

ALARM TRIGGERED MULTIPLE DISPLAY THERMOMETER USING
MC68HC11

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**ALARM TRIGGERED MULTIPLE DISPLAY
THERMOMETER USING MC68HC11**

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This thesis is submitted as partial fulfillment of the requirements for the award of the
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Date : 08 MAY 2008

*Special dedicated to
my beloved mother and family also to those people who have guided
and inspired me throughout my journey of education
and my dear friend that help succeed in my project*

-Firdaus-

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ABSTRACT

The alarm triggered multiple display thermometer is a digital thermometer using microcontroller MC68HC11 and the output will display through LCD and Visual Basic. This project consist the design, programming development, and evaluation of the digital thermometer. It consist the module of the temperature sensor, LCD, control switch, buzzer which integrated with 8-bits microcontroller MC68HC11. The temperature sensor will measure the temperature in range from 0°C to 100°C and the buzzer will triggered if temperature is equal or higher than set temperature. Besides that, the system can store the maximum and minimum temperature in RAM. From Visual Basic, user can save all the data displayed.

ABSTRAK

Termometer digital pelbagai paparan dan berpenggera adalah termometer digital yang menggunakan pengawal mikro MC68HC11 dan bacaan suhu akan di paparkan melalui LCD dan Visual Basic. Projek ini melibatkan proses reka bentuk, pengaturcaraan, dan penilaian termometer digital. Ia terdiri daripada beberapa modul seperti sensor, LCD, suis kawalan, penggera yang mana bersepadu dengan 8-bit pengawal mikro MC68HC11. Sensor suhu boleh mengukur suhu dalam julat dari 0°C hingga 100°C dan penggera akan aktif jika suhu bacaan sama atau lebih besar daripada suhu set. Di samping itu, sistem ini berkebolehan untuk menyimpan maksimum dan minimum suhu dalam RAM. Melalui Visual Basic juga, pengguna juga dapat menyimpan semua bacaan suhu.

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LIST OF ABBREVIATIONS

MCU	Microcontroller Unit
ADC	Analog-to-Digital Converter
RAM	Random access memory
ROM	Read only memory
LCD	Liquid Crystal Display
SCI	Serial Communication Interface
VB	Visual Basic
GUI	Graphical User Interface

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CHAPTER 1

INTRODUCTION

1.1 Background

A thermometer is a device that functions to measure the temperature or temperature gradient. Thermometer was developed in early 11th century, and there are a research and development (R&D) year by year and century by century to improve this invention from various aspects like size and material to design the thermometer, scale and calibration, range, accuracy and precision of measurement and type of thermometer. Now in technology era, the digital thermometer was developed to replace the analog thermometer. Digital thermometer is function like old thermometer which to measure the temperature but in digital version, they are more sophisticated and advanced compare to common mercury thermometer or analog thermometer.

Digital thermometers usually design by using integrated circuit (IC) like temperature sensor, analog-to-digital converter (ADC) and microcontroller. So it size is small compare to the analog thermometer and we can get the size as small as our thumb. It is very useful device, multi-purpose, portable, and user friendly. It can use to monitor

and measure the temperature accurately at any place like a home, office, industrial, hospital and so on. At the laboratory, digital thermometer uses as the scientific tool to measure the temperature with minimum error of reading and the data can be analyze precisely.

However, most digital thermometers available at the market today can only display the temperature reading on the LCD or 7-segment display and it will be problem if users want to keep track their data in computer. For example is the greenhouse, if the owner uses the common digital thermometer, he need write the temperature reading on the paper and then put the data in the computer. This situation is unacceptable and wasting at time. So, we need to develop the digital thermometer which can communicate with the computer and can save the data directly from the digital thermometer.

In this project, I will overcome the problem above by developing a triggered alarm multiple display thermometer using MC68HC11 microcontroller. This thermometer is digital type which functions to sense the temperature and display the reading on 2 display devices, LCD and computer. For the computer, the Visual Basic program will be use as graphical user interface (GUI) to display the temperature reading. The buzzer also will use for set temperature as security element.

1.2 Project Objective

In this project, there are two main objectives. First objective of this project is to design a prototype of alarm triggered multiple displays thermometer. This prototype will develop by using 8-bit microcontroller MC68HC11 manufacture by Motorola which one of most popular microcontroller in the world.

The second objective is to display the temperature reading on the LCD and Visual Basic program. So, the thermometer will communicate with the computer through serial communication interface with RS232. The data from the thermometer will transmit to the computer in real time and display in graphical user interface (GUI) which develops by using Microsoft Visual Basic 6.

1.3 Project Scopes

In order to achieve the objectives of the project like mention before, there are 3 scopes must be follow:

- i. Interface the microcontroller MC68HC11 with the I/O devices like temperature sensor, LCD, buzzer, and computer.
- ii. Develop a microcontroller program by using the assembly language.
- iii. Design the Visual Basic program which able to receive the data from serial port and store the data in log file.

1.4 Problem Statement

In the background, it is already state the problem statement which will overcome. The thermometer at the market usually only for measure the temperature and not for data logging or in other word cannot store the temperature values in the computer. It is a big problem for users who want to keep track their data in computer and will waste their

time if they record the data manually by write in the book. So, this project will develop to overcome and solve that problem by designing the digital thermometer which can communicate with the computer and at the same time can store the temperature data.

1.5 Thesis Outline

The thesis of this project can be divided into 5 chapters. Chapter 1 is introduction which introduces the background, objective, and scope of the project. It also discusses about the problem statement of the project and summarizes the content of each of chapters.

Chapter 2 is about the literature reviews that mean it will discuss the researches, facts, and information which important in process to develop this project.

The methodology of the project will explain in the Chapter 3. It elaborates in details on the project block diagram, flow diagram, hardware design, programming development, and Visual Basic program.

Chapter 4 will shows the result of the project and some discussion about this project. All the result involves the entire system like hardware, programming, and visual basic.

The last chapter is Chapter 5 which discusses the conclusion and the outcome of project. It also have some recommendations are proposed to enhance the digital thermometer for future development.

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

This chapter will discuss about the researches from various source like journals, thesis, books, internet, and so on. It is consists the facts and important information which important in process to develop this project.

2.2 Thermometer Using ATMEL AT90S8535

This digital thermometer is driven by ATMEL AT90S8535 microcontroller chip which controls and interfaces with different I/O components. The Figure 2.1 shows the various I/O components include an array of 7 push buttons which accept user input and form the user interface, A 16 X 1 LCD display for easy viewing of temperature values

and messages, and a National Semiconductor LM34 Precision Fahrenheit Temperature Sensor.

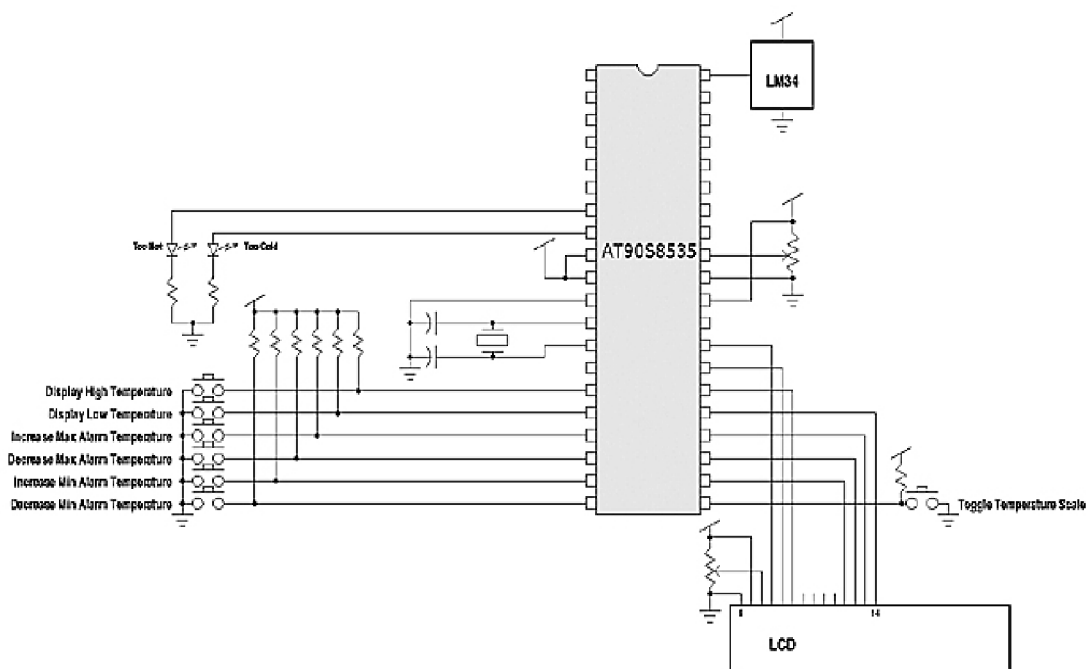


Figure 2.1: Schematic of AT90S8535 Thermometer

There are 4 different scales of temperatures can display on the LCD and that is Fahrenheit (the base scale), Celsius, Kelvin, and Rankine. This digital thermometer also comes equipped with an alarm feature which allows the user to program a specific temperature range. This is accomplished by entering lower and upper bound temperatures via four push buttons on the user interface. When the temperature recorded by this device crosses one of these boundary points, the alarm is triggered by flashing a message (HOT or COLD) in the display window. [7]

2.3 Overview of Digital Thermometer

Digital thermometers are temperature-sensing instruments that are portable, have permanent probes, and a digital display. They are typically battery powered. Digital thermometers can have many display scale characteristics. These include Fahrenheit display, display range and scale divisions, Celsius or Centigrade display, display range and scale divisions. Digital thermometers can display temperature in Fahrenheit or Celsius, or both in a dual scale thermometer. The display range is the minimum and maximum values of temperature that can be displayed. The scale division is the smallest division of degrees that can be displayed. Scale division may also be referred to as resolution in digital instruments. [8]

2.4 MC68HC11 Microcontroller

MC68HC11 is an 8-bit microcontroller manufactured by Motorola. The HCMOS MC68HC11 is an advanced 8-bit MCU with highly sophisticated, on chip peripheral capabilities. This new design technique is used to achieve a nominal bus speed of 2 MHz. In addition, the fully static design allows operation at frequencies down to dc, further reducing power consumption. The HCMOS technology used on the MC68HC11 will ensure that it can be operated at higher speeds with the low power consumption and high noise immunity of CMOS. The pin configuration of the microcontroller is shown in Figure 2.2. [1]

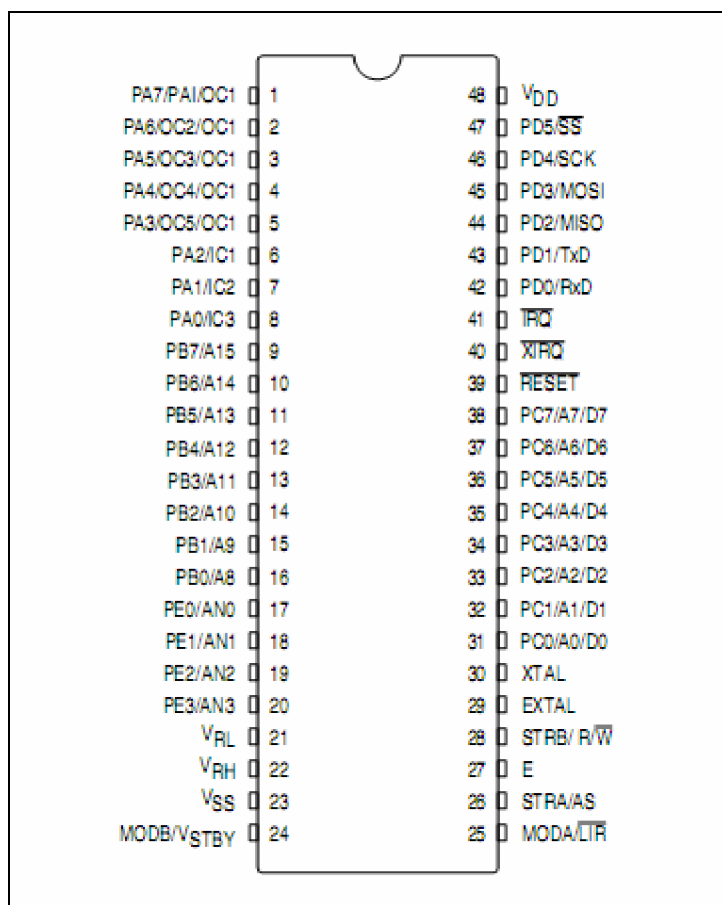


Figure 2.2: The Microcontroller MC68HC11

This on-chip memory system includes 8 Kbytes of read-only memory (ROM), 512 bytes of electrically erasable programmable ROM (EEPROM), and 256 bytes of random-access memory (RAM). Major peripheral functions are provided on-chip. An 8-channel and 8-bit analog-to-digital converter (ADC) is included with 8-bits of resolution, but for MC68HC11A which is used for this project, there are only four input ports. An asynchronous serial communications interface (SCI) and a separate synchronous serial peripheral interface (SPI) are included. The main 16-bit, free-running timer system has three input-capture lines, five output-compare lines, and a real-time interrupt function. The explanation of the function for every port in the microcontroller is shown in Table 2.1. [1]

Table 2.1: The Function of Microcontroller's Ports

PORT	FUNCTION
A	<ul style="list-style-type: none"> - General purpose input / output port - Timer function - Real-time interrupt
B	<ul style="list-style-type: none"> - General purpose output port - High-Order address in expanded mode
C	<ul style="list-style-type: none"> - General purpose input / output port - Lower-Order address in expanded mode - Data bus (D0-D7) in expanded mode
D	<ul style="list-style-type: none"> - General purpose input / output port - Serial communication interface (SCI) - Serial peripheral interface (SPI)
E	<ul style="list-style-type: none"> - General purpose input port - Analog-to-Digital Converter (ADC)

An 8-bit pulse accumulator subsystem can count external events or measure external periods. Self-monitoring circuitry is included on-chip to protect against system errors. A Computer Operating Properly (COP) watchdog system protects against software failures. A clock monitor system generates a system reset in case the clock is lost or runs too slow. An illegal opcode detection circuit provides a non-maskable interrupt if an illegal opcode is detected.

The actual architecture of microcontroller is shown at Figure 2.3. Based on this figure, we can see clearly how the microcontroller actually operates internally starting from the input entering the port of the microcontroller until the microcontroller processes the data input and produces the output through the other port.

Figure 2.4 shows the seven CPU registers available to the programmer. There are two 8-bit accumulators (ACCA and ACCB) can be used by some instructions as a single 16-bit accumulator called the ACCD register, which allows a set of 16-bit operations even though the CPU is technically an 8-bit processor. The largest group of instructions added involves the Y and X index register. These index register are important when the program involve index mode operation. The exchange ACCD with X and exchange ACCD with Y instructions can be used to quickly get index values into the double

accumulator (ACCD) where 16-bit arithmetic can be used. Two 16-bit by 16-bit divide instructions are also included.

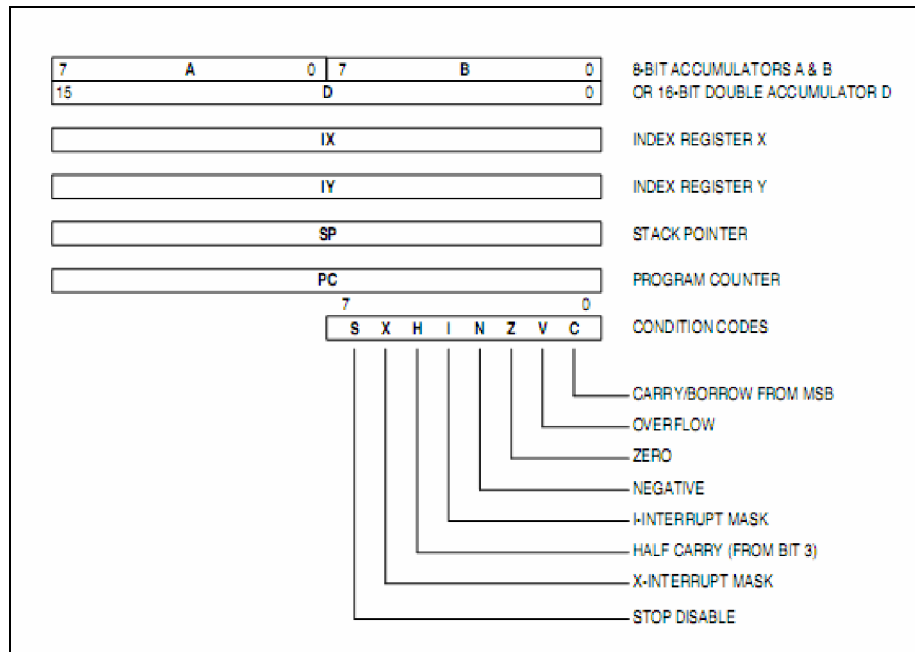


Figure 2.4: MC68HC11 Programmer's Model

Program Counter (PC) which is 16-bit is an indicator to display the next address of instruction that will be executed. And 8-bit Control Code Register (CCR) shows the information result due to execution of instruction where each execution will cause flag in the CCR changed. Stack pointer (SP) are commonly used when the program involving repeating of sequence of instructions.

MC68HC11 can be operated in four modes. They are normal single chip mode, normal expended mode, special bootstrap mode and special test mode as shown in Table 2.2. Mode of the desired operation is determined by inputs of MODA and MODB pins during reset operation.

Table 2.2: Hardware mode select

Inputs		Mode Description
MODA	MODB	
0	0	Special Bootstrap
0	1	Special Test
1	0	Normal Single Chip
1	1	Expanded

Normal single chip normally used for mass production because ROM and RAM are all both been totally used in order to reduce cost of production. Unlike special bootstrap, it is an operation where the program is placed into the RAM where the memory has been divided into several sections or locations so that the program and the hardware can works. For special test mode, it only can be accessed by the manufacturer in testing the functionality of the microcontroller at the factory. Expanded-multiplexed is used when the program is exceeding the total of the amount available internal memory or to increase data and address buses due to use many ports. Port B and port C are used as an address and data buses in expanding the external memory and, input and output lines. Figure 2.5 shows the memory maps of all modes.

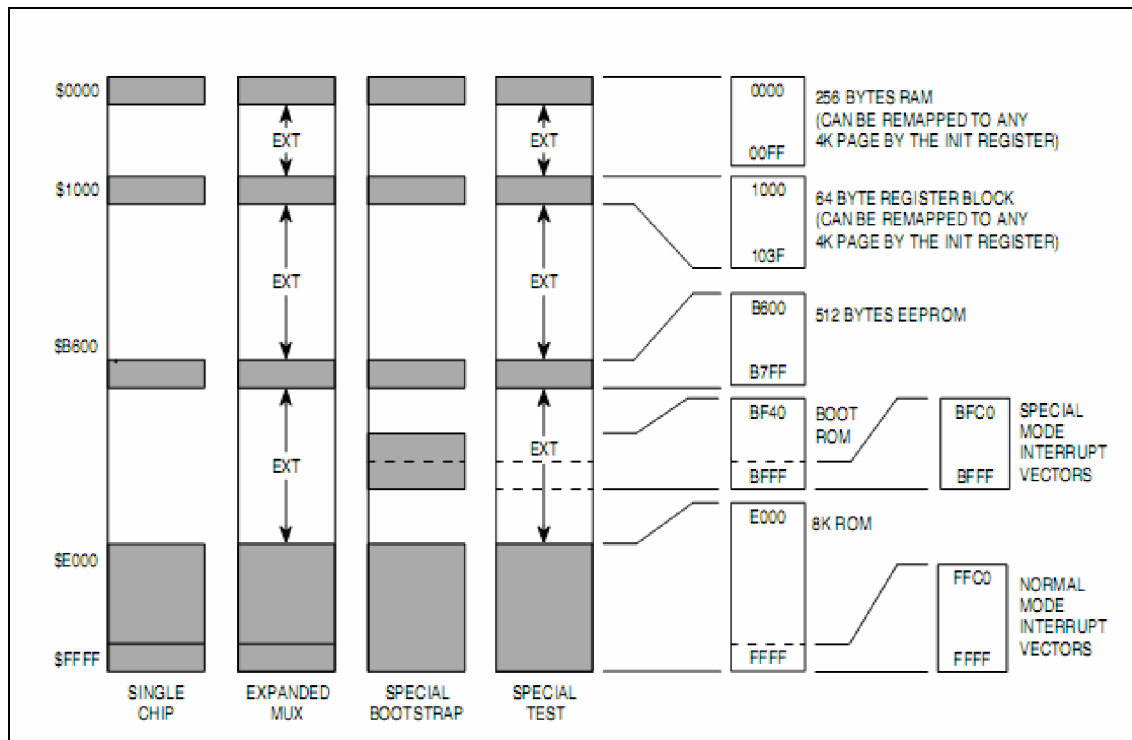


Figure 2.5: MC68HC11 Memory Maps

2.5 Temperature Sensor

A sensor is a device that detects and converts the physical parameter like the pressure, flow, temperature, and more to the electrical signal. Sensor can be classed as active and passive. An active or self-generating sensor is one that can generate a signal without the need for any external power supply. Examples include photovoltaic cells, thermocouples and piezoelectric devices. The more common passive sensors need an external source of energy. These operate by modulating the voltage or current of a supply. Another point that we need to be clear about is the meaning of resolution as applied to a sensor. The resolution of a sensor measures its ability to detect a change in the sensed quantity, and is usually quoted in terms of the smallest change that can be detected. In some cases, resolution is virtually infinite, meaning that a small change in

the sensed quantity will cause a small change in the electrical output, and these changes can be detected to be limits of our measuring capabilities. [4]

The temperature sensor is a passive class of sensor. It functions to convert the temperature parameter to the electrical signal for further process. There are many types of sensors to measure the temperature. Some sensors such as the thermocouples, RTDs, and thermistors are the older classical sensors and they are used extensively due to their big advantages. The new generation of sensors such as the integrated circuit sensors and radiation thermometry devices are popular only for limited applications. The choice of a sensor depends on the accuracy, the temperature range, speed of response, thermal coupling, the environment (chemical, electrical, or physical), and the cost. As shown in Table 2.3, thermocouples are best suited to very low and very high temperature measurements. The typical measuring range is -270°C to $+2600^{\circ}\text{C}$. Thermocouples are low cost and very robust. They can be used in most chemical and physical environments. External power is not required to operate them and the typical accuracy is $\pm 1^{\circ}\text{C}$.

Table 2.3: Temperature sensor

Sensor	Temperature Range, $^{\circ}\text{C}$	Accuracy, $\pm^{\circ}\text{C}$	Cost	Robustness
Thermocouple	-270 to +2600	1	Low	Very High
RTD	-200 to +600	0.2	Medium	High
Thermistor	-50 to +200	0.2	Low	Medium
Integrated Circuit	-40 to +125	1	Low	Low

Semiconductors are low cost and some models offer digital outputs, enabling them to be directly connected to computer equipment without the need of A/D converters. The advantages and disadvantages of various types of temperature sensors are given in Table 2.4.

Table 2.4: Comparison of temperature sensor

Sensor	Advantages	Disadvantages
Thermocouple	<ul style="list-style-type: none"> - Wide operating temperature range - Low cost - Rugged 	<ul style="list-style-type: none"> - Non-linear - Low sensitivity - Subject to electrical noise - Reference junction compensation required
RTD	<ul style="list-style-type: none"> - Wide operating temperature range - Linear - High stability 	<ul style="list-style-type: none"> - Slow response time - Expensive - Current source required - Sensitive to shock
Thermistor	<ul style="list-style-type: none"> - Fast response time - Small size - Low cost - Large change in resistance vs. temperature 	<ul style="list-style-type: none"> - Non-linear - Current source required - Limited operating temperature range - Not easily interchangeable without re-calibration
Integrated Circuit	<ul style="list-style-type: none"> - Highly linear - Low cost - Digital output sensors can be directly connected to microcontroller without an ADC. 	<ul style="list-style-type: none"> - Limited operating - Voltage or current source required - Self heating errors - Not good thermal coupling with the environment

. There are many type of temperature sensor at the market from variable manufacturer and the Figure 2.6 shows the integrated circuit LM35 which was used in this project. The LM35 are precision integrated circuit temperature sensor, 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. [5]

The LM35 does not require any external calibration or trimming to provide typical accuracies of $\pm 1/4^{\circ}\text{C}$ at room temperature and $\pm 3/4^{\circ}\text{C}$ over a full -55 to $+150^{\circ}\text{C}$ 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 $60\text{ }\mu\text{A}$ 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 $+150^\circ\text{C}$ temperature range. [6]

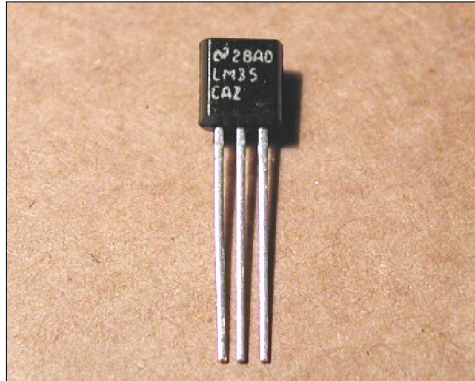


Figure 2.6: LM35 sensor.

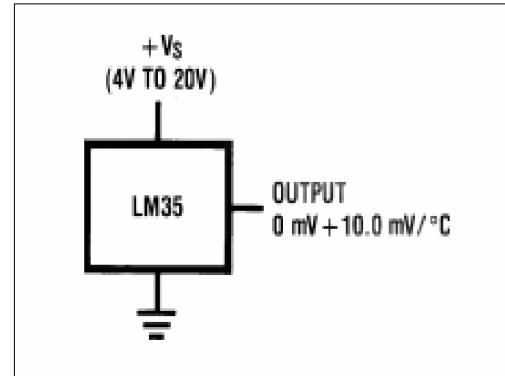


Figure 2.7: LM35 diagram

2.6 Analog-to-Digital Converter (ADC)

The Motorola MC68HC11 microcontroller has built-in ADC and its architecture is shown in Figure 2.8. An analog-to-digital converter (ADC) accepts an analog input, which in our case will be between 0 and 5V, and creates a digital output (between 0 and 255). We will begin by discussing the particular I/O registers used to interface analog signals to individual microcomputers. The common features include 8-channel operation, 8-bit resolution, and successive approximation conversion technique. In its two operation modes, the converter can perform a single sequence of conversions and then stop, or it can continuously perform analog-to-digital conversions. It can convert the same channel multiple times, or it can perform conversions on a group of channels.

For example, it can perform ADC conversions on channels 0,1,2,3 with one action. The ADC uses external V_{RH} , V_{RL} analog high/low references. Normally V_{RH} is tied to +5V and V_{RL} is tied to ground. In both 6811 and 6812, the software can read the port directly, using it as a regular 8-bit digital input port. [2]

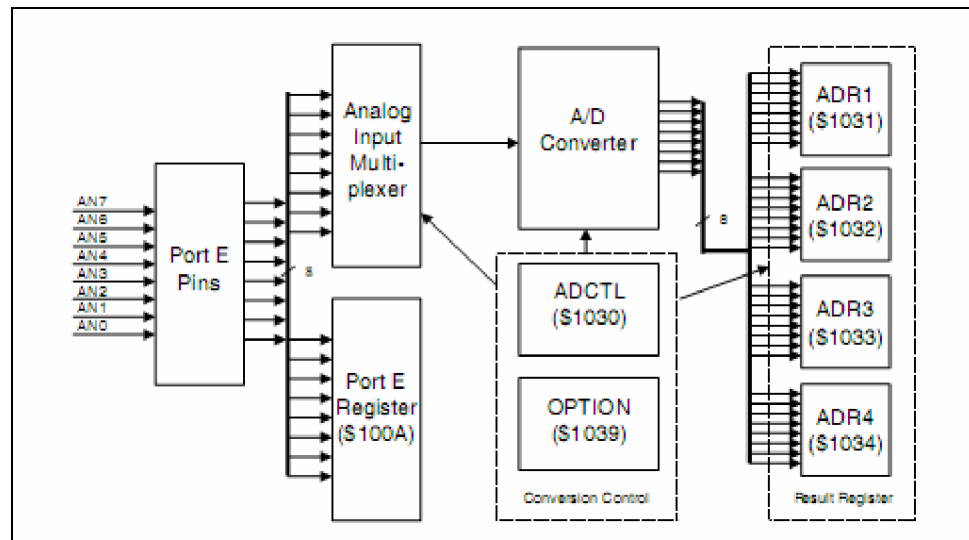


Figure 2.8: ADC architecture in MC68HC11

2.7 Serial Communication Interface (SCI)

The serial communications interface (SCI) is a full-duplex UART-type asynchronous system, using standard non-return-to-zero (NRZ) format (1 start bit, 8 or 9 data bits, and a stop bit). An on-chip baud rate generator derives standard baud-rate frequencies from the MCU oscillator. Both the transmitter and the receiver are double buffered. Thus, back-to-back characters can be handled easily, even if the central processing unit (CPU) is delayed in responding to the completion of an individual character. The SCI transmitter and receiver are functionally independent but use the same data format and baud rate. The Port D1 is used for transmit (TxD) and Port D0 is

used for receive (RxD). The user will usually have to provide external level-shifter buffers to translate the RS232 or RS422 levels (typically ± 12 V) to the 0 to 5-V logic levels used by the microcontroller. [2]

2.8 Liquid Crystal Display (LCD)

Liquid crystal display or LCD as shown in Figure 2.9 is one of the most used devices for alphanumeric output in microcontroller-based circuits. Their advantages are their reduced size and cost and the convenience of mounting the LCD directly on the circuit board. LCD is classified according to their interface into serial and parallel. Serial LCD requires less I/O resources but execute slower than their parallel counterparts. In addition, they are considerably more expensive. In this project, parallel-driven LCD devices based on the Hitachi HD44780 character-based controller, which is by far the most popular controller for microcontroller-driven LCD. [3]

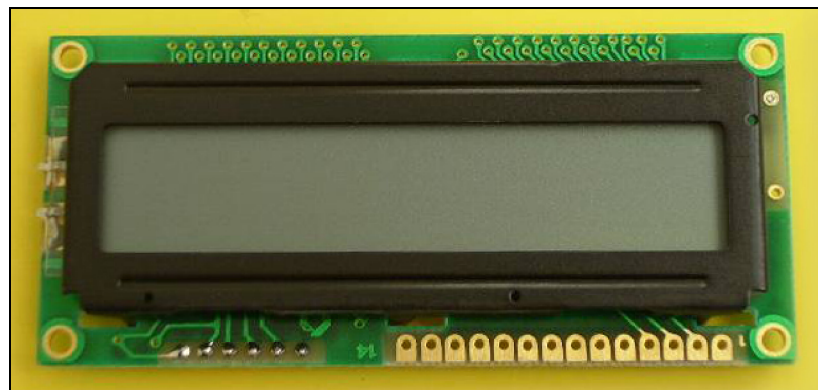


Figure 2.9: LCD

The HD44780 is a dot-matrix liquid crystal display controller and driver. The device displays ASCII alphanumeric characters, Japanese kana characters, and some symbols like in Figure 2.10. A single HD44780 can display up to two 28-character lines.

An available extension diver makes possible addressing up to 80 characters. The HD44780U contains a 9,920 bit character-generator ROM that produces a total of 240 characters: 208 characters with a 5×8 dot resolution and 32 characters at a 5×10 dot resolution. The device is capable of storing 64x8-bit character data in its character generator RAM. This corresponds to eight custom characters in 5x8-dot resolution or four characters in 5x10-dot resolution. The controller is programmable to three different duty cycles: 1/8 for one line of 5×8 dots with cursor, 1/11 for one line of 5×10 dots with cursor, and 1/16 for two lines of 5×8 dots with cursor. [3]

Lower 4 Bits		Upper 4 Bits																
		0000	0001	0010	0011	0100	0101	0110	0111	1000	1001	1010	1011	1100	1101	1110	1111	
xxxx0000		CG RAM (1)			0	1	P	`	P				-	9	3	α	p	
	(2)			!	1	A	Q	a	q				。	ア	チ	4	ä	q
xxxx0010	(3)			"	2	B	R	b	r				「	イ	ツ	×	β	θ
	(4)			#	3	C	S	c	s				」	ウ	テ	モ	ε	ω
xxxx0100	(5)			\$	4	D	T	d	t				、	エ	ト	ホ	μ	Ω
	(6)			%	5	E	U	e	u				・	オ	ナ	1	ε	Ü
xxxx0110	(7)			&	6	F	V	f	v				ヲ	カ	ニ	ヨ	ρ	Σ
	(8)			'	7	G	W	g	w				ア	キ	ヌ	ラ	g	π
xxxx1000	(1)			(8	H	X	h	x				イ	ク	ネ	リ	J	Σ
	(2))	9	I	Y	i	y				ウ	ケ	ル	ル	Y	Y
xxxx1010	(3)			*	:	J	Z	j	z				エ	コ	ン	レ	j	チ
	(4)			+	;	K	L	k	l				オ	サ	ヒ	ロ	*	斤
xxxx1100	(5)			,	<	L	¥	l	l				ホ	シ	フ	ワ	Φ	円
	(6)			-	=	M	J	m	}				ユ	ズ	ヘ	ン	も	÷
xxxx1110	(7)			.	>	N	^	n	÷				ヨ	セ	ホ	°	ん	
	(8)			/	?	O	_	o	←				ッ	ソ	マ	°	ö	■

Figure 2.10: HD44780 Character Set

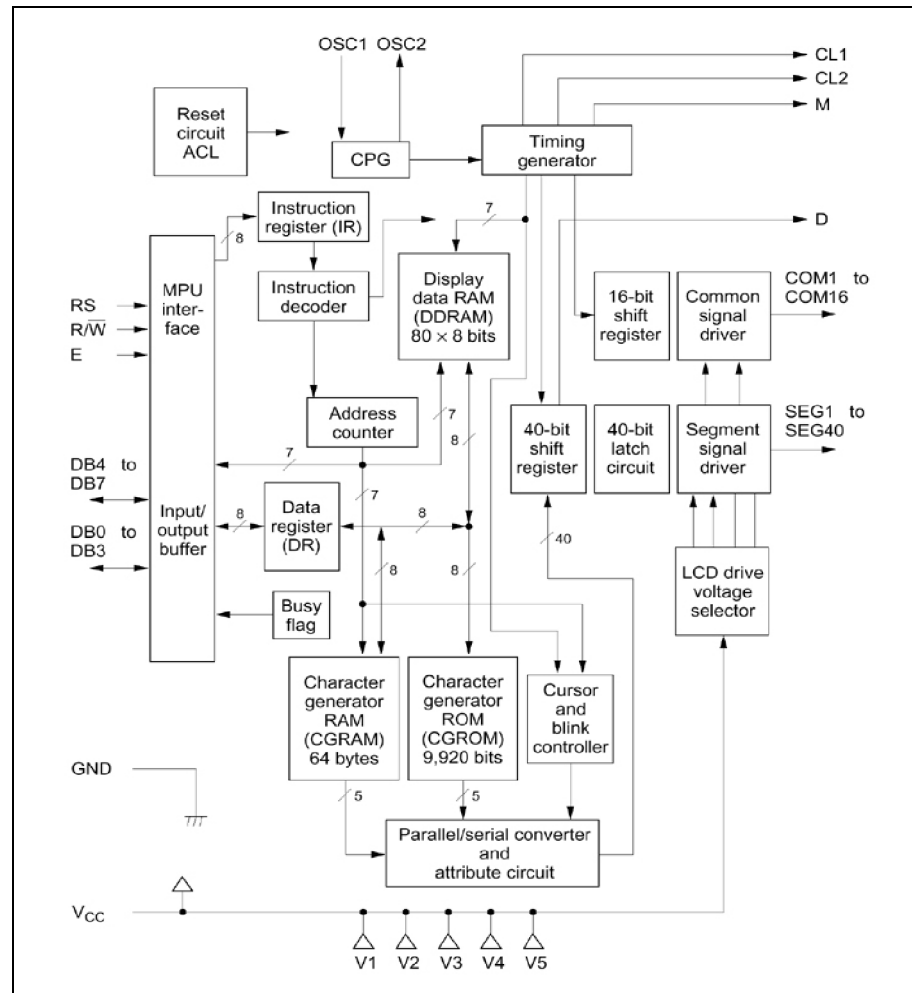


Figure 2.11: Architecture of LCD HD44780

2.9 Microsoft Visual Basic 6

Microsoft Visual Basic 6 (VB) was designed to be easy to learn and use. The language not only allows programmers to easily create simple GUI applications, but also has the flexibility to develop fairly complex applications as well. Programming in VB is a combination of visually arranging components or controls on a form, specifying attributes and actions of those components, and writing additional lines of code for more

functionality. Since default attributes and actions are defined for the components, a simple program can be created without the programmer having to write many lines of code. Figure 2.12 shows the Microsoft Visual Basic 6 layout. [9]

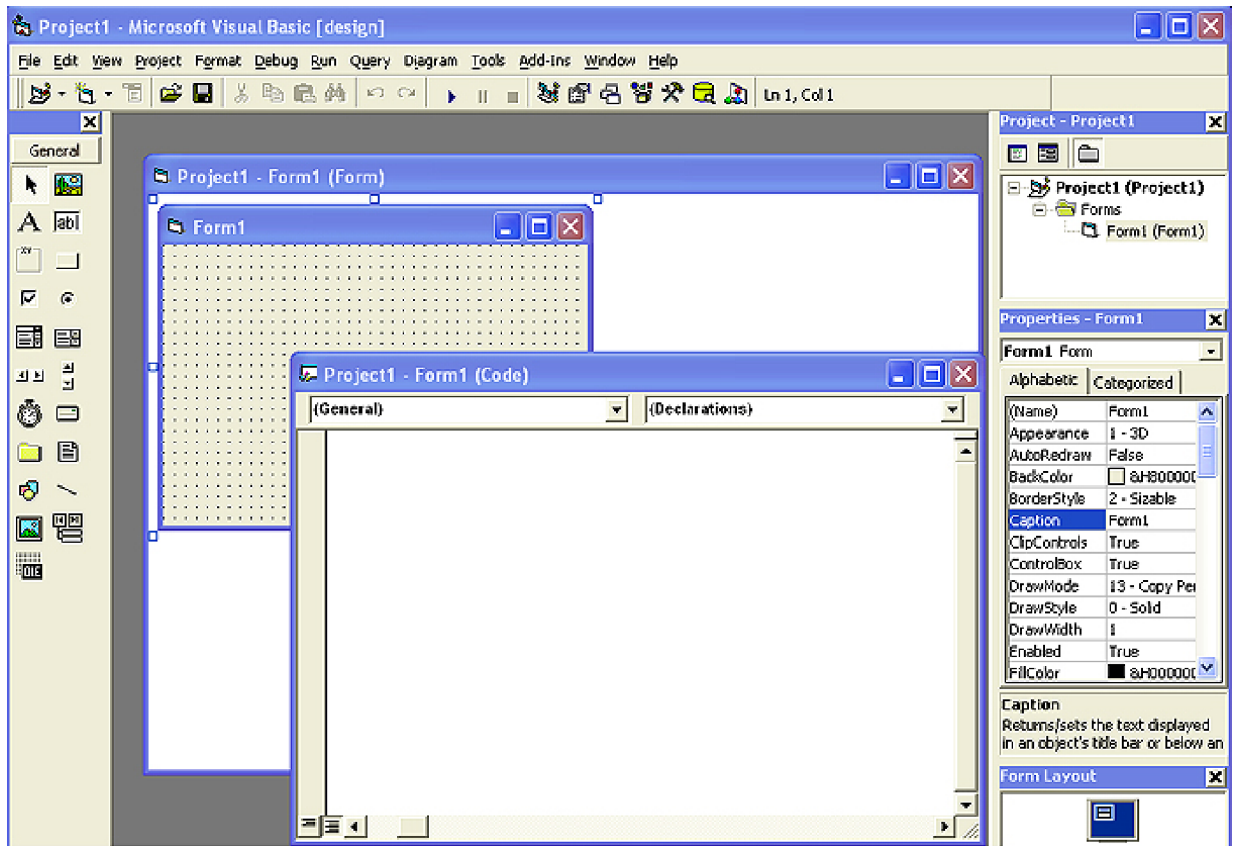


Figure 2.12: Visual Basic 6 layout

CHAPTER 3

METHODOLOGY

3.1 Introduction

The Alarm Triggered Multiple Display Thermometer is developing stage by stage for easy process to design, install, and troubleshoot the project. The Figure 3.1 shows the block diagram of the thermometer system which consist some hardware modules. Actually, there are programming modules embedded in the microcontroller which develop for thermometer system to operate properly and all the hardware and programming module will be explained later. The flow chart in Figure 3.2 shows the flow of the project process and the integration of all modules must be done properly without any mistake or problems for the thermometer system to operate successfully. This project is divided to 3 modules that are;

1. Hardware Module
2. Programming Module
3. Visual Basic (GUI) Module

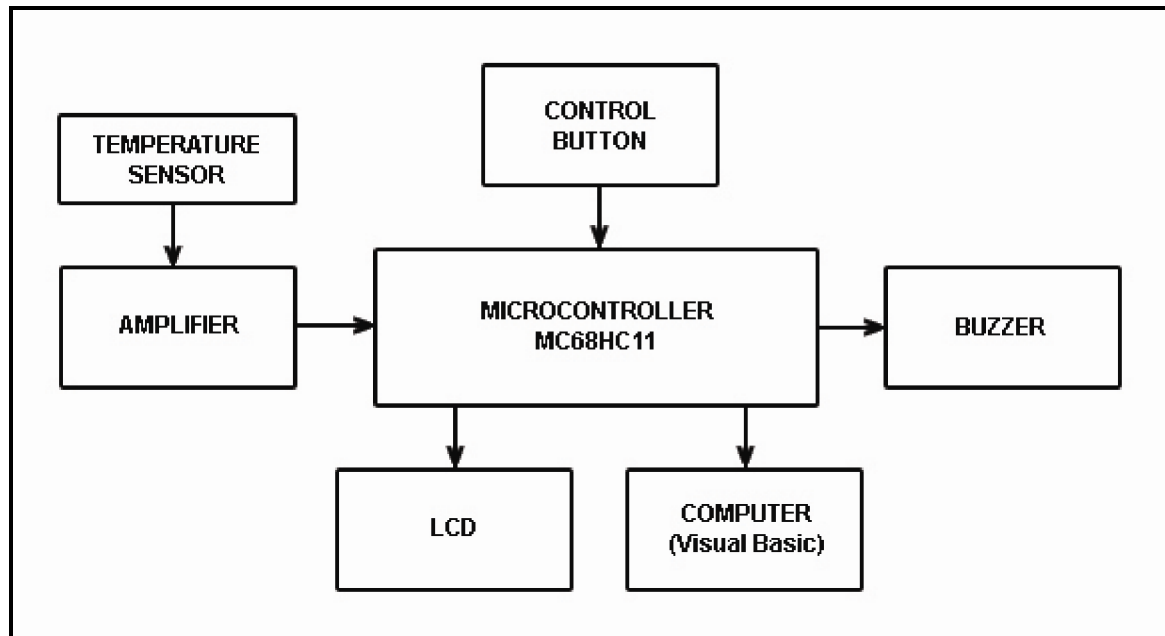


Figure 3.1: Block diagram of the system

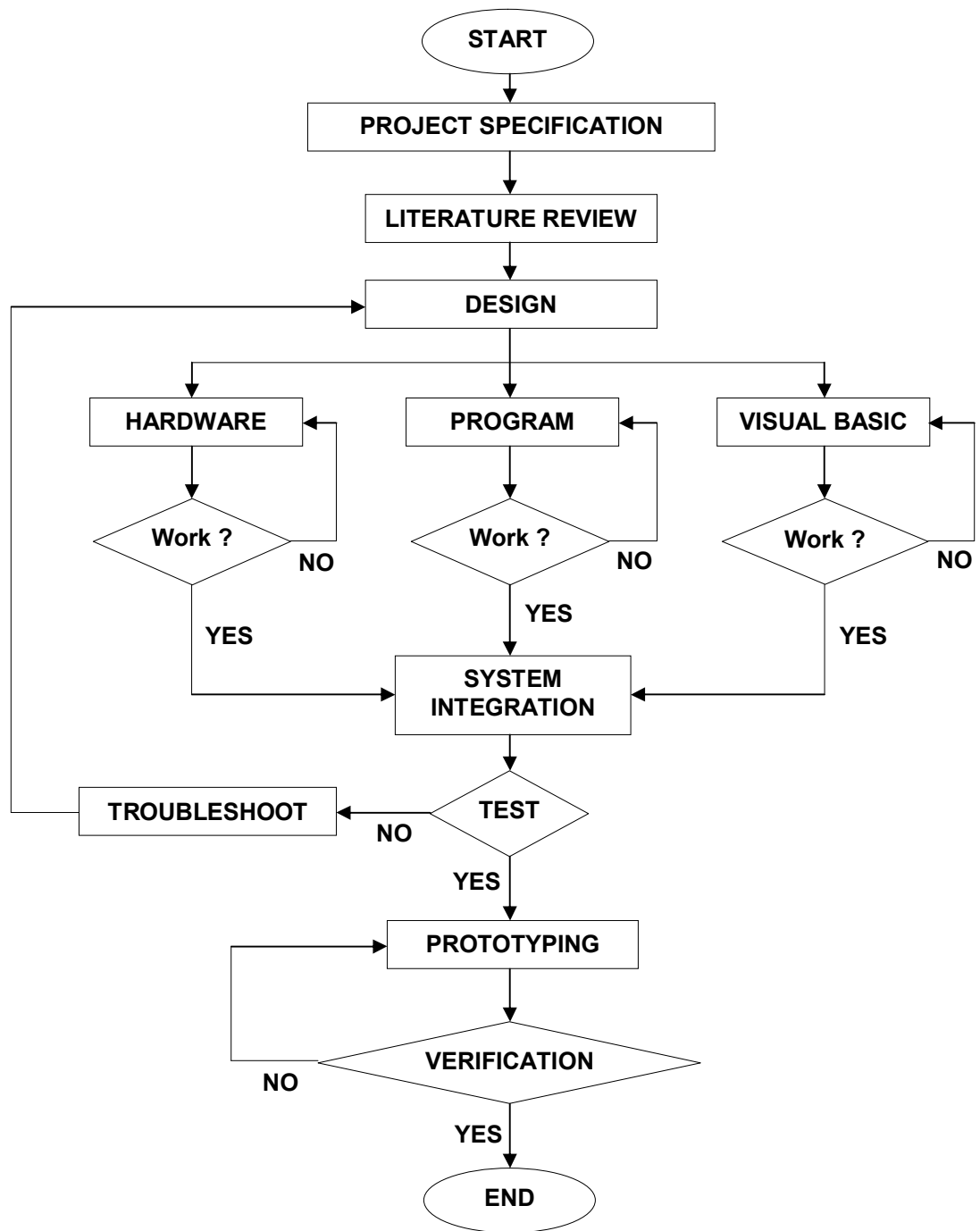


Figure 3.2: Flow of project

3.2 Hardware Module

Hardware module or in the other word is a hardware design which involved the process to design and install the circuits. For easy to manage and complete this module, it was divided into 6 small modules as below;

- Microcontroller Module
- LM35 Sensor Module
- Amplifier Module
- LCD Module
- Buzzer Module
- Control Switch Module

3.2.1 Microcontroller Module

The 8-bit microcontroller, MC68HC11A1 will be use in this project and it will be the main or brain of the system. The block diagram in Figure 3.3 shows the basic circuits that need to be connected with the MC68HC11A1 in order to operate the microcontroller. There are power supply circuit, reset circuit, clock circuit, and RS232 circuit.

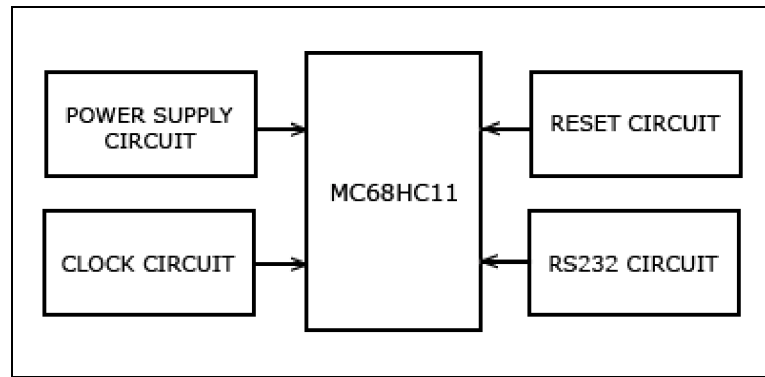


Figure 3.3: Basic circuit to operate the MC68HC11

The microcontroller MC68HC11 can operate in 4 different modes, but only one mode can use in one time and mode selection is depend on the connection of pin MODA and pin MODB as explanation in Chapter 2. In this project, the MC68HC11 will operate in special bootstrap mode, it is that mean the pin MODA and MODB in directly connected to the ground.

3.2.1.1 Power Supply Circuit

In Figure 3.4 is shows the power supply circuit which will provide power +5V for almost all the device in this project especially microcontroller. The LM7805 is a voltage regulator which accepts the unregulated voltage supply to produce regulated voltage $5V \pm 5\%$. The unregulated voltage must bigger than 6V for produce stable regulated 5V and there are capacitor to filter the unwanted ripple and LED as power indicator.

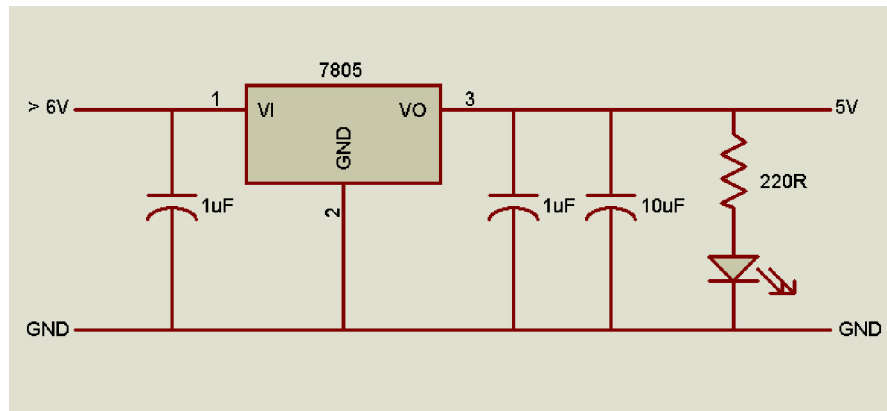


Figure 3.4: Power supply circuit

3.2.1.2 Clock Circuit

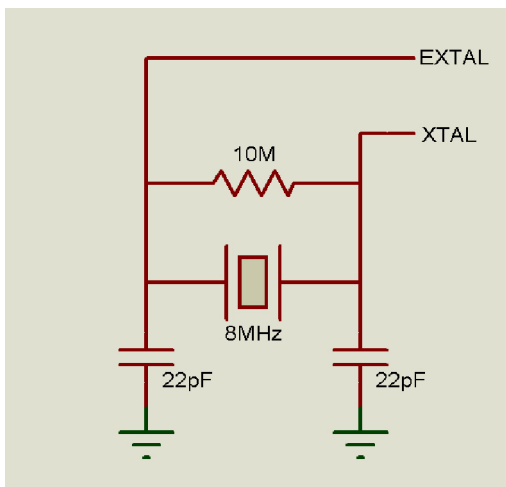


Figure 3.5: Clock circuit

The function of a clock circuit above is to provide an accurate and stable periodic clock signal to a microcontroller. EXTAL and XTAL are used to connect crystal to internal clock circuit to generate clock for the CPU to operate. The internal clock frequency is $\frac{1}{4}$ of that supplied to the crystal pins. A typical system designed for

maximum clock frequency uses an 8MHz crystal. Hence the clock speed (frequency) is 2MHz. This clock is often referred to as the system clock or E clock. When the E clock output is low, an internal process is taking place. When it is high, the MCU is writing or reading data.

3.2.1.3 Reset Circuit

Reset circuit is a circuit that used to reset program in microcontroller. This circuit consists of resistor 10K, reset button and capacitor 4.7uF. Reset pin in microcontroller is active low that mean when push the reset button is push, the reset pin will active and the program will reset. LED is only for reset indicator and the value of capacitor must 4.7uF or bigger than 4.7uF in order to properly reset the microcontroller. The reset circuit is shows in Figure 3.6.

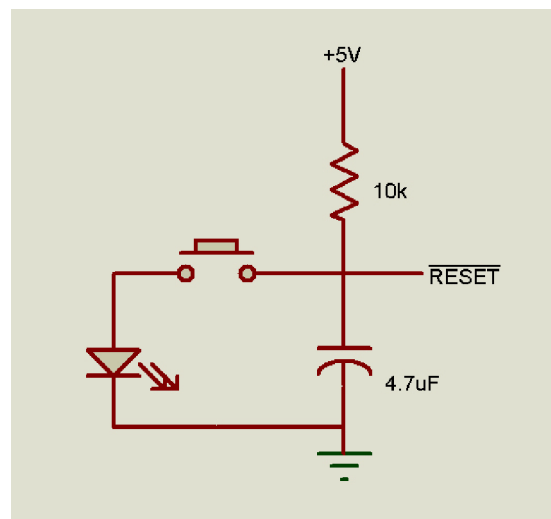


Figure 3.6: Reset circuit

3.2.1.4 RS232 Circuit

The Figure 3.7 show the RS232 circuit which function for serial communication interface (SCI). The IC MAX233 that support the RS232 standard will use in this project in order to process the data whether transmit or receive between the computer and microcontroller. MAX233 is a line driver for serial communication and function to boost the signal from 5 V to 12-15 V. This is important to avoid data losses since data was transmit for long distance. DB9 connector also will use to connect the MAX233 to serial port of the computer. The Figure 3.8 show the DB9 cable which used to connect the MAX233 with the computer.

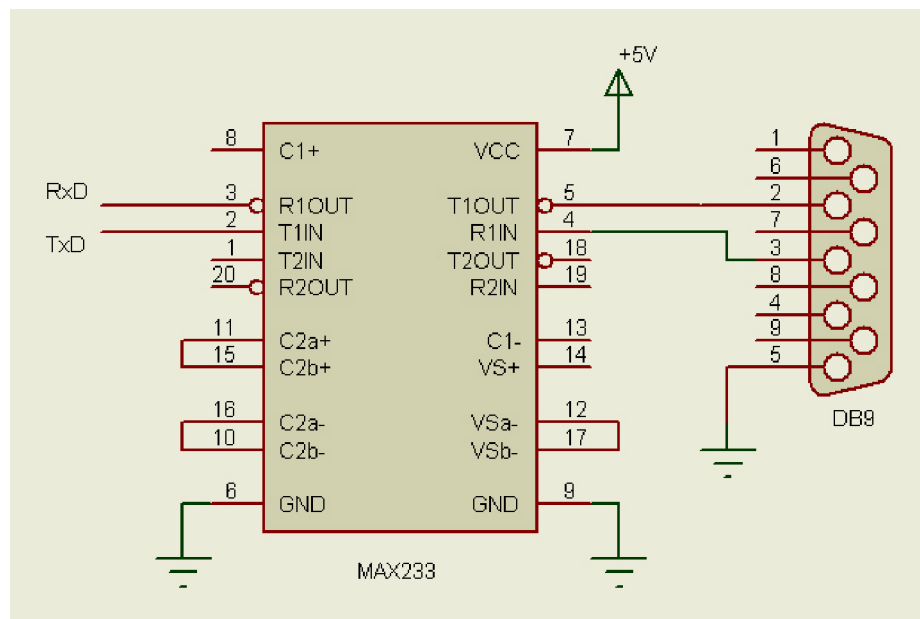


Figure 3.7: RS232 circuit

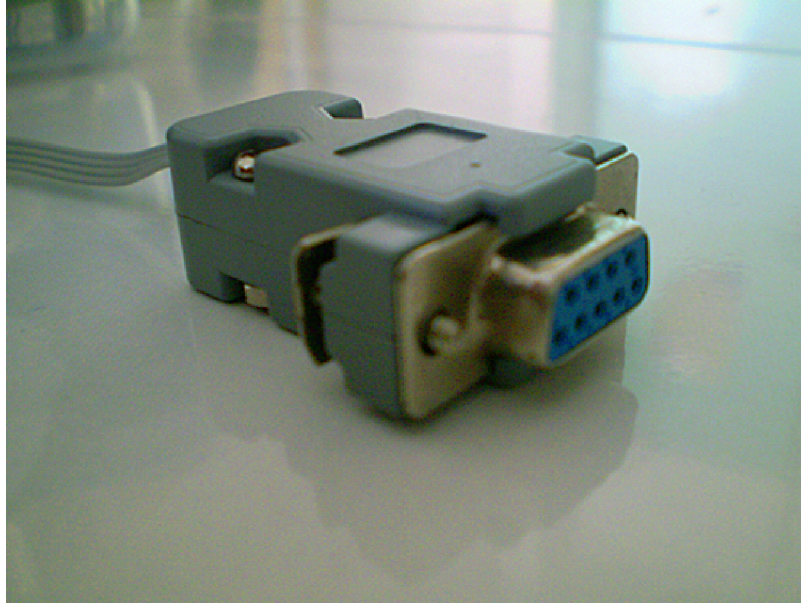


Figure 3.8: DB9 (female)

3.2.2 LM35 Sensor Module

Temperature sensor is a device that converts the temperature parameter to electrical signal. In this project, the LM35 was used to convert the temperature into voltage signal which 10mV for 1°C. That means if the temperature is 30°C, so the voltage from sensor output is 0.3 V. Conversion process from temperature (physical parameter) to electrical signal is important for analog-to-digital conversion because the Analog-to-Digital Converter (ADC) only can accept the electrical voltage as input. The Figure 3.9 below shows the LM35 circuit connection.

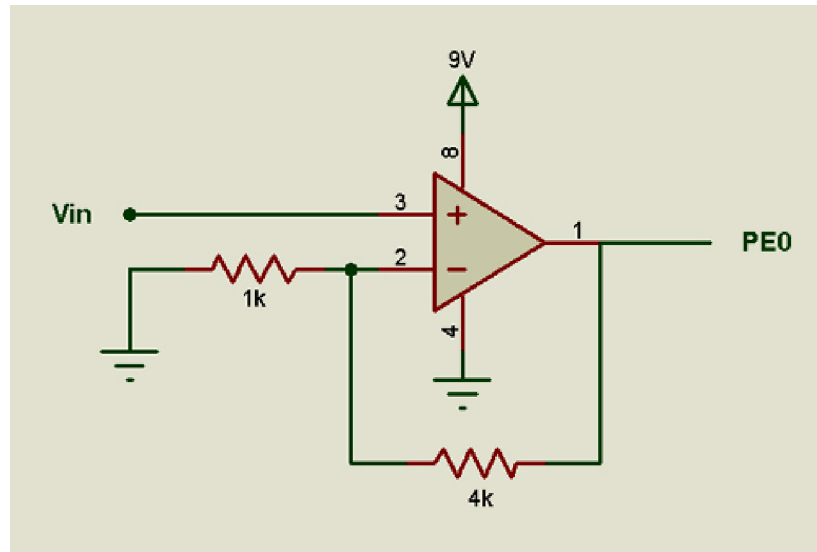


Figure 3.10: Non-inverting amplifier circuit

3.2.4 ADC Module

Actually, this project was used the 8-bit ADC which builds embedded in the MC68HC11 microcontroller. The MC68HC11 have 1 port for ADC purpose, that port is PORT E. However, only 1 channel from 4 channel of PORT E will use in this project. The output of amplifier connected to the PORT E0 and the ADC will receive the analog input.

3.2.5 LCD Module

Liquid Crystal Display (LCD) module is one of output device which was used to display the temperature value for monitoring purpose. LCD can display not just numbers, but also words, letters and symbols, so it make LCD is better than the 7-segment LED display. Figure 3.11 is shows the LCD circuit connection. The R/S and E is a control pin which connected to the PC0 and PC1 of the microcontroller. The data pins are D0 until D7 and they are connected to PORT B of microcontroller.

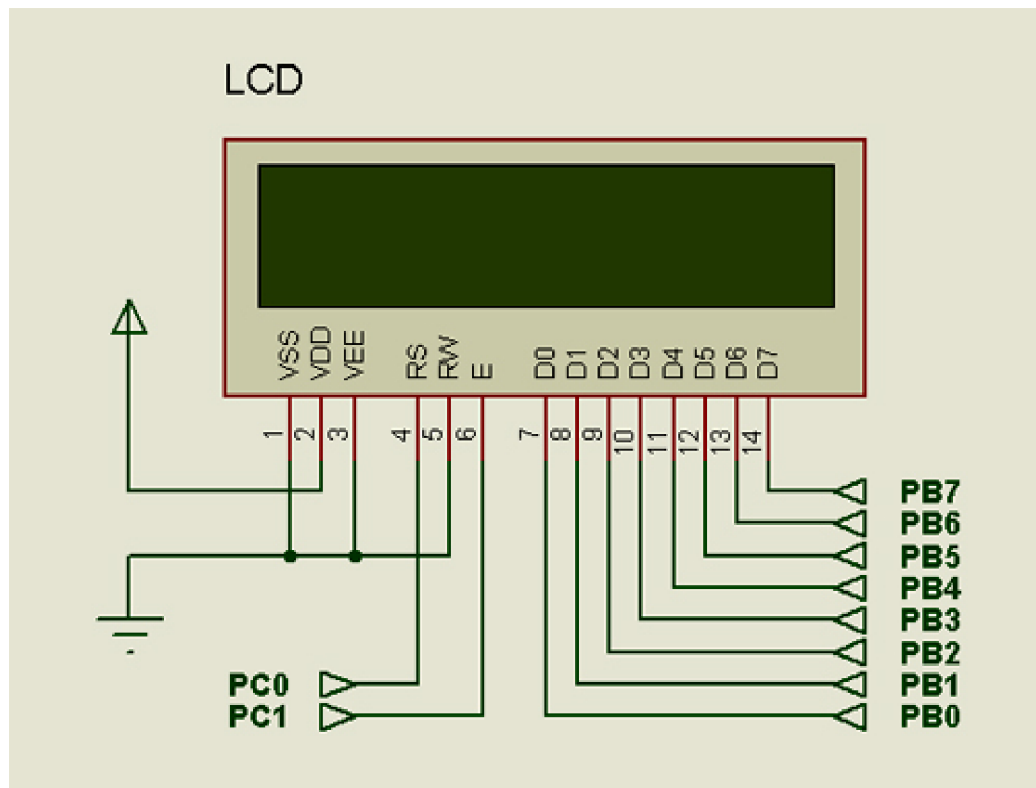


Figure 3.11: LCD circuit

3.2.6 Buzzer Module

The buzzer is function as alarm which triggered when the temperature is equal or higher than set temperature. Interface the buzzer with microcontroller is very simple like show in Figure 3.12. Active or Inactive of buzzer operation will control by microcontroller program which give the input high or low.

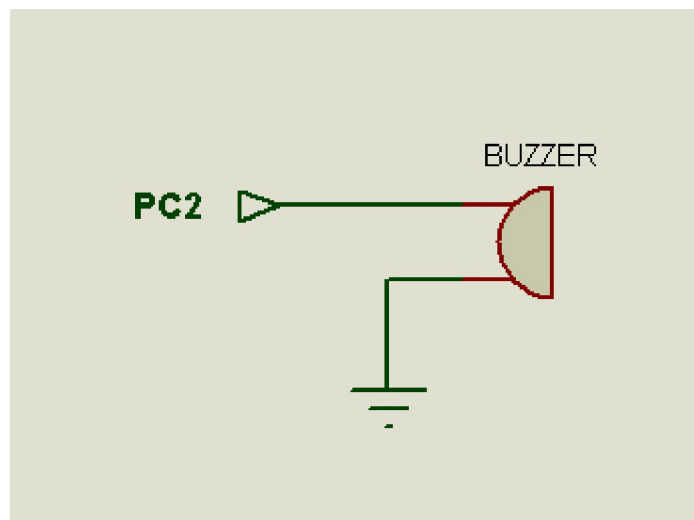


Figure 3.12: Buzzer circuit

3.2.7 Control Switch Module

Figure 3.13 is shows the figure of reset switch which will use as control switch and the control switch circuit in Figure 3.14. There are array of 4 reset switch which interface with microcontroller to control the LCD display.

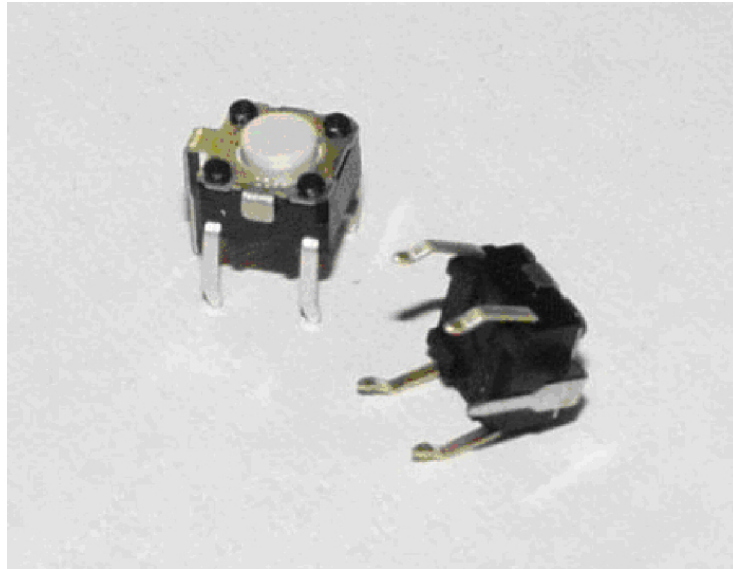


Figure 3.13: Reset switch

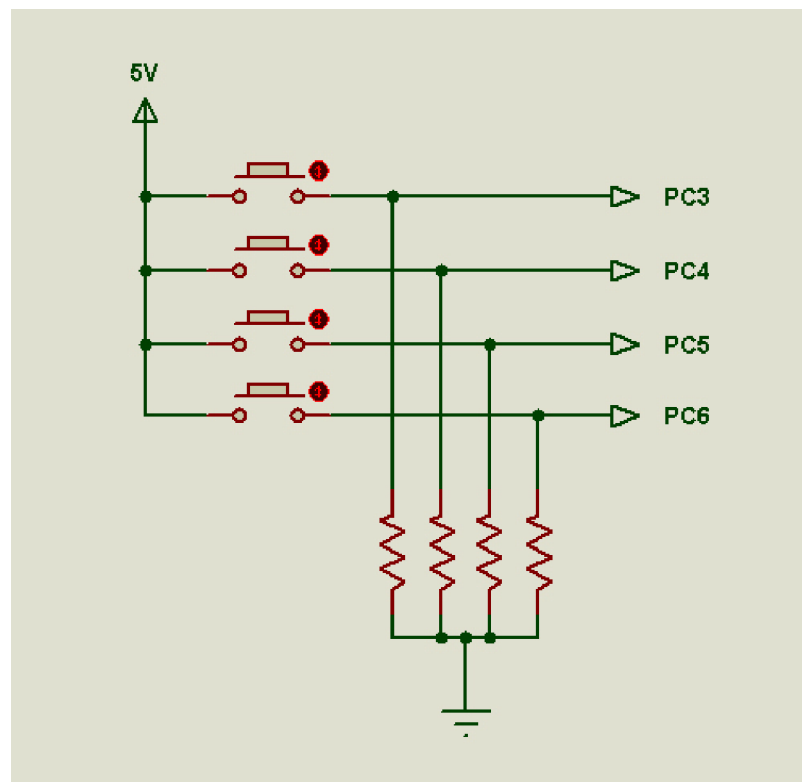


Figure 3.14: Control switch circuit

3.3 Programming Module

A programming language is an artificial language that can be used to control the behavior of a machine, particularly a computer or in other word is to tell machine what to do. So, it means the hardware is useless without programming. There are 3 main programming languages which use in the digital world. First is machine language, this language only can understand by the computer and it is complex but fast execution. Then is an assembly language, it's much easier to write programming and require the assembler to convert to machine code. Third language is high-level language, which very easy to write a program even involves floating point calculation and can solve the problem without much attention to CPU and configuration.

In this project, the assembly language was use to write a program and it's refer to assembly language which developed by Motorola for MC68HC11 microcontroller and consists more than 256 instruction sets. The complete program will be program into EEPROM in the microcontroller. There are sub modules of programming was developed and will be integrate later to be a complete program. Each sub modules will discuss but using the flow chart for easy to see the flow of operation the program.

3.3.1 ADC Module Test

Analog-to-Digital Converter (ADC) is function to convert the analog input to digital value. As state before, the ADC is on-chip with microcontroller, so it is only programming in this project without involve the ADC circuit design. In ADC programming, the register which involves is ADCTL, OPTION, and ADR1. Refer to the flow chart in Figure 3.15, the initialization of ADC is important to power-up ADC,

define the scan process and channel of conversion. The analog input will be used is AN0 or PORT E0 and finished conversion data will store in ADR1. Below is the important things in ADC programming like resolution, step, and so on.

$$\begin{aligned} RESOLUTION &= \frac{1}{2^8} \times 100 \\ &= 0.39\% \end{aligned}$$

$$V_{RH} = 5 \text{ V and } V_{RL} = 0 \text{ V}$$

$$\begin{aligned} STEP &= 2^8 \\ &= 256 \end{aligned}$$

$$\begin{aligned} \text{So, } V_{STEP} &= 5 \text{ V} \times 0.39\% \\ &= 19.5 \times 10^{-3} \text{ V} \end{aligned}$$

Convert the data from ADR1 to Celsius;

- Maximum temperature is 100°C.
- Minimum temperature is 0°C.

$$\therefore \text{Temperature} = \frac{ADR1}{255} \times 100$$

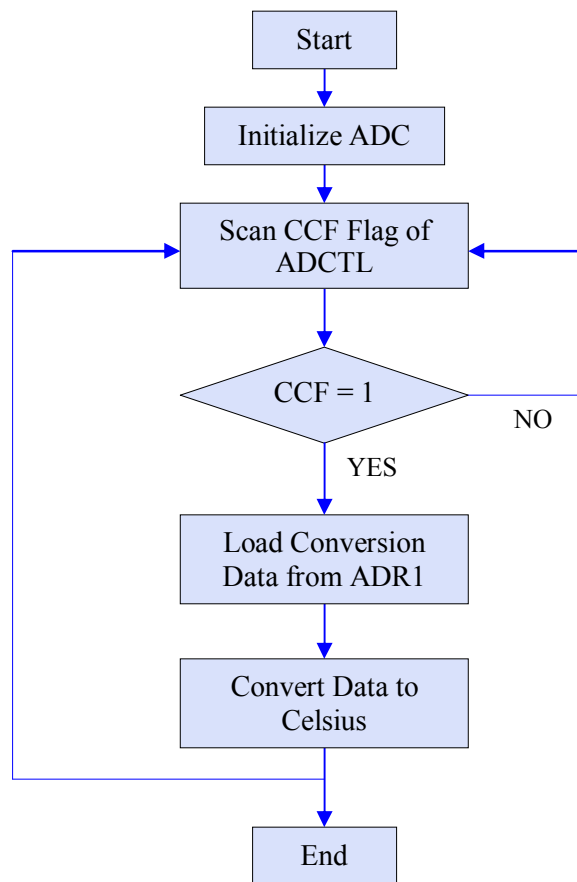


Figure 3.15: Flow chart of ADC module

3.3.2 SCI Module Test

The digital data in ADR1 will be sending to the computer via serial communication interface (SCI) with RS232 standard. The SCI programming module was developed by involving the SCI registers like SCSR, BAUD, SCCR1, SCCR2 and SCDR. Like the ADC module, the first process is initialize the SCI and the most

important process is set the baud rate which must same with Visual Basic program to avoid from received the corrupt data. Figure 3.16 is shows the flow chart of SCI programming.

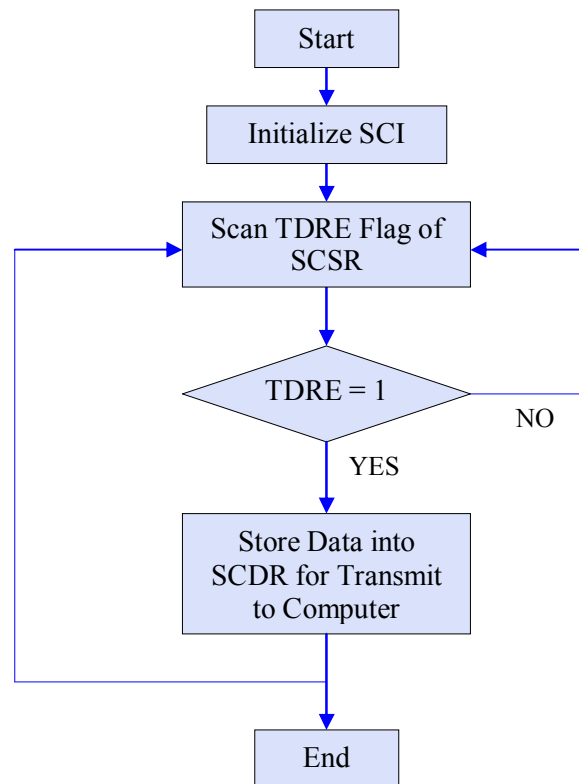


Figure 3.16: Flow chart of SCI module

3.3.3 Control Switch Module Test

There are 4 control switches which connected to PORT C3, C4, C5 and C6. This switches will be use to display the maximum and minimum value and also to change the set temperature. The flow chart in Figure 3.17 shows the simple operation of control buttons.

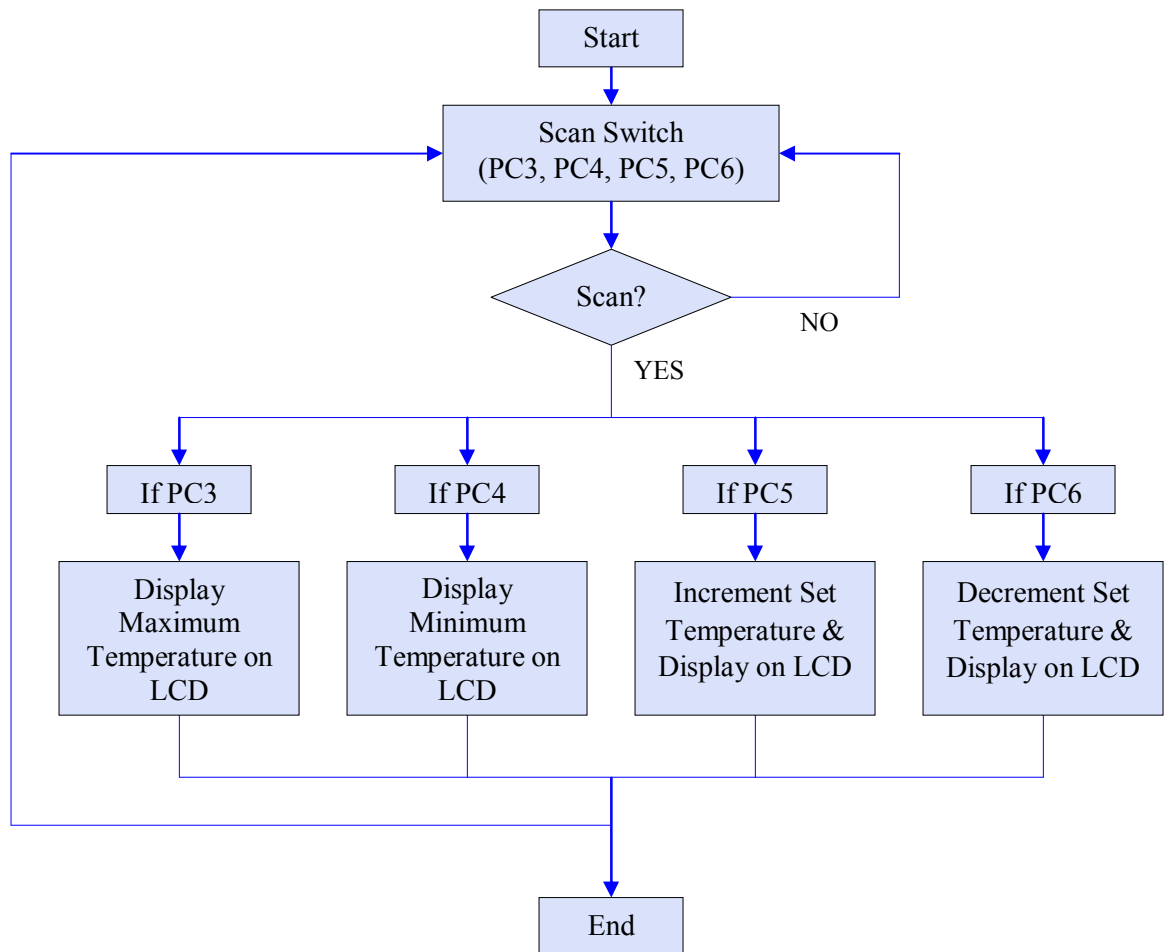


Figure 3.17: Flow chart of Control Switch module

3.3.4 LCD Module Test

The LCD module is more complex than the others programming modules. Actually this module is not difficult if the user really understand the LCD operation and configuration. Flow chart in Figure 3.18 shows the flow of the LCD program. The register select (RS) which set low if want to send the command data and set high to send the character data. The LCD also only understand the ASCII value, so we must convert the hexadecimal to ASCII value.

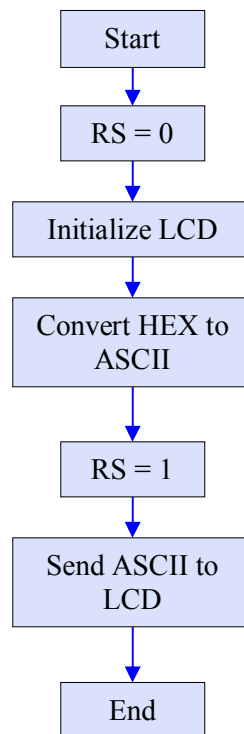


Figure 3.18: Flow chart of LCD module

3.3.5 Integration All Modules

After all the programming modules were tested successfully, the last process in programming is integration of all modules to be one program which free from error or problem in order to sure the system will function properly.

This project was used special bootstrap mode as explain before. So, the program must started at address \$B600 and not exceed address \$B7FF or the program will be error. The subroutine technique will use to reduce the memory of program and each programming module will be subroutine of the program like table below. The flow chart in Figure 3.19 is shows the complete flow chart of the program and the complete assembly program is in appendix B.

Table 3.1: Subroutine of program

Subroutine	Function
ADC	- Initialize ADC and analog to digital conversion process.
LCD	- Initialize LCD and display the data on LCD.
SCI	- Send the value in ADR1 to computer via serial communication interface (SCI).
HEX to ASCII	- To convert the temperature value in hexadecimal to ASCII value for LCD display purpose.

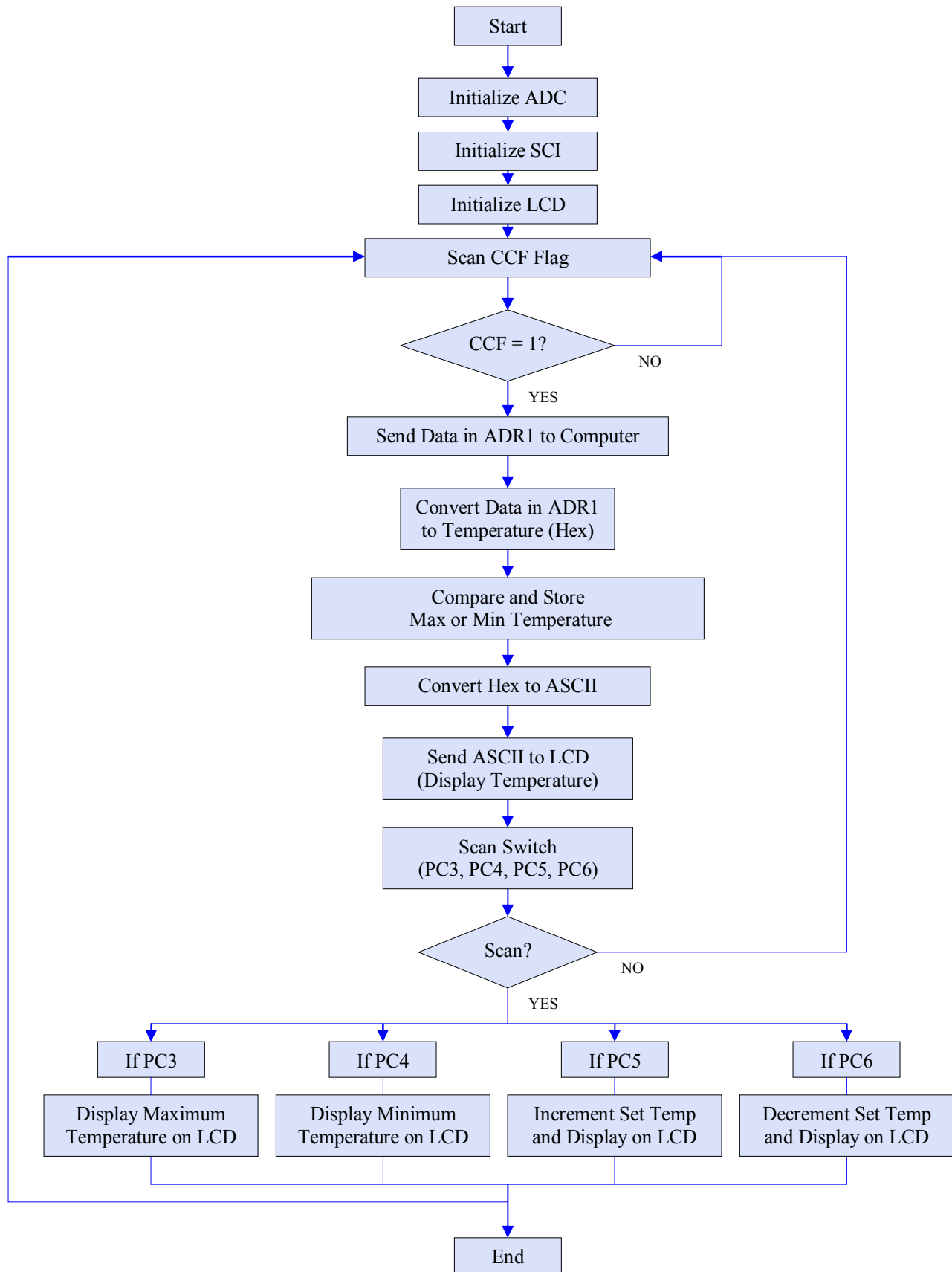


Figure 3.19: Flow chart of complete program

3.4 Visual Basic Module

Visual Basic is an event-driven programming language for creating applications that run under Microsoft's Windows operating systems. It is easy and user friendly software to create a program because it provide the graphical user interface (GUI) method. That mean, user just designs the GUI by drag and drop component, and after that, write a simple coding.

In this project, Visual Basic program was developed to receive data from microcontroller via serial port and display the temperature using Visual Basic GUI. And the most important is to store the temperature history in the log file.

There many elements were used to design the Visual Basic program. For example the basic elements are Text Box, Label, Vertical Scroll Bar, Command Button, Frame, and more. The advance and important element like Microsoft Comm Control (MSComm) also was used. The flow chart the operation of the program is shows in Figure 3.20 and the GUI design in Figure 3.21. For Visual Basic program coding, refer to Appendix C.

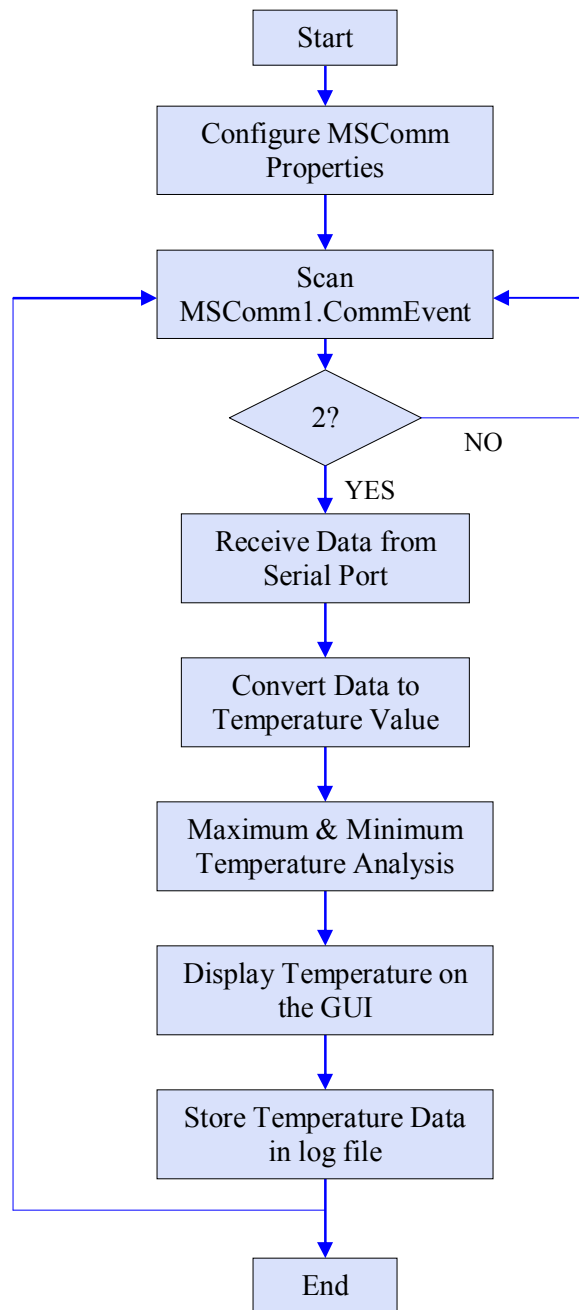


Figure 3.20: Flow chart of Visual Basic program

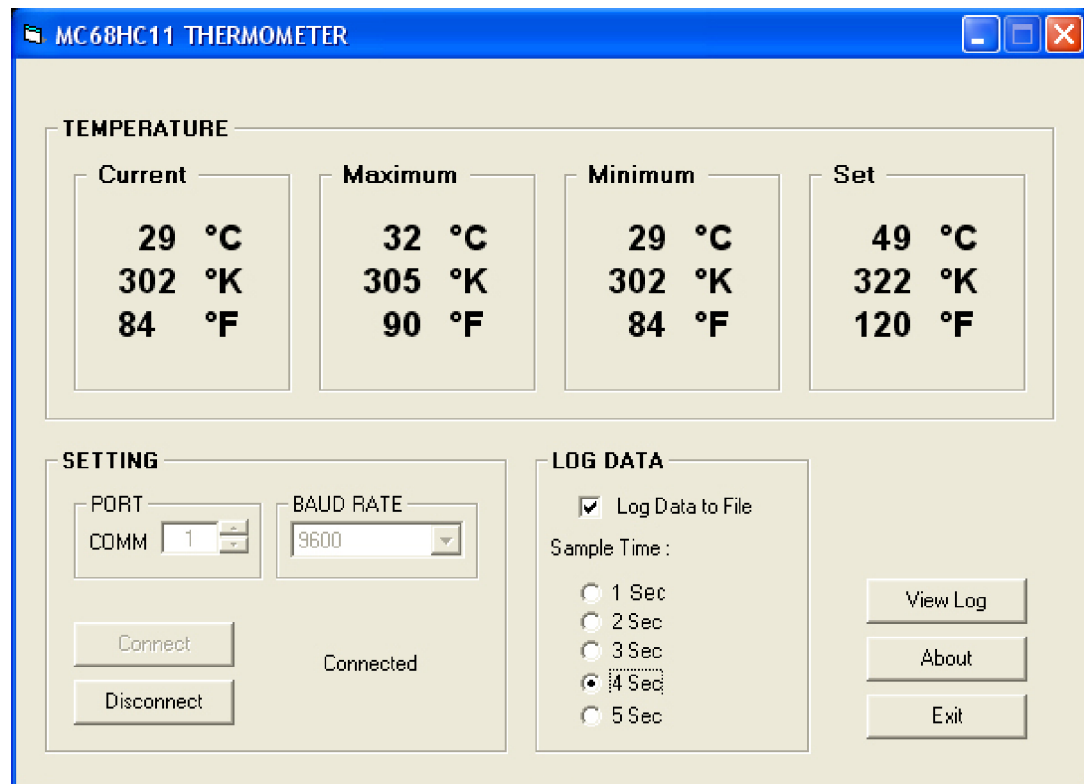


Figure 3.21: GUI of the Visual Basic program

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

After integration of all modules was done, the system proceeds to the testing process in order to ensure the system can function properly. If there are any problem like LCD not display the value or the control switch not functioning, the system need to be troubleshoot to find the problem. So, this chapter will review the testing result of the system which involved the system functionality, system performance, accuracy of measurement, programming performance and so on.

4.2 Testing

In this project, it was involved the hardware and software modules. So, both of modules must be tested to check their functionality and performance. There are 3 sections or part of test process.

- i. Temperature Monitoring
- ii. Alarm
- iii. Visual Basic

4.3 Temperature Monitoring

In this project, the LCD was used to display the current, maximum, minimum, and set temperature. The system was programmed to display only the current temperature on the LCD and there are control switch as shown in Figure 4.2 must be press to display the maximum, minimum, or set temperature. The Figure 4.1, Figure 4.3, Figure 4.4, and Figure 4.5 are shows the current, maximum, minimum, and set temperature on the LCD.

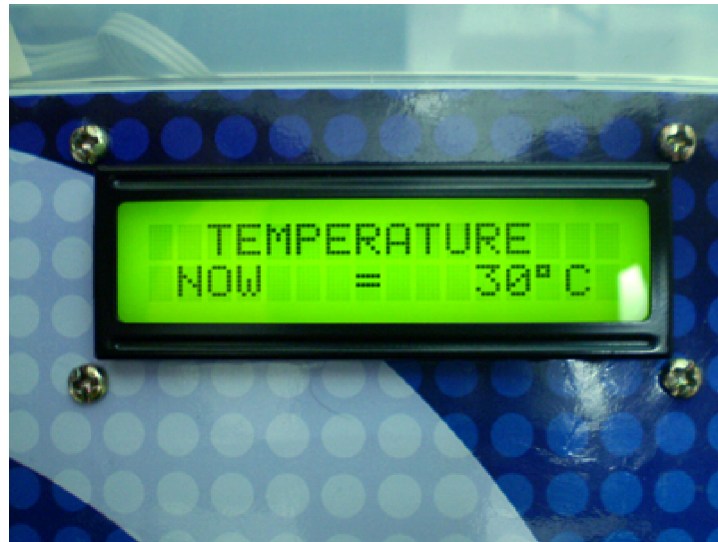


Figure 4.1: Current temperature

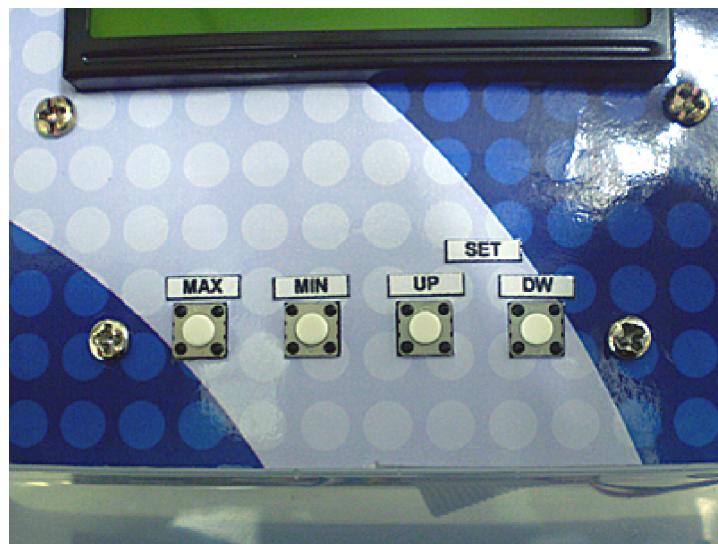


Figure 4.2: Control switch

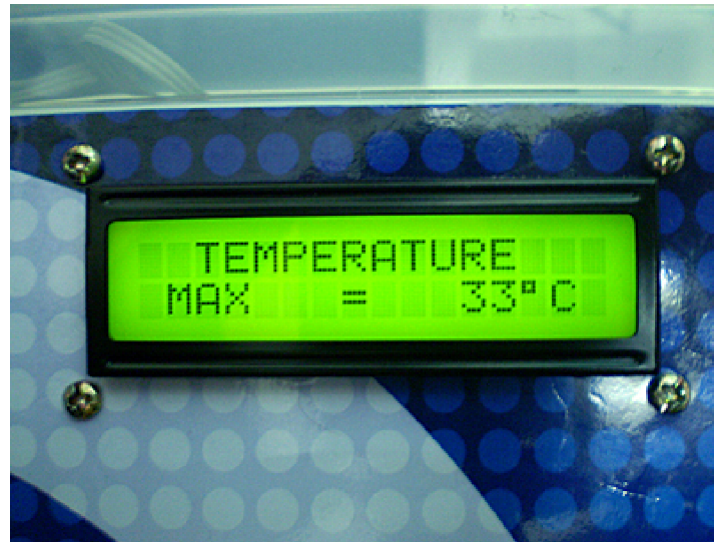


Figure 4.3: Maximum temperature

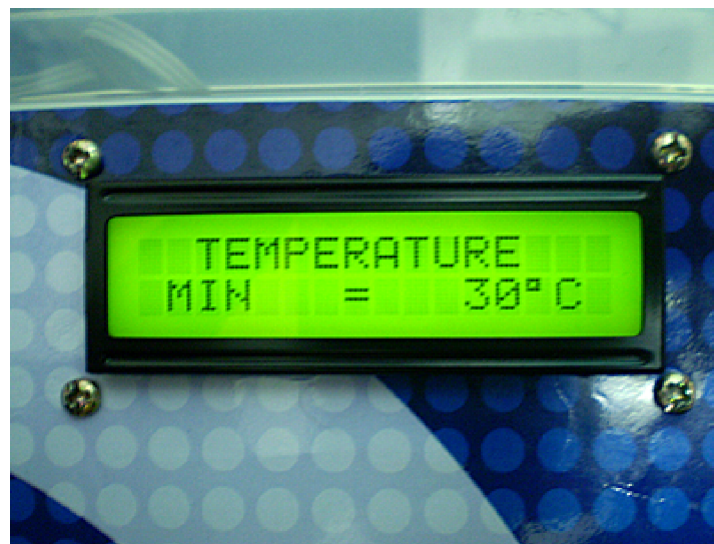


Figure 4.4: Minimum temperature

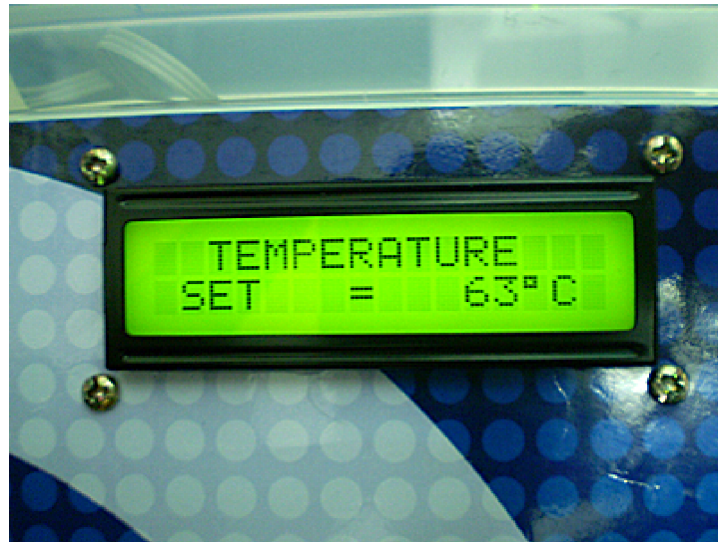


Figure 4.5: Adjustable set temperature

For accuracy of temperature measurement, refer to the literature review about the temperature sensor LM35 which the output voltage of sensor is 10mV per 1°C. That means if temperature is 27°C, the voltage output of sensor is 0.27 V. In this project, the result is show in Figure 4.6 and Figure 4.7 which at the output voltage is 0.31 V, temperature displayed is 30°C and that means the measurement is error about 1°C. So, the system accuracy is $\pm 1^\circ\text{C}$.

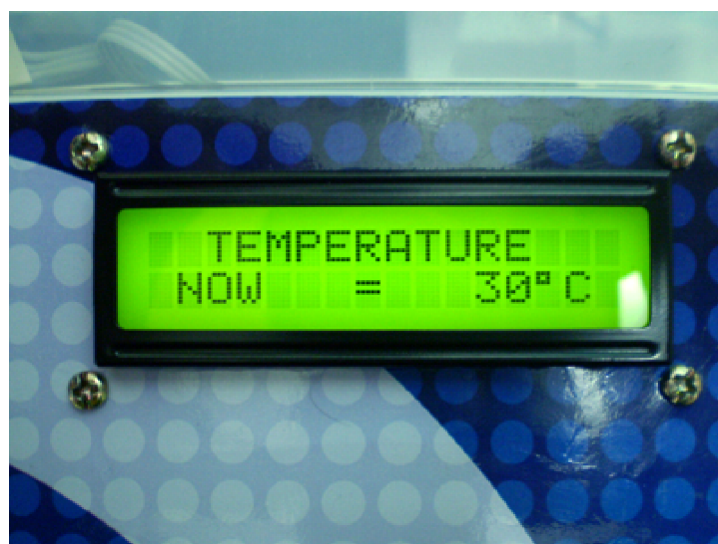


Figure 4.6: Temperature at 30°C



Figure 4.7: Output voltage of sensor LM35

4.4 Alarm

The system also has an alarm feature which trigger when the current temperature is equal or higher than set temperature. It is important part in this system and must function properly to inform the user about the current temperature have reached the set temperature. The test result is successful which alarm was triggered properly according to program.

4.5 Visual Basic Program

The microcontroller was communicating with the computer using serial communication interface and the Visual Basic was develop in order to read the serial port incoming data and display data in graphical user interface (GUI). The system is operates in real time, that means the data or temperature value always transmit to the computer and every changed on the LCD also will changed the Visual Basic program. Figure 4.8 show the GUI of Visual Basic program.

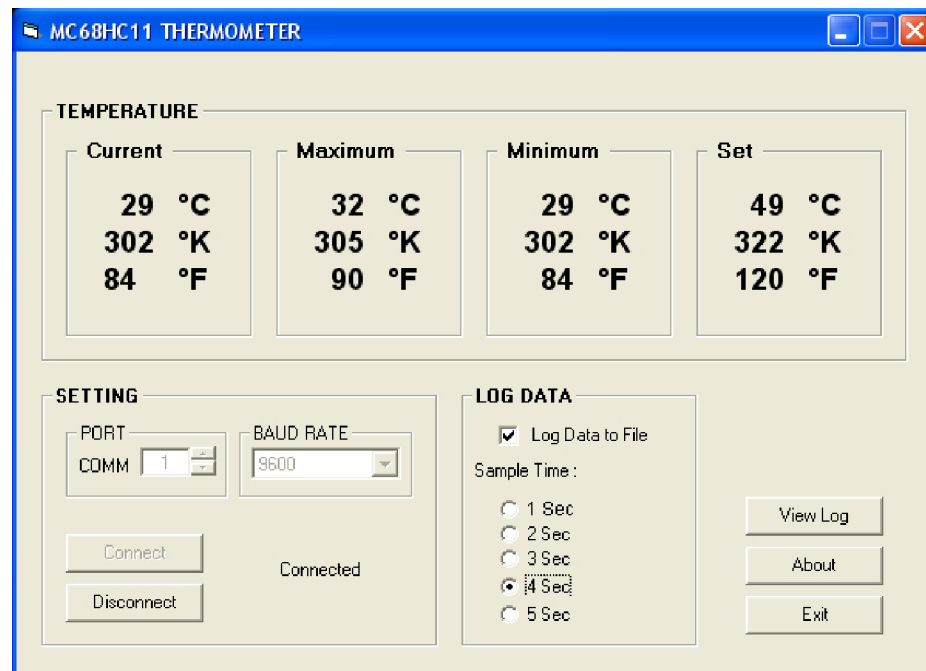
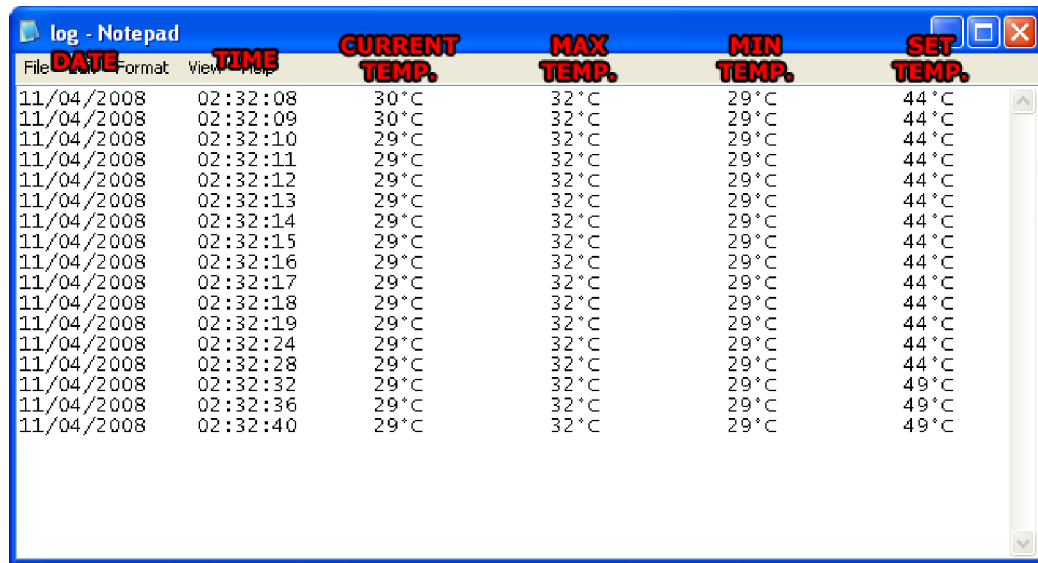


Figure 4.8: GUI of Visual Basic

The most important function of Visual Basic program is to record and store the data or temperature reading in the computer. It was design to record or log the date, time, current, maximum, minimum, and set temperature like in Figure 4.9.



DATE	TIME	CURRENT TEMP.	MAX TEMP.	MIN TEMP.	SET TEMP.
11/04/2008	02:32:08	30°C	32°C	29°C	44°C
11/04/2008	02:32:09	30°C	32°C	29°C	44°C
11/04/2008	02:32:10	29°C	32°C	29°C	44°C
11/04/2008	02:32:11	29°C	32°C	29°C	44°C
11/04/2008	02:32:12	29°C	32°C	29°C	44°C
11/04/2008	02:32:13	29°C	32°C	29°C	44°C
11/04/2008	02:32:14	29°C	32°C	29°C	44°C
11/04/2008	02:32:15	29°C	32°C	29°C	44°C
11/04/2008	02:32:16	29°C	32°C	29°C	44°C
11/04/2008	02:32:17	29°C	32°C	29°C	44°C
11/04/2008	02:32:18	29°C	32°C	29°C	44°C
11/04/2008	02:32:19	29°C	32°C	29°C	44°C
11/04/2008	02:32:24	29°C	32°C	29°C	44°C
11/04/2008	02:32:28	29°C	32°C	29°C	44°C
11/04/2008	02:32:32	29°C	32°C	29°C	49°C
11/04/2008	02:32:36	29°C	32°C	29°C	49°C
11/04/2008	02:32:40	29°C	32°C	29°C	49°C

Figure 4.9: Data log into the notepad

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This project was finished successfully and achieved the scopes of the project. The temperature reading was displayed on the LCD and on the computer by using Visual Basic program. The control switch also was functioned properly which the maximum, minimum, and set temperature was displayed on the LCD when the switch was pressed. When the current temperature is equal or higher than set temperature, the buzzer was triggered properly as the assembly program.

Actually, the scope of this project is not easy and the most difficult part is a programming module using assembly language. With a limit capacity memory of EEPROM, the program was develop must not exceed the EEPROM memory and it can't done if student not have strong knowledge about assembly language. However, this project is still need more development because if compare with the sophisticated digital thermometer, this project is still lack of accuracy in measurement.

5.2 Recommendation

For future, there are a few recommendations can be made to improve this project and it could be list as follows:

- i. The data can transmit to other computer in local area network (LAN) or internet. The short messaging system (SMS) also will be used to inform the user about temperature status.
- ii. Interface the project with heater or cooler which the system is able to control the temperature of environment.
- iii. Use a sensor which capable to measure the temperature in wide range with high accuracy.
- iv. Upgrade the Visual Basic program which can control the system like can set the set temperature from computer.

5.3 Costing and Commercialization

In Appendix D, there are list of the components with price that was used in this project. The total cost of the project is about RM 180 roughly. It is cost only for hardware module or components of the project. The most expensive components are IC MAX233 and microcontroller MC68HC11 which their price is about RM 40 each.

This project is a prototype of digital thermometer and still need some improvement. The measurement accuracy and system stabilization must reach the standard level for commercialization purpose in order to compete with other manufacturers.

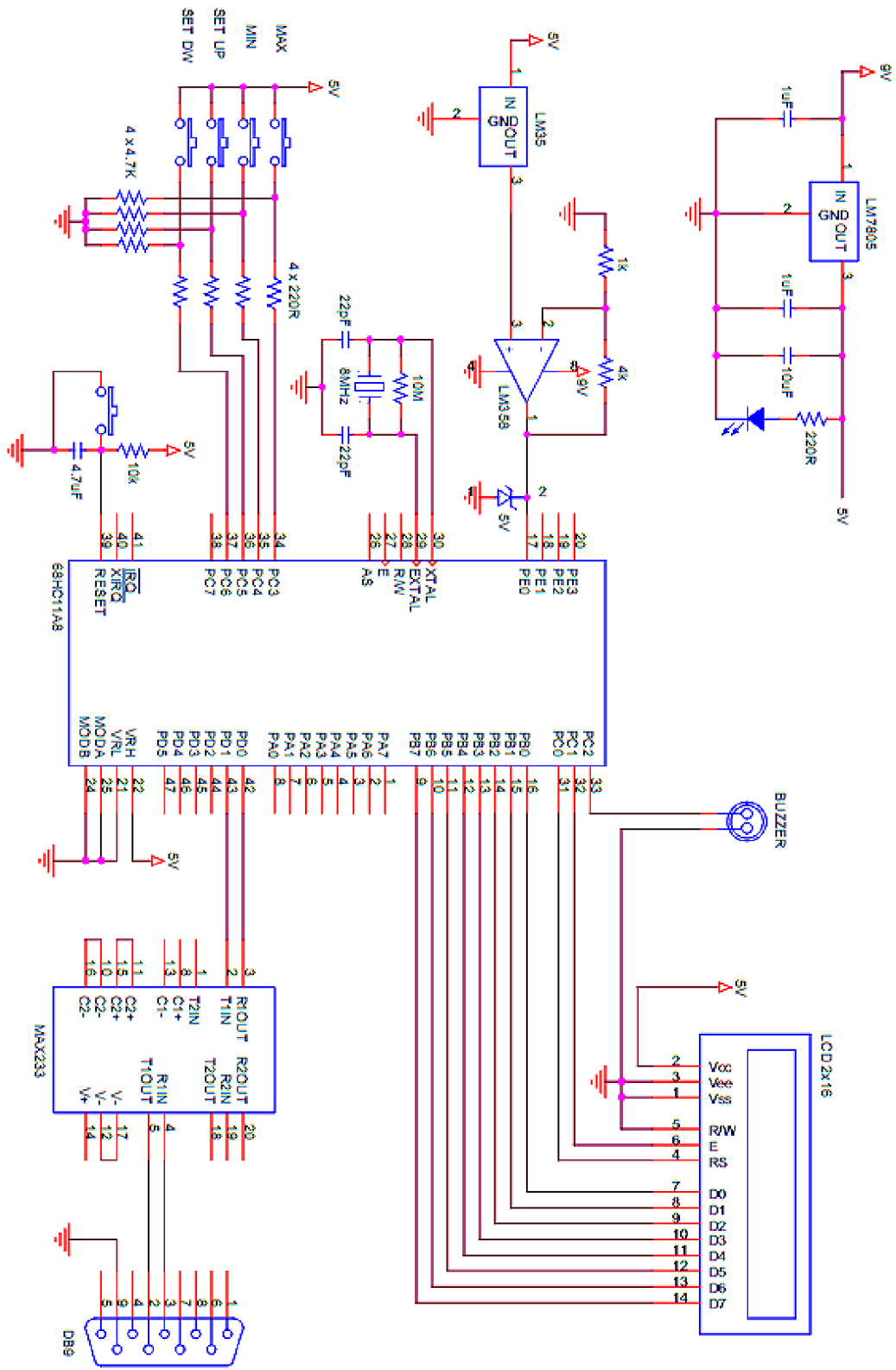
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APPENDIX A

Circuit Schematic



APPENDIX B

MC68HC11 Assembly Program

```

REG      EQU      $1000
PORTB    EQU      $4
PORTC    EQU      $3
PORTD    EQU      $8
PORTE    EQU      $A
DDRC     EQU      $7
OPTION   EQU      $39
ADCTL    EQU      $30
ADR1     EQU      $31
SCCR1    EQU      $2C
SCCR2    EQU      $2D
SCSR     EQU      $2E
SCDR     EQU      $2F
BAUD     EQU      $2B

BUFFER   ORG      $12
          RMB      8

MULA     ORG      $B600
          LDS      #$7F
          LDX      #REG
          BSET     DDRC,X      %00000111
          BCLR     PORTC,X     %11111100
          CLR      BUFFER+5
          LDAA     #$99
          STAA     BUFFER+6
          LDAA     #$40
          STAA     BUFFER+7

          JSR      INIT_LCD
          JSR      DISP3
          JSR      DISPO
LAGI     JSR      INIT_ADC
          JSR      DISP1
          JSR      ADC_DATA
          JSR      HEX_ASCII
          JSR      DISP2
          JSR      TxD_SCI
          JSR      MAX_MIN
          JSR      SWITCH
          JSR      BUZZER
          BRA      LAGI

INIT_LCD LDY      #INI                      ; INITIALIZE LCD
NEXT     LDAA     $0,Y
          BEQ      INIT_SCI
          BSR      COMMAND
          INY
          BRA      NEXT

INIT_SCI CLRA
          STAA     SCCR1,X                  ; INITIALIZE SCI
          LDAA     #$0C
          STAA     SCCR2,X
          LDAA     #$30
          STAA     BAUD,X
          RTS

```

```

INIT_ADC    BSET    OPTION,X    $80        ; INITIALIZE ADC
            BCLR    OPTION,X    $40
            JSR     DELAY
            LDAA    #0
            STAA    ADCTL,X
            RTS

ADC_DATA    BRCLR   ADCTL,X    $80    ADC_DATA
            LDAA    ADR1,X
            STAA    BUFFER
            LDAB    #100
            MUL
            PSHX
            LDX     #$FF
            IDIV
            XGDX
            LDX     #100
            IDIV
            LDX     #10
            IDIV
            STAB    BUFFER+1
            XGDX
            LSLB
            LSLB
            LSLB
            LSLB
            ADDB    BUFFER+1
            SUBA    #2
            STAB    BUFFER+2
            LDAA    BUFFER+2
            PULX
            RTS

HEX_ASCII   TAB                                ; CONVERT HEX to ASCII
            ROLA
            ROLA
            ROLA
            ROLA
            ROLA
            ANDA    #$0F
            ORAA    #$30
            ANDB    #$0F
            ORAB    #$30
            STAA    BUFFER+3
            STAB    BUFFER+4
            RTS

COMMAND     BCLR    PORTC,X    $01        ; R/S = 0, COMMAND MODE
            BSR
            RTS

CHARAC      BSET    PORTC,X    $01        ; R/S = 1, CHARACTER MODE
            BSR
            RTS

```

```

ENABLE      STAA    PORTB,X          ; STORE COMMAND or CHARACTER
             BSET    PORTC,X          $02
             BCLR    PORTC,X          $02      ; TRIGGER ENABLE
             JSR     DELAY
             RTS

DISP0        LDAA    #$CD              ; DISPLAY SYMBOL CELCIUS
             BSR     COMMAND
             LDY     #DATA0
             JSR     YAYA
             RTS

DISP1        LDAA    #$C1              ; DISPLAY TEMP =
             BSR     COMMAND
             LDY     #DATA1
             JSR     YAYA
             RTS

DISP2        LDAA    #$CB              ; DISPLAY TEMPERATURE VALUE
             BSR     COMMAND
             LDAA    BUFFER+3
             BSR     CHARAC
             JSR     DELAY
             LDAA    BUFFER+4
             BSR     CHARAC
             RTS

DISP3        LDAA    #$82              ; DISPLAY LINE 1
             BSR     COMMAND
             LDY     #DATA5
             JSR     YAYA
             RTS

TXD_SCI      LDAA    BUFFER+2          ; TRANSMIT DATA to COMPUTER
TXD0         BRCLR   SCSR,X           $80    TXD0
             STAA    SCDR,X
             JSR     DELAY
             LDAA    BUFFER+7
TXD1         BRCLR   SCSR,X           $80    TXD1
             STAA    SCDR,X
             JSR     DELAY
             RTS

MAX_MIN      LDAA    BUFFER+2          ; SAVE MAX or MIN TEMP
             CMPA    BUFFER+5
             BPL     YEAH
DOLI         CMPA    BUFFER+6
             BMI     YEAS
             BRA     DOLA
YEAH         STAA    BUFFER+5
             BRA     DOLI
YEAS        STAA    BUFFER+6
DOLA         RTS

```

```

SWITCH      BRSET    PORTC,X    %00001000    MAX_D
            BRSET    PORTC,X    %00010000    MIN_D
            BRSET    PORTC,X    %00100000    SET_INC
            BRSET    PORTC,X    %01000000    SET_DEC
            RTS

MAX_D        LDY      #DATA2                ; DISPLAY MAX TEMPERATURE
            BSR      PROCES1
            LDAA     BUFFER+5
            BSR      PROCES2
            BRA      SWITCH

MIN_D        LDY      #DATA3                ; DISPLAY MIN TEMPERATURE
            BSR      PROCES1
            LDAA     BUFFER+6
            BSR      PROCES2
            BRA      SWITCH

PROCES1      LDAA     #$C1
            JSR      COMMAND
            BSR      YAYA
            LDAA     #$CB
            JSR      COMMAND
            RTS

YAYA         LDAA     $0,Y
            BEQ      YOYO
            JSR      CHARAC
            INY
            BRA      YAYA

YOYO         RTS

PROCES2      JSR      HEX_ASCII
            JSR      DISP2
            BSR      DELAY2
            RTS

SET_INC      LDAA     BUFFER+7                ; INCREMENT SET TEMPERATURE
            CMPA     #$99
            BEQ      BOLA
            ADDA     #$1
            DAA
            STAA     BUFFER+7
BOLA         BSR      SET_D
            BRA      SWITCH

SET_DEC      LDAA     BUFFER+7                ; DECREMENT SET TEMPERATURE
            BEQ      BOLO
            ADDA     #$99
            DAA
            STAA     BUFFER+7
BOLO         BSR      SET_D
            BRA      SWITCH

```

```

SET_D      LDY      #DATA4
           BSR      PROCES1
           LDAA     BUFFER+7
           BSR      PROCES2
           BSR      SWITCH
           RTS

BUZZER      LDAA     BUFFER+2          ; TRIGGER BUZZER
           CMPA     BUFFER+7
           BLO      HABIS
           BSET     PORTC,X    %00000100
           BSR      DELAY1
           BSR      DELAY1
           BCLR     PORTC,X    %00000100
HABIS       RTS

DELAY       PSHX                    ; SHORT DELAY
           LDX      #$FFF
REPEAT      DEX
           BNE      REPEAT
           PULX
           RTS

DELAY1      PSHX                    ; SHORT DELAY
           LDX      #$FFF0
REPEAT1     DEX
           BNE      REPEAT1
           PULX
           RTS

DELAY2      PSHA                    ; LONG DELAY
           PSHX
           LDAA     #3
REPEAT2     LDX      $FFFF
LAGI2       DEX
           BNE      LAGI2
           DECA
           BNE      REPEAT2
           PULX
           PULA
           RTS

INI         ORG      $B7D0
DATA0       FCB      $01,$02,$06,$0C,$38,0
DATA1       FCC      "NOW   ="
           FCB      0
DATA2       FCC      "MAX"
           FCB      0
DATA3       FCC      "MIN"
           FCB      0
DATA4       FCC      "SET"
           FCB      0
DATA5       FCC      "TEMPERATURE"
           FCB      0

           END

```


APPENDIX C

Visual Basic Code Program

```

Dim SerByt As String
Dim Max As Integer
Dim Min As Integer
Dim kaka As Integer
Dim kake As Integer
Dim kaki As Integer
Dim kako As Integer
Dim kaku As Integer
Dim kaky As Integer
Dim kala As Integer
Dim kale As Integer

```

```

Private Sub Command1_Click()
On Error GoTo Err
If MSComm1.PortOpen = True Then
MSComm1.PortOpen = False

Else

MSComm1.CommPort = VScroll1.Value
MSComm1.RThreshold = 2
MSComm1.InputLen = 2

Select Case Baud.ListIndex
Case 0
MSComm1.Settings = "9600,N,8,1"
Case 1
MSComm1.Settings = "4800,N,8,1"
Case 3
MSComm1.Settings = "2400,N,8,1"
Case 4
MSComm1.Settings = "1200,N,8,1"
Case 5
MSComm1.Settings = "600,N,8,1"
Case 6
MSComm1.Settings = "300,N,8,1"
Case 7
MSComm1.Settings = "150,N,8,1"
Case 8
MSComm1.Settings = "75,N,8,1"
End Select

```

```

MSComm1.InputMode = comInputModeText
MSComm1.PortOpen = True
Command1.Enabled = False
Command2.Enabled = True
Text1.Enabled = False
Baud.Enabled = False
Label2.Caption = "Connected"
VScroll1.Enabled = False
logging.Enabled = True

End If
Exit Sub
Err:
    MsgBox "Please choose another port" & PrtNumb, vbCritical, "Comm Port Error"
End Sub

```

```

Private Sub Command2_Click()
    logging.Value = False
    logging.Enabled = False
    VScroll1.Enabled = True
    Command2.Enabled = False
    Command1.Enabled = True
    Text1.Enabled = True
    Baud.Enabled = True
    Label2.Caption = "Disconnected"
    MSComm1.PortOpen = False
End Sub

```

```

Private Sub Command3_Click()
    Shell "Notepad.exe " & App.Path & "\log.txt", vbNormalNoFocus
End Sub

```

```

Private Sub Command4_Click()
End
End Sub

```

```

Private Sub Command5_Click()
    frmAbout.Show vbModal
End Sub

```

```

Private Sub Form_Load()
    logging.Enabled = False
    Timer1.Enabled = False
    Option1.Value = True
    Baud.ListIndex = 0
    VScroll1.Value = 1
    Command2.Enabled = False
    Min = 99
    Label15.Visible = False
    Label16.Caption = Date ' for date
    Label17.Caption = Time 'for time
End Sub

```

```

Private Sub logging_Click()
    If logging.Value = 1 Then
        Timer1.Enabled = True
    Else
        Timer1.Enabled = False
    End If
End Sub

```

```

Private Sub MSComm1_OnComm()
    If MSComm1.CommEvent = 2 Then
        SerByt = MSComm1.Input
        lbltemp(0).Caption = Hex(Asc(Mid$(SerByt, 1, 1)))
        lbltemp(9).Caption = Hex(Asc(Mid$(SerByt, 2, 1)))

        If Max < lbltemp(0).Caption Then Max = lbltemp(0).Caption
        If Min > lbltemp(0).Caption Then Min = lbltemp(0).Caption

        'CURRENT
        kaka = lbltemp(0).Caption + 273
        lbltemp(1).Caption = kaka
        kake = lbltemp(0).Caption * (9 / 5) + 32
        lbltemp(2).Caption = kake

        'MAXIMUM
        lbltemp(3).Caption = Max
        kaki = Max + 273
        lbltemp(4).Caption = kaki
        kako = Max * (9 / 5) + 32
        lbltemp(5).Caption = kako
    End If
End Sub

```

```

' MINIMUM
lbltemp(6).Caption = Min
kaku = Min + 273
lbltemp(7).Caption = kaku
kaky = Min * (9 / 5) + 32
lbltemp(8).Caption = kaky

' SET
kala = lbltemp(9).Caption + 273
lbltemp(10).Caption = kala
kale = lbltemp(9).Caption * (9 / 5) + 32
lbltemp(11).Caption = kale

If kaka = kala Then
Label15.Visible = True
Else
Label15.Visible = False
End If
End If
End Sub

Private Sub Option1_Click()
Timer1.Interval = 1000
End Sub

Private Sub Option2_Click()
Timer1.Interval = 2000
End Sub

Private Sub Option3_Click()
Timer1.Interval = 3000
End Sub

Private Sub Option4_Click()
Timer1.Interval = 4000
End Sub

Private Sub Option5_Click()
Timer1.Interval = 5000
End Sub

Private Sub Timer1_Timer()
Open App.Path & "\log.txt" For Append As #1
Print #1, Format$(Date$, "DD/MM/YYYY"), Time$, lbltemp(0).Caption; "°C",
lbltemp(3).Caption; "°C", lbltemp(6).Caption; "°C", lbltemp(9).Caption; "°C"
Close #1
End Sub

Private Sub VScroll11_Change()
Text1.Text = CStr(VScroll11.Value)
End Sub

```

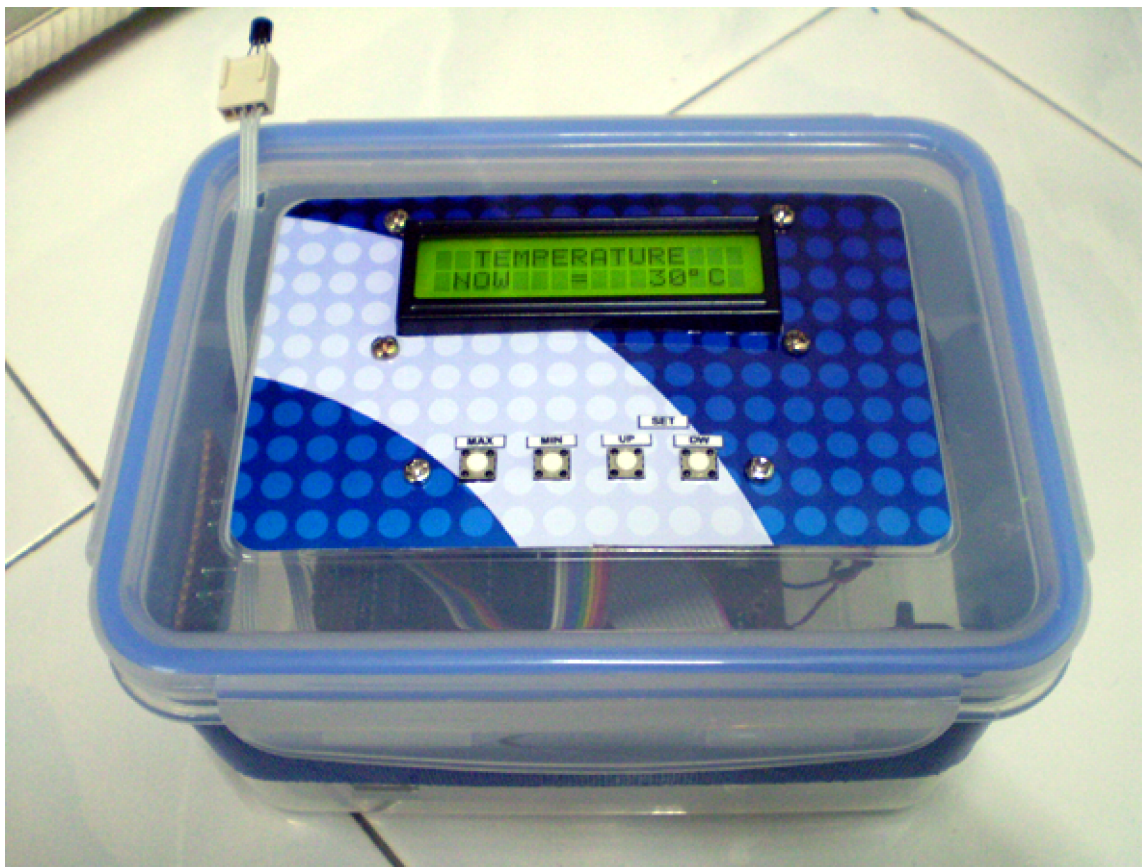
APPENDIX D

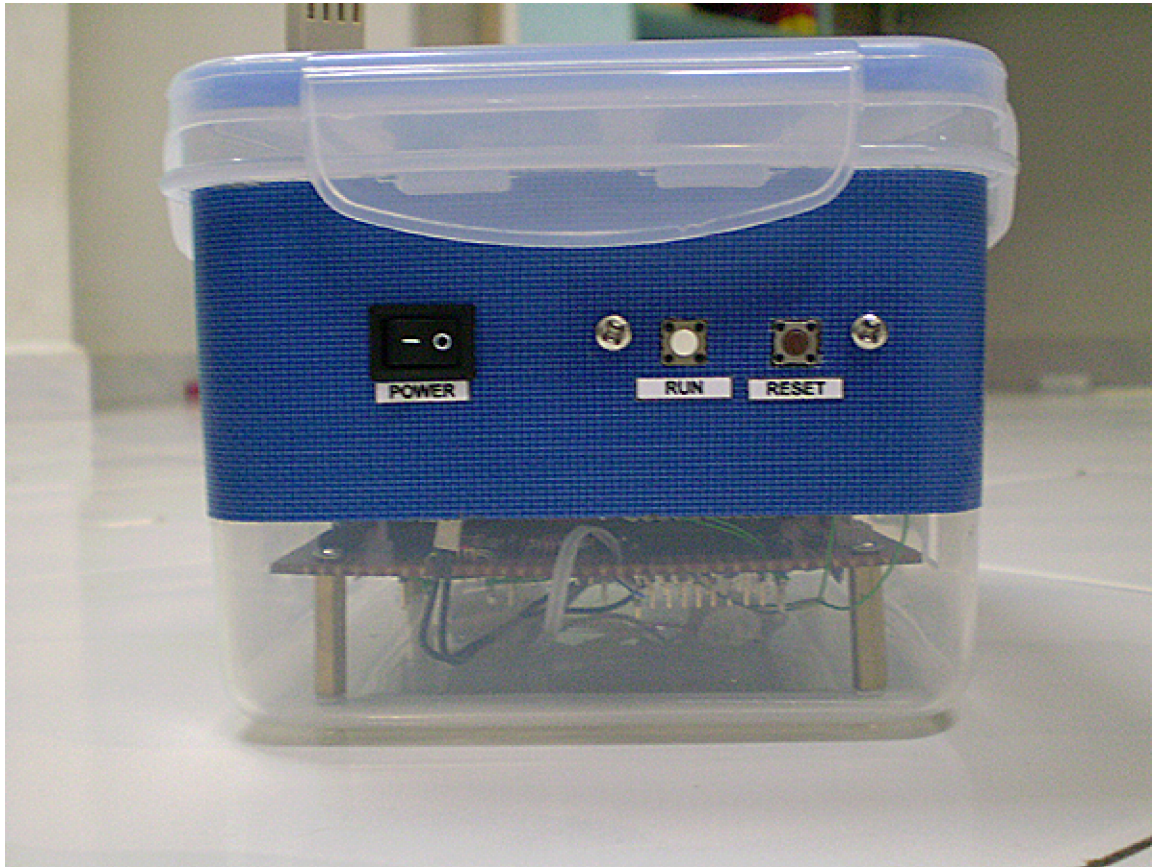
Cost of Project

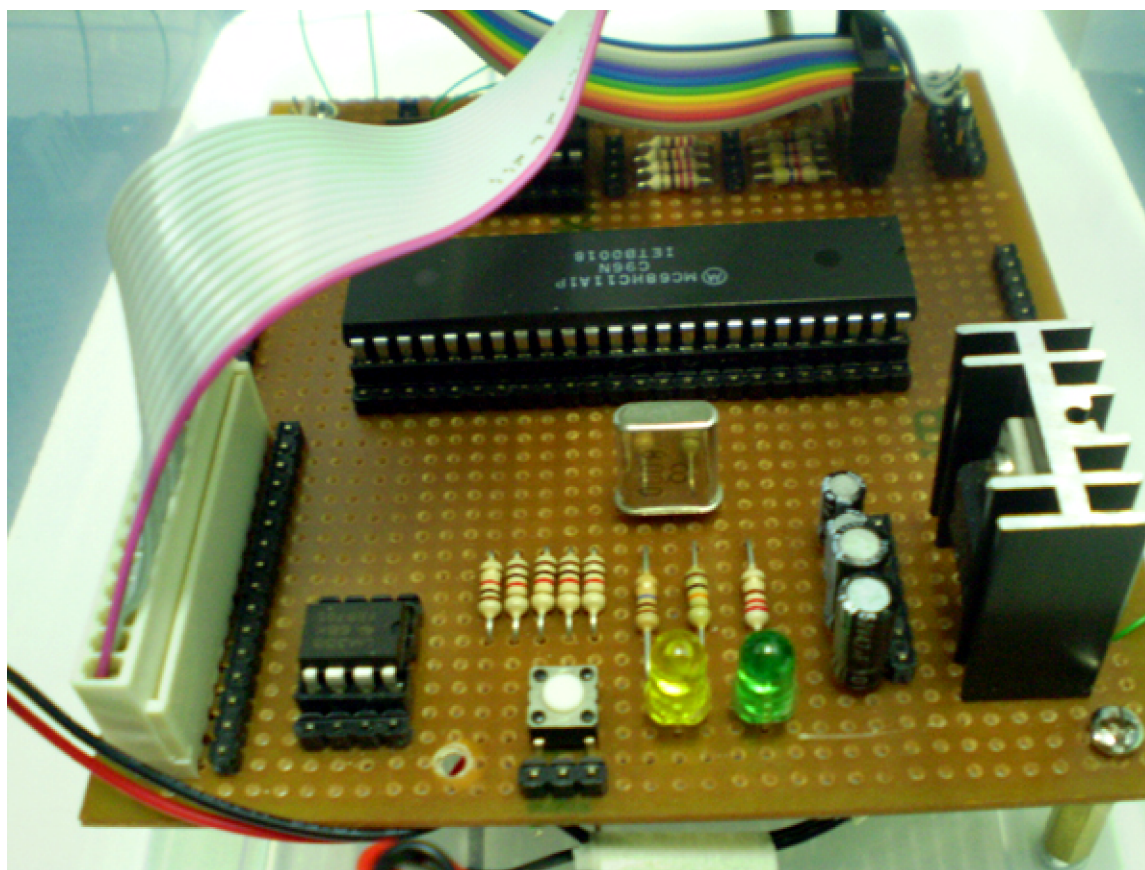
No.	Component	Specification	Price / Unit	Quantity	Price
1	PCB Header	40 ways	0.80	5	4.00
2	IC Base	48 pin	0.65	1	0.65
3	IC Base	20 pin	0.20	2	0.40
4	MC68HC11		40.00	1	40.00
5	Crystal	8 MHz	1.20	1	1.20
6	Wire wrap		15.00	1	15.00
7	Strip Board	10" x 4"	5.00	1	5.00
8	Reset Switch		0.50	6	3.00
9	Regulator 7805		1.00	1	1.00
10	MAX 233		39.00	1	39.00
11	DB9		0.50	1	0.50
12	Ribbon Cable	1 meter	3.00	1	3.00
13	Heat Sink		0.90	1	0.90
14	Resistor	220R	0.06	2	0.12
15		10 M	0.04	1	0.04
16		10 K	0.06	1	0.06
17	Capacitor	22 pF	0.08	2	0.08
18		4.7 uF	0.07	1	0.07
19		1 uF	0.07	2	0.14
20		10 uF	0.07	1	0.07
21	LED		0.15	4	0.60
22	LCD	1x16	30.00	1	30.00
23	Buzzer		3.00	1	3.00
24	LM358		1.00	1	1.00
25	LM35		4.80	1	4.80
Total					153.63

APPENDIX E

Picture of Project







APPENDIX F

Datasheets

MC68HC11A8
MC68HC11A1
MC68HC11A0

Technical Summary
8-Bit Microcontrollers

1 Introduction

The MC68HC11A8, MC68HC11A1, and MC68HC11A0 high-performance microcontroller units (MCUs) are based on the M68HC11 Family. These high speed, low power consumption chips have multiplexed buses and a fully static design. The chips can operate at frequencies from 3 MHz to dc. The three MCUs are created from the same masks; the only differences are the value stored in the CONFIG register, and whether or not the ROM or EEPROM is tested and guaranteed.

For detailed information about specific characteristics of these MCUs, refer to the *M68HC11 Reference Manual* (M68HC11RM/AD).

1.1 Features

- M68HC11 CPU
- Power Saving STOP and WAIT Modes
- 8 Kbytes ROM
- 512 Bytes of On-Chip EEPROM
- 256 Bytes of On-Chip RAM (All Saved During Standby)
- 16-Bit Timer System
 - 3 Input Capture Channels
 - 5 Output Compare Channels
- 8-Bit Pulse Accumulator
- Real-Time Interrupt Circuit
- Computer Operating Properly (COP) Watchdog System
- Synchronous Serial Peripheral Interface (SPI)
- Asynchronous Nonreturn to Zero (NRZ) Serial Communications Interface (SCI)
- 8-Channel, 8-Bit Analog-to-Digital (A/D) Converter
- 38 General-Purpose Input/Output (I/O) Pins
 - 15 Bidirectional I/O Pins
 - 11 Input-Only Pins and 12 Output-Only Pins (Eight Output-Only Pins in 48-Pin Package)
- Available in 48-Pin Dual In-Line Package (DIP) or 52-Pin Plastic Leaded Chip Carrier (PLCC)

This document contains information on a new product. Specifications and information herein are subject to change without notice.



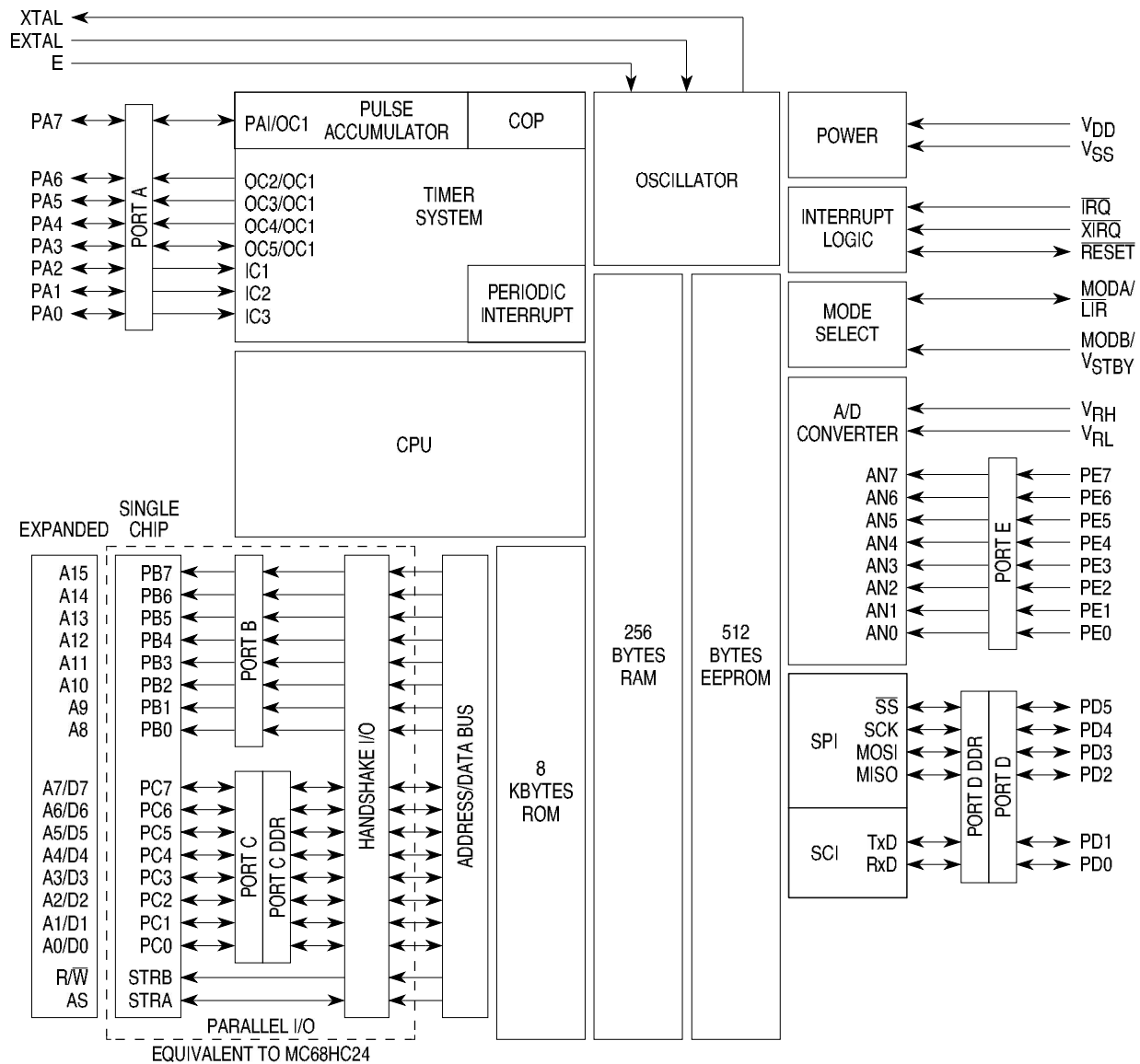


Figure 1 MC68HC11A8 Block Diagram



Figure 3 48-Pin DIP Pin Assignments

2 Operating Modes and Memory Maps

In single-chip operating mode, the MC68HC11A8 is a monolithic microcontroller without external address or data buses.

In expanded multiplexed operating mode, the MCU can access a 64 Kbyte address space. The space includes the same on-chip memory addresses used for single-chip mode plus external peripheral and memory devices. The expansion bus is made up of ports B and C and control signals AS and R/W. The address, R/W, and AS signals are active and valid for all bus cycles including accesses to internal memory locations. The following figure illustrates a recommended method of demultiplexing low-order addresses from data at port C.

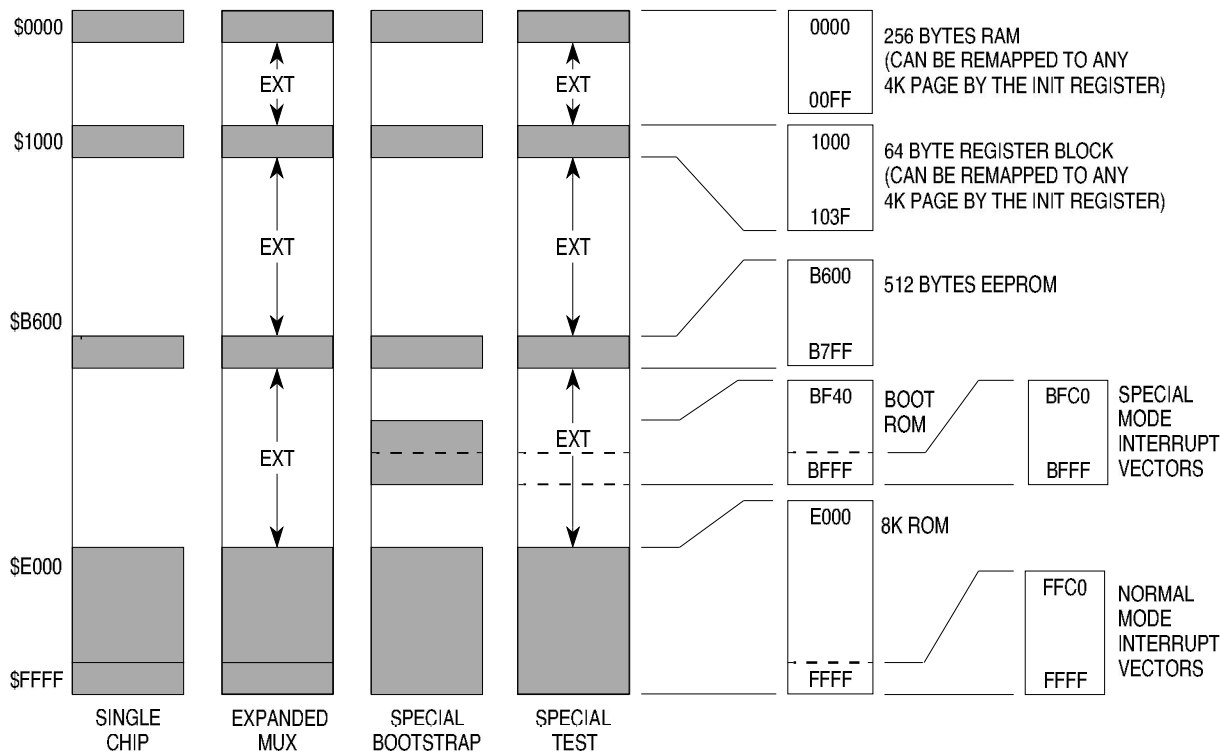


Figure 5 Memory Map

Table 3 MC68HC11A8 Register and Control Bit Assignments (Sheet 1 of 2)

(The register block can be remapped to any 4K boundary.)

	Bit 7	6	5	4	3	2	1	Bit 0	
\$1000	PA7	PA6	PA5	PA4	PA3	PA2	PA1	PA0	PORTA
\$1001									Reserved
\$1002	STAF	STAI	CWOM	HNDS	OIN	PLS	EGA	INVB	PIOC
\$1003	PC7	PC6	PC5	PC4	PC3	PC2	PC1	PC0	PORTC
\$1004	PB7	PB6	PB5	PB4	PB3	PB2	PB1	PB0	PORTB
\$1005	PCL7	PCL6	PCL5	PCL4	PCL3	PCL2	PCL1	PCL0	PORTCL
\$1006									Reserved
\$1007	DDC7	DDC6	DDC5	DDC4	DDC3	DDC2	DDC1	DDC0	DDRC
\$1008	0	0	PD5	PD4	PD3	PD2	PD1	PD0	PORTD
\$1009	0	0	DDD5	DDD4	DDD3	DDD2	DDD1	DDD0	DDRD
\$100A	PE7	PE6	PE5	PE4	PE3	PE2	PE1	PE0	PORTE
\$100B	FOC1	FOC2	FOC3	FOC4	FOC5	0	0	0	CFORC
\$100C	OC1M7	OC1M6	OC1M5	OC1M4	OC1M3	0	0	0	OC1M
\$100D	OC1D7	OC1D6	OC1D5	OC1D4	OC1D3	0	0	0	OC1D
\$100E	Bit 15	14	13	12	11	10	9	Bit 8	TCNT (High)
\$100F	Bit 7	6	5	4	3	2	1	Bit 0	TCNT (Low)
\$1010	Bit 15	14	13	12	11	10	9	Bit 8	TIC1 (High)
\$1011	Bit 7	6	5	4	3	2	1	Bit 0	TIC1 (Low)
\$1012	Bit 15	14	13	12	11	10	9	Bit 8	TIC2 (High)
\$1013	Bit 7	6	5	4	3	2	1	Bit 0	TIC2 (Low)
\$1014	Bit 15	14	13	12	11	10	9	Bit 8	TIC3 (High)
\$1015	Bit 7	6	5	4	3	2	1	Bit 0	TIC3 (Low)
\$1016	Bit 15	14	13	12	11	10	9	Bit 8	TOC1(High)
\$1017	Bit 7	6	5	4	3	2	1	Bit 0	TOC1 (Low)
\$1018	Bit 15	14	13	12	11	10	9	Bit 8	TOC2 (High)
\$1019	Bit 7	6	5	4	3	2	1	Bit 0	TOC2 (Low)
\$101A	Bit 15	14	13	12	11	10	9	Bit 8	TOC3 (High)
\$101B	Bit 7	6	5	4	3	2	1	Bit 0	TOC3 (Low)
\$101C	Bit 15	14	13	12	11	10	9	Bit 8	TOC4 (High)
\$101D	Bit 7	6	5	4	3	2	1	Bit 0	TOC4 (Low)
\$101E	Bit 15	14	13	12	11	10	9	Bit 8	TOC5 (High)
\$101F	Bit 7	6	5	4	3	2	1	Bit 0	TOC5 (Low)
\$1020	OM2	OL2	OM3	OL3	OM4	OL4	OM5	OL5	TCTL1
\$1021	0	0	EDG1B	EDG1A	EDG2B	EDG2A	EDG3B	EDG3A	TCTL2
\$1022	OC1I	OC2I	OC3I	OC4I	OC5I	IC1I	IC2I	IC3I	TMSK1
\$1023	OC1F	OC2F	OC3F	OC4F	OC5F	IC1F	IC2F	IC3F	TFLG1
\$1024	TOI	RTII	PAOVI	PAII	0	0	PR1	PR0	TMSK2
\$1025	TOF	RTIF	PAOVF	PAIF	0	0	0	0	TFLG2

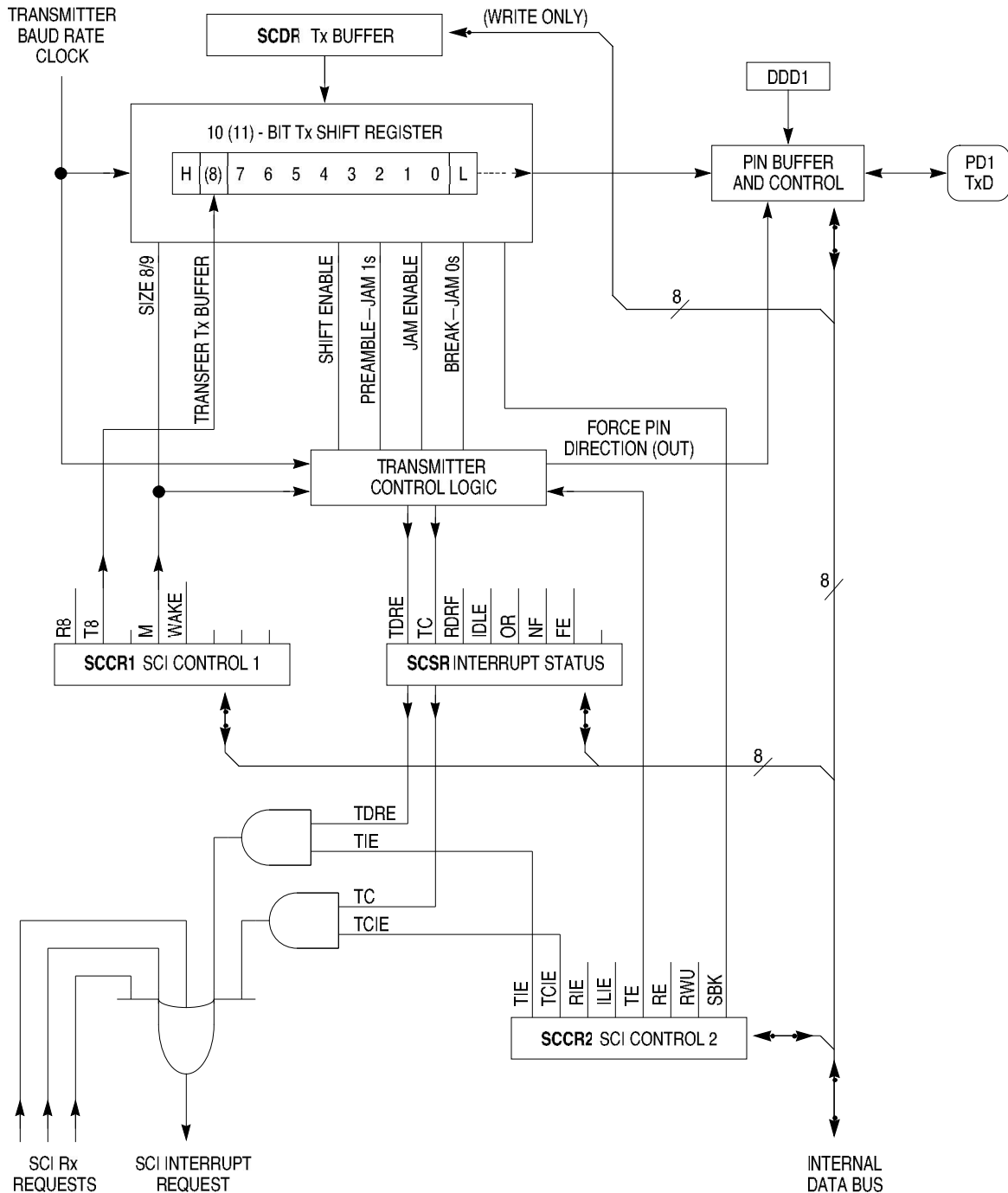
Table 3 MC68HC11A8 Register and Control Bit Assignments (Sheet 2 of 2)

(The register block can be remapped to any 4K boundary.)

	Bit 7	6	5	4	3	2	1	Bit 0	
\$1026	DDRA7	PAEN	PAMOD	PEDGE	0	0	RTR1	RTR0	PACTL
\$1027	Bit 7	6	5	4	3	2	1	Bit 0	PACNT
\$1028	SPIE	SPE	DWOM	MSTR	CPOL	CPHA	SPR1	SPR0	SPCR
\$1029	SPIF	WCOL	0	MODF	0	0	0	0	SPSR
\$102A	Bit 7	6	5	4	3	2	1	Bit 0	SPDR
\$102B	TCLR	0	SCP1	SCP0	RCKB	SCR2	SCR1	SCR0	BAUD
\$102C	R8	T8	0	M	WAKE	0	0	0	SCCR1
\$102D	TIE	TCIE	RIE	ILIE	TE	RE	RWU	SBK	SCCR2
\$102E	TDRE	TC	RDRF	IDLE	OR	NF	FE	0	SCSR
\$102F	R7/T7	R6/T6	R5/T5	R4/T4	R3/T3	R2/T2	R1/T1	R0/T0	SCDR
\$1030	CCF	0	SCAN	MULT	CD	CC	CB	CA	ADCTL
\$1031	Bit 7	6	5	4	3	2	1	Bit 0	ADR1
\$1032	Bit 7	6	5	4	3	2	1	Bit 0	ADR2
\$1033	Bit 7	6	5	4	3	2	1	Bit 0	ADR3
\$1034	Bit 7	6	5	4	3	2	1	Bit 0	ADR4
\$1035									Reserved
\$1038									Reserved
\$1039	ADPU	CSEL	IRQE	DLY	CME	0	CR1	CR0	OPTION
\$103A	Bit 7	6	5	4	3	2	1	Bit 0	COPRST
\$103B	ODD	EVEN	0	BYTE	ROW	ERASE	EELAT	EEPGM	PPROG
\$103C	RBOOT	SMOD	MDA	IRV	PSEL3	PSEL2	PSEL1	PSEL0	HPRIO
\$103D	RAM3	RAM2	RAM1	RAM0	REG3	REG2	REG1	REG0	INIT
\$103E	TILOP	0	OCCR	CBYP	DISR	FCM	FCOP	TCON	TEST1
\$103F	0	0	0	0	NOSEC	NOCOP	ROMON	EEON	CONFIG

6 Serial Communications Interface (SCI)

The SCI, a universal asynchronous receiver transmitter (UART) serial communications interface, is one of two independent serial I/O subsystems in the MC68HC11A8. It has a standard NRZ format (one start, eight or nine data, and one stop bit) and several baud rates available. The SCI transmitter and receiver are independent, but use the same data format and bit rate.



11 SCI TX BLOCK

Figure 6 SCI Transmitter Block Diagram

BAUD — Baud Rate**\$102B**

	Bit 7	6	5	4	3	2	1	Bit 0
	TCLR	0	SCP1	SCP0	RCKB	SCR2	SCR1	SCR0
RESET:	0	0	0	0	0	U	U	U

TCLR — Clear Baud Rate Counters (TEST)

SCP1, SCP0 — SCI Baud Rate Prescaler Selects

SCP[1:0]	Divide Internal Clock By	Crystal Frequency in MHz			
		4.0 MHz (Baud)	8.0 MHz (Baud)	10.0 MHz (Baud)	12.0 MHz (Baud)
00	1	62.50K	125.0K	156.25K	187.5K
01	3	20.83K	41.67K	52.08K	62.5K
10	4	15.625K	31.25K	38.4K	46.88K
11	13	4800	9600	12.02K	14.42K

RCKB — SCI Baud Rate Clock Check (TEST)

SCR2, SCR1, and SCR0 — SCI Baud Rate Selects

Selects receiver and transmitter bit rate based on output from baud rate prescaler stage.

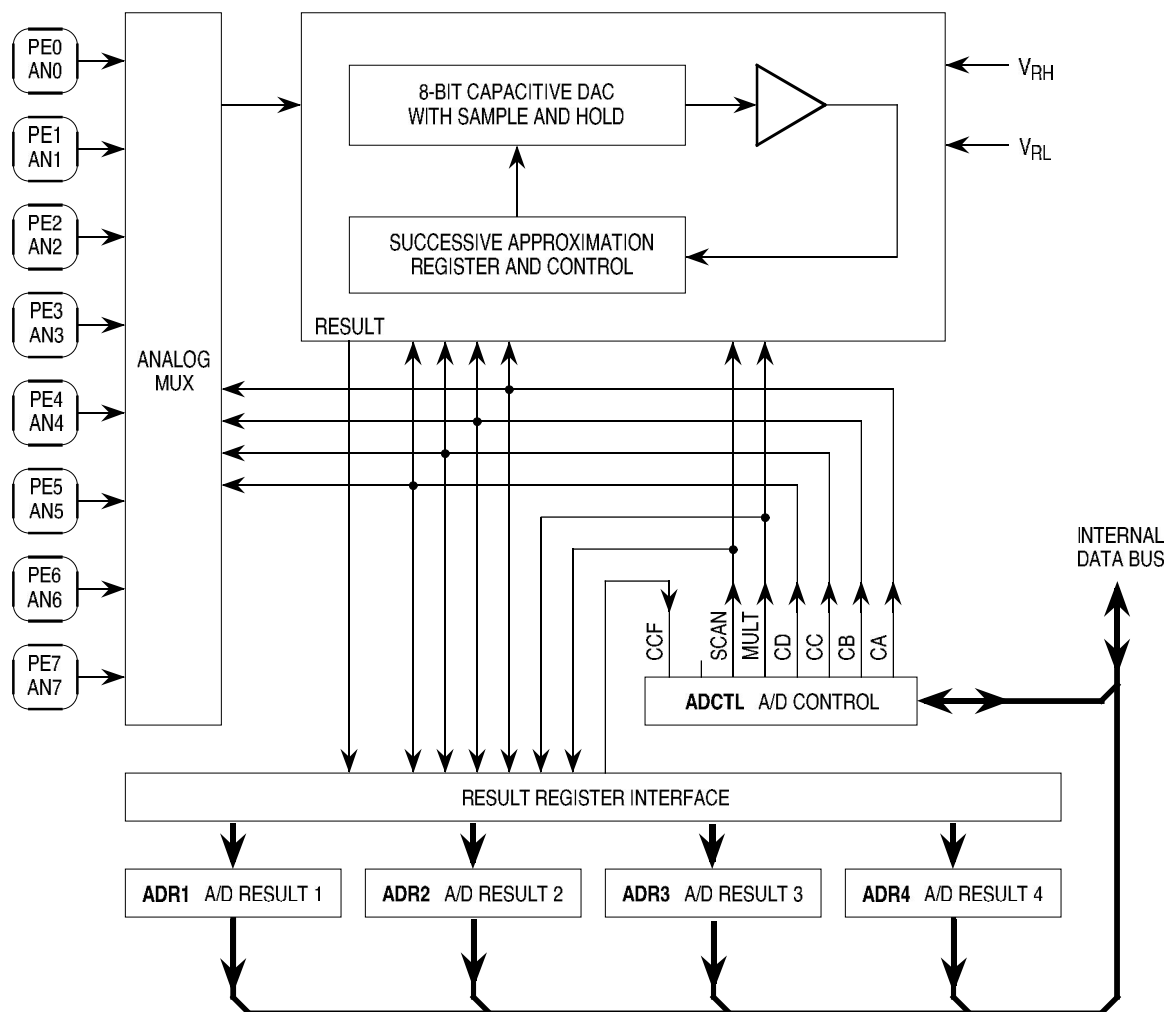
SCP[2:0]	Divide Prescaler By	Highest Baud Rate (Prescaler Output from Previous Table)		
		4800	9600	38.4K
000	1	4800	9600	38.4K
001	2	2400	4800	19.2K
010	4	1200	2400	9600
011	8	600	1200	4800
100	16	300	600	2400
101	32	150	300	1200
110	64	—	150	600
111	128	—	—	300

10 Analog-to-Digital Converter

The A/D converter system uses an all capacitive charge redistribution technique to convert analog signals to digital values. The MC68HC11A8 A/D system is an 8-channel, 8-bit, multiplexed-input, successive-approximation converter and is accurate to ± 1 least significant bit (LSB). It does not require external sample and hold circuits because of the type of charge redistribution technique used.

Dedicated lines V_{RH} and V_{RL} provide the reference supply voltage inputs. Refer to the A/D converter block diagram.

A multiplexer allows the single A/D converter to select one of 16 analog signals, as shown in the ADCTL register description.



EA9 A/D BLOCK

Figure 13 A/D Converter Block Diagram

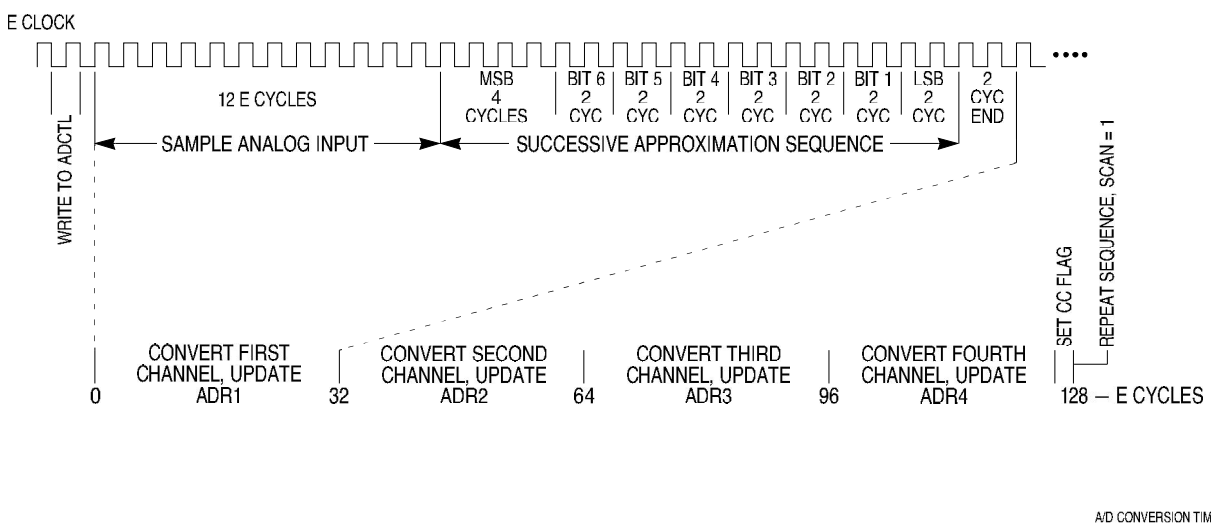


Figure 14 A/D Conversion Sequence

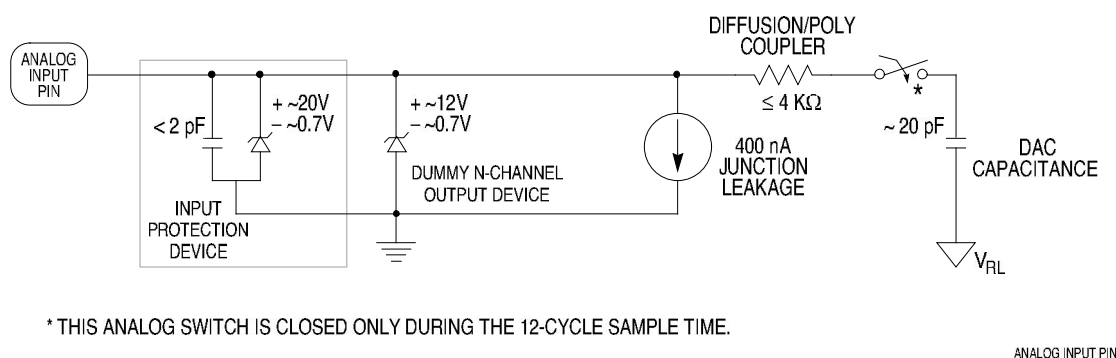


Figure 15 Electrical Model of an Analog Input Pin (Sample Mode)

ADCTL — A/D Control/Status

\$1030

	Bit 7	6	5	4	3	2	1	Bit 0
	CCF	0	SCAN	MULT	CD	CC	CB	CA
RESET:	U	0	U	U	U	U	U	U

CCF — Conversions Complete Flag

Set after an A/D conversion cycle. Cleared when ADCTL is written.

SCAN — Continuous Scan Control

0 = Do four conversions and stop

1 = Convert four channels in selected group continuously

MULT — Multiple Channel/Single Channel Control

0 = Convert single channel selected

1 = Convert four channels in selected group

LM35

Precision Centigrade Temperature Sensors

General Description

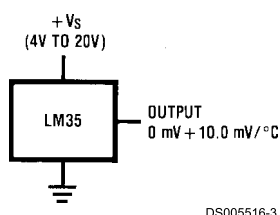
The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of $\pm 1/4^{\circ}\text{C}$ at room temperature and $\pm 3/4^{\circ}\text{C}$ over a full -55 to $+150^{\circ}\text{C}$ 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 $60\text{ }\mu\text{A}$ 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 $+150^{\circ}\text{C}$ temperature range, while the LM35C is rated for a -40° to $+110^{\circ}\text{C}$ range (-10° with improved accuracy). The LM35 series is available pack-

aged 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

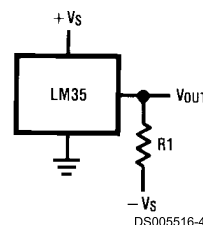
- Calibrated directly in ° Celsius (Centigrade)
- Linear $+10.0\text{ mV}/^{\circ}\text{C}$ scale factor
- 0.5°C accuracy guaranteeable (at $+25^{\circ}\text{C}$)
- Rated for full -55° to $+150^{\circ}\text{C}$ range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than $60\text{ }\mu\text{A}$ current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only $\pm 1/4^{\circ}\text{C}$ typical
- Low impedance output, $0.1\text{ }\Omega$ for 1 mA load

Typical Applications



DS005516-3

FIGURE 1. Basic Centigrade Temperature Sensor
($+2^{\circ}\text{C}$ to $+150^{\circ}\text{C}$)



DS005516-4

Choose $R_1 = -V_S/50\text{ }\mu\text{A}$
 $V_{OUT} = +1,500\text{ mV at } +150^{\circ}\text{C}$
 $= +250\text{ mV at } +25^{\circ}\text{C}$
 $= -550\text{ mV at } -55^{\circ}\text{C}$

FIGURE 2. Full-Range Centigrade Temperature Sensor

Absolute Maximum Ratings (Note 10)

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

Supply Voltage	+35V to -0.2V
Output Voltage	+6V to -1.0V
Output Current	10 mA
Storage Temp.:	
TO-46 Package,	-60°C to +180°C
TO-92 Package,	-60°C to +150°C
SO-8 Package,	-65°C to +150°C
TO-220 Package,	-65°C to +150°C
Lead Temp.:	
TO-46 Package,	
(Soldering, 10 seconds)	300°C

TO-92 and TO-220 Package, (Soldering, 10 seconds)	260°C
SO Package (Note 12)	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C
ESD Susceptibility (Note 11)	2500V
Specified Operating Temperature Range: T_{MIN} to T_{MAX} (Note 2)	
LM35, LM35A	-55°C to +150°C
LM35C, LM35CA	-40°C to +110°C
LM35D	0°C to +100°C

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35A			LM35CA			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy (Note 7)	$T_A = +25^\circ\text{C}$	± 0.2	± 0.5		± 0.2	± 0.5		$^\circ\text{C}$
	$T_A = -10^\circ\text{C}$	± 0.3			± 0.3		± 1.0	$^\circ\text{C}$
	$T_A = T_{MAX}$	± 0.4	± 1.0		± 0.4	± 1.0		$^\circ\text{C}$
	$T_A = T_{MIN}$	± 0.4	± 1.0		± 0.4		± 1.5	$^\circ\text{C}$
Nonlinearity (Note 8)	$T_{MIN} \leq T_A \leq T_{MAX}$	± 0.18		± 0.35	± 0.15		± 0.3	$^\circ\text{C}$
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/ $^\circ\text{C}$
Load Regulation (Note 3) $0 \leq I_L \leq 1 \text{ mA}$	$T_A = +25^\circ\text{C}$	± 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)	$T_A = +25^\circ\text{C}$	± 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)	$V_S = +5V, +25^\circ\text{C}$	56	67		56	67		μA
	$V_S = +5V$	105		131	91		114	μA
	$V_S = +30V, +25^\circ\text{C}$	56.2	68		56.2	68		μA
	$V_S = +30V$	105.5		133	91.5		116	μA
Change of Quiescent Current (Note 3)	$4V \leq V_S \leq 30V, +25^\circ\text{C}$	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		$+0.39$		$+0.5$	$+0.39$		$+0.5$	$\mu\text{A}/^\circ\text{C}$
Minimum Temperature for Rated Accuracy	In circuit of <i>Figure 1</i> , $I_L = 0$	+1.5		+2.0	+1.5		+2.0	$^\circ\text{C}$
Long Term Stability	$T_J = T_{MAX}$, for 1000 hours	± 0.08			± 0.08			$^\circ\text{C}$

Electrical Characteristics

(Notes 1, 6)

Parameter	Conditions	LM35			LM35C, LM35D			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy, LM35, LM35C (Note 7)	$T_A = +25^\circ\text{C}$	± 0.4	± 1.0		± 0.4	± 1.0		$^\circ\text{C}$
	$T_A = -10^\circ\text{C}$	± 0.5			± 0.5		± 1.5	$^\circ\text{C}$
	$T_A = T_{\text{MAX}}$	± 0.8	± 1.5		± 0.8		± 1.5	$^\circ\text{C}$
	$T_A = T_{\text{MIN}}$	± 0.8		± 1.5	± 0.8		± 2.0	$^\circ\text{C}$
Accuracy, LM35D (Note 7)	$T_A = +25^\circ\text{C}$				± 0.6	± 1.5		$^\circ\text{C}$
	$T_A = T_{\text{MAX}}$				± 0.9		± 2.0	$^\circ\text{C}$
	$T_A = T_{\text{MIN}}$				± 0.9		± 2.0	$^\circ\text{C}$
Nonlinearity (Note 8)	$T_{\text{MIN}} \leq T_A \leq T_{\text{MAX}}$	± 0.3		± 0.5	± 0.2		± 0.5	$^\circ\text{C}$
Sensor Gain (Average Slope)	$T_{\text{MIN}} \leq T_A \leq T_{\text{MAX}}$	+10.0	+9.8, +10.2		+10.0		+9.8, +10.2	mV/ $^\circ\text{C}$
Load Regulation (Note 3) $0 \leq I_L \leq 1 \text{ mA}$	$T_A = +25^\circ\text{C}$	± 0.4	± 2.0		± 0.4	± 2.0		mV/mA
	$T_{\text{MIN}} \leq T_A \leq T_{\text{MAX}}$	± 0.5		± 5.0	± 0.5		± 5.0	mV/mA
Line Regulation (Note 3)	$T_A = +25^\circ\text{C}$	± 0.01	± 0.1		± 0.01	± 0.1		mV/V
	$4\text{V} \leq V_S \leq 30\text{V}$	± 0.02		± 0.2	± 0.02		± 0.2	mV/V
Quiescent Current (Note 9)	$V_S = +5\text{V}, +25^\circ\text{C}$	56	80		56	80		μA
	$V_S = +5\text{V}$	105		158	91		138	μA
	$V_S = +30\text{V}, +25^\circ\text{C}$	56.2	82		56.2	82		μA
	$V_S = +30\text{V}$	105.5		161	91.5		141	μA
Change of Quiescent Current (Note 3)	$4\text{V} \leq V_S \leq 30\text{V}, +25^\circ\text{C}$	0.2	2.0		0.2	2.0		μA
	$4\text{V} \leq V_S \leq 30\text{V}$	0.5		3.0	0.5		3.0	μA
Temperature Coefficient of Quiescent Current		+0.39		+0.7	+0.39		+0.7	$\mu\text{A}/^\circ\text{C}$
Minimum Temperature for Rated Accuracy	In circuit of <i>Figure 1</i> , $I_L = 0$	+1.5		+2.0	+1.5		+2.0	$^\circ\text{C}$
Long Term Stability	$T_J = T_{\text{MAX}}$, for 1000 hours	± 0.08			± 0.08			$^\circ\text{C}$

Note 1: Unless otherwise noted, these specifications apply: $-55^\circ\text{C} \leq T_J \leq +150^\circ\text{C}$ for the LM35 and LM35A; $-40^\circ\text{C} \leq T_J \leq +110^\circ\text{C}$ for the LM35C and LM35CA; and $0^\circ\text{C} \leq T_J \leq +100^\circ\text{C}$ for the LM35D. $V_S = +5\text{Vdc}$ and $I_{\text{LOAD}} = 50 \mu\text{A}$, in the circuit of *Figure 2*. These specifications also apply from $+2^\circ\text{C}$ 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 $400^\circ\text{C}/\text{W}$, junction to ambient, and $24^\circ\text{C}/\text{W}$ junction to case. Thermal resistance of the TO-92 package is $180^\circ\text{C}/\text{W}$ junction to ambient. Thermal resistance of the small outline molded package is $220^\circ\text{C}/\text{W}$ junction to ambient. Thermal resistance of the TO-220 package is $90^\circ\text{C}/\text{W}$ 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 $10\text{mV}/^\circ\text{C}$ times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in $^\circ\text{C}$).

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*.

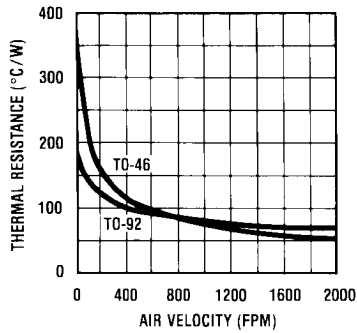
Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

Note 11: Human body model, 100 pF discharged through a $1.5 \text{ k}\Omega$ 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.

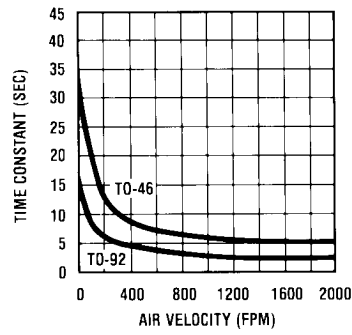
Typical Performance Characteristics

**Thermal Resistance
Junction to Air**



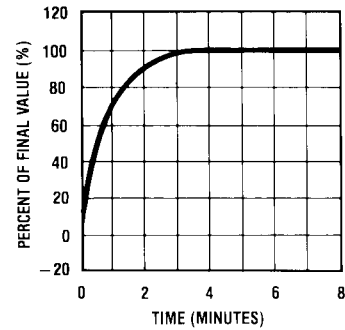
DS005516-25

Thermal Time Constant



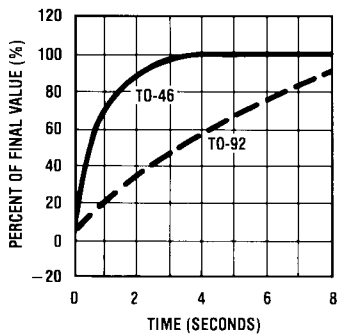
DS005516-26

**Thermal Response
in Still Air**



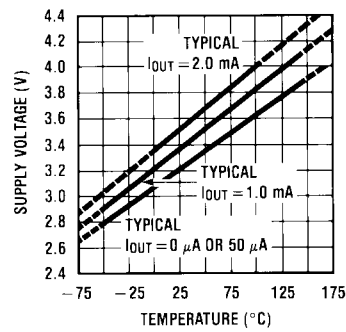
DS005516-27

**Thermal Response in
Stirred Oil Bath**



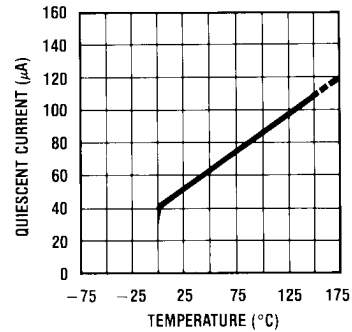
DS005516-28

**Minimum Supply
Voltage vs. Temperature**



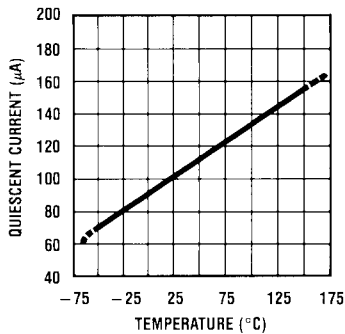
DS005516-29

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



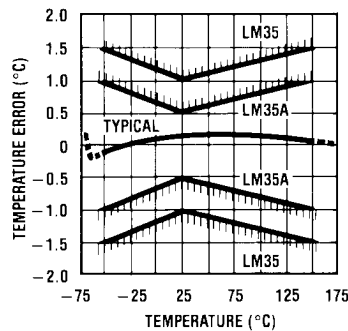
DS005516-30

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



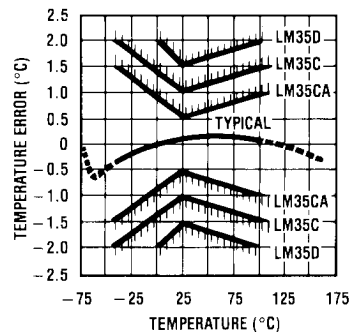
DS005516-31

**Accuracy vs. Temperature
(Guaranteed)**



DS005516-32

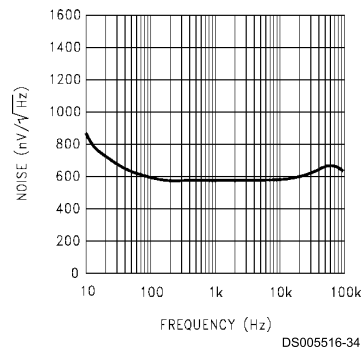
**Accuracy vs. Temperature
(Guaranteed)**



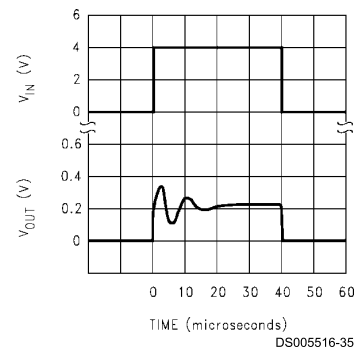
DS005516-33

Typical Performance Characteristics (Continued)

Noise Voltage



Start-Up Response



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 especially 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.

KA78XX/KA78XXA

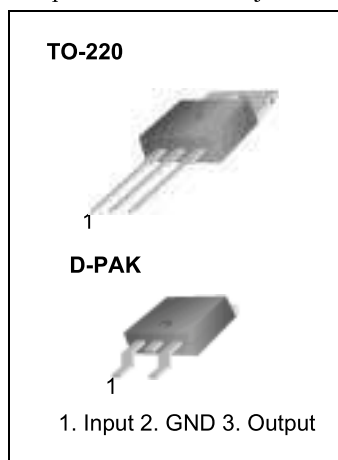
3-Terminal 1A Positive Voltage Regulator

Features

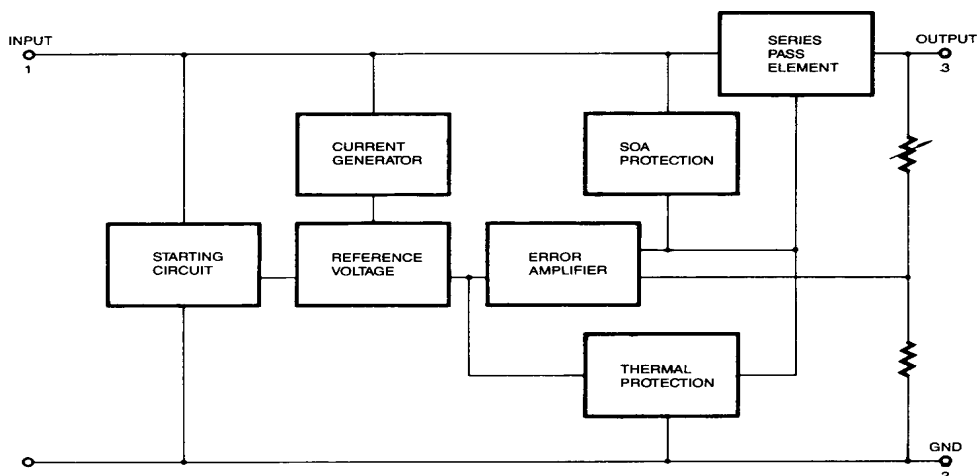
- Output Current up to 1A
- Output Voltages of 5, 6, 8, 9, 10, 12, 15, 18, 24V
- Thermal Overload Protection
- Short Circuit Protection
- Output Transistor Safe Operating Area Protection

Description

The KA78XX/KA78XXA series of three-terminal positive regulator are available in the TO-220/D-PAK package and with several fixed output voltages, making them useful in a wide range of applications. Each type employs internal current limiting, thermal shut down and safe operating area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over 1A output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltages and currents.



Internal Block Diagram



Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Input Voltage (for $V_O = 5V$ to $18V$) (for $V_O = 24V$)	V_I	35	V
	V_I	40	V
Thermal Resistance Junction-Cases (TO-220)	$R_{\theta JC}$	5	$^{\circ}C/W$
Thermal Resistance Junction-Air (TO-220)	$R_{\theta JA}$	65	$^{\circ}C/W$
Operating Temperature Range (KA78XX/A/R)	T_{OPR}	0 ~ +125	$^{\circ}C$
Storage Temperature Range	T_{STG}	-65 ~ +150	$^{\circ}C$

Electrical Characteristics (KA7805/KA7805R)

(Refer to test circuit , $0^{\circ}C < T_J < 125^{\circ}C$, $I_O = 500mA$, $V_I = 10V$, $C_I = 0.33\mu F$, $C_O = 0.1\mu F$, unless otherwise specified)

Parameter	Symbol	Conditions	KA7805			Unit
			Min.	Typ.	Max.	
Output Voltage	V_O	$T_J = +25^{\circ}C$	4.8	5.0	5.2	V
		$5.0mA \leq I_O \leq 1.0A$, $P_O \leq 15W$ $V_I = 7V$ to $20V$	4.75	5.0	5.25	
Line Regulation (Note1)	Regline	$T_J = +25^{\circ}C$	$V_O = 7V$ to $25V$		-	mV
			$V_I = 8V$ to $12V$		-	
Load Regulation (Note1)	Regload	$T_J = +25^{\circ}C$	$I_O = 5.0mA$ to $1.5A$		-	mV
			$I_O = 250mA$ to $750mA$		-	
Quiescent Current	I_Q	$T_J = +25^{\circ}C$	-	5.0	8.0	mA
Quiescent Current Change	ΔI_Q	$I_O = 5mA$ to $1.0A$	-	0.03	0.5	mA
		$V_I = 7V$ to $25V$	-	0.3	1.3	
Output Voltage Drift	$\Delta V_O / \Delta T$	$I_O = 5mA$	-	-0.8	-	mV/ $^{\circ}C$
Output Noise Voltage	V_N	$f = 10Hz$ to $100KHz$, $T_A = +25^{\circ}C$	-	42	-	$\mu V/V_O$
Ripple Rejection	RR	$f = 120Hz$ $V_O = 8V$ to $18V$	62	73	-	dB
Dropout Voltage	V_{Drop}	$I_O = 1A$, $T_J = +25^{\circ}C$	-	2	-	V
Output Resistance	r_O	$f = 1KHz$	-	15	-	m Ω
Short Circuit Current	I_{SC}	$V_I = 35V$, $T_A = +25^{\circ}C$	-	230	-	mA
Peak Current	I_{PK}	$T_J = +25^{\circ}C$	-	2.2	-	A

Note:

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



+5V-Powered, Multichannel RS-232 Drivers/Receivers

General Description

The MAX220–MAX249 family of line drivers/receivers is intended for all EIA/TIA-232E and V.28/V.24 communications interfaces, particularly applications where $\pm 12V$ is not available.

These parts are especially useful in battery-powered systems, since their low-power shutdown mode reduces power dissipation to less than $5\mu W$. The MAX225, MAX233, MAX235, and MAX245/MAX246/MAX247 use no external components and are recommended for applications where printed circuit board space is critical.

Applications

Portable Computers
Low-Power Modems
Interface Translation
Battery-Powered RS-232 Systems
Multidrop RS-232 Networks

Features

Superior to Bipolar

- ◆ Operate from Single +5V Power Supply (+5V and +12V—MAX231/MAX239)
- ◆ Low-Power Receive Mode in Shutdown (MAX223/MAX242)
- ◆ Meet All EIA/TIA-232E and V.28 Specifications
- ◆ Multiple Drivers and Receivers
- ◆ 3-State Driver and Receiver Outputs
- ◆ Open-Line Detection (MAX243)

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX220CPE	0°C to +70°C	16 Plastic DIP
MAX220CSE	0°C to +70°C	16 Narrow SO
MAX220CWE	0°C to +70°C	16 Wide SO
MAX220C/D	0°C to +70°C	Dice*
MAX220EPE	-40°C to +85°C	16 Plastic DIP
MAX220ESE	-40°C to +85°C	16 Narrow SO
MAX220EWE	-40°C to +85°C	16 Wide SO
MAX220EJE	-40°C to +85°C	16 CERDIP
MAX220MJE	-55°C to +125°C	16 CERDIP

Ordering Information continued at end of data sheet.

*Contact factory for dice specifications.

Selection Table

Part Number	Power Supply (V)	No. of RS-232 Drivers/Rx	No. of Ext. Caps	Nominal Cap. Value (μF)	SHDN & Three-State	Rx Active in SHDN	Data Rate (kbps)	Features
MAX220	+5	2/2	4	0.1	No	—	120	Ultra-low-power, industry-standard pinout
MAX222	+5	2/2	4	0.1	Yes	—	200	Low-power shutdown
MAX223 (MAX213)	+5	4/5	4	1.0 (0.1)	Yes	✓	120	MAX241 and receivers active in shutdown
MAX225	+5	5/5	0	—	Yes	✓	120	Available in SO
MAX230 (MAX200)	+5	5/0	4	1.0 (0.1)	Yes	—	120	5 drivers with shutdown
MAX231 (MAX201)	+5 and +7.5 to +13.2	2/2	2	1.0 (0.1)	No	—	120	Standard +5/+12V or battery supplies; same functions as MAX232
MAX232 (MAX202)	+5	2/2	4	1.0 (0.1)	No	—	120 (64)	Industry standard
MAX232A	+5	2/2	4	0.1	No	—	200	Higher slew rate, small caps
MAX233 (MAX203)	+5	2/2	0	—	No	—	120	No external caps
MAX233A	+5	2/2	0	—	No	—	200	No external caps, high slew rate
MAX234 (MAX204)	+5	4/0	4	1.0 (0.1)	No	—	120	Replaces 1488
MAX235 (MAX205)	+5	5/5	0	—	Yes	—	120	No external caps
MAX236 (MAX206)	+5	4/3	4	1.0 (0.1)	Yes	—	120	Shutdown, three state
MAX237 (MAX207)	+5	5/3	4	1.0 (0.1)	No	—	120	Complements IBM PC serial port
MAX238 (MAX208)	+5	4/4	4	1.0 (0.1)	No	—	120	Replaces 1488 and 1489
MAX239 (MAX209)	+5 and +7.5 to +13.2	3/5	2	1.0 (0.1)	No	—	120	Standard +5/+12V or battery supplies; single-package solution for IBM PC serial port
MAX240	+5	5/5	4	1.0	Yes	—	120	DIP or flatpack package
MAX241 (MAX211)	+5	4/5	4	1.0 (0.1)	Yes	—	120	Complete IBM PC serial port
MAX242	+5	2/2	4	0.1	Yes	✓	200	Separate shutdown and enable
MAX243	+5	2/2	4	0.1	No	—	200	Open-line detection simplifies cabling
MAX244	+5	8/10	4	1.0	No	—	120	High slew rate
MAX245	+5	8/10	0	—	Yes	✓	120	High slew rate, int. caps, two shutdown modes
MAX246	+5	8/10	0	—	Yes	✓	120	High slew rate, int. caps, three shutdown modes
MAX247	+5	8/9	0	—	Yes	✓	120	High slew rate, int. caps, nine operating modes
MAX248	+5	8/8	4	1.0	Yes	✓	120	High slew rate, selective half-chip enables
MAX249	+5	6/10	4	1.0	Yes	✓	120	Available in quad flatpack package



Maxim Integrated Products 1

For pricing, delivery, and ordering information, please contact Maxim/Dallas Direct! at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.

MAX220-MAX249

+5V-Powered, Multichannel RS-232 Drivers/Receivers

ABSOLUTE MAXIMUM RATINGS—MAX220/222/232A/233A/242/243

Supply Voltage (V _{CC})	-0.3V to +6V	20-Pin Plastic DIP (derate 8.00mW/°C above +70°C) ..	440mW
Input Voltages		16-Pin Narrow SO (derate 8.70mW/°C above +70°C) ...	696mW
T _{IN}	-0.3V to (V _{CC} - 0.3V)	16-Pin Wide SO (derate 9.52mW/°C above +70°C)	762mW
R _{IN} (Except MAX220)	±30V	18-Pin Wide SO (derate 9.52mW/°C above +70°C)	762mW
R _{IN} (MAX220)	±25V	20-Pin Wide SO (derate 10.00mW/°C above +70°C)	800mW
T _{OUT} (Except MAX220) (Note 1)	±15V	20-Pin SSOP (derate 8.00mW/°C above +70°C)	640mW
T _{OUT} (MAX220)	±13.2V	16-Pin CERDIP (derate 10.00mW/°C above +70°C)	800mW
Output Voltages		18-Pin CERDIP (derate 10.53mW/°C above +70°C)	842mW
T _{OUT}	±15V	Operating Temperature Ranges	
R _{OUT}	-0.3V to (V _{CC} + 0.3V)	MAX2 AC , MAX2 C	0°C to +70°C
Driver/Receiver Output Short Circuited to GND	Continuous	MAX2 AE , MAX2 E	-40°C to +85°C
Continuous Power Dissipation (T _A = +70°C)		MAX2 AM , MAX2 M	-55°C to +125°C
16-Pin Plastic DIP (derate 10.53mW/°C above +70°C)	842mW	Storage Temperature Range	-65°C to +160°C
18-Pin Plastic DIP (derate 11.11mW/°C above +70°C)	889mW	Lead Temperature (soldering, 10s)	+300°C

Note 1: Input voltage measured with T_{OUT} in high-impedance state, $\overline{\text{SHDN}}$ or V_{CC} = 0V.

Note 2: For the MAX220, V₊ and V₋ can have a maximum magnitude of 7V, but their absolute difference cannot exceed 13V.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS—MAX220/222/232A/233A/242/243

(V_{CC} = +5V ±10%, C1–C4 = 0.1μF, MAX220, C1 = 0.047μF, C2–C4 = 0.33μF, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
RS-232 TRANSMITTERS						
Output Voltage Swing	All transmitter outputs loaded with 3kΩ to GND		±5	±8		V
Input Logic Threshold Low				1.4	0.8	V
Input Logic Threshold High	All devices except MAX220		2	1.4		V
	MAX220: V _{CC} = 5.0V		2.4			
Logic Pull-Up/Input Current	All except MAX220, normal operation			5	40	μA
	SHDN = 0V, MAX222/242, shutdown, MAX220			±0.01	±1	
Output Leakage Current	V _{CC} = 5.5V, SHDN = 0V, V _{OUT} = ±15V, MAX222/242			±0.01	±10	μA
	V _{CC} = SHDN = 0V, V _{OUT} = ±15V			±0.01	±10	
Data Rate				200	116	kbps
Transmitter Output Resistance	V _{CC} = V ₊ = V ₋ = 0V, V _{OUT} = ±2V		300	10M		Ω
Output Short-Circuit Current	V _{OUT} = 0V		±7	±22		mA
RS-232 RECEIVERS						
RS-232 Input Voltage Operating Range					±30	V
RS-232 Input Threshold Low	V _{CC} = 5V	All except MAX243 R2 _{IN}	0.8	1.3		V
		MAX243 R2 _{IN} (Note 2)	-3			
RS-232 Input Threshold High	V _{CC} = 5V	All except MAX243 R2 _{IN}		1.8	2.4	V
		MAX243 R2 _{IN} (Note 2)		-0.5	-0.1	
RS-232 Input Hysteresis	All except MAX243, V _{CC} = 5V, no hysteresis in shdn.		0.2	0.5	1	V
	MAX243			1		
RS-232 Input Resistance			3	5	7	kΩ
TTL/CMOS Output Voltage Low	I _{OUT} = 3.2mA			0.2	0.4	V
TTL/CMOS Output Voltage High	I _{OUT} = -1.0mA		3.5	V _{CC} - 0.2		V
TTL/CMOS Output Short-Circuit Current	Sourcing V _{OUT} = GND		-2	-10		mA
	Shrinking V _{OUT} = V _{CC}		10	30		

+5V-Powered, Multichannel RS-232 Drivers/Receivers

MAX220-MAX249

ELECTRICAL CHARACTERISTICS—MAX220/222/232A/233A/242/243 (continued)

(V_{CC} = +5V ±10%, C1–C4 = 0.1μF, MAX220, C1 = 0.047μF, C2–C4 = 0.33μF, T_A = T_{MIN} to T_{MAX}, unless otherwise noted.)

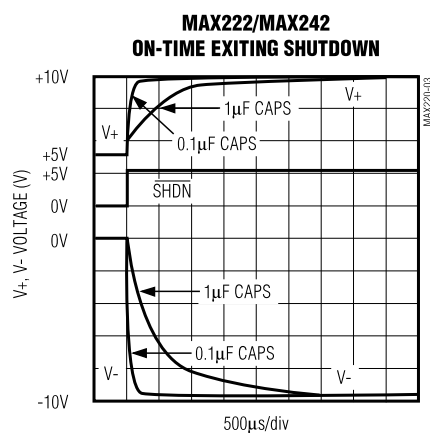
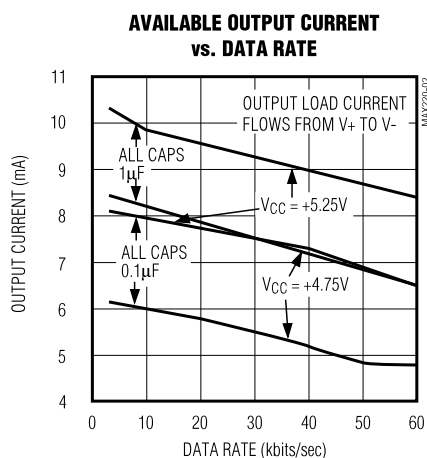
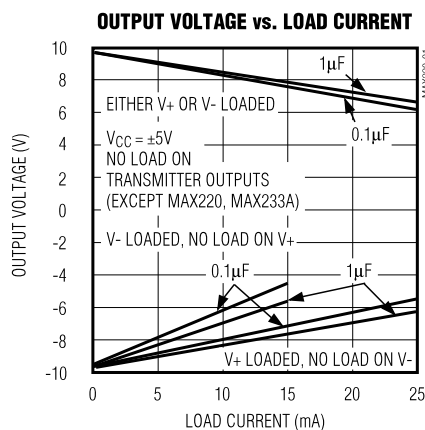
PARAMETER	CONDITIONS		MIN	TYP	MAX	UNITS
TTL/CMOS Output Leakage Current	$\overline{\text{SHDN}} = V_{CC}$ or $\overline{\text{EN}} = V_{CC}$ ($\overline{\text{SHDN}} = 0V$ for MAX222), $0V \leq V_{OUT} \leq V_{CC}$			±0.05	±10	μA
$\overline{\text{EN}}$ Input Threshold Low	MAX242			1.4	0.8	V
$\overline{\text{EN}}$ Input Threshold High	MAX242		2.0	1.4		V
Operating Supply Voltage			4.5		5.5	V
V _{CC} Supply Current ($\overline{\text{SHDN}} = V_{CC}$), Figures 5, 6, 11, 19	No load	MAX220		0.5	2	mA
		MAX222/232A/233A/242/243		4	10	
	3kΩ load both inputs	MAX220		12		
		MAX222/232A/233A/242/243		15		
Shutdown Supply Current	MAX222/242	T _A = +25°C		0.1	10	μA
		T _A = 0°C to +70°C		2	50	
		T _A = -40°C to +85°C		2	50	
		T _A = -55°C to +125°C		35	100	
$\overline{\text{SHDN}}$ Input Leakage Current	MAX222/242				±1	μA
$\overline{\text{SHDN}}$ Threshold Low	MAX222/242			1.4	0.8	V
$\overline{\text{SHDN}}$ Threshold High	MAX222/242		2.0	1.4		V
Transition Slew Rate	C _L = 50pF to 2500pF, R _L = 3kΩ to 7kΩ, V _{CC} = 5V, T _A = +25°C, measured from +3V to -3V or -3V to +3V	MAX222/232A/233A/242/243	6	12	30	V/μs
		MAX220	1.5	3	30	
Transmitter Propagation Delay TLL to RS-232 (Normal Operation), Figure 1	t _{PHLT}	MAX222/232A/233A/242/243		1.3	3.5	μs
		MAX220		4	10	
	t _{PLHT}	MAX222/232A/233A/242/243		1.5	3.5	
		MAX220		5	10	
Receiver Propagation Delay RS-232 to TLL (Normal Operation), Figure 2	t _{PHLR}	MAX222/232A/233A/242/243		0.5	1	μs
		MAX220		0.6	3	
	t _{PLHR}	MAX222/232A/233A/242/243		0.6	1	
		MAX220		0.8	3	
Receiver Propagation Delay RS-232 to TLL (Shutdown), Figure 2	t _{PHLS}	MAX242		0.5	10	μs
	t _{PLHS}	MAX242		2.5	10	
Receiver-Output Enable Time, Figure 3	t _{ER}	MAX242		125	500	ns
Receiver-Output Disable Time, Figure 3	t _{DR}	MAX242		160	500	ns
Transmitter-Output Enable Time ($\overline{\text{SHDN}}$ Goes High), Figure 4	t _{ET}	MAX222/242, 0.1μF caps (includes charge-pump start-up)		250		μs
Transmitter-Output Disable Time ($\overline{\text{SHDN}}$ Goes Low), Figure 4	t _{DT}	MAX222/242, 0.1μF caps		600		ns
Transmitter + to - Propagation Delay Difference (Normal Operation)	t _{PHLT} - t _{PLHT}	MAX222/232A/233A/242/243		300		ns
		MAX220		2000		
Receiver + to - Propagation Delay Difference (Normal Operation)	t _{PHLR} - t _{PLHR}	MAX222/232A/233A/242/243		100		ns
		MAX220		225		

Note 3: MAX243 R2_{OUT} is guaranteed to be low when R2_{IN} is ≥ 0V or is floating.

+5V-Powered, Multichannel RS-232 Drivers/Receivers

Typical Operating Characteristics

MAX220/MAX222/MAX232A/MAX233A/MAX242/MAX243



+5V-Powered, Multichannel RS-232 Drivers/Receivers

MAX220-MAX249

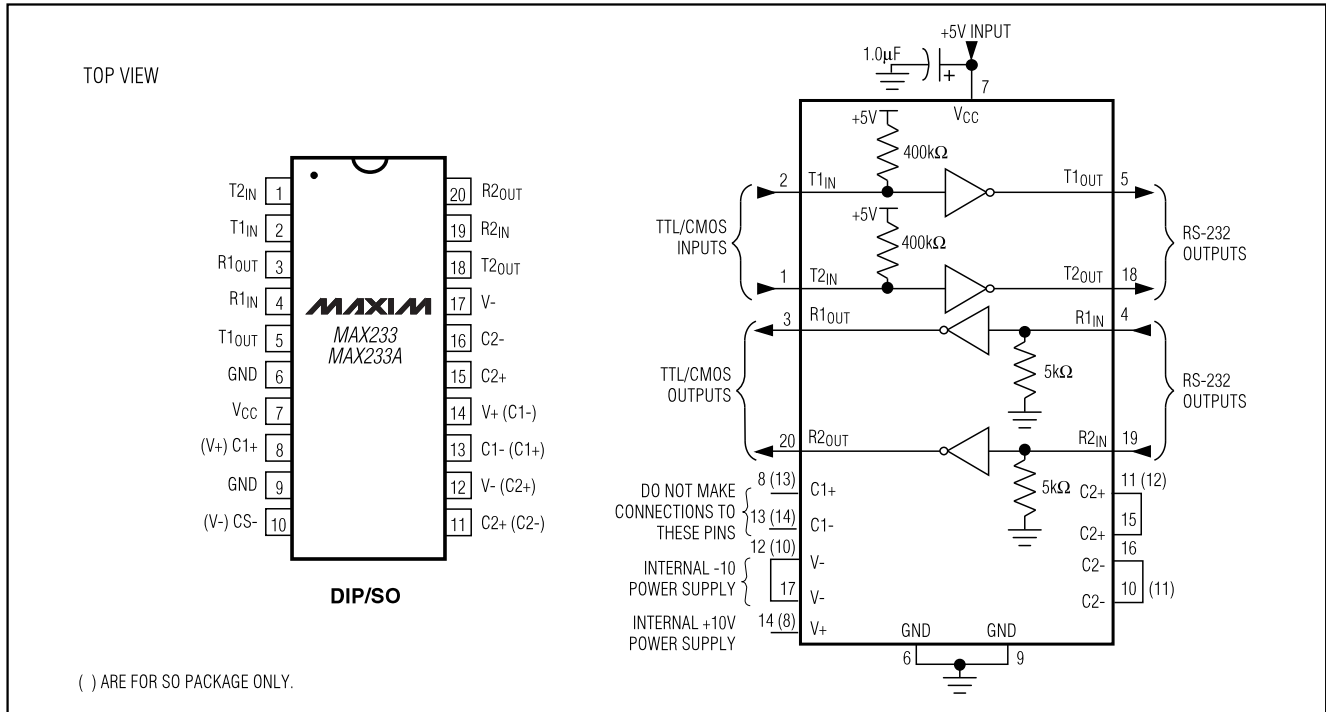


Figure 11. MAX233/MAX233A Pin Configuration and Typical Operating Circuit

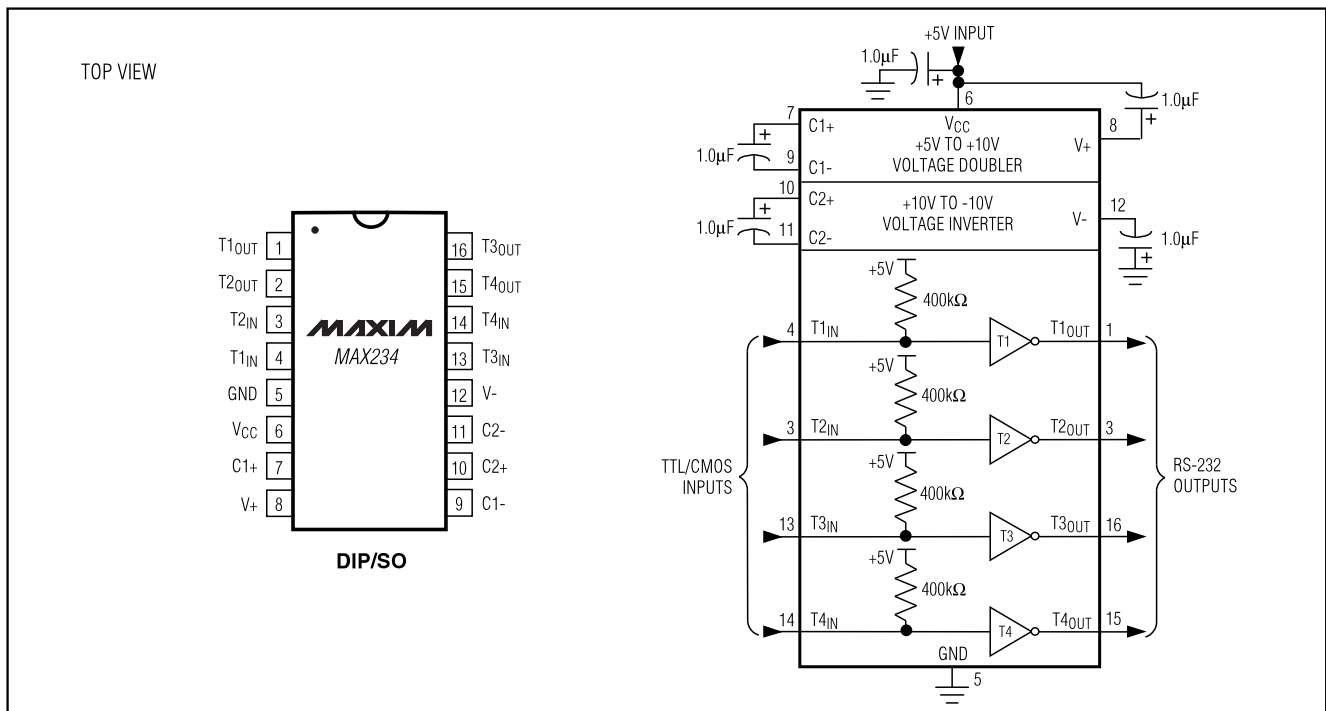


Figure 12. MAX234 Pin Configuration and Typical Operating Circuit