DIGITAL TEMPERATURE INDICATOR USING MICROCONTROLLER

Project Report

Submitted by
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in partial fulfillment of the requirements
for the award of the degree of
BACHELOR OF ENGINEERING IN
ELECTRICAL AND ELECTRONICS ENGINEERING
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Department of Electrical and Electronics Engineering

KUMARAGURU COLLEGE OF TECHNOLOGY
COIMBATORE – 641 006

Certificate

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CERTIFICATE

This is to certify that the project report entitled

DIGITAL TEMPERATURE INDICATOR USING MICROCONTROLLER

has been submitted by

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BACHELOR OF ENGINEERING

with specilisation in

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of the Bharathiar University
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HRD/PROJ-2001
14-March-2001

TO WHOMSOEVER IT MAY CONCERN

This is to certify that the following students doing final year BE (EEE) at Kumaraguru College of Technology – Coimbatore, underwent project work in our organisation.

⇒ *Jacob Tomy*
⇒ *P Tharakeshwari*

The details are :

- Title of Project : *DIGITAL TEMPERATURE INDICATOR USING MICROCONTROLLER*
- Period of Project : *December 2000 to March 2001*
- Department : *Product Engineering (Electronics)*
- Attendance & Conduct : *Good*

We wish them the very best for a bright future.

ANTHONY THIAGARAJAN
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Synopsis

SYNOPSIS

Temperature indicators are almost an indispensable component in the modern automobile industry. They are required to indicate and in many cases to control the temperature of the automobile engines. Monitoring of engine temperature cannot be done with as excess temperature could result in seizure of the automobile engines.

Conventional temperature indicators use temperature dependent resistors, the output of which is scaled and given to an analog indicator. In this project 'Digital Temperature Indicator', it is proposed to use a micro-controller interfaced with a LCD for the indication.

The incorporation of micro-controller in this system provides for accurate, reliable and automatic monitoring and almost free from other external disturbing factors.

In this project a thermistor senses the temperature variations and outputs it to an Hour Meter LCD with the aid of an Operational amplifier(LM393), and a micro-controller(57P21208QFP). A regulated supply using IC7805 is also designed to provide the supply voltage for the IC's. This makes the hardware part. The software part consists of an assembly language program for the micro-controller written in SAM assembly code.

This unit will be of immense use in the automobile industry for the accurate and reliable indication of engine temperature.

Contents

CONTENTS

Introduction

CHAPTER 1

INTRODUCTION

Pricol is a leading automotive instruments manufacturer in India and a pioneer in multi-engineering products for various applications. As a new addition to it's range of products is the micro-controller based digital temperature indicator.

Most digital devices of the modern era play an important role in various fields such as in automatic controls and in measuring readings and many other purposes. Digital devices are used because of their simplicity in design, ruggedness, accuracy and also still because they form compact units. With the use of a micro-controller in a circuit various functions can be performed on the same single chip, thereby reducing the need for a large number of components and consequently the size of the unit.

The micro-controller based digital temperature indicator is designed to indicate the exact temperature of the automobile engine during the running condition. This is achieved by monitoring the slightest changes in temperature and giving it to a micro-controller. The micro-controller drives the LCD and the temperature is indicated on the LCD. It also has the advantage that changes in temperature are indicated in about 0.4 sec.

The entire unit can be split into two parts viz., a hardware part and a software part.

The hardware part consists of the following major components:-

1.) A regulated power supply which gives +5V at it's output.

2.) Samsung 4-bit micro-controller(KS57C21208QFP).

3.) Digital to Analog Converter along with CD4040 – 12-bit binary counter.

4.) LM393 – Low Power Low Offset Voltage Dual Comparator.

5.) LCD – to display the recorded temperature.

6.) Clock circuit Unit.

7.) Reset Unit.

8.) Sensor Unit.

The software part consists of an assembly level language for the micro-controller written in SAM assembly code.

History of Temperature Indicator

CHAPTER 2

HISTORY OF TEMPERATURE INDICATOR

2.1 PREVIOUS MODEL OF TEMPERATURE INDICATOR

The previous model microprocessor based "Temperature Indicating System" had certain disadvantages:-

- It needed separate peripheral devices.
- Separate LCD driver unit.
- Has low operating temperature.
- The resulting kit was large in size and occupied more space in the vehicles, since it will have each unit separately.
- The hardware design should be connected externally to the microprocessor which even occupies more space and then then the time taken to display from one temperature to another will also be more.

Another model with "Micro-controller based Temperature indicator" or "microprocessor based temperature indicator" uses a fluid or water in a beaker which will be heated by a heater. A stirrer is placed to stir the liquid.

This setup will be connected to the microprocessor or the micro-controller which will be programmed to indicate the temperature. This method is not suitable to be installed in automobiles.

The temperature range that will be displayed will also be very low.

2.2 REVISED MODEL OF TEMPERATURE INDICATOR

This is a foolproof rugged model developed to take care of most of the problems of the old model. Listed below are some of the advantages of our project, Digital Temperature Indicator using micro-controllers.

- Compact in size.
- Low power consumption.
- The memory ranges : 512x4-bit ROM.
- The clock pulse is generated by the micro-controller itself.
- The micro-controller has the operating temperature of –40C to 60C.
- Suitable for use in automobiles.
- Compatibility and high efficiency.
- Even a high temperature is displayed very accurately and in a very short span of time(0.4 sec).
- No chemical components like fluid is used.
- The power supply circuitry is so designed as to withstand the spikes and jitters from the battery of the vehicle.

Block Diagram and Functional Description

CHAPTER 3

FUNCTIONAL BLOCK DIAGRAM

The overall block diagram of the project is shown in fig. 3.9

The block diagram consists of the following units :

3.1 Regulated Power Supply Unit.

3.2 Micro-controller Unit.

3.3 Reset Unit.

3.4 Digital to Analog converter Unit.

3.5 Comparator Unit.

3.6 Sensor Unit.

3.7 Clock circuitry Unit.

3.8 LCD module.

3.1 The hardware setup is fitted in the vehicle and draws it's power from the battery(17-32 volt DC) through a circuit comprising of a linear series voltage regulator. The ***regulated power supply*** unit gives an output voltage of +5V and is required with an accepted tolerance of 10%.

3.2 The ***micro-controller*** unit is the brain of the system from where everything is controlled and monitored. The micro-controller KS57C21208 is of the Samsung company and is a single chip CMOS one. This chip has been designed for high performance using Samsung's newest 4-bit CPU core SAM47. The advanced CMOS technology also provides for low power consumption.

3.3 To prevent the micro-controller from awry the appropriate ***reset unit*** circuitry is incorporated to generate a power-on-reset. This starts the hardware initialization and ensures orderly software start-up. If this unit is not loaded then the micro-controller's program counter may have garbage loaded into it and it will not get restarted correctly. Reset sequence takes 20 cycles from the time the reset pulse is released. During RESET, RAM contents remain unchanged.

3.4 The ***digital to analog converter(DAC)*** unit is the main part of the hardware design. The input n- binary word is combined with a reference voltage to give an analog output signal. The output of a 12 stage binary counter is given to the DAC. To the clock pin of the binary counter CD4040 is given clock pulses which is provided by the micro-controller itself.

The software is written to produce each pulse in 100micro sec. Also the display time from one temperature to the other temp is 0.4sec, this is achieved by means of the DAC circuit or the unit. The output of the DAC will be a ramp which will be of 5V reference voltage, with 4096 steps. Since each step takes 100 microsec, 4096 steps takes = 4096x100microsec = 0.4 sec.

In order to get this time accuracy and proper efficiency this R-2R ladder DAC circuit is chosen.

3.5 The ***comparator unit*** together with the DAC acts as a major portion in the block diagram. Only with the help of the output of the comparator circuit the respective temperature is calculated in the micro-controller chip through the means of the software developed for it.

The comparator unit requires two input signals. One of the input signal to the comparator is the output of the DAC circuit i.e., the ramp signal. Another input signal to the comparator unit is the input voltage from the sensor unit(thermistor).

The comparator compares the two input signals and then gives the output as the input to one of the port of the micro-controller. By means of the time period of the output square wave, the counter which is made to run in the micro-controller unit counts the ON time period of the output pulse. Knowing the ON time periods the respective temperatures will be calculated.

3.6 The ***sensor unit*** is the heart of the 'Digital Temperature Indicator'. The sensor unit is one which senses the engine temperature of the vehicle by means of the thermistor and sends it as ane of the input voltages to the comparator the other being the output of the DAC.

The thermistor which is used here is a NTC thermistor ie., negative temperature co-efficient of resistance. This thermistor has the capacity to sense very high temperatures. An NTC thermistor is chosen because, as the temperature increases, resistance decreases and the voltage decreases. Also still this type is well suited for vehicles. Therefore this type is preferred over PTC.

Since we are not using the engine to show the display of this project, we designed the sensor circuit with the help of the potentiometer along with the resistors which is required for the supply voltage of +5V.

The temperature that is displayed using this project is within the range of –30C to +60C with the help of the potentiometer used. This potentiometer has a rating of 100K. Temperature display for high heat engines can be done by placing appropriate ranging NTC thermistor.

The table for the temperature and resistance values and the graph between them is shown in chapter 4.

As regards to the ***clock circuit*** , since we are using the main system clock in this project, the clock circuit is provided in such a way as to give the respective clock frequency to the micro-controller(4MHz), top produce the clock pulse for the DAC circuit in the range of 100microses. The description of the circuit is given in chapter 4.

The ***LCD module*** used for display is an Hour Meter LCD which displays alphanumeric, Japanese characters and symbols. The built in controller and driver provide convenient connectivity between the LCD and the micro-controller. All the functions required for the LCD drive are internally provided. The CMOS technology makes the drive ideal for applications in hand held portable and other battery provided instruments. The segment and common pins from the micro-controller is connected to the respective LCD module pins. The segment codes are given in the program. The details are given in the appendix.

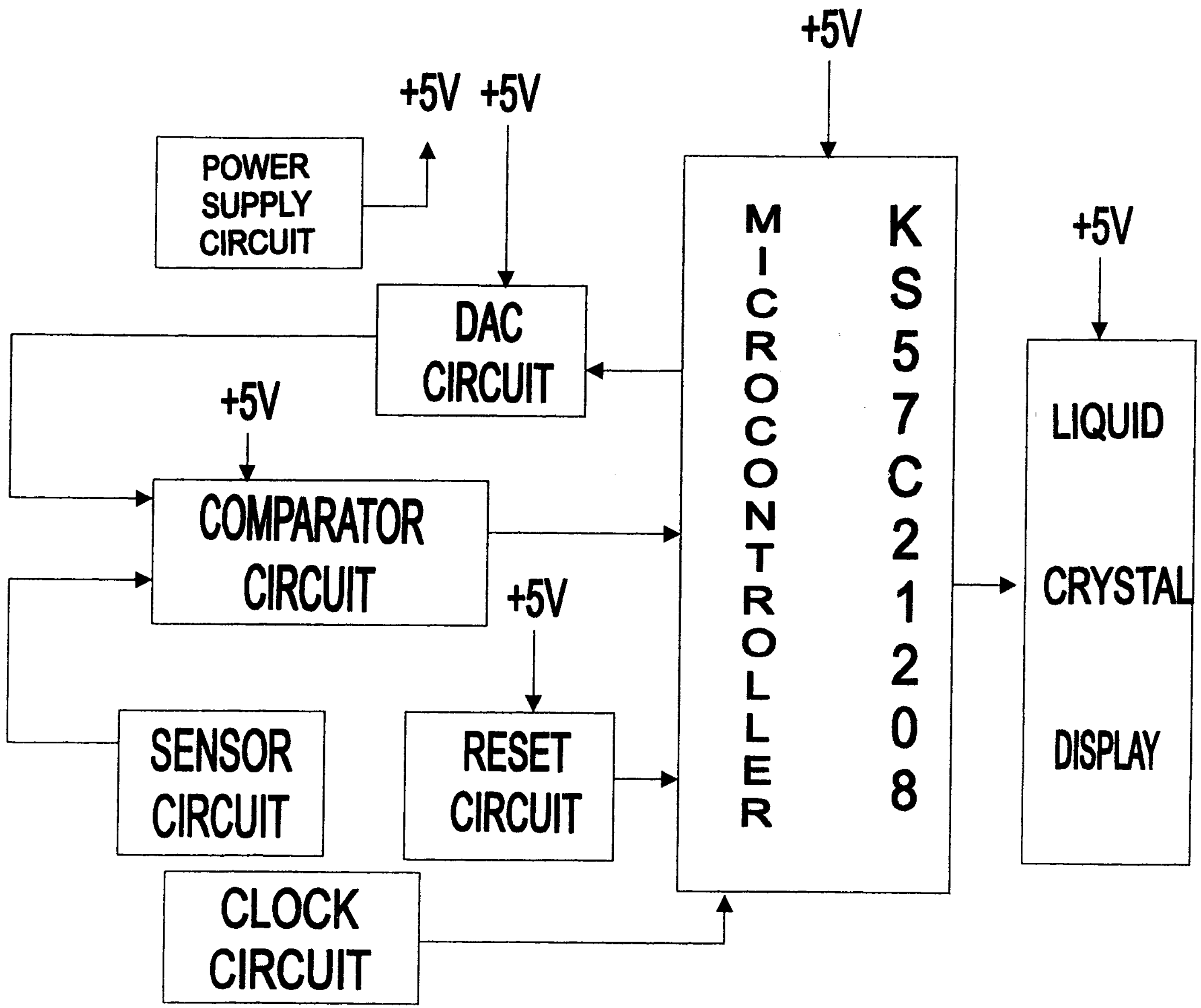


Fig 3.9 Functional Block Diagram of Digital Temperature Indicator

Hardware Description

CHAPTER –4

HARDWARE UNIT

This chapter presents a discussion on the on the overall block diagram of the project and the various components of the hardware used. The hardware is perfectly simple but very effective. The components have been chosen in such a way as to precisely fit in and fulfill the requirements of the project.

OVERALL CIRCUIT DIAGRAM AND IT'S DESCRIPTION

The overall circuit diagram is shown in fig 4.9 . The unit consists of the following parts :-

1.) A regulated power supply which gives +5V at it's output.

2.) Samsung 4-bit micro-controller 57P21208QFP.

3.) CD4040 – 12-bit binary counter.

4.) DAC Circuitry at the output of the 12-bit binary counter.

5.) LM393 – Low Power Low Offset Voltage Dual Comparator.

6.) Reset Circuitry.

7.) Sensor Circuitry.

8.) Clock circuitry.

9.) LCD module.

4.1 REGULATED POWER SUPPLY CIRCUITRY:

The regulated power supply has at it's input(17-32V D.C.) provided from the car battery. The regulated power supply circuitry is shown in fig 4.1. A diode (IN4007) is connected to the battery –ve in such a way as to protect the circuit in case of reversal of connections of the battery at the input. Thus the diode acts as a polarity protection diode.

A LED of 5mA is connected across the diode to indicate the presence of supply. The resistor (1.2KΩ) connected between the battery +ve terminal and one end of the LED provides the current required for the LED to glow.

The resistors 180Ω and 330Ω prevent the excess flow of current in the circuit. The polyester capacitor (0.022 μF/63V) is connected across 180Ω resistor end and the GND terminals to reduce noise which is externally generated. Also, the capacitor is normally selected with voltage range double than the input supply voltage. So the 63V rating capacitor is chosen.

The zener diode (20V/1W) clamps the voltage down to 20V. The linear series voltage regulator (LM 7805) is used to provide a regulated output supply of +5V at the point Vcc (Output of regulator). Prior to point Vcc and GND are connected two capacitors (0.1μF/63V) that filter the noise from the supply. Further details of regulator – 7805 is given in the appendix.

4.2 MICRO-CONTROLLER UNIT:

The micro-controller (KS57C21208) has more robust features added to enhance performance and enable application technologies. The improved features include new watch dog timer, low power modes, clock module, ROM security, serial communication interface, timers, interrupts, output ports and LCD driver. The micro-controller is widely used in automotive applications and has proved to be very apt for the automobile industry. The block diagram ofthe micro-controller is shown in fig 4.2

The KS57C21208 single-chip CMOS microcontroller has been designed for high performance using Samsung's newest 4-bit CPU core, SAM47 (Samsung Arrangeable Microcontrollers).

With an up-to-96-dot LCD direct drive capability flexible 16-bit timer/counter, and 4-chanel comparator, the KS57C21208 offers an excellent design solution for a low CDP and a card reader.

Up to 28 pins of the 44-pin QFP or up to 26 pins of the 42-pin SDIP package can be dedicated to I/O. Eight vectored interrupts provide fast response to internal and external events. In addition, the KS57C21208's advanced CMOS technology provides for low power consumption.

OTP

The KS57C21208 microcontroller is also available in OTP (One Time Programmable) version, KS57P21208microcontroller has an on-chip 8K-byte one-time-programable EPROM instead of masked ROM. The KS57P21208 is comparable to KS57C21208, both in function and in pin configuration.

CPU :

The KS57C21208 micro-controller's 4-bit CPU has an arithmetic and logic unit, program status word, instruction decoder, stack pointer, program counter and interrupt control block. The CPU uses the register file as working registers, accessed on the internal bus on it's bus cycle.

INTERRUPTS :

Three kinds of interrupts are supported.

1. Internal interrupts generated by on-chip processes.
2. External interrupts generated by external peripheral devices.
3. Quasi interrupts used for edge detection and as a clock source.

For further details of CPU please refer to the appendix.

PROGRAM MEMORY:

Program memory is nothing but ROM. ROM maps in this micro-controller are mask programmable at the factory. The devices' 8, 192x8-bit program memory has three areas that are directly addressable by the program counter(PC).

DATA MEMORY :

Data memory is nothing but RAM. The data memory areas has three banks namely,

1. Bank 0
2. Bank 1
3. Bank 2

To support program control of peripheral hardware, I/O addresses for peripherals are memory mapped to bank –15 of the RAM. Further details of RAM, ROM and memory mapping are given in the appendix.

TIMER :

The KS57C21208 micro-controller has three counter and timer/counter modules.

- 8-bit basic timer.
- 16-bit timer counter.
- Watch dog timer(WT).

The overall functions of the timers are

- To generate interrupt request at a fixed time interval
- Used to determine clock oscillation stabilisation time.
- To generate clock signal that can be used by the serial I/O interface.
- To generate a clock signal for the LCD controller.

The timer has many registers in it. Further details of the timer are given in the appendix.

INPUT/OUTPUT PORTS :

The KS57C21208 module has 8 ports. There are a total of 26 configurable I/O pins (42pin SDIP, 44-pinQFP) and 2 O/P. Pin addresses for all the ports are mapped to Bank 15 of the RAM.

The 8-bit ports are ports 0,1,2,3,4,5,6 and 7. Ports 0,1,2,5,6 and 7 are 4-bit I/O ports. Port-3 is a 2-bit I/O port and port-4 is a 2-bit output port. Each of the ports can be programmed bit by bit to function as either a digital input or a digital output port.

Further details are given in the appendix.

COMPARATOR :

Port 2.0, port 2.1, port 2.2 and port 2.3 can be used as analog input port for a comparator. The reference voltage for the 4-channel comparator can be supplied internally or externally at port 2.3

The comparator module has the following components :

- Comparator.
- Internal reference voltage generator (4-bit resolution).
- External reference voltage source at port 2.3.
- Comparator mode register(CMOD).
- Comparator result register(CMPREG).

Further details of the comparator are given in the appendix.

OTHER DETAILS :

The micro-controller package is a 44-pinQFP. The pin diagram and description are given in the appendix.

- Pin 5(Vdd) of the micro-controller is given power supply from the regulator output Vcc and pin 6(Vss) is grounded.
- Pin 9 of the micro-controller is used as a test pin. A resistor of 100KΩ is connected to it.
- Pin 16 (Port 0.0) of the micro-controller is used to generate and give the clock pulse to the 10^{th} pin of CD4040.
- The output of the micro-controller is connected to the 39^{th} pin (Port1.0) of the micro-controller.

4.3 RESET CIRCUITRY :

The reset circuitry is shown in fig. 4.3.

- The reset circuitry is connected to the 12^{th} pin of the micro-controller. This circuit is given power supply from the point Vcc of the power supply.
- The RC network of 10KΩ and 10μF provides a power-up rise time.
- The 1KΩ resistor protects the reset pin of the micro-controller from the discharging of the capacitor directly into the pin when the pin is pulled low internally.

- The diode (IN4148) allows the capacitor to discharge quickly during a burn out or power – OFF situations.

The operations during a reset are :

- Initializes CPU register and the program counter.
- Starts the program execution with the op-code fetch from the address pointed to by the program counter.

4.4 DAC CIRCUITRY (CD4040 WITH R-2R LADDER NETWORK) :

The DAC circuitry is shown in fig 4.4.

This is one of the most important circuit in the 'Digital Temperature Indicator'.

The IC CD4040 along with the R-2R ladder network acts as the Digital to Analog converter.

Pin 16 of CD4040 is given the power supply +5V from the output of the regulator Vcc.

Capacitor 0.1µF is connected across pin 16(Vdd) and pin 8 (GND) of CD4040, to prevent any spikes or jitters from entering into it.

The pins 1,2,3,4,5,6,7,9,13,14,15 of CD4040 acts as the converter part or 12-bit binary counter.

Pin 11 of CD4040 is the RESET pin and is connected to the port 0.1 of the micro-controller

Pin 10 (CLK) of CD4040 is connected to the port 0.0 of the micro-controller from where the clock pulse is generated.

R-2R ladder network is connected across the pins 1,2,3,4,5,6,7,9,13,14 and 15 of CD4040 using 10KΩ and 20KΩ resistors.

Further details of CD4040 are given in the appendix.

As shown in fig. 4.4 of the DAC circuit, the output of the DAC is taken at the junction of 10KΩ and 20KΩ resistors connected across pin 1.

The clock pulse is generated every 100μ sec from the micro-controller.

Fig. 4.5 shows the input to CD4040(DAC) and the output from CD4040(DAC).

The input to the DAC is the square pulse and the output has the voltage of +5V. the ramp output is shown in the form of steps in fig. 4.6.

Resolution of the converter $= 2^N$

$= 2^{12}$ (Since 12-bit converter)

$= 4096.$

As we have seen the resolution of the 12-bit counter is 4096 and the total voltage is 5V, we can write it as,

4096 counts = 5V.

So, 1 count = 5/4096

= 1.22 mV.

Therefore the ramp generated at the output has 4096 steps. The voltage range of each step is 1.22mV. As we have seen in the introduction, the time accuracy i.e., the time interval between the display of one temperature and the other temperature is got by means of this converter circuit.

As it is seen in the fig 4.7, the output of the DAC consists of 4096 steps. One step is got for one clock pulse. So 5V is reached at the end of the 4096^{th} step.

Since the time period for one step is 100μ sec, 4096 steps will reach at the time of

4096x100μ sec = 409.6 m sec.

= 0.4 sec.

In order to get this accuracy of 0.4 sec, we used a 12-bit converter and we generated the clock pulse for 100μ sec for the same reason.

The display time from one temperature to another temperature is less than a second which is a major highlight of this project.

4.5 COMPARATOR CIRCUITRY (LM393) :

The comparator circuit is shown in fig. 4.5. The comparator IC we used is LM393. This device consists of two independent comparators. LM393 is mainly manufactured to demand automotive requirements.
Further details and pin configuration is given in the appendix.

Various connections in the circuit are :

- Pin 4 of the comparator is connected to the ground.
- Pin 8 of the comparator is given to the supply 5V from the output of the regulator Vcc.
- The 2 inputs required for the comparator are given in pins 2 and 3.
- The input Vref given to the pin3 of the comparator is the output of the converter. Thus the ramp of +5V is entering as one of the inputs of the comparator.
- The other input Vin is given through a voltage divider circuit.
- Pin 1 of the comparator acts as the output pin. The output waveform from the pin is given to port 1.0 of the micro-controller (39^{th} pin) which act as both Input/Output.
- A resistor 4.7KΩ is connected to the pin 1 of the comparator which is given +5V to ensure proper current flow through the output pulse.
- A capacitor (0.1μF) which is a decoupling capacitor is connected across pin 8 and pin 1 to prevent any spikes entering the output pulse. The capacitor (0.01μF) connected across pin1 and GND is also for the same purpose.
- A resistor (330KΩ) connected across pin3and pin 1 acts as feedback resistor.

Since the reference voltage 5V (Vref), is a ramp type, the input Vin should cut the ramp waveform within that 5V (or) at 5V. For this reason, the voltage divider circuit is designed with the resistors and the potentiometer to get a min of 0.5V, and a maximum of 4.5V, for the min and maximum values of the potentiometer(100KΩ) .

So we designed the resistor range with the formula :

$$V_o = \frac{V_{in} \times R2}{R1 + R2}$$

Another point in the display of the temperature is that, the temperature shown in the display is from –30C to +60C. So the minimum voltage 0.5 should be for –30C and the maximum voltage 5V should be for +60C.

In order to get R2 we need a parallel combination of resistors. In that, one resistor will be a variable resistor i.e., a potentiometer. The values of that potentiometer which should be multiplied by it's parallel resistor is taken from table 4.10.

The table 4.10 shown corresponds to the resistance values for the respective temperatures of the NTC thermistor (SIEMENS B 5786-1-S302-F40) that is used in our project.

The R1 resistance values and the POT's parallel resistor values when designed has been got as 6.2KΩ and 47KΩ.

Thus we got Vo of 4.5V when putting the POT's resistance value at 53KΩ and 0.5V when putting a resistance value of 746.4Ω. Thus we kept the POT in the range of 100KΩ.

The output voltage is given as one of the input(Vin) of the comparator. The voltage divider circuit is shown in fig 4.8.

The input and output waveforms of the comparator for various input voltages are shown in fig 4.11.

With the plot in fig 4.11 it is seen that, for varying input voltages, the ON time and the OFF time of the output pulse varies. This output is given to port 1.0 (pin39) of the micro-controller unit.

Thus the software is written in such a way that a check is made at the signal entering port 1.0. When the bit is set as 1 at this time, we will toggle the counter inside the micro controller and count the on time period and thus calculate the temperature in the following way.

Temp displayed = -30°C to 60°C

Hence total counts = 90 units.

4096 counts = 90°C

So 2048 counts = 45°C(2048x90/4096)

= 45°C - 30°C

= 15°C

Like this the temp will be calculated for different counts and the negative sign is set if the temp is below 0°C.

4.7 SENSOR CIRCUITRY

In this project the sensor circuit is a thermistor part. A thermistor is a device whose resistance value varies with temp. These devices have very high negative temp co-efficient of resistance.

We used NTC (negative temp co-efficient) thermistors, because the resistance change is gradual and more or less linear in this case. I n case of PTC thermistors the change is rather abrupt.

The NTC thermistor we used is SIEMENS B 5786-1-S302-F40 whose operating range is from –35°C to 65°C.

FEATURES OF THE THERMISTOR USED:

- Fast response
- Excellent long term stability
- Epoxy resin encapsulation and silver plated monel leads.

APPLICATIONS

- Heating and air-conditioning systems.
- Subjected to different climatic conditions.
- Industrial electronics and automotive electronics.

For the purpose of demonstration we design the sensor by the voltage divider circuitry using a potentiometer. But in practice this sensor will be kept in the close proximity of the automobile engine.

The thermistor has been checked and the temperature values are linear with the resistance values. The linearity between the temperature and the resistance has been shown in fig 4.12.

4.8 CLOCK CIRCUITRY:

There are two types of clocks in the micro controller namely

- Main system clock
- Sub system clock

The frequency which we are using is 4Mhz. The fig. 4.13 shows the clock circuit which we designed to produce the required clock frequency.

Connected across pin 7 (X out) and pin 8 (X in) of the micro-controller is a 4Mhz crystal.

Pins 7 and 8 are grounded through 22pF capacitors each.

The combination results in a LC oscillator circuit, which produces system clock frequency of 4Mhz.

Only with the help of this frequency the clock pulse of 100µ sec is given as input to the DAC circuit through Port 0.0.

4.9 LCD HOUR METER(LCD SK 001039-02C) :

Series digital panel meters are low cost, high performance indicators. The LCD used for display in this project is an hour meter LCD. The hour meter LCD provides a large easy to read display in a conventional size package. The hour meter LCD's are available in a variety of mounting styles and voltage ranges that will fit virtually any application. The LCD module can display alphanumeric and Japanese characters and symbols. The built –in controller and the driver provide connectivity between the LCD and the micro-controller. All the functions required for the LCD drive are internally provided. The CMOS technology makes the drive ideal for applications in hand held portable and other battery provided instruments. The segment and common pins from the micro-controller is connected to the respective LCD module pins.

The 16 – pin LCD module that has been used in this project is LCD SK 001039-02C.

The LCD driver is built in the micro-controller. It consists of 16 LCD segment display output pins, SEG0-SEG15 and 8 LCD common output pins, COM0-COM7. These pin configuration are given in the appendix in the pin configuration of KS57C21208.

These pins are connected to the respective pins of the LCD module.

- Pin 38(COM0) is connected to pin 1 of LCD.
- Pin 37(COM1) is connected to pin 2 of LCD
- Pin 36(COM2) is connected to pin 3 of LCD.
- Pin 35(COM3) is connected to pin 16 of LCD.
- Pin 19(SEG0) is connected to pin 4 of LCD.
- Pin 20(SEG1) is connected to pin 5 of LCD.
- Pin 21(SEG2) is connected to pin 6 of LCD.
- Pin 22(SEG3) is connected to pin 7 of LCD.
- Pin 23(SEG4) is connected to pin 8 of LCD.
- Pin 240(SEG5) is connected to pin 9 of LCD.
- Pin 25(SEG6) is connected to pin 10 of LCD.
- Pin 26(SEG7) is connected to pin 11 of LCD.
- Pin 27(SEG8) is connected to pin 12 of LCD.
- Pin 28(SEG9) is connected to pin 13 of LCD.
- Pin 29(SEG10) is connected to pin 14 of LCD.
- Pin 30(SEG11) is connected to pin 15 of LCD.

Display RAM are sent out through segment pins SEG0-SEG15 using the Direct Memory Access (DMA) method.

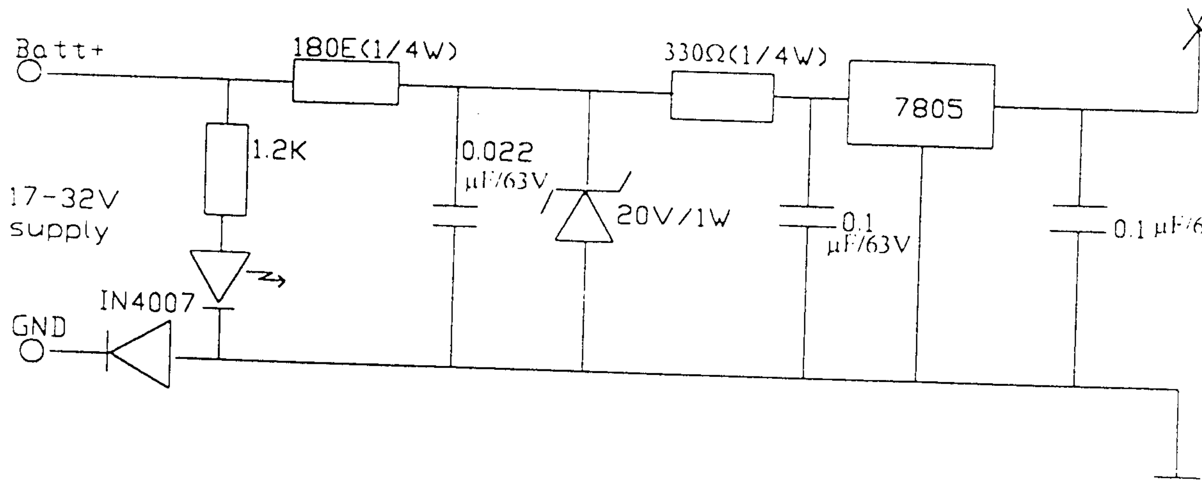


Fig. 4.1 Power Supply Circuit

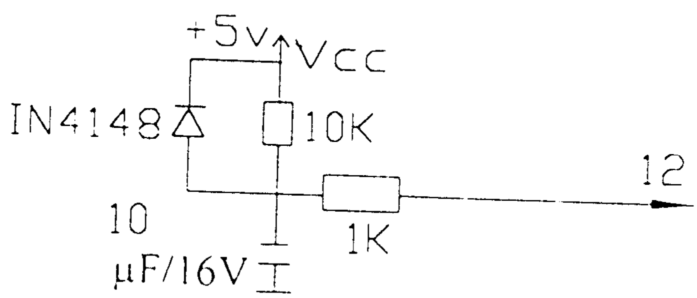


Fig 4.3 Reset Circuit

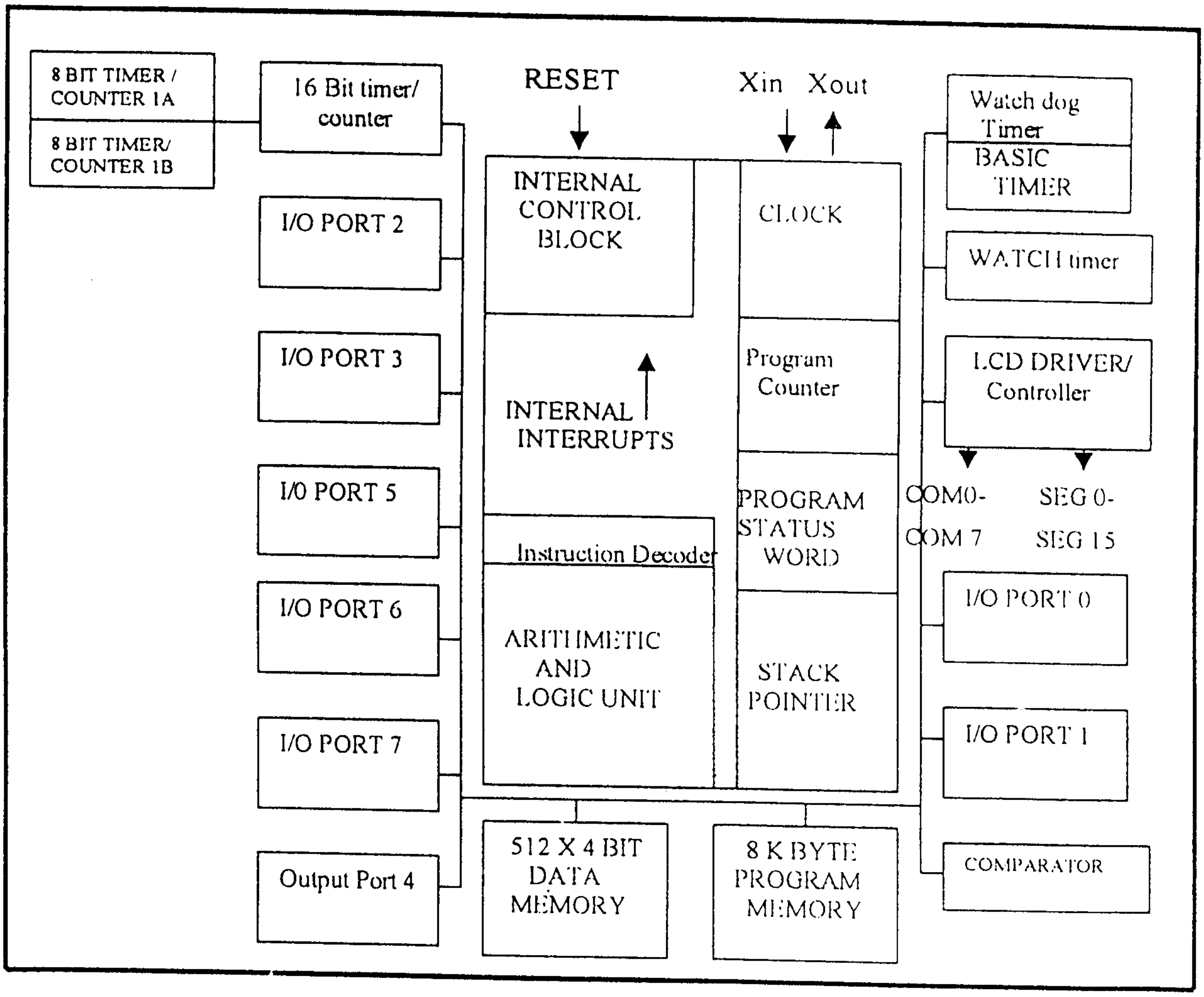


Fig 4.2 Block diagram of KS57C21208 micro-controller

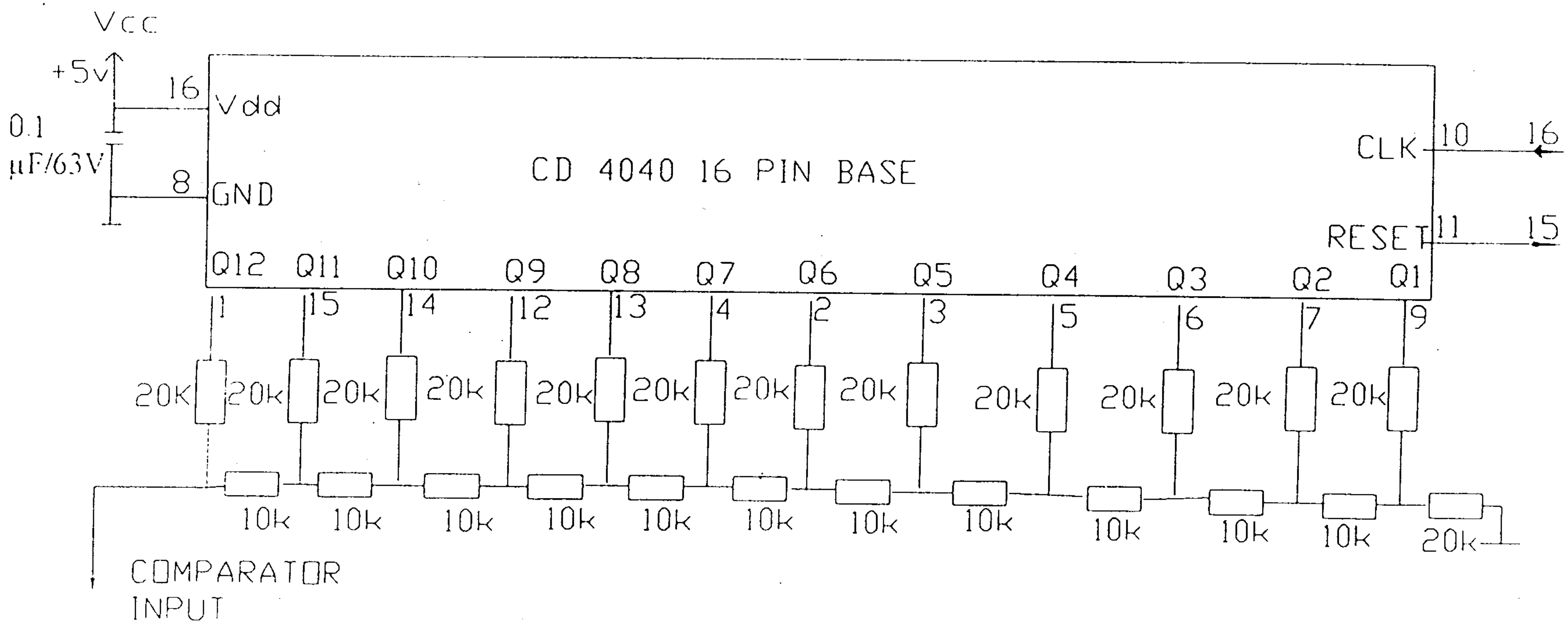


Fig 4.4 DAC Circuit

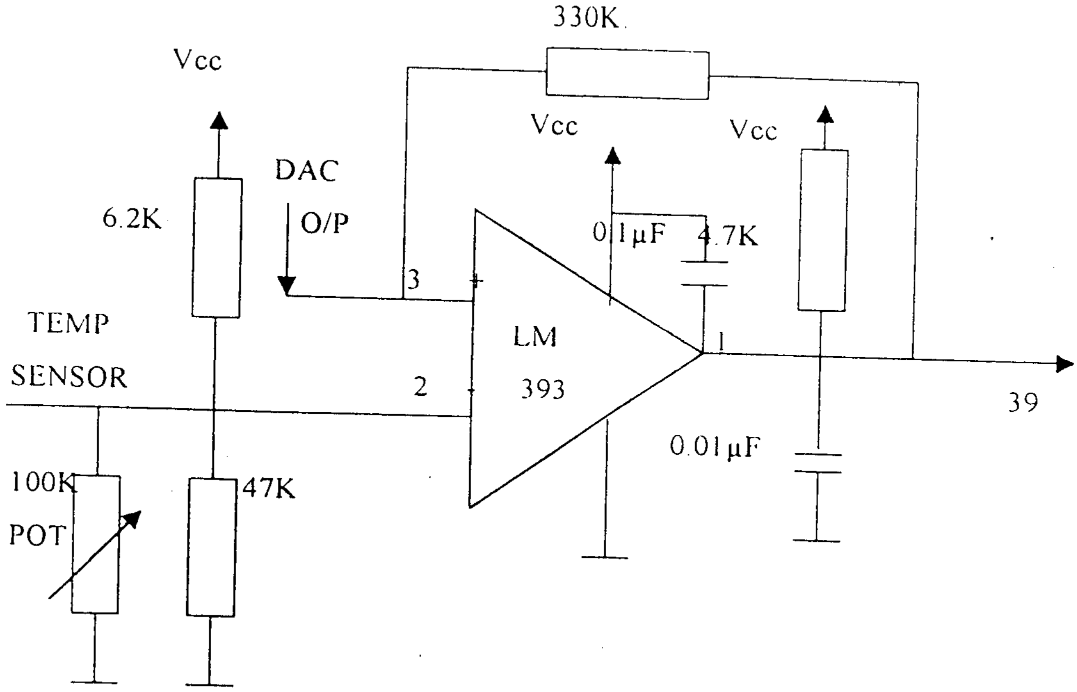


Fig 4.5 Comparator Circuit

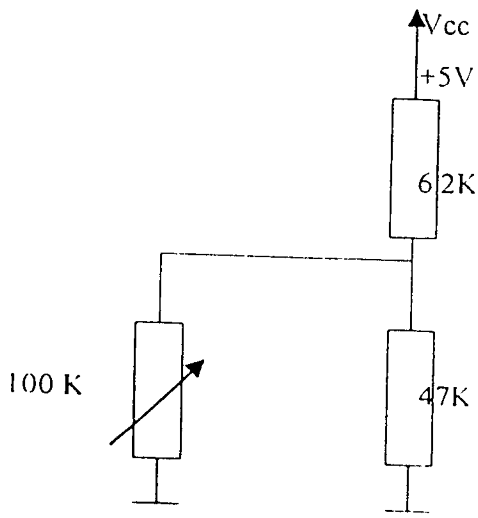


Fig 4.8 Voltage divider circuit

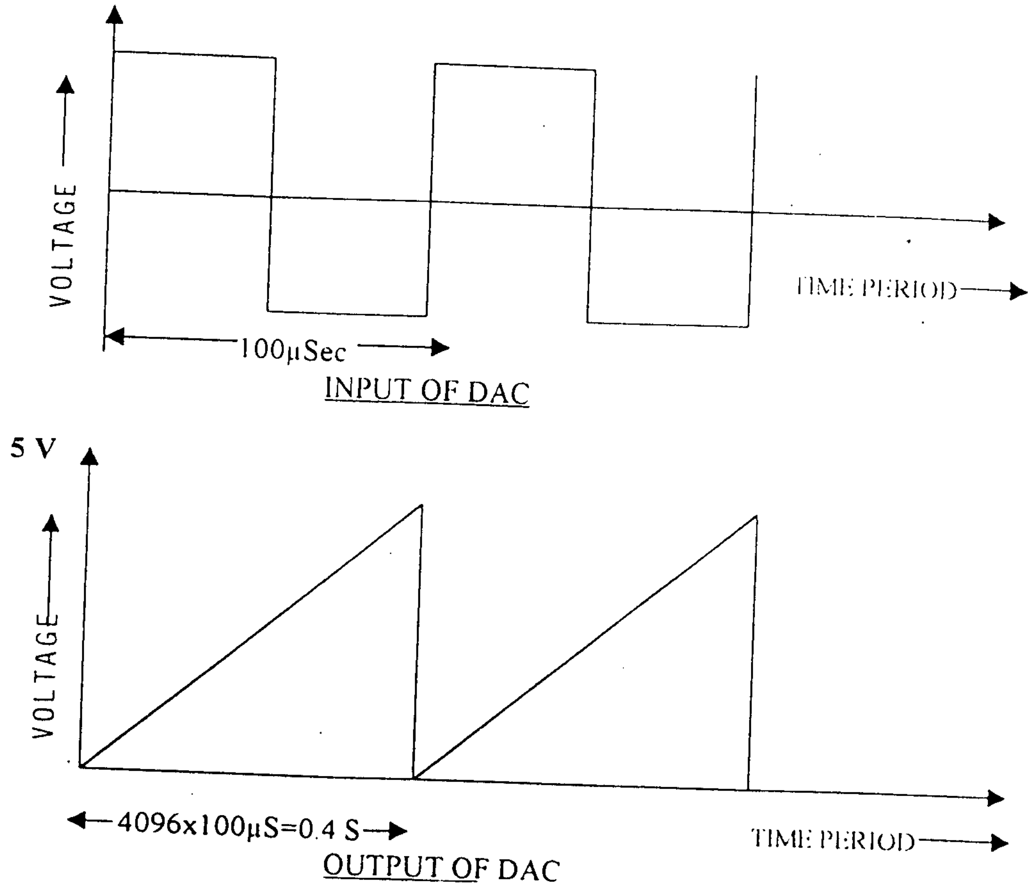


Fig 4.6 Input and Output of DAC.

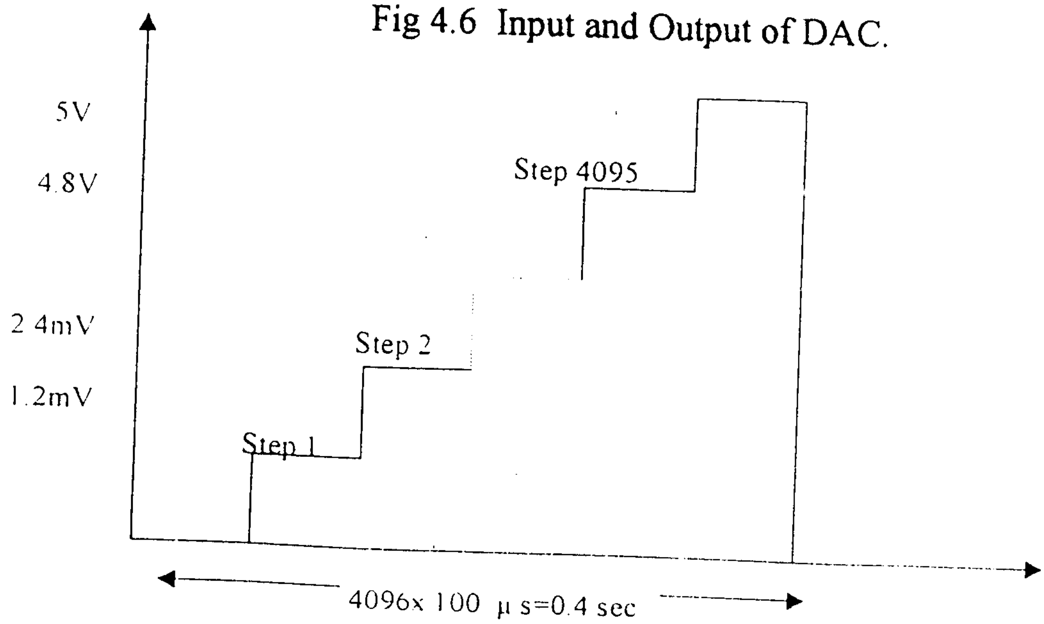


Fig. 4.7 Output of ramp in the form of steps.

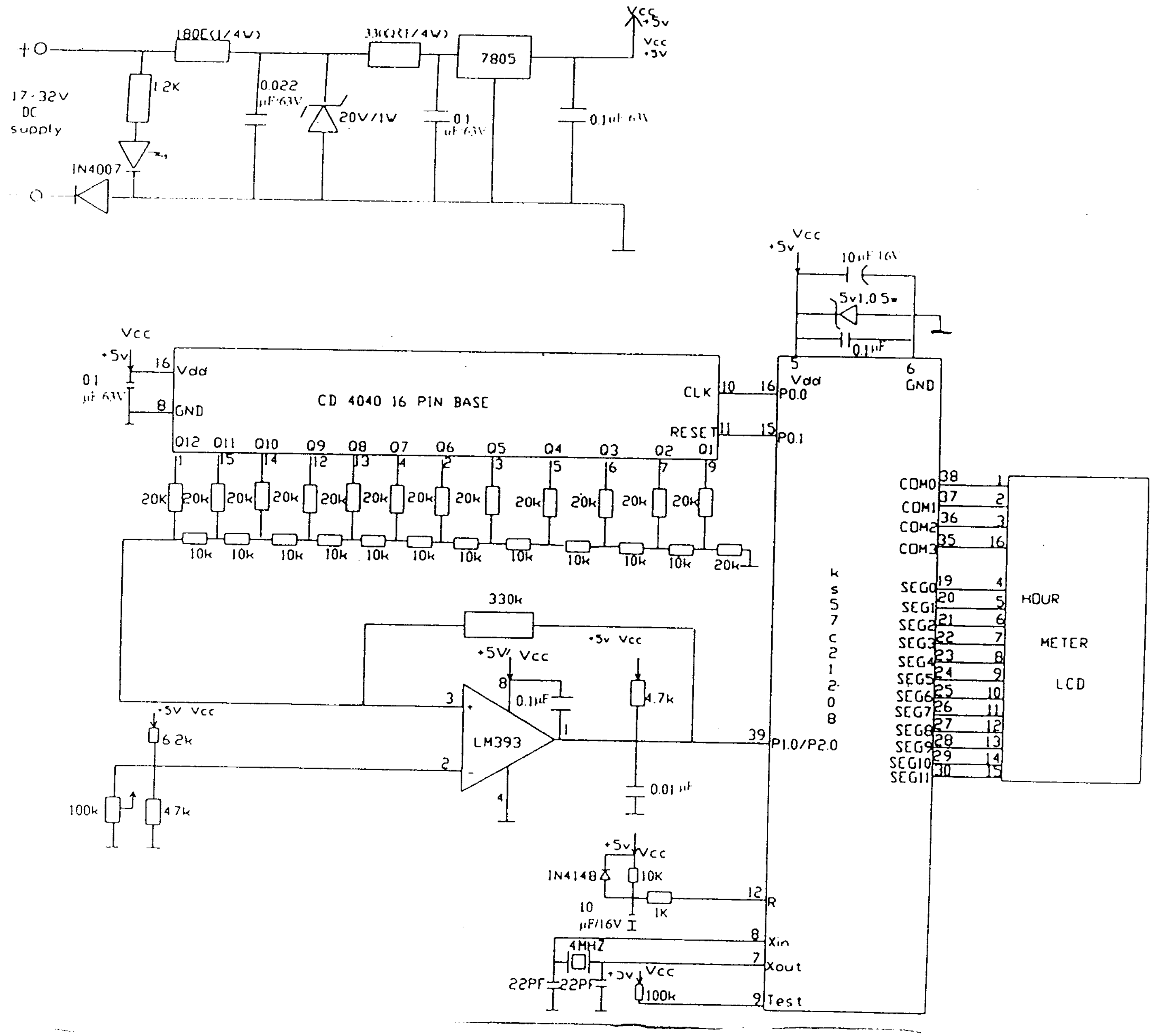


Fig 4.9 Overall Circuit Diagram

RESISTANCE VALUES CORRESPONDING TO THE TEMPERATURE VALUES OF THE NTC THERMISTOR

TABLE 4.10

S.No	TEMPERATURE(C)	RESISTANCE(ohms)
1.)	-30	53100.0
2.)	-25	39111.0
3.)	-20	29121.0
4.)	-15	21879.0
5.)	-10	16599.0
6.)	-5	12695.0
7.)	0	9795.0
8.)	1	9308.1
9.)	2	8848.5
10.)	3	8414.3
11.)	4	8004.0
12.)	5	7616.3
13.)	6	7249.6
14.)	7	6902.8
15.)	8	6574.7
16.)	9	6264.1
17.)	10	5970.0
18.)	11	5690.7
19.)	12	5426.1
20.)	13	5175.4

S.No	TEMPERATURE(C)	RESISTANCE(ohms)
21.)	14	4937.7
22.)	15	4712.3
23.)	16	4498.6
24.)	17	4295.8
25.)	18	4103.3
26.)	19	3920.6
27.)	20	3747.0
28.)	21	3528.1
29.)	22	3425.3
30.)	23	3276.4
31.)	24	3134.7
32.)	25	3000.0
33.)	26	2871.6
34.)	27	2749.5
35.)	28	2633.2
36.)	29	2522.5
37.)	30	2417.1
38.)	31	2316.5
39.)	32	2220.7
40.)	33	2129.4

S.No	TEMPERATURE(C)	RESISTANCE(ohms)
41.)	34	2042.4
42.)	35	1959.4
43.)	36	1880.2
44.)	37	1804.7
45.)	38	1732.6
46.)	39	1663.8
47.)	40	1598.1
48.)	45	1310.6
49.)	50	1080.9
50.)	60	764.4

The Input and Output waveforms of the comparator circuit is shown in *figure.4.10.*

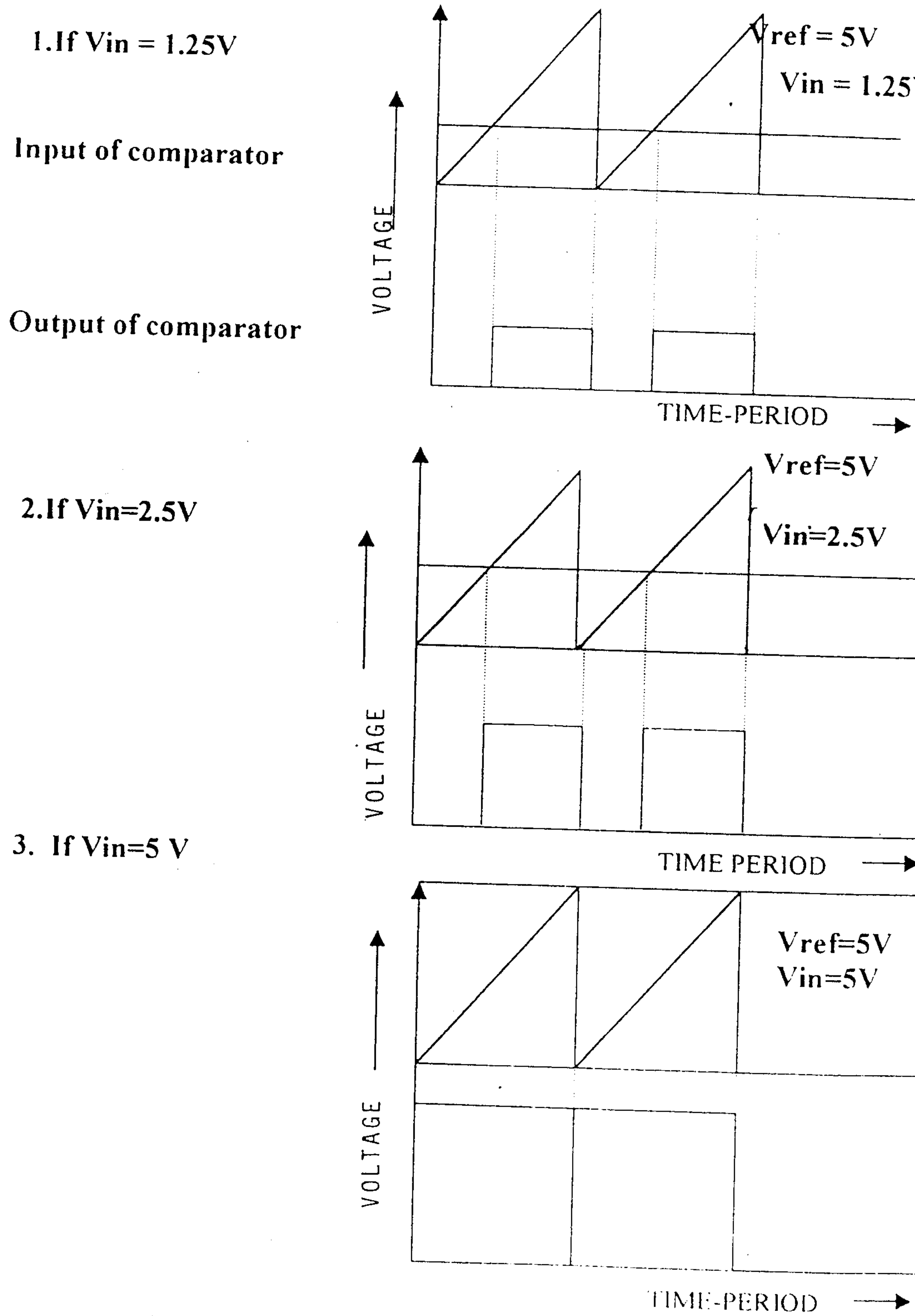


Fig 4.11 Input and output waveforms of the comparator.

TEMPERATURE Vs RESISTANCE GRAPH

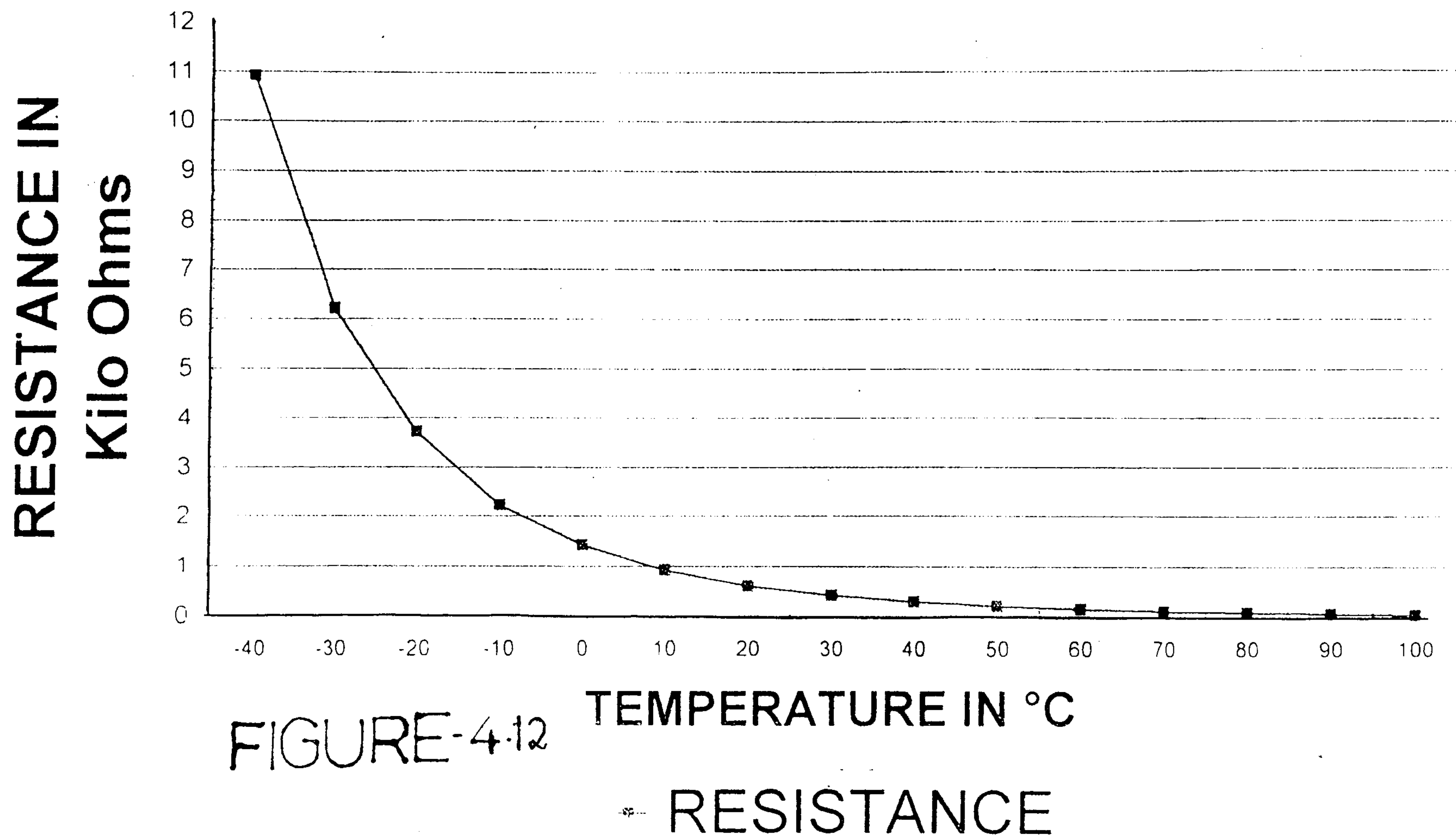


FIGURE-4.12

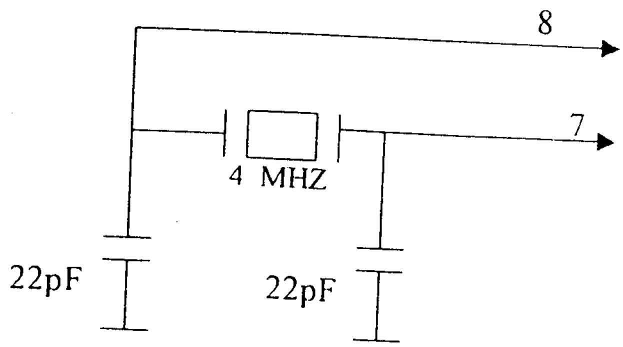


Fig 4.13 Clock circuit.

Software Description

CHAPTER 5

SOFTWARE DESCRIPTION

5.1 INTERRUPT FEATURES

Generally the interrupts are used whenever it is necessary for a program to respond as quickly as possible to external events. This interrupt is given for the measurement of the temperature on the digital display.

The KS57P21208's interrupt control circuit has five functional components :

- Interrupt enable flags (IEx)
- Interrupt request flags(IRQx)
- Interrupt master enable register(IME)
- Interrupt priority register(IPR)
- Power-down release signal circuit

The interrupt used here is a software generated one. To generate an interrupt request from software, the program manipulates the appropriate IRQx flag. When the interrupt request flag is set, it is retained until all the other conditions for the vectored interrupt have been met, and the service routine can be initiated.

The following are the interrupt types and corresponding port pins:

External interrupts	INT0, INT1, INT 4	P1.0, P1.1, P1.3
	INTP, INTK	P2
Quasi interrupts	INT2	P1.2

5.2 TEMPERATURE CALCULATIONS :

The main purpose of the 'Digital Temperature Indicator' is to measure the temperature and to display it accurately. By varying the potentiometer, the output of the comparator pulses ON time-period varies.

The temperature to be displayed is calculated in the software by the formula :

$$\text{TEMP} = \frac{\text{ON TIME COUNTS X TOTAL UNITS}}{\text{TOTAL COUNTS}}$$

$$\text{Here TEMP} = \frac{\text{ON TIME COUNTS X 90}}{4096}$$

The total units is taken as 90 because, the temperature range is from -30C to 60C and using simple calculations this –30C to 60C is totally taken as 90 units. Since we have –30C to 0C, we can subtract 30C from the calculated temperature.

The flowchart here corresponds to the logic of the program

- Port 0.0 ⟹ INPUT/OUTPUT Port which generates the clock pulse of 100microsec and gives the clock pulse as an input to the DAC.
- Port 1.0 ⟹ OUTPUT of the comparator is given as the input of the Port and the bit setting (1 or 0) of the comparator's output is checked here.

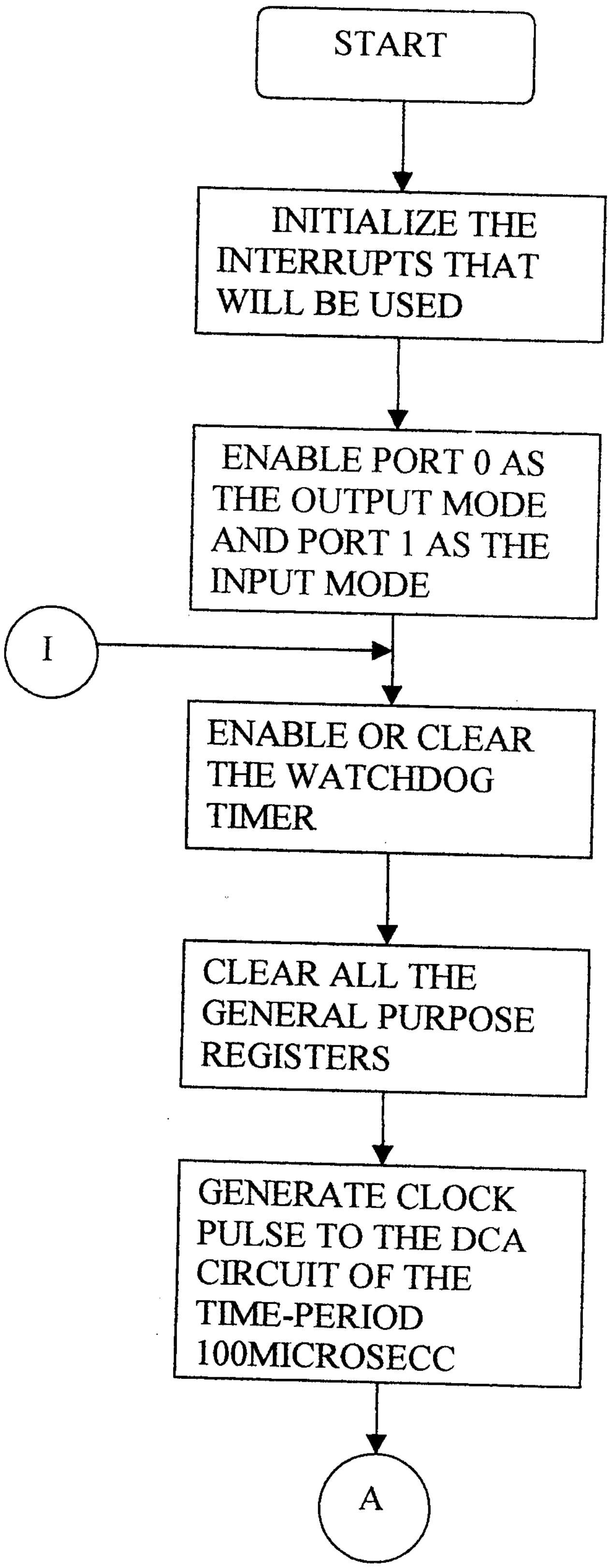
5.3 FLOWCHART

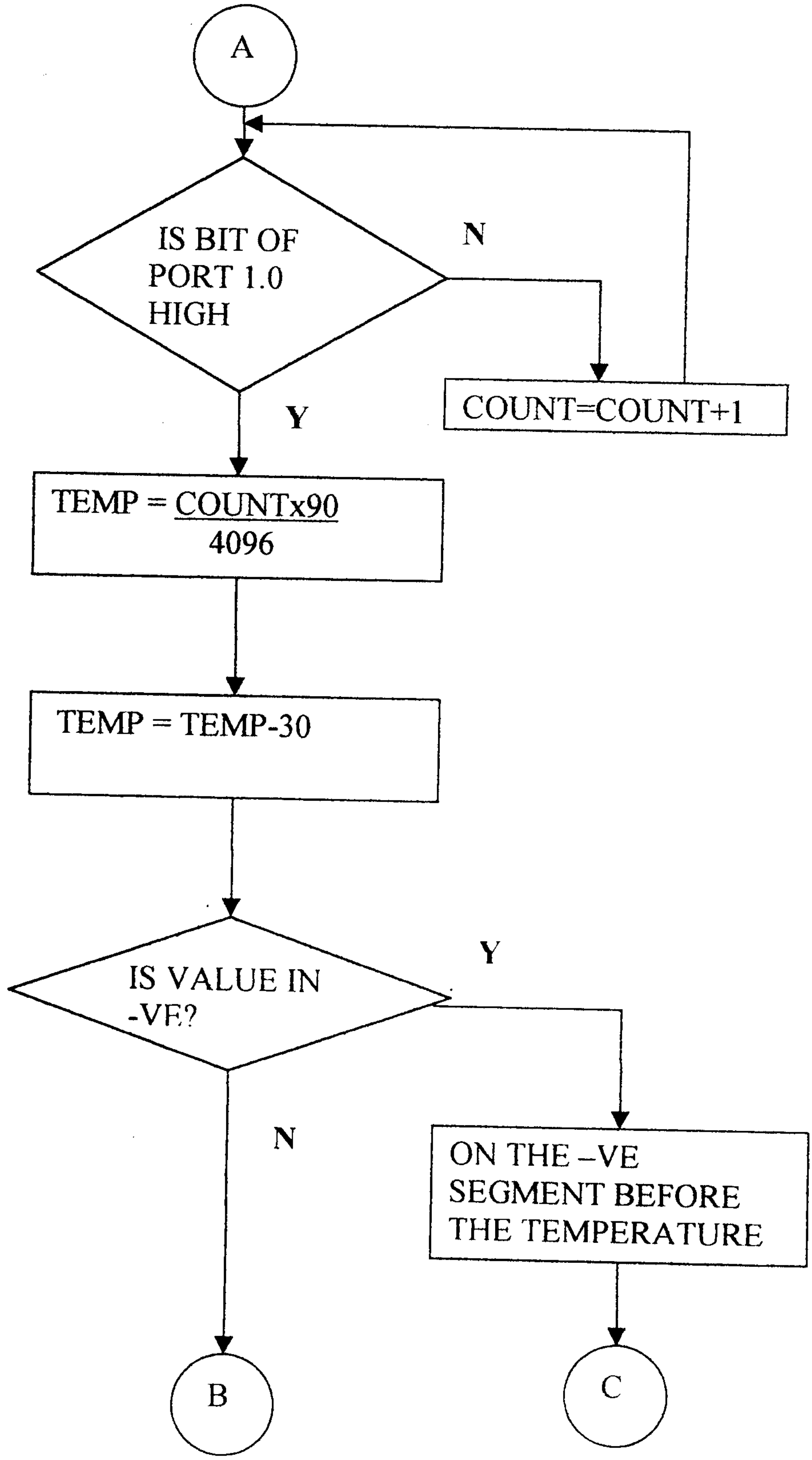
The various steps carried out in the display of the correct temperature on the LCD display is depicted in the flowchart given in fig 5.3

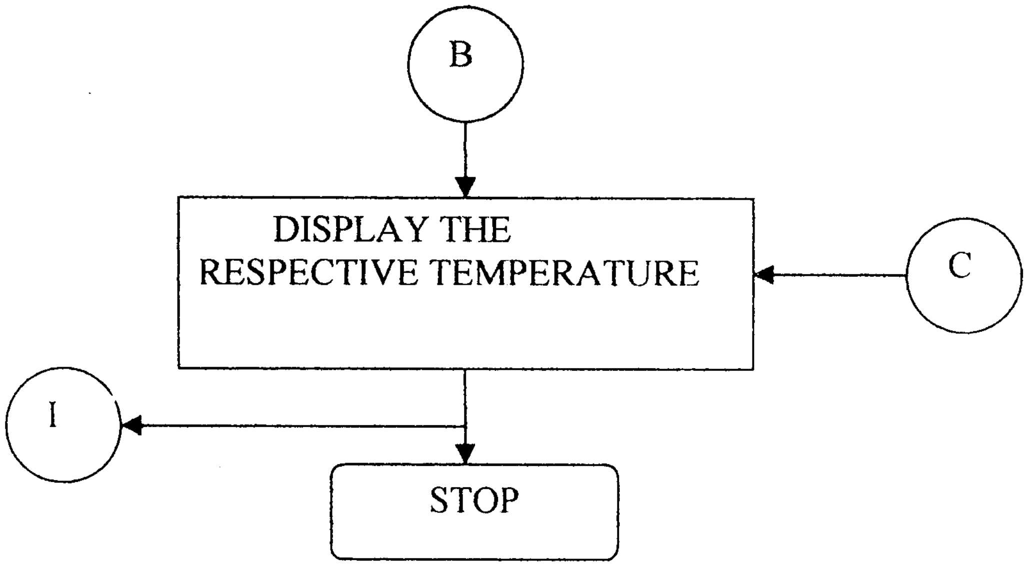
5.4 ASSEMBLY LANGUAGE PROGRAM

The detailed developed program in SAM assembly code for temperature monitoring and displaying is given at the end of this chapter.

5.3 FLOWCHART




A
IS BIT OF PORT 1.0 HIGH
N
COUNT=COUNT+1
Y
TEMP = COUNTx90 / 4096
TEMP = TEMP-30
IS VALUE IN -VE?
Y
N
ON THE –VE SEGMENT BEFORE THE TEMPERATURE
B
C


B
DISPLAY THE RESPECTIVE TEMPERATURE
C
I
STOP

5.4 ASSEMBLY LANGUAGE PROGRAM :

```
;**********************************************************
**************************************
;
;                 LCD BASED TEMPERATURE INDICATOR
;
;**********************************************************
**************************************

;MC KS57C21208Q
;font arial,bold,10

         .include
    "c:\winshine\include\reg\57c21208.reg"
         .list on

temp_disp:        equ 32h
adcnt:            equ 3ch            ; 3 locations
clk_count:        equ 40h            ; 3 locations
dec_dat:          equ 4ah            ; Decimal data
during hex2bcd conversion
mult_plicand:     equ 50h
multi_plier:      equ 60h
mul_result:       equ 70h

disbuf:           equ   20h              ; display buffer
-12 locations
disram:           equ   0e8h             ; 12 locations

adc_high_flag:    .bit 30h.0
sign_flag:        .bit 30h.1
segflg:           .bit 30h.2


         org 00h
         vent0    0,0,RESET          ;emb=0,erb=0

         org 02h          ;INTB/INT4,not used
         iret

         org 04h          ;INT0 will be used for
reading adc count
         iret
```

```
        org 06h             ;INT1, not used
        iret

        org 08h             ;INTS,not used
        iret

        org 0ah             ;INTP,not used
        iret

        org 0ch             ;INTT1,timer interrupt
        iret

        org 0eh             ;INTK,not used
        iret

;*****************************************************
***************************************
;
; Ref memory area (20h - 7fh)
;
;*****************************************************
***************************************

            org     20h
aa:         ld      @hl,a
            incs    hl
bb:         ld      a,@hl
            decs    a

;*****************************************************
***************************************
;
; Main program module
;
;*****************************************************
***************************************


        .org    80h
RESET:
        bits    emb
        smb     15
        bitr    scmod.3         ;select main system
clock
        bitr    scmod.0
```

```
        ld      a,#0011b      ;1 enable normal cpu
operating mode
        ld   pcon,a        ;scmod.0=0,fx/8=4Mhz/8=0.5Mhz

        ld   ea,#0fah
        ld   sp,ea

        ld   a,#1000b          ; p2.0-2=not
used,p2.3=analog input
        ld   p2mod,a

        ld   ea,#00000011b     ; p0.0,1 o/p mode,p0.2,3
and p1.0-3as i/p mode
        ld   pmg1,ea

        ld   a,#0fh
        ld   pmg3,a

        ld   ea,#0h
        ld   pne1,ea        ; p0,1 as n channel push-pull

        ld   ea,#5ah        ; disable watchdog
        ld   wdmod,ea

        ld      ea,#00000100b          ; Enable watch
dog timer for LCD
        ld      wmod,ea

        ld      ea,#00001011b
        ld      lmod,ea

        ld      a,#0101b
        ld      lcon,a

        ld      a,#0000b
        ld      lpot,a

        smb    0
        ld     ea,#04h
        ld     hl,ea
        ld     a,#0h
ramclr: ld     @hl,a           ; Clear general purpose
registers
        incs   hl
```

```
        jp      ramclr

lcdini: ld      hl,#0e8h
all_on: ld      a,#00h
        ref     aa
        jr      all_on

main:
        call    rst_4040
        call    clock              ;  To generate clock
for 4040 and read ADC count
        call    hex2bcd
        call    multiply
        call    scale_to_25deg
        call    dislod             ;  Load with temp. data
        jp      main

;*****************************************************
*************************************
;
;    1. Generates clock for 4040
;    2. Reads ADC count when comparator output goes
high
;
;*****************************************************
*************************************

clock:  call    delay
        ldb     c,p0.0
        ccf
        ldb     p0.0,c
        btsf    p0.0
        jp      chk_adc
        ld      hl,#clk_count      ;   Increment clock
counter
        incs    @hl
        jp      inv_clk
        incs    l
        incs    @hl
        jp      inv_clk
        incs    l
        incs    @hl
        jr      inv_clk
        ret
```

```
inv_clk: btsf     adc_high_flag
         jp       clock
         ld       hl,#adcnt              ;    Decrement adc
count

nxt:     ld       a,@hl
         decs     a
         jp       out
         ld       @hl,a
         incs     l
         cpse     l,#0fh
         jr       nxt

out:     ld       @hl,a
         jp       clock

chk_adc: btst     p1.0
         jp       clock
         bits     adc_high_flag          ;    Check for
comparator output
         jp       clock

delay:   ld       l,#0
d1:      incs     l
         jr       d1
         ld       l,#8
d2:      incs     l
         jr       d2
         ret

;*************************************************************
*****************************************
;
; Converts 4 digit (ffff @40h) to 5 digit bcd number
(@4a)
;
;*************************************************************
*****************************************


hex2bcd: ld       hl,#dec_dat
p1:      ld       a,#0
         xchi     a,@hl
         jr       p1
         ld       y,#0fh
```

```
bcdconv: rcf
         ld       hl,#adcnt
hloop:            ld   a,@hl
         adc      a,@hl
         xchi     a,@hl
         jr       hloop

         ld       hl,#dec_dat
dec_loop:         ld   a,#6
         ads      a,@hl
         adc      a,@hl
         ads      a,#10
         xchi     a,@hl
         cpse     l,#0fh
         jr       dec_loop
         decs     y
         jps      bcdconv
         ret

;*************************************************************************************
;
;    10 digit BCD multiplication
;
;    Multiplicand : 50h
;    Multiplier   : 60h
;    Result       : 70h
;
;*************************************************************************************


multiply:    ld   ea,#08h               ;loading const. 208
         ld   multi_plier,ea
         ld   a,#2h
         ld   multi_plier + 2,a
         ld   ea,dec_dat
         ld   mult_plicand,ea
         ld   ea,dec_dat + 2
         ld   mult_plicand + 2,ea
         ld   a,dec_dat + 4
         ld   mult_plicand + 4,a
         ld   a,#0h
         ld   mult_plicand + 5,a
```

```
            ld    mult_plicand + 6,a
            ld    hl,#mul_result

clrc:       ld    a,#0h
            xchi  a,@hl
            cpse  l,#0ah
            jr    clrc
            ld    z,#6h

loop:       ld    hl,#mul_result
            ld    a,#0h

shft:       xchi  a,@hl
            cpse  l,#0ah
            jr    shft

            ld    hl,#mult_plicand

shft1:      xchi  a,@hl
            cpse  l,#0ah
            jr    shft1
            xch   a,y

figure:
            decs  y
            jp    add
            incs  z
            jps   loop
            ret

add:        ld    wx,#multi_plier
            ld    hl,#mul_result
            calls dec_add
            ld    hl,#mult_plicand
            btst  c
            jps   figure

inca:       incs  @hl
            cpse  @hl,#0ah
            jps   figure
            ld    a,#0h
            xchi  a,@hl
            jr    inca

dec_add: rcf
```

```
add10:  ld      a,@wl
        ads     a,#6h
        adc     a,@hl
        ads     a,#0ah
        xchi    a,@hl
        cpse    l,#0ah
        jr      add10
        ret

                org     0430h                   ;lower
nibble

dig00           db      0dh                     ;0
dig01           db      05h                     ;1
dig02           db      0bh                     ;2
dig03           db      0fh                     ;3
dig04           db      07h                     ;4
dig05           db      0eh                     ;5
dig06           db      0eh                     ;6
dig07           db      05h                     ;7
dig08           db      0fh                     ;8
dig09           db      07h                     ;9
dig0a           db      07h                     ;a
dig0b           db      0eh                     ;b
dig0c           db      0ah                     ;c
dig0d           db      0fh                     ;d
dig0e           db      02h                     ;e
dig0f           db      00h                     ;blank

                org     0440h                   ;upper
nibble

dig10           db      07h                     ;0
dig11           db      00h                     ;1
dig12           db      05h                     ;2
dig13           db      01h                     ;3
dig14           db      02h                     ;4
dig15           db      03h                     ;5
dig16           db      07h                     ;6
dig17           db      01h                     ;7
dig18           db      07h                     ;8
dig19           db      03h                     ;9
dig1a           db      07h                     ;a
dig1b           db      06h                     ;b
```

```
digic       db    04h                     ;c
digid       db    04h                     ;d
digie       db    00h                     ;e
digif       db    00h                     ;blank


segtrn:     ld      e,#4
seglp1:     ld      a,@wx

seglp2:     ldc     ea,@ea
            xch     a,@hl
            btst    segflg
            jr      nextp
            bitr    segflg
            incs    hl
            decs    wx
            ret

nextp:      incs    hl
            ld      e,#3
            bits    segflg
            jps     seglp1

dislod:     bitr    segflg
            ld      wx,#temp_disp + 5               ; data
to be displayed
            ld      hl,#disbuf

dl_lp1:     call    segtrn

            ld      ea,#2ch
            cpse    ea,hl
            jr      dl_lp1

            call    distrn
            ret


distrn:     ld      hl,#2ah                         ;dpon
            ld      a,@hl
            or      a,#1000b
            xch     a,@hl

            ld      wx,#disbuf
            ld      hl,#disram
```

```
        ld      y,#0ch
        bits    emb
        smb     1

dit01:  ld      a,@wx
        xch     a,@hl
        incs    hl
        incs    hl
        nop
        incs    wx
        decs    y
        jr      dit01
        smb     0
        bitr    emb
        ret

;*****************************************************
**************************************
;
;    1. Subtracts 250 from the calculated temperature
;    2. Sets sign flag if the value is below zero
;
;*****************************************************
**************************************

scale_to_25deg:

        ld      hl,#mult_plicand + 2
        ld      a,#0
        ld      @hl,a                          ; Subtrahend as
2500
        incs    l
        ld      a,#0
        ld      @hl,a
        incs    l
        ld      a,#5
        ld      @hl,a
        incs    l
        ld      a,#2
        ld      @hl,a
        bitr    sign_flag
        ld      wx,#mult_plicand + 2
        ld      hl,#mul_result + 2
        rcf
```

```
loop1s: ld      a,@wl
        sbc     a,@hl
        ads     a,#0ah
        xchi    a,@hl
        jr      loop1s
        btst    c
        jp      cpy

        rcf
loop2s: ld      a,#0h
        sbc     a,@hl
        ads     a,#0ah
        xchi    a,@hl
        jr      loop2s
        bits    sign_flag
cpy:
        ld      hl,#temp_disp
        ld      a,73h
        ld      @hl,a
        incs    l
        ld      a,74h
        ld      @hl,a
        incs    l
        ld      a,75h               ; mul_result+3
        ld      @hl,a
        ld      a,#0fh
        btst    sign_flag
        ld      a,#0eh              ; Switch on negative
segment
        incs    l
        ld      @hl,a
        ld      a,#0fh
        incs    l
        ld      @hl,a
        incs    l
        ld      @hl,a
        ret

;**********************************************************
***************************************
;
;    1. To reset 4040
;    2. Loads down counter for adc
;
```

```
;***************************************************
**************************************

rst_4040:  bits     p0.1          ;reset 4040
           ld       ea,#0ffh
           ld       hl,#adcnt
        ld       @hl,ea
        incs     l
        incs     l
        ld       ea,#0fh
        ld       @hl,ea
        bitr     p0.1
        bitr     adc_high_flag
        ret

        .end
```

Testing & Debugging of T1

CHAPTER 6

TESTING AND DEBUGGING OF THE TEMPERATURE INDICATOR

6.1 POWER SUPPPLY SYSTEM :

- Introducing the diode 1N 4007 rectified the problems of reversing the connections of the power supply.
- During the power failure, the availability of power to the micro-controller was made possible using an electrolytic capacitor(10micro F/16V), it provides power to the microcontroller for approximately 10 sec thereby rectifying the above problem.
- To indicate the presence of supply the LED was incorporated in the circuit.

6.2 DAC CIRCUIT :

- The output of the DAC circuit(ramp output) certainly has some spikes in it. This has been overcome by connecting a capacitor (0.1microF/63V) between the pin 8 and pin 16 of the IC CD4040.

6.3 SENSOR CIRCUIT :

- The NTC has been tested both in the hot bath and in the cold bath and the resistance values we measured through the multi-meter has been absolutely correct for the respective temperatures.

6.4 COMPARATOR CIRCUIT :

- The output of the comparator did not start from the reference line. This problem has been overcome by connecting a feedback resistor (330K) between the pin 1 and pin 3 of the IC LM393.

6.5 NOISE :

- Sometimes the micro-controller and the LCD would hay-up. This problem was rectified by introducing the watch-dog timer into the software routine.

Modification and Further work that can be done

CHAPTER 7

MODIFICATION AND FURTHUR WORK THAT CAN BE DONE

The digital temperature indicator is designed to display the temperature of the automobile engine.

7.1 MODIFICATION :

This circuit can be used to indicate temperatures of a variety of devices that are used in industries. Temperature dependent resistors of a wide range can be used as the sensor depending on the type of application. These can be tested in the labooratory by replacing the temperature sensors with voltage dividers eg. Potentiometers in the circuit. Thus with a slight modification which can be easily made the circuit can be used to measure temperatures of a wide range of devices.

7.2 FURTHUR WORK THAT CAN BE DONE :

Some more work that can be incorporated into this project are

- Relays can be constructed in the design and place an LED or an alarm which triggers and indicates when the temperature increases the normal level.
- We can alter the program in such a way as to indicate the battery current together with the temperature.
- We can write a program, and provide another LCD to indicate how fast or effectively the cooler or fan should be ON for the corresponding temperature that has been displayed.

Conclusion

CHAPTER 8

CONCLUSION

The digital temperature indicator has been successfully designed and fabricated.

This project digital temperature indicator is a fool proof device which provides a mean by which we can monitor the temperature of the vehicle's engine and thereby ensure safety.

This unit can be placed in an automobile with the sensor fitted at the proximity of the engine. The drivers can monitor the temperature and make alternative arrangement if the temperature is high by cooling the engine etc.

This system is applicable to any vehicle and can be installed very easily. The State transport and the other private vehicle owners can also benefit from this device.

This unit is water proof and is not affected by vibrations or shock.. This digital temperature indicator is used not only for indication of engine temperature, but also to indicate the temperatures in electric arc furnaces and in chemical industries.

References

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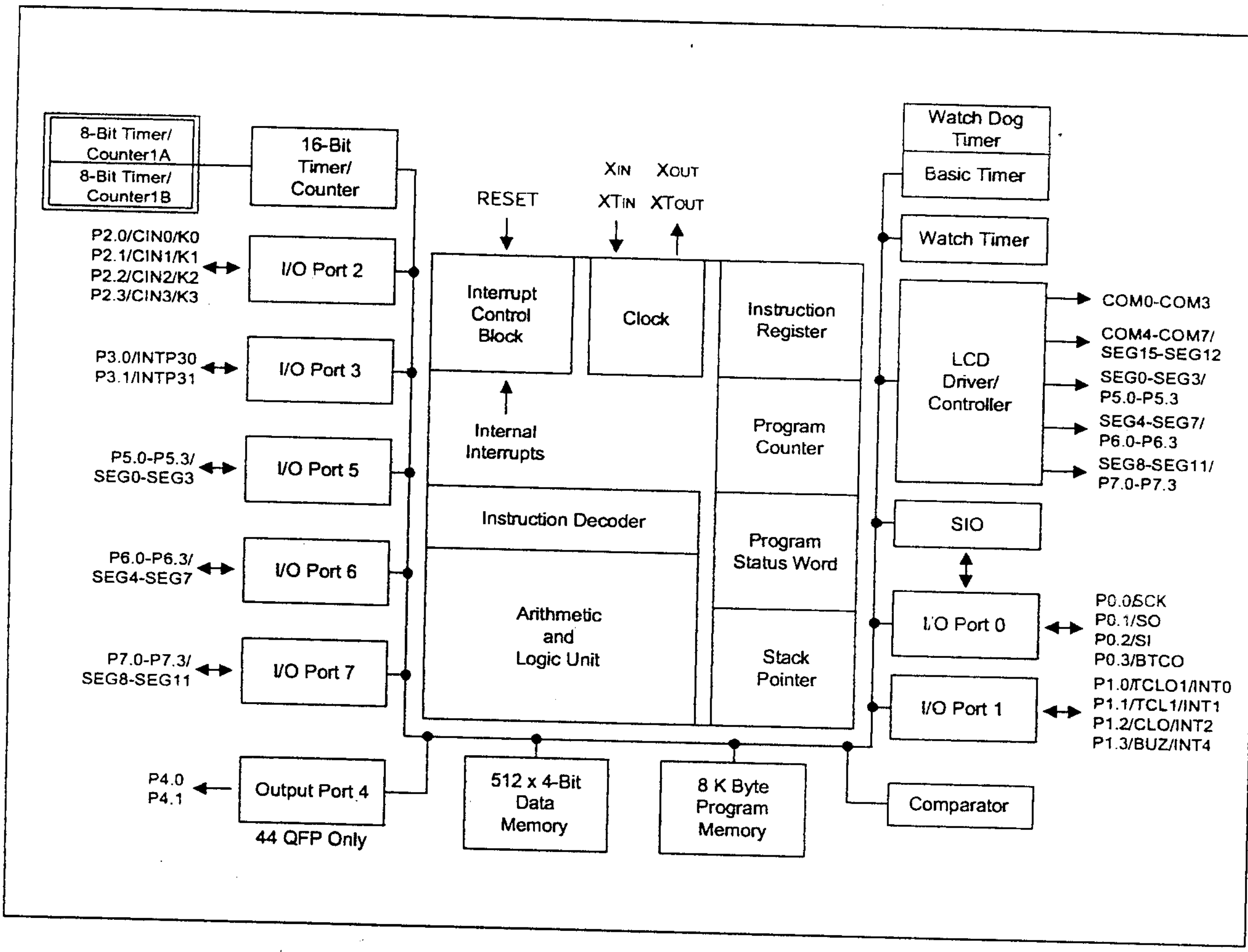
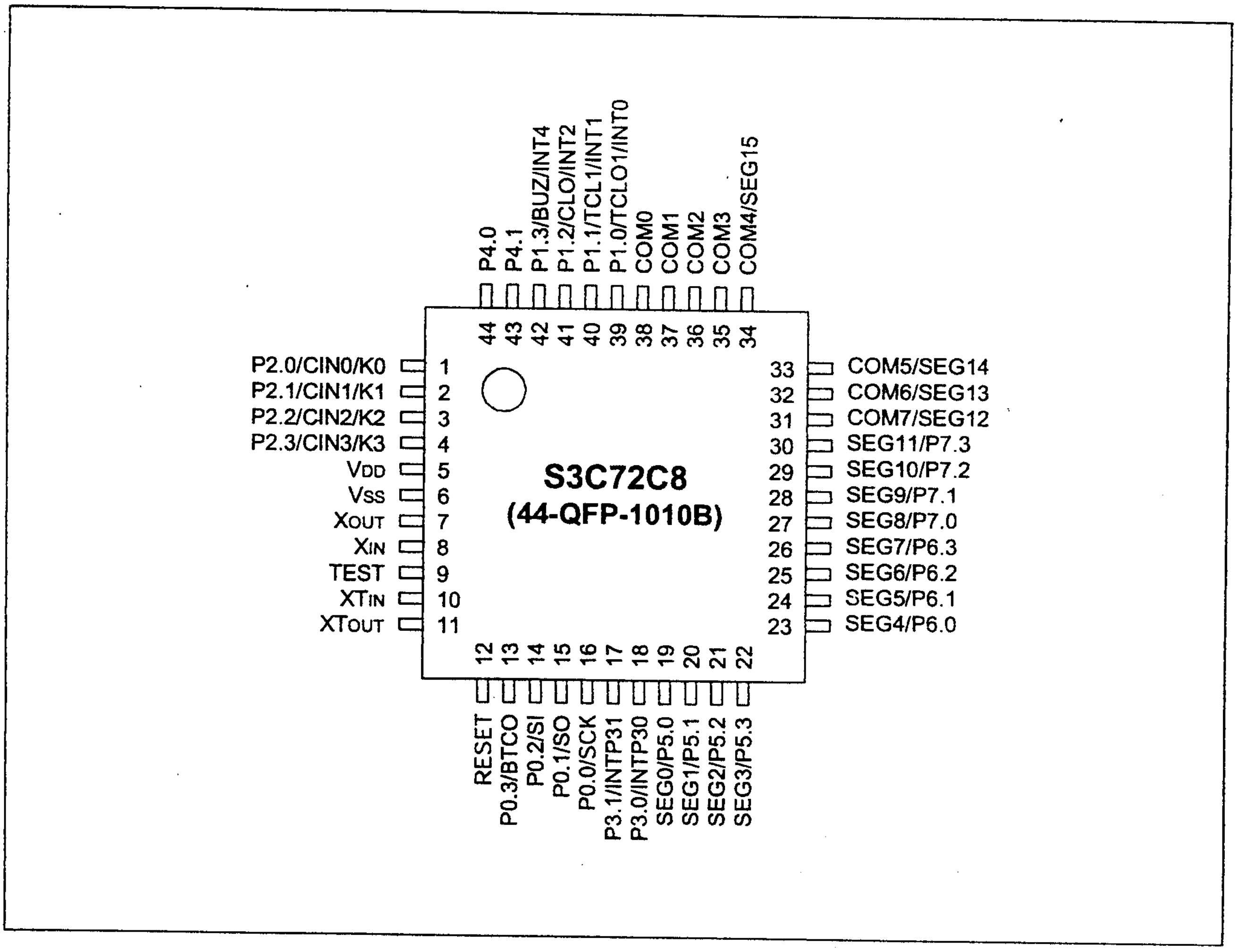
Appendix



BLOCK DIAGRAM OF KS57C21208

PIN ASSIGNMENTS



PIN DIAGRAM OF KS57C21208QFP

FEATURES

Memory

- 512 × 4-bit RAM (including LCD display RAM)
- 8,192 × 8-bit ROM

28 I/O Pins

- I/O: 26 pins (44-pin QFP, 42-pin SDIP)
- Output only: 2 pins (44-pin QFP)

LCD Controller/Driver

- 12 segments and 8 common terminals (3, 4, and 8 common selectable)
- Internal resistor circuit for LCD bias
- All dot can be switched on/off

8-bit Basic Timer

- 4 interval timer functions
- Watch-dog timer

16-bit Timer/Counter 1

- Programmable 16-bit timer/counter
- Arbitrary clock output
- External event counter
- External clock signal divider
- Configurable as two 8-bit timer/counters
- Serial I/O interface clock generator

Watch Timer

- Time interval generation: 0.5 s, 3.9 ms at 32768 Hz
- Four frequency outputs to BUZ pin
- Clock source generation for LCD

8-bit Serial I/O Interface

- 8-bit transmit/receive mode
- 8-bit receive mode
- LSB-first or MSB-first transmission selectable
- Internal or external clock source

Comparator

- 4 channel mode: internal reference (4-bit resolution)
- 3 channel mode: external reference

Interrupts

- Four internal vectored interrupts
- Five external vectored interrupts
- Two quasi-interrupts

Bit Sequential Carrier

- Supports 16-bit serial data transfer in arbitrary format

Memory-Mapped I/O Structure

- Data memory bank 15

Power-Down Modes

- Idle mode (only CPU clock stops)
- Stop mode (main system oscillation stops)
- Sub system clock stop mode

Oscillation Sources

- Crystal, ceramic, or RC for main system clock
- Crystal oscillator for subsystem clock
- Main system clock frequency: 0.4 MHz-6 MHz
- Subsystem clock frequency: 32.768 kHz
- CPU clock divider circuit (by 4, 8, or 64)

Instruction Execution Times

- 0.67, 1.33, 10.7 μs at 6 MHz (main)
- 0.95, 1.91, 15.3 μs at 4.19 MHz (main)
- 122 μs at 32.768 kHz (subsystem)

Operating Temperature

- – 40 °C to 85 °C

Operating Voltage Range

- 1.8 V to 5.5 V

Package Type

- 44-pin QFP, 42-pin SDIP

Table 1-1. KS57C21208 Pin Descriptions

Pin Name	Pin Type	Description	Circuit Type	Number	Share Pin
P0.0 P0.1 P0.2 P0.3	I/O	4-bit I/O port. 1-bit and 4-bit read/write and test are possible. Individual pins are software configurable as input or output; Individual pins are software configurable as open-drain or push-pull output; Individual pull-up resistors are software assignable; pull-up resistors are automatically disabled for output pins.	E–1	16 (22) 15 (21) 14 (20) 13 (19)	SCK SO SI BTCO
P1.0 P1.1 P1.2 P1.3	I/O	Same as port 0.	E–1	39 (3) 40 (4) 41 (5) 42 (6)	TCLO1/INT0 TCL1/INT1 CLO/INT2 BUZ/INT4
P2.0 P2.1 P2.2 P2.3	I/O	Same as port 0 except that port 2 is not configurable as n-channel open drain and is configurable as analog input pin.	F–8	1 (7) 2 (8) 3 (9) 4 (10)	K0/CIN0 K1/CIN1 K2/CIN2 K3/CIN3
P3.0 P3.1	I/O	2-bit I/O port 1-bit and 4-bit read/write and test is possible. Individual pins are software configurable as input or output; Individual pins are software configurable as open-drain or push-pull output; 2-bit pull-up resistors are software assignable; pull-up resistors are automatically disabled for output pins.	E–3	18 (24) 17 (23)	INTP30 INTP31
P4.0 P4.1	O	2-bit output port. 1-bit and 4-bit read/write and test is possible. Individual pins are software configurable as open-drain or push-pull output.	E-2	44 43	
P5.0-P5.3	I/O	4-bit I/O port. 1-bit and 4-bit read/write and test is possible. Individual pins are software configurable as input or output; Individual pins are software configurable as open-drain or push-pull output; 4-bit pull-up resistors are software assignable; pull-up resistors are automatically disabled for output pins.	H-13	19-22 (25-28)	SEG0-SEG3
P6.0-P6.3	I/O	Same as port5	H-13	23-26 (29-32)	SEG4-SEG7
P7.0-P7.3	I/O	Same as port5	H-13	27-30 (33-36)	SEG8-SEG11

Table 1-1. KS57C21208 Pin Descriptions (Continued)

Pin Name	Pin Type	Description	Circuit Type	Number	Share Pin
SEG0-SEG3	I/O	LCD segment display signal output pins	H–13	19-22 (25-28)	P5.0-P5.3
SEG4-SEG7				23-26 (29-32)	P6.0-P6.3
SEG8-SEG11				27-30 (33-36)	P7.0-P7.3
SEG12-SEG15	O	LCD segment display output pins	H–6	31-34 (37-40)	COM7-COM4
COM0-COM3	O	LCD common signal output pins	H–4	38-35 (2-1, 42-41)	–
COM4-COM7	I/O	LCD common signal output pins	H–6	34-31 (40-37)	SEG12–SEG15
SCK	I/O	Serial interface clock signal	E–1	16 (22)	P0.0
SO	I/O	Serial data output	E–1	15 (21)	P0.1
SI	I/O	Serial data input	E–1	14 (20)	P0.2
BTCO	I/O	Basic timer overflow signal	E–1	13 (19)	P0.3
TCLO1	I/O	Timer/counter external clock output	E–1	39 (3)	P1.0/INT0
TCL1	I/O	Timer/counter external clock input	E–1	40 (4)	P1.1/INT1
CLO	I/O	Clock output	E–1	41 (5)	P1.2/INT2
BUZ	I/O	Frequency output to buzzer	E–1	42 (6)	P1.3/INT4
RESET	I	System RESET pin	B	12 (18)	–
X_{in}, X_{out}	–	Clock input and output pins for main system clock	–	8-7 (14-13)	–
XT_{in}, XT_{cut}	–	Clock input and output pins for subsystem clock	–	10-11 (16-17)	–
CIN0–CIN3	I	Analog Input port for Comparator	F–8	1-4 (7-10)	P2.0/K0 -P2.3/K3
K0–K3	I/O	External interrupts. The triggering edge is selectable.	F–8	1-4 (7-10)	P2.0/CIN0 -P2.3/CIN3
INT0 INT1	I	External interrupts. The triggering edge for INT0 and INT1 is selectable.	E–1	39 (3) 40 (4)	P1.0/TCLO1 -P1.1/TCL1

Table 1-1. KS57C21208 Pin Descriptions (Continued)

Pin Name	Pin Type	Description	Circuit Type	Number	Share Pin
INT2	I	Quasi-interrupt with detection of rising or falling edges.	E-1	41 (5)	P1.2/CLO
INT4	I	External interrupt with detection of rising or falling edges.	E-1	42 (6)	P1.3/BUZ
INTP30 INTP31	I	Ket scan interrupts inputs.	E-3	18-17 (24-23)	P3.0, P3.1
TEST	I	System test pin	–	9 (15)	–
V_{DD}	–	Power supply pin	–	5 (11)	–
V_{SS}	–	Ground pin	–	6 (12)	–

NOTES:

1. Parentheses indicate pin number for 42-SDIP package.
2. Pull-up resistors for all I/O ports are automatically disabled if they are configured to output mode.

INSTRUCTION REFERENCE AREA

Using 1-byte REF instructions, you can easily reference instructions with larger byte sizes that are stored in addresses 0020H–007FH of program memory. This 96-byte area is called the REF instruction reference area, or look-up table. Locations in the REF look-up table may contain two 1-byte instructions, a one 2-byte instruction, one 3-byte instruction such as a JP (jump) or CALL. The starting address of the instruction you are referencing must always be an even number. To reference a JP or CALL instruction, it must be written to the reference area in a two-byte format: for JP, this format is TJP; for CALL, it is TCALL. In summary, there are three ways to the REF instruction:

By using REF instructions, you can execute instructions larger than one byte. In summary, there are three ways you can use the REF instruction:

- Using the 1-byte REF instruction to execute one 2-byte or two 1-byte instructions.
- Branching to any location by referencing a branch instruction stored in the look-up table.
- Calling subroutines at any location by referencing a call instruction stored in the look-up table.

☞ PROGRAMMING TIP — Using The REF Look-up Table

Here is one example of how to use the REF instruction look-up table:

```
        ORG     0020H
;
JMAIN   TJP     MAIN            ; 0, MAIN
KEYCK   BTSF    KEYFG           ; 1, KEYFG CHECK
WATCH   TCALL   CLOCK           ; 2, Call CLOCK
INCHL   LD      @HL,A           ; 3, (HL) ← A
        INCS    HL
        •
        •
        •
ABC     LD      EA,#00H         ; 47, EA ← #00H
        ORG     0080
;
MAIN    NOP
        NOP
        •
        •
        •
        REF     KEYCK           ; BTSF KEYFG (1-byte instruction)
        REF     JMAIN           ; KEYFG = 1, jump to MAIN (1-byte instruction)
        REF     WATCH           ; KEYFG = 0, CALL  CLOCK (1-byte instruction)
        REF     INCHL           ; LD @HL,A
                                ; INCS HL
        REF     ABC             ; LD EA,#00H (1-byte instruction)
        •
        •
        •
```

DATA MEMORY (RAM)

OVERVIEW

In its standard configuration, the data memory has four areas:

— 32 × 4-bit working register area in bank 0

— 224 × 4-bit general-purpose area in bank 0 which is also used as the stack area

— 232 × 4-bit general-purpose area in bank 1

— 24 × 4-bit area for LCD data in bank 1

— 128 × 4-bit area in bank 15 for memory-mapped I/O addresses

To make it easier to reference, the data memory area has three memory banks — bank 0, bank 1, and bank 15. The select memory bank instruction (SMB) is used to select the bank you want to select as working data memory. Data stored in RAM locations are 1-, 4-, and 8-bit addressable.

Initialization values for the data memory area are not defined by hardware and must therefore be initialized by program software after the power RESET. However, when RESET signal is generated in power-down mode, most of the data memory contents are held.

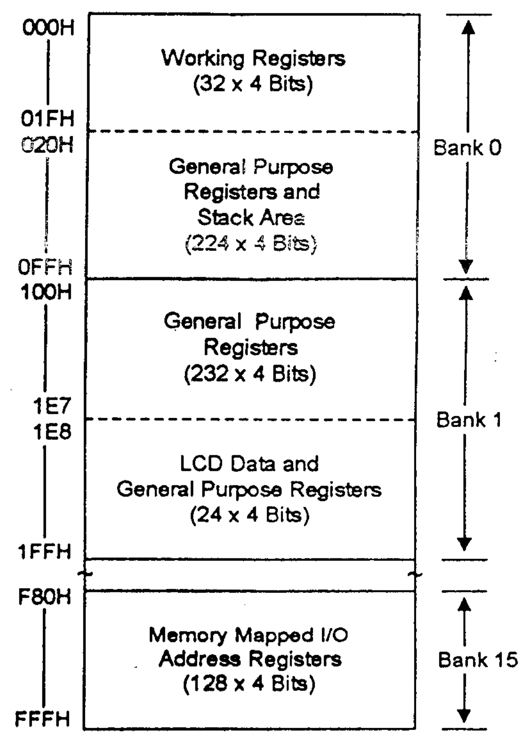


Figure 2-3. Data Memory (RAM) Map

MEMORY MAPPING

To support program control of peripheral hardware, I/O addresses for peripherals are memory-mapped to bank 15 of the RAM. Memory mapping lets you use a mnemonics as the operand of an instruction in place of the specific memory location

Access to bank 15 is controlled by the select memory bank (SMB) instruction and by the enable memory bank flag (EMB) setting. If the EMB flag is "0" , bank 15 can be addressed using direct addressing , regardless of the current SMB value . 1 bit direct and indirect addressing can be used for specific location in Bank 15 ,regardless of the current EMB value.

The memory mapping gives you the following information.

- Register address.
- Register name(mnemonic for program addressing)
- Bit values(both addressable and non-manipulable)
- Read-only,write-only.or read and write addressability
- 1-bit,4-bit or 8-bit data manipulation characteristics.

INTERRUPTS

The KS57C21208's interrupt control circuit has five functional components .

-Interrupt enable flags (IEX)

-Interrupt request flags (IRQX)

-Interrupt master enable register (IME)

-Interrupt priority register (IPR)

-Power-down release signal circuit

Three kinds of interrupts are supported:

-Internal interrupts generated by on-chip processes

-External interrupts generated by external peripheral devices

-Quasi-interrupts used for edge detection and as clock sources

INTERRUPT REGISTERS

IEW,IRQW – INTW Interrupt Enable/Request flags.

REGISTER NAME	BIT 3	BIT 2	BIT 1	BIT 0
IEW,IRQW	ZERO BIT	ZERO BIT	INTERRUPT ENABLE FLAG(IEW)	INTERRUPT REQUEST FLAG(IRQW)

BIT 3 – Always logic zero

BIT 2 – Always logic zero

BIT 1 – (IEW) When 0-Disable INTW interrupt requests

- (IEW) When 1-Enable INTW interrupt requests

BIT 0 - (IRQW) –This bit is set when the timer interval is to set 0.5 seconds or 3.91 milliseconds.

IMOD 0 – External Interrupt 0 (INT 0) Mode Register.

REGISTER NAME	BIT 3	BIT 2	BIT 1	BIT 0
IMOD 0	ZERO BIT	ZERO BIT	EXTERNAL INTERRUPT MODE CONTROL BIT	EXTERNAL INTERRUPT MODE CONTROL BIT

BIT 3 – Always zero

BIT 2 – Always zero

BIT 1 & BIT 0

- When 0 0-Interrupt request is triggered by rising edge.
- When 0 1-Interrupt request is triggered by a falling edge.
- When 1 0 & 1 1-Interrupt request is triggered by both falling and rising edges.

CLOCK

The KS 57C 21208 micro-controller has two oscillator circuits :a main system clock circuit and a subsystem clock circuit.The clock pulse is required by the following modules

- LCD controller
- Basic timer
- Timer/counter 1
- Watch timer
- Serial I/O interface
- Clock output circuit
- Comparator

The notations used in the clock are

fx main system clock

fxt subsystem clock

fxx selected subsystem clock

CLOCK CONTROL REGISTERS:

The port control register PCON is used to select normal CPU operating mode.

The system clock mode control register,SCMOD lets to select the main system clock or a subsystem clock as per the main/subsystem clock oscillation.

The main system clock is selected and oscillation started when all SCMOD bits are cleared to 0.By setting SCMOD.3,SCMOD.2 and SCMOD.0 to different values,you can select a subsystem click source and start or stop main/subsystem clock oscillation. To stop main system clock oscillation,you must use the STOP instruction.

The main system clock frequencies can be divided by 4,8 or 64 and a subsystem clock frequencies can only be divided by 4.By manipulating PCON bits 1 and 0,you can select one of the following frequencies as the CPU clock fx/4,fxt/4,fx/8,fx/64

CLOCK REGISTERS

CLMOD – Clock output mode Register

REGISTERNAME	BIT 3	BIT 2	BIT 1	BIT 0
CLMOD	CLOCK CONTROL BIT	ZERO BIT	FREQUENCY SELECTION BIT	FREQUENCY SELECTION BIT

BIT 1 – When 0-disable clock output

- When 0-enable clock output

BIT 2 – Always zero

BIT 1 & BIT 0

- When 0 0 select CPU clock source
- When 0 1 select system clock fxx/8
- When 1 0 select system clock fxx/16
- When 1 1 select system clock fxx/64.

SCMOD-System clock mode control regieter

REGISTER NAME	BIT 3	BIT 2	BIT 1	BIT 0
SCMOD	MAIN SYSTEM CLOCK	SUB SYSTEM CLOCK	ZERO BIT	MAIN AND SUBSYSTEM CLOCK

BIT 3-When 0 & 1-Enable and disable main system clock.

BIT 2-When 0 & 1-Enable and disable subsystem clock

BIT 1-Always zero

BIT 0-When 0 & 1-select main and subsystem clock.

TIMER/COUNTERS

The kS57C21208 micro-controller has three timer and timer/counter modules:

- 8-bit basic timer (BT)
- 16-bit timer/counter (TC1, configurable as two 8-bit timer/counter 1A/1B)
- watch timer (WT)

The 8-bit basic timer (BT) is the microcontroller's main interval timer.It generates an interrupt request at a fixed time interval when the appropriate is made to its mode register. The basic timer also functions as a 'watchdog' timer and is used to determine clock stabilization time when stop mode is released by an interrupt and after a RESET.

The 16-bit timer/counter (TC1) is programmable timer/counter that is used primarily for clock frequency modification and output. In addition, TC1 generates a clock signal that can be used by the serial I/O interface.

The watch timer (WT) module consists of an 8-bit watch timer register, a clock selector , and a frequency divider circuit. Watch timer functions include real-time and watch-time measurement, main and sub clock interval timing

TIMER REGISTERS

WDMOD-Watch dog timer control register

It has 8 bits BIT 0-BIT 7

When BIT 7-BIT 0 is 01011010 it will disable watchdog timer function.

When BIT 7-BIT 0 contains other values it will enable watchdog timer function.

LCD CIRCUIT DIAGRAM

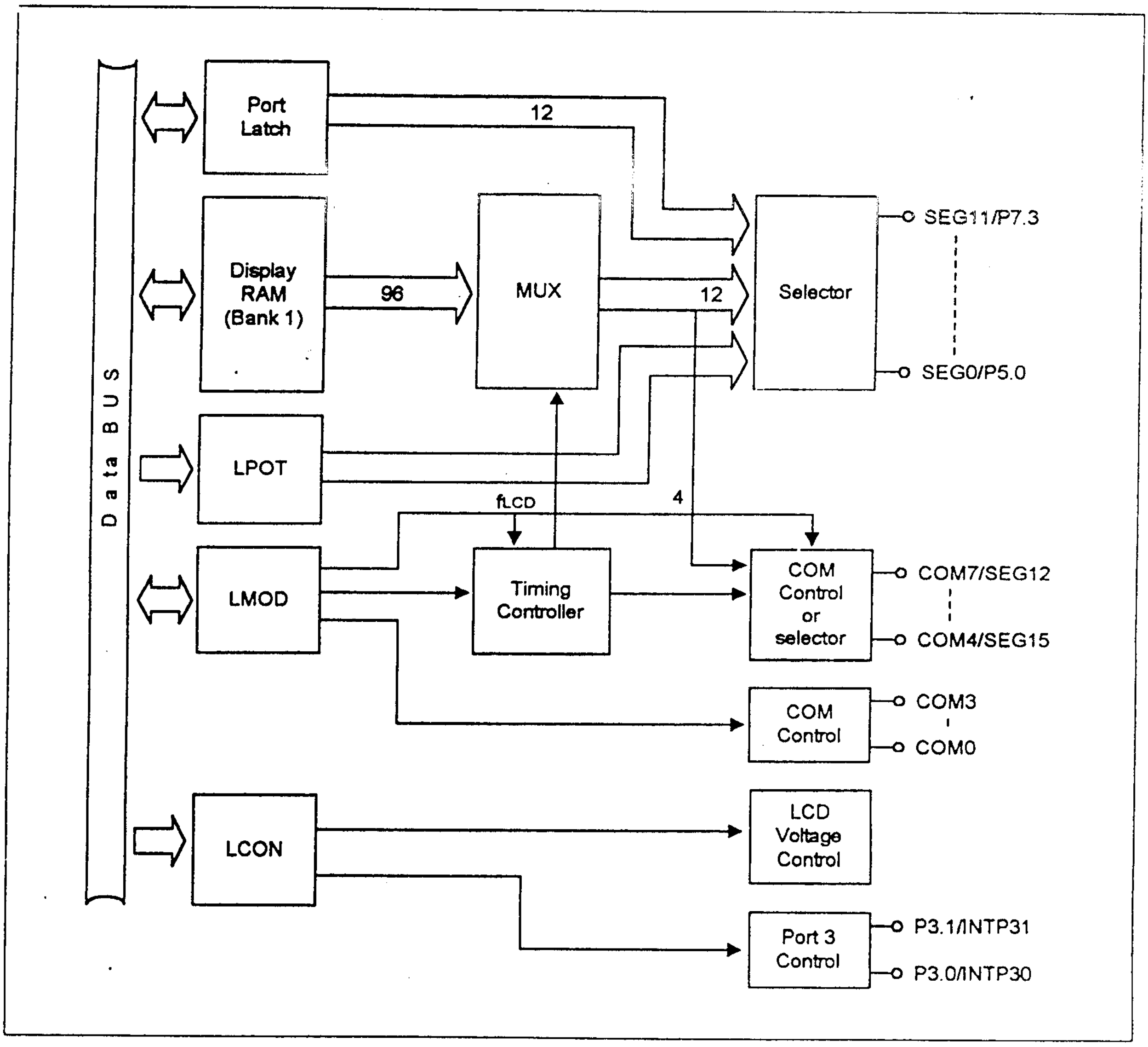


Figure 12-2. LCD Circuit Diagram

LCD REGISTERS

LCON –LCD OUTPUT CONTROL REGISTER

REGISTER NAME	BIT 3	BIT 2	BIT 1	BIT 0
LCON	ZERO BIT	LCD BIAS SELECTION BIT	PORT 3 CONTROL BIT	LCD CONTROL BIT

BIT 3-always zero

BIT 2-when 0-select ¼ bias

-when 1-select 1/3 bias

BIT 1-when 0-disable Port 3 high impedance

-when 1-enable Port 3 high impedance

BIT 0-when 0-display off

-when 1-normal display on

LCD- LCD PORT CONTROL REGISTER

REGISTER NAME	BIT 3	BIT 2	BIT 1	BIT 0
LCD	HIGH IMPEDANCE CONTROL BIT	ZERO BIT	LCD PORT CONTROL BIR	LCD PORT CONTROL BIT

BIT 3-when 0-normal COMs signal output

-when 1-COM 0-COM 7 are at high impedance

BIT 2-always zero

BIT 1& BIT 0

- when 0 0-Port 5,6,7 as SEG port
- when 0 1-Port 6,7 as SEG port and port 5 as normal I/O port
- when 1 0-Port 7 as SEG port and port 5,6 as normal I/O port
- when 1 1-Port 5,6,7 as normal I/O port.

LMOD-LCD MODE REGISTER.

LMOD has 8 register bits from BIT 7-BIT 0

BIT 7&BIT 6-always zero

BIT 5&BIT 4

- when 0 0-work with frequency as 128 HZ.
- when 0 1-work with frequency as 256 HZ.
- when 1 0-work with frequency as 512 HZ.
- when 1 1-work with frequency as 1024 HZ.

BIT 3&BIT 2

- when 0 0&0 1-1/8 duty cycle
- when 1 0 -1/4 duty cycle
- when 1 1 -1/3 duty cycle

BIT 1&BIT 0

- when 0 0-all LCD dots off
- when 0 1-all LCD dots on
- when 1 1-common and segment signal output corresponds to display data.

National Semiconductor

LM193/LM293/LM393/LM2903 Low Power Low Offset Voltage Dual Comparators

General Description

The LM193 series consists of two independent precision voltage comparators with an offset voltage specification as low as 2.0 mV max for two comparators which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage. These comparators also have a unique characteristic in that the input common-mode voltage range includes ground, even though operated from a single power supply voltage.

Application areas include limit comparators, simple analog to digital converters; pulse, squarewave and time delay generators; wide range VCO; MOS clock timers; multivibrators and high voltage digital logic gates. The LM193 series was designed to directly interface with TTL and CMOS. When operated from both plus and minus power supplies, the LM193 series will directly interface with MOS logic where their low power drain is a distinct advantage over standard comparators.

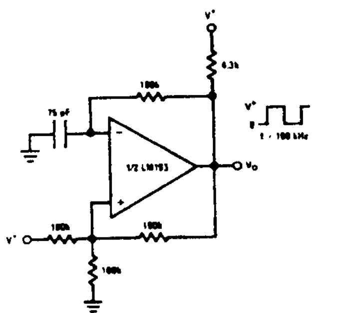
Advantages

- High precision comparators
- Reduced V_{OS} drift over temperature
- Eliminates need for dual supplies
- Allows sensing near ground
- Compatible with all forms of logic
- Power drain suitable for battery operation

Features

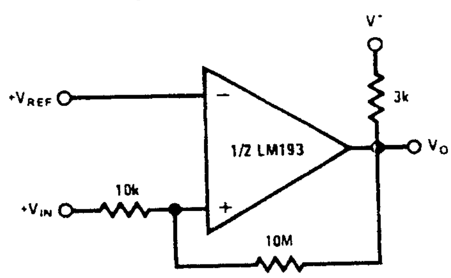
- Wide supply
  - — Voltage range: 2.0V to 36V
  - — single or dual supplies: ±1.0V to ±18V
- Very low supply current drain (0.4 mA) — independent of supply voltage
- Low input biasing current: 25 nA
- Low input offset current: ±5 nA
- Maximum offset voltage: ±3 mV
- Input common-mode voltage range includes ground
- Differential input voltage range equal to the power supply voltage
- Low output saturation voltage,: 250 mV at 4 mA
- Output voltage compatible with TTL, DTL, ECL, MOS and CMOS logic systems

Squarewave Oscillator



DS005709-38

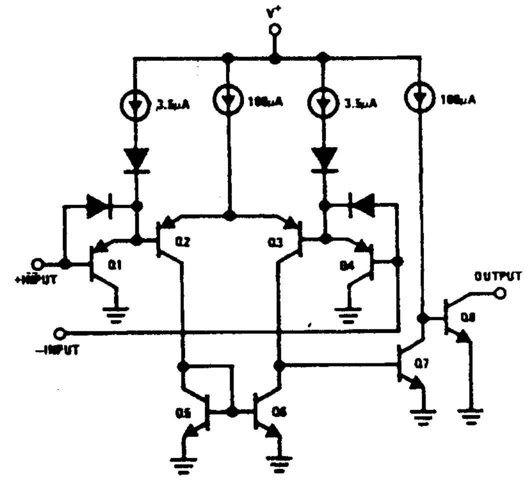
Non-Inverting Comparator with Hysteresis



DS005709-9

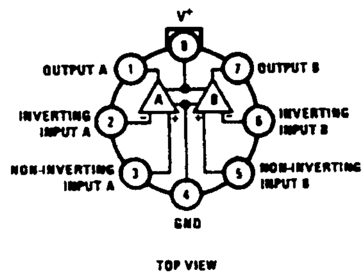
 DS005709

Schematic and Connection Diagrams



DS005709-2

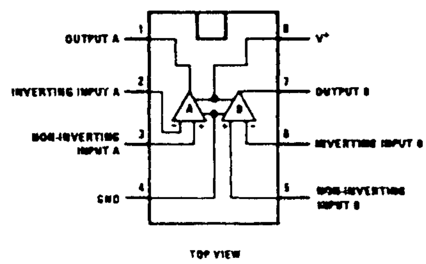
Metal Can Package



DS005709-3

Order Number LM193H * LM193H/883 , LM193AH-QMLV ** LM193AH, LM193AH/883, LM293H or LM393H See NS Package Number H08C

Dual-In-Line Package



DS005709-1

Order Number LM193J/883 * LM193AJ/883, LM193AJ-QMLV ** LM393M, LM393MX, LM2903M, LM2903MX, LM393N or LM2903N See NS Package Number J08A, M08A or N08E

Note: * Also available per JM38510/11202

Note: ** See STD Mil DWG 5962-94526

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, V+	36V
Differential Input Voltage (Note 8)	36V
Input Voltage	−0.3V to +36V
Input Current (V_{IN}<−0.3V) (Note 3)	50 mA
Power Dissipation (Note 1)	
Molded DIP	780 mW
Metal Can	660 mW
Small Outline Package	510 mW
Output Short-Circuit to Ground (Note 2)	Continuous
Operating Temperature Range	
LM393/LM393A	0°C to +70°C
LM293/LM293A	−25°C to +85°C
LM193/LM193A	−55°C to +125°C
LM2903	−40°C to +85°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	+260°C
Soldering Information	
Dual-In-Line Package	
Soldering (10 seconds)	260°C
Small Outline Package	215°C
Vapor Phase (60 seconds)	
Infrared (15 seconds)	220°C

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

ESD rating (1.5 kΩ in series with 100 pF)	1300V

Electrical Characteristics

(V^+=5V, T_A = 25°C, unless otherwise stated)

Parameter	Conditions		LM193A Min	LM193A Typ	LM193A Max	LM293A, LM393A Min	LM293A, LM393A Typ	LM293A, LM393A Max	Units
Input Offset Voltage	(Note 9)			1.0	2.0		1.0	2.0	mV
Input Bias Current	$I_{IN}(+)$ or $I_{IN}(-)$ with Output In Linear Range, V_{CM} = 0V (Note 5)			25	100		25	250	nA
Input Offset Current	$I_{IN}(+)-I_{IN}(-)$ V_{CM} = 0V			3.0	25		5.0	50	nA
Input Common Mode Voltage Range	V+ = 30V (Note 6)		0		V+−1.5	0		V+−1.5	V
Supply Current	R_L=∞	V^+=5V		0.4	1		0.4	1	mA
		V^+=36V		1	2.5		1	2.5	mA
Voltage Gain	R_L≥15 kΩ, V^+=15V V_O = 1V to 11V		50	200		50	200		V/mV
Large Signal Response Time	V_{IN}=TTL Logic Swing, V_{REF}=1.4V V_{RL}=5V, R_L=5.1 kΩ			300			300		ns
Response Time	V_{RL}=5V, R_L=5.1 kΩ (Note 7)			1.3			1.3		μs
Output Sink Current	$V_{IN}(-)$=1V, $V_{IN}(+)$=0, V_O≈1.5V		6.0	16		6.0	16		mA
Saturation Voltage	$V_{IN}(-)$=1V, $V_{IN}(+)$=0, I_{SINK}≤4 mA			250	400		250	400	mV
Output Leakage Current	$V_{IN}(-)$=0, $V_{IN}(+)$=1V, V_O=5V			0.1			0.1		nA

Electrical Characteristics

(V^+=5V, T_A = 25°C, unless otherwise stated)

Parameter	Conditions		LM193 Min	LM193 Typ	LM193 Max	LM293, LM393 Min	LM293, LM393 Typ	LM293, LM393 Max	LM2903 Min	LM2903 Typ	LM2903 Max	Units
Input Offset Voltage	(Note 9)			1.0	5.0		1.0	5.0		2.0	7.0	mV
Input Bias Current	$I_{IN}(+)$ or $I_{IN}(-)$ with Output In Linear Range, V_{CM} = 0V (Note 5)			25	100		25	250		25	250	nA
Input Offset Current	$I_{IN}(+)-I_{IN}(-)$ V_{CM} = 0V			3.0	25		5.0	50		5.0	50	nA
Input Common Mode Voltage Range	V+ = 30V (Note 6)		0		V+−1.5	0		V+−1.5	0		V+−1.5	V
Supply Current	R_L=∞	V^+=5V		0.4	1		0.4	1		0.4	1.0	mA
		V^+=36V		1	2.5		1	2.5		1	2.5	mA

Electrical Characteristics (Continued)

(V^+=5V, T_A = 25°C, unless otherwise stated)

Parameter	Conditions	LM193			LM293, LM393			LM2903			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Voltage Gain	R_L≥15 kΩ, V^+=15V V_O = 1V to 11V	50	200		50	200		25	100		V/mV
Large Signal Response Time	V_{IN}=TTL Logic Swing, V_{REF}=1.4V V_{RL}=5V, R_L=5.1 kΩ		300			300			300		ns
Response Time	V_{RL}=5V, R_L=5.1 kΩ (Note 7)		1.3			1.3			1.5		μs
Output Sink Current	$V_{IN}(-)$=1V, $V_{IN}(+)$=0, V_O≤1.5V	6.0	16		6.0	16		6.0	16		mA
Saturation Voltage	$V_{IN}(-)$=1V, $V_{IN}(+)$=0, I_{SINK}≤4 mA		250	400		250	400		250	400	mV
Output Leakage Current	$V_{IN}(-)$=0, $V_{IN}(+)$=1V, V_O=5V		0.1			0.1			0.1		nA

Electrical Characteristics

(V+ = 5V) (Note 4)

Parameter	Conditions	LM193A			Units
		Min	Typ	Max	
Input Offset Voltage	(Note 9)			4.0	mV
Input Offset Current	$I_{IN(+)}-I_{IN(-)}$, V_{CM}=0V			100	nA
Input Bias Current	$I_{IN}(+)$ or $I_{IN}(-)$ with Output in Linear Range, V_{CM}=0V (Note 5)			300	nA
Input Common Mode Voltage Range	V^+=30V (Note 6)	0		V^+−2.0	V
Saturation Voltage	$V_{IN}(-)$=1V, $V_{IN}(+)$=0, I_{SINK}≤4 mA			700	mV
Output Leakage Current	$V_{IN}(-)$=0, $V_{IN(+)}$=1V, V_O=30V			1.0	μA
Differential Input Voltage	Keep All V_{IN}'s≥0V (or V^-, if Used), (Note 8)			36	V

Electrical Characteristics

(V+ = 5V) (Note 4)

Parameter	Conditions	LM193			LM293, LM393			LM2903			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	(Note 9)			9			9		9	15	mV
Input Offset Current	$I_{IN(+)}-I_{IN(-)}$, V_{CM}=0V			100			150		50	200	nA
Input Bias Current	$I_{IN}(+)$ or $I_{IN}(-)$ with Output in Linear Range, V_{CM}=0V (Note 5)			300			400		200	500	nA
Input Common Mode Voltage Range	V^+=30V (Note 6)	0		V^+−2.0	0		V^+−2.0	0		V^+−2.0	V
Saturation Voltage	$V_{IN}(-)$=1V, $V_{IN}(+)$=0, I_{SINK}≤4 mA			700			700		400	700	mV
Output Leakage Current	$V_{IN}(-)$=0, $V_{IN(+)}$=1V, V_O=30V			1.0			1.0			1.0	μA
Differential Input Voltage	Keep All V_{IN}'s≥0V (or V^-, if Used), (Note 8)			36			36			36	V

Note 1: For operating at high temperatures, the LM393/LM393A and LM2903 must be derated based on a 125°C maximum junction temperature and a thermal resistance of 170°C/W which applies for the device soldered in a printed circuit board, operating in a still air ambient. The LM193/LM193A/LM293/LM293A must be derated based on a 150°C maximum junction temperature. The low bias dissipation and the "ON-OFF" characteristic of the outputs keeps the chip dissipation very small (P_D≤100 mW), provided the output transistors are allowed to saturate.

Note 2: Short circuits from the output to V^+ can cause excessive heating and eventual destruction. When considering short circuits to ground, the maximum output current is approximately 20 mA independent of the magnitude of V^+.

Note 3: This input current will only exist when the voltage at any of the input leads is driven negative. It is due to the collector-base junction of the input PNP transistors becoming forward biased and thereby acting as input diode clamps. In addition to this diode action, there is also lateral NPN parasitic transistor action on the IC chip. This transistor action can cause the output voltages of the comparators to go to the V^+ voltage level (or to ground for a large overdrive) for the time duration that an input is driven negative. This is not destructive and normal output states will re-establish when the input voltage, which was negative, again returns to a value greater than −0.3V.

Note 4: These specifications are limited to −55°C≤T_A≤+125°C, for the LM193/LM193A. With the LM293/LM293A all temperature specifications are limited to −25°C≤T_A≤+85°C and the LM393/LM393A temperature specifications are limited to 0°C≤T_A≤+70°C. The LM2903 is limited to −40°C≤T_A≤+85°C.

LM78XX Series Voltage Regulators

General Description

The LM78XX series of three terminal regulators is available with several fixed output voltages making them useful in a wide range of applications. One of these is local on card regulation, eliminating the distribution problems associated with single point regulation. The voltages available allow these regulators to be used in logic systems, instrumentation, HiFi, and other solid state electronic equipment. Although designed primarily as fixed voltage regulators these devices can be used with external components to obtain adjustable voltages and currents.

The LM78XX series is available in an aluminum TO-3 package which will allow over 1.0A load current if adequate heat sinking is provided. Current limiting is included to limit the peak output current to a safe value. Safe area protection for the output transistor is provided to limit internal power dissipation. If internal power dissipation becomes too high for the heat sinking provided, the thermal shutdown circuit takes over preventing the IC from overheating.

Considerable effort was expanded to make the LM78XX series of regulators easy to use and mininize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

For output voltage other than 5V, 12V and 15V the LM117 series provides an output voltage range from 1.2V to 57V.

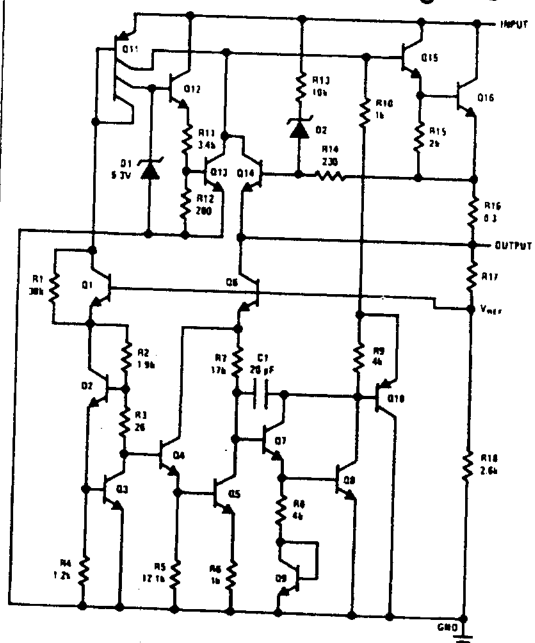
Features

- Output current in excess of 1A
- Internal thermal overload protection
- No external components required
- Output transistor safe area protection
- Internal short circuit current limit
- Available in the aluminum TO-3 package

Voltage Range

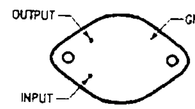
LM7805C	5V
LM7812C	12V
LM7815C	15V

Schematic and Connection Diagrams



TL/H/7746-1

Metal Can Package
TO-3 (K)
Aluminum

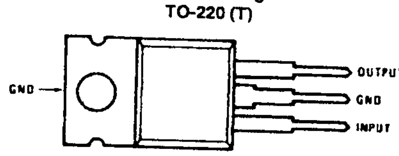


TL/H/7746-2

Bottom View

Order Number LM7805CK, LM7812CK or LM7815CK
See NS Package Number KC02A

Plastic Package
TO-220 (T)



TL/H/7746-3

Top View

Order Number LM7805CT, LM7812CT or LM7815CT
See NS Package Number T03B

Absolute Maximum Ratings

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

Input Voltage (V_O = 5V, 12V and 15V)	35V
Internal Power Dissipation (Note 1)	Internally Limited
Operating Temperature Range (T_A)	0°C to +70°C
Maximum Junction Temperature	
(K Package)	150°C
(T Package)	150°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec.)	
TO-3 Package K	300°C
TO-220 Package T	230°C

Electrical Characteristics LM78XXC (Note 2) 0°C ≤ Tj ≤ 125°C unless otherwise noted.

		Output Voltage		5V			12V			15V			Units
		Input Voltage (unless otherwise noted)		10V			19V			23V			
Symbol	**Parameter**	**Conditions**		**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	**Min**	**Typ**	**Max**	
V_O	Output Voltage	T_j = 25°C, 5 mA ≤ I_O ≤ 1A		4.8	5	5.2	11.5	12	12.5	14.4	15	15.6	V
		P_D ≤ 15W, 5 mA ≤ I_O ≤ 1A		4.75		5.25	11.4		12.6	14.25		15.75	V
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}		(7.5 ≤ V_{IN} ≤ 20)			(14.5 ≤ V_{IN} ≤ 27)			(17.5 ≤ V_{IN} ≤ 30)			V
ΔV_O	Line Regulation	I_O = 500 mA	T_j = 25°C		3	50		4	120		4	150	mV
			ΔV_{IN}	(7 ≤ V_{IN} ≤ 25)			14.5 ≤ V_{IN} ≤ 30)			(17.5 ≤ V_{IN} ≤ 30)			V
			0°C ≤ Tj ≤ +125°C			50			120			150	mV
			ΔV_{IN}	(8 ≤ V_{IN} ≤ 20)			(15 ≤ V_{IN} ≤ 27)			(18.5 ≤ V_{IN} ≤ 30)			V
		I_O ≤ 1A	T_j = 25°C			50			120			150	mV
			ΔV_{IN}	(7.5 ≤ V_{IN} ≤ 20)			(14.6 ≤ V_{IN} ≤ 27)			(17.7 ≤ V_{IN} ≤ 30)			V
			0°C ≤ Tj ≤ +125°C			25			60			75	mV
			ΔV_{IN}	(8 ≤ V_{IN} ≤ 12)			(16 ≤ V_{IN} ≤ 22)			(20 ≤ V_{IN} ≤ 26)			V
ΔV_O	Load Regulation	T_j = 25°C	5 mA ≤ I_O ≤ 1.5A		10	50		12	120		12	150	mV
			250 mA ≤ I_O ≤ 750 mA			25			60			75	mV
		5 mA ≤ I_O ≤ 1A, 0°C ≤ Tj ≤ +125°C				50			120			150	mV
I_Q	Quiescent Current	I_O ≤ 1A	T_j = 25°C			8			8			8	mA
			0°C ≤ Tj ≤ +125°C			8.5			8.5			8.5	mA
ΔI_Q	Quiescent Current Change	5 mA ≤ I_O ≤ 1A				0.5			0.5			0.5	mA
		T_j = 25°C, I_O ≤ 1A				1.0			1.0			1.0	mA
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}		(7.5 ≤ V_{IN} ≤ 20)			(14.8 ≤ V_{IN} ≤ 27)			(17.9 ≤ V_{IN} ≤ 30)			V
		I_O ≤ 500 mA, 0°C ≤ Tj ≤ +125°C				1.0			1.0			1.0	mA
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}		(7 ≤ V_{IN} ≤ 25)			(14.5 ≤ V_{IN} ≤ 30)			(17.5 ≤ V_{IN} ≤ 30)			V
V_N	Output Noise Voltage	T_A = 25°C, 10 Hz ≤ f ≤ 100 kHz			40			75			90		μV
$\frac{\Delta V_{IN}}{\Delta V_{OUT}}$	Ripple Rejection	f = 120 Hz	I_O ≤ 1A, Tj = 25°C or	62	80		55	72		54	70		dB
			I_O ≤ 500 mA 0°C ≤ Tj ≤ +125°C	62			55			54			dB
		V_{MIN} ≤ V_{IN} ≤ V_{MAX}		(8 ≤ V_{IN} ≤ 18)			(15 ≤ V_{IN} ≤ 25)			(18.5 ≤ V_{IN} ≤ 28.5)			V
R_O	Dropout Voltage	T_j = 25°C, I_{OUT} = 1A			2.0			2.0			2.0		V
	Output Resistance	f = 1 kHz			8			18			19		mΩ
	Short-Circuit Current	T_j = 25°C			2.1			1.5			1.2		A
	Peak Output Current	T_j = 25°C			2.4			2.4			2.4		A
	Average TC of V_{OUT}	0°C ≤ Tj ≤ +125°C, I_O = 5 mA			0.6			1.5			1.8		mV/°C
V_{IN}	Input Voltage Required to Maintain Line Regulation	T_j = 25°C, I_O ≤ 1A			7.5		14.6			17.7			V

Note 1: Thermal resistance of the TO-3 package (K, KC) is typically 4°C/W junction to case and 35°C/W case to ambient. Thermal resistance of the TO-220 package (T) is typically 4°C/W junction to case and 50°C/W case to ambient.

Note 2: All characteristics are measured with capacitor across the input of 0.22 μF, and a capacitor across the output of 0.1μF. All characteristics except noise voltage and ripple rejection ratio are measured using pulse techniques (t_w ≤ 10 ms, duty cycle ≤ 5%). Output voltage changes due to changes in internal temperature must be taken into account separately.

National Semiconductor

February 1988

CD4020BM/CD4020BC 14-Stage Ripple Carry Binary Counters CD4040BM/CD4040BC 12-Stage Ripple Carry Binary Counters CD4060BM/CD4060BC 14-Stage Ripple Carry Binary Counters

General Description

The CD4020BM/CD4020BC, CD4060BM/CD4060BC are 14-stage ripple carry binary counters, and the CD4040BM/CD4040BC is a 12-stage ripple carry binary counter. The counters are advanced one count on the negative transition of each clock pulse. The counters are reset to the zero state by a logical "1" at the reset input independent of clock.

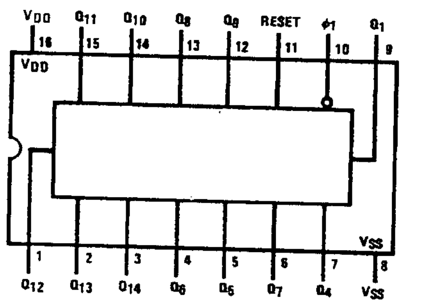
Features

- Wide supply voltage range — 1.0V to 15V
- High noise immunity — 0.45 V_{DD} (typ.)
- Low power TTL compatibility — Fan out of 2 driving 74L or 1 driving 74LS
- Medium speed operation — 8 MHz typ. at V_{DD} = 10V
- Schmitt trigger clock input

Connection Diagrams

Dual-In-Line Package

CD4020BM/CD4020BC



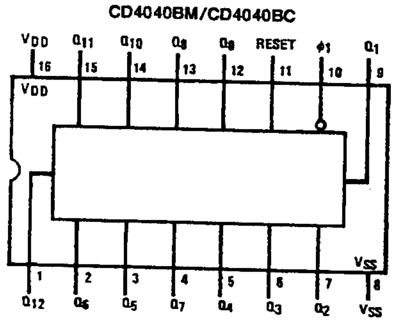
TL/F/5953-1

Top View

Order Number CD4020B, CD4040B or CD4060B

Dual-In-Line Package

CD4040BM/CD4040BC

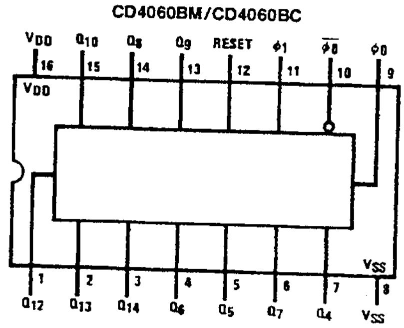


TL/F/5953-2

Top View

Dual-In-Line Package

CD4060BM/CD4060BC



TL/F/5953-3

Top View

RRD-B30M105/Printed in U. S. A.

Absolute Maximum Ratings (Notes 1 and 2)

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

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

Recommended Operating Conditions

Supply Voltage (V_{DD})	+3V to +15V
Input Voltage (V_{IN})	0V to V_{DD}
Operating Temperature Range (T_A)	
CD40XXBM	−55°C to +125°C
CD40XXBC	−40°C to +85°C

DC Electrical Characteristics CD40XXBM (Note 2)

Symbol	Parameter	Conditions	−55°C		+25°C			+125°C		Units
			Min	Max	Min	Typ	Max	Min	Max	
I_{DD}	Quiescent Device Current	V_{DD} = 5V, V_{IN} = V_{DD} or V_{SS}		5			5		150	μA
		V_{DD} = 10V, V_{IN} = V_{DD} or V_{SS}		10			10		300	μA
		V_{DD} = 15V, V_{IN} = V_{DD} or V_{SS}		20			20		600	μA
V_{OL}	Low Level Output Voltage	V_{DD} = 5V		0.05		0	0.05		0.05	V
		V_{DD} = 10V		0.05		0	0.05		0.05	V
		V_{DD} = 15V		0.05		0	0.05		0.05	V
V_{OH}	High Level Output Voltage	V_{DD} = 5V	4.95		4.95	5		4.95		V
		V_{DD} = 10V	9.95		9.95	10		9.95		V
		V_{DD} = 15V	14.95		14.95	15		14.95		V
V_{IL}	Low Level Input Voltage	V_{DD} = 5V, V_O = 0.5V or 4.5V		1.5		2	1.5		1.5	V
		V_{DD} = 10V, V_O = 1.0V or 9.0V		3.0		4	3.0		3.0	V
		V_{DD} = 15V, V_O = 1.5V or 13.5V		4.0		6	4.0		4.0	V
V_{IH}	High Level Input Voltage	V_{DD} = 5V, V_O = 0.5V or 4.5V	3.5		3.5	3		3.5		V
		V_{DD} = 10V, V_O = 1.0V or 9.0V	7.0		7.0	6		7.0		V
		V_{DD} = 15V, V_O = 1.5V or 13.5V	11.0		11.0	9		11.0		V
I_{OL}	Low Level Output Current (See Note 3)	V_{DD} = 5V, V_O = 0.4V	0.64		0.51	0.88		0.36		mA
		V_{DD} = 10V, V_O = 0.5V	1.6		1.3	2.25		0.9		mA
		V_{DD} = 15V, V_O = 1.5V	4.2		3.4	8.8		2.4		mA
I_{OH}	High Level Output Current (See Note 3)	V_{DD} = 5V, V_O = 4.6V	−0.64		−0.51	−0.88		−0.36		mA
		V_{DD} = 10V, V_O = 9.5V	−1.6		−1.3	−2.25		−0.9		mA
		V_{DD} = 15V, V_O = 13.5V	−4.2		−3.4	−8.8		−2.4		mA
I_{IN}	Input Current	V_{DD} = 15V, V_{IN} = 0V		−0.10		-10^{-5}	−0.10		−1.0	μA
		V_{DD} = 15V, V_{IN} = 15V		0.10		10^{-5}	0.10		1.0	μA

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

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

Note 3: Data does not apply to oscillator points ϕ_0 and $\overline{\phi_0}$ of CD4060BM/CD4060BC. I_{OH} and I_{OL} are tested one output at a time.

DC Electrical Characteristics 40XXBC (Note 2)

Symbol	Parameter	Conditions	−40°C		+25°C			+85°C		Units
			Min	Max	Min	Typ	Max	Min	Max	
I_{DD}	Quiescent Device Current	V_{DD} = 5V, V_{IN} = V_{DD} or V_{SS}		20			20		150	μA
		V_{DD} = 10V, V_{IN} = V_{DD} or V_{SS}		40			40		300	μA
		V_{DD} = 15V, V_{IN} = V_{DD} or V_{SS}		80			80		600	μA
V_{OL}	Low Level Output Voltage	V_{DD} = 5V		0.05		0	0.05		0.05	V
		V_{DD} = 10V		0.05		0	0.05		0.05	V
		V_{DD} = 15V		0.05		0	0.05		0.05	V

DC Electrical Characteristics 40XXBC (Note 2) (Continued)

Symbol	Parameter	Conditions	−40°C		+25°C			+85°C		Units
			Min	Max	Min	Typ	Max	Min	Max	
V_{OH}	High Level Output Voltage	V_{DD} = 5V	4.95		4.95	5		4.95		V
		V_{DD} = 10V	9.95		9.95	10		9.95		V
		V_{DD} = 15V	14.95		14.95	15		14.95		V
V_{IL}	Low Level Input Voltage	V_{DD} = 5V, V_O = 0.5V or 4.5V		1.5		2	1.5		1.5	V
		V_{DD} = 10V, V_O = 1.0V or 9.0V		3.0		4	3.0		3.0	V
		V_{DD} = 15V, V_O = 1.5V or 13.5V		4.0		6	4.0		4.0	V
V_{IH}	High Level Input Voltage	V_{DD} = 5V, V_O = 0.5V or 4.5V	3.5		3.5	3		3.5		V
		V_{DD} = 10V, V_O = 1.0V or 9.0V	7.0		7.0	6		7.0		V
		V_{DD} = 15V, V_O = 1.5V or 13.5V	11.0		11.0	9		11.0		V
I_{OL}	Low Level Output Current (See Note 3)	V_{DD} = 5V, V_O = 0.4V	0.52		0.44	0.88		0.36		mA
		V_{DD} = 10V, V_O = 0.5V	1.3		1.1	2.25		0.9		mA
		V_{DD} = 15V, V_O = 1.5V	3.6		3.0	8.8		2.4		mA
I_{OH}	High Level Output Current (See Note 3)	V_{DD} = 5V, V_O = 4.6V	−0.52		−0.44	−0.88		−0.36		mA
		V_{DD} = 10V, V_O = 9.5V	−1.3		−1.1	−2.25		−0.9		mA
		V_{DD} = 15V, V_O = 13.5V	−3.6		−3.0	−8.8		−2.4		mA
I_{IN}	Input Current	V_{DD} = 15V, V_{IN} = 0V		−0.30		-10^{-5}	−0.30		−1.0	μA
		V_{DD} = 15V, V_{IN} = 15V		0.30		10^{-5}	0.30		1.0	μA

AC Electrical Characteristics* CD4020BM/CD4020BC, CD4040BM/CD4040BC

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

Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_{PHL1}, t_{PLH1}	Propagation Delay Time to Q_1	V_{DD} = 5V		250	550	ns
		V_{DD} = 10V		100	210	ns
		V_{DD} = 15V		75	150	ns
t_{PHL}, t_{PLH}	Interstage Propagation Delay Time from Q_n to Q_{n+1}	V_{DD} = 5V		150	330	ns
		V_{DD} = 10V		60	125	ns
		V_{DD} = 15V		45	90	ns
t_{THL}, t_{TLH}	Transition Time	V_{DD} = 5V		100	200	ns
		V_{DD} = 10V		50	100	ns
		V_{DD} = 15V		40	80	ns
t_{WL}, t_{WH}	Minimum Clock Pulse Width	V_{DD} = 5V		125	335	ns
		V_{DD} = 10V		50	125	ns
		V_{DD} = 15V		40	100	ns
t_{rCL}, t_{fCL}	Maximum Clock Rise and Fall Time	V_{DD} = 5V			No Limit	ns
		V_{DD} = 10V			No Limit	ns
		V_{DD} = 15V			No Limit	ns
f_{CL}	Maximum Clock Frequency	V_{DD} = 5V	1.5	4		MHz
		V_{DD} = 10V	4	10		MHz
		V_{DD} = 15V	5	12		MHz
$t_{PHL(R)}$	Reset Propagation Delay	V_{DD} = 5V		200	450	ns
		V_{DD} = 10V		100	210	ns
		V_{DD} = 15V		80	170	ns
$t_{WH(R)}$	Minimum Reset Pulse Width	V_{DD} = 5V		200	450	ns
		V_{DD} = 10V		100	210	ns
		V_{DD} = 15V		80	170	ns
C_{in}	Average Input Capacitance	Any Input		5	7.5	pF
C_{pd}	Power Dissipation Capacitance			50		pF

*AC Parameters are guaranteed by DC correlated testing.

AC Electrical Characteristics* CD4060BM/CD4060BC

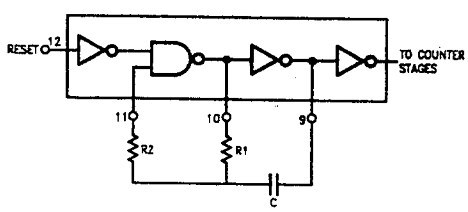
$T_A = 25°C$, $C_L = 50$ pF, $R_L = 200k$, $t_r = t_f = 20$ ns, unless otherwise noted

Symbol	Parameter	Conditions	Min	Typ	Max	Units
t_{PHL4}, t_{PLH4}	Propagation Delay Time to Q_4	$V_{DD} = 5V$ $V_{DD} = 10V$ $V_{DD} = 15V$		550 250 200	1300 525 400	ns ns ns
t_{PHL}, t_{PLH}	Interstage Propagation Delay Time from Q_n to Q_{n+1}	$V_{DD} = 5V$ $V_{DD} = 10V$ $V_{DD} = 15V$		150 60 45	330 125 90	ns ns ns
t_{THL}, t_{TLH}	Transition Time	$V_{DD} = 5V$ $V_{DD} = 10V$ $V_{DD} = 15V$		100 50 40	200 100 80	ns ns ns
t_{WL}, t_{WH}	Minimum Clock Pulse Width	$V_{DD} = 5V$ $V_{DD} = 10V$ $V_{DD} = 15V$		170 65 50	500 170 125	ns ns ns
t_{rCL}, t_{fCL}	Maximum Clock Rise and Fall Time	$V_{DD} = 5V$ $V_{DD} = 10V$ $V_{DD} = 15V$			No Limit No Limit No Limit	ns ns ns
f_{CL}	Maximum Clock Frequency	$V_{DD} = 5V$ $V_{DD} = 10V$ $V_{DD} = 15V$	1 3 4	3 8 10		MHz MHz MHz
$t_{PHL(R)}$	Reset Propagation Delay	$V_{DD} = 5V$ $V_{DD} = 10V$ $V_{DD} = 15V$		200 100 80	450 210 170	ns ns ns
$t_{WH(R)}$	Minimum Reset Pulse Width	$V_{DD} = 5V$ $V_{DD} = 10V$ $V_{DD} = 15V$		200 100 80	450 210 170	ns ns ns
C_{in}	Average Input Capacitance	Any Input		5	7.5	pF
C_{pd}	Power Dissipation Capacitance			50		pF

*AC Parameters are guaranteed by DC correlated testing.

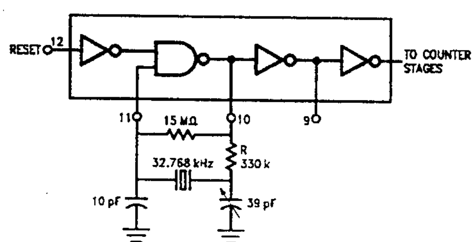
CD4060B Typical Oscillator Connections

RC Oscillator



TL/F/5953-4

Crystal Oscillator



TL/F/5953-5