Palestine Polytechnic University

College of Engineering and Technology

Electrical and Computer Engineering Department

Graduation Project

Design and Build of an Infant Incubator with Alarm Systems.

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ABSTRACT

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The care of premature newborns often requires that they be in an environment in which temperature , humidity , and oxygen are elevated and controlled because they are unable to regulate their own temperature and their lungs unable to supply enough oxygen to meet elevated demands , therefore they placed in an incubator to control these parameters .

In this project we designed a feedback control system to control the infant incubator parameters including temperature , humidity and the oxygen by use microcontroller unit, and the project include the graphical user interface design which used in the PC.

ملخص المشروع

الخليل – فلسطين
كلية الهندسة والتكنولوجيا
دائرة الهندسة الكهربائية والحاسوب

اسم المشروع

Design and Build of an Infant Incubator with Alarm System

اسماء الطلبة

فداء قباجة　　　نبيل الزبيدي　　　مرفت الطردة

الأطفال الخدج الذين يولدون قبل إتمام فترة الحمل الطبيعية يحتاجون إلى عناية خاصة وذلك لعدم اكتمال نموهم ووجود مشاكل لديهم في الرئتين أو الكبد أو لعدم اكتمال الجهاز العصبي وهذا يتطلب وجود جو مناسب مشابه لجو رحم الأم يتضمن حرارة مناسبة ونسبة رطوبة وأكسجين ملائمة وذلك من خلال توفير جهاز طبي يتحكم بكل من الحرارة والأكسجين والرطوبة يدعى(الحاضنة).

وقد تم في هذا المشروع تصميم جهاز الحاضنة حيث تم التحكم بالحرارة والرطوبة والأكسجين.

كما تم بناء نظام إنذار يقوم على إعطاء صوت وضوء للدلالة على وجود خلل عند ارتفاع درجة حرارة الحاضنة وعند فتح باب الحاضنة وعند انقطاع التيار الكهربائي.

كما تم في هذا المشروع تصميم برنامج محوسب (Graphical user interface) يتم من خلاله إدخال بيانات خاصة بالمريض و الحاضنة وذلك لتسهيل التعامل مع ملفات المرضى.

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Chapter 1

Introduction

1.1 Project Description

It's obvious that biomedical engineering technology has a great importance on the health-care field which makes our life easier and more comfortable.This is because it offers to us what we need to make it easy to the human life, the reason of being a live as much possible by development and construct of anew different equipment and tools that service these goals.

There are a lot of types of these equipment or devices with different specification usage. In This project we will have one of these equipment that have magnificent importance in health care field this device is the infant incubator.

Premature infants born before the end of a full intra uterine pregnancy, so they have some difficulties in controlling (temperature, humidity and oxygen) to this these babies who need special care to maintain a healthy body temperature, regulate oxygen concentration, also humidity level.

The care of premature new born may requires to put them in an environment in which temperature is elevated and controlled, because they are unable to regulate their own temperature, when infants are kept in a small sized house, they maintain with specific temperature range and oxygen concentration and humidity level too.

By placing an infant in an incubator doctors and nurses can set and monitor different aspects of the child's environment in order to create ideal conditions for survival. In addition to the regulating of oxygen, temperature and humidity level; incubators protect infants from pollutants and infection.

1.2 Project Objectives

In this project we will design and build an electrical system that controls the whole incubator parameters including (temperature, humidity and oxygen) by using microcontroller and special sensors to create the best environment for the growth of infants inside the incubator.

1.3 Time Plan

The time planning includes two time schedules, the first one shows what is done in the first semester and the second shows the tasks scheduling for the second semester.

Task / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Literature Review																
Design and Analysis																
Documentation																

Tab (1.3): Time Planning (first semester)

Task/Week	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Implementation																
System Testing																
Documentation																

Tab(1.3): Time Planning (second semester).

1.4 The Estimated Cost And Budget Breakdown

This section lists the overall cost of the components that will be used to implement the system.

Component	Quantity	Price
(Encoder) 74922	2	**40 NIS**
Microcontroller (MC) 8051	2	**40 NIS**
LCD	2	**50 NIS**
E-PROM (27C64)	2	**30 NIS**
TMP.Sensor LM 35	3	**15 NIS**
HUM.Sensor	2	**50 NIS**
Keybad	1	**40 NIS**
ADC 0808	2	**40 NIS**

74LS00,74LS02,74LS04	3,3,3	4,4,4 NIS
74LS373,74LS244	2,2	8,8 NIS
Switches, Relays	6,5	5,12 NIS
Buzzers	4	10 NIS
Crystals	5	5 NIS
Potentiometer	4	3 NIS
LM 324	5	5 NIS
Board	---	50 NIS
Wire Rapping	---	30 NIS
Power Supply	1	50 NIS
Resistors, Capacitors, Diodes	30,30,5	0.25,0.35,1 NIS
Heater, Fan	1,1	50,50 NIS
Extras	---	200 NIS
Total		1300 NIS

Tab(1.3): The Estimated Cost And Budget Breakdown

1.5 Risk Management

There are many risks can be occurred during implementing the system processes; determining and analyzing the system requirements, designing ,implementing and testing the whole system.

1.5.1 Technology Risk

Technology risks can be classified as hardware and software risks:

❖ Hardware risks includes :

- Malfunction of any system component.
- Some chips unavailable or cannot be obtained easily.
- Chips behaviors can be affected by environment changes.
- Interface connection Malfunctions.

❖ Software risks includes:

- The program may follow undesirable algorithm.

1.5.2 People Risks

- Illness of group members.
- Member of the team becomes unavailable for any reason.

Organizational Risks:

- The system component are very expensive to be obtained.
- The graduation projects lab is not opened for any reason.

1.5.4 Requirement Risks:

- The specified requirements are not clear.
- Risks that might occur if new changes are required in the system equirements that need major changes in the system design.

1.5.5 Risks Avoidance:

- Taking care when using hardware components and using them according to their specifications.
- Taking care of the team's member's health during the project development.
- Determining true system requirements.
- Including an extra amount of the hardware components we already have, so when any problem occurs we can find an alternative for the component we lost.
- Work as a team if any mission cannot be performed by any member for any reason other members should be helpful.

1.6 Description of Project Parts

This Project contains eight chapters, and these chapters can be summarized as the following:

Chapter 1: This chapter gives a general idea and an introduction about infant incubator, also about the whole project.

Chapter 2: Describes the premature infants and their classifications, also infants physiological test (APGAR).

Chapter 3: This chapter talks about the incubators (history, types), also the Block Diagram of the incubator.

Chapter 4: This chapter includes the control and the sensing system.

Chapter 5: Talks about the microcontroller which is (8051).

Chapter 6: Talk about the hardware and software implementation.

Chapter 7: Talk about the testing .

Chapter 8: Talk about conclusion and future work .

Chapter 2

Infants

2.1 Classification of premature infants

2.2 Infants Physiological Test

2.3 Summary

Chapter 2

Infants

Premature infants are babies born before the end of a gestation period of two hundred and sixty days, and these babies need a special care to control their problems such as temperature, humidity,and oxygen.

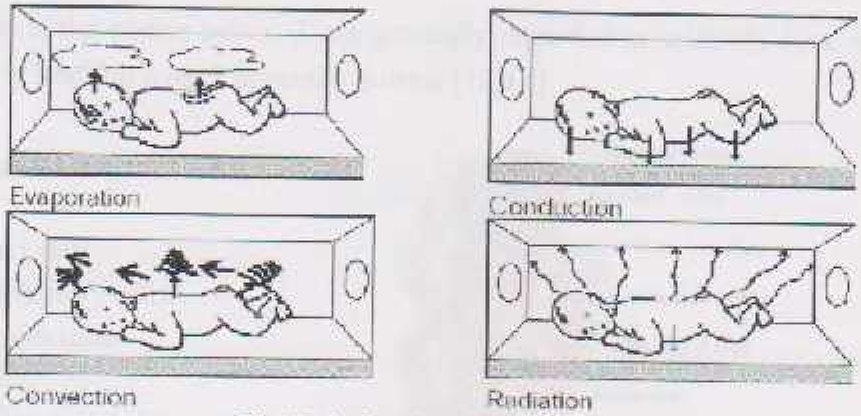
2.1Classification of premature infants

1. Premature infants, with no pathological changes.
2. Premature infants, with pathological changes, due to:
    a. Constitutional disease and chronic infections in the parents.
    b. Maternal factors influencing the fetal nutrition, such as overwork, under nourishment, and acute illnesses during pregnancy.
    c. Local conditions in the mother.
    d. Multiple pregnancies.
    e. Constitutional defects and congenital malformations in the fetus.
    f. Infants born to parents late in life.
3. Full-term infants with pathological changes [3,12].

Why premature need a special care??

Many premature infants, born before the end of a normal term(before the end of a full intra-uterine pregnancy), and consequently their organs are not fully developed, so these infants need special care untill the organs are completed, also the premature infants and full-term (younger) infant when leaving the uterus, their physiological systems are under developed making the infant vulnerable to a number of health complications [3].

- Jaundice caused by an immature liver.
- Respiratory complications caused by fragile, underdeveloped lungs.
- immature response of the nervous system to cold stress, this may cause death.
- Heat is lost via evaporative, conductive, convective and radiative means as shown in figure (2.1).



Fig(2.1): loosing temperature

In study of premature and congenitally debilitated infants at least two factors in the life history of the fetus must be considered :

1. the term of its intra-uterine life.
2. the state of its functional development at birth as evidenced by the presence or absence of an inherited disease [12].

2.2 Infants Physiological Test

The newborn is commonly assessed with the APGAR score, a quick test performed at 1 and 5 minutes after birth to determine the physical condition of the newborn as shown in fig (2.2).

- **APGAR** mean:
  - **A**ppearance: Skin color.
  - **P**ulse: Heart rate.
  - **G**rimace: Reflex irritability.
  - **A**ctivity: Muscle tone.
  - **R**espiration: Respiration [13].

- APGAR it is a simple and repeatable method to quickly and summarily assess the health of new born children immediately after the child birth.
- The APGAR score is determined by evaluating the new born baby on five simple criteria on scale from zero to two , and summing up the five values thus obtained.

❖ And if the scores below 3 are generally regarded as critically low, with 4 to 7 fairly low and over 7 generally normal [12,13].

Five categories are assessed

- Heart rate
- Respiratory effort
- Muscle tone
- Color
- Reflex irritability

Fig (2.2): APGAR test

Each of these categories is scored with 0, 1 or2, depending on the observed condition of the newborn, as shown in tab(2.1).

	Score of 0	Score of 1	Score of 2	Acronym
Skin color	blue all over	blue at extremities	normal	Appearance
Heart rate	absent	<100	>100	Pulse
Reflex irritability	no response to stimulation	grimace/feeble cry when stimulated	sneeze/cough/pulls away when stimulated	Grimace
Muscle tone	none	some flexion	active movement	Activity
Respiration	absent	weak or irregular	strong	Respiration

Tab (2.1):The five criteria of the Apgar score

2.3 Summary

It is concluded that any infant baby, who has been born before normal needs a special care, which is achivied by putting the baby in an instrument that controls his temperature this instrument is called the incubator which we will talk about in this research.

Chapter 3

Incubators

3.1 Definition

3.2 History

3.3 How it work!!

3.4 The air circulation in the incubator

3.5 Types of incubators

3.6 Block diagram of an incubator

3.7 Instrumentation

Chapter 3

Incubators

Premature infants are babies born before the end of a full – intra uterine pregnancy, so they have difficulties in controlling (temperature, humidity, and oxygen), so these babies need special conditions to adjust the temperature, regulate oxygen concentration, and humidity level.

So that very little house sized designed to fit the space and functional requirements of an infant occupant, this design called an infant incubator.

3.1 Definition

Infant incubator is a device used during the care of such in-risk infants and designed with the intent of producing environmental conditions that suites to each unique infant particular needs.

3.2 History

Keeping small babies warm swaddling with multiple layers of clothes, providing body constant with the mother.	prior to the eighteen century.
Von Ruehl warming tube	1835
First idea to construct an infant incubator	1891
First infant placed in an exhibit incubator in India	1901
A study released on regulating the infant body temperature	1907
First incubator proposed a mechanism for the additional of oxygen supplementation	1932
A report on the improved survival of a new born infant nurtured with humidity has released [1,9].	1933 ↓ Upt to day

3.3 How does it works

The mattress where the baby lies is completely enclosed by a clear plastic canopy. The temperature in the incubator is increased by a heating element below the mattress. A motor driven fan near the heater brings in fresh air through a filter and blows it post the heater, warming the air .the air is directed up through slots into the area above the mattress and circulated around. The air temperature is monitored by temperature sensor and is adjusted by controlling the current to the heater.

The incubator can also monitor the baby's skin temperature probe ,which is stuck onto the skin .The user can set the incubator to control the temperature of the baby's skin.

Oxygen supplementary can be taken in by an oxygen inlet connection where it is mixed with the fresh air through the filter.

The humidity can be increased by the use of water baths (passive humidification) or by dripping water on a heating element (active humidification). The baby is cared for through special access called arm ports [7,9].

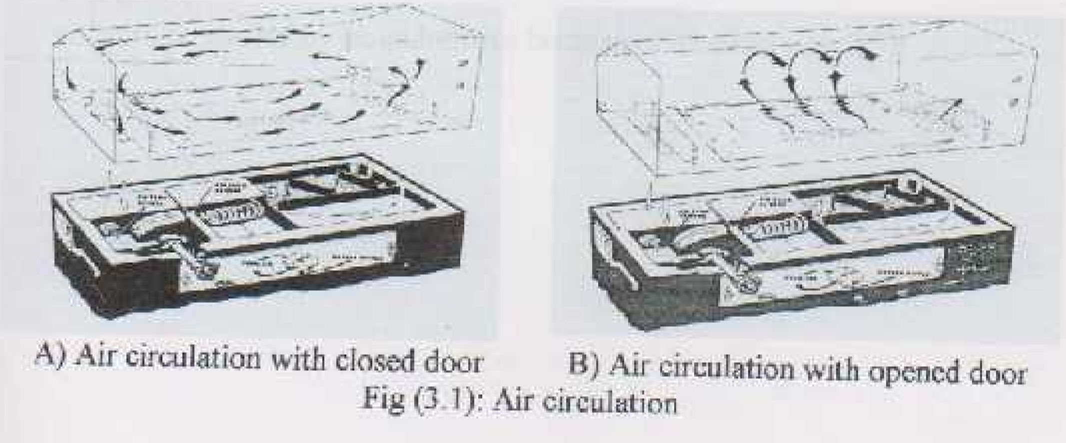
3.4 The air circulation in the incubator

The forced air circulation system of the incubator:

- Permits stable temperature control
- Uniform heat distribution
- Humidification
- Effective isolation of the infant from air born contaminants
- Control of oxygen concentration.

In the air circulation with closed door in fig (3.1-A), the circulation will be around the x- axis in order to spreed the heated air around the infant baby.

In the other hand the air circulation with opened door in fig (3.1-B) will be around the y- axis in order to keep the heated air inside the hood [6].



A) Air circulation with closed door B) Air circulation with opened door

Fig (3.1): Air circulation

3.5 Types of incubators

There are many different kinds of incubator, and they variate in the details how they are constructed, heated and controlled. Inspite of these differences, they provide a mattress for the infant to lie upon when surrounded by a warmed microclimate that is controlled by a logical system governing the amount of heat needed to keep the environmental temperature within a limited range and the types of incubators are:

1) **closed incubator**

- In this incubator the microclimate is produced within a rigid walled chamber.
- They are heated by using a fan to force air over a metallic heating coil prior to enter into the infant chamber [1].
- This type includes :

❖ **Intensive care incubator (IC):-**

- Must be found at any hospital in the intensive care unit, and emergency part, as shown in fig (3.2).

Fig(3.2): IC incubator

- It is the most important type because it provides controlled environment for (temperature, humidity, and air flow) [7].

❖ **Transport incubator:-**

- This incubator has a light and an easily movable one.
- It is safe.
- It can be carried by an ambulance because of its small size [11].

2) **Open incubator**

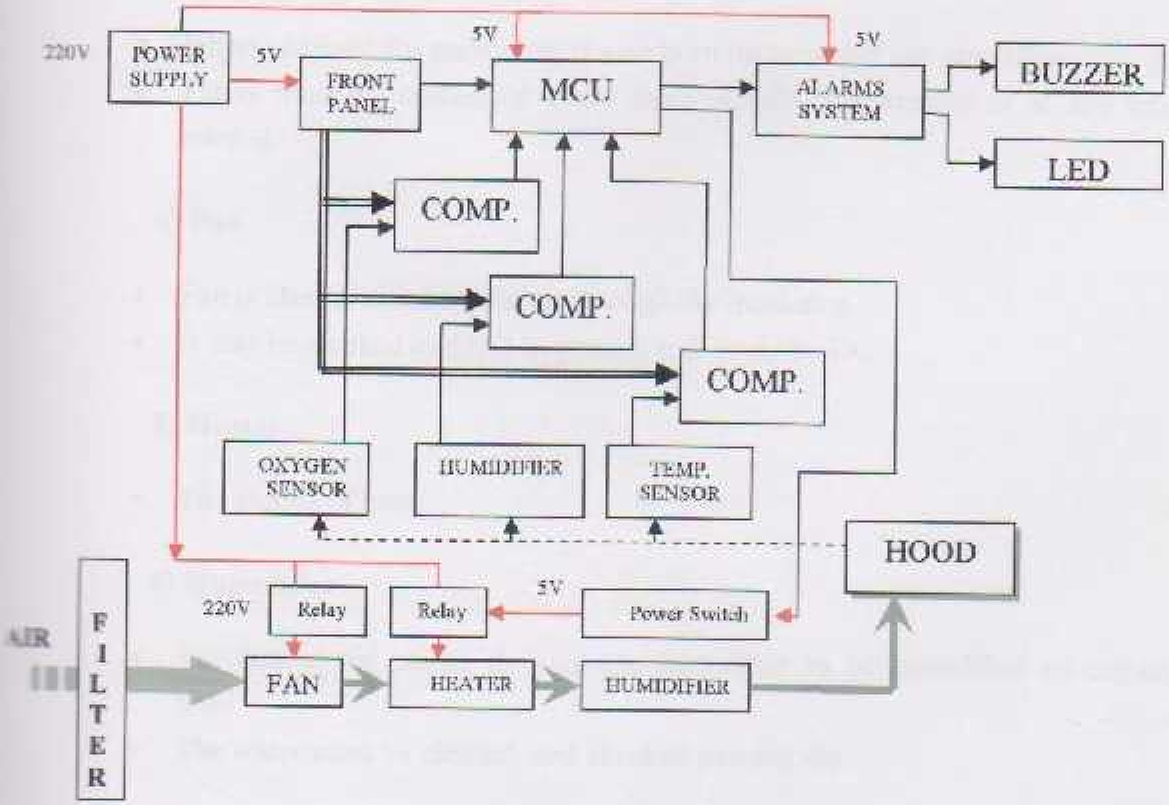
- It has no wall ,and therefor no chamber surrounding the mattress.
- They need to the be heated by using a radiant warmer focused over the mattress area [1].
- This type includes :

❖ **radiant heater**

- It is designed to provide a quick and an effective treatment for new born who suffer from extreme heat loss as shown in fig (3.3).
- It is not supplied with oxygen source.

Fig(3.3): radiant warmer

3.6 Block diagram of an incubator



Fig(3.4): Block diagram of an incubator

1) Power supply

- 220V, 50HZ.
- Supplise DC voltage to feed the electrical circuit such as 5V, 12V, 18V, 24V for IC's.

2) Front panel

- Front panel is the interface part that gives us the external controlling process on all machine variables (temperature, humidity, and oxygen).
- In front panel, we also see display and indicators, which give us feedback about the setting values.
- Also contains alarm signals in different colors (each type of alarm has a special color).

3) Filter

- Filters are used for preventing the air born bacteria and any impurities.
- Filters must be exchanged every three months, Six months or at any time needed.

4) Fan

- Fan is used to circulate the air through the incubator.
- It may be worked by (AC) in general and rarely by DC.

5) Heater

- The source of heat.

6) Humidifier

- The heated air passes through the humidifier to be humidified to certain level.
- The water must be cleaned, and checked periodically.

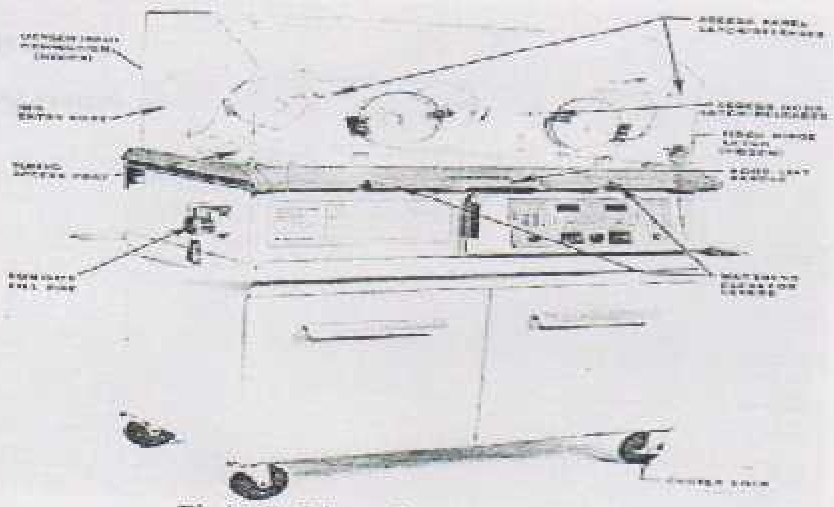
7) Processor

- Main unit that used to control data traffic into and out from the incubator.

8) Incubator

- The enclosed box which provides the infant with the controlled environment.
- It has doors for the nurses in order take care of the baby.

3.7 Instrumentation



Fig(3.5): View of an incubator

1) Hood lift handle: used to lift hood assembly for cleaning and maintenance.
2) Hood hinge latch: located on the right rear corner of the incubator, latches hood assembly in open position; released when depressed.
3) Mattress elevator levers: used to position mattress in fowler or trend elenberg position.
4) Iris entry port: provides access to infant compartment.
5) Access door release/latch: release/latches access panel.
6) Access panel release/latch: rotates to latch or release access panel.
7) Humidity fill pipe: provides means of filling humidity reservoir.
8) Tubing access port: provides routing for tubing, probe leads, etc. into infant compartment.
9) Castor lock: located on diagonal corners of cabinet stand, restricts incubator movement.
10) Oxygen input connection: located in the rear, provides connection point oxygen limited [6,7].

Chapter 4

Control and sensing system

4.1 Temperature control

4.2 Humidity control

4.3 Oxygen control

4.4 Warning alarms

4.5 Failure alarms

4.6 Sensing system

Chapter 4

Control and sensing system

To control the environment inside the hood of the incubator we have three main control circuits:-

- Temperature control.
- Humidity control.
- Oxygen control.

4.1 Temperature control

In most incubators there are two ways of controlling temperature:

- Air temperature mode.
- Skin temperature mode.

In both ways the heaters output will be proportional to the amount of heat required to maintain the desired temperature [3].

4.1.1 Air temperature mode

Incubator temperature is regulated by means of the temperature sensor located in the air path because (the control of temperature is achieved by means of a forced air circulation system) [7].

- ❖ The incubator temperature can be maintained from 22 C° to 38 C°.
- ❖ The temperature is sensed by a probe located below the desk compared with set point.
- ❖ The initial set point is preset to 35 C° ± 0.1C°, and the incubator will heat up to this temperature until the setting is changed.
- ❖ An additional sensor can be used to monitor and control the maximum air temperature and at this time an alarm is activated and the heater shut off. As shownin fig (4.1)

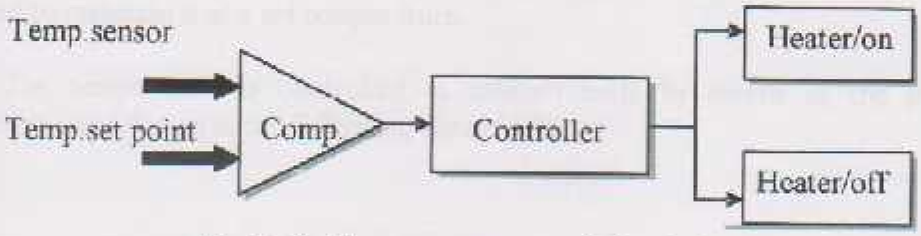


Fig (4.1): Temperature control Block diagram

4.1.2 Skin temperature mode

- The thermistor is placed against the skin of the infant, and the controller is set to maintain the infant's skin at a given temperature.
- In this mode the infant's skin temperature can be maintained at a temperature from 34.0 to 37.90 C° as selected by the user.
- In the air temperature mode the alarm is activated when temperature exceeds 39.0 and 40.0 C°.
- Skin temperature mode use more accurate and expensive probes that those used in air the temperature mode [6].

4.1.3 Temperature Regulation

- Temperature is measured in degrees. It is usually given in terms of degree celsius (C°), degrees Fahrenheit (F°), or degrees Kelvin (K°). The Celsius scale was determined such that 0C° is the freezing temperature of water and 100 C° is the boiling temperature of water (at one atmospheric pressure). The relationship between the various temperature scales are:
  - $C^{o} = 5/9(^{o}F-32)$.
  - $F^{o} = 9/5(C^{o}) + 32$.
  - $K^{o} = C^{o}-273.15$.

The temperature -273.15 C° (or 0K°) is the absolute zero. The internal body of the baby requires a constant temperature (about 37 C°) in order to function effectively. The biological system is supplied with a sophisticated control system, that keeps this temperature (the Systemic Temperature) constant in spite of vast variations in ambient temperatures and heat producing body function [6,7].

4.1.4 Block diagram

Temperature - controlled air is passed through the chamber in which the baby is located to maintain it at a set temperature.

The temperature is controlled in modern units by means of the proportional control system shown in the following figure(4.2):

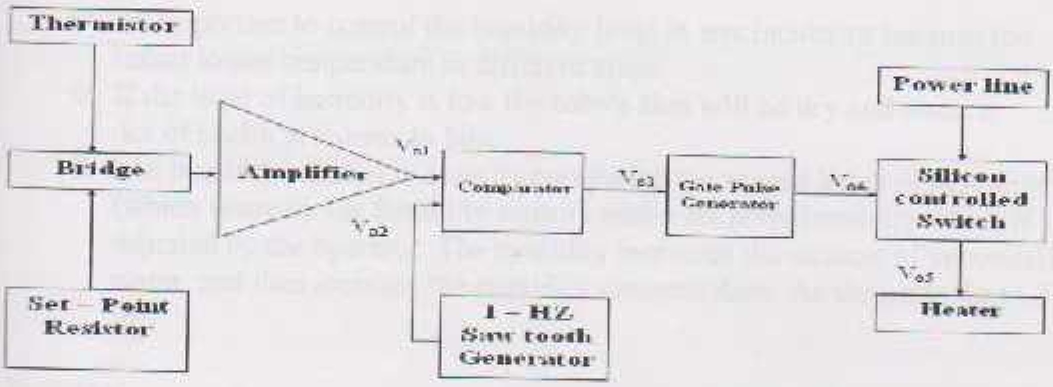


Fig (4.2): block diagram of temperature control circuit.

The temperature in the air supply line varies a thermistor resistance that is compared with a fixed resistance that corresponds to the set temperature. If the temperature of the air entering the infant's chamber is lower than the set, temperature power is applied to the heater to correct this difference in the proportional controller system, the amount of power applied to the heater is proportional to the difference between the actual air temperature and the set point, this means that the amount of power decreases as the temperature approaches the set point.

The control system uses the thermistor in a bridge circuit with the set point resistance as another arm of the bridge. The bridge output is amplified, giving the voltage V_1 at the output, which is proportional to the difference in temperature between the thermistor and the set point .a 1-HZ low frequency saw tooth generator produce voltage V_2 having an amplitude equal to the maximum value of V_1 over which proportional control is desired, then V_1 and V_2 are compared in a comparator circuit that produces an output voltage V_3 during that period of time when V_1 is greater than V_2.

This voltage, in turn, controls a gate – pulse generator that produces turn-on pulses for the silicon –control switch while V_3 is high. The silicon control switch allows the power - line voltage to be applied to the heater of the incubator during the period of time when V_1 is grater than V_2.

Thus, as the temperature approaches the set point V_1 decreases toward zero. This reduces the interval over the saw tooth cycle during which heater power is applied, there by reducing the output of the heater [7,9].

4.2 Humidity control

- It's important to control the humidity level in any incubator because the infant losses temperature in different ways.
- If the level of humidity is low the baby's skin will be dry and cause a lot of health problems to him.
- The humidity control is done by comparing the sensed value of humidity (which sense by the humidity sensor) with a set point humidity which is adjusted by the operator. The humidity incraeses the amount of vaporization water, and then increase the humidity concentration. As shown in fig (4.3) [6].

Fig (4.3): Humidity control Block diagram

4.2.1 Definition

- Humidity is defined as the percent of the water molecules that carried by the air.
- The passive humidifier is active whenever the water is in the fill tray (champer).

4.2.2 Humidity reservoir

Humidity champer in the incubator must be completely drained and refilled daily with distilled water. This is shown in figure (4.4).

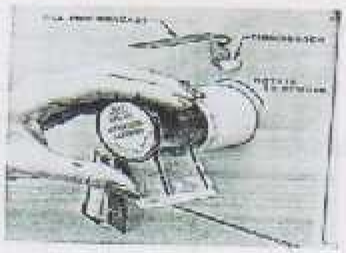


Fig (4.4): humidity champer.

4.2.3 Humidity probe

Humidity transducers principle is the capacitive changing types that mean any change in humidity will cause a change in capacitive and the change in capacitive will be translated to a change in voltage using bridge circuit.

Fig (4.5): humidity transducer.

4.3 Oxygen control

- The air in the room must be (approximately 35 lpm) and this can be handled through the air/oxygen intake filter by means of the motor driven impeller on the controller.
- Since the amount of the room air is controlled by the impeller/filter, the characteristics and the amount of oxygen is controlled by the flow meter setting. Predictable oxygen concentration within the incubator can be attained.
- When oxygen flow exceeds 8 lpm, a valve within the oxygen inlet housing is activated to restrict air intake so that higher oxygen concentrations can be achieved without excess oxygen flow. At 12 lpm maximum air intake restrictive is achieved.
- The total flow of fresh and recirculated air is directed post the air flow sensor and around the heater with a predetermined portion being directed over the humidity reservoir for humidifier.As shown in fig (4.6) [9].

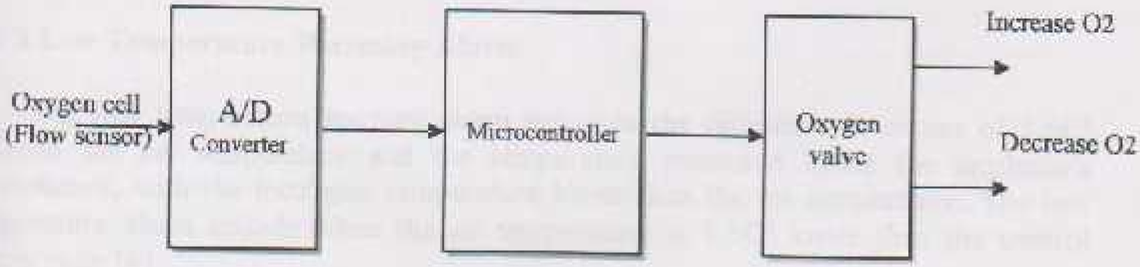


Figure (4.6): Oxygen control Block diagram

4.4 Warning alarms

4.4.1 High temperature warning alarm

The high temperature alarm indicates a difference in excess of 1.5 C° between the set temperature and the temperature measured inside the incubator environment, with the incubator temperature higher than the set temperature. The high air temperature alarm sounds when the air temperature is 1.5C° above the control temperature setting [6,9].

The high air temperature alarm has two modes of operation:

1) The alarm mode

Which indicates a possibly dangerous condition, in this mode the air temperature alarm LED will flash and the audible alarm will sound. This mode indicates an alarm condition in which the air temperature has risen unexpectedly and this may endanger the infant.

This may be caused by the following conditions:

- The hood door has been left open for an extended period of time.
- The incubator is in direct sunlight.

The incubator should not be left in direct sunlight .This is due to the fact that the sunlight will heat up the air temperature inside the hood, which may cause the air temperature to rise to a dangerous level even when the incubator 's heater is off.

2) The indication mode

This indicates that the air temperature is too high. in this mode the high air temperature alarm led will flash but the andible alarm will not sound .The high temperature alarm led is only being used as a warning that the temperature is too high .This condition occurs when the control temperature has been lowered but the incubator has not yet cooled to the desired air temperature

4.4. 2 Low Temperature Warming Alarm

The low temperature warning alarm indicates the difference in excess of 1.5C° between the set temperature and the temperature measured inside the incubator's environment, with the incubator temperature lower than the set temperature. The low temperature alarm sounds when the air temperature is 1.5C° lower than the control temperature [6].

The low air temperature alarm has two modes of operation:

1) The alarm mode

This indicates a possibly dangerous condition. in this mode the air temperature alarm LED will flash and the audible alarm will sound. This mode indicates an alarm condition in which the air temperature has risen unexpectedly which may endanger the infant.

This may be caused by the following condition:

- The hood door has been left open.
- A number of portholes have been left open.

2) The indication alarm

This indicates that the air temperature is too low. In this mode the low air temperature alarm LED will flash but the audible alarm will not sound .the low temperature alarm LED is only being used as warning that the temperature is too low. This condition occurs when the control temperature has been raised but the incubator has not heated to the desired air temperature yet.

4.4.3 Opening hood warning alarm

The opening hood warning alarm indicates that the hood has been opened; this alarm can be detected by audible alarm [11].

4.5 Failure alarms

4.5.1 Air circulation failure alarm

The air circulation failure alarm indicates that the air flow inside the incubator has been interrupted A sensor monitors the temperature at the heater. If the heater begins to overheat it means that the incubator is unable to circulate hot air a way from the upper incubator region. The interruption of the air flow could be caused by the following:

- The fan has gone suddenly off.
- The front air outlet has been blocked by an obstacle.
- The rear air inlet has been blocked by an obstacle.
- The inner cover has not been inserted properly [1,5].

4.5.2 Temperature Sensor Failure Alarm

The temperature sensor failure alarm indicates that the air temperature sensor is malfunctioning and the incubator is getting erronous readings from this sensor. This must be replaced or repaired immediately as the system cannot control temperature without it. This alarm is indicated by the sensor failure alarm LED flashing [9].

4.5.3 System Failure Alarm

The system failure alarm indicates that a critical fault condition has occurred in the electronics. This alarm can be instigated by the following two condition:

- The incubator electronics had a fatal error.
- The air temperature is above 38.5 C° [9].

4.6 Sensing system

An electrical sensor is a device that converts a quantity or an energy form into an electrical output signal. The form of an output signal whether it is an AC or a DC signal whether the output is a change in resistance or a change in capacitance, and whether the signal is digital or analage. The sensing system of the incubator consists of temperature, humidity and oxygen sensor [2].

4.6.1 Temperature sensor

The thermometer mercury is most known and common biomedical temperature transducer.

4.6.1.1 Advantages of mercury thrermometere

- It is a temperature to displacement.
- It is relativly inexpensive.
- Easy to use.
- It's output not electrical.

But this type of sensor gives electric output and therefore not used whenever automatic temperature regisrtration or control is required. There are many types of such transducers; used in biomedical field such as: LM35 temperature sensor, lock fig (4.7) [2,8].

Fig (4.7) LM35 sensor

4.6.1.2 Features of LM35 sensor

- The LM35 are precision integrated circiut temperature sensor.
- It is output voltage is linearly proportional to the celsius temperature.
- It is calibrated in kelven °
- The LM35 does not require any external calibration to provied typical accuracies of ± 1/4 C° at roam temperature, and ± 3/4 C° over a full -55 to 150 C° temperature range.
- Low cost due to the wafer-level tinity.
- Low impedance output 0.1 ohm for 1mA load.
- Linear output and precise inherent calibration make interfacing to control circiutry easily.
- *It can be used with single power supplies or with plus and minus supplies.*
- low self heating 0.08 C° in still air.
- Lower than 60 mA current drain.

- Operates within a voltage rang from 4 to 30 volts [8].

Operating Temperature Range as shown in tab (4.1):

Operating Temperature Rating	To +100 Deg C, -40 to +110 Deg C, -55 to +150 Deg C
Sensor Grain (Tmin to Tmax)	10 mV/Deg C
Supply Voltage Range	+4V to +30V
Min. Accuracy	-2 Deg C, -1.5 Deg C, -1 Deg C
Max Accuracy	+2 Deg C, +1.5 Deg C, +1 Deg C
Temp. Reselution	Analog Output

Tab (4.1) Parametric for LM35

4.6.2 Oxygen sensor

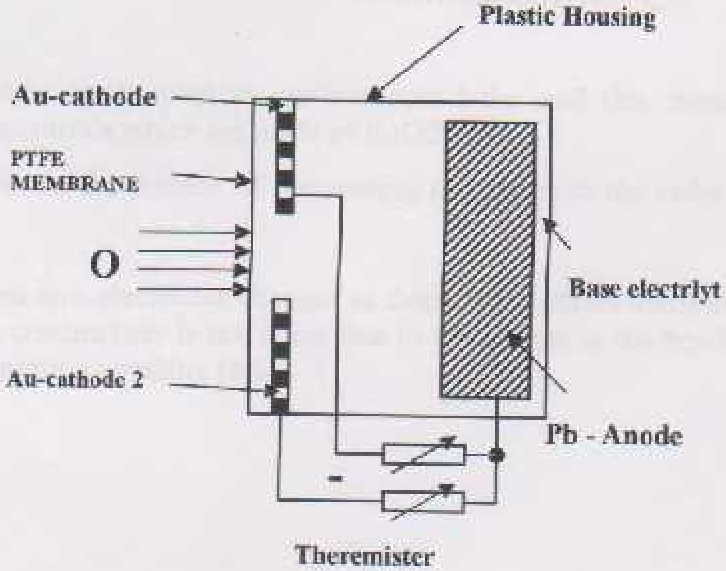
There are two independent O_2 sensor capsules which are enclosed in the environmental sensor.

The cell consists of a capsule including the electrolytes and the gold cathode with the teflon membrane.

4.6.2.1 The construction of O2 sensor

- Two gold cathodes.
- Teflon membrane.
- Plastic housing.
- Base electrolytes.
- Pb- anode.
- Thermister.

As shown in fig (4.8)



Fig(4.8)Functional Principle of the O2 Sensor

4.6.2.2 The princible operation of the O2 sensor

- The oxygen to be measured diffuses a teflon membran, and then the oxygen react with the gold cathodes, and produce oxide lead, and water at the lead anode. This reaction requires a specific voltage which is proportional to the oxygen partial pressure.
- Then the thermister is switched in parallel to sensors which correct the measurement voltage in connection with the internal resistance.
- The oxidaton process limits the life of the sensor. The surface of the electrodes determines the internal rersistance the internal is 700 Ω at normal conditions, the distance detemins the oxygen diffusion velocity [2,3].

4.6.3 Humidity sensor

- The Humidity sensor is designed for measuring the range of relative humidity between 10% and 90%.
- The Humidity Sensor contains a capasitive humidity sensor and evaluation stretched membrane of anon conductive foil coated in both sides with the membrane and coating from respectively the dielectric of aparallel pale capacitor.
- The output voltage is calculated by:

$$V_{humidity} = \frac{7.1}{relativehumidity(\%) + 1.5V}$$

- The sensor element is constructed in amricoscopic holes and this element sandwished by two electrods which are made of RuO2.
- The size of the holes on the surface of the sensing element is in the order of 1μm or less.

The conductivity between two electrodes changes as these holes attract miostares, and the rate of change of the conductivity is not linear due to the change in the hmidity and it requires to have compensation amplifier [6,8].

Chapter 5

Microcontroller

5.1 Features of 8051 Microcontroller

5.2 The Pins On 8051 Microcontroller

Chapter 5

Microcontroller

Amicrocontroller is an entire computer manufactured on a single chip. Microcontrollers are usually dedicated devices embedded within an application. For example, micricontroller are used as engine controllers in automobiles and as exposure and focus controllers in cameras. In order to serve these applications, they have a high concentration of on-chip facilities such as serial port, parallel input-output ports, timers, counters, interrupt control, analog-to-digital converters, random access memory, read only memory , atc.The I/O, memory, and on-chip peripherals of a microcontrollers are powerful digital processors, the degree of control and programmability they provide significantly anhances the effectiveness of the application [4].

5.1 Features of 8051 Microcontroller

- 8-bit CPU optimized for control applications.
- Extensive Boolean processing (single-bit logic) capabilities.
- 64K Program Memory address space.
- 64K Data Memory address space.
- Up to 64K bytes of on-chip Program Memory (ROM).
- 128 byte of on-chip Data RAM.
- 4, 8 bit wide, port outputs (byte or bit addressable).
- 4, 8 bit wide, port inputs (byte or bit addressable).
- 6-source/5-vector interrupt structure with two priority levels priority levels .
- Two 16-bit timer/counters [4,5].

These features are shown in the Fig (5.1).

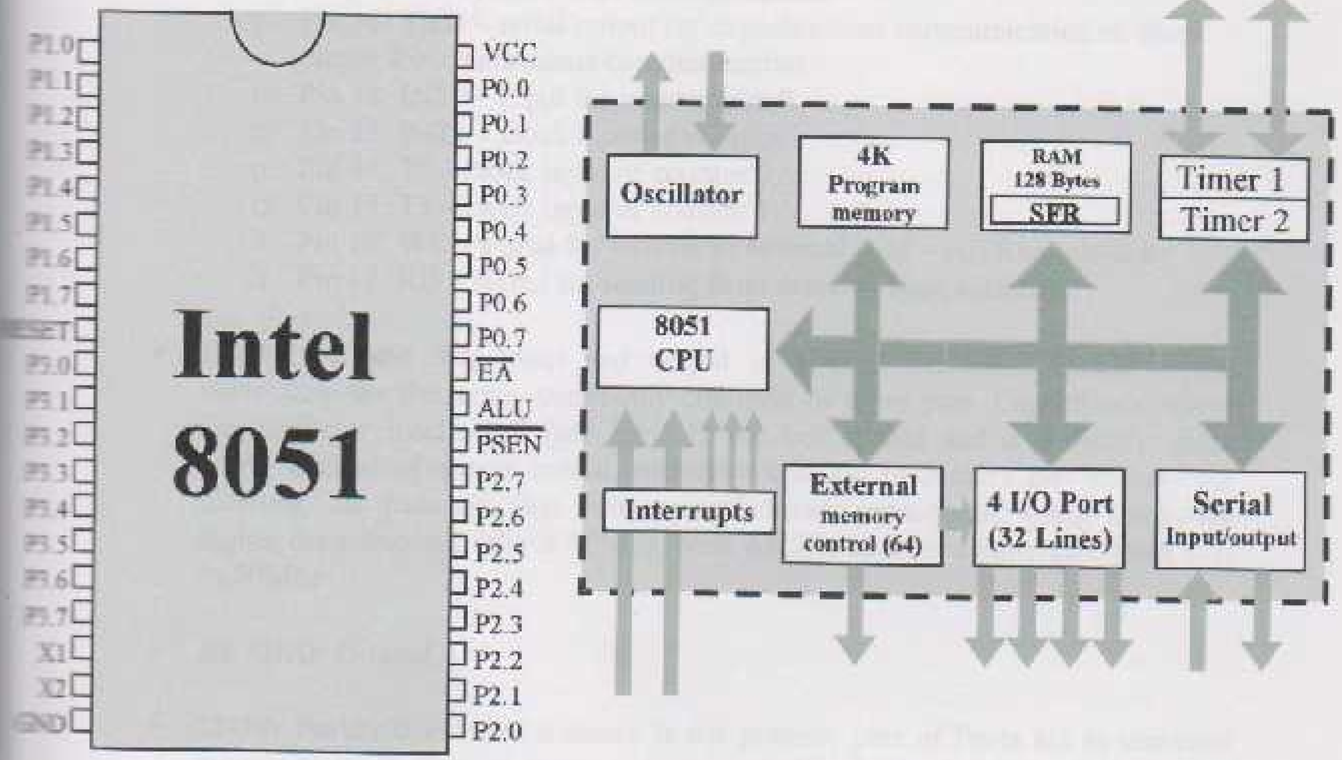


Fig (5.1): 8051 Microcontroller block diagram.

5.2 The Pins On 8051 Microcontroller

- **1-8: Port 1;** Each of thses pins can be used as either input or output according to your needs. Alos, pins 1 and 2 (P1.0 and P1.1) have special functions associated with time 2.

- **9: Reset Signal;** high logical state on this input halts the MCU and clears all the registers. Bringing this pin back to logical state zero starts the program new as if the power has been turned on. In another words, positive voltage impulses on this pin resets the MCU. Depending on the devices's purpose and environs, this pin in usually connected to the push-button, rest-upon-start circuit or a brown out reset circuit. The image shows one simple circuit for safe reset-upon-start circuit or a brwon out reset circuit. The image shows one simple circuit for safe reset upon starting the controller. It is utilized in situations when power fails to reach its optimal voltage.

- **10-17: Port3**; As with Port1, each of these pins can be used as universal input or output. However, each pin of Port3 has an alternative function:
  - Pin 10: RXD – serial input for asynchronous communication or serial output for a synchronous communicattion.
  - Pin 11: TXD – serial output for asynchronous communication or clock output for synchronous communication.
  - Pin 12: INT0 – input for interruption 0.
  - Pin 13: INT1 – clock input of counter 1.
  - Pin 14: T0 – clock input of counter 0.
  - Pin 15: T1 – clock input of counter 1.
  - Pin 16: WR – signal for writing to external (add – on) Ram memory.
  - Pin 17: RD – signal for reading from external Ram memory.

- **18-19: X2 and X1**; Input and output of internal oscillator. Quartz crystal controlling the frequency commonly connects to these pins. Capacitance within the oscillator mechanism (see fig 5.1) are not critical and is normally about 30pF. Instead of quartz crystal, miniature ceramic resonators can be used for dictating the pace. In that case, manufacturers recommend using somewhat higher capacitancees (about 47 pF). New MCUs wrok at frequencies from 0Hz to 50Mhz+.

- **20: GND**; Ground.

- **21-28: Port2;** If external memory is not present, pins of Ports act as universal input/output. If external memory is present, this is the location of the higher addres byte, I.e. addresses A8 – A15. It is important to note that in cases when not all the 8 bits are used for addressing memory (i.e. memory is smaller than 64KB), the rest of the unused bits are not available as input/output.

- **29: PSEN**; MCU activates this bit (brings to low state) upon each reading of byte (instructions) from program memory. If external ROM is used for storing the program. PSEN is directly connected to its control pins.

- **30: ALE**; Before each reading of the external memory, MCU sends the lower bytes of the address register (sddresses A0 – A7) to port P0 and activates the output ALE. External register (74HCT373 or 74HCT375 circuits are common), memorizes the state of the port P0 upon receiving a signal from ALE pin, and uses it as a part of the address for memory chip. During the second part of the mechanical MCU cycle, signal on ALE is off, and port P0 is used as Data Bus. In this way, by adding only one cheap integrated circuit, data from port can be multiplexed and the port simultaineuosly used for transferring both addresses and data.

- **31: EA**; Bringing this pin to the logical state of zero (mass) designates the ports P2 and P3 for transferring addresses regardless of the presence of the internal memory. This means that even if there is a program loaded in the MCU it will not be executed, but the one from the external ROM will be used instead. Conversly, bringing the pin to the high logical state causes the controller to use both memories, first the internal, and then the external (if present).

- **32-39: Port 0**; similar to part 2, pins of 0 can be used as universal input/output, if external memory is not used, P0 behaves address output (A0-A7) when ALE pin is at high logical level, or as data ouptut (Data Bus) when ALE pin is low logical level [4,5].

- **40: VCC**; Power +5V

Input – Output (I/O) Ports

Every MCU from 8051 family has 41 I/O ports of bits each. This provides the user with 32 I/O lines for connecting MCU to the environs. Unlike the case with other controlers, there is no specific SFR register for designating pins as input or output. Instead, the port itself is in charge: 0=output, 1=input. If particualr pin on the case is needed as output, the apporpriate bit of I/O port should be cleared. This will generate 0V on the specified controler pin. Similarly, if particular pin on the case is needed as input, the appropriate bit of I/O port should be set. This will designate the pin as input, generating +5V as a side effect (as with every TTL input).

Port 0

Port 0 has two fold role: if external memory is used, it contains the lower address byte (addresses A0 – A7), otherwise all the bits of either input or the output. Another feature of this port comes to play when it has been designated as output. Unlike other ports, Port 0 lacks the "pull up" resistor (resistor with +5V on one end). This seemingly insignificant change has the following consequences:

- When designated as input, pin of the port 0 acts as high impedance offering the infinite input resistance with no "inner" voltage.
- When is designated as output, pin acts as "open crain". Clearing a port bit grounds the appropriate pin on the case (0V). Setting a port bit makes the pin act as impedance. Therefore, to get positive logic (5v) at output, external "pull up" resistor needs to be added for connecting the pin to the positive pole.

Therfore, to get one (5V) on the output, external "pull up" resistor needs to be added for connecting the pin to the positive pole.

Port 1

This is "true" I/O port, devoid of dual function chracteristics for Port 0. Having the "pull up" resistor, Port 1 is fully compatible with TTL circuits.

Port 2

When using external memory, this port contains the higher address byte (addresses A8 – A15), similar to port 0. otherwise, it can be used as universal I/O port.

Part3

Beside its role as universal I/O port, each pin of port 3 has an alternative function, In order to use one of these functions, the pin in question has to be designated as input, i.e. the appropriate bit of register P3 needs to be set. From a hardware standpoint, Port3 is similar to port 0.

As can be seen from the individual descriptions of the ports, they all share highly similar structure. However, you need to consider which task should be assigned to which port. For example: if utilizing port as output with high level (5V), avoid using Port 0 as its pins cannot produce high logical level without an additional resistor connected to +5V. If using other port to a same end, bear in mind that built-in resistor have relatively high values, producing the current limited to few hunders of amperes as pin output [4,5].

Chapter 6

HARDWARE AND SOFTWARE IMPLEMENTATION

6.1 8051 MCU

6.2 Key board

6.3 Liquid Crystal Display (LCD)

6.4 Analogue-to-Digital converter (ADC)

6.5 Power supply unit

6.6 Software design

6.7 Graphical user interface

Chapter 6

HARDWARE AND SOFTWARE IMPLEMENTATION

6.1 8051 MCU

Designing the MCU basically depends on system requirement such as determine the external Interfacing units with the MCU and the methods used to transfer data between the units that Connected to the MCU.

Because the control unit of the infant incubator always contains the basic components of the Microcomputer such as the key board and liquid Crystal Display (LCD), so designing the controlled Unit is similar to the designing of the microcomputer unit.

We can separate the designing operation into the following parts:

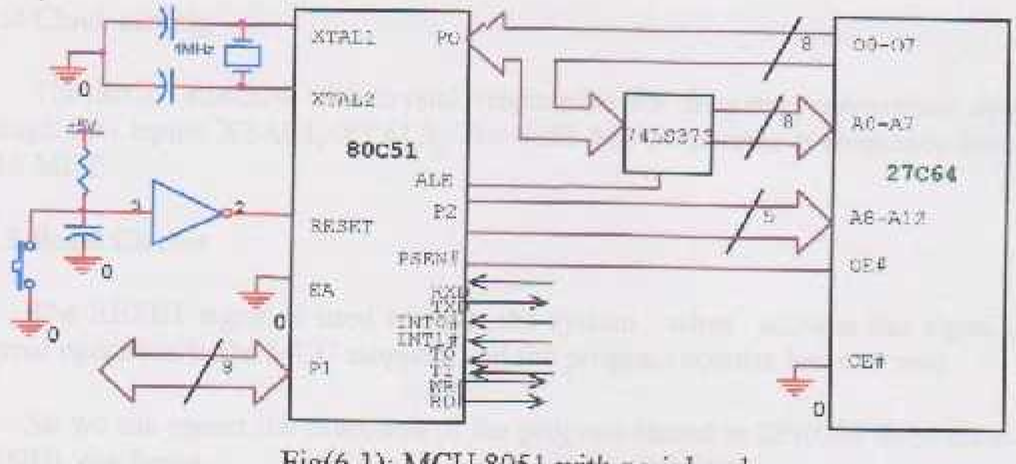
- Data and Address Buss.
- Control signals.
- I/O PORTS.
- Clock Circuit.
- Reset Circuit.

6.1.1 Data and Address Buss

To use the external memory in the MCU we use the first port (port 0) for transferring data and the lower order byte, the transferring data occur through the first port by two phases, in the first phase we transfer the the lower order byte when the signal address latch enable (ALE) is active low and in the second phase we transfer the data when the signal ALE is active high.

So we must use octal latch to latch the lower order byte and transfer the data from the MCU to EPROM, The high order byte is transferred through the third port (port 2).

Figure 6.1 shows the interface between octal latch 74LS373and MCU.



Fig(6.1): MCU 8051 with peripherals

6.1.2 Control Signals

8051 microcontroller unit contains a set of control signals that exit from the forth port (port 3).

MCU contains three control signals to control the memory, RD# signal used to activate data read process from the RAM, WR# signal used to activate data write process, which comes from the MCU to the RAM, and the third signal is PSEN# that used to activate read process from the EPROM.

These three signals are active low signals that mean it works when the input signal logic is zero.

Because there is a signal to activate reading process for each type of memory, so MCU can support external RAM reads to 64 k byte and external ROM of 64k byte, Also MC contains signals to connect external units with the peripheral.

There are two external signals for interrupts INT0#, INT1# and external signals to increase the value in each counter T0, T1.

Two signals for the serial port TXD, RXD. These signals can be used to control Input/Output lines which can be determined by special register in MCU.

6.1.3 I/O ports

There are 4 I/O ports in 8051 MCU, These lines are used for input and output when using internal ROM and when using external ROM we used three ports to interface the EPROM with MCU, *port 0, port 1, port 3, The second port (port1) used for* input and output operation, this port transfer data rather in bytes or in bits.

6.1.4 Clock circuit

The MCU attached with crystal responsible for frequency generation operation through two inputs XTAL1, XTAL2, The 8051 MCU operates at frequency between 2 to 16 MHZ.

6.1.5 Reset Circuit

The RESET signal is used to reset the system. when activate this signal all the internal operation in the MCU stopped, and the program counter become zero

So we can repeat the execution of the program stored in EPROM from the address (0000H). see figure ……

6.1.6 EPROM

This kind of memory used to store the data .the size of this memory is 8KB, that means it need 12 address lines to interfacing it with the MCU, The signal PSEN# of the MCU connected to the signal OE# of the EPROM to activate the reading from the EPROM.

6.2 Key board

We used MM74C922 encoder to interface hexadecimal key board, this encoder contains 4 pins X1-X4 connected with the row lines in the keyboard. And 4 pins Y1-Y4 Connected with columns lines in the keyboard, The signal DA in the encoder connect to one of the interrupts of the 8051 MCU, figar6-2 shows the interface between the key board and MCU.

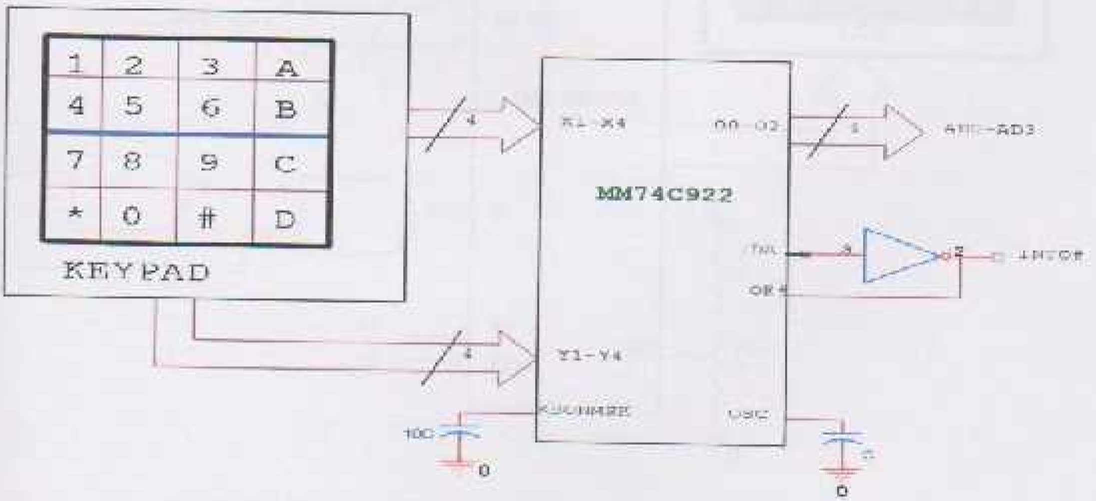


Fig (6.2): the interface of MM74C922 with 8051 MCU.

6.3 Liquid Crystal Display (LCD)

Figure 6-3 shows a diagram for interfacing LCD Hitachi HD44780 with the 8051 MCU, LCD module consists of 2 lines and 16 characters (2x6). We use two address lines to address LCD module with MCU.

To determine the process of transmission and receive of data between each controller, The controller has two kind of eight bit registers: the instruction register (IR) and the data register (DR).

Register select (RS)is a signal used to select between (IR) and (DR) in LCD module, To transmit or receive data from or to LCD controller we use R/W to select between read write processes.

To activate read / write process from LCD we connect E signal in LCD with WR#, RD# control signal in MCU, and one of the address line. LCD is considered one of the slow peripheral devices, so we must in account the timing diagram necessary for the LCD module through read/write process.

And to achieve the synchronization between the LCD and MCU we must decrease the clock time of MCU to synchronize with time variable that needed for LCD.

And we must add the necessary time delay to make sure that the LCD controller not busy before making any write signal to the LCD.

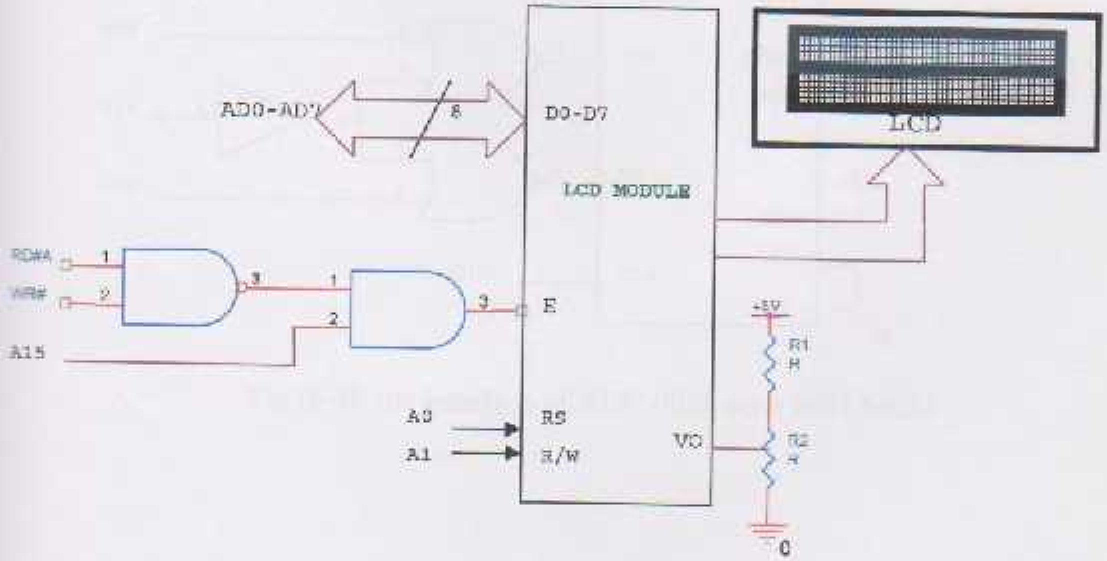


Fig (6.3): the interface of LCD with 8051MCU

6.4 Analogue-to-Digital converter (ADC):

This type of converter is used to convert analogue data to digital values, Figure 6.4 shoes a diagram interfacing an 8 bit ADC with 8051 MCU, Start conversion (SC), end of conversion (EOC) are two signals used for interfacing.

To start conversion process MCU send start signals SC to the ADC through the activation of WR# to the active address channel of the 8bit ADC.

After that the MCU wait until the reaching of EOC which means End of conversion process, the MCU start the reading of data from the ADC temporary register by activation of reading process from the address of active channel of the ADC, to use the interrupt method for interfacing of ADC with MCU we connect EOC.

Signal to one of the external interrupt request terminal in MCU، but in case of using continuous conversion mode we connect SC or START signals with EOC signal in ADC, And produce a start conversion pulse directly after switching MCU on.

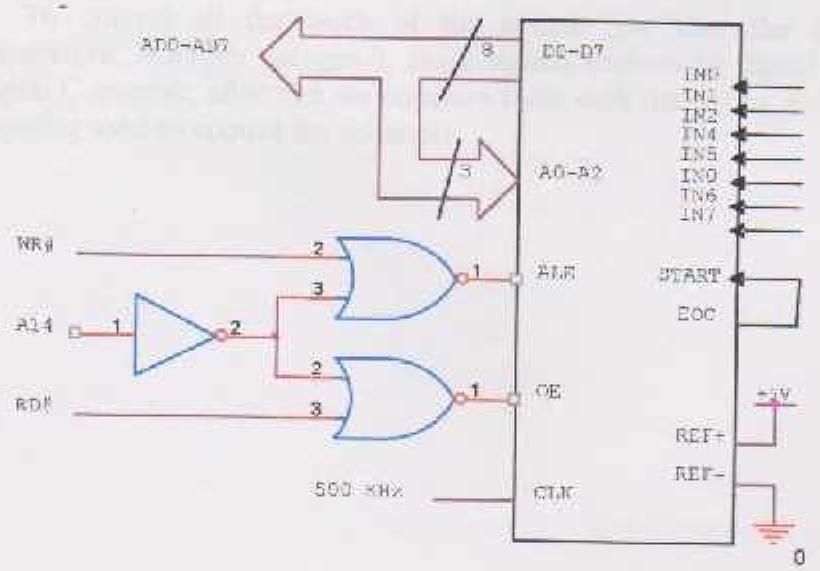


Fig (6.4): the interface of ADC 0808 with 8051 MCU

6.5 Power supply unit

The power supply converts AC voltage to DC voltage . it supplies the control circuit with 5 and 12 voltages.

The power supply unit consist with the following devices:

- Transformer .
- Rectifier .
- Filters .
- Regulators .

6.6 Software design

Software plays the main role in developing control system . it used to operate all the work of the system , in our project can be implemented in low level language (assembly language), it's stored in EPROM by using EPROM programmer in the laboratory .

To control all the work of the system ,we read the input sensors signal (temperature ,humidity ,oxygen), these signals convert to digital by the Analog To Digital Converter, after that we compare them with the setting points, the result of the comparing used to control the actuators.

6.6.1 Temperature Control Flowchart

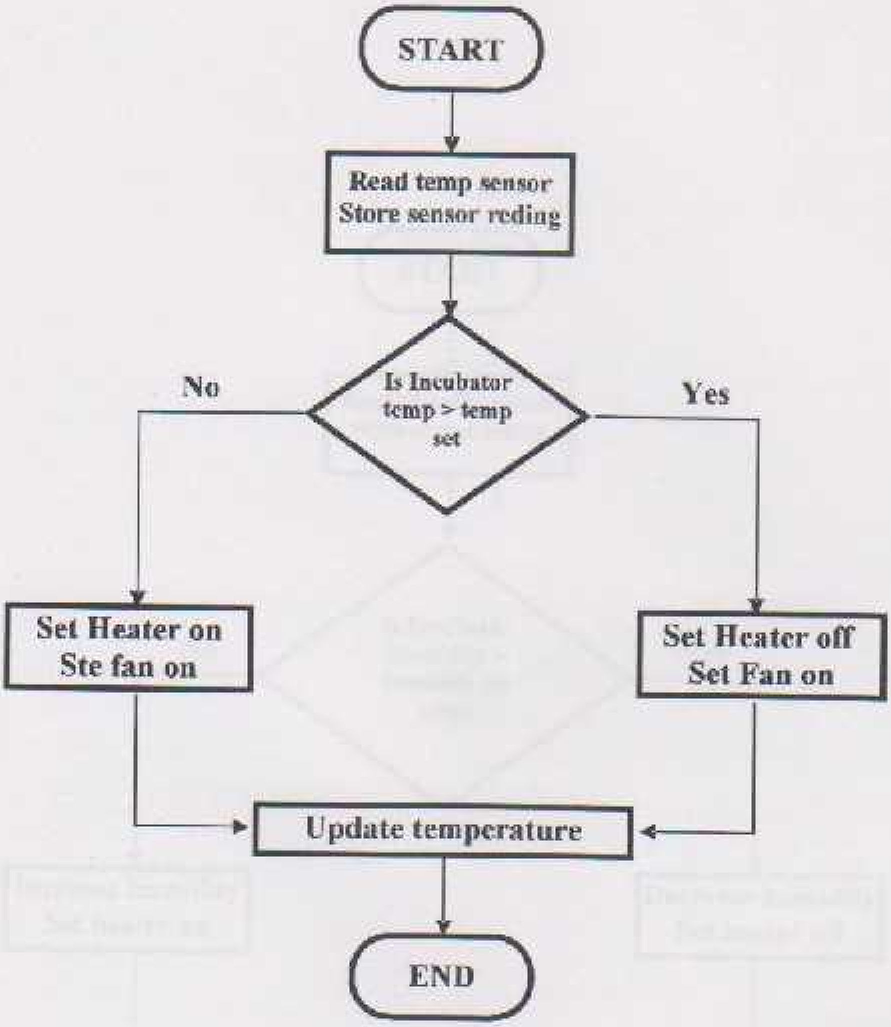


Fig (6.5): Temperature Control Flowchart.

6.6.2 Humidity Control Flowchart

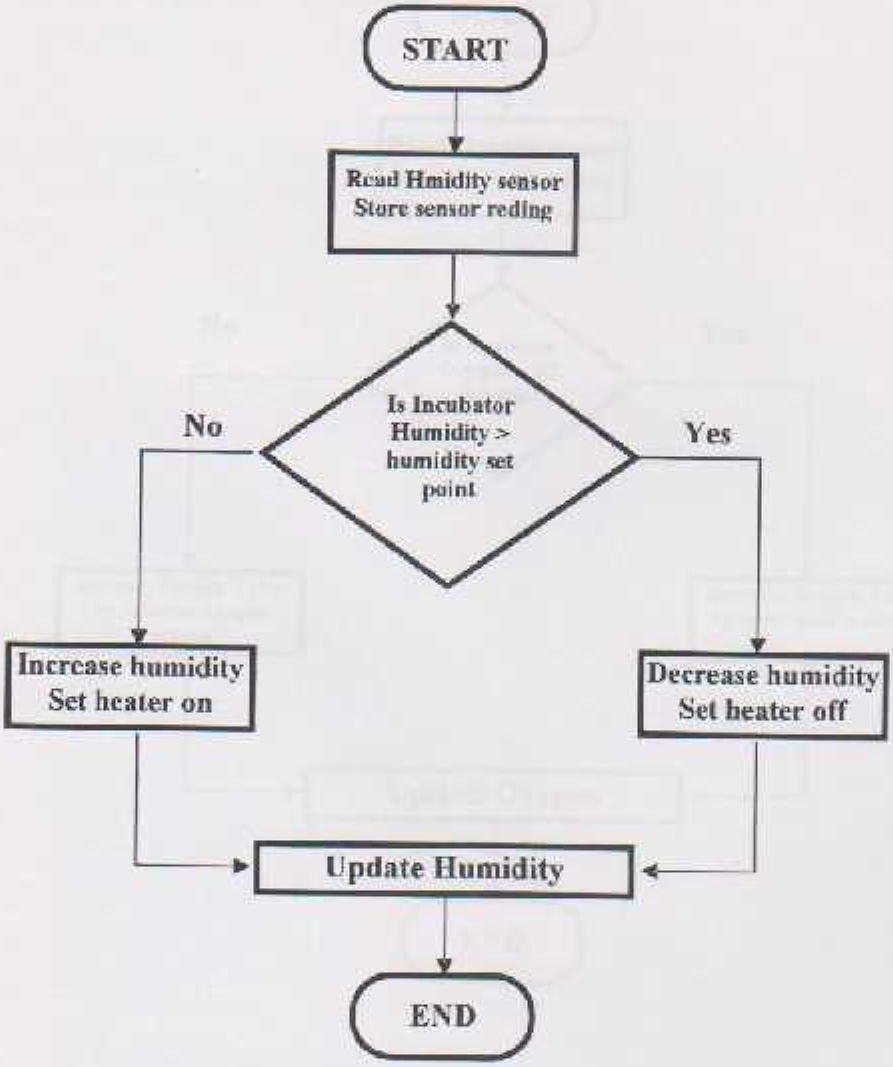


Fig (6.6): Humidity Control Flowchart.

6.6.3 Oxygen Control Flowchart

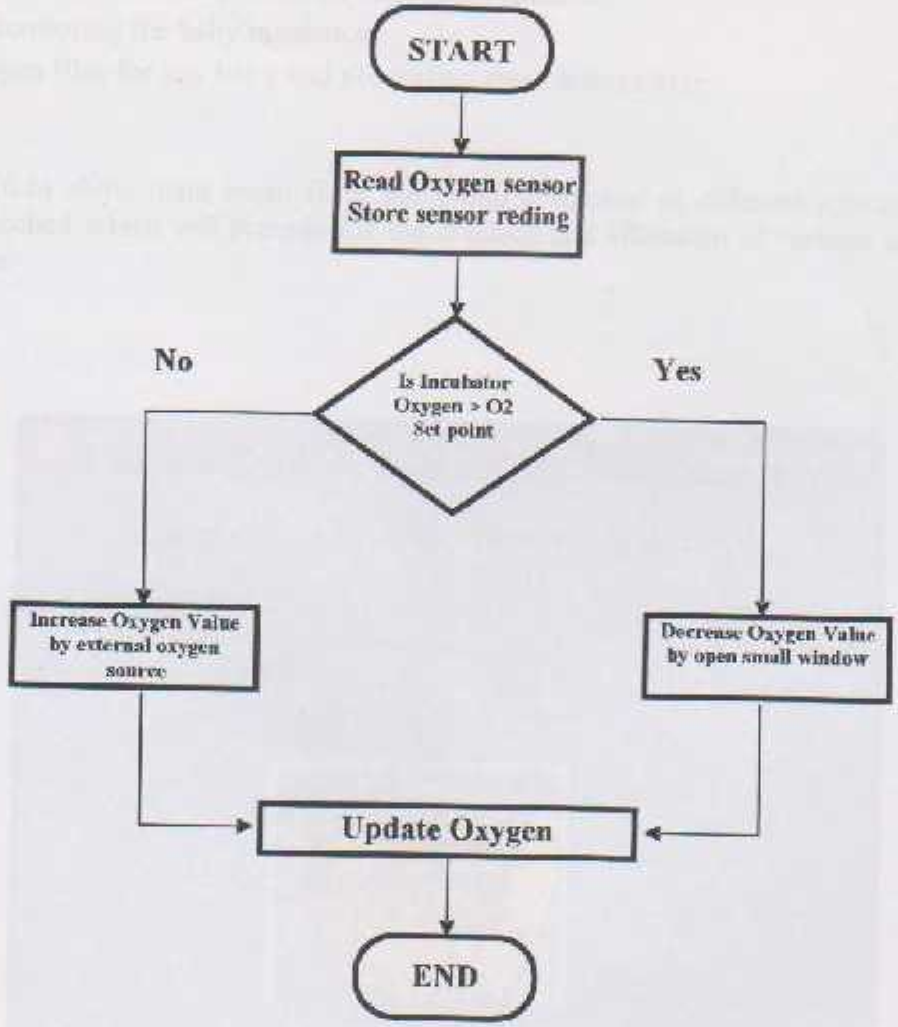


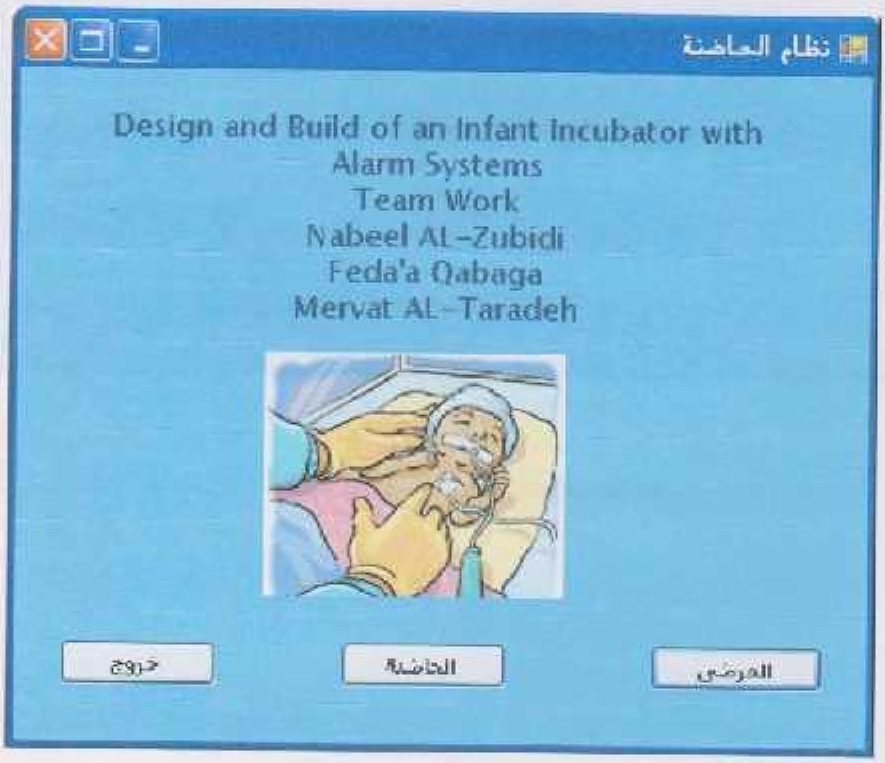
Fig (6.7): Oxygen Control Flowchart.

6.8 Graphical user interface

The infant incubator computer system has a user interface that allows:

- Creation and modification of the system function.
- Monitoring the baby incubator.
- Open files for any baby and processing there information.

Fig(6.8) show main menu from this menu a number of different editors options can be lunched which will provide for the creation and alteration of various aspects of the system.



Fig(6.8) The main menu

6.8.1 The incubator window:

In this menu all information that needed in calculation to find the suitable incubators variable value.

As shown in fig(6.9), incubator number, baby number, temperature, humidity, and oxygen value entered.

Fig(6.9) The incubator window

6.8.2 The patient window:

In this window include information's a bout the baby , as shown in fig(6.10) the baby name , age , sex , and address.

Fig(6.10) The patient window

Also this window include data a bout the date of enter the hospital , and the date of exist.

Chapter 7

TESTING

7.1 Chip Testing

7.2 System Testing

Chapter 7

TESTING

The testing procedure is the most important part in the design of the hardware, to make sure that the hardware parts are working correctly and there are no errors. The process that followed in testing the system must depends on sequence form.

7.1 Chip Testing

7.1.1 8051 MCU Testing

We followed two methods for testing MCU, the first method by using 8051 MCU kit,The second method of MC chip testing after connected it as shown in fig(7.1) and ensure that the

- clock IN is 4 MHz
- clock OUT is 2 MHz

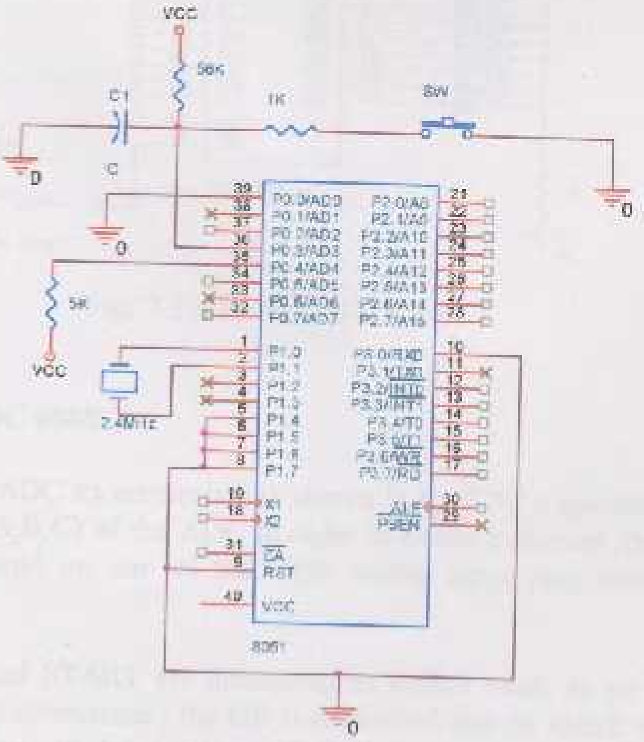


Fig (7.1):Testing MC 8051

7.1.2 EPROM TESTING (27C64)

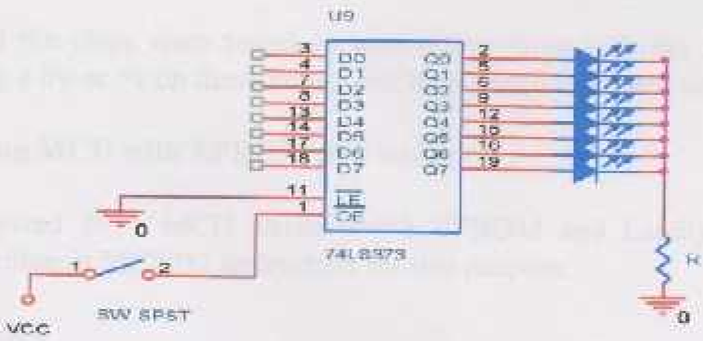
The EPROM was testing by using the chip lap program under windows, when it is read for the first time ,its found empty and the contents of it are (FF).

A small program was written in it and read after a period of time ,then it was erased by the EPROM eraser .

```
MVI     A,C0
SIM
MVI     A,40
SIM
JUMP    0000
```

7.1.3 LATCH (74LS373) TESTING

For testing this chip, the input (D0,…….D7) were connected to switches to change them as required, and the output (O0……O7) were connected to LEDS as shown in fig(7.2) ,changing the enable (E) pin from low to high will latch the data to the output pins.

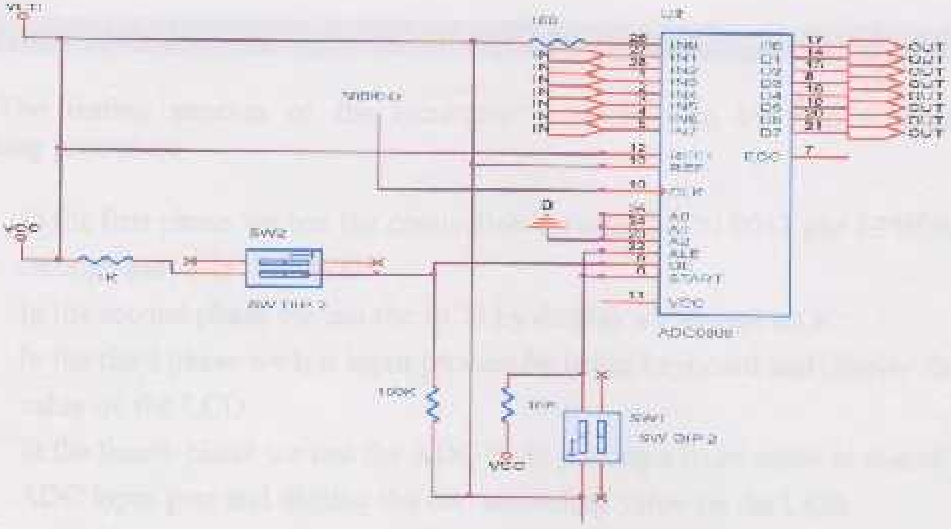


Fig(7.2): Testing 74373 latch

7.1.4 Testing the ADC 0808

For testing the ADC its connected as shown in fig(7.3), a specific number was entered on the pins (A,B,C) of the ADC in order to chose a channel ,then the analog input voltage is entered on one of the eight analog input pins according to the channel number.

And the ALE and START are connected to switch when its go from high to low the ADC start the conversion , the OE is connected also to switch when go from low to high the ADC output data corresponds to the input voltage is presented at the output pins D(0…….7) which are connected to leds.



Figer (7.3) Testing ADC 0808

7.1.5 Other chip testing

In the incubator system design some other common gates were used such as 7400 (NAND gate), 7402 (NOR gate), 7404 (Inverter).

And the chips were tested by connecting them with the 5v on the vcc, and then putting a 0v or 5v on these inputs and then watch the result on there outputs.

7.1.5 Testing MCU with EPROM and latch

We tested 8051 MCU circuit (with EPROM and Latch) by using a small program written in MC8051 instruction for this purpose.

```
ORG    0000H

MOV    A,#00H

LOOP:

MOV    P1,A

INC A

LJMP   LOOP
```

This program outputs square wave on port 1 of the 8051 MCU, which mean that the circuit is working well.

7.2 System Testing

The testing process of the incubator achieved step by step through the designing procedure.

- In the first phase we test the connection between MCU 8051 and EPROM through port 1 in the MCU
- In the second phase we test the LCD by display a message on it.
- In the third phase we test input process by using keyboard and display the key value on the LCD.
- In the fourth phase we test the ADC by in putting a fixed value in one of the ADC input port and display the corresponding value on the LCD.
- In the last phase we connect LEDs at the output ports of the MCU instead of internal units (fan, heater,.......etc) to make sure that it works well.

Chapter 8

Conclusions and Future Work

8.1 Conclusions

8.2 Problems

8.3 Future Work

8.4 Summary

Chapter 8

Conclusions and Future Work

This chapter presents some conclusions that resulted from implementing and testing the project, also it explains in details the goals that were achieved from the project. Finally, it proposes some suggestions and recommendations for developing the system in the future.

8.1 Conclusions

Although there were many difficulties during the implementation , we have succeeded to solve it, on the other hand these difficulties enhanced the work team experience; through implementation of new technologies that was covered briefly in the text books, through some hardware components that were all new, and through improving the team ability to deal with the used software. The following are the obtained outputs from the whole project work:

- In the first semester, the team of the project put the aims of the project and studied the theoretical part of the project (theories and laws), the general block diagram to the system and explained how the system works.
- In the second semester, the team designs the incubator to control the temperature and humidity circuits.
- Then the team bought the 8051 MC and the ICs which need to build incubator design.
- After that, the team starts to connect the system on the board.
- Then the team starts to test chips, and then part by part of the system.
- After the team connects the system, they start to program the system in assembly language.

8.2 Problems

Every project may face several problems while working in. These problems can be divided into two parts HW problems and SW problems.

8.2.1 Hardware Problems

- The implementation of the humidity circuit, to control the incubator humidity, we need humidity sensor, and this sensor not found and expensive put the team solve this problem by founding humidity sensor instead of biomedical humidity sensor.
- The humidity sensor which used in the project is low sensitivity compared with biomedical humidity sensor.
- The oxygen sensor is not available, because it is very expensive, above $1000.
- Some of the IC's not available, such as EPROM IC (27C64).
- The work was paused for three weeks at lest, because the wire rapping not available.

8.2.2 Software Problems

- The team face problems in programming 8051 MC.
- Difficulties that appears through connecting the LCD and Keypad with MC.

8.3 Future Work

We can add some ideas that the students can work on in the future such that:

- Develop the system by making interface to control a group of incubator at the same time, through display data for every incubator on the screen.

8.4 Summary

This chapter summarized the conclusions that came from implementing the project; it describes the problems that occurred during the project implementation. Finally it suggests some future ideas for the interested researchers.

References

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[4.] S.Yeralan, Programming and Interfacing the 8051 Microcontroller, Third Edition, August 1997.

[5.] R.Barnet, The 8051 Family of Microcontrollers, Fourth Edition, McGraw-Hill,2001.

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[7.] Service Manual, V-850 Atom Infant Incubator, In Alia Hospital.

[8.] http://WWW.National.com/PF/LM/LM35.htm

[9.] http://WWW.Infant_Incubator-Basics.com.

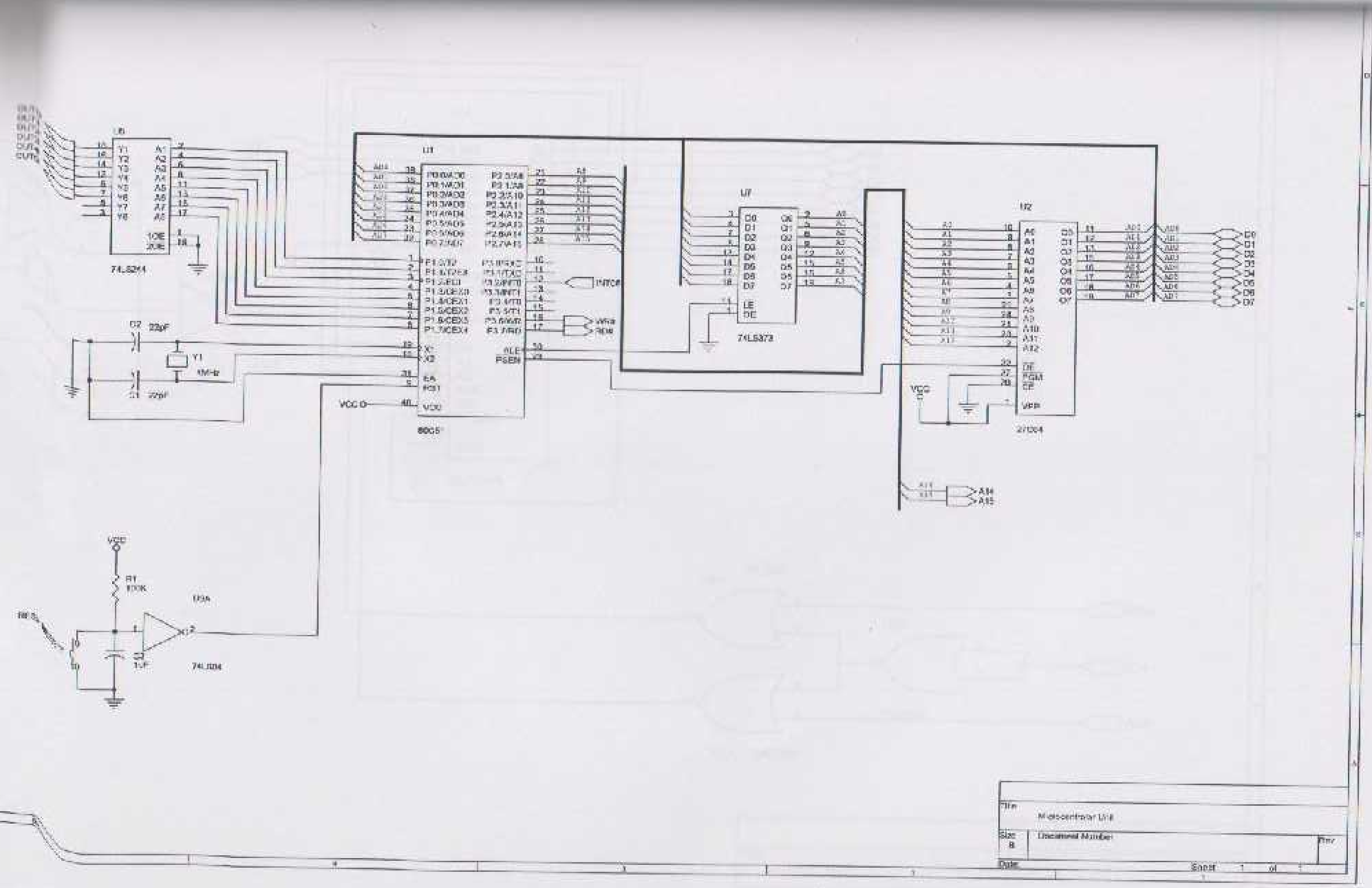
[10.] http://WWW.Infant_Warmers.com.

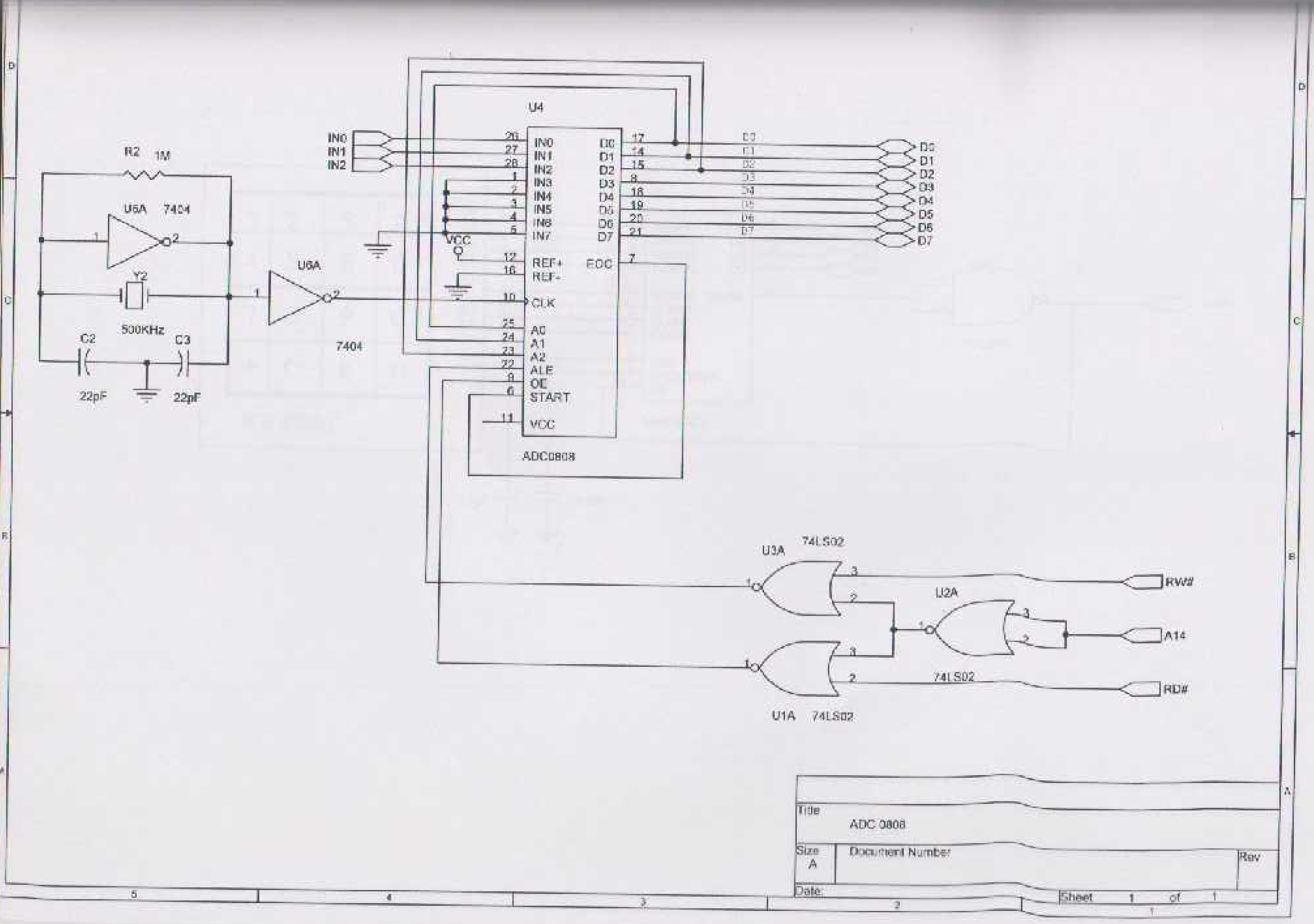
[11.] http://WWW.Transport_Incubator.com.

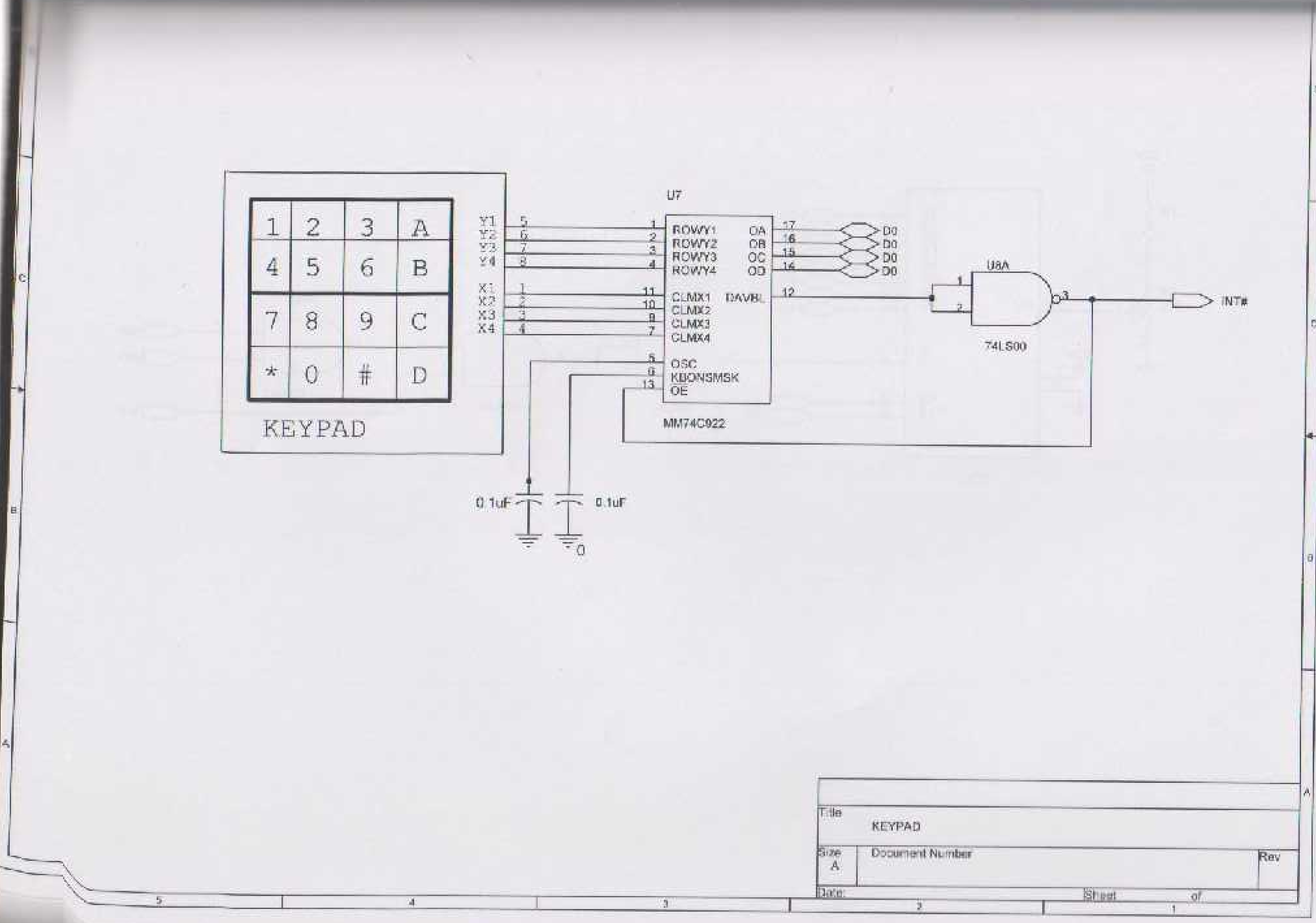
[12.] http://WWW.Encyclopeedia_of_Children's_Health.com

[13.] http://WWW.APGAR_Scoring.com/Apgar_score.htm

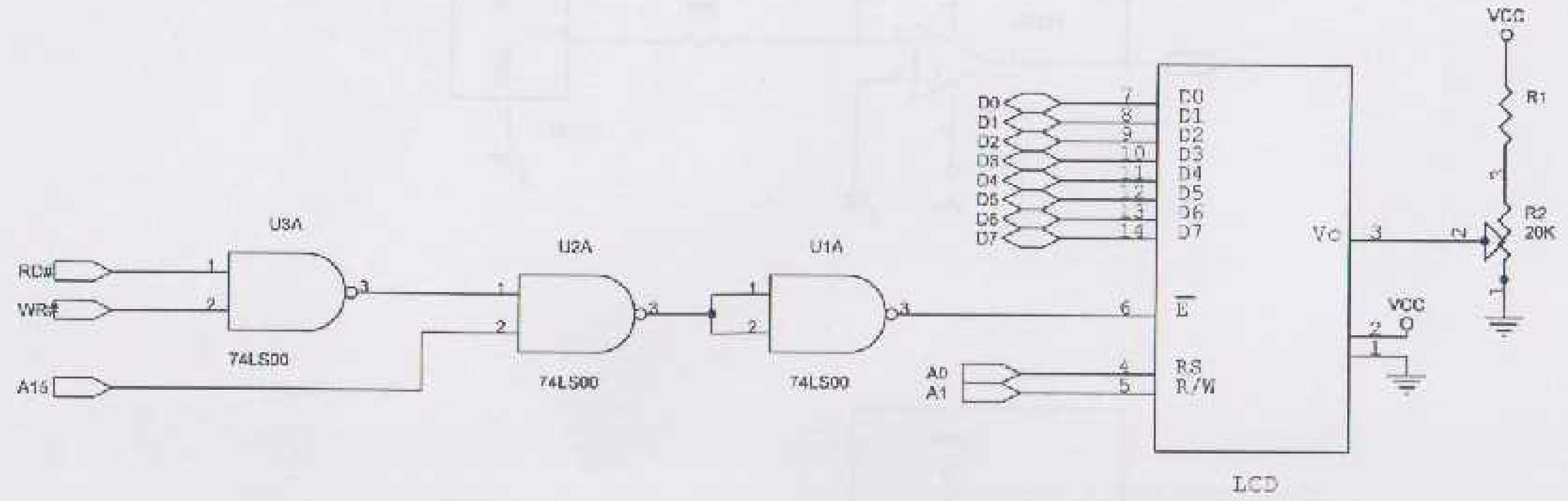
Appendix A
Schematic


U6
74LS244
1OE
2OE
U1
8051
U7
74LS373
U2
27C64
Y1
1MHz
22pF
C2
C1
VCC
R1
100K
U3A
74LS04
C3
1uF
RES
ALE
PSEN
EA
RST
INTO#
WR#
RD#
A14
A15
D0
D1
D2
D3
D4
D5
D6
D7
Title
Microcontroller Unit
Size
B
Document Number
Rev
Date
Sheet 1 of 1

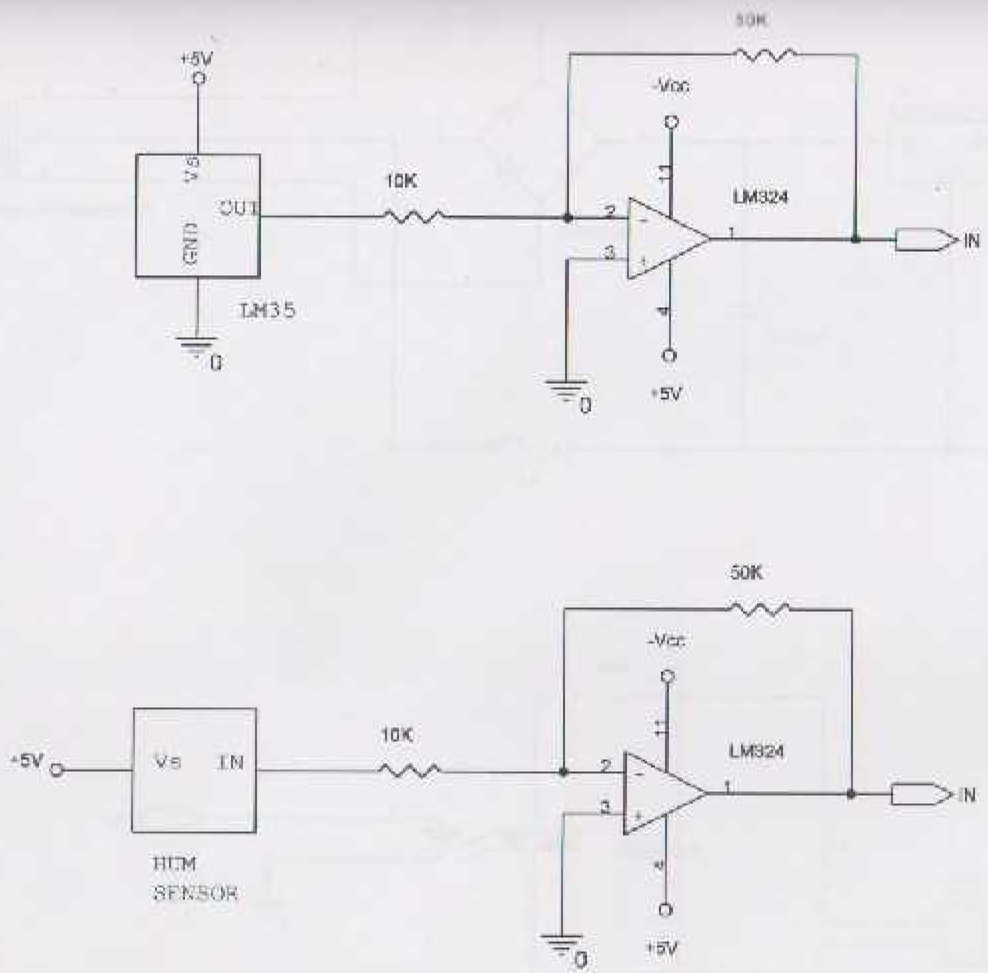

U4
ADC0808
IN0
IN1
IN2
IN3
IN4
IN5
IN6
IN7
REF+
REF-
CLK
A0
A1
A2
ALE
OE
START
VCC
D0
D1
D2
D3
D4
D5
D6
D7
EOC
VCC
R2 1M
U5A 7404
U6A
7404
Y2
500KHz
C2
C3
22pF
22pF
U3A 74LS02
U2A
74LS02
U1A 74LS02
RW#
A14
RD#
Title
ADC 0808
Size
A
Document Number
Rev
Date:
Sheet 1 of 1



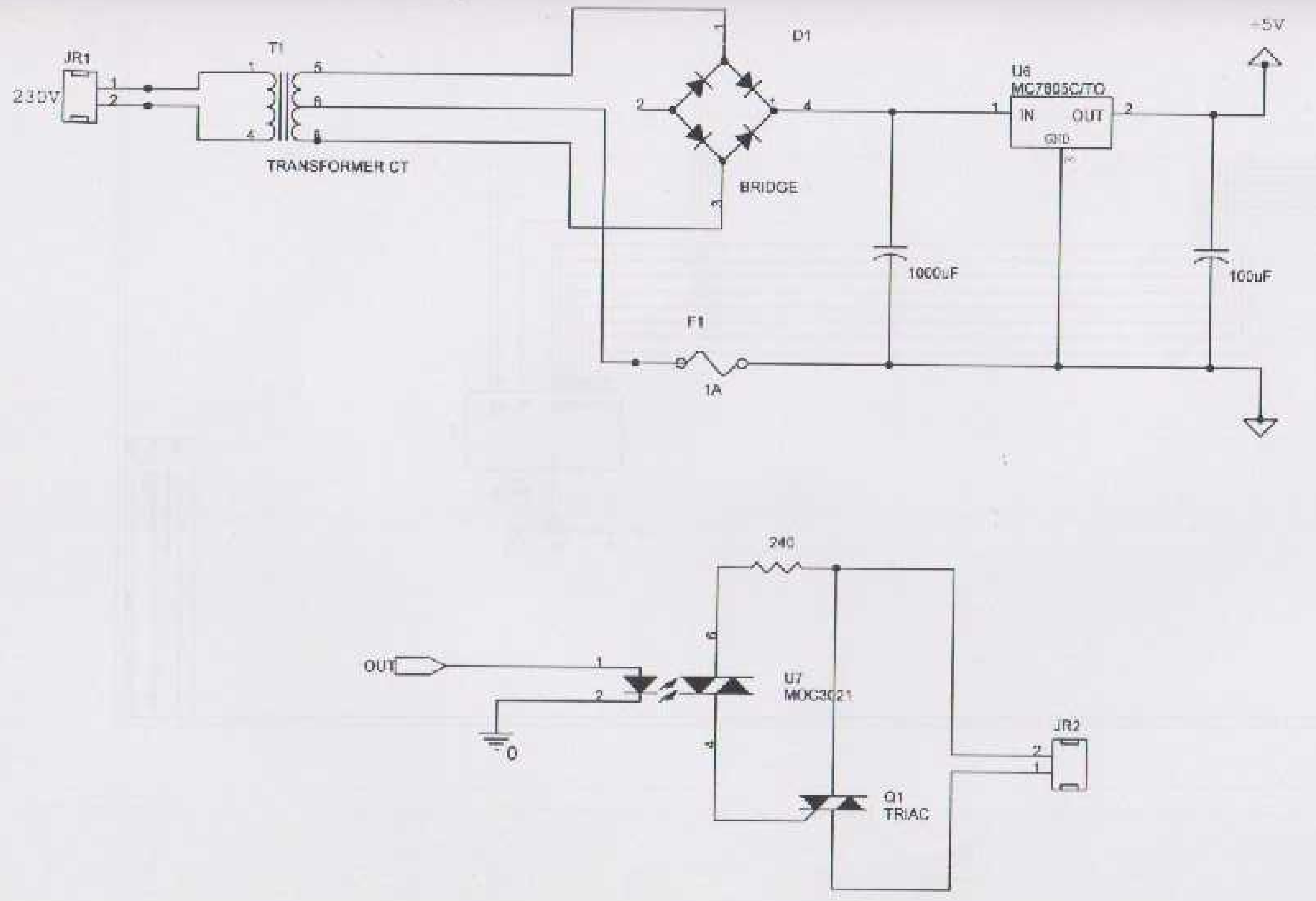
KEYPAD
1 2 3 A
4 5 6 B
7 8 9 C
* 0 # D
Y1 Y2 Y3 Y4
X1 X2 X3 X4
U7
ROWY1
ROWY2
ROWY3
ROWY4
CLMX1
CLMX2
CLMX3
CLMX4
OSC
KBONSMSK
OE
OA
OB
OC
OD
DAVBL
MM74C922
D0
D0
D0
D0
U8A
74LS00
INT#
0.1uF
0.1uF
0
Title
KEYPAD
Size
A
Document Number
Rev
Date:
Sheet
of



Title LCD		
Size A	Document Number	Rev
Date	Sheet of	



Title Temp Sensor HUM Sensor			
Size A	Document Number		Rev <RevCode>
Date:	Friday, May 25, 2007	Sheet 1 of 1	



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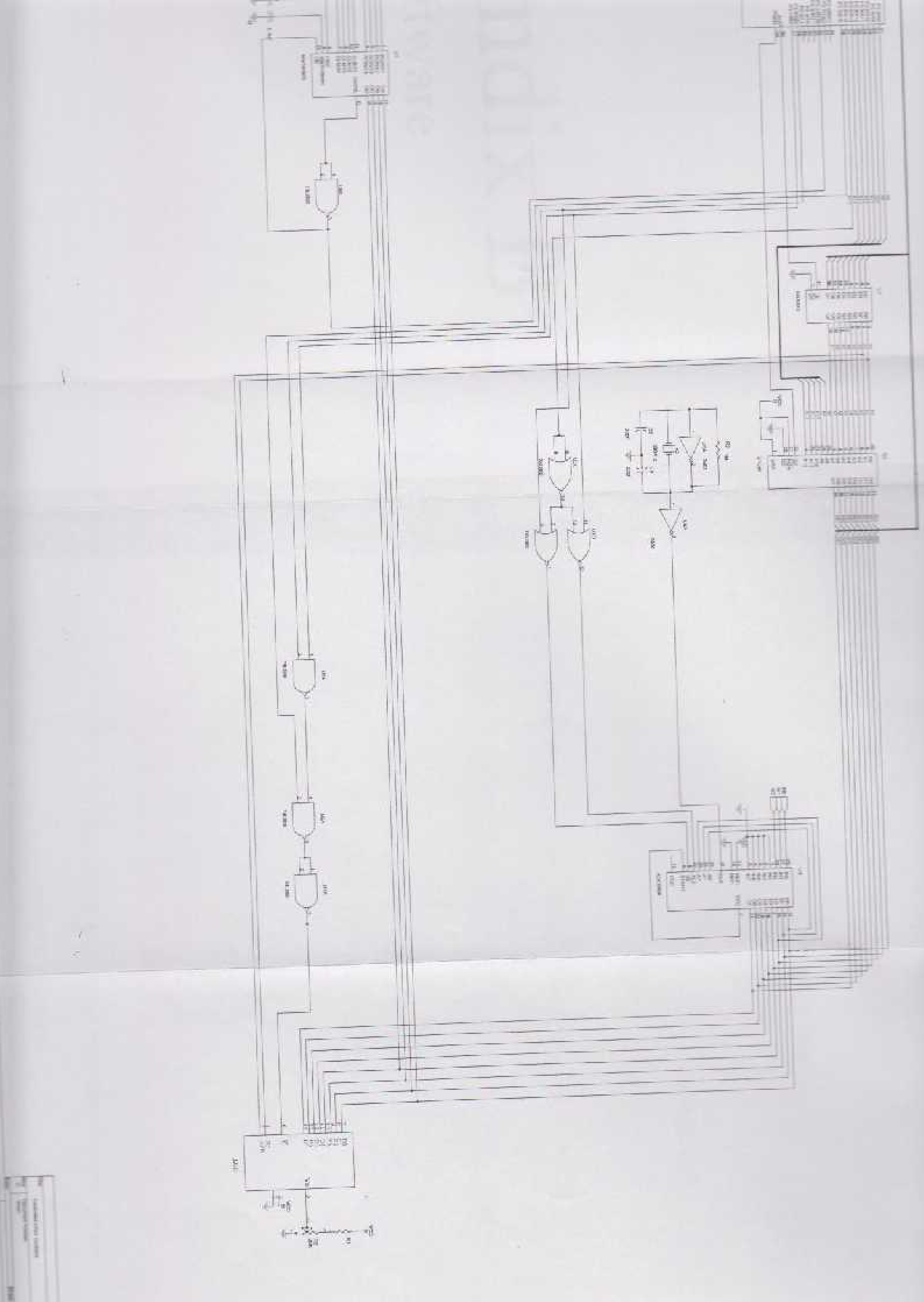
Size A	Document Number	Rev
Date	Sheet 1 of



Appendix B
Software

```
;infant incubator control program
;LCD IO module
        LCD_COMMAND  EQU 8000H
        LCD_DATA     EQU 8001H
        LCD_STATUS   EQU 8002H

;ADC IO
        ADC    EQU  4000H

;Heater IO
        HTR    EQU P1.0;heater

;LEDS I/O
        HI    EQU P1.1;high temp alarm
        LO     EQU P1.2;low temp alarm

;constants
        S1    EQU 00H;temperature sensor
        S2    EQU 01H;humidity sensor

;variables
        TMP    EQU 20H;incubator air temperature
        HMY    EQU 21H;incubator humidity
        SP1    EQU 22H;temp setpoint
        SP2    EQU 23H;humidity setpoint
        KEY    EQU 24H;key value
        NUM    EQU 25H;decimal number

;interrupt vector table
        ORG    00H
        LJMP START ;reset
        ORG  03H
        LJMP KEYPAD _ISR;external 0
        ORG  0BH
        LJMP TIMER _ISR;timer/counter 0

;main program
          30H
START:  MOV   SP,#2FH

;print sign-on message
        LCALL INI-LCD
         LCD_PRINT
        DB"Wait",0
```

```
;initialize variables
        MOV SP1,#37
        MOV SP2,#0

;enable all interrupts
        LCALL INI_KEYPAD

;print complet message
        LCALL LCD_CLR_DISPLAY
        LCALL LCD_PRINT
        DB"Ready",0
        MOV  A,#2
        LCALL TIME

;read sensors and stor their reading
        MOV  A,#S1
        LCALL ADC_SELECT
        LCALL ADC_READ
        MOV TMP,A
        MOV A,#S2
        LCALL ADC_SELECT
        LCALL ADC_READ
        MOV HMY,A

;compare incubator temperature with setpoint
        LCALL LCD-CLR-DISPLAY
        MOV A,TMP
        SUBB A,SP1
        SUBB A,TMP
        JNC  MODE2
        LCALL LCD_PRINT
        DB "High Temp",0
        CLR  HI
        SETB LO
        SETB HTR
        LJMP  BREAK
        MODE2:  LCALL LCD_PRINT
        DB "Low Temp",0
        CLR LO
        SETB HI
        CLR  HTR
BREAK:  MOV A,#16
        LCALL LCD_SET_CURSOR
```

```
        MOV  A,TMP
        LCALL TEMP_DISPLAY

;continue after 1 second
NEXT:  MOV A,#1
        LCALL TIME
         LJMP LOOP



;initialize LCD
        INI_LCD:
        LCALL DELAY
        MOV A,#38;function set
        LCALL LCD_COM_OUT
        MOV A,#06;entry mode set
        LCALL LCD_COM_OUT
        LCALL LCD_CLR_DISPLAY
        LCALL LCD_HOM_CURSOR
        LCAL  LCD_CURSOR_OFF
        MOV A,#0
        LCALL LCD_SET_CURSOR
        RET

;time delay (1ms(
DELAY:
         MOV R1,A
LOOP2:  MOV R0,#199
LOOP1:  DJNZ R0,LOOP1
        R1,LOOP2
        RET

;time delay (1s(
TIME:  MOV R2,A
LOOP4: MOV R3,#100
LOOP3: LCALL DELY
        DJNZ R3,LOOP3
        DJNZ R2,LOOP4
        RET

;write command to LCD
        LCD_COM_OUT
        PUSH DPL
```

```
        PUSH DPH
        LCALL LCD_CHK_STATUS
        MOV DPTR,#LCD-COMMAND
            MOVX @DPTR,A
        POP DPH
        POP DPL
        RET

;check LCD status
        LCD_CHK_STATUS:
        PUSH ACC
        MOV DPTR,#LCD_STATUS
BUSY: MOVX A,@DPTR
        JB ACC.7,BUSY
        POP ACC
        RET

;write data to LCD
        LCD DATA_OUT:
        PUSH DPL
        PUSH DPH
        LCALL LCD_CHK_STATUS
        MOV DPTR,#LCD DATA
        MOVX @DPTR,A
        POP DPH
        POP DPL
        RET

;print message to LCD
        LCD_PRINT:
        POP DPH
        POP DPL
NXTCH: CLR A
        MOVC A,@A+DPTR
        CJNE A,#0,OUTCH
        MOV A,#1H
        JMP @A+DPTR
        OUTCH: LCALL LCD_DATA_OUT
        INC DPTR
        LJMP NXTCH

;clear display
        LCALL CLR_DISPLAY:
        PUSH ACC
```

```
        MOV A,#01H
        LCALL LCD_COM_OUT
        POP ACC
        RET

;return cursor to home
        LCD_HOM_CURSOR:
        MOV A,#02H
        LCALL LCD_COM_OUT
        POP ACC
        RET

;set cursor on
        LCD_CURSOR_ON
        PUSH ACC
        MOV A,#0FH
        LCALL LCD_COM_OUT
        POP ACC
        RET


;set cursor off
        LCD_CURSOR _OFF:
        PUSH ACC
        MOV A,#0CH
        LCALL LCD_COM_OUT
        POP ACC
        RET

;set cursor position
        LCD_SET_CURSOR:
        MOV R0,A
        SUBB A,#16
        JNC LINE2
        MOV A,R0
        ADD A,#080H
        LJMP SEND
LINE2: ADD A,#0C0H
SEND: LCALL LCD_COM_OUT
        RET
```

```
;initialize keypad
        INI_KEYPAD:
       SETB EA;enable all control bit
       SET IT0;falling edge low level triggered interrupt
       SETB EX0;enable external interrupt 0
        RET

;keypad ISR
        KEYPAD_ISR:
        PUSH PSW
        PUSH ACC
        PUSH DPL
        PUSH DPH
        MOVX A,@DPTR
        ANL A,#0FH
        LCALL KEYPAD_XLATE
        MOV KEY,A
        LCALL KEY_SERVICE
        POP DPH
        POP DPL
        POP ACC
        POP PSW
        RETI

;translate key value
        KEYPAD_XLATE:
        ADD A,#1
        MOVC A,@A+PC
        RET
        DB 01H,02H,03H,0AH
        DB 04H,05H,06H,0BH
        DB 07H,08H,09H,0CH
        DB 0EH,00H,OFH,0DH

;key service routine
        KEY_SERVICE:
        MOV A,KEY
        CJNE A,#0AH,FUNCT2
        LCALL TEMPR
        RET

FUNCT2: CJNE A,#0BH,FUNCT3
        LCALL HUMID
        RET
```

```
FUNCT3: CJNE A,#08H,FUNCT4
        INC NUM
        RET

FUNCT4: CJNE A,#02H,REJECT
        DEC NUM
REJECT:RET

;temp option
TEMPR:
        MOV NUM,SP1
        LCALL LCD_CLR-DISPLAY
        LCALL LCD_PRINT
        DB "Temp Setpoint",0
LPI: MOV A,#16
        LCALL LCD_SET_CURSOR
        MOV A,NUM
        LCALL TEMP_DISPLAY
         MOV A,KEY
        CJNE,#0EH,LP1
        MOV SP1,NUM
        RET

;humidity option
HUMID:
        MOV NUM,SP2
        LCALL LCD_CLR_DISPLAY
        LCALL LCD_PRINT
        DB "Humidity Setpoint",0
LP2:  MOV A,#16
        LCALL LCD_SET_CURSOR
        MOV A,NUM
        ADD A,#30H
        LCALL LCD_DATA_OUT
         MOV A,KEY
        CJNE A,#0EH,LP2
          MOV SP2,NUM
        RET

;select ADC analog channel
        ADC_SELECT:
        PUSH DPL
        PUSH DPH
        MOV DPTR,#ADC
```

```
        MOVX @DPTR,A
        MOV A,#4
        LCALL DELAY
        POP DPH
        POP DPL
        RET

;read ADC output
ADC_READ:
        PUSH DPL
        PUSH DPH
        MOV DPTR,#ADC
        MOVX A,@DPTR
        LCALL ADC-XLATE
        PO DPH
        POP DPL
        RET

;translate ADC reading
        ADC_XLATE:
        ADD A,#1
        MOVC A,@A+PC
        RET

DB 00,00,01,01,01;0-4
DB 02,02,03,03,03;5-9
DB 04,04,05,05,05;10-14
DB 06,06,07,07,07;15-19
DB 08,08,09,09,09;20-24
DB 10,10,11,11,11;25-29
DB 12,12,13,13,13;30-34
DB 14,14,15,15,15;35-39
DB 16,16,17,17,17;40-44
DB 18,18,19,19,19;45-49
DB 20,20,21,21,21;50-54
DB 22,22,23,23,23;55-59
DB 24,24,25,25,25;60-64
DB 25,25,26,26,26;65-69
DB 26,26,27,27,27;70-74
DB 28,28,29,29,29;75-79
DB 30,30,31,31,31;80-84
DB 32,32,33,33,33;85-89
```

```
DB 34,34,35,35,35;90-94
DB 36,36,37,37,37;95-99
DB 38,38,39,39,39;105-109
DB 40,40,41,41,41;110-114
DB 42,42,43,43,43;115-119
DB 44,44,45,45,45;120-124
DB 46,46,47,47,47;125-129
DB 48,48,49,49,49;130-134
DB 50,50,51,51,51;135-139
DB 52,52,53,53,53;140-144
DB 54,54,55,55,55;145-149
DB 56,56,57,57,57;150-154
DB 58,58,59,59,59;155-159
DB 60,60,61,61,61;160-164
DB 62,62,63,63,63;165-169
DB 64,64,65,65,65;170-174
DB 66,66,67,67,67;175-179
DB 68,68,69,69,69;180-184
DB 70,70,71,71,71;185-189
DB 72,72,73,73,73;190-194
DB 74,74,75,75,75;195-199
DB 76,76,77,77,77;200-204
DB 78,78,79,79,79;205-209
DB 80,80,81,81,81;210-214


;display temperature on LCD
TEMP_DIPLAY:
        MOVX R0,A
        MOV B,#10
        DIV AB
        MOV B,#10
        DIV AB
        MOV A,B
        ADD A,#30H
        LCALL LCD_DATA_OUT
        MOV A,R0
        MOV B,#10
        DIV AB
        MOV A,B
        ADD A,#30H
        LCALL LCD_DATA_OUT
        MOV A,#20H;space code
```

```
        LCALL LCD_DATA_OUT
        MOV A,#0DFH
        LCALL LCD_DATA_OUT
        MOV A,#43H
        LCALL LCD_DATA_OUT
        RET

;initilize timer 0
        timer preload=-(osc(kHz) * delay tme(ms))/ 12
        INI_TIMER:
        ANL TMOD,#0F0H
        ORL TMOD,#2;8-bit auto_reload mode
        SETB ET0;enable timer 0 interrupt
        RET

;start timer 0 running
TIMER_START:
        SETPT0;set T0 interrupt yo hogh priority
        MOV TLO,#0;preload LSB
        MOV TH0,#0FFH;preload MSB
        SETB TR0; run timer 0
        RET

;stop timer0
TIMER_STOP:
        CLR TR0
        CLR PT0
        RET

;timer 0 ISR
TIMER_ISR:
        RETI
```

Appendix C

DATA SHEET

National Semiconductor

November 2000

LM35
Precision Centigrade Temperature Sensors

General Description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ˚ Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼˚C at room temperature and ±¾˚C over a full −55 to +150˚C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1˚C in still air. The LM35 is rated to operate over a −55˚ to +150˚C temperature range, while the LM35C is rated for a −40˚ to +110˚C range (−10˚ with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features

- Calibrated directly in ˚ Celsius (Centigrade)
- Linear + 10.0 mV/˚C scale factor
- 0.5˚C accuracy guaranteeable (at +25˚C)
- Rated for full −55˚ to +150˚C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- Low self-heating, 0.08˚C in still air
- Nonlinearity only ±¼˚C typical
- Low impedance output, 0.1 Ω for 1 mA load

Typical Applications

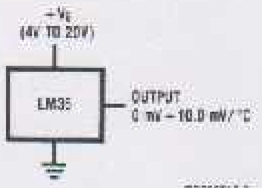
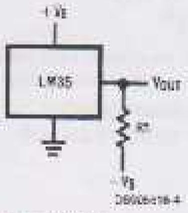


FIGURE 1. Basic Centigrade Temperature Sensor (+2˚C to +150˚C)



Choose $R_1 = -V_S/50\ \mu A$

V_{OUT} = +1,500 mV at +150˚C

= +250 mV at +25˚C

= −550 mV at −55˚C

FIGURE 2. Full-Range Centigrade Temperature Sensor

 DS005516

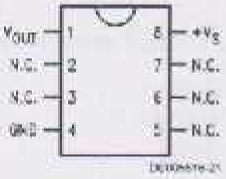
Connection Diagrams

TO-46
Metal Can Package*

*Case is connected to negative pin (GND)

Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH
See NS Package Number H03H

SO-8
Small Outline Molded Package



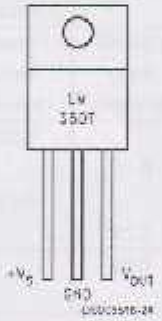
N.C. = No Connection

Top View
Order Number LM35DM
See NS Package Number M08A

TO-92
Plastic Package

Order Number LM35CZ, LM35CAZ or LM35DZ
See NS Package Number Z03A

TO-220
Plastic Package*



*Tab is connected to the negative pin (GND).
Note: The LM35DT pinout is different than the discontinued LM35DP.

Order Number LM35DT
See NS Package Number TA03F

Absolute Maximum Ratings (Note 10)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage	+35V to −0.2V
Output Voltage	+6V to −1.0V
Output Current	10 mA
Storage Temp.:	
TO-46 Package,	−60°C to +180°C
TO-92 Package,	−60°C to +150°C
SO-8 Package,	−65°C to +150°C
TO-220 Package,	−65°C to +150°C
Lead Temp.:	
TO-46 Package, (Soldering, 10 seconds)	300°C
TO-92 and TO-220 Package, (Soldering, 10 seconds)	260°C
SO Package (Note 12)	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C
ESD Susceptibility (Note 11)	2500V
Specified Operating Temperature Range: T_{MIN} to T_{MAX} (Note 2)	
LM35, LM35A	−55°C to +150°C
LM35C, LM35CA	−40°C to +110°C
LM35D	0°C to +100°C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35A			LM35CA			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy (Note 7)	T_A=+25°C	±0.2	±0.5		±0.2	±0.5		°C
	T_A=−10°C	±0.3			±0.3		±1.0	°C
	$T_A=T_{MAX}$	±0.4	±1.0		±0.4	±1.0		°C
	$T_A=T_{MIN}$	±0.4	±1.0		±0.4		±1.5	°C
Nonlinearity (Note 8)	$T_{MIN}≤T_A≤T_{MAX}$	**±0.18**		**±0.35**	**±0.15**		**±0.3**	°C
Sensor Gain (Average Slope)	$T_{MIN}≤T_A≤T_{MAX}$	**+10.0**	**+9.9, +10.1**		**+10.0**		**+9.9, +10.1**	mV/°C
Load Regulation (Note 3) $0≤I_L≤1$ mA	T_A=+25°C	±0.4	±1.0		±0.4	±1.0		mV/mA
	$T_{MIN}≤T_A≤T_{MAX}$	**±0.5**		**±3.0**	**±0.5**		**±3.0**	mV/mA
Line Regulation (Note 3)	T_A=+25°C	±0.01	±0.05		±0.01	±0.05		mV/V
	$4V≤V_S≤30V$	**±0.02**		**±0.1**	**±0.02**		**±0.1**	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25°C	56	67		56	67		µA
	V_S=+5V	**105**		**131**	**91**		**114**	µA
	V_S=+30V, +25°C	56.2	68		56.2	68		µA
	V_S=+30V	**105.5**		**133**	**91.5**		**116**	µA
Change of Quiescent Current (Note 3)	$4V≤V_S≤30V$, +25°C	0.2	1.0		0.2	1.0		µA
	$4V≤V_S≤30V$	**0.5**		**2.0**	**0.5**		**2.0**	µA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.5**	**+0.39**		**+0.5**	µA/°C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, I_L=0	+1.5		+2.0	+1.5		+2.0	°C
Long Term Stability	$T_J=T_{MAX}$, for 1000 hours	±0.08			±0.08			°C

National Semiconductor

August 2000

LM124/LM224/LM324/LM2902
Low Power Quad Operational Amplifiers

General Description

The LM124 series consists of four independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifiers, DC gain blocks and all the conventional op amp circuits which now can be more easily implemented in single power supply systems. For example, the LM124 series can be directly operated off of the standard +5V power supply voltage which is used in digital systems and will easily provide the required interface electronics without requiring the additional ±15V power supplies.

Unique Characteristics

- In the linear mode the input common-mode voltage range includes ground and the output voltage can also swing to ground, even though operated from only a single power supply voltage
- The unity gain cross frequency is temperature compensated
- The input bias current is also temperature compensated

Advantages

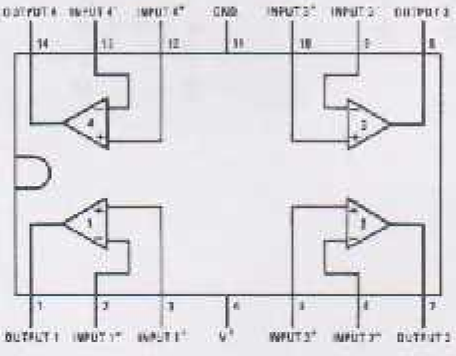
- Eliminates need for dual supplies
- Four internally compensated op amps in a single package
- Allows directly sensing near GND and V_{OUT} also goes to GND
- Compatible with all forms of logic
- Power drain suitable for battery operation

Features

- Internally frequency compensated for unity gain
- Large DC voltage gain 100 dB
- Wide bandwidth (unity gain) 1 MHz (temperature compensated)
- Wide power supply range:
  Single supply 3V to 32V
  or dual supplies ±1.5V to ±16V
- Very low supply current drain (700 μA)—essentially independent of supply voltage
- Low input biasing current 45 nA (temperature compensated)
- Low input offset voltage 2 mV and offset current: 5 nA
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Large output voltage swing 0V to V^+ − 1.5V

Connection Diagrams

Dual-In-Line Package



Top View

Order Number LM124J, LM124AJ, LM124J/883 (Note 2), **LM124AJ/883** (Note 1), **LM224J, LM224AJ, LM324J, LM324M, LM324MX, LM324AM, LM324AMX, LM2902M, LM2902MX, LM324N, LM324AN, LM324MT, LM324MTX or LM2902N LM124AJRQML and LM124AJRQMLV**(Note 3)
See NS Package Number J14A, M14A or N14A

Connection Diagrams (Continued)

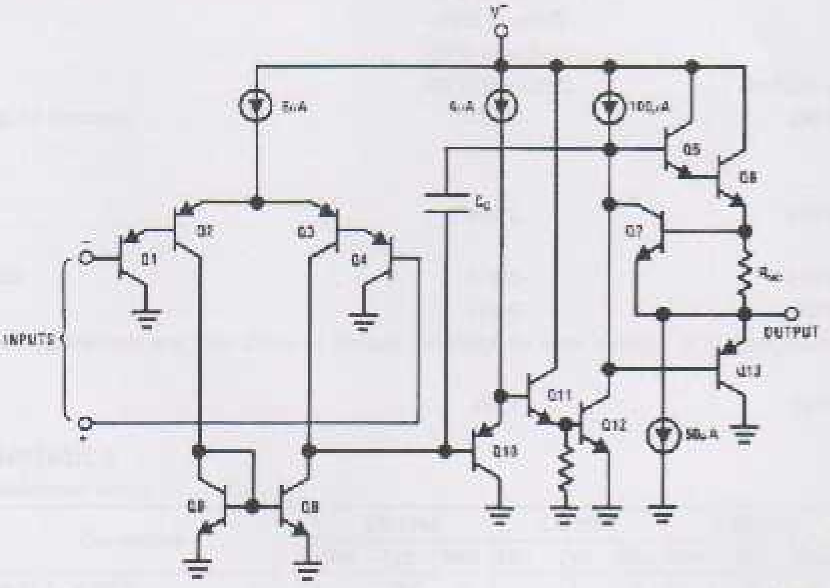
Order Number LM124AW/883, LM124AWG/883, LM124W/883 or LM124WG/883
LM124AWRQML and LM124AWRQMLV(Note 3)
See NS Package Number W14B
LM124AWGRQML and LM124AWGRQMLV(Note 3)
See NS Package Number WG14A

Note 1: LM124A available per JM38510/11006

Note 2: LM124 available per JM38510/11005

Note 3: See STD Mil DWG 5962R99504 for Radiation Tolerant Device

Schematic Diagram (Each Amplifier)



Absolute Maximum Ratings (Note 12)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

	LM124/LM224/LM324 LM124A/LM224A/LM324A	LM2902
Supply Voltage, V^+	32V	26V
Differential Input Voltage	32V	26V
Input Voltage	−0.3V to +32V	−0.3V to +26V
Input Current		
(V_{IN} < −0.3V) (Note 6)	50 mA	50 mA
Power Dissipation (Note 4)		
Molded DIP	1130 mW	1130 mW
Cavity DIP	1260 mW	1260 mW
Small Outline Package	800 mW	800 mW
Output Short-Circuit to GND		
(One Amplifier) (Note 5)		
$V^+ \le 15V$ and $T_A = 25°C$	Continuous	Continuous
Operating Temperature Range		−40°C to +85°C
LM324/LM324A	0°C to +70°C	
LM224/LM224A	−25°C to +85°C	
LM124/LM124A	−55°C to +125°C	
Storage Temperature Range	−65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	260°C	260°C
Soldering Information		
Dual-In-Line Package		
Soldering (10 seconds)	260°C	260°C
Small Outline Package		
Vapor Phase (60 seconds)	215°C	215°C
Infrared (15 seconds)	220°C	220°C

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

ESD Tolerance (Note 13)	250V	250V

Electrical Characteristics

$V^+ = +5.0V$, (Note 7), unless otherwise stated

Parameter	Conditions	LM124A			LM224A			LM324A			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	(Note 8) $T_A = 25°C$		1	2		1	3		2	3	mV
Input Bias Current (Note 9)	$I_{IN(+)}$ or $I_{IN(-)}$, $V_{CM} = 0V$, $T_A = 25°C$		20	50		40	80		45	100	nA
Input Offset Current	$I_{IN(+)}$ or $I_{IN(-)}$, $V_{CM} = 0V$, $T_A = 25°C$		2	10		2	15		5	30	nA
Input Common-Mode Voltage Range (Note 10)	$V^+ = 30V$, (LM2902, $V^+ = 26V$), $T_A = 25°C$	0		$V^+-1.5$	0		$V^+-1.5$	0		$V^+-1.5$	V
Supply Current	Over Full Temperature Range $R_L = \infty$ On All Op Amps										mA
	$V^+ = 30V$ (LM2902 $V^+ = 26V$)		1.5	3		1.5	3		1.5	3	
	$V^+ = 5V$		0.7	1.2		0.7	1.2		0.7	1.2	
Large Signal Voltage Gain	$V^+ = 15V$, $R_L \ge 2k\Omega$, (V_O = 1V to 11V), $T_A = 25°C$	50	100		50	100		25	100		V/mV
Common-Mode	DC, V_{CM} = 0V to $V^+ - 1.5V$,	70	85		70	85		65	85		dB

National Semiconductor

March 2007

ADC0808/ADC0809
8-Bit µP Compatible A/D Converters with 8-Channel Multiplexer

General Description

The ADC0808, ADC0809 data acquisition component is a monolithic CMOS device with an 8-bit analog-to-digital converter, 8-channel multiplexer and microprocessor compatible control logic. The 8-bit A/D converter uses successive approximation as the conversion technique. The converter features a high impedance chopper stabilized comparator, a 256R voltage divider with analog switch tree and a successive approximation register. The 8-channel multiplexer can directly access any of 8-single-ended analog signals.

The device eliminates the need for external zero and full-scale adjustments. Easy interfacing to microprocessors is provided by the latched and decoded multiplexer address inputs and latched TTL TRI-STATE outputs.

The design of the ADC0808, ADC0809 has been optimized by incorporating the most desirable aspects of several A/D conversion techniques. The ADC0808, ADC0809 offers high speed, high accuracy, minimal temperature dependence, excellent long-term accuracy and repeatability, and consumes minimal power. These features make this device ideally suited to applications from process and machine control to consumer and automotive applications. For 16-channel multiplexer with common output (sample/hold port) see ADC0816 data sheet. (See AN-247 for more information.)

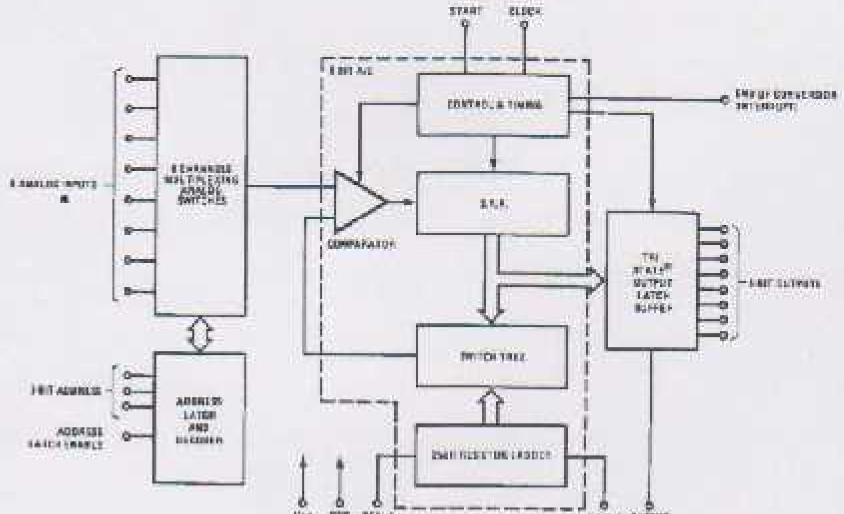
Features

- Easy interface to all microprocessors
- Operates ratiometrically or with 5 V_{DC} or analog span adjusted voltage reference
- No zero or full-scale adjust required
- 8-channel multiplexer with address logic
- 0V to V_{CC} input range
- Outputs meet TTL voltage level specifications
- ADC0808 equivalent to MM74C949
- ADC0809 equivalent to MM74C949-1

Key Specifications

Resolution	8 Bits
Total Unadjusted Error	±½ LSB and ±1 LSB
Single Supply	5 V_{DC}
Low Power	15 mW
Conversion Time	100 µs

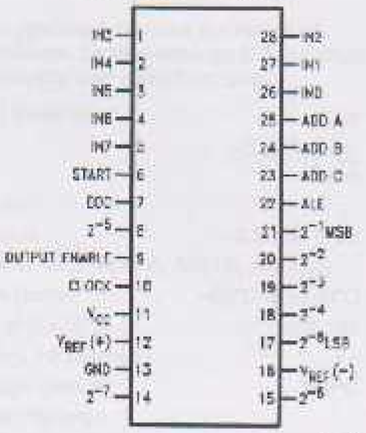
Block Diagram



See Ordering Information

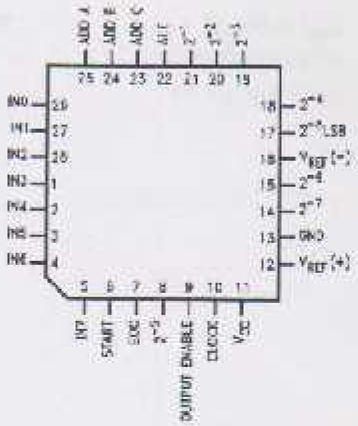
Connection Diagrams

Dual-In-Line Package



Order Number ADC0808CCN or ADC0809CCN
See NS Package J28A or N28A

Molded Chip Carrier Package



Order Number ADC0808CCV or ADC0809CCV
See NS Package V28A

Ordering Information

Temperature Range		−40°C to +85°C		
Package Outline		N28A Molded DIP	V28A Molded Chip Carrier	V28A Molded Chip Carrier (Tape and Reel)
Error	±½ LSB Unadjusted	ADC0808CCN	ADC0808CCV	ADC0808CCVX
	±1 LSB Unadjusted	ADC0809CCN	ADC0809CCV	ADC0809CCVX

Absolute Maximum Ratings

(Notes 2, 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/ Distributors for availability and specifications.

Supply Voltage (V_{CC}) (Note 3)	6.5V
Voltage at Any Pin	−0.3V to (V_{CC} +0.3V)
Except Control Inputs	
Voltage at Control Inputs	−0.3V to +15V
(START, OE, CLOCK, ALE, ADD A, ADD B, ADD C)	
Storage Temperature Range	−65°C to +150°C
Package Dissipation at T_A=25°C	875 mW
Lead Temp. (Soldering, 10 seconds)	
Dual-In-Line Package (plastic)	260°C
Molded Chip Carrier Package	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C
ESD Susceptibility (Note 8)	400V

Operating Conditions

(Notes 1, 2)

Temperature Range	$T_{MIN} \leq T_A \leq T_{MAX}$
	−40°C≤T_A≤+85°C
Range of V_{CC}	4.5 V_{DC} to 6.0 V_{DC}

Electrical Characteristics – Converter Specifications

Converter Specifications: V_{CC}=5 V_{DC}=V_{REF+}, $V_{REF(-)}$=GND, $T_{MIN} \leq T_A \leq T_{MAX}$ and f_{CLK}=640 kHz unless otherwise stated.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
	ADC0808					
	Total Unadjusted Error	25°C			±½	LSB
	(Note 5)	T_{MIN} to T_{MAX}			±¾	LSB
	ADC0809					
	Total Unadjusted Error	0°C to 70°C			±1	LSB
	(Note 5)	T_{MIN} to T_{MAX}			±1¼	LSB
	Input Resistance	From Ref(+) to Ref(−)	1.0	2.5		kΩ
	Analog Input Voltage Range	(Note 4) V(+) or V(−)	GND − 0.1		V_{CC} + 0.1	V_{DC}
[illegible]	Voltage, Top of Ladder	Measured at Ref(+)		V_{CC}	V_{CC} + 0.1	V
$\frac{V_{REF(+)}+V_{REF(-)}}{2}$	Voltage, Center of Ladder		(V_{CC}/2) − 0.1	V_{CC}/2	(V_{CC}/2) + 0.1	V
[illegible]	Voltage, Bottom of Ladder	Measured at Ref(−)	−0.1	0		V
[illegible]	Comparator Input Current	f_c=640 kHz, (Note 6)	−2	±0.5	2	μA

Electrical Characteristics – Digital Levels and DC Specifications

Digital Levels and DC Specifications: ADC0808CCN, ADC0808CCV, ADC0809CCN and ADC0809CCV, 4.75≤V_{CC}≤5.25V, −40°C≤T_A≤+85°C unless otherwise noted

Symbol	Parameter	Conditions	Min	Typ	Max	Units
LOG MULTIPLEXER						
[illegible]	OFF Channel Leakage Current	V_{CC}=5V, V_{IN}=5V,				
		T_A=25°C		10	200	nA
		T_{MIN} to T_{MAX}			1.0	μA
[illegible]	OFF Channel Leakage Current	V_{CC}=5V, V_{IN}=0,				
		T_A=25°C	−200	−10		nA
		T_{MIN} to T_{MAX}	−1.0			μA
TROL INPUTS						
[illegible]	Logical "1" Input Voltage		(V_{CC} − 1.5)			V
[illegible]	Logical "0" Input Voltage				1.5	V

27C64

64K (8K x 8) CMOS EPROM

FEATURES

- High speed performance
  - 120 ns access time available
- CMOS Technology for low power consumption
  - 20 mA Active current
  - 100 µA Standby current
- Factory programming available
- Auto-insertion-compatible plastic packages
- Auto ID aids automated programming
- Separate chip enable and output enable controls
- High speed "express" programming algorithm
- Organized 8K x 8: JEDEC standard pinouts
  - 28-pin Dual-in-line package
  - 32-pin PLCC Package
  - 28-pin SOIC package
  - Tape and reel
- Available for the following temperature ranges
  - Commercial: 0°C to +70°C
  - Industrial: -40°C to +85°C

DESCRIPTION

The Microchip Technology Inc. 27C64 is a CMOS 64K bit (electrically) Programmable Read Only Memory. The device is organized as 8K words by 8 bits (8K bytes). Accessing individual bytes from an address transition or from power-up (chip enable pin going low) is accomplished in less than 120 ns. CMOS design and processing enables this part to be used in systems where reduced power consumption and high reliability are requirements.

A complete family of packages is offered to provide the most flexibility in applications. For surface mount applications, PLCC or SOIC packaging is available. Tape and reel packaging is also available for PLCC or SOIC packages.

PACKAGE TYPES

DIP/SOIC

PLCC

1.0 ELECTRICAL CHARACTERISTICS

1.1 Maximum Ratings*

Vcc and input voltages w.r.t. Vss.......-0.6V to + 7.25V

VPP voltage w.r.t. Vss during programming ....-0.6V to +14V

Voltage on A9 w.r.t. Vss ....-0.6V to +13.5V

Output voltage w.r.t. Vss .... -0.6V to Vcc +1.0V

Storage temperature ....-65°C to +150°C

Ambient temp. with power applied .....-65°C to +125°C

*Notice: Stresses above those listed under "Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

TABLE 1-1: PIN FUNCTION TABLE

Name	Function
A0-A12	Address Inputs
$\overline{CE}$	Chip Enable
$\overline{OE}$	Output Enable
$\overline{PGM}$	Program Enable
VPP	Programming Voltage
O0 - O7	Data Output
VCC	+5V Power Supply
VSS	Ground
NC	No Connection; No Internal Connections
NU	Not Used; No External Connection Is Allowed

TABLE 1-2: READ OPERATION DC CHARACTERISTICS

Vcc = +5V (±10%)
Commercial: Tamb = 0°C to +70°C
Industrial: Tamb = -40°C to +85°C

Parameter	Part*	Status	Symbol	Min	Max	Units	Conditions
Input Voltages	all	Logic "1" Logic "0"	VIH VIL	2.0 -0.5	Vcc+1 0.8	V V	
Input Leakage	all	—	ILI	-10	10	μA	VIN = 0 to Vcc
Output Voltages	all	Logic "1" Logic "0"	VOH VOL	2.4	 0.45	V V	IOH = -400 μA IOL = 2.1 mA
Output Leakage	all	—	ILO	-10	10	μA	VOUT = 0V to Vcc
Input Capacitance	all	—	CIN	—	6	pF	VIN = 0V; Tamb = 25°C; f = 1 MHz
Output Capacitance	all	—	COUT	—	12	pF	VOUT = 0V; Tamb = 25°C; f = 1 MHz
Power Supply Current, Active	C I	TTL input TTL input	ICC1 ICC2	— —	20 25	mA mA	Vcc = 5.5V; VPP = Vcc; f = 1 MHz; $\overline{OE}$ = $\overline{CE}$ = VIL; IOUT = 0 mA; VIL = -0.1 to 0.8V; VIH = 2.0 to Vcc; Note 1
Power Supply Current, Standby	C I all	TTL input TTL input CMOS input	ICC(S) — —	— — —	2 3 100	mA mA μA	 CE = Vcc ± 0.2V
IPP Read Current VPP Read Voltage	all all	Read Mode Read Mode	IPP VPP	 Vcc-0.7	100 Vcc	μA V	VPP = 5.5V

* Parts: C=Commercial Temperature Range; I=Industrial Temperature Range.

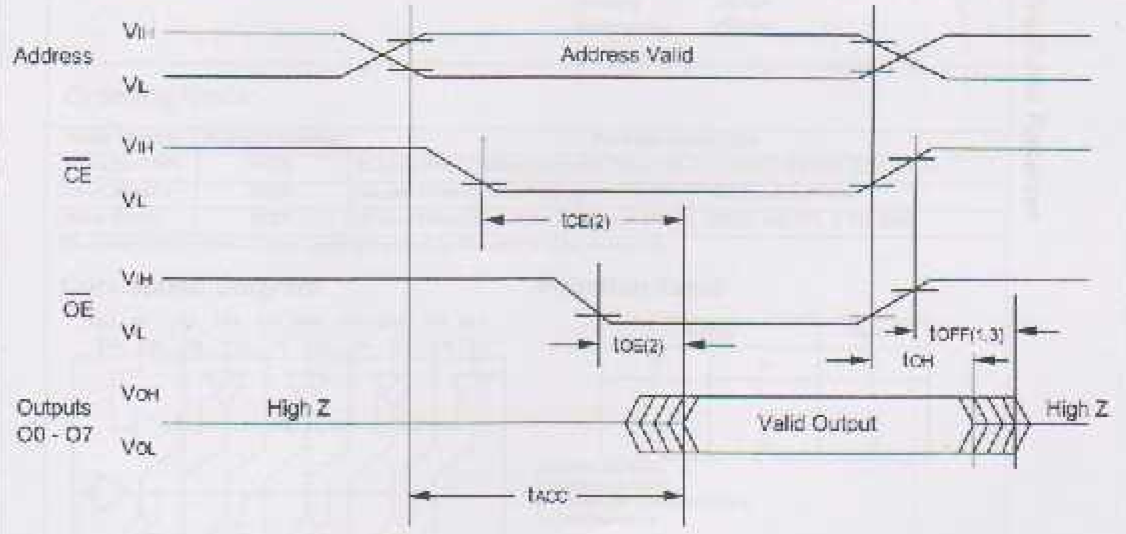
Note 1: Typical active current increases .5 mA per MHz up to operating frequency for all temperature ranges.

TABLE 1-3: READ OPERATION AC CHARACTERISTICS

AC Testing Waveform:	V_{IH} = 2.4V and V_{IL} = 0.45V; V_{OH} = 2.0V V_{OL} = 0.8V		
Output Load:	1 TTL Load + 100 pF		
Input Rise and Fall Times:	10 ns		
Ambient Temperature:	Commercial:	Tamb = 0°C to +70°C	
	Industrial:	Tamb = -40°C to +85°C	

Parameter	Sym	27C64-12		27C64-15		27C64-17		27C64-20		27C64-25		Units	Conditions
		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max		
Address to Output Delay	tACC	—	120	—	150	—	170	—	200	—	250	ns	$\overline{CE}$ = $\overline{OE}$ = VIL
$\overline{CE}$ to Output Delay	tCE	—	120	—	150	—	170	—	200	—	250	ns	$\overline{OE}$ = VIL
$\overline{OE}$ to Output Delay	tOE	—	65	—	70	—	70	—	75	—	100	ns	$\overline{CE}$ = VIL
$\overline{CE}$ or $\overline{OE}$ to O/P High Impedance	tOFF	0	50	0	50	0	50	0	55	0	60	ns	
Output Hold from Address $\overline{CE}$ or $\overline{OE}$, whichever occurs first	tOH	0	—	0	—	0	—	0	—	0	—	ns	

FIGURE 1-1: READ WAVEFORMS



Note 1: tOFF is specified for $\overline{OE}$ or $\overline{CE}$, whichever occurs first.
2: $\overline{OE}$ may be delayed up to tCE - tOE after the falling edge of $\overline{CE}$ without impact on tCE.
3: This parameter is sampled and is not 100% tested.

FAIRCHILD
SEMICONDUCTOR™

August 1986
Revised March 2000

DM74LS244
Octal 3-STATE Buffer/Line Driver/Line Receiver

General Description

These buffers/line drivers are designed to improve both the performance and PC board density of 3-STATE buffers/drivers employed as memory-address drivers, clock drivers, and bus-oriented transmitters/receivers. Featuring 400 mV of hysteresis at each low current PNP data line input, they provide improved noise rejection and high fanout outputs and can be used to drive terminated lines down to 133Ω.

Features

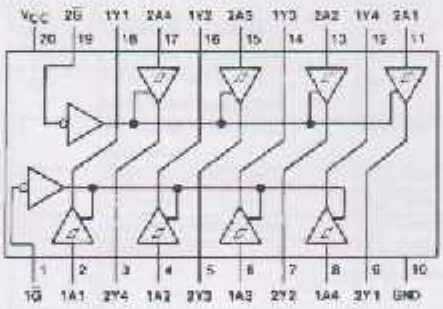
- 3-STATE outputs drive bus lines directly
- PNP inputs reduce DC loading on bus lines
- Hysteresis at data inputs improves noise margins
- Typical I_{OL} (sink current) 24 mA
- Typical I_{OH} (source current) −15 mA
- Typical propagation delay times
  - Inverting 10.5 ns
  - Noninverting 12 ns
- Typical enable/disable time 18 ns
- Typical power dissipation (enabled)
  - Inverting 130 mW
  - Noninverting 135 mW

Ordering Code:

Order Number	Package Number	Package Description
DM74LS244WM	M20B	20-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-013, 0.300 Wide
DM74LS244SJ	M20D	20-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide
DM74LS244N	N20A	20-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 Diagram



Function Table

Inputs		Output
$\overline{G}$	A	Y
L	L	L
L	H	H
H	X	Z

L = LOW Logic Level
H = HIGH Logic Level
X = Either LOW or HIGH Logic Level
Z = High Impedance

Absolute Maximum Ratings(Note 1)

Supply Voltage	7V
Input Voltage	7V
Operating Free Air Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°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 tables are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.

Recommended Operating Conditions

Symbol	Parameter	Min	Nom	Max	Units
V_{CC}	Supply Voltage	4.75	5	5.25	V
V_{IH}	HIGH Level Input Voltage	2			V
V_{IL}	LOW Level Input Voltage			0.8	V
I_{OH}	HIGH Level Output Current			−15	mA
I_{OL}	LOW Level Output Current			24	mA
T_A	Free Air Operating Temperature	0		70	°C

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
HYS	Hysteresis ($V_{T+} - V_{T-}$) Data Inputs Only	V_{CC} = Min		0.2	0.4		V
V_{OH}	HIGH Level Output Voltage	V_{CC} = Min, V_{IH} = Min, V_{IL} = Max, I_{OH} = −1 mA		2.7			V
		V_{CC} = Min, V_{IH} = Min, V_{IL} = Max, I_{OH} = −3 mA		2.4	3.4		
		V_{CC} = Min, V_{IH} = Min, V_{IL} = 0.5V, I_{OH} = Max		2			
V_{OL}	LOW Level Output Voltage	V_{CC} = Min, V_{IL} = Max, V_{IH} = Min	I_{OL} = 12 mA			0.4	V
			I_{OL} = Max			0.5	
I_{OZH}	Off-State Output Current, HIGH Level Voltage Applied	V_{CC} = Max, V_{IL} = Max, V_{IH} = Min	V_O = 2.7V			20	μA
I_{OZL}	Off-State Output Current, LOW Level Voltage Applied		V_O = 0.4V			−20	μA
I_I	Input Current at Maximum 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	−0.5		−200	μA
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 3)		−40		−225	mA
I_{CC}	Supply Current	V_{CC} = Max, Outputs Open	Outputs HIGH		13	23	mA
			Outputs LOW		27	46	
			Outputs Disabled		32	54	

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.

Switching Characteristics

at $V_{CC} = 5V$, $T_A = 25°C$

Symbol	Parameter	Conditions	Max	Units
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	$C_L = 45$ pF, $R_L = 667\Omega$	18	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	$C_L = 45$ pF, $R_L = 667\Omega$	18	ns
t_{PZL}	Output Enable Time to LOW Level	$C_L = 45$ pF, $R_L = 667\Omega$	30	ns
t_{PZH}	Output Enable Time to HIGH Level	$C_L = 45$ pF, $R_L = 667\Omega$	23	ns
t_{PLZ}	Output Disable Time from LOW Level	$C_L = 5$ pF, $R_L = 667\Omega$	25	ns
t_{PHZ}	Output Disable Time from HIGH Level	$C_L = 5$ pF, $R_L = 667\Omega$	18	ns
t_{PLH}	Propagation Delay Time LOW-to-HIGH Level Output	$C_L = 150$ pF, $R_L = 667\Omega$	21	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output	$C_L = 150$ pF, $R_L = 667\Omega$	22	ns
t_{PZL}	Output Enable Time to LOW Level	$C_L = 150$ pF, $R_L = 667\Omega$	33	ns
t_{PZH}	Output Enable Time to HIGH Level	$C_L = 150$ pF, $R_L = 667\Omega$	26	ns

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.

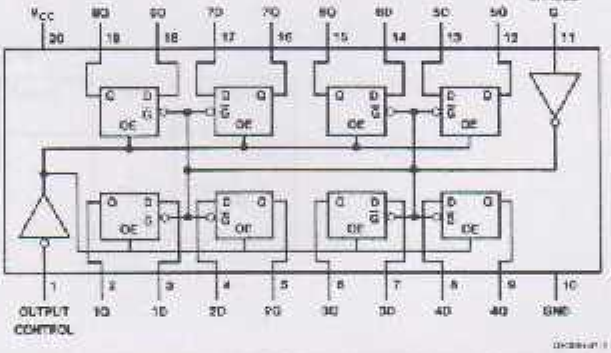
The output control does not affect the internal operation of the latches or flip-flops. That is, the old data can be retained or new data can be entered even while the outputs are off.

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

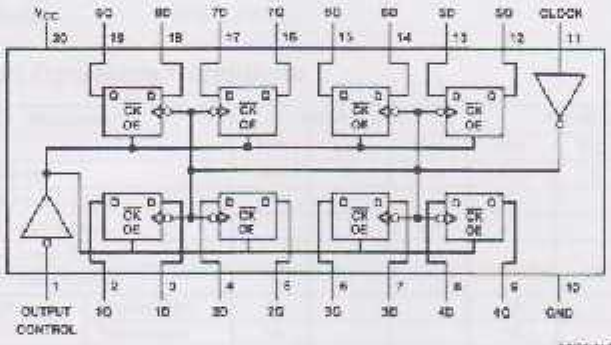
Dual-In-Line Packages
'LS373



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

Connection Diagrams (Continued)

'LS374



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

Absolute Maximum Ratings (Note 1)

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

Recommended Operating Conditions

Symbol	Parameter		DM54LS373			DM74LS373			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				−1			−2.6	mA
I_{OL}	Low Level Output Current				12			24	mA
t_W	Pulse Width (Note 3)	Enable High	15			15			ns
		Enable Low	15			15			
t_{SU}	Data Setup Time (Notes 2, 3)		5↓			5↓			ns
t_H	Data Hold Time (Notes 2, 3)		20↓			20↓			ns
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.

Note 2: The symbol (↓) indicates the falling edge of the clock pulse is used for reference.

Note 3: $T_A = 25°C$ and $V_{CC} = 5V$.

'LS373 Electrical Characteristics

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

<table>
<tr><th>Symbol</th><th>Parameter</th><th colspan="2">Conditions</th><th>Min</th><th>Typ (Note 4)</th><th>Max</th><th>Units</th></tr>
<tr><td>V_I</td><td>Input Clamp Voltage</td><td colspan="2">V_{CC} = Min, I_I = −18 mA</td><td></td><td></td><td>−1.5</td><td>V</td></tr>
<tr><td rowspan="2">V_{OH}</td><td rowspan="2">High Level Output Voltage</td><td rowspan="2">V_{CC} = Min
I_{OH} = Max
V_{IL} = Max
V_{IH} = Min</td><td>DM54</td><td>2.4</td><td>3.4</td><td></td><td rowspan="2">V</td></tr>
<tr><td>DM74</td><td>2.4</td><td>3.1</td><td></td></tr>
<tr><td rowspan="3">V_{OL}</td><td rowspan="3">Low Level Output Voltage</td><td rowspan="2">V_{CC} = Min
I_{OL} = Max
V_{IL} = Max
V_{IH} = Min</td><td>DM54</td><td></td><td>0.25</td><td>0.4</td><td rowspan="3">V</td></tr>
<tr><td>DM74</td><td></td><td>0.35</td><td>0.5</td></tr>
<tr><td>I_{OL} = 12 mA
V_{CC} = Min</td><td>DM74</td><td></td><td></td><td>0.4</td></tr>
<tr><td>I_I</td><td>Input Current @ Max Input Voltage</td><td colspan="2">V_{CC} = Max, V_I = 7V</td><td></td><td></td><td>0.1</td><td>mA</td></tr>
<tr><td>I_{IH}</td><td>High Level Input Current</td><td colspan="2">V_{CC} = Max, V_I = 2.7V</td><td></td><td></td><td>20</td><td>μA</td></tr>
<tr><td>I_{IL}</td><td>Low Level Input Current</td><td colspan="2">V_{CC} = Max, V_I = 0.4V</td><td></td><td></td><td>−0.4</td><td>mA</td></tr>
<tr><td>I_{OZH}</td><td>Off-State Output Current with High Level Output Voltage Applied</td><td colspan="2">V_{CC} = Max, V_O = 2.7V
V_{IH} = Min, V_{IL} = Max</td><td></td><td></td><td>20</td><td>μA</td></tr>
<tr><td>I_{OZL}</td><td>Off-State Output Current with Low Level Output Voltage Applied</td><td colspan="2">V_{CC} = Max, V_O = 0.4V
V_{IH} = Min, V_{IL} = Max</td><td></td><td></td><td>−20</td><td>μA</td></tr>
<tr><td rowspan="2">I_{OS}</td><td rowspan="2">Short Circuit Output Current</td><td rowspan="2">V_{CC} = Max
(Note 5)</td><td>DM54</td><td>−20</td><td></td><td>−100</td><td rowspan="2">mA</td></tr>
<tr><td>DM74</td><td>−50</td><td></td><td>−225</td></tr>
</table>

'LS373 Electrical Characteristics (Continued)

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

Symbol	Parameter	Conditions	Min	Typ (Note 4)	Max	Units
I_{CC}	Supply Current	V_{CC} = Max, OC = 4.5V, D_n, Enable = GND		24	40	mA

'LS373 Switching Characteristics

at V_{CC} = 5V and T_A = 25°C

Symbol	Parameter	From (Input) To (Output)	R_L = 667Ω				Units
			C_L = 45 pF		C_L = 150 pF		
			Min	Max	Min	Max	
t_{PLH}	Propagation Delay Time Low to High Level Output	Data to Q		18		26	ns
t_{PHL}	Propagation Delay Time High to Low Level Output	Data to Q		18		27	ns
t_{PLH}	Propagation Delay Time Low to High Level Output	Enable to Q		30		36	ns
t_{PHL}	Propagation Delay Time High to Low Level Output	Enable to Q		30		36	ns
t_{PZH}	Output Enable Time to High Level Output	Output Control to Any Q		28		36	ns
t_{PZL}	Output Enable Time to Low Level Output	Output Control to Any Q		36		50	ns
t_{PHZ}	Output Disable Time from High Level Output (Note 5)	Output Control to Any Q		20			ns
t_{PLZ}	Output Disable Time from Low Level Output (Note 5)	Output Control to Any Q		25			ns

Note 4: All typicals are at V_{CC} = 5V, T_A = 25°C.

Note 5: Not more than one output should be shorted at a time, and the duration should not exceed one second.

Note 6: C_L = 5 pF.

Recommended Operating Conditions

Symbol	Parameter	DM54LS374			DM74LS374			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			-1			-2.6	mA
I_{OL}	Low Level Output Current			12			24	mA

National Semiconductor

July 1993

MM54C922/MM74C922 16-Key Encoder
MM54C923/MM74C923 20-Key Encoder

General Description

These CMOS key encoders provide all the necessary logic to fully encode an array of SPST switches. The keyboard scan can be implemented by either an external clock or external capacitor. These encoders also have on-chip pull-up devices which permit switches with up to 50 kΩ on resistance to be used. No diodes in the switch array are needed to eliminate ghost switches. The internal debounce circuit needs only a single external capacitor and can be defeated by omitting the capacitor. A Data Available output goes to a high level when a valid keyboard entry has been made. The Data Available output returns to a low level when the entered key is released, even if another key is depressed. The Data Available will return high to indicate acceptance of the new key after a normal debounce period; this two-key roll-over is provided between any two switches.

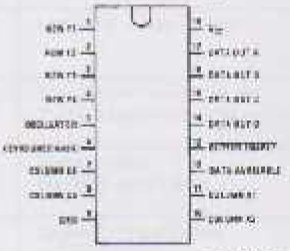
An internal register remembers the last key pressed even after the key is released. The TRI-STATE® outputs provide for easy expansion and bus operation and are LPTTL compatible.

Features

- 50 kΩ maximum switch on resistance
- On or off chip clock
- On-chip row pull-up devices
- 2 key roll-over
- Keybounce elimination with single capacitor
- Last key register at outputs
- TRI-STATE output LPTTL compatible
- Wide supply range 3V to 15V
- Low power consumption

Connection Diagrams

Pin Assignment for Dual-In-Line Package



TL/F/6037-1

Top View

Order Number MM54C922 or MM74C922

Pin Assignment for SOIC

TL/F/6037-14

Top View

Order Number MM74C922

Pin Assignment for DIP and SOIC Package

TL/F/6037-2

Top View

Order Number MM54C923 or MM74C923

TRI-STATE® is a registered trademark of National Semiconductor Corporation.

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Voltage at Any Pin	V_{CC} − 0.3V to V_{CC} + 0.3V
Operating Temperature Range	
MM54C922, MM54C923	−55°C to +125°C
MM74C922, MM74C923	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Power Dissipation (P_D)	
Dual-In-Line	700 mW
Small Outline	500 mW
Operating V_{CC} Range	3V to 15V
V_{CC}	18V
Lead Temperature	
(Soldering, 10 seconds)	260°C

DC Electrical Characteristics Min/Max limits apply across temperature range unless otherwise specified

Symbol	Parameter	Conditions	Min	Typ	Max	Units
CMOS TO CMOS						
V_{T+}	Positive-Going Threshold Voltage at Osc and KBM Inputs	V_{CC} = 5V, I_{IN} ≥ 0.7 mA V_{CC} = 10V, I_{IN} ≥ 1.4 mA V_{CC} = 15V, I_{IN} ≥ 2.1 mA	3.0 6.0 9.0	3.6 6.8 10	4.3 8.6 12.9	V V V
V_{T-}	Negative-Going Threshold Voltage at Osc and KBM Inputs	V_{CC} = 5V, I_{IN} ≥ 0.7 mA V_{CC} = 10V, I_{IN} ≥ 1.4 mA V_{CC} = 15V, I_{IN} ≥ 2.1 mA	0.7 1.4 2.1	1.4 3.2 5	2.0 4.0 6.0	V V V
$V_{IN(1)}$	Logical "1" Input Voltage, Except Osc and KBM Inputs	V_{CC} = 5V V_{CC} = 10V V_{CC} = 15V	3.5 8.0 12.5	4.5 9 13.5		V V V
$V_{IN(0)}$	Logical "0" Input Voltage Except Osc and KBM Inputs	V_{CC} = 5V V_{CC} = 10V V_{CC} = 15V		0.5 1 1.5	1.5 2 2.5	V V V
I_{rp}	Row Pull-Up Current at Y1, Y2, Y3, Y4 and Y5 Inputs	V_{CC} = 5V, V_{IN} = 0.1 V_{CC} V_{CC} = 10V V_{CC} = 15V		−2 −10 −22	−5 −20 −45	µA µA µA
$V_{OUT(1)}$	Logical "1" Output Voltage	V_{CC} = 5V, I_O = −10 µA V_{CC} = 10V, I_O = −10 µA V_{CC} = 15V, I_O = −10 µA	4.5 9 13.5			V V V
$V_{OUT(0)}$	Logical "0" Output Voltage	V_{CC} = 5V, I_O = 10 µA V_{CC} = 10V, I_O = 10 µA V_{CC} = 15V, I_O = 10 µA			0.5 1 1.5	V V V
R_{on}	Column "ON" Resistance at X1, X2, X3 and X4 Outputs	V_{CC} = 5V, V_O = 0.5V V_{CC} = 10V, V_O = 1V V_{CC} = 15V, V_O = 1.5V		500 300 200	1400 700 500	Ω Ω Ω
I_{CC}	Supply Current Osc at 0V, (one Y low)	V_{CC} = 5V V_{CC} = 10V V_{CC} = 15V		0.55 1.1 1.7	1.1 1.9 2.5	mA mA mA
$I_{IN(1)}$	Logical "1" Input Current at Output Enable	V_{CC} = 15V, V_{IN} = 15V		0.005	1.0	µA
$I_{IN(0)}$	Logical "0" Input Current at Output Enable	V_{CC} = 15V, V_{IN} = 0V	−1.0	−0.005		µA
CMOS/LPTTL INTERFACE						
$V_{IN(1)}$	Logical "1" Input Voltage, Except Osc and KBM Inputs	54C, V_{CC} = 4.5V 74C, V_{CC} = 4.75V	V_{CC} − 1.5 V_{CC} − 1.5			V V
$V_{IN(0)}$	Logical "0" Input Voltage, Except Osc and KBM Inputs	54C, V_{CC} = 4.5V 74C, V_{CC} = 4.75V			0.8 0.8	V V
$V_{OUT(1)}$	Logical "1" Output Voltage	54C, V_{CC} = 4.5V I_O = −360 µA 74C, V_{CC} = 4.75V I_O = −360 µA	2.4 2.4			V V
$V_{OUT(0)}$	Logical "0" Output Voltage	54C, V_{CC} = 4.5V I_O = −360 µA 74C, V_{CC} = 4.75V I_O = −360 µA			0.4 0.4	V V

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

DC Electrical Characteristics

Min/Max limits apply across temperature range unless otherwise specified (Continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
OUTPUT DRIVE (See 54C/74C Family Characteristics Data Sheet) (Short Circuit Current)						
I_{SOURCE}	Output Source Current (P-Channel)	$V_{CC} = 5V$, $V_{OUT} = 0V$, $T_A = 25°C$	−1.75	−3.3		mA
I_{SOURCE}	Output Source Current (P-Channel)	$V_{CC} = 10V$, $V_{OUT} = 0V$, $T_A = 25°C$	−8	−15		mA
I_{SINK}	Output Sink Current (N-Channel)	$V_{CC} = 5V$, $V_{OUT} = V_{CC}$, $T_A = 25°C$	1.75	3.6		mA
I_{SINK}	Output Sink Current (N-Channel)	$V_{CC} = 10V$, $V_{OUT} = V_{CC}$, $T_A = 25°C$	8	16		mA

AC Electrical Characteristics*

$T_A = 25°C$, $C_L = 50$ pF, unless otherwise noted

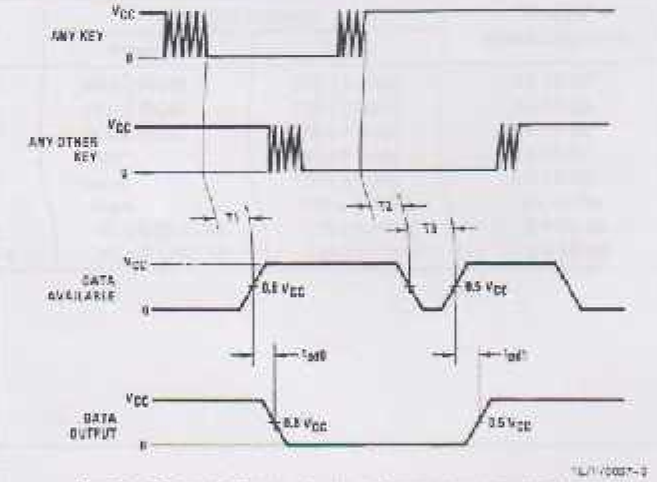
Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_{pd0}, t_{pd1}	Propagation Delay Time to Logical "0" or Logical "1" from D.A.	$C_L = 50$ pF (*Figure 1*)				
		$V_{CC} = 5V$		60	150	ns
		$V_{CC} = 10V$		35	80	ns
		$V_{CC} = 15V$		25	60	ns
t_{0H}, t_{1H}	Propagation Delay Time from Logical "0" or Logical "1" into High Impedance State	$R_L = 10k$, $C_L = 10$ pF (*Figure 2*)				
		$V_{CC} = 5V$, $R_L = 10k$		80	200	ns
		$V_{CC} = 10V$, $C_L = 10$ pF		65	150	ns
		$V_{CC} = 15V$		50	110	ns
t_{H0}, t_{H1}	Propagation Delay Time from High Impedance State to a Logical "0" or Logical "1"	$R_L = 10k$, $C_L = 50$ pF (*Figure 2*)				
		$V_{CC} = 5V$, $R_L = 10k$		100	250	ns
		$V_{CC} = 10V$, $C_L = 50$ pF		55	125	ns
		$V_{CC} = 15V$		40	90	ns
C_{IN}	Input Capacitance	Any Input (Note 2)		5	7.5	pF
C_{OUT}	TRI-STATE Output Capacitance	Any Output (Note 2)		10		pF

*AC Parameters are guaranteed by DC correlated testing.

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

Note 2: Capacitance is guaranteed by periodic testing.

Switching Time Waveforms



T1 = T2 = RC, T3 = 0.7 RC where R = 10k and C is external capacitor at KBM input.

FIGURE 1

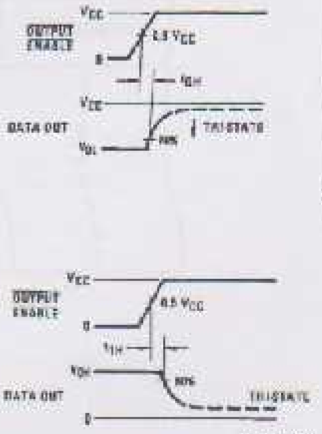


FIGURE 2

PRELIMINARY

intel®

T-49-19-07

MCS®-51 8-BIT CONTROL-ORIENTED MICROCOMPUTERS 8031/8051 8031AH/8051AH 8032AH/8052AH 8751H/8751H-8

- **High Performance HMOS Process**
- **Internal Timers/Event Counters**
- **2-Level Interrupt Priority Structure**
- **32 I/O Lines (Four 8-Bit Ports)**
- **64K Program Memory Space**
- **Security Feature Protects EPROM Parts Against Software Piracy**
- **Boolean Processor**
- **Bit-Addressable RAM**
- **Programmable Full Duplex Serial Channel**
- **111 Instructions (64 Single-Cycle)**
- **64K Data Memory Space**

The MCS®-51 products are optimized for control applications. Byte-processing and numerical operations on small data structures are facilitated by a variety of fast addressing modes for accessing the internal RAM. The instruction set provides a convenient menu of 8-bit arithmetic instructions, including multiply and divide instructions. Extensive on-chip support is provided for one-bit variables as a separate data type, allowing direct bit manipulation and testing in control and logic systems that require Boolean processing.

The 8051 is the original member of the MCS-51 family. The 8051AH is identical to the 8051, but it is fabricated with HMOS II technology.

The 8751H is an EPROM version of the 8051AH; that is, the on-chip Program Memory can be electrically programmed, and can be erased by exposure to ultraviolet light. It is fully compatible with its predecessor, the 8751-8, but incorporates two new features: a Program Memory Security bit that can be used to protect the EPROM against unauthorized read-out, and a programmable baud rate modification bit (SMOD). The 8751H-8 is identical to the 8751H but only operates up to 8 MHz.

The 8052AH is an enhanced version of the 8051AH. It is backwards compatible with the 8051AH and is fabricated with HMOS II technology. The 8052AH enhancements are listed in the table below. Also refer to this table for the ROM, ROMless, and EPROM versions of each product.

Device	Internal Memory		Timers/ Event Counters	Interrupts
	Program	Data		
8052AH	8K x 8 ROM	256 x 8 RAM	3 x 16-Bit	6
8051AH	4K x 8 ROM	128 x 8 RAM	2 x 16-Bit	5
8051	4K x 8 ROM	128 x 8 RAM	2 x 16-Bit	5
8032AH	none	256 x 8 RAM	3 x 16-Bit	6
8031AH	none	128 x 8 RAM	2 x 16-Bit	5
8031	none	128 x 8 RAM	2 x 16-Bit	5
8751H	4K x 8 EPROM	128 x 8 RAM	2 x 16-Bit	5
8751H-8	4K x 8 EPROM	128 x 8 RAM	2 x 16-Bit	5

October 1988
Order Number: 270048-004

T-49-19-07

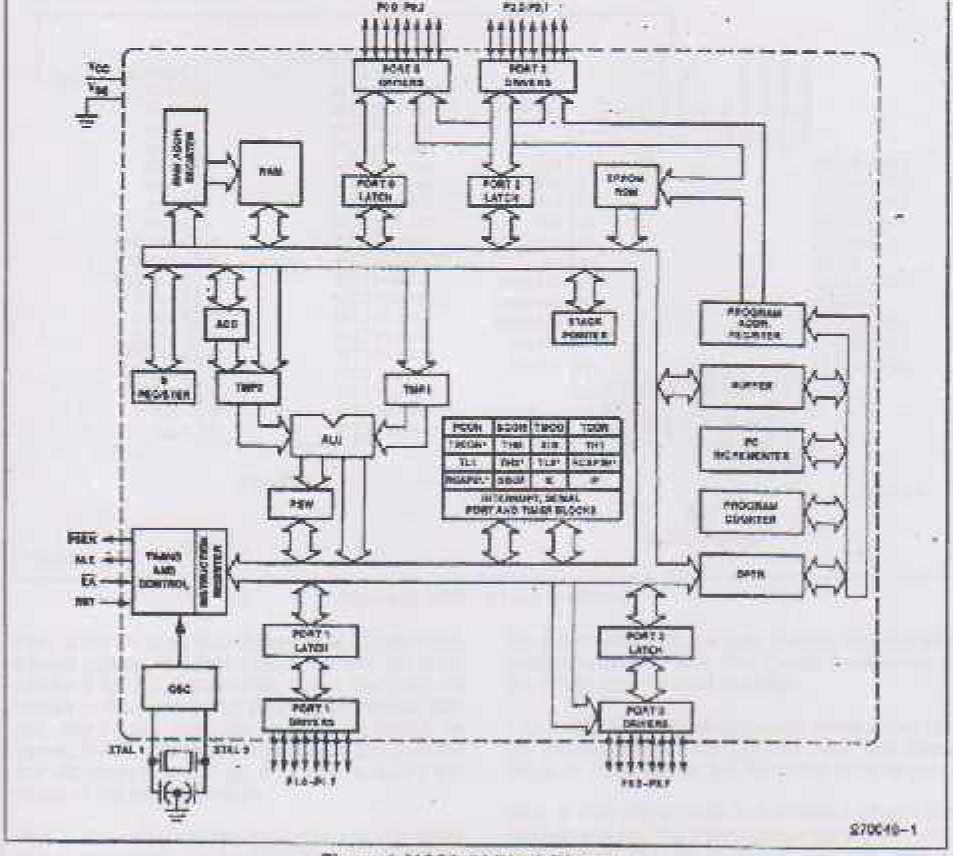


Figure 1. MCS®-51 Block Diagram

PACKAGES

Part	Prefix	Package Type
8051AH/ 8031AH	P D N	40-Pin Plastic DIP 40-Pin CERDIP 44-Pin PLCC
8052AH/ 8032AH	P D N	40-Pin Plastic DIP 40-Pin CERDIP 44-Pin PLCC
8751H/ 8751H-8	D R	40-Pin CERDIP 44-Pin LCC

PIN DESCRIPTIONS

V_{CC}: Supply voltage.

V_{SS}: Circuit ground.

Port 0: Port 0 is an 8-bit open drain bidirectional I/O port. As an output port each pin can sink 8 LS TTL inputs.

Port 0 pins that have 1s written to them float, and in that state can be used as high-impedance inputs.

Port 0 is also the multiplexed low-order address and data bus during accesses to external Program and Data Memory. In this application it uses strong internal pullups when emitting 1s and can source and sink 8 LS TTL inputs.

Port 0 also receives the code bytes during programming of the EPROM parts, and outputs the code bytes during program verification of the ROM and EPROM parts. External pullups are required during program verification.

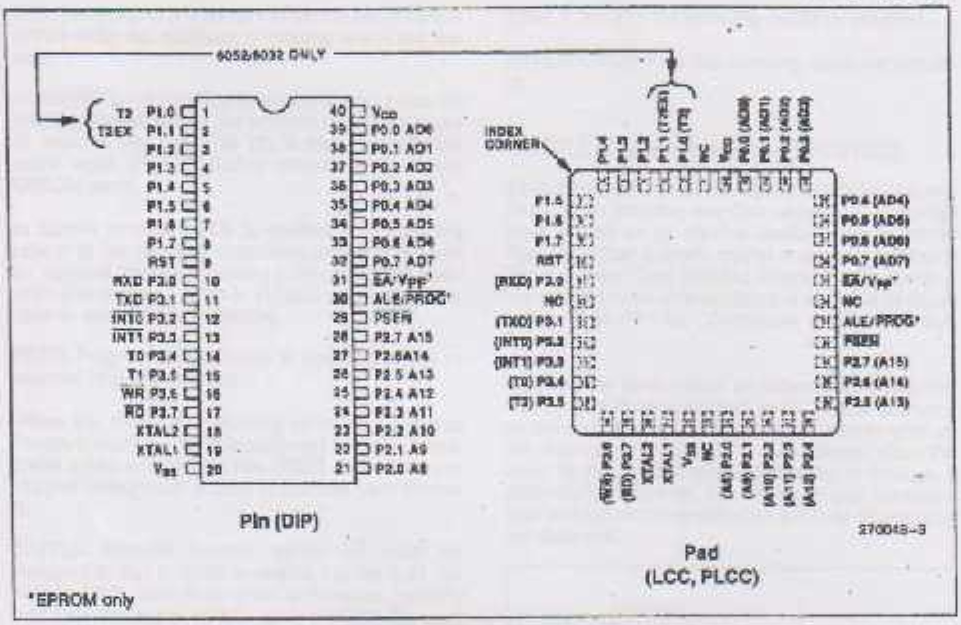


Figure 2. MCS®-51 Connections

Port 1: Port 1 is an 8-bit bidirectional I/O port with internal pullups. The Port 1 output buffers can sink/source 4 LS TTL inputs. Port 1 pins that have 1s written to them are pulled high by the internal pullups, and in that state can be used as inputs. As inputs, Port 1 pins that are externally being pulled low will source current (I_{IL} on the data sheet) because of the internal pullups.

Port 1 also receives the low-order address bytes during programming of the EPROM parts and during program verification of the ROM and EPROM parts.

In the 8032AH and 8052AH, Port 1 pins P1.0 and P1.1 also serve the T2 and T2EX functions, respectively.

Port 2: Port 2 is an 8-bit bidirectional I/O port with internal pullups. The Port 2 output buffers can sink/source 4 LS TTL inputs. Port 2 pins that have 1s written to them are pulled high by the internal pullups, and in that state can be used as inputs. As inputs, Port 2 pins that are externally being pulled low will source current (I_{IL} on the data sheet) because of the internal pullups.

Port 2 emits the high-order address byte during fetches from external Program Memory and during accesses to external Data Memory that use 16-bit addresses (MOVX @DPTR). In this application it uses strong internal pullups when emitting 1s. During accesses to external Data Memory that use 8-bit addresses (MOVX @Ri), Port 2 emits the contents of the P2 Special Function Register.

Port 2 also receives the high-order address bits during programming of the EPROM parts and during program verification of the ROM and EPROM parts.

Port 3: Port 3 is an 8-bit bidirectional I/O port with internal pullups. The Port 3 output buffers can sink/source 4 LS TTL inputs. Port 3 pins that have 1s written to them are pulled high by the internal pullups, and in that state can be used as inputs. As inputs, Port 3 pins that are externally being pulled low will source current (I_{IL} on the data sheet) because of the pullups.

Port 3 also serves the functions of various special features of the MCS-51 Family, as listed below:

Port Pin	Alternative Function
P3.0	RXD (serial input port)
P3.1	TXD (serial output port)
P3.2	$\overline{\text{INT0}}$ (external interrupt 0)
P3.3	$\overline{\text{INT1}}$ (external interrupt 1)
P3.4	T0 (Timer 0 external input)
P3.5	T1 (Timer 1 external input)
P3.6	$\overline{\text{WR}}$ (external data memory write strobe)
P3.7	$\overline{\text{RD}}$ (external data memory read strobe)

RST: Reset input. A high on this pin for two machine cycles while the oscillator is running resets the device.

ALE/$\overline{PROG}$: Address Latch Enable output pulse for latching the low byte of the address during accesses to external memory. This pin is also the program pulse input ($\overline{PROG}$) during programming of the EPROM parts.

In normal operation ALE is emitted at a constant rate of ⅙ the oscillator frequency, and may be used for external timing or clocking purposes. Note, however, that one ALE pulse is skipped during each access to external Data Memory.

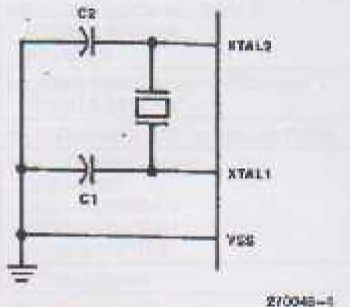
$\overline{PSEN}$: Program Store Enable is the read strobe to external Program Memory.

When the device is executing code from external Program Memory, $\overline{PSEN}$ is activated twice each machine cycle, except that two $\overline{PSEN}$ activations are skipped during each access to external Data Memory.

$\overline{EA}$/V_{PP}: External Access enable $\overline{EA}$ must be strapped to V_{SS} in order to enable any MCS-51 device to fetch code from external Program memory locations starting at 0000H up to FFFFH. $\overline{EA}$ must be strapped to V_{CC} for internal program execution.

Note, however, that if the Security Bit in the EPROM devices is programmed, the device will not fetch code from any location in external Program Memory.

This pin also receives the 21V programming supply voltage (VPP) during programming of the EPROM parts.



C1, C2 = 30 pF ± 10 pF for Crystals
= 40 pF ± 10 pF for Ceramic Resonators

Figure 3. Oscillator Connections

XTAL1: Input to the inverting oscillator amplifier.

XTAL2: Output from the inverting oscillator amplifier.

OSCILLATOR CHARACTERISTICS

XTAL1 and XTAL2 are the input and output, respectively, of an inverting amplifier which can be configured for use as an on-chip oscillator, as shown in Figure 3. Either a quartz crystal or ceramic resonator may be used. More detailed information concerning the use of the on-chip oscillator is available in Application Note AP-155, "Oscillators for Microcontrollers."

To drive the device from an external clock source, XTAL1 should be grounded, while XTAL2 is driven, as shown in Figure 4. There are no requirements on the duty cycle of the external clock signal, since the input to the internal clocking circuitry is through a divide-by-two flip-flop, but minimum and maximum high and low times specified on the Data Sheet must be observed.

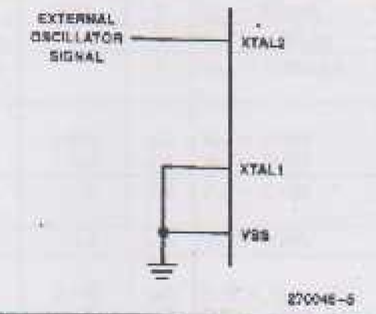


Figure 4. External Drive Configuration

DESIGN CONSIDERATIONS

If an 8751BH or 8752BH may replace an 8751H in a future design, the user should carefully compare both data sheets for DC or AC Characteristic differences. Note that the V_{IH} and I_{IH} specifications for the $\overline{EA}$ pin differ significantly between the devices.

Exposure to light when the EPROM device is in operation may cause logic errors. For this reason, it is suggested that an opaque label be placed over the window when the die is exposed to ambient light.

ABSOLUTE MAXIMUM RATINGS*

Ambient Temperature Under Bias ......0°C to 70°C
Storage Temperature ....−65°C to +150°C
Voltage on $\overline{EA}/V_{PP}$ Pin to V_{SS} ... −0.5V to +21.5V
Voltage on Any Other Pin to V_{SS} .... −0.5V to +7V
Power Dissipation.........................1.5W

**Notice: Stresses above 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 device reliability.*

D.C. CHARACTERISTICS $T_A = 0°C$ to $70°C$; $V_{CC} = 5V \pm 10\%$; $V_{SS} = 0V$

Symbol	Parameter		Min	Max	Units	Test Conditions
V_{IL}	Input Low Voltage (Except $\overline{EA}$ Pin of 8751H & 8751H-8)		−0.5	0.8	V	
V_{IL1}	Input Low Voltage to $\overline{EA}$ Pin of 8751H & 8751H-8		0	0.7	V	
V_{IH}	Input High Voltage (Except XTAL2, RST)		2.0	V_{CC} + 0.5	V	
V_{IH1}	Input High Voltage to XTAL2, RST		2.5	V_{CC} + 0.5	V	XTAL1 = V_{SS}
V_{OL}	Output Low Voltage (Ports 1, 2, 3)*			0.45	V	I_{OL} = 1.6 mA
V_{OL1}	Output Low Voltage (Port 0, ALE, $\overline{PSEN}$)*					
		8751H, 8751H-8		0.60 0.45	V V	I_{OL} = 3.2 mA I_{OL} = 2.4 mA
		All Others		0.45	V	I_{OL} = 3.2 mA
V_{OH}	Output High Voltage (Ports 1, 2, 3, ALE, $\overline{PSEN}$)		2.4		V	I_{OH} = −80 µA
V_{OH1}	Output High Voltage (Port 0 in External Bus Mode)		2.4		V	I_{OH} = −400 µA
I_{IL}	Logical 0 Input Current (Ports 1, 2, 3, RST) 8032AH, 8052AH All Others			−800 −500	µA µA	V_{IN} = 0.45V V_{IN} = 0.45V
I_{IL1}	Logical 0 Input Current to $\overline{EA}$ Pin of 8751H & 8751H-8 Only			−15	mA	V_{IN} = 0.45V
I_{IL2}	Logical 0 Input Current (XTAL2)			−3.2	mA	V_{IN} = 0.45V
I_{LI}	Input Leakage Current (Port 0) 8751H & 8751H-8 All Others			 ±100 ±10	 µA µA	 0.45 ≤ V_{IN} ≤ V_{CC} 0.45 ≤ V_{IN} ≤ V_{CC}
I_{IH}	Logical 1 Input Current to $\overline{EA}$ Pin of 8751H & 8751H-8			500	µA	V_{IN} = 2.4V
I_{IH1}	Input Current to RST to Activate Reset			500	µA	V_{IN} < (V_{CC} − 1.5V)
I_{CC}	Power Supply Current: 8031/8051 8031AH/8051AH 8032AH/8052AH 8751H/8751H-8			 160 125 175 250	 mA mA mA mA	All Outputs Disconnected; $\overline{EA}$ = V_{CC}
C_{IO}	Pin Capacitance			10	pF	Test freq = 1 MHz

*NOTE:
Capacitive loading on Ports 0 and 2 may cause spurious noise pulses to be superimposed on the V_{OL}s of ALE and Ports 1 and 3. The noise is due to external bus capacitance discharging into the Port 0 and Port 2 pins when these pins make 1-to-0 transitions during bus operations. In the worst cases (capacitive loading > 100 pF), the noise pulse on the ALE line may exceed 0.8V. In such cases it may be desirable to qualify ALE with a Schmitt Trigger, or use an address latch with a Schmitt Trigger STROBE input.

National Semiconductor

June 1989

54LS00/DM54LS00/DM74LS00
Quad 2-Input NAND Gates

General Description

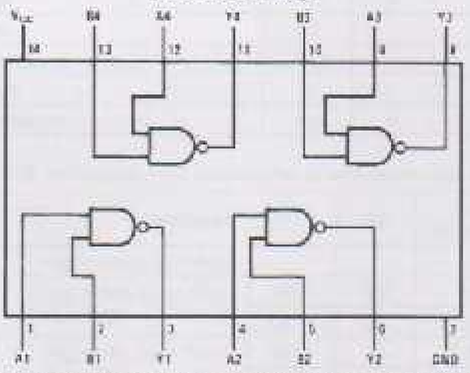
This device contains four independent gates each of which performs the logic NAND function.

Features

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

Connection Diagram

Dual-In-Line Package



TL/F/6439-1

Order Number 54LS00DMQB, 54LS00FMQB, 54LS00LMQB, DM54LS00J, DM54LS00W, DM74LS00M or DM74LS00N
See NS 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

Printed in U.S.A.

Absolute Maximum Ratings (Note)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

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

Note: *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.*

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

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

Symbol	Parameter	Conditions		Min	Typ (Note 1)	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 2)	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 (See Section 1 for Test Waveforms and Output Load)

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

Note 2: Not more than one output should be shorted at a time, and the duration should not exceed one second.

FAIRCHILD
SEMICONDUCTOR™

May 1986
Revised March 2000

DM74LS02
Quad 2-Input NOR Gate

General Description

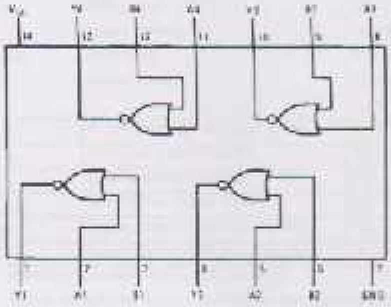
This device contains four independent gates each of which performs the logic NOR function.

Ordering Code:

Order Number	Package Number	Package Description
DM74LS02M	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-120, 0.150 Narrow
DM74LS02SJ	M14D	14-Lead Small Outline Package (SOP), EIAJ TYPE II, 5.3mm Wide
DM74LS02N	N14A	14-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 Diagram



Function Table

$Y = \overline{A + B}$

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

H = HIGH Logic Level
L = LOW Logic Level

DM74LS02

Absolute Maximum Ratings (Note 1)

Supply Voltage	7V
Input Voltage	7V
Operating Free Air Temperature Range	0°C to +70°C
Storage Temperature Range	−65°C to +150°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 tables are not guaranteed at the absolute maximum ratings. The "Recommended Operating Conditions" table will define the conditions for actual device operation.

Recommended Operating Conditions

Symbol	Parameter	Min	Nom	Max	Units
V_{CC}	Supply Voltage	4.75	5	5.25	V
V_{IH}	HIGH Level Input Voltage	2			V
V_{IL}	LOW Level Input Voltage			0.8	V
I_{OH}	HIGH Level Output Current			−0.4	mA
I_{OL}	LOW Level Output Current			8	mA
T_A	Free Air Operating Temperature	0		70	°C

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	2.7	3.4		V
V_{OL}	LOW Level Output Voltage	V_{CC} = Min, I_{OL} = Max, V_{IH} = Min		0.35	0.5	V
		I_{OL} = 4 mA, V_{CC} = Min		0.25	0.4	V
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			−0.40	mA
I_{OS}	Short Circuit Output Current	V_{CC} = Max (Note 3)	−20		−100	mA
I_{CCH}	Supply Current with Outputs HIGH	V_{CC} = Max		1.6	3.2	mA
I_{CCL}	Supply Current with Outputs LOW	V_{CC} = Max		2.8	5.4	mA

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.

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		13		16	ns
t_{PHL}	Propagation Delay Time HIGH-to-LOW Level Output		10		15	ns

National Semiconductor

June 1989

54LS04/DM54LS04/DM74LS04 Hex Inverting Gates

General Description

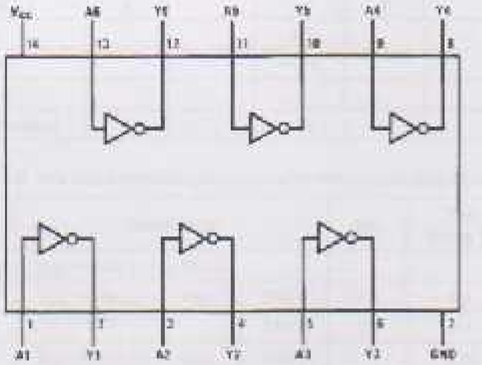
This device contains six independent gates each of which performs the logic INVERT function.

Features

- Alternate Military/Aerospace device (54LS04) is available. Contact a National Semiconductor Sales Office/Distributor for specifications.

Connection Diagram

Dual-In-Line Package



TL/F/6345–1

Order Number 54LS04DMQB, 54LS04FMQB, 54LS04LMQB, DM54LS04J, DM54LS04W, DM74LS04M or DM74LS04N
See NS Package Number E20A, J14A, M14A, N14A or W14B

Function Table

$Y = \overline{A}$

Input	Output
A	Y
L	H
H	L

H = High Logic Level
L = Low Logic Level

54LS04/DM54LS04/DM74LS04 Hex Inverting Gates

Absolute Maximum Ratings (Note)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

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

Note: *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.*

Recommended Operating Conditions

Symbol	Parameter	DM54LS04			DM74LS04			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

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

Symbol	Parameter	Conditions		Min	Typ (Note 1)	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 2)	DM54	−20		−100	mA
			DM74	−20		−100	
I_{CCH}	Supply Current with Outputs High	V_{CC} = Max			1.2	2.4	mA
I_{CCL}	Supply Current with Outputs Low	V_{CC} = Max			3.6	6.6	mA

Switching Characteristics at V_{CC} = 5V and T_A = 25°C (See Section 1 for Test Waveforms and Output Load)

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

Note 2: Not more than one output should be shorted at a time, and the duration should not exceed one second.

National Semiconductor

July 1993

MM54C922/MM74C922 16-Key Encoder
MM54C923/MM74C923 20-Key Encoder

General Description

These CMOS key encoders provide all the necessary logic to fully encode an array of SPST switches. The keyboard scan can be implemented by either an external clock or external capacitor. These encoders also have on-chip pull-up devices which permit switches with up to 50 kΩ on resistance to be used. No diodes in the switch array are needed to eliminate ghost switches. The internal debounce circuit needs only a single external capacitor and can be defeated by omitting the capacitor. A Data Available output goes to a high level when a valid keyboard entry has been made. The Data Available output returns to a low level when the entered key is released, even if another key is depressed. The Data Available will return high to indicate acceptance of the new key after a normal debounce period; this two-key roll-over is provided between any two switches.

An internal register remembers the last key pressed even after the key is released. The TRI-STATE® outputs provide for easy expansion and bus operation and are LPTTL compatible.

Features

- 50 kΩ maximum switch on resistance
- On or off chip clock
- On-chip row pull-up devices
- 2 key roll-over
- Keybounce elimination with single capacitor
- Last key register at outputs
- TRI-STATE outputs LPTTL compatible
- Wide supply range 3V to 15V
- Low power consumption

Connection Diagrams

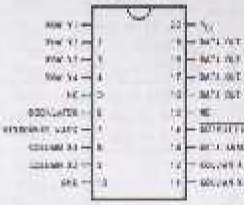
Pin Assignment for Dual-In-Line Package

TL/F/6037-1

Top View

Order Number MM54C922 or MM74C922

Pin Assignment for SOIC

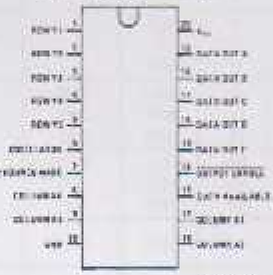


TL/F/6037-14

Top View

Order Number MM74C922

Pin Assignment for DIP and SOIC Package



TL/F/6037-2

Top View

Order Number MM54C923 or MM74C923

TRI-STATE® is a registered trademark of National Semiconductor Corporation.

Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Voltage at Any Pin	$V_{CC} - 0.3V$ to $V_{CC} + 0.3V$
Operating Temperature Range	
MM54C922, MM54C923	$-55°C$ to $+125°C$
MM74C922, MM74C923	$-40°C$ to $+85°C$
Storage Temperature Range	$-65°C$ to $+150°C$
Power Dissipation (P_D)	
Dual-In-Line	700 mW
Small Outline	500 mW
Operating V_{CC} Range	3V to 15V
V_{CC}	18V
Lead Temperature (Soldering, 10 seconds)	260°C

DC Electrical Characteristics

Min/Max limits apply across temperature range unless otherwise specified

Symbol	Parameter	Conditions	Min	Typ	Max	Units
CMOS TO CMOS						
V_{T+}	Positive-Going Threshold Voltage at Osc and KBM Inputs	$V_{CC} = 5V$, $I_{IN} \geq 0.7$ mA $V_{CC} = 10V$, $I_{IN} \geq 1.4$ mA $V_{CC} = 15V$, $I_{IN} \geq 2.1$ mA	3.0 6.0 9.0	3.6 6.8 10	4.3 8.6 12.9	V V V
V_{T-}	Negative-Going Threshold Voltage at Osc and KBM Inputs	$V_{CC} = 5V$, $I_{IN} \geq 0.7$ mA $V_{CC} = 10V$, $I_{IN} \geq 1.4$ mA $V_{CC} = 15V$, $I_{IN} \geq 2.1$ mA	0.7 1.4 2.1	1.4 3.2 5	2.0 4.0 6.0	V V V
$V_{IN(1)}$	Logical "1" Input Voltage, Except Osc and KBM Inputs	$V_{CC} = 5V$ $V_{CC} = 10V$ $V_{CC} = 15V$	3.5 8.0 12.5	4.5 9 13.5		V V V
$V_{IN(0)}$	Logical "0" Input Voltage, Except Osc and KBM Inputs	$V_{CC} = 5V$ $V_{CC} = 10V$ $V_{CC} = 15V$		0.5 1 1.5	1.5 2 2.5	V V V
I_{rp}	Row Pull-Up Current at Y1, Y2, Y3, Y4 and Y5 Inputs	$V_{CC} = 5V$, $V_{IN} = 0.1\ V_{CC}$ $V_{CC} = 10V$ $V_{CC} = 15V$		−2 −10 −22	−5 −20 −45	µA µA µA
$V_{OUT(1)}$	Logical "1" Output Voltage	$V_{CC} = 5V$, $I_O = -10$ µA $V_{CC} = 10V$, $I_O = -10$ µA $V_{CC} = 15V$, $I_O = -10$ µA	4.5 9 13.5			V V V
$V_{OUT(0)}$	Logical "0" Output Voltage	$V_{CC} = 5V$, $I_O = 10$ µA $V_{CC} = 10V$, $I_O = 10$ µA $V_{CC} = 15V$, $I_O = 10$ µA			0.5 1 1.5	V V V
R_{on}	Column "ON" Resistance at X1, X2, X3 and X4 Outputs	$V_{CC} = 5V$, $V_O = 0.5V$ $V_{CC} = 10V$, $V_O = 1V$ $V_{CC} = 15V$, $V_O = 1.5V$		500 300 200	1400 700 500	Ω Ω Ω
I_{CC}	Supply Current Osc at 0V, (one Y low)	$V_{CC} = 5V$ $V_{CC} = 10V$ $V_{CC} = 15V$		0.55 1.1 1.7	1.1 1.9 2.6	mA mA mA
$I_{IN(1)}$	Logical "1" Input Current at Output Enable	$V_{CC} = 15V$, $V_{IN} = 15V$		0.005	1.0	µA
$I_{IN(0)}$	Logical "0" Input Current at Output Enable	$V_{CC} = 15V$, $V_{IN} = 0V$	−1.0	−0.005		µA
CMOS/LPTTL INTERFACE						
$V_{IN(1)}$	Logical "1" Input Voltage, Except Osc and KBM Inputs	54C, $V_{CC} = 4.5V$ 74C, $V_{CC} = 4.75V$	$V_{CC} - 1.5$ $V_{CC} - 1.5$			V V
$V_{IN(0)}$	Logical "0" Input Voltage, Except Osc and KBM Inputs	54C, $V_{CC} = 4.5V$ 74C, $V_{CC} = 4.75V$			0.8 0.8	V V
$V_{OUT(1)}$	Logical "1" Output Voltage	54C, $V_{CC} = 4.5V$, $I_O = -360$ µA 74C, $V_{CC} = 4.75V$, $I_O = -360$ µA	2.4 2.4			V V
$V_{OUT(0)}$	Logical "0" Output Voltage	54C, $V_{CC} = 4.5V$, $I_O = -360$ µA 74C, $V_{CC} = 4.75V$, $I_O = -360$ µA			0.4 0.4	V V

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

DC Electrical Characteristics

Min/Max limits apply across temperature range unless otherwise specified (Continued)

Symbol	Parameter	Conditions	Min	Typ	Max	Units
OUTPUT DRIVE (See 54C/74C Family Characteristics Data Sheet) (Short Circuit Current)						
I_{SOURCE}	Output Source Current (P-Channel)	$V_{CC} = 5V$, $V_{OUT} = 0V$, $T_A = 25°C$	−1.75	−3.3		mA
I_{SOURCE}	Output Source Current (P-Channel)	$V_{CC} = 10V$, $V_{OUT} = 0V$, $T_A = 25°C$	−8	−15		mA
I_{SINK}	Output Sink Current (N-Channel)	$V_{CC} = 5V$, $V_{OUT} = V_{CC}$, $T_A = 25°C$	1.75	3.6		mA
I_{SINK}	Output Sink Current (N-Channel)	$V_{CC} = 10V$, $V_{OUT} = V_{CC}$, $T_A = 25°C$	8	16		mA

AC Electrical Characteristics* $T_A = 25°C$, $C_L = 50$ pF, unless otherwise noted

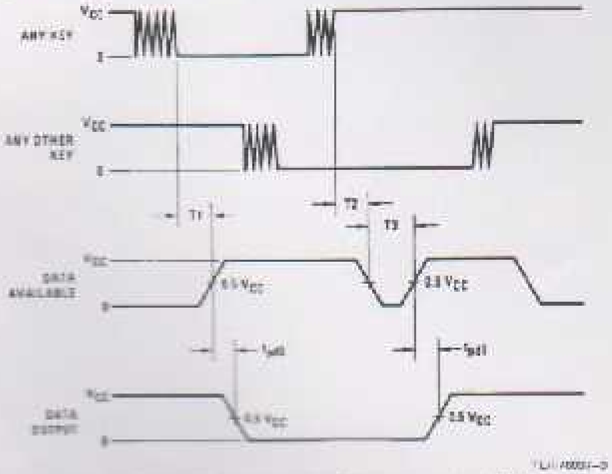
Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_{pd0}, t_{pd1}	Propagation Delay Time to Logical "0" or Logical "1" from D.A.	$C_L = 50$ pF *(Figure 1)* $V_{CC} = 5V$ $V_{CC} = 10V$ $V_{CC} = 15V$		 60 35 25	 150 80 60	 ns ns ns
t_{0H}, t_{1H}	Propagation Delay Time from Logical "0" or Logical "1" into High Impedance State	$R_L = 10k$, $C_L = 10$ pF *(Figure 2)* $V_{CC} = 5V$, $R_L = 10k$ $V_{CC} = 10V$, $C_L = 10$ pF $V_{CC} = 15V$		 80 65 50	 200 150 110	 ns ns ns
t_{H0}, t_{H1}	Propagation Delay Time from High Impedance State to a Logical "0" or Logical "1"	$R_L = 10k$, $C_L = 50$ pF *(Figure 2)* $V_{CC} = 5V$, $R_L = 10k$ $V_{CC} = 10V$, $C_L = 50$ pF $V_{CC} = 15V$		 100 55 40	 250 125 90	 ns ns ns
C_{IN}	Input Capacitance	Any Input (Note 2)		5	7.5	pF
C_{OUT}	TRI-STATE Output Capacitance	Any Output (Note 2)		10		pF

*AC Parameters are guaranteed by DC correlated testing.

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

Note 2: Capacitance is guaranteed by periodic testing.

Switching Time Waveforms



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T1 ≈ T2 ≈ RC, T3 ≈ 0.7 RC, where R ≈ 10k and C is external capacitor at KBM input.

FIGURE 1

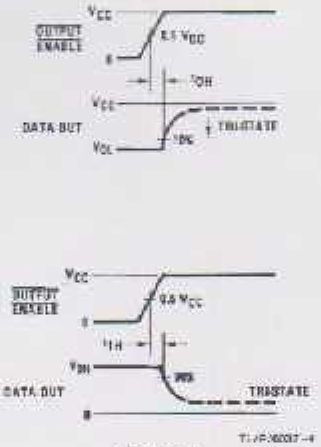

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FIGURE 2