Palestine Polytechnic University

College of Engineering and Technology
Electrical & computer Engineering Department

Graduation Project

PC Controlled Alarm System

Project Team:
Raef Mashaaleh
Naser Shalaldah
Bassam Al-Kawasmeh

Project Supervisor
Eng. Abdallah Arman

Hebron – Palestine

June, 2005

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جامعة بوليتكنك فلسطين
الخليل – فلسطين
كلية الهندسة و التكنولوجيا
دائرة الهندسة الكهربائيه والحاسوب

اسم المشروع

PC Controlled Alarm System

أسماء الطلبة

رائف هلال ناصر الشلالده بسام القواسمه

بناء على نظام كلية الهندسة و التكنولوجيا وإشراف ومتابعة المشرف المباشر على المشروع وموافقة أعضاء اللجنة الممتحنة تم تقديم هذا المشروع إلى دائرة الهندسة الكهربائيه و الحاسوب وذلك للوفاء بمتطلبات درجة البكالوريوس في الهندسة تخصص هندسة أنظمة الحاسوب.

توقيع المشرف

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توقيع اللجنة الممتحنة

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توقيع رئيس الدائرة

....

Palestine Polytechnic University

Abstract

PC Controlled Alarm System

By

Raef Mashaaleh

Naser Shlaldeh

Bassam Kawasmah

Supervisor

Eng. Abdallah Arman

Our project is a PC controlled alarm system for heat and smoke. The system is mainly depends on a set of smoke and heat sensors located in different locations in a building (for example, 2 sensor at each room or floor). The system checks the status of the sensors continuously, and check for alarm conditions, if any alarm condition is detected the system give an audible and flasher alarm to indicate that there is a problem, also it includes a complete software that display the location and the degree of the alarm on the computer screen.

Dedication

- *For that long-suffering mother and plodding father*
  - *To all martyrs in Palestine and the whole world*
    - *To all PPU Instructors and Technical employees*
      - *To every one assist us to reach this great point,*

We dedicate this effort

Work Team,
Raef Mashaaleh
Naser Shlaldeh
Bassam Kawasmeh

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Introduction

1.1General Idea About the Project and its Importance

The computer revolution has changed manufacturing! There are many factories, working non-stop, where humans are called in only when repairs are necessary. The world's largest manufacturers have installed Computer Integrated Manufacturing (CIM) systems to schedule, track, and even to perform production tasks. Some manufacturers have their computers connected via Wide Area Networks so that they receive daily data updates from other corporate facilities worldwide (e.g., product design changes). Even tiny manufacturers find that they need some automation, in the office and on the production floor.

Computer-based control system needed because they are powerful; in fact it is not advised that a user attempt to install such a system until the user has experience with less sophisticated systems.

Our system is a PC-based controlled alarm system for multi-channel alarm system. The system is mainly depending on the number of sensors placed at different location in building or factory such as sensor at each floor or at each room.

The objective behind the Alarm System was to create a reliable control system that will operate Heat and smoke system and take some actions in case of certain alarm conditions.

One of the most important field that uses computers is security and fire prevention, and a PC-control system or a microprocessor may also used and each one have advantage and disadvantage, so, the system will design is PC-Controlled Alarm System.

This Project has to deal with the alarm system controlled by using computer based on realistic practical utilization. The designed and constructed alarm system (smoke, heat) is found to be useful. This is because the controller possesses not only more efficiency but also more accuracy.

The PC controlled alarm system is more convenient to control and to installation. Because all information such as the characteristic of working state, date and time in each part of day are recorded, hence, this is useful not only for review but also improving the further alarm system.

1.2 literatures Review

Their was graduate project in the library , we read it and we find it very useful but it is different of reaction ,because our system is PC-Controlled while the Graduation project was built on the 8085 Microprocessor, also it is for fire only while our system is for fire and smoke.

The previous system was a microprocessor based system for multi channel fire alarm system. The system is mainly depending on a number of sensors located in different locations in a building. That system scan the input line to check if there is a sensor on, if any one is on, then the system will give an alarm to indicate that there is a fire in the building. It also determines which sensor is on then determines the floor where the fire occurred and outputs the floor number on the display.

New features added in our system:

Firstly, our project is a PC controlled alarm system for heat and smoke. The system is mainly depends on a set of smoke and heat sensors located in different locations in a building (for example, 2 sensor at each room or floor). The system checks the status of the sensors continuously, and check for alarm conditions, if any alarm condition is detected the system give an audible and flasher alarm to indicate that there is a problem, also it includes a complete software that display the location and the degree of the alarm on the computer screen and save these conditions by date and time.

So the new features in our system can be summarized in the following points:

- The use of computer instead of the microprocessor, which will give us more visual capabilities to display the status of each room.
- The use of heat sensor beside the smoke sensor in each room, which will give us more accurate information about the status of each room.
- The alarm circuit will contain more information as follows:
    - It will display on the computer screen all information about each room.
    - It will give an audible and flasher in case of alarm condition.
    - Also, it will switch on a fan for other conditions.

- The system also will give other signal that can be used to turn on a water sprinkles for the high risk situations.
- If the time permits, we will develop the system to directly call the firemen or the municipality to tell them about the fire.

So we can see that the system will be very modern to be adopted in any institute, and you can notice that the system is easily expanded to use more sensors for large use.

1.3 Estimated Cost

The work team had collects the initial equipments cost for the project, the following table shows the approximate estimated cost for the system:

Item	Number of units	Unit Cost	Subtotal
Desktop computer P4, 2 GHz, 512 MB RAM, 40G HD	1	$	700
Heat Sensor	3	$	10
Smoke Sensor	3	$	65
Digital IC's	30	$	1.5
Cables	--	$	5
Bell	1	$	5
Control panel	1	$	5
Software	1	$	100
Total			$1080

Table 1.1 estimated cost

1.4 Time Plan

The work had been divided into two semesters; first semester includes the collection of data, analysis, system specification, software basic algorithms and the design. On the next semester we well start interfacing the devices that well create the alarm system, testing and maintenance.

The time of the project is scheduled over 32 week; table 1.2 shows how the work is scheduled over these weeks:

Task/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Collection of data	■	■	■	■	■	■	■	■																								
Data Analysis				■	■	■	■	■	■	■																						
System Specification									■	■	■	■																				
Software Requirement										■	■	■																				
Software Design												■	■	■	■		■	■	■	■												
Interfacing and Coding SW																	■	■	■	■	■	■	■	■	■	■	■					
Testing																												■	■			
Maintenance																														■	■	
Documentation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	

Table 1.2 Time Schedule

1.5Report Contents

This report will cover the design and implementation of the PC-Controlled alarm system including the following chapters:

Chapter one gives a general idea about project and its importance, literature review, estimated cost, time plan and report contents.

Chapter two gives a theoretical background subjects related to the main ideas of the project and some information about special components.

Chapter three gives a general description of the project, defining the objectives to be performed by the system its include some block diagram of system such as ,general design block diagram sensors and display block diagram ,also it include the whole system block diagram .

Chapter four discussing design options and justifying those chosen for the project, shows some major elements and detailed description of project parts.

Chapter five talk about system software design, it includes the algorithm and flowchart of the whole system, main program, and all things related to the system software, such that system main operations, system routines.....etc.

Chapter six and seven includes testing and implementation, summary and conclusion.

Chapter Two

Theoretical Background

Theoretical Background

2.1 Theoretical subjects related to the main idea of the project

In this part we well give the theory for each component used for our project including how these components are working, the input and output, how these inputs are taken from previous components and how this output is used by other components.

The project, well consist of three main parts:

- Interfacing the smoke sensor to the parallel port
- Interfacing the heat sensor to the parallel port of the computer
- Use these signals (from smoke and heat sensor) to give an alarm

The following block diagram shows the basic elements of the project in figure 2.1:

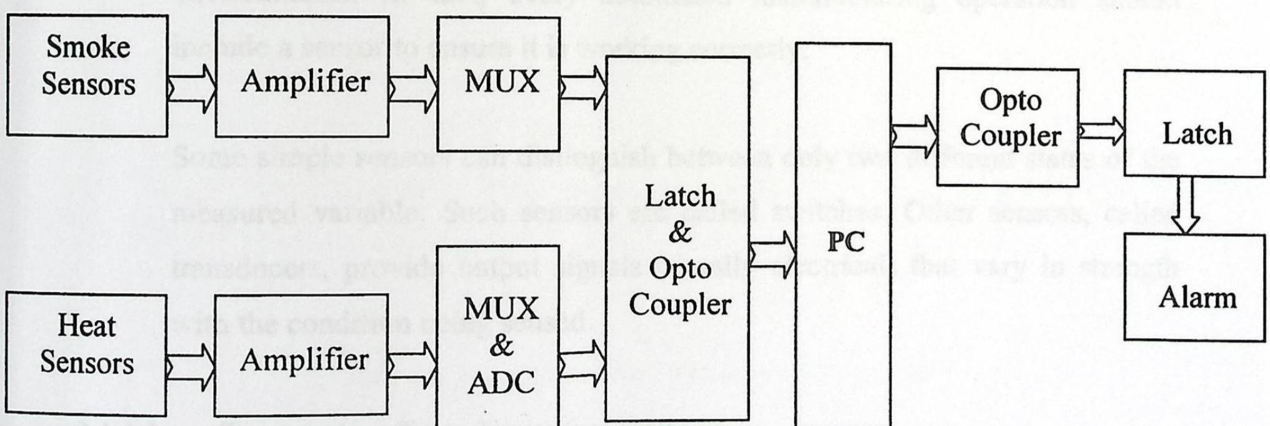

Figure 2.1 the general block diagram of basic elements

Firstly the sensor will detect any condition that is above the permitted range (above a specified temperature for the heat sensor or the existence of smoke for the smoke sensor) and well send an analog signal from the heat sensor for the amplifier which in turn will amplify this signal to +5 volt and send it to the analog to digital converter (ADC).

The ADC will convert this signal from analog to digital and then send these data to the MUX, which in turn will send it to the computer through the parallel port. Inside the computer this signal will be firstly identified by its address and then will take the required action in turn (giving an alarm and display on the screen the location and type of warning).

In the smoke sensor, the signal will be digital, and so there is no need for the ADC and thus the signal will be sent directly to the Mux and then through the Opto coupler to the PC.

In the following subsections we describe each element:

2.1.1 Sensors:

Good sensors are essential in any automated system. Some sensors detect only part presence. Other sensors, bar code readers, for example, help to track materials, tooling, and products as they enter, go through, and leave CIM environments. In fact, every automated manufacturing operation should include a sensor to ensure it is working correctly.

Some simple sensors can distinguish between only two different states of the measured variable. Such sensors are called switches. Other sensors, called transducers, provide output signals (usually electrical) that vary in strength with the condition being sensed.

2.1.1.1 Temperature Transducers (sensor):

There are four types of temperature sensors we will pick.

Probably the most common temperature sensor is the metal RTD, or Resistive Temperature Detector, which responds to heat by increasing its resistance to electric current. The thermistor type of temperature sensor is similar, except that its resistance decreases as it is heated. In either case, there is only a tiny variation in current flow due to temperature change. Current through an RTD or thermistor must be compared to current through another circuit containing identical devices at a reference temperature to detect the change. The freezing temperature of water is used as the reference temperature.

Semiconductor integrated circuit temperature detectors respond to temperature increases by increasing reverse-bias current across P-N junctions, generating a small but detectable current or voltage proportional to temperature. The integrated circuit may contain its own amplifier.

Thermocouple type temperature sensors generate a small voltage proportional to the temperature at the location where dissimilar metals are joined. The reason a voltage is generated is still a source of debate. One possible reason may be that heat causes electrons in metals to migrate away from the heated portion of the conductor, and that this tendency is greater in one of the metals than in the other.

Sensors are connected to the PC through the parallel port as shown in figure 2.2

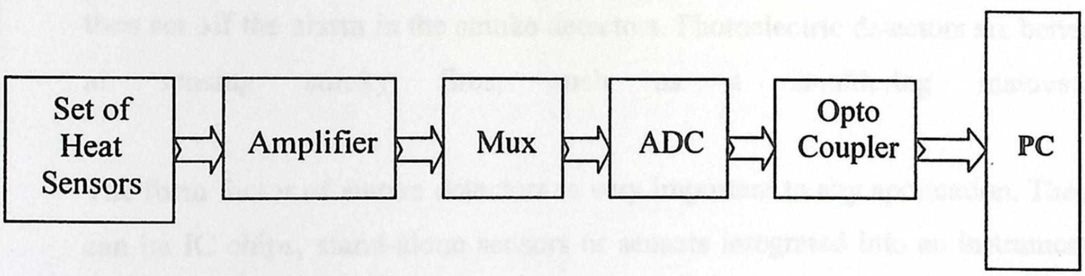

Figure 2.2 Interfacing the Heat sensors to the PC

2.1.1.2 Smoke Detector:

There are two common types of technologies for smoke detectors: ionizing and photoelectric detectors. Ionizing smoke detectors use an ionization chamber and a source of ionizing radiation to detect smoke. This type of smoke detector is very common because it is inexpensive and good at detecting smaller amounts of smoke produced by flaming fires. An ionization chamber is very simple. It consists of 2 plates with a voltage across them, along with a source of ionizing radiation. The alpha particles generated by the small radioactive source ionize the oxygen and nitrogen atoms of the air in the chamber. Ionization means that you end up with a free electron (with a negative charge) and an atom missing one electron (with a positive charge). The negative electron is attracted to the plate with a positive voltage, and the positive atom is attracted to the plate with a negative voltage. The electronics in the smoke detector sense the small amount of electrical current that these electrons and ions moving toward the plates represent. When smoke enters the ionization chamber it disrupts this current - the smoke particles attach to the ions and neutralize them. The smoke detector senses the drop in current between the plates and sets off the alarm.

Inside photoelectric smoke detectors are a light and a sensor at 90-degree angles to one another. In the normal case, the light shoots straight across and misses the sensor. When smoke enters the chamber, however, the smoke particles scatter the light and some amount of light hits the sensor. The sensors then set off the alarm in the smoke detectors. Photoelectric detectors are better at sensing smoky fires, such as a smoldering mattress.

The form factor of smoke detectors is very important to any application. They can be IC chips, stand-alone sensors or sensors integrated into an instrument with displays, control and sometimes computer signal output. Some smoke detectors have features such as interconnectability with other sensors and integral temperature sensors or switches. They can have adjustable sensitivities and visual or audible alarms. They can work off AC or DC power. Typical mounting positions for smoke detectors are on walls, ceilings or inside air ducts.

Sensors are connected to the Parallel port as Shown in figure 2.3

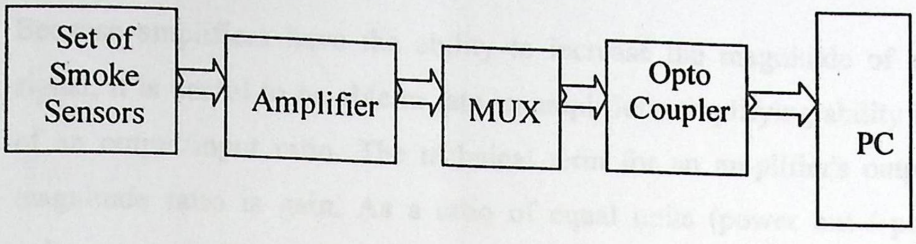

Figure 2.3 Interfacing the Smoke Sensor to the PC

2.1.2 Amplifier

Because active devices have the ability to control a large amount of electrical power with a small amount of electrical power, they may be arranged in circuit so as to duplicate the form of the input signal power from a larger amount of power supplied by an external power source. The result is a device that appears to magically magnify the power of a small electrical signal (usually an AC voltage waveform) into an identically-shaped waveform of larger magnitude. The Law of Energy Conservation is not violated because the additional power is supplied by an external source, usually a DC battery or equivalent. The amplifier neither creates nor destroys energy, but merely reshapes it into the waveform desired:

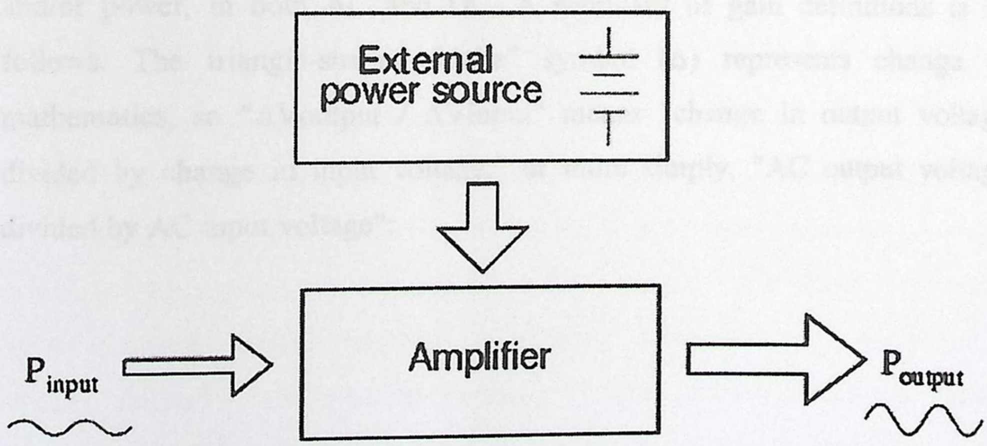

Figure 2.4 The Law of Energy Conservation for the amplifier

Sensors are connected to the Parallel port as Shown in figure 2.3

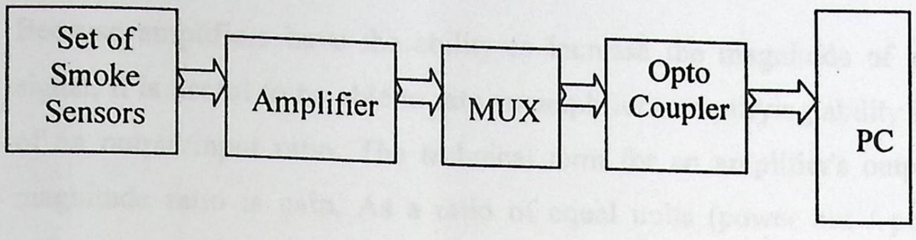

Figure 2.3 Interfacing the Smoke Sensor to the PC

2.1.2 Amplifier

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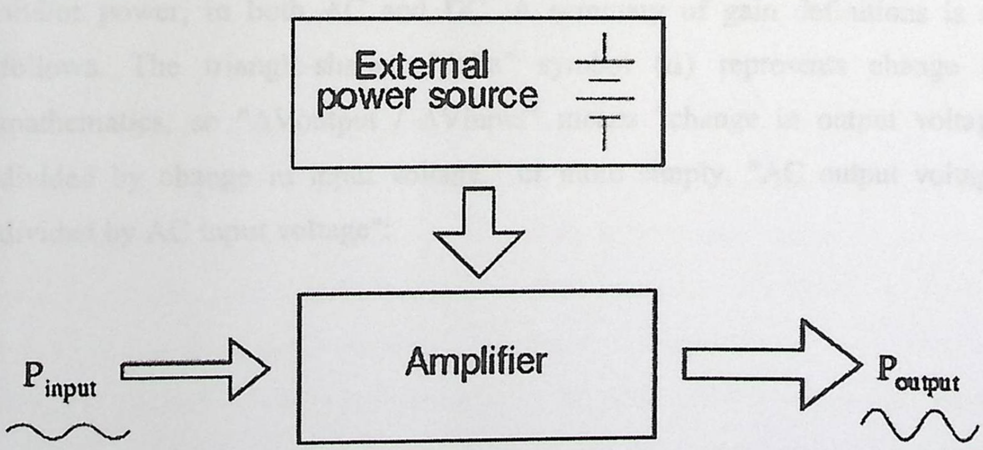

Figure 2.4 The Law of Energy Conservation for the amplifier

Amplifier gain

Because amplifiers have the ability to increase the magnitude of an input signal, it is useful to be able to rate an amplifier's amplifying ability in terms of an output/input ratio. The technical term for an amplifier's output/input magnitude ratio is gain. As a ratio of equal units (power out / power in, voltage out / voltage in, or current out / current in), gain is naturally a unitless measurement. Mathematically, gain is symbolized by the capital letter "A". Correspondingly, if we know the gain of an amplifier and the magnitude of the input signal, we can calculate the magnitude of the output.

Electronic amplifiers often respond differently to AC and DC input signals, and may amplify them to different extents. Another way of saying this is that amplifiers often amplify changes or variations in input signal magnitude (AC) at a different ratio than steady input signal magnitudes (DC). The specific reasons for this are too complex to explain at this time, but the fact of the matter is worth mentioning. If gain calculations are to be carried out, it must first be understood what type of signals and gains are being dealt with, AC or DC.

Electrical amplifier gains may be expressed in terms of voltage, current, and/or power, in both AC and DC. A summary of gain definitions is as follows. The triangle-shaped "delta" symbol (Δ) represents change in mathematics, so "ΔVoutput / ΔVinput" means "change in output voltage divided by change in input voltage," or more simply, "AC output voltage divided by AC input voltage":

	DC gains	AC gains
Voltage	$A_V = \frac{V_{output}}{V_{input}}$	$A_V = \frac{\Delta V_{output}}{\Delta V_{input}}$
Current	$A_I = \frac{I_{output}}{I_{input}}$	$A_I = \frac{\Delta I_{output}}{\Delta I_{input}}$
Power	$A_P = \frac{P_{output}}{P_{input}}$	$A_P = \frac{(\Delta V_{output})(\Delta I_{output})}{(\Delta V_{input})(\Delta I_{input})}$
	$A_P = (A_V)(A_I)$	

Δ = *"change in . . ."*

Figure 2.5 DC and AC Gain

If multiple amplifiers are staged, their respective gains form an overall gain equal to the product (multiplication) of the individual gains:

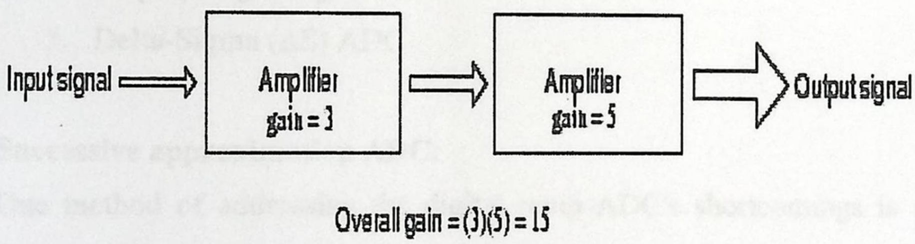

Figure 2.6 overall gain of the amplifier

2.1.3 Analog to Digital Converter (ADC)

Connecting digital circuitry to sensor devices is simple if the sensor devices are inherently digital themselves. Switches, relays, and encoders are easily interfaced with gate circuits due to the on/off nature of their signals. However, when analog devices are involved, interfacing becomes much more complex. What is needed is a way to electronically translate analog signals into digital (binary) quantities, and visa-versa. An analog-to-digital converter, or ADC, performs the former task while a digital-to-analog converter, or DAC, performs the latter.

An ADC inputs an analog electrical signal such as voltage or current and outputs a binary number. In block diagram form, it can be represented as such:

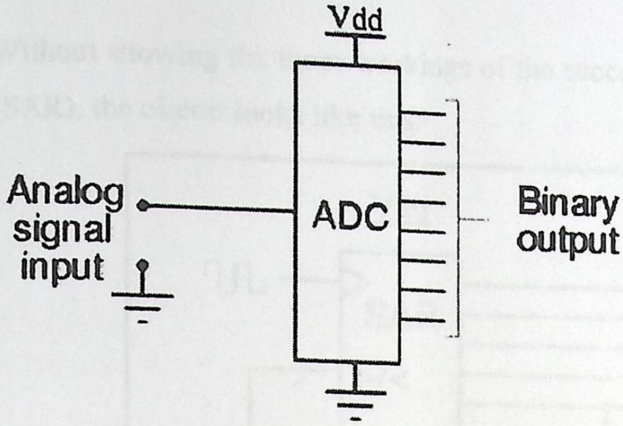

Figure 2.7 analog to digital converter

There are many approaches for converting analog signals to digital , the following are the most common approaches:

1. Successive approximation ADC
2. Digital ramp ADC
3. Tracking ADC
4. Slope (integrating) ADC
5. Delta-Sigma (ΔΣ) ADC

Successive approximation ADC:

One method of addressing the digital ramp ADC's shortcomings is the so-called successive-approximation ADC. The only change in this design is a very special counter circuit known as a successive-approximation register. Instead of counting up in binary sequence, this register counts by trying all values of bits starting with the most-significant bit and finishing at the least-significant bit. Throughout the count process, the register monitors the comparator's output to see if the binary count is less than or greater than the analog signal input, adjusting the bit values accordingly. The way the register counts is identical to the "trial-and-fit" method of decimal-to-binary conversion, whereby different values of bits are tried from MSB to LSB to get a binary number that equals the original decimal number. The advantage to this counting strategy is much faster results: the DAC output converges on the analog signal input in much larger steps than with the 0-to-full count sequence of a regular counter.

Without showing the inner workings of the successive-approximation register (SAR), the circuit looks like this:

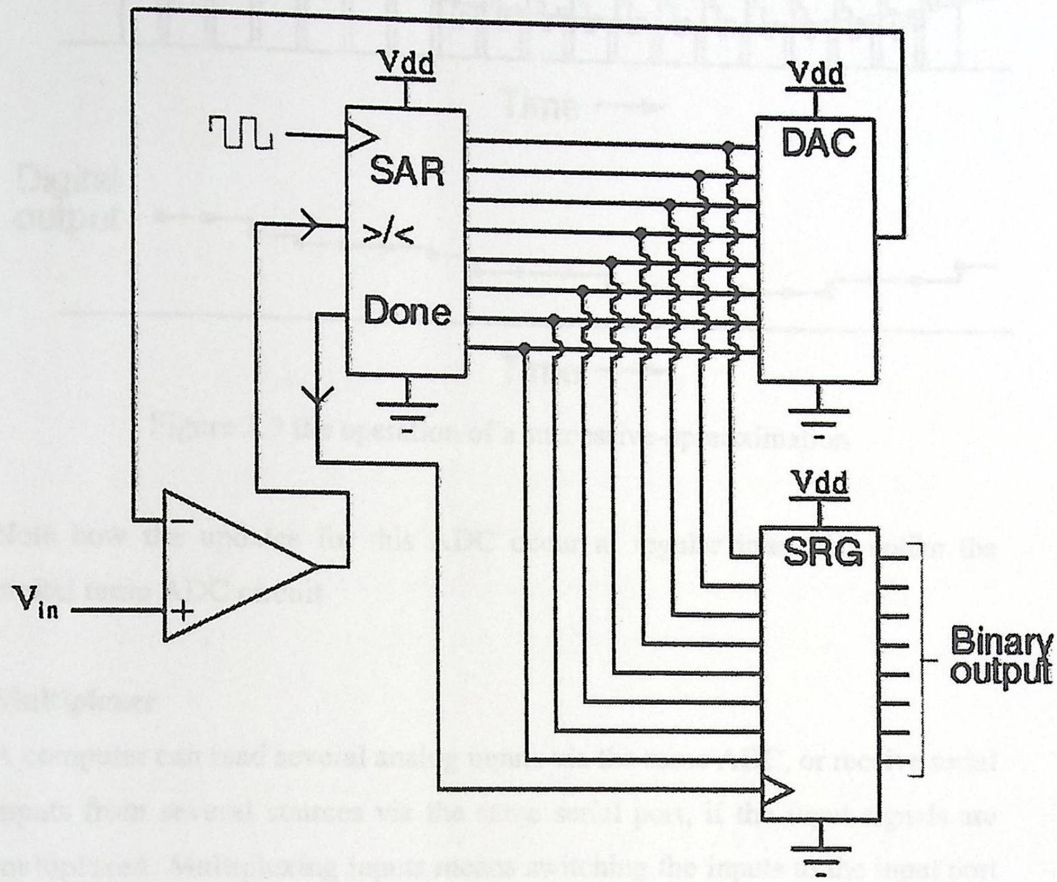

Figure 2.8 successive approximation

It should be noted that the SAR is generally capable of outputting the binary number in serial (one bit at a time) format, thus eliminating the need for a shift register. Plotted over time, the operation of a successive-approximation ADC looks like this:

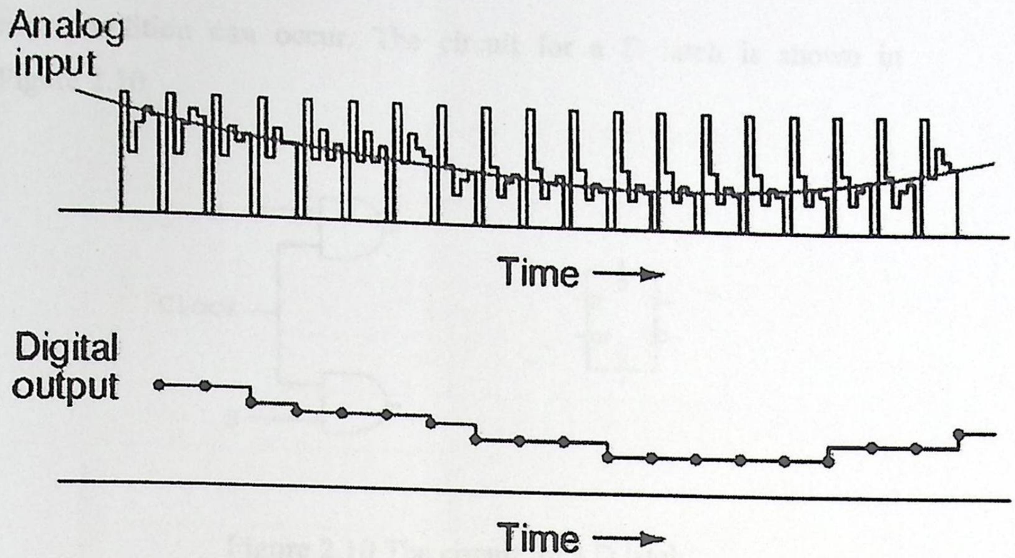

Figure 2.9 the operation of a successive-approximation

Note how the updates for this ADC occur at regular intervals, unlike the digital ramp ADC circuit.

2.1.4 Multiplexer

A computer can read several analog inputs via the same ADC, or receive serial inputs from several sources via the same serial port, if the input signals are multiplexed. Multiplexing inputs means switching the inputs to the input port one at a time, under computer control. Similarly, a computer can use a single DAC to output analog values to more than one output circuit, or a single serial port to output serial data to more than one output channel, if the outputs are multiplexed.

Analog values may have to be held via capacitors during multiplexing. Serial input must be either spooled into an external memory device or simply disallowed while the computer is switched away from a serial input channel.

2.1.5 The D Latch and the D flip-flop

It is possible to create a latch which has no race condition, simply by providing only one input to a RS latch, and generating an inverted signal to present to the other terminal of the latch. In this case, the S and R inputs are always inverted with respect to each other, and no race condition can occur. The circuit for a D latch is shown in Figure 2.10

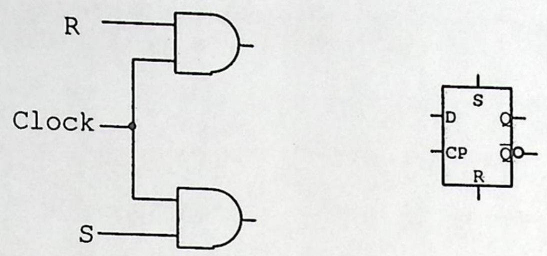

Figure 2.10 The circuit for a D latch

The D latch is used to capture, or ``latch'' the logic level which is present on the Data line when the clock input is high. If the data on the *D* line changes state while the clock pulse is high, then the output, Q, follows the input, D. This effect can be seen in the timing diagram, Figure 2.11 (a).

The D flip-flop, while a slightly more complicated circuit, performs a function very similar to the D latch. In the case of the D flip-flop, however, the rising edge of the clock pulse is used to ``capture'' the input to the flip flop. This device is very useful when it is necessary to ``capture'' a logic level on a line which is very rapidly varying. Figure 2.11 (b) shows a timing diagram for a D-type flip-flop. This type of device is said to be ``edge triggered'' -- either rising edge triggered (*i.e.* a 0-1 transition) or falling edge triggered (*i.e.*, a 1-0 transition) devices are available.

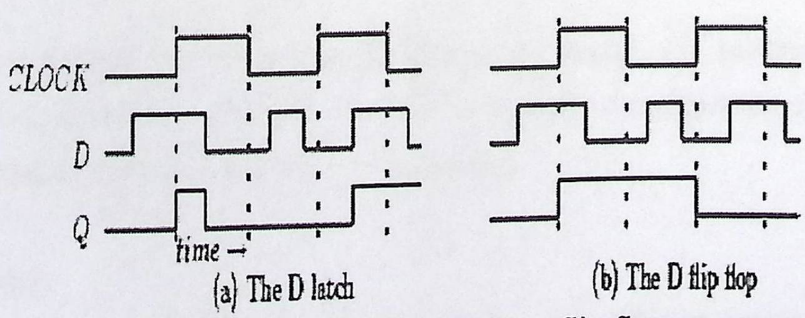

Figure 2.11 D latch and D-type flip-flop

Both the D latch and D flip-flop have the following truth table:

$\overline{Preset}$	$\overline{Clear}$	CLOCK	D	Q	$\overline{Q}$
0	1	x	x	1	0
1	0	x	x	0	1
0	0	x	x	1	1
1	1	↑ or 1	0	0	1
1	1	↑ or 1	1	1	0
1	1	0	X	Q_0	$\overline{Q_0}$

Table 2.1 the D latch and D flip-flop truth table

The symbol ↑ means a leading edge, or 0 − 1 transition as the clock input to the flip flop. For a D latch, it would be the level

2.1.6 Opto-Coupler

Opto-couplers as the name suggests isolates two devices using light. It contains of LED (Light Emitting Diode) and a sensor. In order to isolate a device you can connect a LED to one side and a sensor to the other side. When current flows on one side the LED glows and makes the sensor aware of it. The sensor when hit by the light also makes current flow in effect simulating a connection between the two wires.

In our project (as we use an external power supply, i.e. not from computer power supply) we will use this device in order to connect the circuit of the sensors to the parallel port of the computer.

2.1.7 Diplay:

A screen is used in this system to show the status of each sensor for the user including the address of each sensor(whether it is smoke or heat).

The Interface will be programmed by the VB.6 programing language.

2.1.8 Alarm:

The alarm circuit consists of bell connected to to the PC via an output Parallel Port.

The follwing block diagram show how the alarm circuit is connected to the parallel port:

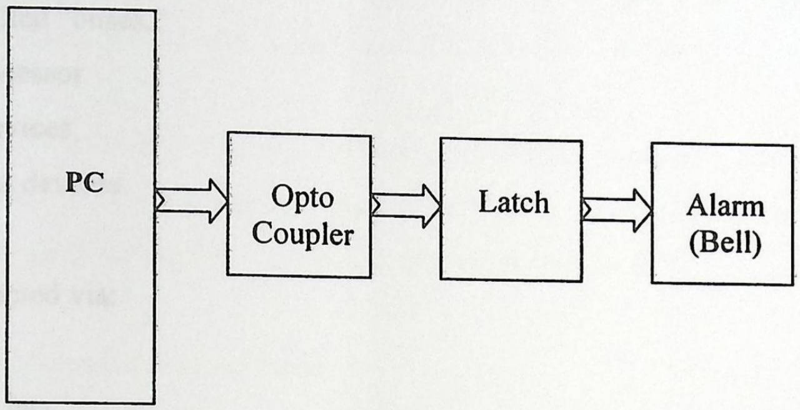

Figure 2.12 Alarm block diagram

2.2 Information about Special Components:

This part will give some information about special components that will be used in implementing the project. This will include information about the PC and its parallel port:

2.2.1 Digital Computer, the Heart of Automated Control:

A computer consists of three types of devices, interconnected by three sets of conductors called "buses."

· Central processor

· Memory devices

· Input/output devices

All interconnected via:

· A data bus

· An address bus

· A control bus

The Central Processing Unit (CPU) is the unit that controls the computer. The CPU reads the computer program from memory and executes the instructions. It manipulates values stored in memory and inputs or outputs data via input/output (I/O) devices. The CPU will be discussed in more detail later in this section.

The buses are sets of parallel conductors. An 8 bit computer has 8 conductors in its data bus and thus can move 8 bits of data at a time. A 16 (32, or 64) bit computer has 16 (32, or 64) data bus conductors and can process 16 (32, or 64) bit data "words" at a time. Some computers use bus-sharing techniques to reduce the number of conductors required in the data bus

The CPU: A CPU contains several types of registers in which binary numbers can be stored, Every CPU or MPU has at least one accumulator, where it holds the data it is using. With some exceptions, the CPU can change data only if the data is in an accumulator. To keep track of where it is in a program, the CPU stores the memory location of the next instruction in a register called a program counter.

Choosing the Right Computer:

Choosing the right computer is not that big of a concern. Anything from an old 8086 to IBM's new Deep Blue supercomputer will work.

2.2.2 The Parallel Port of the PC:

For fast data input and output, whole data words can be sent or received, with all their bits carried simultaneously on parallel conductors. Data sent to a parallel output port by the CPU is "buffered" in the output port (stays in the most recently written state), until the CPU writes to it again.

Sensors, actuators, or other computer peripherals such as printers can be connected to a computer via parallel I/O ports. Computers do not usually communicate with other computers via parallel interfaces.

Parallel Port Characteristics:

The parallel port consists of eight data lines, four control lines, five status lines, and eight ground lines. In normal usage, the lines are controlled by the host computer software and the peripheral device following a protocol such as IEEE Standard 1284-1994. The protocol defines procedures for transferring data such as handshaking, returning status information, and so on. However, the toolbox uses the parallel port as a basic digital I/O device, and no protocol is needed. Therefore, you can use the port to input and output digital values just as you would with a typical DIO subsystem.

To access the physical parallel port lines, most PCs come equipped with one 25-pin female connector, which is shown below.

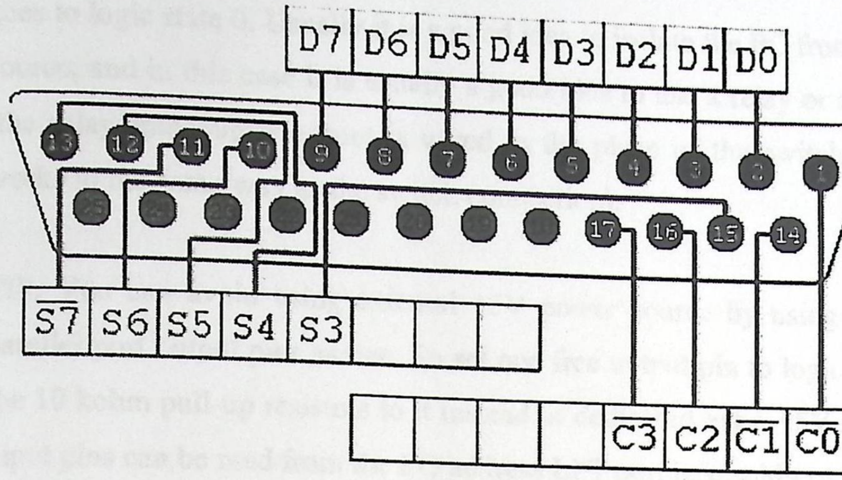

Figure 2.13 25-way Female D-Type Connector

The lines use TTL logic levels. A line is high (true or asserted) when it is a TTL high level, while a line is low (false or unasserted) when it is a TTL low level. The exceptions are lines 1, 11, 14, and 17, which are hardware inverted.

The toolbox groups the 17 nonground lines into three separate ports. The port IDs and the associated pin numbers are given below.

Port ID	Pin	Description
0	2-9	Eight I/O lines with 9 being the most significant bit (MSB)
1	10-13 and 15	Five Input lines used for status
2	1,14,16 and 17	Four I/O lines used for control

Table 2.2 Parallel Port IDs and Pin Numbers

Reading the input pins in parallel port

PC parallel port has 5 input pins. Those inputs can accept TTL level signals (0-0.7V = logic 0, 2.4-5V = logic 1). You can connect a TTL level output signal to it directly (remember to attach the signal source ground to parallel port ground). You can connect simple switches to the inputs by connecting the switch between parallel port ground and input pin, and then adding a 10 kohm pull-up resistor from the pin to +5V. When the switch is activated, the pin goes to logic state 0. Usually it is a good idea to isolate the PC from the signal source, and in this case it is usually a good idea to use a relay or optocoupler (the r elay/optocoupler o utput is wired in the place of the switch, o therwise works in the same way as the switch connection).

TIP: You can avoid using external +5V power source by using one of the parallel port output pins as one. So set one free output pin to logic 1 and wire the 10 kohm pull-up resistors to it instead of dedicated extra +5V source. The input pins can be read from the I/O address LPT port base address + 1.

The meaning of the buts in byte you read from that I/O port:

- D0: state not specified
- D1: state not specified
- D2: state not specified
- D3: state of pin 15 (ERROR) inverted
- D4: state of pin 13 (SELECTED)
- D5: state of pin 12 (PAPER OUT)
- D6: state of pin 10 (ACK)
- D7: state of pin 11 (BUSY) inverted

Using the Parallel Port to Input 8 Bits:

If your Parallel Port doesn't support bi-directional mode, don't despair. You can input a maximum of 9 bits at any one given time. To do this you can use the 5 input lines of the Status Port and the 4 inputs (open collector) lines of the Control Port.

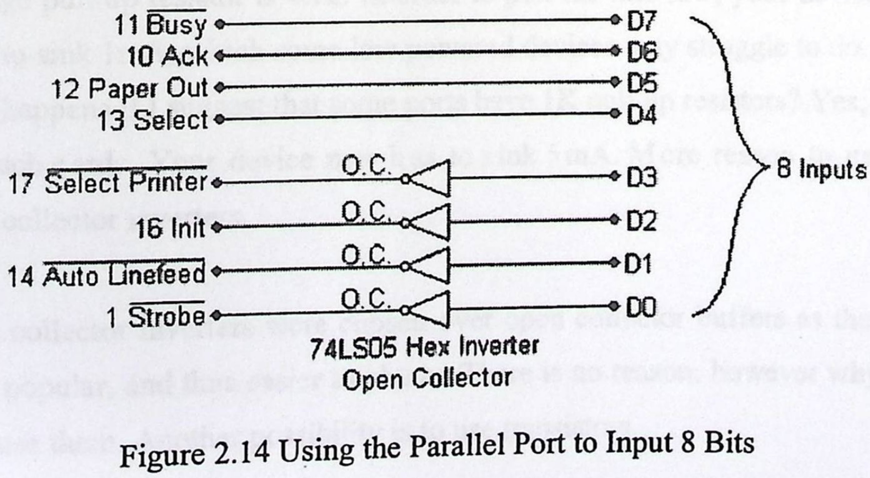

Figure 2.14 Using the Parallel Port to Input 8 Bits

The inputs to the Parallel Port has be chosen as such, to make life easier for us. Busy just happens to be the MSB (Bit 7) of the Status Port, then in ascending order comes Ack, Paper Out and Select, making up the most significant nibble of the Control Port. The Bars are used to represent which inputs are Hardware inverted, i.e. +5v will read 0 from the register, while GND will read 1. The Status Port only has one inverted input.

The Control port is used to read the least significant nibble. As described before, the control port has open collector outputs, i.e. two possible states, high impedance and GND. If we connect our inputs directly to the port (For example an ADC0804 with totem pole outputs), a conflict will result if the input is high and the port is trying to pull it down. Therefore we use open collector inverters.

However this is not always entirely necessary. If we were connecting single pole switches to the port with a pull up resistor, then there is no need to bother with this protection. Also if your software initializes the control port with xxxx0100 so that all the pins on the control port are high, then it may be unnecessary. If however you don't bother and your device is connected to the Parallel Port before your software has a chance to initialize then you may encounter problems.

Another problem to be aware of is the pull up resistors on the control port. The average pull-up resistor is 4.7k. In order to pull the line low, your device will need to sink 1mA, which some low powered devices may struggle to do. Now what happens if I suggest that some ports have 1K pull up resistors? Yes, there are such cards. Your device now has to sink 5mA. More reason to use the open collector inverters.

Open collector inverters were chosen over open collector buffers as they are more popular, and thus easier to obtain. There is no reason, however why you can't use them. Another possibility is to use transistors.

The input, D3 is connected via the inverter to Select Printer. Select Printer just happens to be bit 3 of the control port. D2, D1 & D0 are connected to Init, Auto linefeed and strobe, respectively to make up the lower nibble. Now this is done, all we have to do is assemble the byte using software. The first thing we must do is to write xxxx0100 to the Control Port. This places all the control port lines high, so they can be pulled down to input data.

```
outportb(CONTROL, inportb(CONTROL) & 0xF0 | 0x04);
```

Now that this is done, we can read the most significant nibble. This just happens to be the most significant nibble of the status port. As we are only interested in the MSnibble we will AND the results with 0xF0, so that the LSnibble is clear. Busy is hardware inverted, but we won't worry about it now. Once the two bytes are constructed, we can kill two birds with one stone by toggling Busy and Init at the same time.

```
a = (inportb(STATUS) & 0xF0); /* Read MSnibble */
```

We can now read the LSnibble. This just happens to be LSnibble of the control port - How convenient! This time we are not interested with the MSnibble of the port, thus we AND the result with 0x0F to clear the MSnibble. Once this is done, it is time to combine the two bytes together. This is done by OR'ing the two bytes. This now leaves us with one byte, however we are not finished yet. Bits 2 and 7 are inverted. This is overcome by XOR'ing the byte with 0x84, which toggles the two bits.

```
a = a |(inportb(CONTROL) & 0x0F); /* Read LSnibble */
a = a ^ 0x84; /* Toggle Bit 2 & 7 */
```

How to connect circuits to parallel port

PC parallel port is 25 pin D-shaped female connector in the back of the computer. It is normally used for connecting computer to printer, but many other types of hardware for that port is available today.

Not all 25 are needed always. Usually you can easily do with only 8 output pins (data lines) and signal ground. I have presented those pins in the table below. Those output pins are adequate for many purposes.

pin	function
2	D0
3	D1
4	D2
5	D3
6	D4
7	D5
8	D6
9	D7

Pins 18,19,20,21,22,23,24 and 25 are all ground pins.

Those datapins are TTL level output pins. This means that they put out ideally 0V when they are in low logic level (0) and +5V when they are in high logic level (1). In real world the voltages can be something different from ideal when the circuit is loaded. The output current capacity of the parallel port is limited to only few milliamperes.

```
    Dn Out ------+
                 |+
 Sourcing        Load (up to 2.6 mA @ 2.4 v)
                 |-
    Ground ------+
```

Chapter Three

Design Concepts

3.1 Project Objectives

3.2 General Block Diagram

3.3 How System Works

Chapter Three

Design Concepts

3.1 Project Objectives

3.2 General Block Diagram

3.3 How System Works

Design Concepts

3.1 Project Objectives

The main objectives behind the project are:

1- Monitor all the parts of building or factory, to determine any event may cause a fire in the factory as high temperature or leakage of gas --- etc

2- When the system determines a fire or an event could cause a fire the system has to determine the exact position of that fire.

3- When the system detects a fire then the system had to make some reactions which aim to inform the supervisor about the event by giving a bell and flasher.

4- Conventional alarm systems having hard wire layout and normally opened warning devices like heat detector and smoke detector in general specifications, have a good view in low price, but have a bad view in low efficiency to warn and to communicate to human, difficult of maintenance, hard expansion and transformation of working no record. This alarm system is designed and built to solve those problem.

3.2 General Block Diagram

The General block Diagram is as shown in figure 3.1

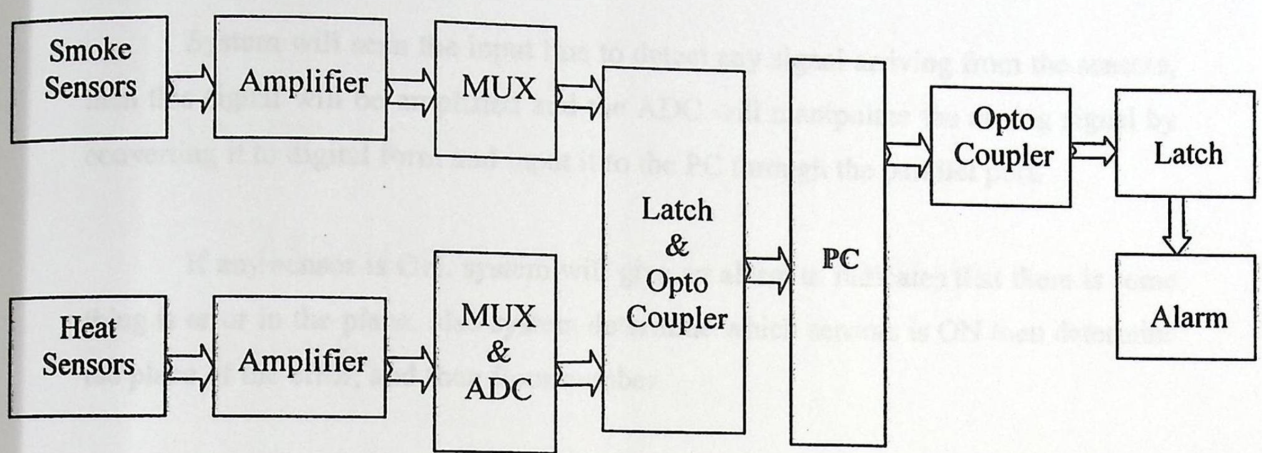

Figure 3.1 the general block diagram

3.3 How System Works

Our system is mainly depending on a number of sensors located in a different location in a building for example sensor at each floor or sensor at each room in each floor.

System will scan the input line to detect any signal arriving from the sensors, then this signal will be amplified and the ADC will manipulate the analog signal by converting it to digital form and input it to the PC through the parallel port.

If any sensor is ON, system will give an alarm to indicates that there is some thing is error in the place, also system determine which sensors is ON then determine the place of the error, and then floor number.

So the system inform the controller or the administrator about the position of the problem (fire and heat) and also the system will continuing to scan input line to check the status of the sensors

Chapter Four

Hardware System Design

4.1 Design Options:

- **4.1.1 Options for Processor unit**
- **4.1.2 Options for the Ports**
- **4.1.3 Programming Language**
- **4.1.4 Opto Coupler**
- **4.1.5 ADC0808/ADC0809**

4.2 Circuit Design

4.3 Detailed Description of the Project Parts

- **4.3.1 LM35 (Precision Centigrade Temperature Sensors)**
- **4.3.2 Smoke DI-3 Sensor (Ionization Smoke Detector)**
- **4.3.3 A741 Amplifier**
- **4.3.4 ADC0808/ADC0809**
- **4.3.5 The SN7475, SN74LS75 (4-Bit Bistable Latch)**
- **4.3.6 Opto Coupler (4N25)**

Hardware System Design

4.1 Design Options:

In the design process we encounter many options for each component, the design options are illustrated below:

4.1.1 Options for Processor unit:

In our project we will use a PC to process the signals from the sensors. There are other options such as:

- Microprocessor (8085, 8086, …etc)
- Microcontroller

The reasons behind choosing the PC over the above options are:

- It has more capabilities
- More convenient in use
- Easier for user in that it offers a good display

4.1.2 Options for the Ports:

We will use the parallel port in order to connect the circuit to the PC. There are other ports that can be used such as:

- USB (Universal Serial Port)
- Serial Bus
- Network Adapter

We used the Parallel Port in our project for the following reasons

- It provides a parallel 9 lines for inputting the signal
- Can be used to out up to 9 signals at a time.
- The team has complete information about the parallel port.

4.1.3 Programming Language:

In order to deal with the parallel we must use a programming language such as Java, Matlab, C++,…etc.
We will use VB.6 in order to deal with the Parallel Port for the following reasons:

- It provides a good user interface
- It has the capability to deal with the parallel port
- Work team experience with this language

4.1.4 Opto Coupler:

The Opto coupler will be used to interface the signal to the PC. Other option that may be used is the power from the PC.
As the sensors will be far from the PC, it is more easier to get the power from outside the PC, so we will the Opto coupler in order to use power from outside the PC.

4.1.5 ADC0808/ADC0809

Instead of using the ADC0808/ADC0809 we can use ADC0804 and 8 Mux's of 74LS150 which will make the circuit more complex, so the work team decides to use the ADC0808/ADC0809 to reduce the connections, which will make the circuit easier.

4.2 Circuit Design:

The alarm circuit that will be used in the project support up to 16 sensors (8 for the smoke and 8 for the heat as an example).

The smoke sensor will give us a digital signal (binary 0, 1), so the path to the parallel port of the PC will consist of the following stages:

- The DI – 3 will give us a binary data zero volt if no sense of smoke, or +5 volt if it senses a smoke in the room.
- This signal will be amplified by the UA 741 amplifier to +5 volt so that we can use it as an input signal for the other digital IC's and the Parallel port of the PC.
- After that a set of 8 similar signals will be multiplexed by the 74LS150 MUX, so that only one signal pass to the PC.
- This signal will be saved for a moment in the SN7475 latch before it passes to the parallel port through the 4N25 Opto Coupler.
- Inside the PC this signal will be manipulated by the Visual Basic 6.0 programming language.

The Heat sensor will give us an analog signal (differs according to the temperature it sense), so the path to the parallel port of the PC will consist of the following stages:

- The LM35 will give us an analog signal that determines the temperature.
- After that a set of 8 similar signals will be multiplexed and converted to digital by the ADC 0809.
- This signal will be amplified by the UA 741 amplifier to +5 volt so that we can use it as an input signal for the other digital IC's and the Parallel port of the PC.
- This signal will be saved for a moment in the SN7475 latch before it continues to the parallel port through the 4N25 Opto Coupler.
- Inside the PC this signal will be manipulated by the Visual Basic 6.0 programming language.

Figure 4.1 shows the circuit design of the PC Controlled Alarm System:

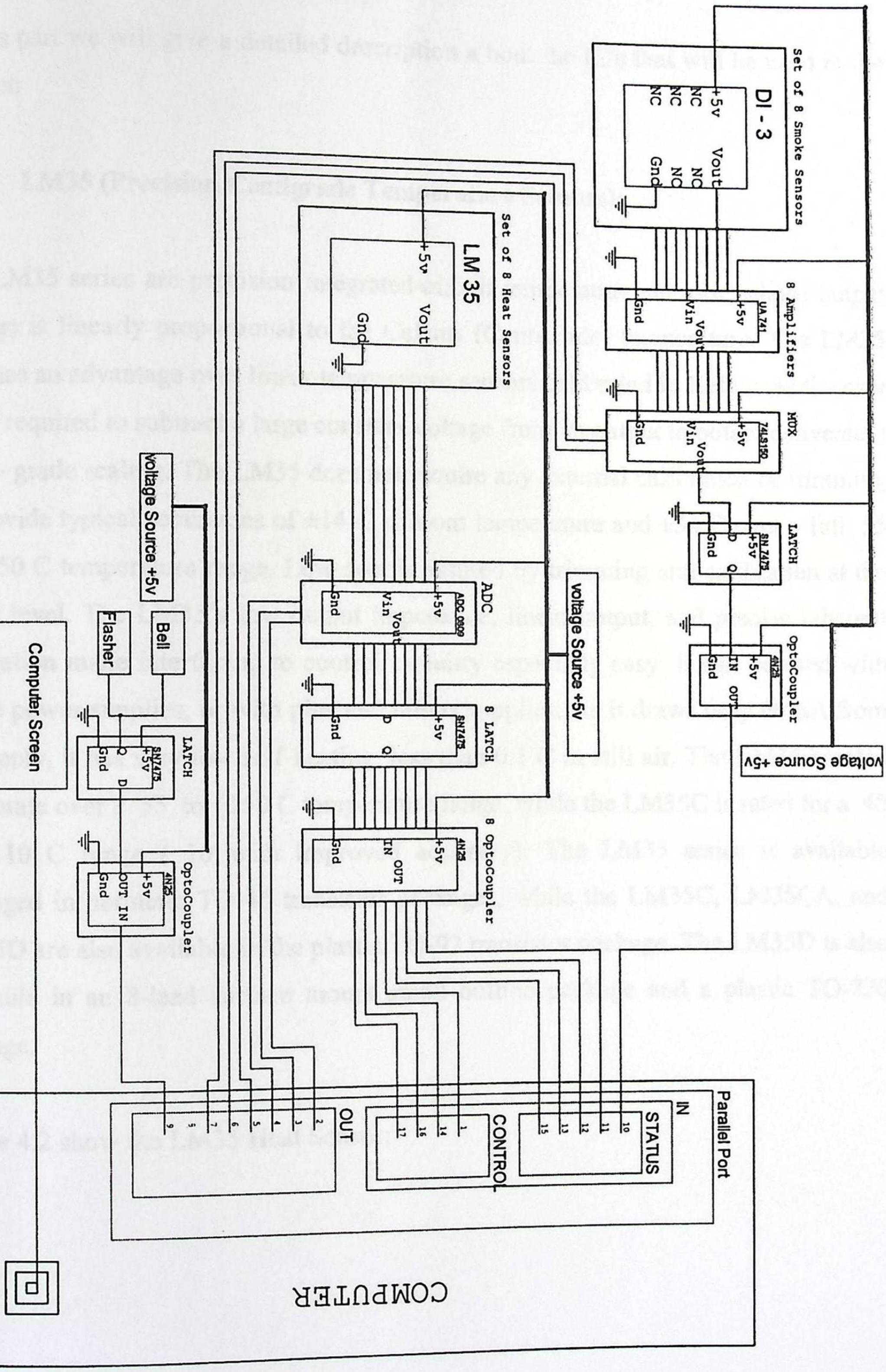

Figure 4.1 Alarm Circuit Design

4.3 Detailed Description of the Project Parts:

In this part we will give a detailed description a bout the IC's that will be used in the project:

4.3.1 LM35 (Precision Centigrade Temperature Sensors):

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 Centi- grade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±14 C at room temperature and ±34 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 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.

Figure 4.2 show the LM35 Heat Sensor:

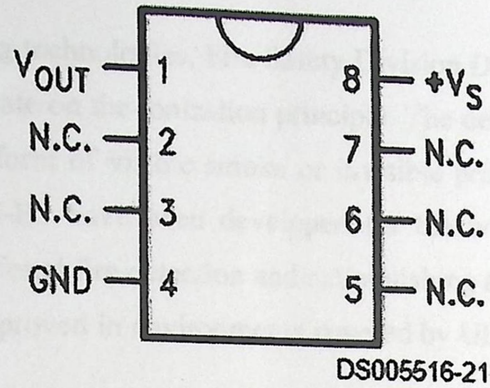

Figure 4.2 LM35 Heat Sensor

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 ±14 C typical
- Low impedance output, 0.1 for 1 mA load

4.3.2 Smoke DI-3 Sensor (Ionization Smoke Detector)

The Siemens Building technologies, Fire Safety Division DI-3, DI-A3 and DI-B3 fire smoke detectors operate on the ionization principle. The detectors respond to the first traces of fire in the form of visible smoke or invisible products of combustion. The DI-3, DI-A3 and DI-B3 have been developed for the wide range of commercial, industrial and institutional fire detection and extinguishing applications. The DI-3, DI-A3 and DI-B3 are approved in environments covered by UL 268 & UL 268A.

Figure 4.3 show the DI-3 Smoke Detector

Figure 4.3 DI-3 Smoke Detector

Features

- Adjustable Sensitivity
- Dual Chamber
- Sensitivity Test Points
- Simple Twist/Lock Assembly
- Optional Auxiliary Relay
- Screw-Clamp Terminals
- Alarm LED
- Listed, ULC Listed, NYMEA, FM, CSFM Approved

4.3.3 A741 Amplifier

The µA741 is a general-purpose operational amplifier featuring offset-voltage null capability. The high common-mode input voltage range and the absence of latch-up make the amplifier ideal for voltage-follower applications. The device is short-circuit protected and the internal frequency compensation ensures stability without external components. A low value potentiometer may be connected between the offset null inputs to null out the offset voltage. The µA741C is characterized for operation from 0°C to 70°C. The µA741I is characterized for operation from –40°C to 85°C.The µA741M is characterized for operation over the full military temperature range of –55°C to 125°C.

Figure 4.4 shows the UA741 Amplifier:

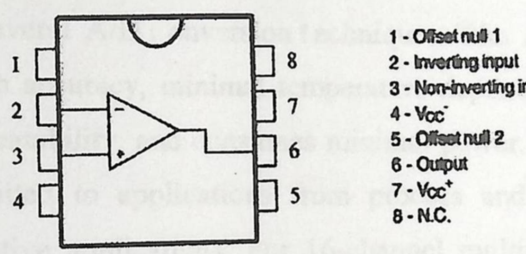

Figure 4.4 shows the UA741 Amplifier:

Features

- Short-Circuit Protection
- Offset-Voltage Null Capability
- Large Common-Mode and Differential Voltage Ranges
- No Frequency Compensation Required
- Low Power Consumption
- No Latch-Up
- Designed to Be Interchangeable With Fairchild µA741

4.3.4 ADC0808/ADC0809

(8-Bit µP Compatible A/D Converters with 8-Channel Multiplexer)

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)

Figure 4.5 shows the Dual In Line Package for the ADC 0809

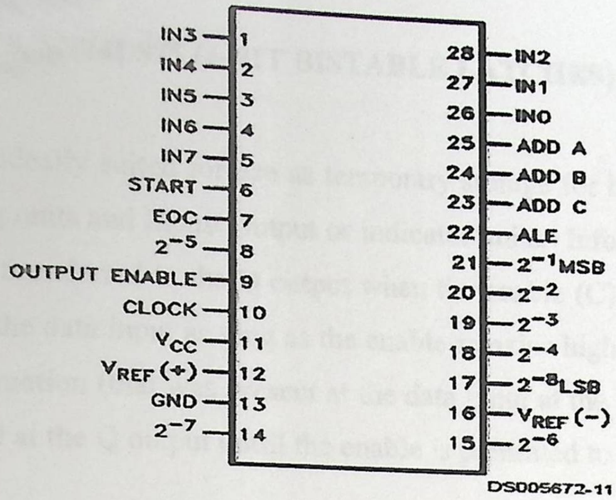

Figure 4.5 Dual In Line Package for the ADC 0809

Features

- Easy interface to all microprocessors
- Operates ratiometrically or with 5 VDC or analog span
- djusted voltage reference
- No zero or full-scale adjust required
- 8-channel multiplexer with address logic
- 0V to 5V input range with single 5V power supply
- Outputs meet TTL voltage level specifications
- Standard hermetic or molded 28-pin DIP package
- 28-pin molded chip carrier package
- ADC0808 equivalent to MM74C949
- ADC0809 equivalent to MM74C949-1

Key Specifications

- Resolution 8 Bits
- Total Unadjusted Error ±1⁄2 LSB and ±1 LSB
- Single Supply 5 VDC
- Low Power 15 mW
- Conversion Time 100 μs

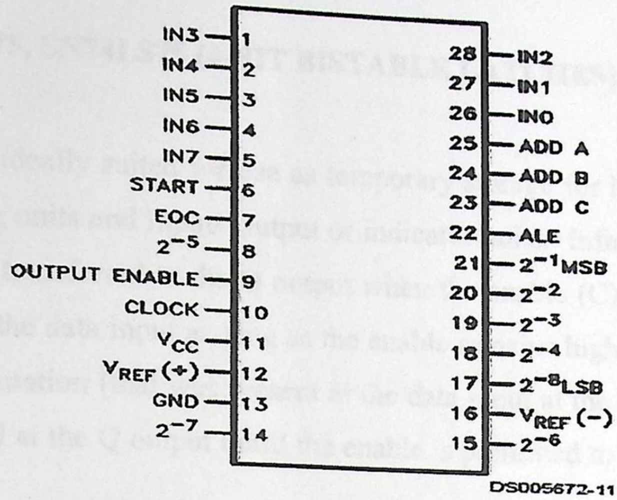

Figure 4.5 Dual In Line Package for the ADC 0809

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- Easy interface to all microprocessors
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- 0V to 5V input range with single 5V power supply
- Outputs meet TTL voltage level specifications
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Key Specifications

- Resolution 8 Bits
- Total Unadjusted Error ±1/2 LSB and ±1 LSB
- Single Supply 5 VDC
- Low Power 15 mW
- Conversion Time 100 µs

4.3.5 The SN7475, SN74LS75 (4-BIT BISTABLE LATCHES):

These Latches are ideally suited for use as temporary storage for binary information between processing units and Input/ Output or indicator units. Information present at a data (D) input is transferred to the Q output when the enable (C) is high and the Q output will follow the data input as long as the enable remains high. When the enable goes low, the information (that was present at the data input at the time the transition occured) is retained at the Q output untill the enable is premitted to go high.

The '75 and 'LS75 features complementary Q and Q' output from a 4-bit latch, and are available in various 16-pin packages. For higher component density applications, the '77 and 'LS77 4-bit latches are available in 14-pin flat packages.

The SN7475, SN74LS75 circuits are completely compatible with all populare TTL families. All inputs are diode-clamped to minimize transmission-Line effects and simplify system design. Series 54 and 54LS devices are characterized for operation over the full military temreture range of –55 C ; Series 74 and 74LS devices are characterized for operation from 0 C to 70 C.

The figure below shows the SN7475 Latch:

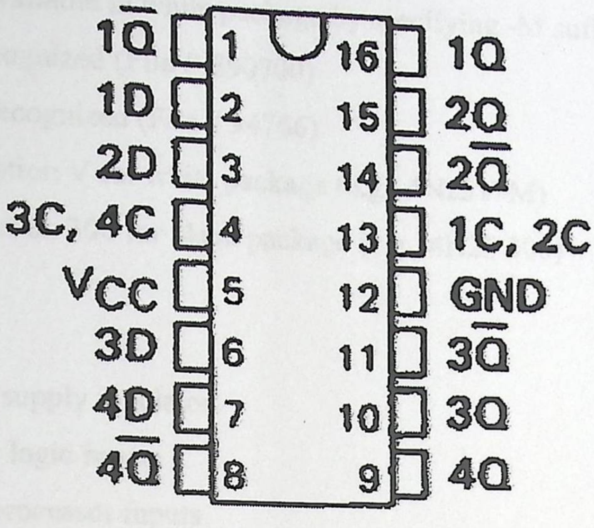

Figure 4.6 SN7475 Latch

4.3.6 Opto Coupler (4N25):

The general purpose optocouplers consist of a gallium arsenide infrared emitting diode driving a silicon phototransistor in a 6-pin dual in-line package.

The figure below shows the 4N25 Schematic:

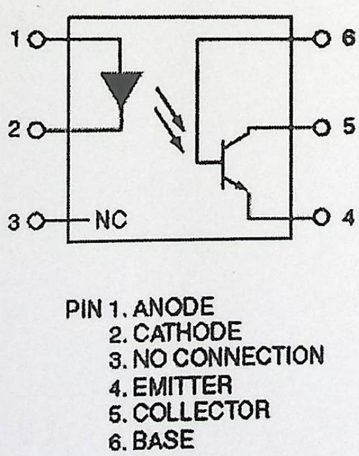

Figure 4.7 4N25 Schematic

Features

- Also available in white package by specifying -M suffix, eg. 4N25-M
- UL recognized (File # E90700)
- VDE recognized (File # 94766)
- Add option V for white package (e.g., 4N25V-M)
- Add option 300 for black package (e.g., 4N25.300)

Applications:

- Power supply regulators
- Digital logic inputs
- Microprocessor inputs

Chapter Five

Software System Design

5.1 Introduction

5.2 Programming the Parallel Port in Visual Basic

5.3 System Flowcharts

Software System Design

5.1 Introduction:

As the project is PC Controlled, we have to use one of the programming languages Known that is capable to deal with the parallel port.

After a large research is done over the Internet, the work team decided to program the parallel ports inputs and outputs by Visual Basic for many reasons:

- Ease of Visual Basic
- The large capabilities offered by Visual Basic including the capability to deal with the Parallel Port
- Work Team knowledge of Visual Basic.

In the following section we will give a detailed description of how to deal with the parallel port in VB.6 including

- preparing the VB.6 to deal with the parallel port
- Basic Read algorithms
- Basic Write algorithms.

5.2 Programming the Parallel Port in Visual Basic:

VB cannot directly access the hardware on a system. All hardware requests must go through Windows. Because of this, the closest we can get to manipulate the parallel port is the Printer object. While this is all fine and good when you want to actually print something, it is useless when we want direct hardware control. In order to control the port directly, we must use something external to our program. It just so happens that there is a great, free product that does exactly what we want. Use VBASM.DLL (in the VBASM.ZIP package) for VB1, VB2, VB3 or VB4 16Bit. Use WIN95IO.DLL (in the WIN95IO.ZIP package) for VB4 32bit, VB5 or VB6. No matter which one you choose, the DLL file itself must be in the windows\system directory in any machine the interface control software is to be used or developed on.

The parallel port is made up of three different sections. These are the data lines, control lines and status lines. There are 8 data lines, and they are the primary means of getting information out of the port. In simple projects, one will concentrate mostly on the data lines. The control lines are another 4 outputs. They are meant to provide control signals to the printer (such as form feed or initialize). The status lines are a standard parallel port's only inputs. There are 5 of them. They were meant to allow the printer to communicate things such as error, paper out and busy to the PC.

Each section is accessed by it's own address and will act independently from the rest. This is almost as if they were different ports. The addresses are as follows:

Port	Address (Decimal)	Address (Hex)
Data Lines	888	378h
Control Lines	890	37Ah
Status Lines	889	379h

Figure 5.1 parallel port addresses

One need to know the address of the port that will be used. Another two things are needed; the command to access the port and the number set it to. The command will

5.2 Programming the Parallel Port in Visual Basic:

VB cannot directly access the hardware on a system. All hardware requests must go through Windows. Because of this, the closest we can get to manipulate the parallel port is the Printer object. While this is all fine and good when you want to actually print something, it is useless when we want direct hardware control. In order to control the port directly, we must use something external to our program. It just so happens that there is a great, free product that does exactly what we want. Use VBASM.DLL (in the VBASM.ZIP package) for VB1, VB2, VB3 or VB4 16Bit. Use WIN95IO.DLL (in the WIN95IO.ZIP package) for VB4 32bit, VB5 or VB6. No matter which one you choose, the DLL file itself must be in the windows\system directory in any machine the interface control software is to be used or developed on.

The parallel port is made up of three different sections. These are the data lines, control lines and status lines. There are 8 data lines, and they are the primary means of getting information out of the port. In simple projects, one will concentrate mostly on the data lines. The control lines are another 4 outputs. They are meant to provide control signals to the printer (such as form feed or initialize). The status lines are a standard parallel port's only inputs. There are 5 of them. They were meant to allow the printer to communicate things such as error, paper out and busy to the PC.

Each section is accessed by it's own address and will act independently from the rest. This is almost as if they were different ports. The addresses are as follows:

Port	Address (Decimal)	Address (Hex)
Data Lines	888	378h
Control Lines	890	37Ah
Status Lines	889	379h

Figure 5.1 parallel port addresses

One need to know the address of the port that will be used. Another two things are needed; the command to access the port and the number set it to. The command will be explained in a little while. The ports work with numbers. These can be expressed in hex, binary or decimal, but in this project all values will be expressed in decimal. It's just easier that way. Anyway, you operate the port by sending it a number that represents the binary pattern of the physical outputs on the port. For example, to set the 8 data lines to 11111111, you would send 255. To set them to 00000000 you would send 0. Note that these are all 8 bit binary numbers, and the port is also 8 outputs.

Before we can use any of the functions contained within either DLL, we must declare them. These declarations are to be placed in any module in your program in the General_Declarations section.

For 16bit VB (VBASM.DLL), use:

```
Declare Function vbInp Lib "VBASM.DLL" (ByVal nPort As Integer) As
Integer

Declare Sub vbOut Lib "VBASM.DLL" (ByVal nPort As Integer, ByVal
nData As Integer)
```

For 32bit VB (WIN95IO.DLL), use:

```
Declare Sub vbOut Lib "WIN95IO.DLL" (ByVal nPort As Integer, ByVal
nData As Integer)
Declare Sub vbOutw Lib "WIN95IO.DLL" (ByVal nPort As Integer, ByVal
nData As Integer)
Declare Function vbInp Lib "WIN95IO.DLL" (ByVal nPort As Integer) As
Integer
Declare Function vbInpw Lib "WIN95IO.DLL" (ByVal nPort As Integer) As
Integer
```

Once you declare the functions, you will have two new commands available. These are vbInp and vbOut. vbOut is a statement and is used to send a bit to a port, like the following:

```
vbOut [port],[number]
```

We will get to vbInp later. As you can see, the two parameters required are the port address and the value we want to set it to. The address can be decimal or hex, as can the value. Because there are only 8 data lines, we can only send a maximum of 255 to the port (255 is decimal for binary 11111111). The examples below illustrate sending a few different bit patterns to the data lines.

```
'set port to 00000000
vbOut 888, 0
'set port to 10000000
vbOut 888, 1
'set port to 01000000
vbOut 888, 2
'set port to 00100000
vbOut 888, 4
'set port to 00010000
vbOut 888, 8
```

Of course, you can also turn on more than one bit:

```
'set port to 10110000
vbOut 888, 11
```

Note that when you send a bit pattern to the port everything that was there previously is cleared. This is a convenience and also a annoyance. For example, what if we want bit 2 to always stay at 1, but want to turn bit 5 on and off in sequence? Every time we set bit 5, bit 2 is turned off, and vice versa. We will discuss how to get around this when we get to the vbInp function.

The control lines are just as easy to control, but there are a few differences. First, the address of the port is 890. Second is that there are only 4 outputs, so the highest decimal representation of the binary bit pattern you will be using is 15 (binary 1111).

Outputting information is easy, and inputting is just as easy. If you actually want to get information into the computer, you will be using the 5 status lines. Reading the bit pattern of a port is done using the vbInp function. This function is used in the following way:

```
[variable]=vbInp([port])
```

So if we wanted to get the current status of the status lines (port 889) we would use:

```
PortNum%=vbInp(889)
```

`PortNum%` would then contain the decimal representation of the binary bit pattern present at the 5 status lines. If you try this and get 31 (11111) with nothing connected to the port don't be surprised. When there is nothing connected to the input of a TTL logic chip, a high input is usually assumed.

Not only can you perform inputs on ports actually designed for inputting, but you can also use vbInp to read the status of an output port. For example:

```
PortNum%=vbInp(888)
```

The above would set PortNum% to the current value of the data lines (port 888). We can prove this by doing the following:

```
vbOut 888, 56
PortNum%=vbInp(888)
MsgBox PortNum%
```

If all is well, the number 56 will appear in a message box on the screen.

Now that we know the vbInp function we can use it to solve the problem of keeping the state of one bit while changing the state of another. For that we will define a subroutine that uses both functions:

```
SUB OutPort(PortAddress%, OutNum%)

PortState% = vbInp(PortAddress%)
PortNum% = PortState% + OutNum%
vbOut PortAddress%, PortNum%
```

```
END SUB
```

Note how the sub adds the current port state to the number we send it. This has the effect of keeping all previous bits at the same state they were in, but either turning on or off the bit or bits represented by the number we pass to the sub. This also requires a change in the way the function is used. To turn on bit 1, we would:

```
OutPort 888, 1
```

This example assumes a current port status of 0 (00000000). If bit 1 is already high, you will get unexpected results, so keeping track of the port is important. To turn bit 1 back off, we would:

```
OutPort 888, -1
```

Now this sub introduces a problem. How do we clear everything on the port as if we were doing vbOut 888, 0? Sending 0 to the sub has no effect (adding or subtracting 0 will always give you the original number), so we will need to add a statement to specifically react to a 0. This done by a simple IF...THEN decision:

```
SUB OutPort(PortAddress%, OutNum%)

PortState% = vbInp(PortAddress%)
PortNum% = PortState% + OutNum%
vbOut PortAddress%, PortNum%
IF OutNum% = 0 THEN vbOut PortAddress%, 0

END SUB
```

The sub does all it's normal stuff, but also sets the port to 0 if a 0 was passed to it. This is a very easy to clear up a port if you create strange bit patterns by trying to turn a bit on twice. You may want to keep track of the state you expect the port to be and compare it to the actual state by using the vbInp function. If the two do not match, clear the port and reset all the bits using your other variable.

Now that we know a few useful functions with respect to output, we should look at a very useful input function. When using the port in software, you will very likely need to know the status of a single bit at one time or another. There are various ways of doing this, the function below is the most useful:

```
FUNCTION BitStatus(PortAddress%, BitYouWant%) AS INTEGER
IF PortAddress% = 888 THEN
NumOfBits% = 8
ELSE IF PortAddress% = 889 THEN
NumOfBits% = 5
ELSE
NumOfBits% = 4
REDIM PortBits(NumOfBits%) AS INTEGER
PortNum% = vbInp(PortAddress%)
FOR i = 1 To NumOfBits%
PortBits%(i) = PortNum% MOD 2
PortNum% = FIX(PortNum% / 2)
NEXT I
BitStatus% = PortBits%(BitYouWant%)
END FUNCTION
```

The function first decides how many bits it has to work with by looking at the address of the port. Note that in all other examples it was really irrelevant if you used decimal or HEX addresses. In this function you will need to change the numbers if you work in HEX. Now, back to how the function functions (he he he). After deciding how many bits there are in the port, it makes an array of the same number of elements. It then goes through a loop, performing integer division on the number returned from the port. It performs one division for each bit in the port. This is probably the easiest way to convert to binary, as VB has no built in decimal to binary function. Again, if you work in HEX you will have to adjust the function here. The function then assigns itself the value of the array element you specify with the BitYouWant% variable.

5.3 System Flowcharts

The Software includes three main subprograms

1. Updating the program information
2. analyzing smoke circuit information and take required action
3. analyzing Heat circuit information and take required action

5.3.1 Updating the program information

This flowchart shows haw the system loads the information related to both smoke and heat circuits:

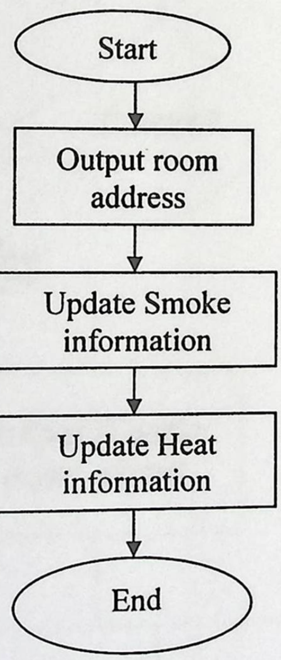

Figure 5.1 Updating the program information

5.3.2 Analyzing smoke circuit information and take required action:

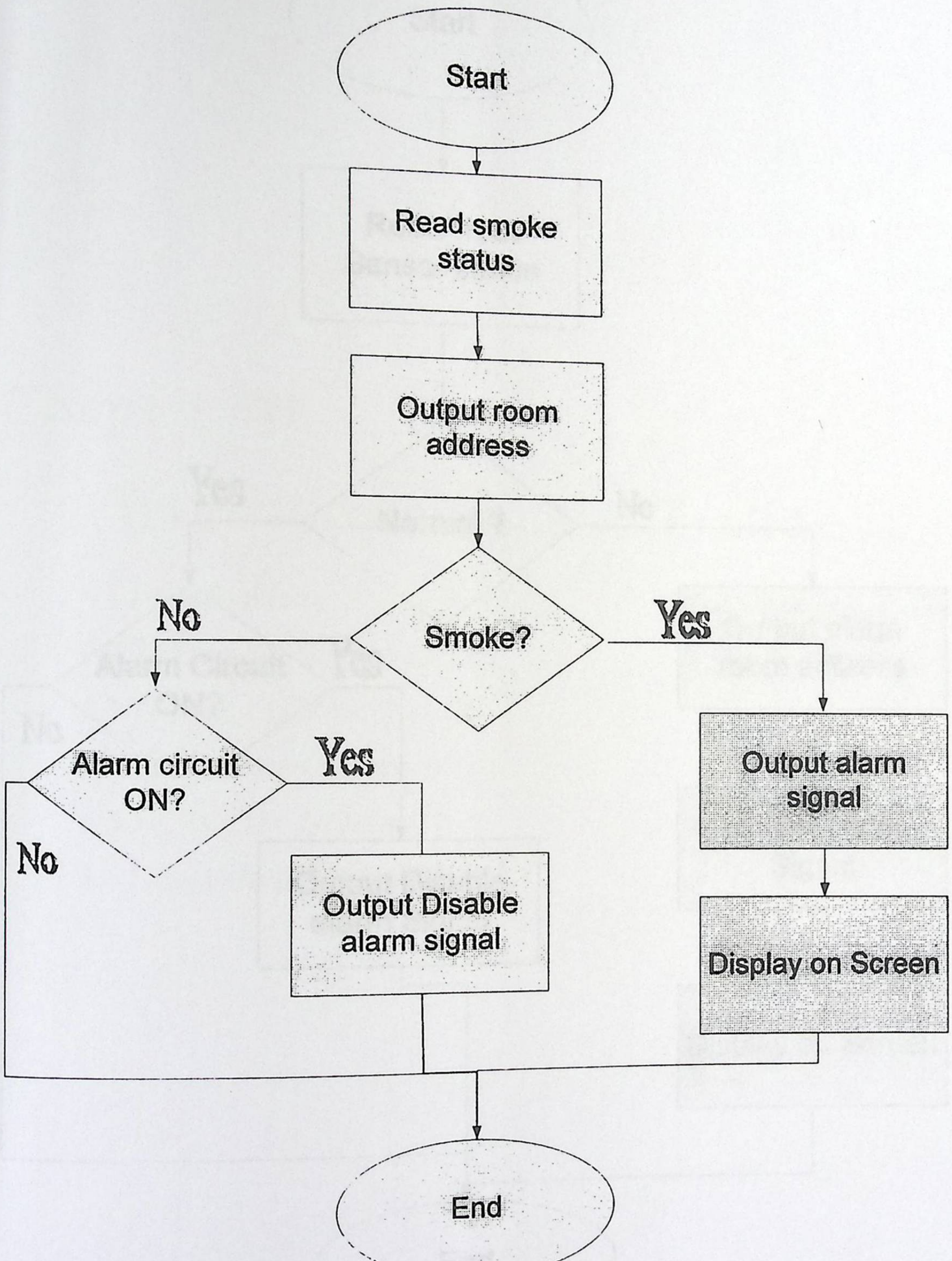

Figure 5.2 Analyzing smoke circuit information and take required action

5.3.3 Analyzing Heat circuit information and take required action:

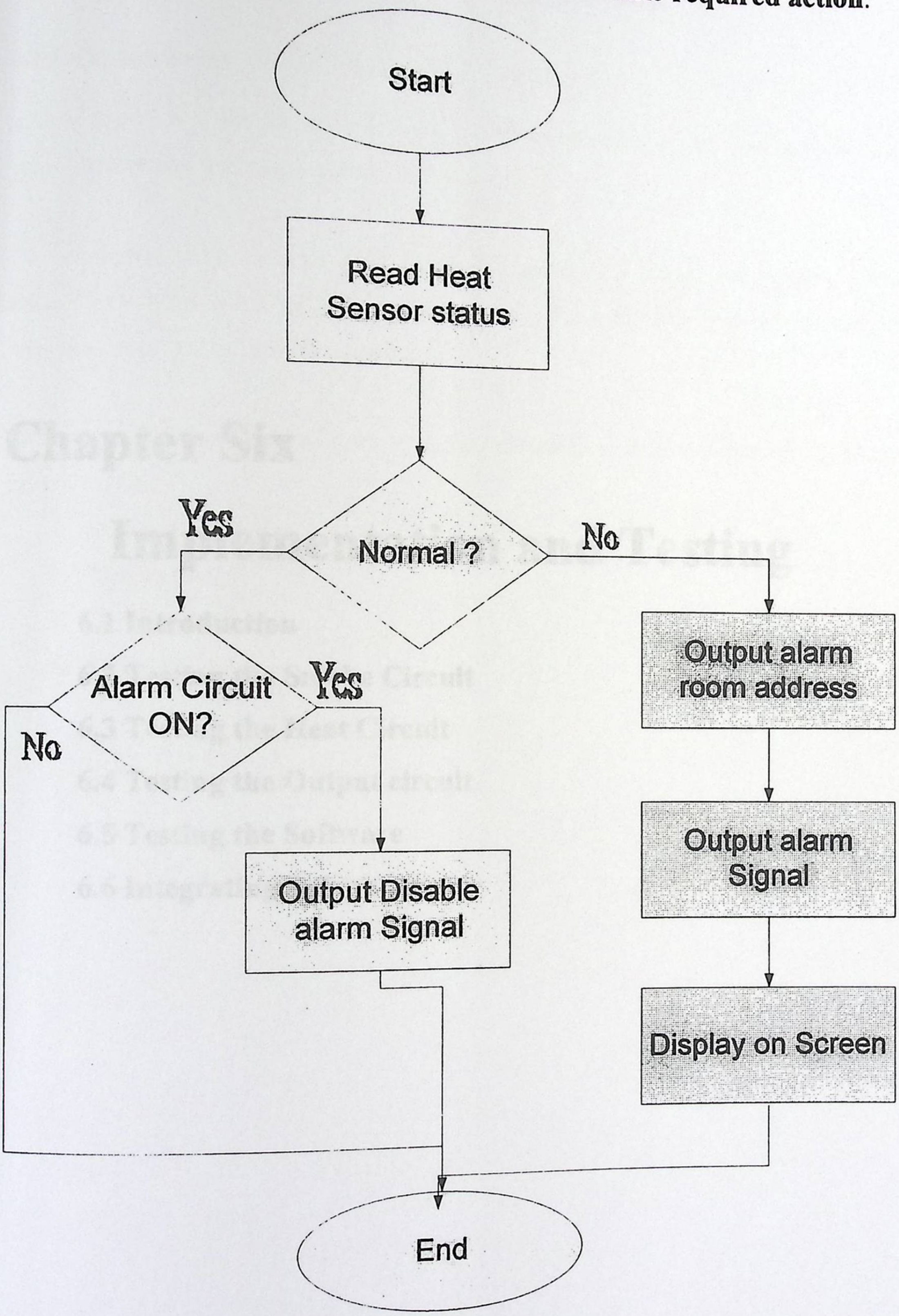

Figure 5.3 Analyzing smoke circuit information and take required action

Chapter Six

Implementation and Testing

Implementation and Testing

6.1 Introduction

In this chapter we will illustrate the implementation process of the system including both software and hardware testing.

The implementation process deals with the system as small subsystems, each subsystem will be tested and implemented alone. Finally all these subsystems will be integrated together to form the system.

The system is divided into subsystems so that we can deal with each part alone. These subsystems are:

1. Smoke circuit
2. Heat circuit
3. Output circuit
4. Software

6.2 Testing the Smoke Circuit

The smoke circuit consists of three sensors, each sensor located at different room. These sensors are multiplexed through the 74251 MUX so that one sensor is selected at a time under software control.

Smoke circuit is illustrated well in the general block diagram (Figure 3.1). As shown in the bloke diagram the signal will be adjusted to give digital values 0 or +5 volt. Each part is tested alone before integrating the whole circuit; this includes testing the DI-3 smoke sensor and observes its output, then the MUX and latch and opto coupler each one alone.

Finally integrate all parts to form the smoke sensor circuit illustrated in figure 6.1 below. The circuit was tested before connecting it to the PC parallel port as follows:

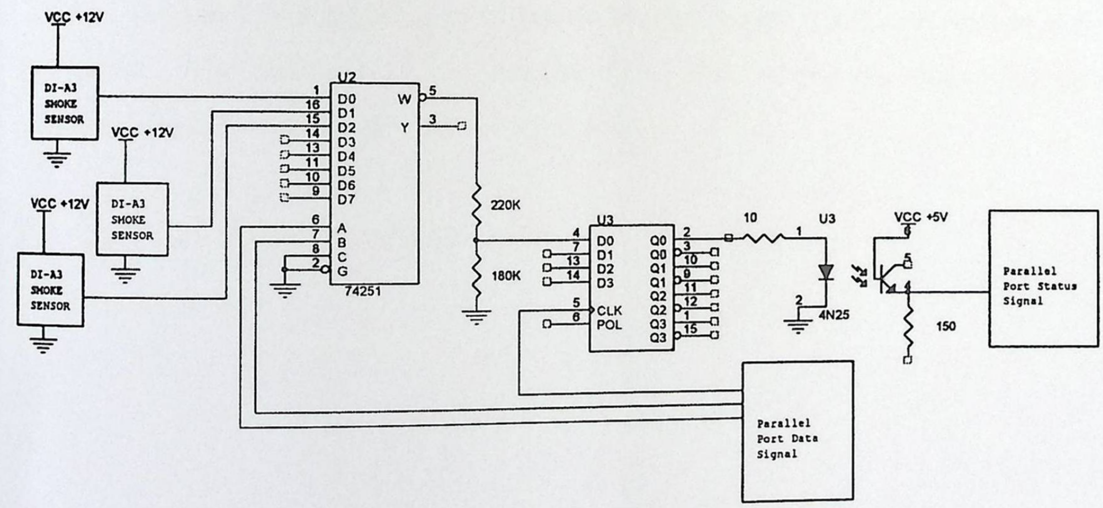

Figure 6.1 Smoke Sensor Circuit

The Di-3 smoke sensor is firstly tested, and it had give us 10 volt in the presence of smoke and 1 volt with no smoke.

In order to test this circuit we use a power supply of +5 Volt and the Ground as logic 1 and 0 respectively. The pin 6 and 7 of the MUX were connected to GND so that the first sensor signal is passed through the latch and opto coupler to the output pin. After that pin 6 is connected to +5 Volt so that the second Sensor is selected. The same is repeated for the third sensor.

The circuit had worked properly probably.

6.3 Testing the Heat Circuit:

The Heat circuit consists of three sensors, each sensor located at different room. These sensors are multiplexed and converted to digital through the ADC0808 so that one sensor is selected at a time under software control, and is passed in digital to the parallel port.

The heat sensor circuit is will illustrated in figure 6.2 below. The circuit was tested before connecting it to the PC parallel port.

The LM35 Heat sensor is firstly tested, and it gives us 24 mVolt at the room temperature which indicates that the temperature is 24 C.

In order to test this circuit we use a power supply of +5 Volt and the Ground as logic 1 and 0 respectively. The pin 24 and 25 (A0, A1) of the ADC0808 was connected to GND so that the first sensor signal is passed through the latch and opto coupler to the output pin. After that pin 24 is connected to +5 Volt so that the second Sensor is selected. The same is repeated for the third sensor.

The circuit had worked properly probably.

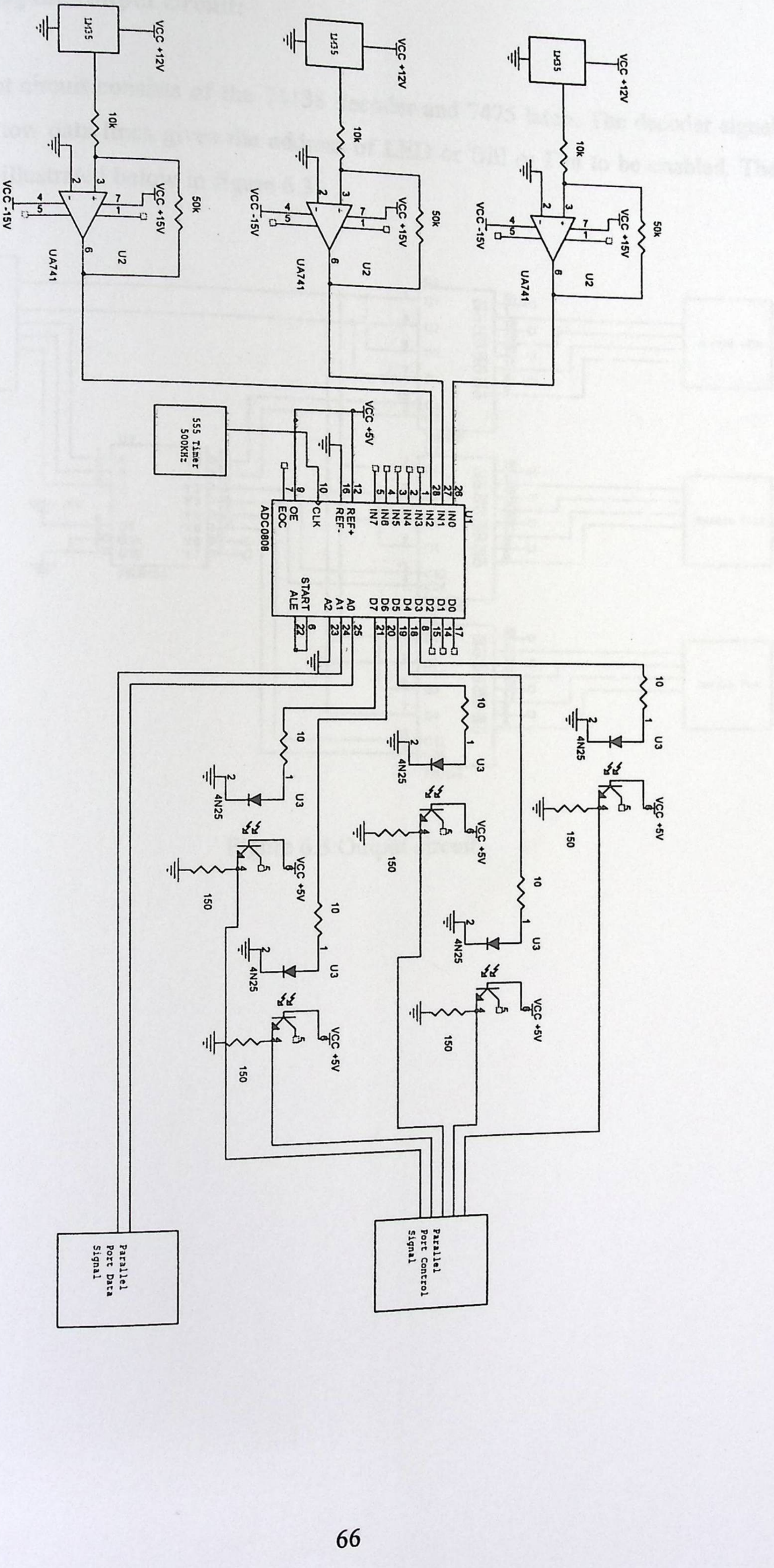

Figure 6.2 Heat Sensors Circuit

6.4 Testing the Output circuit:

the output circuit consists of the 74138 decoder and 7475 latch. The decoder signal with the tow data lines gives the address of LED or Bill or Fan to be enabled. The circuit is illustrated below in figure 6.3:

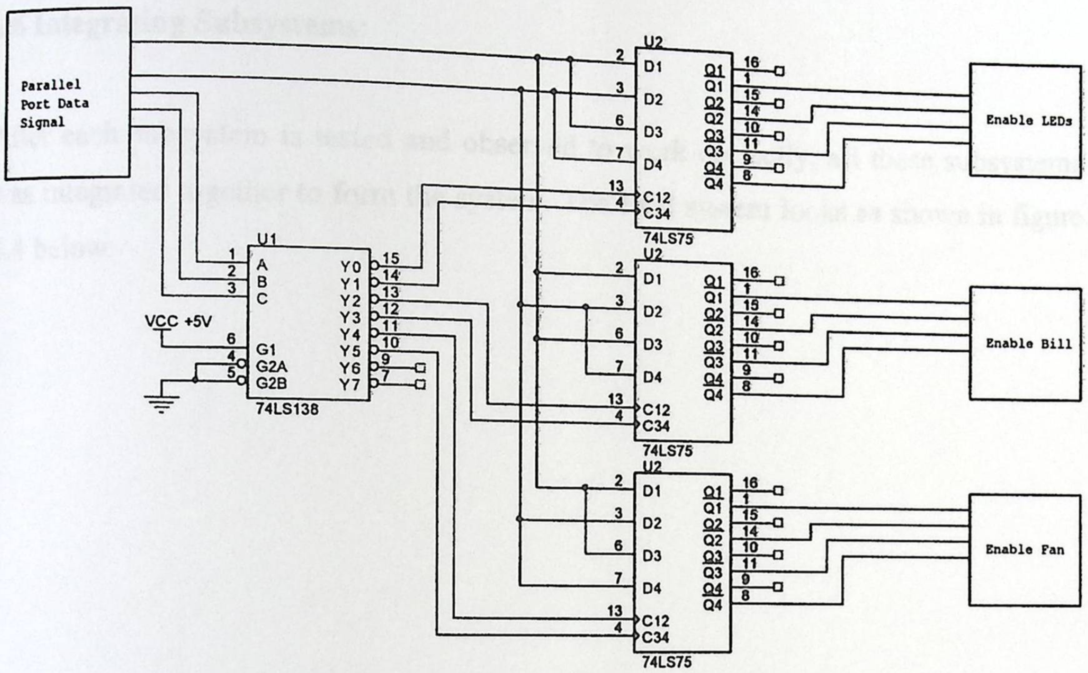

Figure 6.3 Output circuit

6.5 Testing the Software:

The program was tested by giving digital inputs through switch (+5 volt as logic 1 and GND as logic 0), and observing the output on LEDs.
The program had worked properly.

6.6 Integrating Subsystems:

After each subsystem is tested and observed to work correctly, all these subsystems was integrated together to form the system. The final system looks as shown in figure 6.4 below:

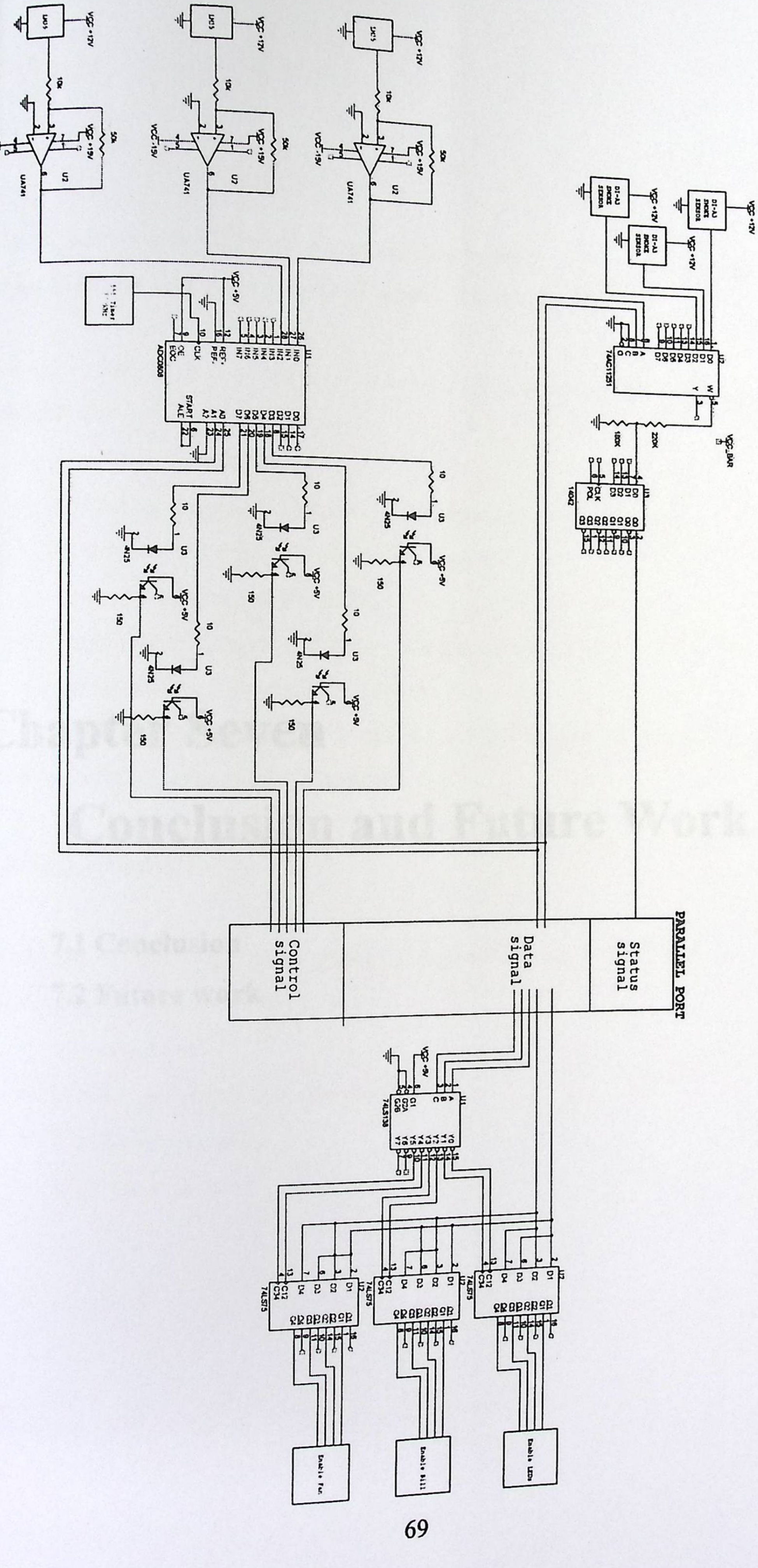

Figure 6.4 Alarm Circuit

Chapter Seven

Conclusion and Future Work

7.1 Conclusion

7.2 Future work

7.1 Conclusion:

The PC had become the heart of the automated control, and so we are trying to make an alarm system that controls a set of sensors through the PC.

We had collected all data required to build such a system in the previous semester, this includes:

- Reading Literature review
- Collecting the theory required for the system
- Scheduling the time to perform this project
- Drawing the General Block Diagram
- Designing the Circuit and determining the required IC's
- Understanding the principles of these IC's
- Determination of the software to be used and writing the general algorithms

And we build the system in this semester.

7.2 Future work:

The system is now ready, as suggested in the previous semester. For future work one can develop the system so that it can:

- Use telephone.
- Use the gas sensor and analyzer.
- Use Water sprinkles.
- Cope more sensors.

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Appendices

Appendix A

Data Sheet

SIEMENS

Fire Safety

DI-3, DI-A3 and DI-B3

Ionization Smoke Detector

ENGINEER AND ARCHITECT SPECIFICATIONS

- Adjustable Sensitivity
- Dual Chamber
- Sensitivity Test Points
- Simple Twist/Lock Assembly
- Optional Auxiliary Relay
- Screw-Clamp Terminals
- Alarm LED
- UL Listed, ULC Listed, NYMEA, FM, CSFM Approved

Introduction

The Siemens Building technologies, Fire Safety Division DI-3, DI-A3 and DI-B3 fire smoke detectors operate on the ionization principle. The detectors respond to the first traces of fire in the form of visible smoke or invisible products of combustion. The DI-3, DI-A3 and DI-B3 have been developed for the wide range of commercial, industrial and institutional fire detection and extinguishing applications. The DI-3, DI-A3 and DI-B3 are approved in environments covered by UL 268 & UL 268A. The DI-B3 must be utilized with a Series 3™ air duct housing.

Description

The DI-3 Series detector is a plug-in, ionization detector and is designed for two wire system operation. The DI-3 is designed with adjustable sensitivity while the DI-A3 and the DI-B3 have a fixed sensitivity designed for their individual high air flow applications.

The DI-3, DI-A3 and DI-B3 consist of self-compensating dual ionization chambers and a highly stable solid state amplifier-switching circuit. One chamber detects the presence of combustion products, the second chamber serves as a reference, to stabilize the detector's sensitivity for changes in environmental conditions. As products of combustion enter the sampling chamber, the chamber current is reduced producing a voltage change. At the time the voltage range exceeds the pre-determined threshold, an alarm is signaled to the control unit. The detector locks in upon alarm and must be reset from the control panel.

The sensitivity of the DI-3, DI-A3 and DI-B3 is preset at the factory. The electrical sensitivity can be monitored in the field using the Fire Safety sensitivity tester, test module TM-I3. The sensitivity test jack on the DI-3, DI-A3 and DI-B3 and the adjustment screw on the DI-3 are accessible from the front of the detector housing enabling the user to perform all sensitivity adjustments and tests without removing the detector from its base.

The detectors utilize a low profile surface mounting base, model DB-3S, which may be attached to either a 4" octagonal, single gang outlet box or 4" square wiring box — or the audible base model ADB-3, which must be attached to a 4" square, deep wiring box. The DB-3S base and ADB-3 audible base utilize screw-clamp terminals for all electrical connections, self-wiping contacts for reliability and contain provision for an optional concealed locking mechanism to prevent unauthorized removal of the detector head.

The DI-3 Series ionization detector has been designed to meet a wide range of system design parameters. The DI-3 detector is designed for open area protection in areas with air velocities up to 300 feet per minute.

SIEMENS

Fire Safety

DI-3, DI-A3 and DI-B3

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SIEMENS

DI-3, DI-A3 and DI-B3

Ionization Smoke Detector

Fire Safety

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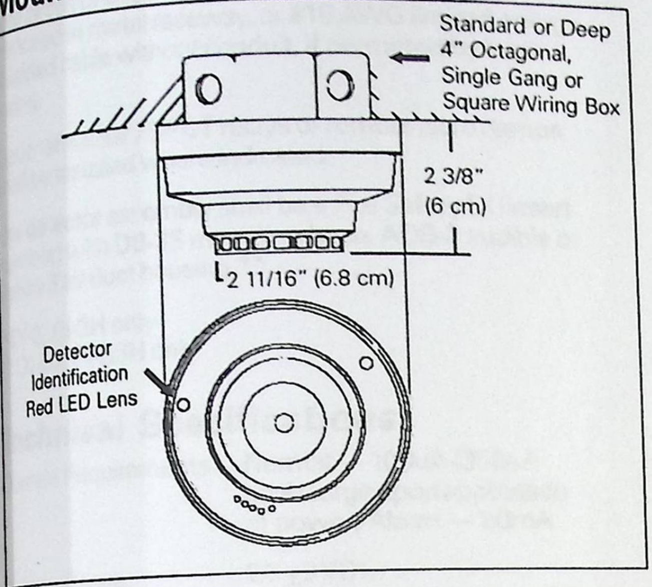
Mounting Data



DI-A3 is recommended for use in high air velocity applications such as computer room underfloor areas. The model DI-A3 contains a specially designed internal chamber cover and a pre-selected fixed sensitivity setting which provides extremely stable operation. Model DI-A3 has been UL listed for operation in air velocities of 0 to 1200 feet per minute. Since air velocity has an effect on detector sensitivity and performance, the DI-A3 should be used only in applications which meet this established air velocity range.

The DI-B3 is designed specifically for use with the Fire Safety Series 3 air duct housings and, like the DI-A3, contains a specially designed internal chamber cover and a pre-selected fixed sensitivity setting. The DI-B3 must be utilized with the Series 3 air duct housing in air duct applications with air velocities of 500-4000 FPM.

The DI-3, DI-A3 and DI-B3 are also available for high altitude applications, (3000 to 8000 feet above sea level) as model numbers DI-3H, DI-A3H and DI-B3H.

The DI-3 and DI-A3 are capable of operating a remote alarm lamp, RLI1, RLI2, RL-30, RL-40 or auxiliary relay, model RR-3. The model RR-3/3S relay contains one set of double pole, double throw contacts rated at 120 VAC, 2 Amp. Resistive and requires a deep outlet box when mounted to the DB-3S. The DI-B3 is capable of utilizing the remote relay as supplied in the Series 3 air duct housing model AD-3 with a DA-3SR Relay Board which contains one set of double pole, double throw contacts rated at 125 VAC/24 VDC, 3 Amp. Resistive.

When multiple detector/relay combinations are used on the same circuit, the zone module current limit will restrict the number of guaranteed detector/relay actuations to one per zone.

The DI-3, DI-A3, DI-B3 , DI-3H, DI-A3H and DI-B3H ionization detectors are Underwriters Laboratories, Inc. Listed. The series is also FM, CSFM and NYMEA approved.

An FM approved, intrinsically safe DI-3 is available under model DI-3IS. The DI-3IS must be utilized with the intrinsically safe System 3 zone module, model ZS-30 or MXL zone module CZM-1/ISI-1.

Application Data

The DI-3, DI-A3, DI-B3, DI-3H, DI-A3H and DI-B3H detectors are fully compatible with other Fire Safety System 3 compatible detectors and may be intermixed on the same zone circuit. No more than thirty (30) detectors of any type of combination (other than thermals or manual stations) may be used on any one Fire Safety detector circuit.

This detector is applicable to the 30-foot center spacing (900 sq. ft.) as referred to in NFPA 72. This spacing, however, is based on ideal conditions namely, smooth ceiling, no air movement, and no physical obstructions between the fire source and the detector. This spacing should be used as a guide or starting point in the detector installation layout. Do not mount detectors in areas close to ventilating or air conditioning outlets. Exposed joists or beamed ceilings may also affect safe spacing limitations for detectors. It is mandatory that engineering judgment be applied regarding detector location and spacing.

Engineer and Architect Specifications

The ionization smoke detector shall be a dual chamber plug-in unit which mounts to a twist/lock base and shall be UL listed.

The smoke detector shall operate on a two-wire circuit and shall contain an alarm indicating LED which will illuminate to signal actuation of the detector.

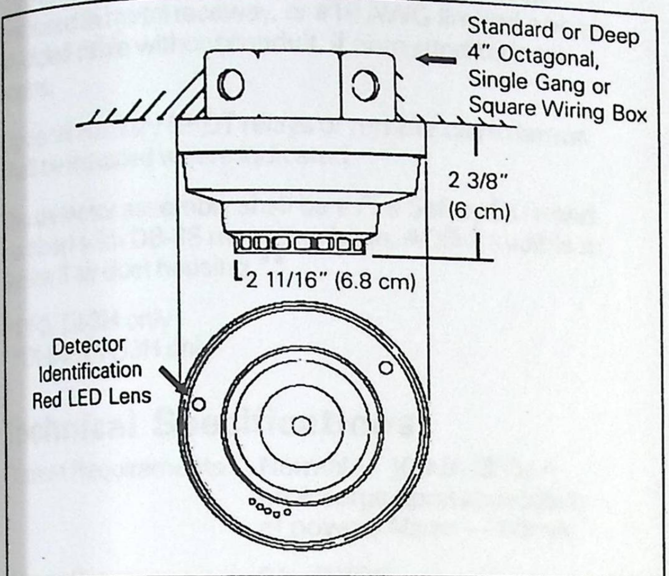
DI-A3 ONLY The detector shall be specifically designed for use in high air velocity applications of between 0 and 1200 ft./min. Detectors which are not UL listed for the stated air velocity range shall not be accepted.

DI-B3 ONLY The detector shall be specifically designed for use in air ducts with air velocities between 500-4000 FPM when used with Fire Safety Series 3 air duct housings. Detectors not listed to UL 268A for the stated air velocity range shall not be accepted.

The detector shall be available in a model that is acceptable for and UL listed for use in altitudes of 3000-8000 feet above sea level if desired models DI-3H, DI-A3H or DI-B3H.

Field adjustment* and monitoring of the detector sensitivity shall be possible without removal of the detector head from its base. The measurement of detector sensitivity shall provide a discrete electrical value. Test methods which do not provide an output signal proportional to smoke concentrations shall not be considered equal. The base assembly into which the detector is installed shall be of the twist/lock design with screw-clamp terminals. The base shall utilize self-wiping con-tacts for reliability and shall accept other compatible plug-in detectors. A security lock shall be installed in those areas where tamper resistant installation is required as indicated on the drawings.

Mounting Data



DI-A3 is recommended for use in high air velocity applications such as computer room underfloor areas. The model DI-A3 contains a specially designed internal chamber cover and a pre-selected fixed sensitivity setting which provides extremely stable operation. Model DI-A3 has been UL listed for operation in air velocities of 0 to 1200 feet per minute. Since air velocity has an effect on detector sensitivity and performance, the DI-A3 should be used only in applications which meet this established air velocity range.

The DI-B3 is designed specifically for use with the Fire Safety Series 3 air duct housings and, like the DI-A3, contains a specially designed internal chamber cover and a pre-selected fixed sensitivity setting. The DI-B3 must be utilized with the Series 3 air duct housing in air duct applications with air velocities of 500-4000 FPM.

The DI-3, DI-A3 and DI-B3 are also available for high altitude applications, (3000 to 8000 feet above sea level) as model numbers DI-3H, DI-A3H and DI-B3H.

The DI-3 and DI-A3 are capable of operating a remote alarm lamp, RLI1, RLI2, RL-30, RL-40 or auxiliary relay, model RR-3. The model RR-3/3S relay contains one set of double pole, double throw contacts rated at 120 VAC, 2 Amp. Resistive and requires a deep outlet box when mounted to the DB-3S. The DI-B3 is capable of utilizing the remote relay as supplied in the Series 3 air duct housing model AD-3 with a DA-3SR Relay Board which contains one set of double pole, double throw contacts rated at 125 VAC/24 VDC, 3 Amp. Resistive.

When multiple detector/relay combinations are used on the same circuit, the zone module current limit will restrict the number of guaranteed detector/relay actuations to one per zone.

The DI-3, DI-A3, DI-B3 , DI-3H, DI-A3H and DI-B3H ionization detectors are Underwriters Laboratories, Inc. Listed. The series is also FM, CSFM and NYMEA approved.

An FM approved, intrinsically safe DI-3 is available under model DI-3IS. The DI-3IS must be utilized with the intrinsically safe System 3 zone module, model ZS-30 or MXL zone module CZM-1/ISI-1.

Application Data

The DI-3, DI-A3, DI-B3, DI-3H, DI-A3H and DI-B3H detectors are fully compatible with other Fire Safety System 3 compatible detectors and may be intermixed on the same zone circuit. No more than thirty (30) detectors of any type of combination (other than thermals or manual stations) may be used on any one Fire Safety detector circuit.

This detector is applicable to the 30-foot center spacing (900 sq. ft.) as referred to in NFPA 72. This spacing, however, is based on ideal conditions namely, smooth ceiling, no air movement, and no physical obstructions between the fire source and the detector. This spacing should be used as a guide or starting point in the detector installation layout. Do not mount detectors in areas close to ventilating or air conditioning outlets. Exposed joists or beamed ceilings may also affect safe spacing limitations for detectors. It is mandatory that engineering judgment be applied regarding detector location and spacing.

Engineer and Architect Specifications

The ionization smoke detector shall be a dual chamber plug-in unit which mounts to a twist/lock base and shall be UL listed.

The smoke detector shall operate on a two-wire circuit and shall contain an alarm indicating LED which will illuminate to signal actuation of the detector.

DI-A3 ONLY The detector shall be specifically designed for use in high air velocity applications of between 0 and 1200 ft./min. Detectors which are not UL listed for the stated air velocity range shall not be accepted.

DI-B3 ONLY The detector shall be specifically designed for use in air ducts with air velocities between 500-4000 FPM when used with Fire Safety Series 3 air duct housings. Detectors not listed to UL 268A for the stated air velocity range shall not be accepted.

The detector shall be available in a model that is acceptable for and UL listed for use in altitudes of 3000-8000 feet above sea level if desired models DI-3H, DI-A3H or DI-B3H.

Field adjustment* and monitoring of the detector sensitivity shall be possible without removal of the detector head from its base. The measurement of detector sensitivity shall provide a discrete electrical value. Test methods which do not provide an output signal proportional to smoke concentrations shall not be considered equal. The base assembly into which the detector is installed shall be of the twist/lock design with screw-clamp terminals. The base shall utilize self-wiping con-tacts for reliability and shall accept other compatible plug-in detectors. A security lock shall be installed in those areas where tamper resistant installation is required as indicated on the drawings.

NOTICE: The use of other than Fire Safety detectors and bases with Fire Safety control equipment will be considered a misapplication of Fire Safety equipment and as such void all warranties either expressed or implied with regards to loss, damage, liabilities and/or service problems.

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Supersedes sheet dated 1/00

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

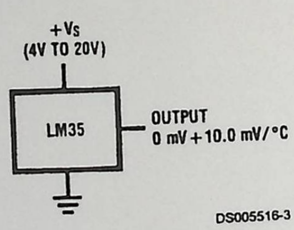
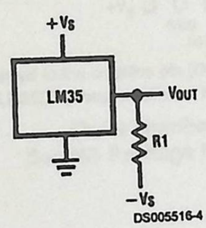


FIGURE 1. Basic Centigrade Temperature Sensor (+2˚C to +150˚C)



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

National Semiconductor

November 2000

LM35
Precision Centigrade Temperature Sensors

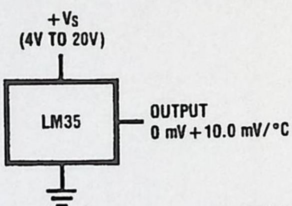
General Description

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

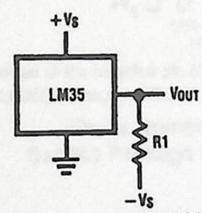
- Calibrated directly in ˚ Celsius (Centigrade)
- Linear + 10.0 mV/˚C scale factor
- 0.5˚C accuracy guaranteeable (at +25˚C)
- Rated for full −55˚ to +150˚C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- 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



DS005516-3

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



DS005516-4

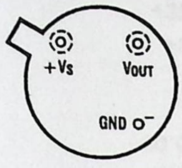
Choose $R_1 = -V_S/50\ \mu A$

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

Connection Diagrams

TO-46
Metal Can Package*

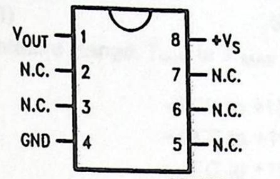


BOTTOM VIEW
DS005516-1

*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

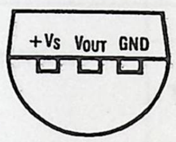


DS005516-21

N.C. = No Connection

Top View
Order Number LM35DM
See NS Package Number M08A

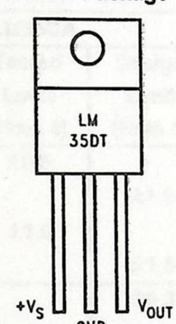
TO-92
Plastic Package



BOTTOM VIEW
DS005516-2

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

TO-220
Plastic Package*



DS005516-24

*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 Typical	LM35A Tested Limit (Note 4)	LM35A Design Limit (Note 5)	LM35CA Typical	LM35CA Tested Limit (Note 4)	LM35CA Design Limit (Note 5)	Units (Max.)
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

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 Typical	LM35A Tested Limit (Note 4)	LM35A Design Limit (Note 5)	LM35CA Typical	LM35CA Tested Limit (Note 4)	LM35CA Design Limit (Note 5)	Units (Max.)
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)	$T_{MIN}\leq T_A\leq T_{MAX}$	**±0.18**		**±0.35**	**±0.15**		**±0.3**	°C
Sensor Gain (Average Slope)	$T_{MIN}\leq T_A\leq T_{MAX}$	**+10.0**	**+9.9, +10.1**		**+10.0**		**+9.9, +10.1**	mV/°C
Load Regulation (Note 3) $0\leq I_L\leq 1$ mA	T_A=+25°C	±0.4	±1.0		±0.4	±1.0		mV/mA
	$T_{MIN}\leq T_A\leq T_{MAX}$	**±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
	$4V\leq V_S\leq 30V$	**±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)	$4V\leq V_S\leq 30V$, +25°C	0.2	1.0		0.2	1.0		μA
	$4V\leq V_S\leq 30V$	**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

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35 Typical	LM35 Tested Limit (Note 4)	LM35 Design Limit (Note 5)	LM35C, LM35D Typical	LM35C, LM35D Tested Limit (Note 4)	LM35C, LM35D Design Limit (Note 5)	Units (Max.)
Accuracy, LM35, LM35C (Note 7)	T_A=+25°C	±0.4	±1.0		±0.4	±1.0		°C
	T_A=−10°C	±0.5			±0.5		±1.5	°C
	$T_A=T_{MAX}$	±0.8	±1.5		±0.8		±1.5	°C
	$T_A=T_{MIN}$	±0.8		±1.5	±0.8		±2.0	°C
Accuracy, LM35D (Note 7)	T_A=+25°C				±0.6	±1.5		°C
	$T_A=T_{MAX}$				±0.9		±2.0	°C
	$T_A=T_{MIN}$				±0.9		±2.0	°C
Nonlinearity (Note 8)	$T_{MIN}≤T_A≤T_{MAX}$	**±0.3**		**±0.5**	**±0.2**		**±0.5**	°C
Sensor Gain (Average Slope)	$T_{MIN}≤T_A≤T_{MAX}$	**+10.0**	**+9.8, +10.2**		**+10.0**		**+9.8, +10.2**	mV/°C
Load Regulation (Note 3) 0≤I_L≤1 mA	T_A=+25°C	±0.4	±2.0		±0.4	±2.0		mV/mA
	$T_{MIN}≤T_A≤T_{MAX}$	**±0.5**		**±5.0**	**±0.5**		**±5.0**	mV/mA
Line Regulation (Note 3)	T_A=+25°C	±0.01	±0.1		±0.01	±0.1		mV/V
	4V≤V_S≤30V	**±0.02**		**±0.2**	**±0.02**		**±0.2**	mV/V
Quiescent Current (Note 9)	V_S=+5V, +25°C	56	80		56	80		µA
	V_S=+5V	**105**		**158**	**91**		**138**	µA
	V_S=+30V, +25°C	56.2	82		56.2	82		µA
	V_S=+30V	**105.5**		**161**	**91.5**		**141**	µA
Change of Quiescent Current (Note 3)	4V≤V_S≤30V, +25°C	0.2	2.0		0.2	2.0		µA
	4V≤V_S≤30V	**0.5**		**3.0**	**0.5**		**3.0**	µA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.7**	**+0.39**		**+0.7**	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

Note 1: Unless otherwise noted, these specifications apply: −55°C≤T_J≤+150°C for the LM35 and LM35A; −40°≤T_J≤+110°C for the LM35C and LM35CA; and 0°≤T_J≤+100°C for the LM35D. V_S=+5Vdc and I_{LOAD}=50 µA, in the circuit of *Figure 2*. These specifications also apply from +2°C to T_{MAX} in the circuit of *Figure 1*. Specifications in **boldface** apply over the full rated temperature range.

Note 2: Thermal resistance of the TO-46 package is 400°C/W, junction to ambient, and 24°C/W junction to case. Thermal resistance of the TO-92 package is 180°C/W junction to ambient. Thermal resistance of the small outline molded package is 220°C/W junction to ambient. Thermal resistance of the TO-220 package is 90°C/W junction to ambient. For additional thermal resistance information see table in the Applications section.

Note 3: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Note 4: Tested Limits are guaranteed and 100% tested in production.

Note 5: Design Limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

Note 6: Specifications in **boldface** apply over the full rated temperature range.

Note 7: Accuracy is defined as the error between the output voltage and 10mv/°C times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in °C).

Note 8: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device's rated temperature range.

Note 9: Quiescent current is defined in the circuit of *Figure 1*.

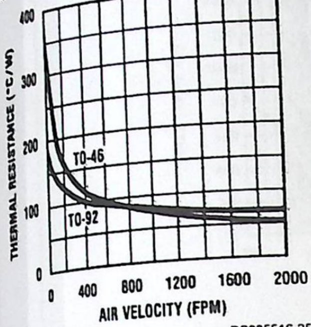
Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

Note 11: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Note 12: See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" or the section titled "Surface Mount" found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

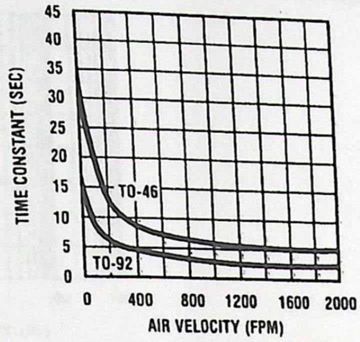
Typical Performance Characteristics

Thermal Resistance Junction to Air



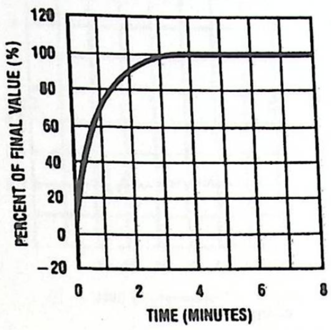
DS005516-25

Thermal Time Constant



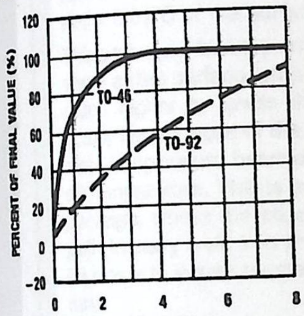
DS005516-26

Thermal Response in Still Air



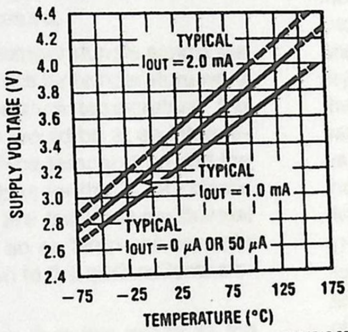
DS005516-27

Thermal Response in Stirred Oil Bath



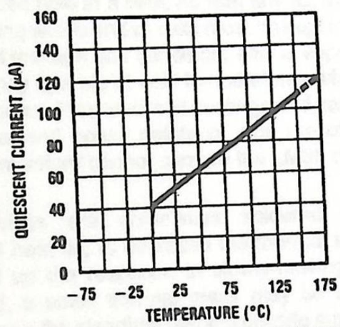
DS005516-28

Minimum Supply Voltage vs. Temperature



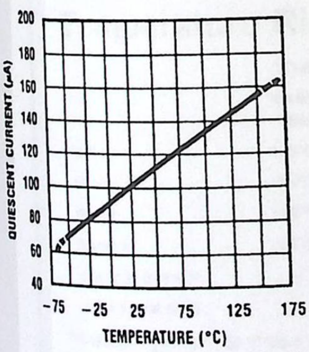
DS005516-29

Quiescent Current vs. Temperature (In Circuit of *Figure 1*.)



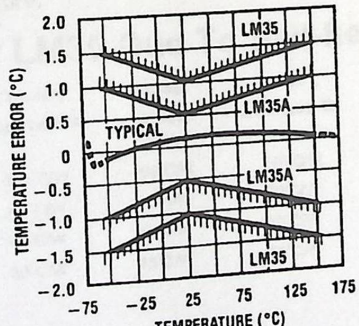
DS005516-30

Quiescent Current vs. Temperature (In Circuit of *Figure 2*.)



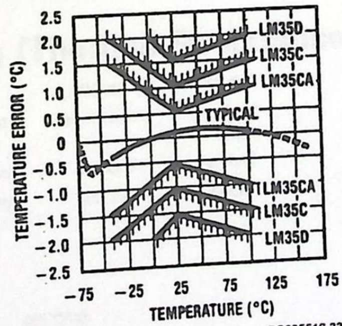
DS005516-31

Accuracy vs. Temperature (Guaranteed)



DS005516-32

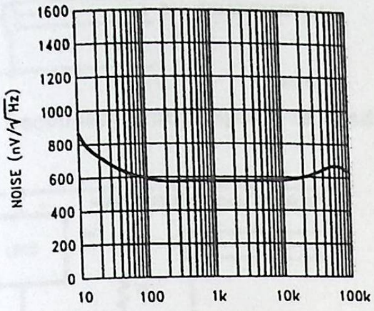
Accuracy vs. Temperature (Guaranteed)



DS005516-33

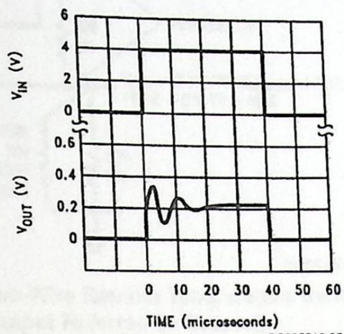
Typical Performance Characteristics (Continued)

Noise Voltage



DS005516-34

Start-Up Response



DS005516-35

Applications

The LM35 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface and its temperature will be within about 0.01˚C of the surface temperature.

This presumes that the ambient air temperature is almost the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature. This is expecially true for the TO-92 plastic package, where the copper leads are the principal thermal path to carry heat into the device, so its temperature might be closer to the air temperature than to the surface temperature.

To minimize this problem, be sure that the wiring to the LM35, as it leaves the device, is held at the same temperature as the surface of interest. The easiest way to do this is to cover up these wires with a bead of epoxy which will insure that the leads and wires are all at the same temperature as the surface, and that the LM35 die's temperature will not be affected by the air temperature.

The TO-46 metal package can also be soldered to a metal surface or pipe without damage. Of course, in that case the V− terminal of the circuit will be grounded to that metal. Alternatively, the LM35 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the LM35 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. Printed-circuit coatings and varnishes such as Humiseal and epoxy paints or dips are often used to insure that moisture cannot corrode the LM35 or its connections.

These devices are sometimes soldered to a small light-weight heat fin, to decrease the thermal time constant and speed up the response in slowly-moving air. On the other hand, a small thermal mass may be added to the sensor, to give the steadiest reading despite small deviations in the air temperature.

Temperature Rise of LM35 Due To Self-heating (Thermal Resistance, θ_{JA})

	TO-46, no heat sink	TO-46*, small heat fin	TO-92, no heat sink	TO-92**, small heat fin	SO-8 no heat sink	SO-8** small heat fin	TO-220 no heat sink
Still air	400˚C/W	100˚C/W	180˚C/W	140˚C/W	220˚C/W	110˚C/W	90˚C/W
Moving air	100˚C/W	40˚C/W	90˚C/W	70˚C/W	105˚C/W	90˚C/W	26˚C/W
Still oil	100˚C/W	40˚C/W	90˚C/W	70˚C/W			
Stirred oil	50˚C/W	30˚C/W	45˚C/W	40˚C/W			
(Clamped to metal, Infinite heat sink)		(24˚C/W)				(55˚C/W)	

*Wakefield type 201, or 1" disc of 0.020" sheet brass, soldered to case, or similar.
**TO-92 and SO-8 packages glued and leads soldered to 1" square of 1/16" printed circuit board with 2 oz. foil or similar.

Typical Applications

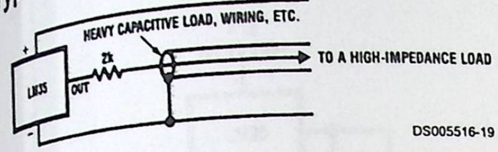


FIGURE 3. LM35 with Decoupling from Capacitive Load

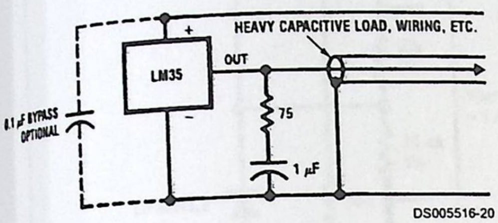


FIGURE 4. LM35 with R-C Damper

CAPACITIVE LOADS

Like most micropower circuits, the LM35 has a limited ability to drive heavy capacitive loads. The LM35 by itself is able to drive 50 pf without special precautions. If heavier loads are anticipated, it is easy to isolate or decouple the load with a resistor; see *Figure 3*. Or you can improve the tolerance of capacitance with a series R-C damper from output to ground; see *Figure 4*.

When the LM35 is applied with a 200Ω load resistor as shown in *Figure 5*, *Figure 6* or *Figure 8* it is relatively immune to wiring capacitance because the capacitance forms a bypass from ground to input, not on the output. However, as with any linear circuit connected to wires in a hostile environment, its performance can be affected adversely by intense electromagnetic sources such as relays, radio transmitters, motors with arcing brushes, SCR transients, etc, as its wiring can act as a receiving antenna and its internal junctions can act as rectifiers. For best results in such cases, a bypass capacitor from V_{IN} to ground and a series R-C damper such as 75Ω in series with 0.2 or 1 μF from output to ground are often useful. These are shown in *Figure 13*, *Figure 14*, and *Figure 16*.

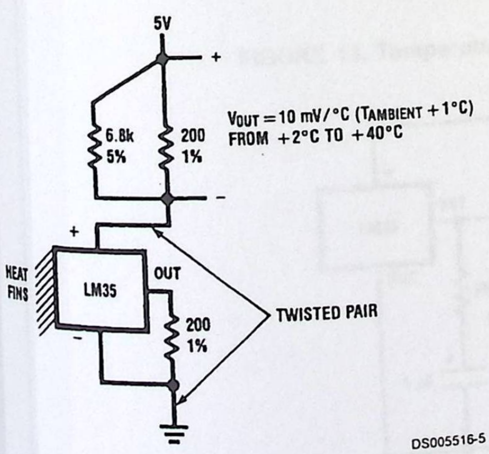


FIGURE 5. Two-Wire Remote Temperature Sensor (Grounded Sensor)

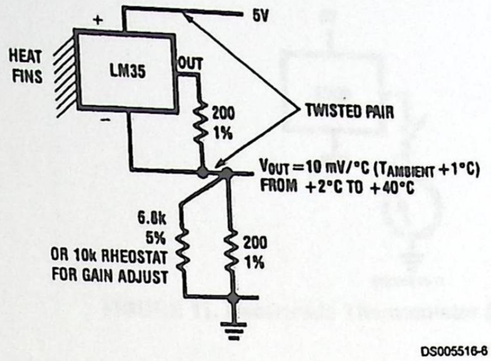


FIGURE 6. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

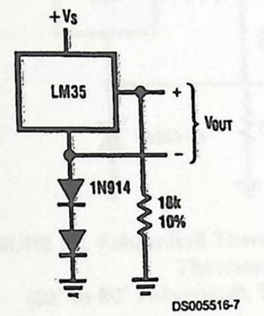


FIGURE 7. Temperature Sensor, Single Supply, −55˚ to +150˚C

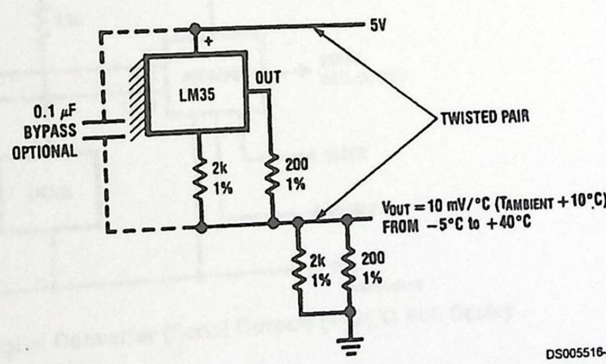


FIGURE 8. Two-Wire Remote Temperature Sensor (Output Referred to Ground)

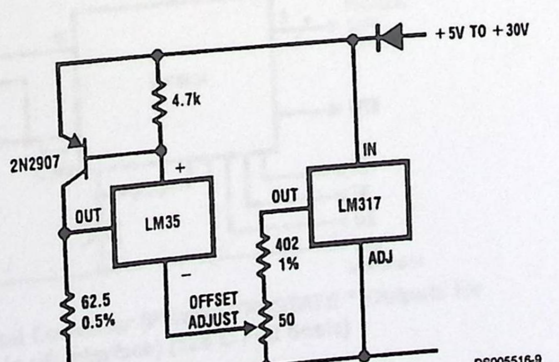


FIGURE 9. 4-To-20 mA Current Source (0˚C to +100˚C)

Typical Applications (Continued)

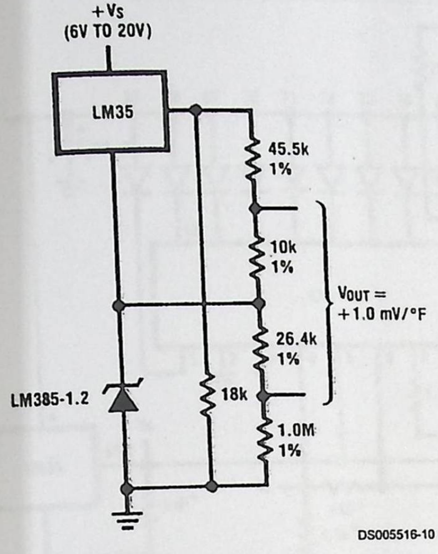


FIGURE 10. Fahrenheit Thermometer

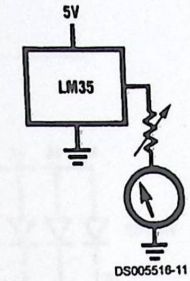


FIGURE 11. Centigrade Thermometer (Analog Meter)

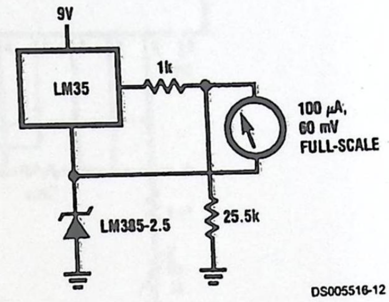


FIGURE 12. Fahrenheit ThermometerExpanded Scale Thermometer (50° to 80° Fahrenheit, for Example Shown)

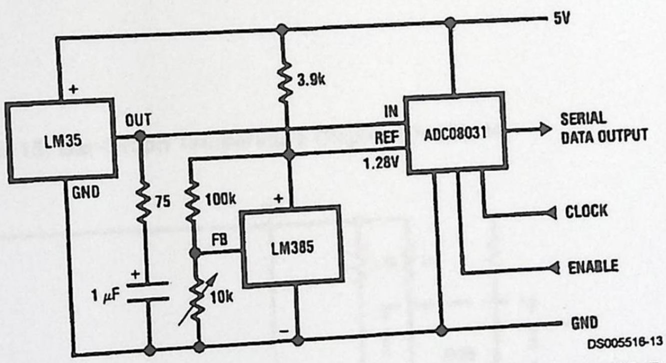


FIGURE 13. Temperature To Digital Converter (Serial Output) (+128°C Full Scale)

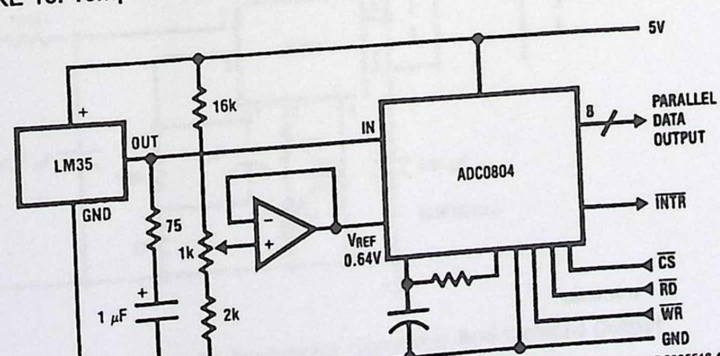
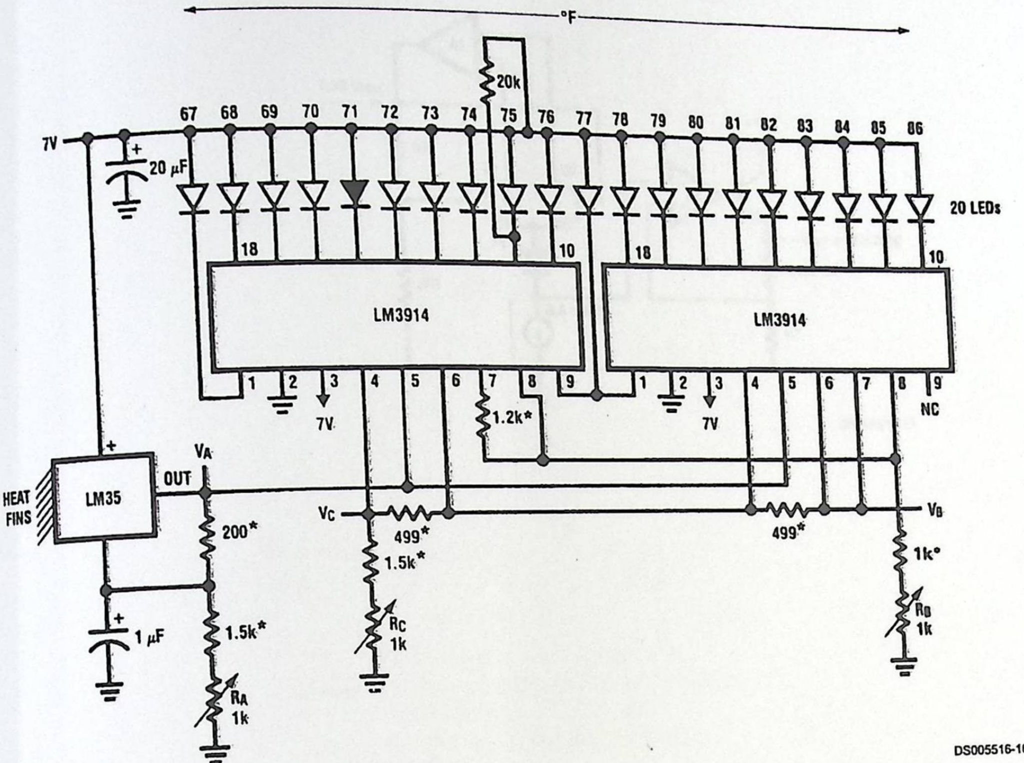


FIGURE 14. Temperature To Digital Converter (Parallel TRI-STATE™ Outputs for Standard Data Bus to µP Interface) (128°C Full Scale)

Typical Applications (Continued)



*=1% or 2% film resistor
Trim R_B for V_B=3.075V
Trim R_C for V_C=1.955V
Trim R_A for V_A=0.075V + 100mV/°C x $T_{ambient}$
Example, V_A=2.275V at 22°C

FIGURE 15. Bar-Graph Temperature Display (Dot Mode)

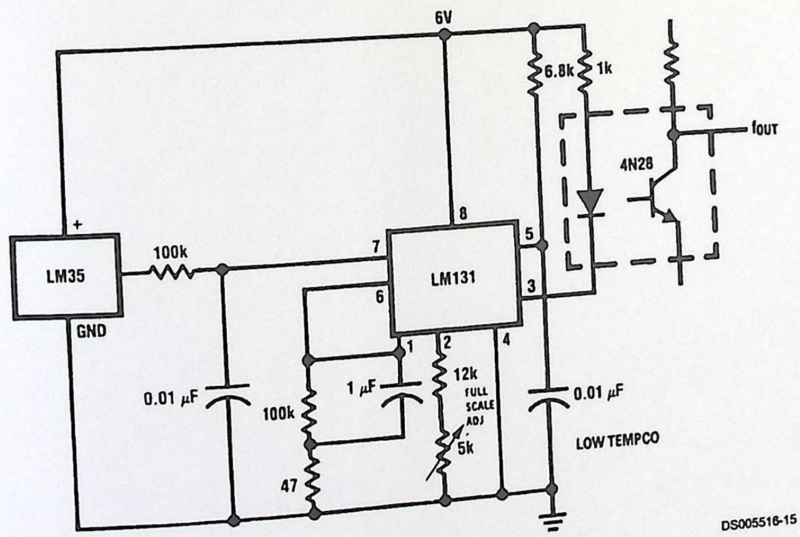
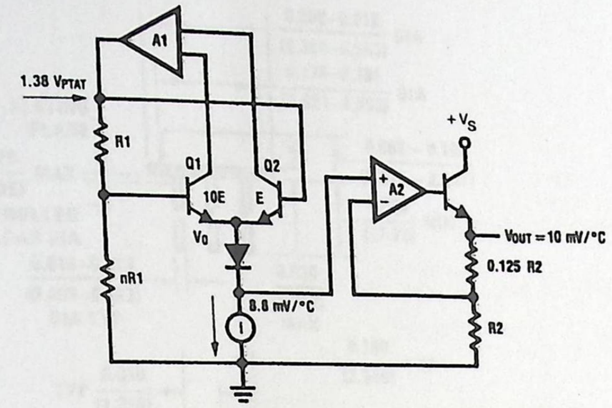


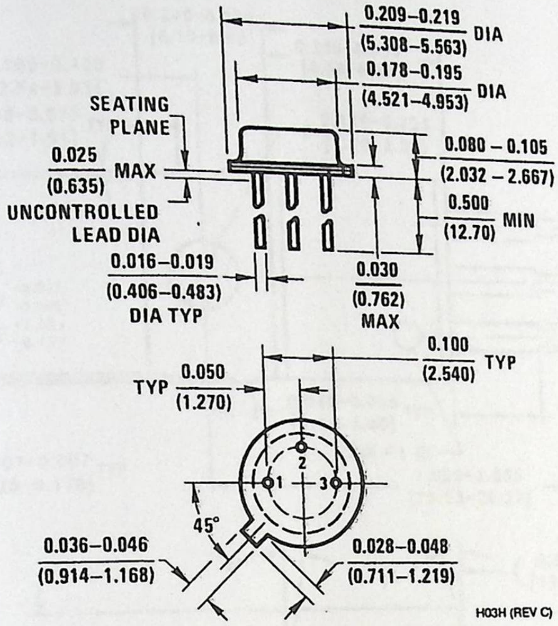
FIGURE 16. LM35 With Voltage-To-Frequency Converter And Isolated Output (2°C to +150°C; 20 Hz to 1500 Hz)

Block Diagram

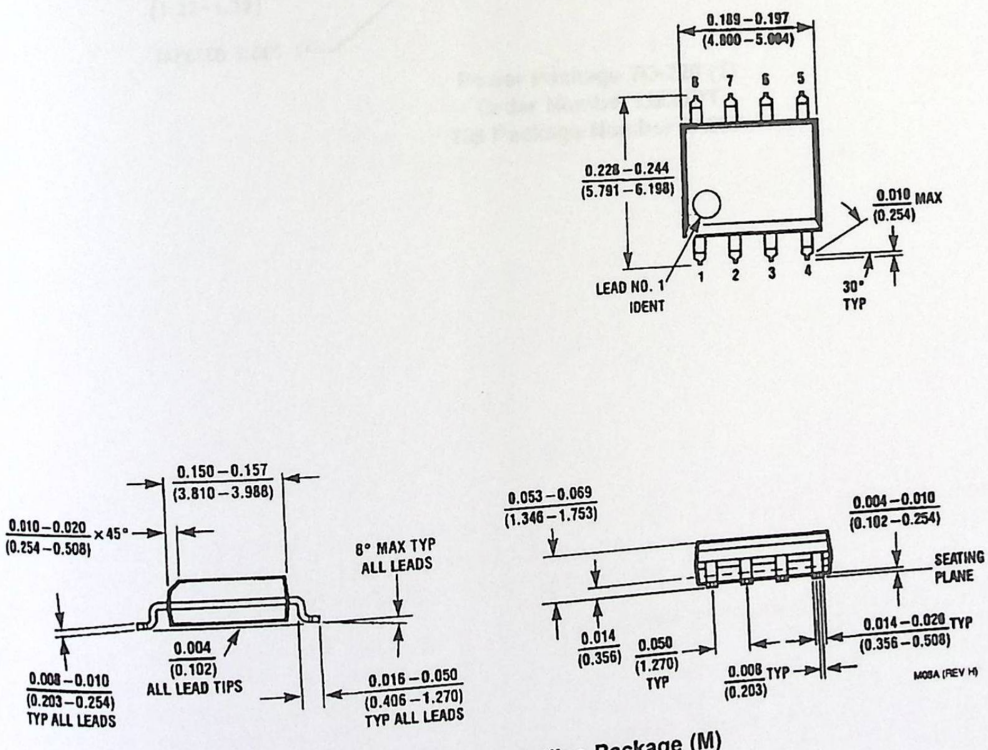


DS005516-23

Physical Dimensions inches (millimeters) unless otherwise noted

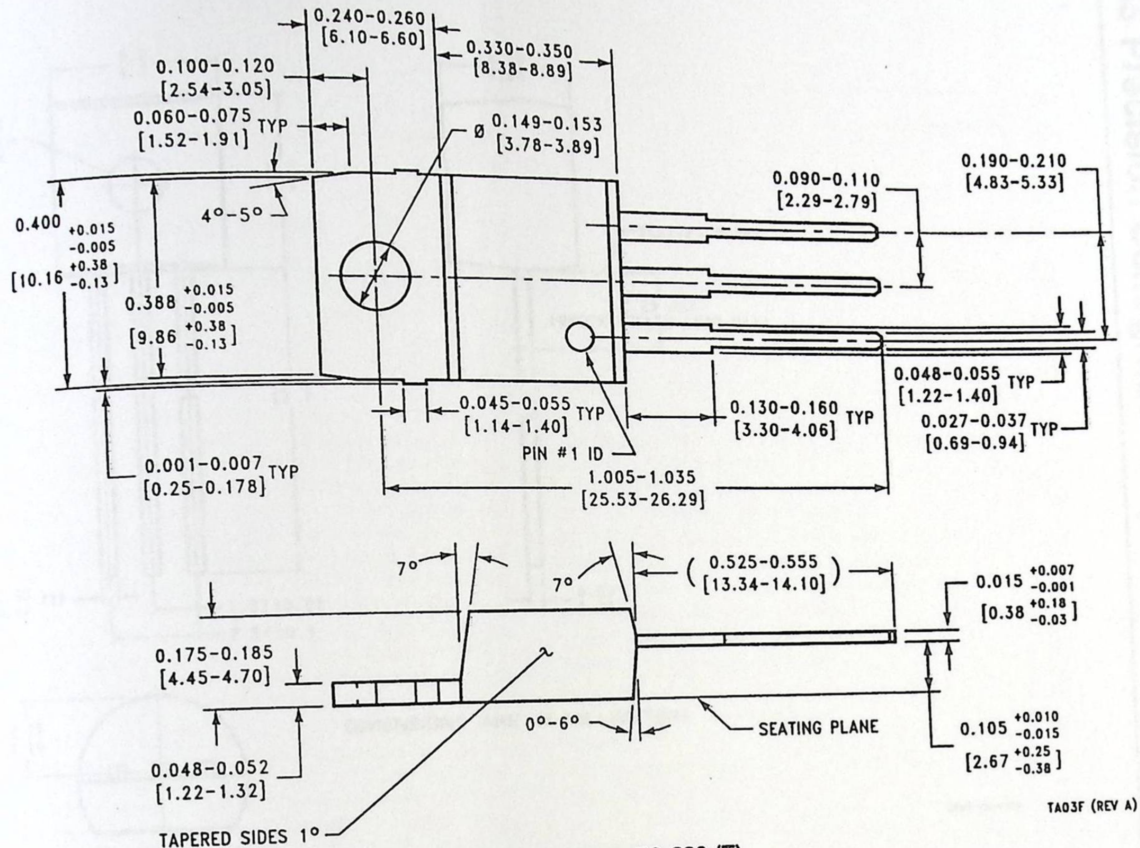


TO-46 Metal Can Package (H)
Order Number LM35H, LM35AH, LM35CH, LM35CAH, or LM35DH
NS Package Number H03H



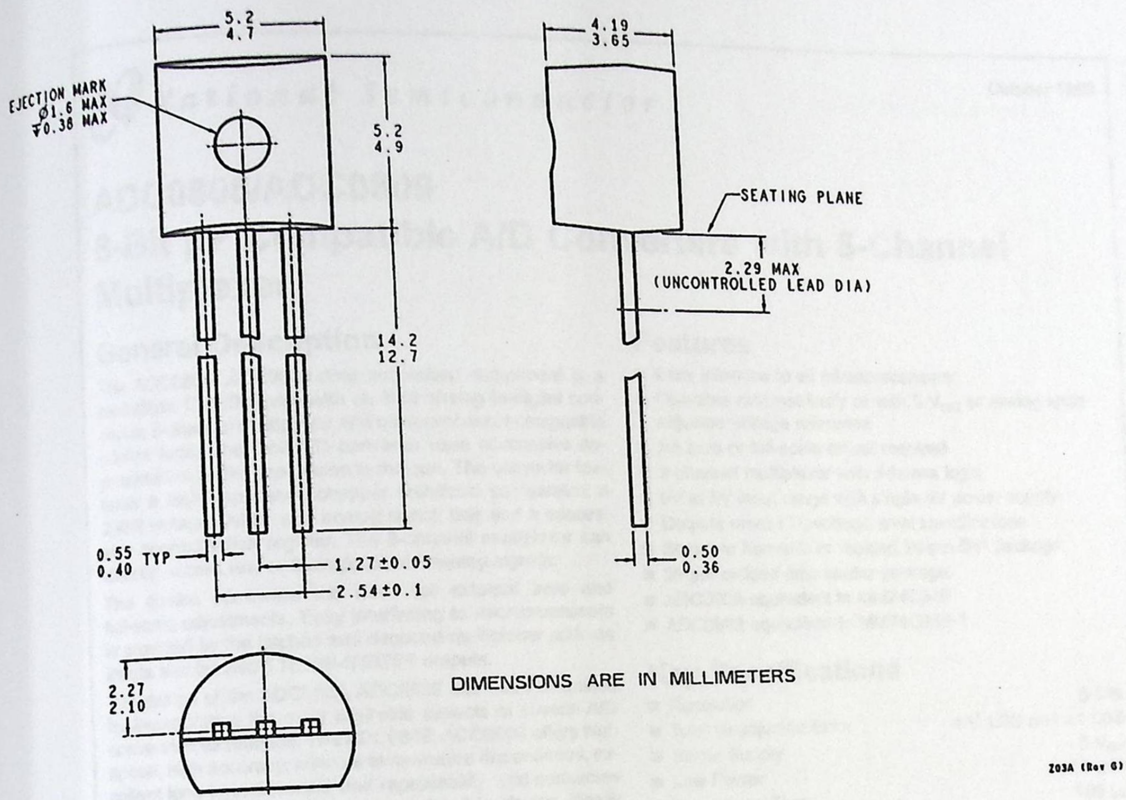
SO-8 Molded Small Outline Package (M)
Order Number LM35DM
NS Package Number M08A

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



Power Package TO-220 (T)
Order Number LM35DT
NS Package Number TA03F

Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



TO-92 Plastic Package (Z)
Order Number LM35CZ, LM35CAZ or LM35DZ
NS Package Number Z03A

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National Semiconductor

October 1999

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.)

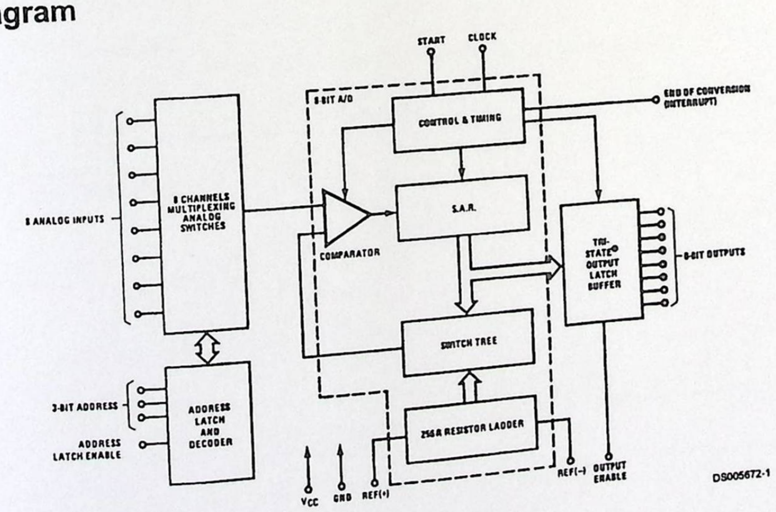
Features

- 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 5V input range with single 5V power supply
- Outputs meet TTL voltage level specifications
- Standard hermetic or molded 28-pin DIP package
- 28-pin molded chip carrier package
- 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

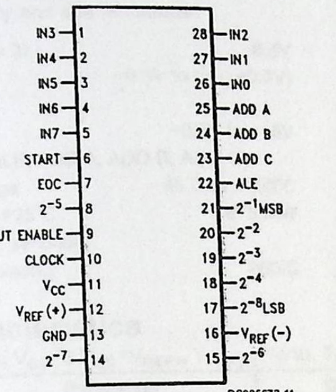
Block Diagram



See Ordering Information

Connection Diagrams

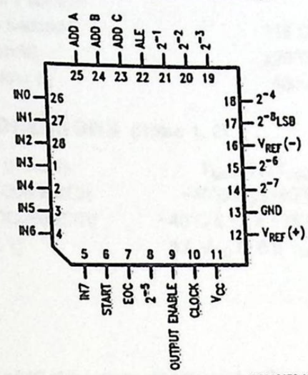
Dual-In-Line Package



DS005672-11

Order Number ADC0808CCN or ADC0809CCN
See NS Package J28A or N28A

Molded Chip Carrier Package



DS005672-12

Order Number ADC0808CCV or ADC0809CCV
See NS Package V28A

Ordering Information

TEMPERATURE RANGE		−40°C to +85°C			−55°C to +125°C
Error	±½ LSB Unadjusted	ADC0808CCN	ADC0808CCV	ADC0808CCJ	ADC0808CJ
	±1 LSB Unadjusted	ADC0809CCN	ADC0809CCV		
Package Outline		N28A Molded DIP	V28A Molded Chip Carrier	J28A Ceramic DIP	J28A Ceramic DIP

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
Dual-In-Line Package (ceramic)	300˚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 (Note 1)	T_{MIN}≤T_A≤T_{MAX}
ADC0808CCN,ADC0809CCN	−40˚C≤T_A≤+85˚C
ADC0808CCV, ADC0809CCV	−40˚C ≤ T_A ≤ +85˚C
Range of V_{CC} (Note 1)	4.5 V_{DC} to 6.0 V_{DC}

Electrical Characteristics

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

Symbol	Parameter	Conditions	Min	Typ	Max	Units
	ADC0808 Total Unadjusted Error (Note 5)	25˚C T_{MIN} to T_{MAX}			±½ ±¾	LSB LSB
	ADC0809 Total Unadjusted Error (Note 5)	0˚C to 70˚C T_{MIN} to T_{MAX}			±1 ±1¼	LSB LSB
	Input Resistance	From Ref(+) to Ref(−)	1.0	2.5		kΩ
	Analog Input Voltage Range	(Note 4) V(+) or V(−)	GND−0.10		V_{CC}+0.10	V_{DC}
$V_{REF(+)}$	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
$V_{REF(-)}$	Voltage, Bottom of Ladder	Measured at Ref(−)	−0.1	0		V
I_{IN}	Comparator Input Current	f_c=640 kHz, (Note 6)	−2	±0.5	2	μA

Electrical Characteristics

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
ANALOG MULTIPLEXER						
$I_{OFF(+)}$	OFF Channel Leakage Current	V_{CC}=5V, V_{IN}=5V, T_A=25˚C T_{MIN} to T_{MAX}		10	200 1.0	nA μA
$I_{OFF(-)}$	OFF Channel Leakage Current	V_{CC}=5V, V_{IN}=0, T_A=25˚C T_{MIN} to T_{MAX}	−200 −1.0	−10		nA μA
CONTROL INPUTS						
$V_{IN(1)}$	Logical "1" Input Voltage		V_{CC}−1.5			V
$V_{IN(0)}$	Logical "0" Input Voltage				1.5	V
$I_{IN(1)}$	Logical "1" Input Current (The Control Inputs)	V_{IN}=15V			1.0	μA
$I_{IN(0)}$	Logical "0" Input Current (The Control Inputs)	V_{IN}=0	−1.0			μA
I_{CC}	Supply Current	f_{CLK}=640 kHz		0.3	3.0	mA

Electrical Characteristics (Continued)

Digital Levels and DC Specifications: ADC0808CCN, ADC0808CCV, ADC0809CCN and ADC0809CCV, $4.75 \le V_{CC} \le 5.25V$, $-40^{\circ}C \le T_A \le +85^{\circ}C$ unless otherwise noted

Symbol	Parameter	Conditions	Min	Typ	Max	Units
DATA OUTPUTS AND EOC (INTERRUPT)						
$V_{OUT(1)}$	Logical "1" Output Voltage	V_{CC} = 4.75V I_{OUT} = −360µA I_{OUT} = −10µA		 2.4 4.5		 V(min) V(min)
$V_{OUT(0)}$	Logical "0" Output Voltage	I_O=1.6 mA			0.45	V
$V_{OUT(0)}$	Logical "0" Output Voltage EOC	I_O=1.2 mA			0.45	V
I_{OUT}	TRI-STATE Output Current	V_O=5V			3	µA
		V_O=0	−3			µA

Electrical Characteristics

Timing Specifications $V_{CC}=V_{REF(+)}=5V$, $V_{REF(-)}=GND$, $t_r=t_f=20$ ns and $T_A=25^{\circ}C$ unless otherwise noted.

Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_{WS}	Minimum Start Pulse Width	(*Figure 5*)		100	200	ns
t_{WALE}	Minimum ALE Pulse Width	(*Figure 5*)		100	200	ns
t_s	Minimum Address Set-Up Time	(*Figure 5*)		25	50	ns
t_H	Minimum Address Hold Time	(*Figure 5*)		25	50	ns
t_D	Analog MUX Delay Time From ALE	R_S=0Ω (*Figure 5*)		1	2.5	µs
t_{H1}, t_{H0}	OE Control to Q Logic State	C_L=50 pF, R_L=10k (*Figure 8*)		125	250	ns
t_{1H}, t_{0H}	OE Control to Hi-Z	C_L=10 pF, R_L=10k (*Figure 8*)		125	250	ns
t_c	Conversion Time	f_c=640 kHz, (*Figure 5*) (Note 7)	90	100	116	µs
f_c	Clock Frequency		10	640	1280	kHz
t_{EOC}	EOC Delay Time	(*Figure 5*)	0		8+2 µS	Clock Periods
C_{IN}	Input Capacitance	At Control Inputs		10	15	pF
C_{OUT}	TRI-STATE Output Capacitance	At TRI-STATE Outputs		10	15	pF

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its specified operating conditions.

Note 2: All voltages are measured with respect to GND, unless othewise specified.

Note 3: A zener diode exists, internally, from V_{CC} to GND and has a typical breakdown voltage of 7 V_{DC}.

Note 4: Two on-chip diodes are tied to each analog input which will forward conduct for analog input voltages one diode drop below ground or one diode drop greater than the V_{CC}n supply. The spec allows 100 mV forward bias of either diode. This means that as long as the analog V_{IN} does not exceed the supply voltage by more than 100 mV, the output code will be correct. To achieve an absolute $0V_{DC}$ to $5V_{DC}$ input voltage range will therefore require a minimum supply voltage of 4.900 V_{DC} over temperature variations, initial tolerance and loading.

Note 5: Total unadjusted error includes offset, full-scale, linearity, and multiplexer errors. See *Figure 3*. None of these A/Ds requires a zero or full-scale adjust. However, if an all zero code is desired for an analog input other than 0.0V, or if a narrow full-scale span exists (for example: 0.5V to 4.5V full-scale) the reference voltages can be adjusted to achieve this. See *Figure 13*.

Note 6: Comparator input current is a bias current into or out of the chopper stabilized comparator. The bias current varies directly with clock frequency and has little temperature dependence (*Figure 6*). See paragraph 4.0.

Note 7: The outputs of the data register are updated one clock cycle before the rising edge of EOC.

Note 8: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Functional Description

Multiplexer. The device contains an 8-channel single-ended analog signal multiplexer. A particular input channel is selected by using the address decoder. *Table 1* shows the input states for the address lines to select any channel. The address is latched into the decoder on the low-to-high transition of the address latch enable signal.

TABLE 1.

SELECTED ANALOG CHANNEL	ADDRESS LINE C	B	A
IN0	L	L	L
IN1	L	L	H
IN2	L	H	L
IN3	L	H	H
IN4	H	L	L
IN5	H	L	H
IN6	H	H	L
IN7	H	H	H

CONVERTER CHARACTERISTICS

The Converter

The heart of this single chip data acquisition system is its 8-bit analog-to-digital converter. The converter is designed to give fast, accurate, and repeatable conversions over a wide range of temperatures. The converter is partitioned into 3 major sections: the 256R ladder network, the successive approximation register, and the comparator. The converter's digital outputs are positive true.

The 256R ladder network approach (*Figure 1*) was chosen over the conventional R/2R ladder because of its inherent monotonicity, which guarantees no missing digital codes. Monotonicity is particularly important in closed loop feedback control systems. A non-monotonic relationship can cause oscillations that will be catastrophic for the system. Additionally, the 256R network does not cause load variations on the reference voltage.

The bottom resistor and the top resistor of the ladder network in *Figure 1* are not the same value as the remainder of the network. The difference in these resistors causes the output characteristic to be symmetrical with the zero and full-scale points of the transfer curve. The first output transition occurs when the analog signal has reached +½ LSB and succeeding output transitions occur every 1 LSB later up to full-scale.

The successive approximation register (SAR) performs 8 iterations to approximate the input voltage. For any SAR type converter, n-iterations are required for an n-bit converter. *Figure 2* shows a typical example of a 3-bit converter. In the ADC0808, ADC0809, the approximation technique is extended to 8 bits using the 256R network.

The A/D converter's successive approximation register (SAR) is reset on the positive edge of the start conversion (SC) pulse. The conversion is begun on the falling edge of the start conversion pulse. A conversion in process will be interrupted by receipt of a new start conversion pulse. Continuous conversion may be accomplished by tying the end-of-conversion (EOC) output to the SC input. If used in this mode, an external start conversion pulse should be applied after power up. End-of-conversion will go low between 0 and 8 clock pulses after the rising edge of start conversion.

The most important section of the A/D converter is the comparator. It is this section which is responsible for the ultimate accuracy of the entire converter. It is also the comparator drift which has the greatest influence on the repeatability of the device. A chopper-stabilized comparator provides the most effective method of satisfying all the converter requirements.

The chopper-stabilized comparator converts the DC input signal into an AC signal. This signal is then fed through a high gain AC amplifier and has the DC level restored. This technique limits the drift component of the amplifier since the drift is a DC component which is not passed by the AC amplifier. This makes the entire A/D converter extremely insensitive to temperature, long term drift and input offset errors.

Figure 4 shows a typical error curve for the ADC0808 as measured using the procedures outlined in AN-179.

Functional Description (Continued)

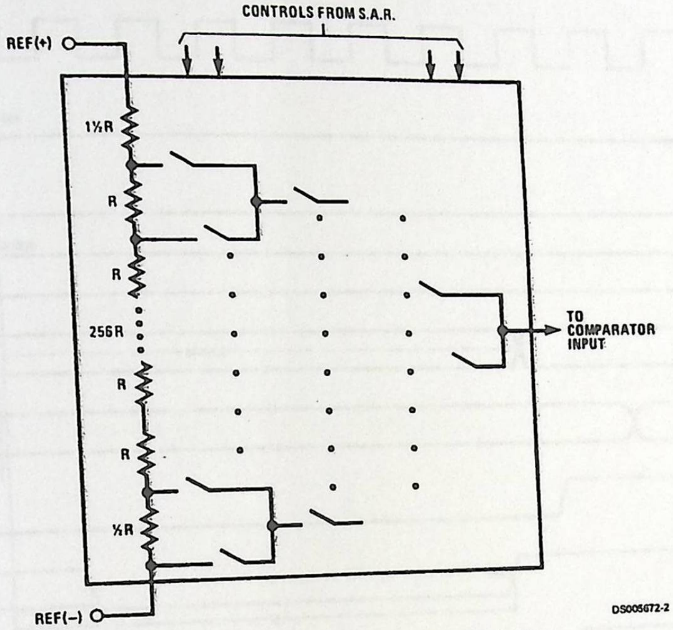


FIGURE 1. Resistor Ladder and Switch Tree

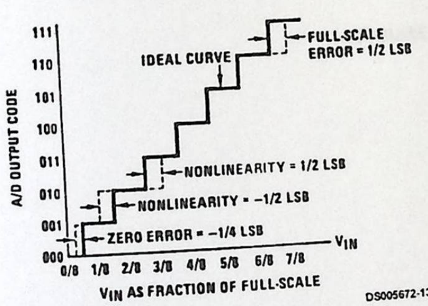


FIGURE 2. 3-Bit A/D Transfer Curve

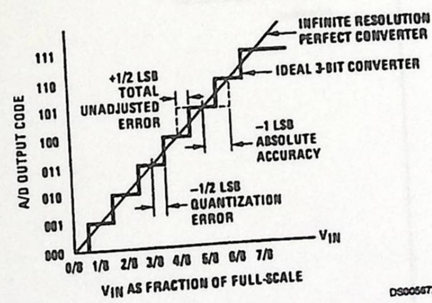


FIGURE 3. 3-Bit A/D Absolute Accuracy Curve

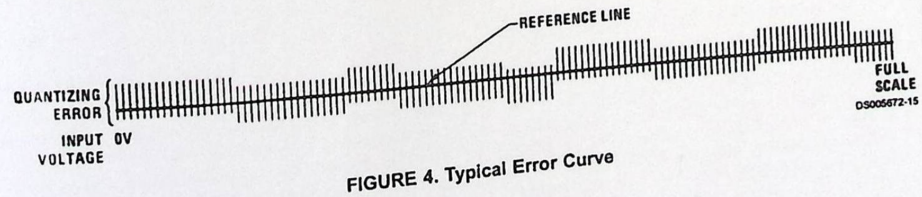


FIGURE 4. Typical Error Curve

Timing Diagram

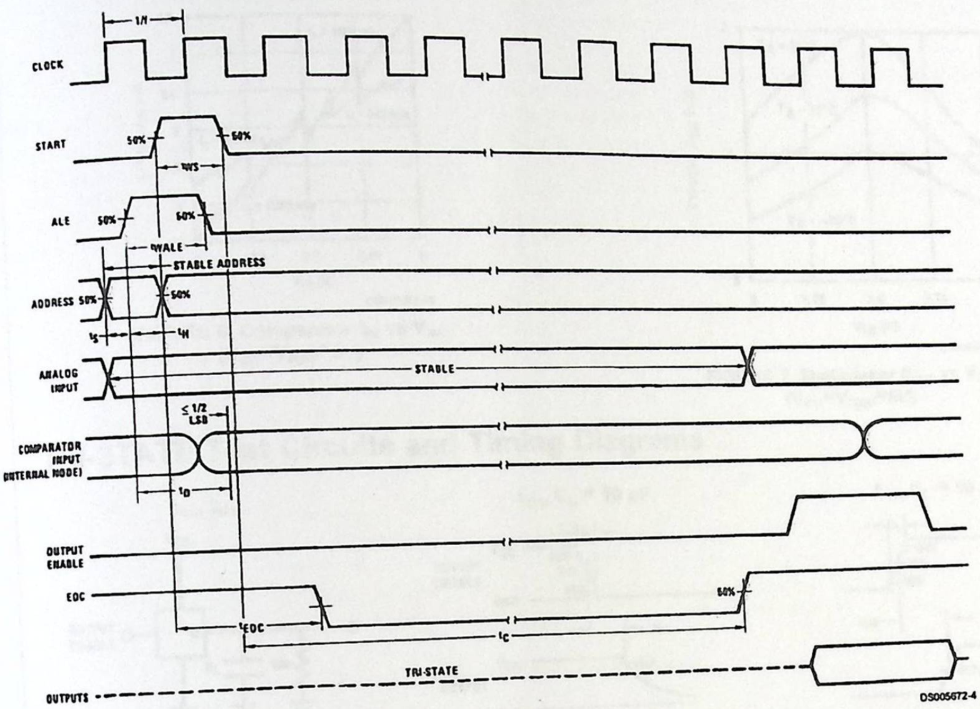


FIGURE 5.

Typical Performance Characteristics

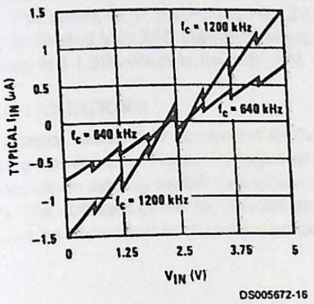


FIGURE 6. Comparator I_{IN} vs V_{IN} (V_{CC}=V_{REF}=5V)

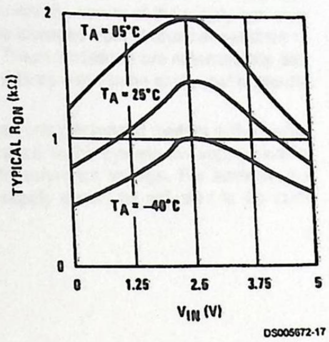


FIGURE 7. Multiplexer R_{ON} vs V_{IN} (V_{CC}=V_{REF}=5V)

TRI-STATE Test Circuits and Timing Diagrams

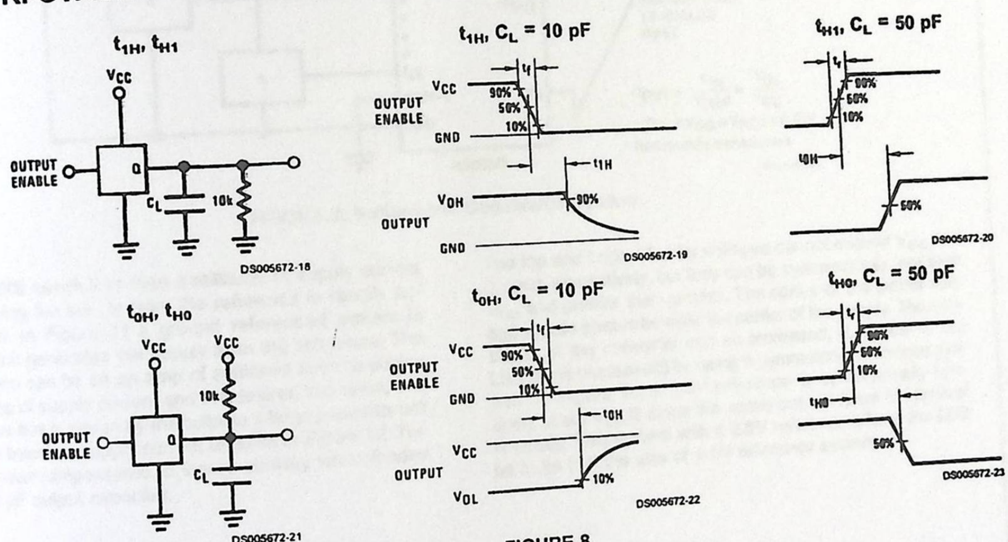


FIGURE 8.

Applications Information

OPERATION

1.0 RATIOMETRIC CONVERSION

The ADC0808, ADC0809 is designed as a complete Data Acquisition System (DAS) for ratiometric conversion systems. In ratiometric systems, the physical variable being measured is expressed as a percentage of full-scale which is not necessarily related to an absolute standard. The voltage input to the ADC0808 is expressed by the equation

$$\frac{V_{IN}}{V_{fs}-V_Z}=\frac{D_X}{D_{MAX}-D_{MIN}} \qquad (1)$$

V_{IN}=Input voltage into the ADC0808

V_{fs}=Full-scale voltage

V_Z=Zero voltage

D_X=Data point being measured

D_{MAX}=Maximum data limit

D_{MIN}=Minimum data limit

A good example of a ratiometric transducer is a potentiometer used as a position sensor. The position of the wiper is directly proportional to the output voltage which is a ratio of the full-scale voltage across it. Since the data is represented as a proportion of full-scale, reference requirements are greatly reduced, eliminating a large source of error and cost for many applications. A major advantage of the ADC0808, ADC0809 is that the input voltage range is equal to the supply range so the transducers can be connected directly across the supply and their outputs connected directly into the multiplexer inputs, (*Figure 9*).

Ratiometric transducers such as potentiometers, strain gauges, thermistor bridges, pressure transducers, etc., are suitable for measuring proportional relationships; however, many types of measurements must be referred to an absolute standard such as voltage or current. This means a sys-

Applications Information (Continued)

tem reference must be used which relates the full-scale voltage to the standard volt. For example, if $V_{CC}=V_{REF}=5.12V$, then the full-scale range is divided into 256 standard steps. The smallest standard step is 1 LSB which is then 20 mV.

2.0 RESISTOR LADDER LIMITATIONS

The voltages from the resistor ladder are compared to the selected into 8 times in a conversion. These voltages are coupled to the comparator via an analog switch tree which is referenced to the supply. The voltages at the top, center and bottom of the ladder must be controlled to maintain proper operation.

The top of the ladder, Ref(+), should not be more positive than the supply, and the bottom of the ladder, Ref(−), should not be more negative than ground. The center of the ladder voltage must also be near the center of the supply because the analog switch tree changes from N-channel switches to P-channel switches. These limitations are automatically satisfied in ratiometric systems and can be easily met in ground referenced systems.

Figure 10 shows a ground referenced system with a separate supply and reference. In this system, the supply must be trimmed to match the reference voltage. For instance, if a 5.12V is used, the supply should be adjusted to the same voltage within 0.1V.

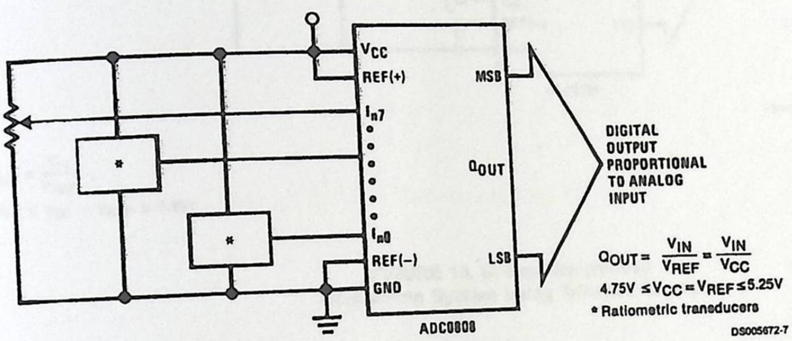
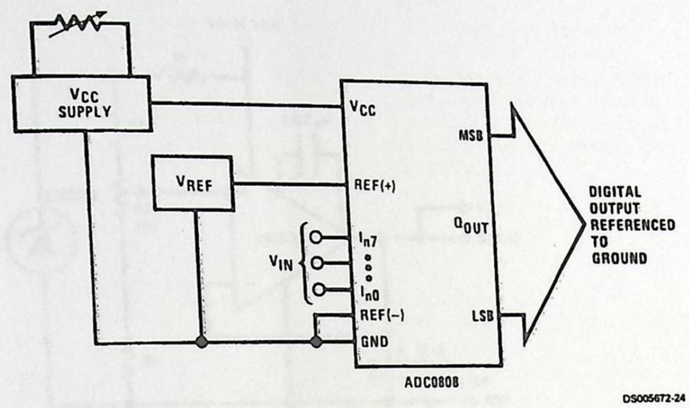


FIGURE 9. Ratiometric Conversion System

The ADC0808 needs less than a milliamp of supply current so developing the supply from the reference is readily accomplished. In *Figure 11* a ground referenced system is shown which generates the supply from the reference. The buffer shown can be an op amp of sufficient drive to supply the milliamp of supply current and the desired bus drive, or if a capacitive bus is driven by the outputs a large capacitor will supply the transient supply current as seen in *Figure 12*. The LM301 is overcompensated to insure stability when loaded by the 10 µF output capacitor.

The top and bottom ladder voltages cannot exceed V_{CC} and ground, respectively, but they can be symmetrically less than V_{CC} and greater than ground. The center of the ladder voltage should always be near the center of the supply. The sensitivity of the converter can be increased, (i.e., size of the LSB steps decreased) by using a symmetrical reference system. In *Figure 13*, a 2.5V reference is symmetrically centered about $V_{CC}/2$ since the same current flows in identical resistors. This system with a 2.5V reference allows the LSB bit to be half the size of a 5V reference system.

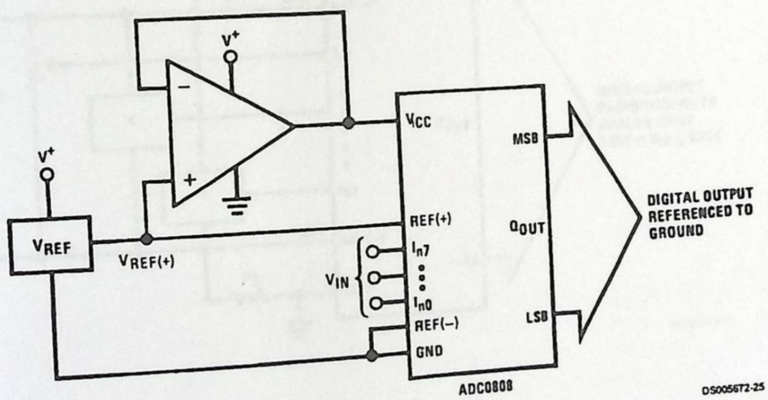
Applications Information (Continued)



$Q_{OUT} = \frac{V_{IN}}{V_{REF}}$

$4.75V \le V_{CC} = V_{REF} \le 5.25V$

FIGURE 10. Ground Referenced Conversion System Using Trimmed Supply



$Q_{OUT} = \frac{V_{IN}}{V_{REF}}$

$4.75V \le V_{CC} = V_{REF} \le 5.25V$

FIGURE 11. Ground Referenced Conversion System with Reference Generating V_{CC} Supply

Applications Information (Continued)

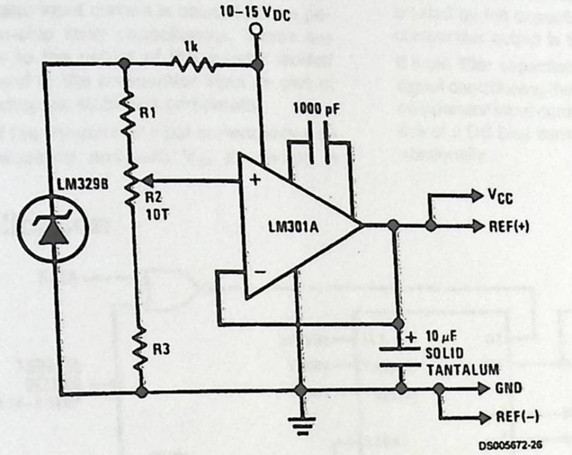
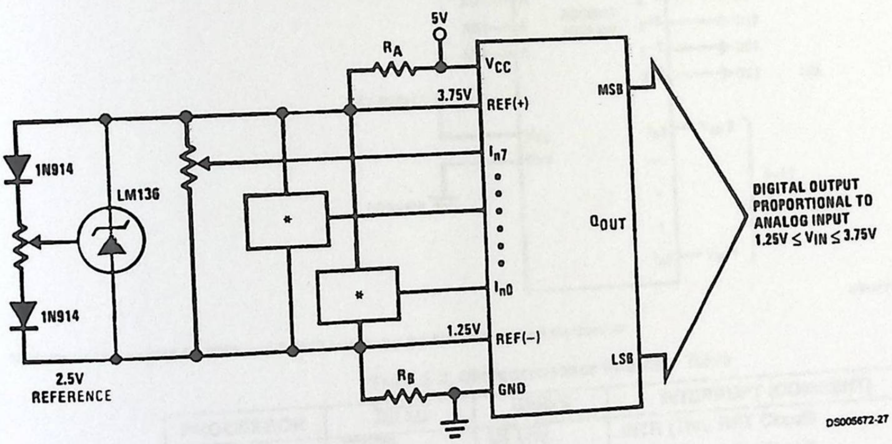


FIGURE 12. Typical Reference and Supply Circuit



$R_A = R_B$

*Ratiometric transducers

FIGURE 13. Symmetrically Centered Reference

3.0 CONVERTER EQUATIONS

The transition between adjacent codes N and N+1 is given by:

$$V_{IN} = \left\{ (V_{REF(+)} - V_{REF(-)}) \left[\frac{N}{256} + \frac{1}{512} \right] \pm V_{TUE} \right\} + V_{REF(-)} \quad (2)$$

The center of an output code N is given by:

$$V_{IN} \left\{ (V_{REF(+)} - V_{REF(-)}) \left[\frac{N}{256} \right] \pm V_{TUE} \right\} + V_{REF(-)} \quad (3)$$

The output code N for an arbitrary input are the integers within the range:

$$N = \frac{V_{IN} - V_{REF(-)}}{V_{REF(+)} - V_{REF(-)}} \times 256 \pm \text{Absolute Accuracy} \quad (4)$$

Where: V_{IN}=Voltage at comparator input
$V_{REF(+)}$=Voltage at Ref(+)
$V_{REF(-)}$=Voltage at Ref(−)
V_{TUE}=Total unadjusted error voltage (typically $V_{REF(+)} \div 512$)

Applications Information (Continued)

4.0 ANALOG COMPARATOR INPUTS

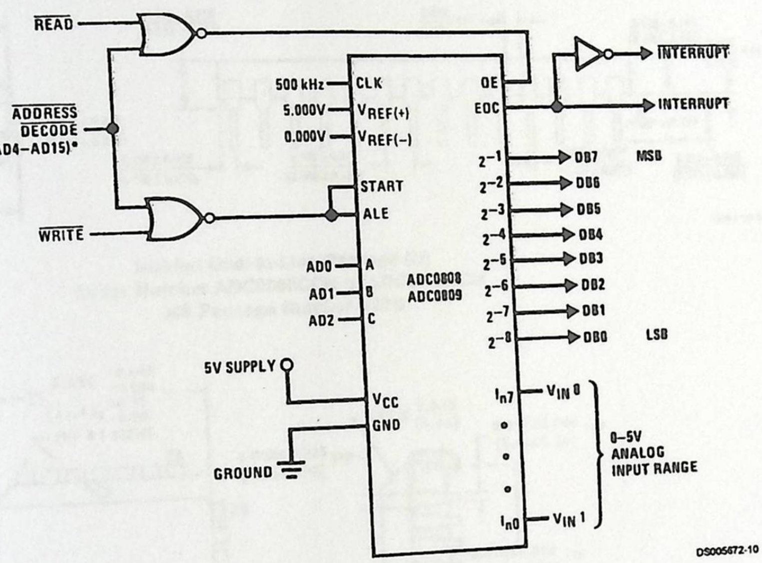
The dynamic comparator input current is caused by the periodic switching of on-chip stray capacitances. These are connected alternately to the output of the resistor ladder/switch tree network and to the comparator input as part of the operation of the chopper stabilized comparator.

The average value of the comparator input current varies directly with clock frequency and with V_{IN} as shown in *Figure 6*.

If no filter capacitors are used at the analog inputs and the signal source impedances are low, the comparator input current should not introduce converter errors, as the transient created by the capacitance discharge will die out before the comparator output is strobed.

If input filter capacitors are desired for noise reduction and signal conditioning they will tend to average out the dynamic comparator input current. It will then take on the characteristics of a DC bias current whose effect can be predicted conventionally.

Typical Application

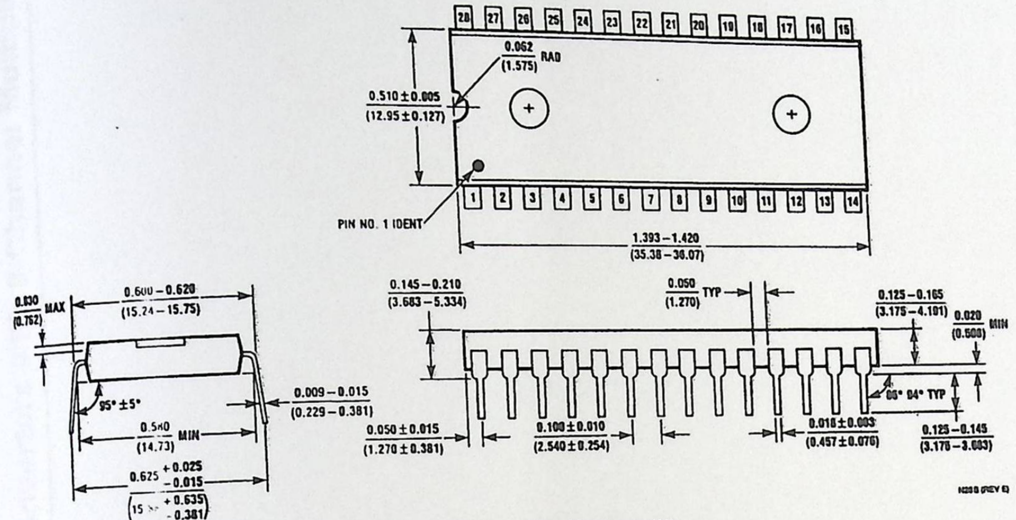


*Address latches needed for 8085 and SC/MP interfacing the ADC0808 to a microprocessor

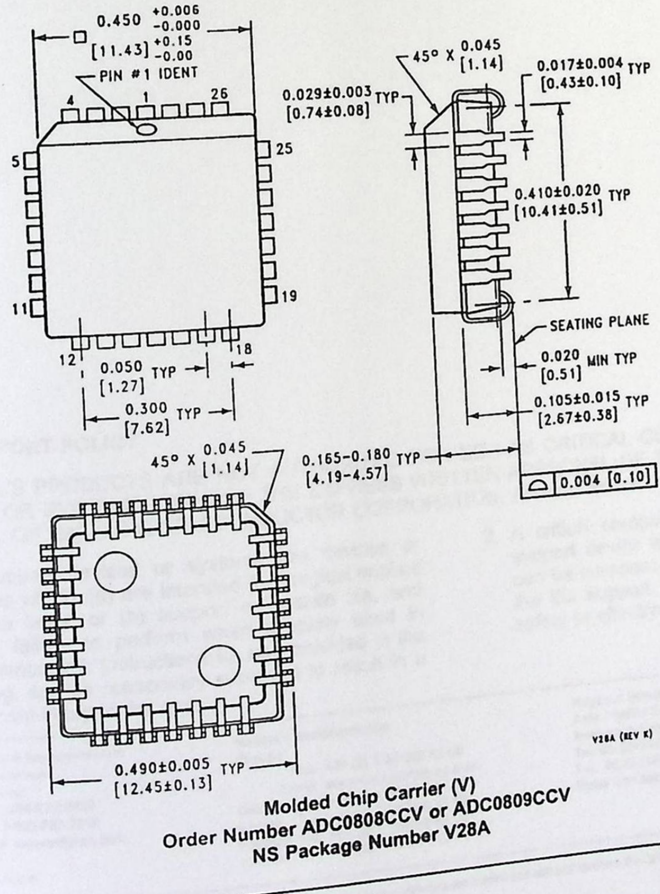
TABLE 2. Microprocessor Interface Table

PROCESSOR	$\overline{READ}$	$\overline{WRITE}$	INTERRUPT (COMMENT)
8080	$\overline{MEMR}$	$\overline{MEMW}$	INTR (Thru RST Circuit)
8085	$\overline{RD}$	$\overline{WR}$	INTR (Thru RST Circuit)
Z-80	$\overline{RD}$	$\overline{WR}$	$\overline{INT}$ (Thru RST Circuit, Mode 0)
SC/MP	NRDS	NWDS	SA (Thru Sense A)
6800	VMA•ϕ2•R/W	VMA•ϕ•$\overline{R/W}$	$\overline{IRQA}$ or $\overline{IRQB}$ (Thru PIA)

Physical Dimensions inches (millimeters) unless otherwise noted



Molded Dual-In-Line Package (N)
Order Number ADC0808CCN or ADC0809CCN
NS Package Number N28B



Molded Chip Carrier (V)
Order Number ADC0808CCV or ADC0809CCV
NS Package Number V28A

Notes

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Appendix B

Sample Source Program

```
Declare Sub vbOut Lib "WIN95IO.DLL" (ByVal nPort As Integer, ByVal nData As Integer)
Declare Sub vbOutw Lib "WIN95IO.DLL" (ByVal nPort As Integer, ByVal nData As Integer)
Declare Function vbInp Lib "WIN95IO.DLL" (ByVal nPort As Integer) As Integer
Declare Function vbInpw Lib "WIN95IO.DLL" (ByVal nPort As Integer) As Integer
```

....

```
Private Sub Timer1_Timer()
vbOut 888, 196
Call delay
s1 = vbInp(890)
h1 = vbInp(889)

vbOut 888, 197
Call delay
s2 = vbInp(890)
h2 = vbInp(889)

vbOut 888, 198
Call delay
s3 = vbInp(890)
h3 = vbInp(889)

Timer2.Enabled = True
Timer1.Enabled = False
End Sub

Private Sub Timer2_Timer()
If s1 = 0 Then
vbOut 888, 40
Label1.BackColor = &HFF&
Frame1.BackColor = &HFF&
Label1.Caption = "Smoke Detected"
End If

If s2 = 0 Then
vbOut 888, 104
Label2.BackColor = &HFF&
Frame6.BackColor = &HFF&
Label2.Caption = "Smoke Detected"
End If

If s3 = 0 Then
vbOut 888, 144
Label3.BackColor = &HFF&
Frame4.BackColor = &HFF&
Label3.Caption = "Smoke Detected"

End If
```

```
Timer3.Enabled = True
Timer2.Enabled = False
End Sub

Private Sub Timer3_Timer()
If h1 >= 16 Then
h1 = h1 - 16
Else: h1 = h1 + 16
End If

If h2 >= 16 Then
h2 = h2 - 16
Else: h2 = h2 + 16
End If

If h3 >= 16 Then
h3 = h3 - 16
Else: h3 = h3 + 16
End If

If h1 >= 10 Then
vbOut 888, 8
Frame2.BackColor = &H80C0FF
Label5.BackColor = &H80C0FF
Label5.Caption = "High Tempreture"
End If
If h1 >= 15 Then
vbOut 888, 40
Frame2.BackColor = &HFF&
Label5.BackColor = &HFF&
Label5.Caption = "Very High Tempreture"
End If

If h2 >= 10 Then
vbOut 888, 72
Frame3.BackColor = &H80C0FF
Label13.BackColor = &H80C0FF
Label13.Caption = "High Tempreture"
End If
If h2 >= 15 Then
vbOut 888, 104
Frame3.BackColor = &HFF&
Label13.BackColor = &HFF&
Label13.Caption = "Very High Tempreture"
End If

If h3 >= 10 Then
vbOut 888, 136
Frame5.BackColor = &H80C0FF
```

```
Label9.BackColor = &H80C0FF
Label9.Caption = "High Tempreture"
End If
If h3 >= 15 Then
vbOut 888, 168
Frame5.BackColor = &HFF&
Label9.BackColor = &HFF&
Label9.Caption = "Very High Tempreture"
End If

Timer1.Enabled = True
Timer3.Enabled = False
End Sub
```

....