range (unless otherwise noted)

Symbol	Parameter	Conditions		Min	Typ (Note 2)	Max	Units
V_I	Input Clamp Voltage	V_{CC} = Min, I_I = −18 mA				−1.5	V
V_{OH}	High Level Output Voltage	V_{CC} = Min, I_{OH} = Max, V_{IL} = Max	DM54	2.5	3.4		V
			DM74	2.7	3.4		
V_{OL}	Low Level Output Voltage	V_{CC} = Min, I_{OL} = Max, V_{IH} = Min	DM54		0.25	0.4	V
			DM74		0.35	0.5	
		I_{OL} = 4 mA, V_{CC} = Min	DM74		0.25	0.4	
I_I	Input Current @ Max Input Voltage	V_{CC} = Max, V_I = 7V				0.1	mA
I_{IH}	High Level Input Current	V_{CC} = Max, V_I = 2.7V				20	μA
I_{IL}	Low Level Input Current	V_{CC} = Max, V_I = 0.4V				−0.36	mA
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 3)	DM54	−20		−100	mA
			DM74	−20		−100	
I_{CCH}	Supply Current with Outputs High	V_{CC} = Max			0.8	1.6	mA
I_{CCL}	Supply Current with Outputs Low	V_{CC} = Max			2.4	4.4	mA

Switching Characteristics

at V_{CC} = 5V and T_A = 25°C

Symbol	Parameter	R_L = 2 kΩ				Units
		C_L = 15 pF		C_L = 50 pF		
		Min	Max	Min	Max	
t_{PLH}	Propagation Delay Time Low to High Level Output	3	10	4	15	ns
t_{PHL}	Propagation Delay Time High to Low Level Output	3	10	4	15	ns

Note 2: All typicals are at V_{CC} = 5V, T_A = 25°C.

Note 3: Not more than one output should be shorted at a time, and the duration should not exceed one second.

FAIRCHILD
SEMICONDUCTOR™

October 1987
Revised April 2002

CD4049UBC • CD4050BC
Hex Inverting Buffer • Hex Non-Inverting Buffer

General Description

The CD4049UBC and CD4050BC hex buffers are monolithic complementary MOS (CMOS) integrated circuits constructed with N- and P-channel enhancement mode transistors. These devices feature logic level conversion using only one supply voltage (V_{DD}). The input signal high level (V_{IH}) can exceed the V_{DD} supply voltage when these devices are used for logic level conversions. These devices are intended for use as hex buffers, CMOS to DTL/TTL converters, or as CMOS current drivers, and at V_{DD} = 5.0V, they can drive directly two DTL/TTL loads over the full operating temperature range.

Features

- Wide supply voltage range: 3.0V to 15V
- Direct drive to 2 TTL loads at 5.0V over full temperature range
- High source and sink current capability
- Special input protection permits input voltages greater than V_{DD}

Applications

- CMOS hex inverter/buffer
- CMOS to DTL/TTL hex converter
- CMOS current "sink" or "source" driver
- CMOS HIGH-to-LOW logic level converter

Ordering Code:

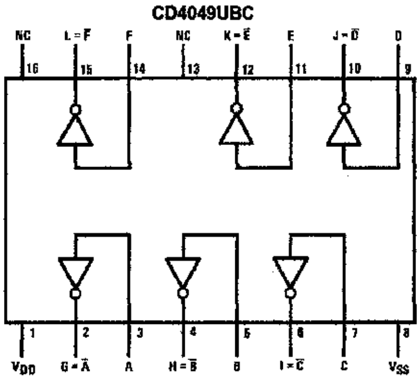
Order Number	Package Number	Package Description
CD4049UBCM	M16A	16-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow
CD4049UBCN	N16E	16-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide
CD4050BCM	M16A	16-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow
CD4050BCN	N16E	16-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide

Devices also available in Tape and Reel. Specify by appending the suffix letter "X" to the ordering code.

Connection Diagrams

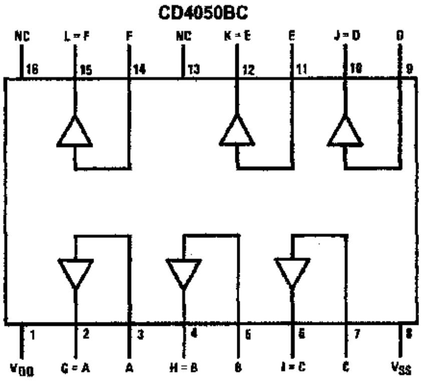
Pin Assignments for DIP

CD4049UBC



Top View

CD4050BC

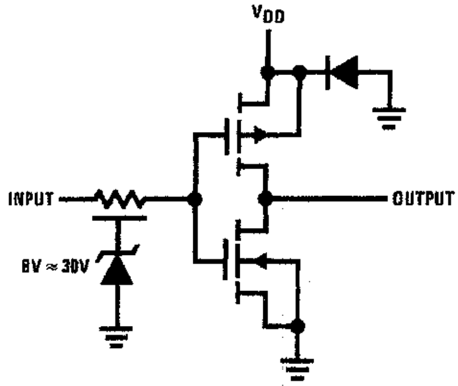


Top View

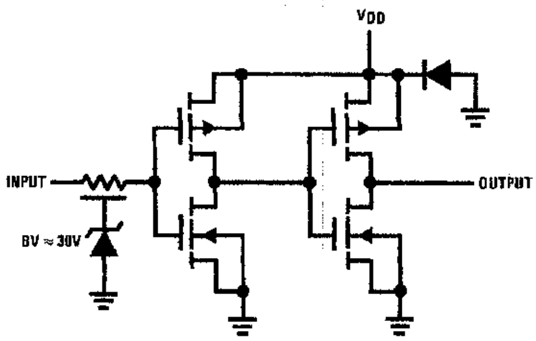
 DS005971 www.fairchildsemi.com

Schematic Diagrams

CD4049UBC
1 of 6 Identical Units



CD4050BC
1 of 6 Identical Units



Absolute Maximum Ratings (Note 1)

(Note 2)

Supply Voltage (V_{DD})	−0.5V to +18V
Input Voltage (V_{IN})	−0.5V to +18V
Voltage at Any Output Pin (V_{OUT})	−0.5V to V_{DD} + 0.5V
Storage Temperature Range (T_S)	−65°C to +150°C
Power Dissipation (P_D)	
Dual-In-Line	700 mW
Small Outline	500 mW
Lead Temperature (T_L)	
(Soldering, 10 seconds)	260°C

Recommended Operating Conditions (Note 2)

Supply Voltage (V_{DD})	3V to 15V
Input Voltage (V_{IN})	0V to 15V
Voltage at Any Output Pin (V_{OUT})	0 to V_{DD}
Operating Temperature Range (T_A)	
CD4049UBC, CD4050BC	−55°C to +125°C

Note 1: "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed; they are not meant to imply that the devices should be operated at these limits. The table of "Recommended Operating Conditions" and "Electrical Characteristics" provides conditions for actual device operation.

Note 2: V_{SS} = 0V unless otherwise specified.

DC Electrical Characteristics (Note 3)

Symbol	Parameter	Conditions	−55°C		+25°C			+125°C		Units
			Min	Max	Min	Typ	Max	Min	Max	
I_{DD}	Quiescent Device Current	V_{DD} = 5V		1.0		0.01	1.0		30	
		V_{DD} = 10V		2.0		0.01	2.0		60	µA
		V_{DD} = 15V		4.0		0.03	4.0		120	
V_{OL}	LOW Level Output Voltage	V_{IH} = V_{DD}, V_{IL} = 0V,								
		$\|I_O\| < 1$ µA								
		V_{DD} = 5V		0.05		0	0.05		0.05	
		V_{DD} = 10V		0.05		0	0.05		0.05	V
		V_{DD} = 15V		0.05		0	0.05		0.05	
V_{OH}	HIGH Level Output Voltage	V_{IH} = V_{DD}, V_{IL} = 0V,								
		$\|I_O\| < 1$ µA								
		V_{DD} = 5V	4.95		4.95	5		4.95		
		V_{DD} = 10V	9.95		9.95	10		9.95		V
		V_{DD} = 15V	14.95		14.95	15		14.95		
V_{IL}	LOW Level Input Voltage	$\|I_O\| < 1$ µA								
	(CD4050BC Only)	V_{DD} = 5V, V_O = 0.5V		1.5		2.25	1.5		1.5	
		V_{DD} = 10V, V_O = 1V		3.0		4.5	3.0		3.0	V
		V_{DD} = 15V, V_O = 1.5V		4.0		6.75	4.0		4.0	
V_{IL}	LOW Level Input Voltage	$\|I_O\| < 1$ µA								
	(CD4049UBC Only)	V_{DD} = 5V, V_O = 4.5V		1.0		1.5	1.0		1.0	
		V_{DD} = 10V, V_O = 9V		2.0		2.5	2.0		2.0	V
		V_{DD} = 15V, V_O = 13.5V		3.0		3.5	3.0		3.0	
V_{IH}	HIGH Level Input Voltage	$\|I_O\| < 1$ µA								
	(CD4050BC Only)	V_{DD} = 5V, V_O = 4.5V	3.5		3.5	2.75		3.5		
		V_{DD} = 10V, V_O = 9V	7.0		7.0	5.5		7.0		V
		V_{DD} = 15V, V_O = 13.5V	11.0		11.0	8.25		11.0		
V_{IH}	HIGH Level Input Voltage	$\|I_O\| < 1$ µA								
	(CD4049UBC Only)	V_{DD} = 5V, V_O = 0.5V	4.0		4.0	3.5		4.0		
		V_{DD} = 10V, V_O = 1V	8.0		8.0	7.5		8.0		V
		V_{DD} = 15V, V_O = 1.5V	12.0		12.0	11.5		12.0		
I_{OL}	LOW Level Output Current	V_{IH} = V_{DD}, V_{IL} = 0V								
	(Note 4)	V_{DD} = 5V, V_O = 0.4V	5.6		4.6	5		3.2		
		V_{DD} = 10V, V_O = 0.5V	12		9.8	12		6.8		mA
		V_{DD} = 15V, V_O = 1.5V	35		29	40		20		
I_{OH}	HIGH Level Output Current	V_{IH} = V_{DD}, V_{IL} = 0V								
	(Note 4)	V_{DD} = 5V, V_O = 4.6V	−1.3		−1.1	−1.6		−0.72		
		V_{DD} = 10V, V_O = 9.5V	−2.6		−2.2	−3.6		−1.5		mA
		V_{DD} = 15V, V_O = 13.5V	−8.0		−7.2	−12		−5		
I_{IN}	Input Current	V_{DD} = 15V, V_{IN} = 0V		−0.1		-10^{-5}	−0.1		−1.0	µA
		V_{DD} = 15V, V_{IN} = 15V		0.1		10^{-5}	0.1		1.0	

Note 3: V_{SS} = 0V unless otherwise specified.

DC Electrical Characteristics (Continued)

Note 4: These are peak output current capabilities. Continuous output current is rated at 12 mA maximum. The output current should not be allowed to exceed this value for extended periods of time. I_{OL} and I_{OH} are tested one output at a time.

AC Electrical Characteristics (Note 5)

CD4049UBC

$T_A = 25°C$, $C_L = 50$ pF, $R_L = 200k$, $t_r = t_f = 20$ ns, unless otherwise specified

Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_{PHL}	Propagation Delay Time	$V_{DD} = 5V$		30	65	
	HIGH-to-LOW Level	$V_{DD} = 10V$		20	40	ns
		$V_{DD} = 15V$		15	30	
t_{PLH}	Propagation Delay Time	$V_{DD} = 5V$		45	85	
	LOW-to-HIGH Level	$V_{DD} = 10V$		25	45	ns
		$V_{DD} = 15V$		20	35	
t_{THL}	Transition Time	$V_{DD} = 5V$		30	60	
	HIGH-to-LOW Level	$V_{DD} = 10V$		20	40	ns
		$V_{DD} = 15V$		15	30	
t_{TLH}	Transition Time	$V_{DD} = 5V$		60	120	
	LOW-to-HIGH Level	$V_{DD} = 10V$		30	55	ns
		$V_{DD} = 15V$		25	45	
C_{IN}	Input Capacitance	Any Input		15	22.5	pF

Note 5: AC Parameters are guaranteed by DC correlated testing.

AC Electrical Characteristics (Note 6)

CD4050BC

$T_A = 25°C$, $C_L = 50$ pF, $R_L = 200k$, $t_r = t_f = 20$ ns, unless otherwise specified

Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_{PHL}	Propagation Delay Time	$V_{DD} = 5V$		60	110	
	HIGH-to-LOW Level	$V_{DD} = 10V$		25	55	ns
		$V_{DD} = 15V$		20	30	
t_{PLH}	Propagation Delay Time	$V_{DD} = 5V$		60	120	
	LOW-to-HIGH Level	$V_{DD} = 10V$		30	55	ns
		$V_{DD} = 15V$		25	45	
t_{THL}	Transition Time	$V_{DD} = 5V$		30	60	
	HIGH-to-LOW Level	$V_{DD} = 10V$		20	40	ns
		$V_{DD} = 15V$		15	30	
t_{TLH}	Transition Time	$V_{DD} = 5V$		60	120	
	LOW-to-HIGH Level	$V_{DD} = 10V$		30	55	ns
		$V_{DD} = 15V$		25	45	
C_{IN}	Input Capacitance	Any Input		5	7.5	pF

Note 6: AC Parameters are guaranteed by DC correlated testing.

CMOS Static RAM
16K (2K x 8-Bit)

IDT6116SA
IDT6116LA

Features

- **High-speed access and chip select times**
  - *Military: 20/25/35/45/55/70/90/120/150ns (max.)*
  - *Industrial: 20/25/35/45ns (max.)*
  - *Commercial: 15/20/25/35/45ns (max.)*
- **Low-power consumption**
- **Battery backup operation**
  - *2V data retention voltage (LA version only)*
- **Produced with advanced CMOS high-performance technology**
- **CMOS process virtually eliminates alpha particle soft-error rates**
- **Input and output directly TTL-compatible**
- **Static operation: no clocks or refresh required**
- **Available in ceramic and plastic 24-pin DIP, 24-pin Thin Dip, 24-pin SOIC and 24-pin SOJ**
- **Military product compliant to MIL-STD-833, Class B**

Description

The IDT6116SA/LA is a 16,384-bit high-speed static RAM organized as 2K x 8. It is fabricated using IDT's high-performance, high-reliability CMOS technology.

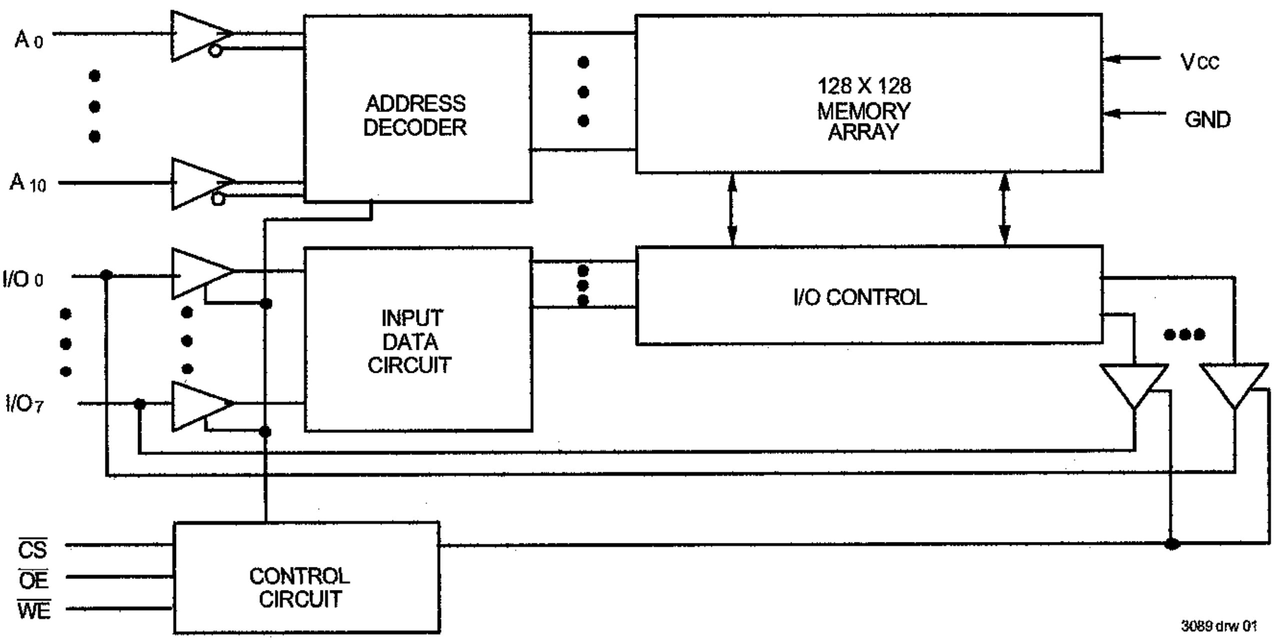
Access times as fast as 15ns are available. The circuit also offers a reduced power standby mode. When $\overline{CS}$ goes HIGH, the circuit will automatically go to, and remain in, a standby power mode, as long as $\overline{CS}$ remains HIGH. This capability provides significant system level power and cooling savings. The low-power (LA) version also offers a battery backup data retention capability where the circuit typically consumes only 1µW to 4µW operating off a 2V battery.

All inputs and outputs of the IDT6116SA/LA are TTL-compatible. Fully static asynchronous circuitry is used, requiring no clocks or refreshing for operation.

The IDT6116SA/LA is packaged in 24-pin 600 and 300 mil plastic or ceramic DIP, 24-lead gull-wing SOIC, and 24-lead J-bend SOJ providing high board-level packing densities.

Military grade product is manufactured in compliance to the latest version of MIL-STD-883, Class B, making it ideally suited to military temperature applications demanding the highest level of performance and reliability.

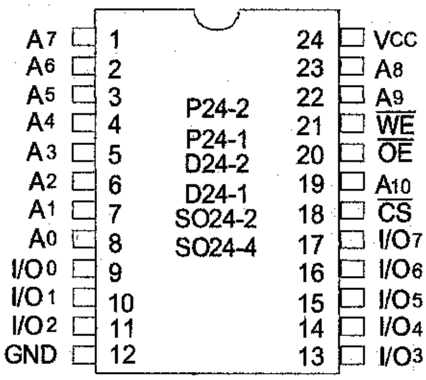
Functional Block Diagram



FEBRUARY 2001

DSC-3089/03

Pin Configurations



3089 drw 02

DIP/SOIC/SOJ
Top View

Pin Description

Name	Description
A_0 - A_{10}	Address Inputs
I/O_0 - I/O_7	Data Input/Output
$\overline{CS}$	Chip Select
$\overline{WE}$	Write Enable
$\overline{OE}$	Output Enable
Vcc	Power
GND	Ground

3089 tbl 01

Truth Table(1)

Mode	$\overline{CS}$	$\overline{OE}$	$\overline{WE}$	I/O
Standby	H	X	X	High-Z
Read	L	L	H	$DATA_{OUT}$
Read	L	H	H	High-Z
Write	L	X	L	$DATA_{IN}$

3089 tbl 02

NOTE:
1. H = V_{IH}, L = V_{IL}, X = Don't Care.

Capacitance (T_A = +25°C, f = 1.0 MHz)

Symbol	Parameter(1)	Conditions	Max.	Unit
C_{IN}	Input Capacitance	V_{IN} = 0V	8	pF
$C_{I/O}$	I/O Capacitance	V_{OUT} = 0V	8	pF

3089 tbl 03

NOTE:
1. This parameter is determined by device characterization, but is not production tested.

Absolute Maximum Ratings(1)

Symbol	Rating	Com'l.	Mil.	Unit
V_{TERM}(2)	Terminal Voltage with Respect to GND	-0.5 to +7.0	-0.5 to +7.0	V
T_A	Operating Temperature	0 to +70	-55 to +125	°C
T_{BIAS}	Temperature Under Bias	-55 to +125	-65 to +135	°C
T_{STG}	Storage Temperature	-55 to +125	-65 to +150	°C
P_T	Power Dissipation	1.0	1.0	W
I_{OUT}	DC Output Current	50	50	mA

3089 tbl 04

NOTES:
1. Stresses greater than those listed under ABSOLUTE MAXIMUM RATINGS may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.
2. V_{TERM} must not exceed Vcc +0.5V.

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MC78XX/LM78XX/MC78XXA

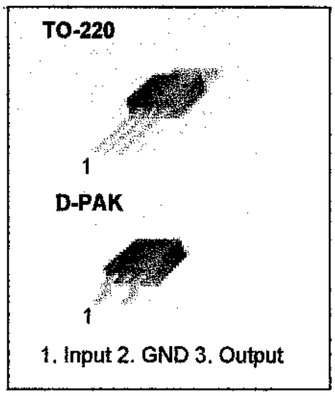
3-Terminal 1A Positive Voltage Regulator

Features

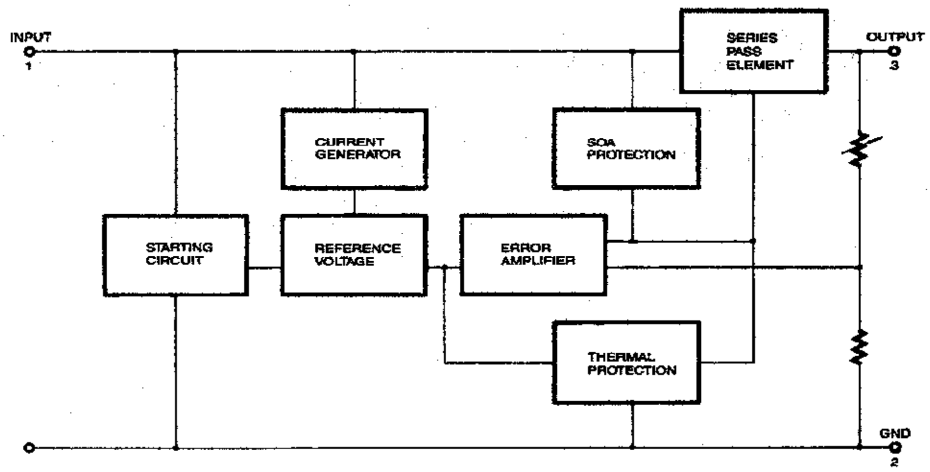
- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

Description

The MC78XX/LM78XX/MC78XXA series of three terminal positive regulators are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.



Internal Block Digram



Rev. 1.0.1

Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Input Voltage (for V_O = 5V to 18V) (for V_O = 24V)	V_I V_I	35 40	V V
Thermal Resistance Junction-Cases (TO-220)	$R_{\theta JC}$	5	°C/W
Thermal Resistance Junction-Air (TO-220)	$R_{\theta JA}$	65	°C/W
Operating Temperature Range	T_{OPR}	0 ~ +125	°C
Storage Temperature Range	T_{STG}	-65 ~ +150	°C

Electrical Characteristics (MC7805/LM7805)

(Refer to test circuit ,0°C < T_J < 125°C, I_O = 500mA, V_I = 10V, C_I= 0.33µF, C_O= 0.1µF, unless otherwise specified)

Parameter	Symbol	Conditions		MC7805/LM7805			Unit
				Min.	Typ.	Max.	
Output Voltage	V_O	T_J =+25 °C		4.8	5.0	5.2	V
		5.0mA ≤ Io ≤ 1.0A, P_O ≤ 15W V_I = 7V to 20V		4.75	5.0	5.25	
Line Regulation (Note1)	Regline	T_J=+25 °C	V_O = 7V to 25V	-	4.0	100	mV
			V_I = 8V to 12V	-	1.6	50	
Load Regulation (Note1)	Regload	T_J=+25 °C	I_O = 5.0mA to1.5A	-	9	100	mV
			I_O =250mA to 750mA	-	4	50	
Quiescent Current	I_Q	T_J =+25 °C		-	5.0	8.0	mA
Quiescent Current Change	ΔI_Q	I_O = 5mA to 1.0A		-	0.03	0.5	mA
		V_I= 7V to 25V		-	0.3	1.3	
Output Voltage Drift	$\Delta V_O/\Delta T$	I_O= 5mA		-	-0.8	-	mV/ °C
Output Noise Voltage	V_N	f = 10Hz to 100KHz, T_A=+25 °C		-	42	-	µV/Vo
Ripple Rejection	RR	f = 120Hz V_O = 8V to 18V		62	73	-	dB
Dropout Voltage	V_{Drop}	I_O = 1A, T_J =+25 °C		-	2	-	V
Output Resistance	r_O	f = 1KHz		-	15	-	mΩ
Short Circuit Current	I_{SC}	V_I = 35V, T_A =+25 °C		-	230	-	mA
Peak Current	I_{PK}	T_J =+25 °C		-	2.2	-	A

Note:

1. Load and line regulation are specified at constant junction temperature. Changes in V_O due to heating effects must be taken into account separately. Pulse testing with low duty is used.

APPENDIX E

Microcontroller program

```
main:
        mov A, p1       ;read sensor status from p1 - load to accumulator
        mov p2, #01h
        mov p3, #01h
        ljmp condition

condition:
        cjne A, #00h, condition1        ; check for 4 junction
        ljmp status

status:
        mov p2, #01h  ; mouse turn left
        mov p3, #08h
        mov A, p1       ; read current input from p1
        cjne A, #05h, main
        ljmp status


condition1:
        cjne A, #01h, condition2        ; check 4 T left corner
        ljmp status1

status1
        mov p2, #01h  ; mouse turn left
        mov p3, #08h
        mov A, p1       ; read current input from p1
        cjne A, #05h, main
        ljmp status1

condition2:
        cjne A, #02h, condition3        ; check 4 T junction
        ljmp status2

status2
        mov p2, #01h  ; mouse turn left
        mov p3, #08h
        mov A, p1       ; read current input from p1
        cjne A, #05h, main
        ljmp status2

condition3:
        cjne A, #03h, condition4        : check 4 left corner
        ljmp status3

status3
        mov p2, #01h  ; mouse turn left
        mov p3, #08h
```

```
        mov A, p1       ; read current input from p1
        cjne A, #05h, main
        ljmp status3

condition4:
        cjne A, #04h, condition5        ; check 4 T right junction
        lmjp status4

status4:
        mov p2, #08h  ; mouse turn right
        mov p3, #01h
        mov A, p1       ; read current input from p1
        cjne A, #05h, main
        ljmp status4

condition5:
        cjne A, #05h, condition6        ; check 4 straight line
        lmjp status5

status5:
        mov p2, #01h  ; port 2 to right motor
        mov p3, #01h  ; port 3 to left motor
        mov A, p1       ; read current input from p1
        cjne A, #05h, main
        ljmp status5

condition6:
        cjne A, #06h, condition7        ; check for right corner
        ljmp status6;

status6:
        mov p2, #08h  ;mouse turn right
        mov p3, #01h
        mov A, p1       ; read current input from p1
        cjne A, #05h, main
        ljmp status6

condition7:
        cjne A, #07h, condition                 ; check for dead end

status7:
        mov p2, #08h  ;mouse turn right
        mov p3, #01h
        mov A, p1       ; read current input from p1
        cjne A, #05h, main
        ljmp status7
```