Near East University

Faculty of Engineering

Department of Biomedical Engineering

THIS PROJECT IS ABOUT THE DESIGNED AND CONSTRUCTION OF A MICROCONTROLLER BASED TEMPERATURE MEASURING DEVICE WITH ALARM

Students: 1. Çağdaş Sadık YILDIRIM
20101680

2. Metin ÖZBUDAK
20101699

3. Esra YEŞİL
20101756

Project Supervisor: Prof. Dr. Doğan İ. AKAY

Department Head : Assist. Prof. Dr. Terin ADALI

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ABSTRACT

This Project is about the design and construction of a microcontroller based digital thermometer with alarm facility.

The designed device measures the temperature and than display on an LCD . If the temperature is higher than 37 C than a message is that the LCD say that the temperature high and the buzzer is sounded continuosly . If on the other hand; the temperature is bellow 34 C than a message is that the LCD say that the temperature is bellow normal and the buzzer is the turned on . If the temperature is normal than the buzzer is silent while the temperature is displayed on the LCD .

ACKNOWNLEDGEMENTS

First , i would like Prof. Dr. Doğan I. AKAY , my Project supervisor opportunity to work within was intellectually rewarding and fulfilling .

Many thanks to the department staff , who patiently answered my question and problems and supported me through various ways trought the academic year . I would also like the thank to my student colleagues who helped me all through the years full of class work and exams .

ÖZ

Vücut sıcaklığı sağlığımız için oldukça önemlidir İnsan vücudunun normal şartlardaki ısısı 36,8 +- 0,4 0C'dir. . Vücut tüm fonksiyonlarını bu ısı değerleri arasında yerine getirdiği için "ateş" diye adlandırılan vücut ısısının yükselmesi vücudun normal dengelerinde bir bozulma olduğunu gösterir. İnsan vücudu 37 C nin çok üstüne çıktığında ölüm tehlikesi yaşanabilir.İnsan vücut sıcaklığının gereğinden daha fazla olması sonucunda ateşe bağlı kalıcı rahatsızlıklar meydana gelebilir.Bu sıcaklığın çok altına düşmesi ve bu sıcaklıktan daha fazla sıcaklığa çıkması da sağlığımız açısından tehlikeli bir durumdur ve ölüme kadar gidebilir.Vücudun 37 C nin çok çok altına inmesi hipotermiye yol açar.Hipotermi halk arasında donma adını alır.Normal vücut ısısı 24 saat içinde de değişim gösterir. Isı sabah en düşük , öğleden sonra en yüksektir ve bu sınırlar arasında 0,5 0Clik bir fark olabilir. Beyinde hipofiz-hipotalamus bölgesinde bulunan termoregülatör bölgede (ısı düzenleme merkezinde) düzenlenmiş ısı pratik olarak ana atar damar (aort kanı) ısısı ile aynıdır.Klinik olarak , kulak zarı ve özofagus ısıları , aort kanı ısısına en yakın olanlardır. Oral (ağız içi) ısı aort kanından ortalama 0,25 0C kadar düşük, koltuk altı ısısı 0,9 0C kadar düşük iken , rektal (makat bölgesi) ısı 0,5 0C daha fazladır. Teknolojinin gelişmesi ile ısı değerlerini de dijital olarak görmek günümüz için kaçınılmaz olmuştur Bu makalemizde bir dijital alarmlı termometreden bahsedilmektedir.Tasarımı yapılmış olan sistem sayesinde ısı değerini santigrat olarak dijital ekranda gösteren ve insan vücut sıcaklığının normal şartlardaki ısısının değişme durumu olup olmadığı kullanıcıya belirtilmektedir

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CHAPTER 1

INTRODUCTION

The project seems to be very popular because it is so simple and still has a very useful and practical application. It is the perfect circuit to get started with PIC microcontrollers.This thermometer can be used as a standalone thermometer with LCD display or it can be read out with a PC running Linux, Windows, MacOSX or solaris. BSD Unix and others are probably also possible to use for reading the temperatures. No special drivers are needed.

1.1.What is Thermometer?

A thermometer (from the meaning "hot", "measure") is a device that measures temperature ortemperature gradient using a variety of different principles.[1] A thermometer has two important elements: the temperature sensor (e.g. the bulb on a mercury-in-glass thermometer) in which some physical change occurs with temperature, plus some means of converting this physical change into a numerical value (e.g. the visible scale that is marked on a mercury-in-glass thermometer).

There are many types and many uses for thermometers, as detailed below in sections of this article.

1.2.History of thermometer

Several inventors invented a version of the thermoscope at the same time. In 1593, Galileo Galilei invented a rudimentary water thermoscope, which for the first time, allowed temperature variations to be measured. Today, Galileo's inventioni is called the Galileo Thermometer, even though by definition it was really a thermoscope. It was a container filled with bulbs of varying mass, each with a temperature marking, the buoyancy of water changes with temperature, some of the bulbs sink while others float, the lowest bulb indicated what temperature it was.

In 1612, the Italian inventor Santorio Santorio became the first inventor to put a numerical scale on his thermoscope. It was perhaps the first crude clinical thermometer, as it was designed to be place in a patient's mouth for temperature taking.

Both Galilei's and Santorio's instruments were not very accurate.

In 1654, the first enclosed liquid-in-a-glass thermometer was invented by the Grand Duke of Tuscany, Ferdinand II. The Duke used alcohol as his liquid. However, it was still inaccurate and used no standardized scale.

1.3.Development

Various authors have credited the invention of the thermometer to Cornelis Drebbel, Robert Fludd, Galileo Galilei or Santorio Santorio. The thermometer was not a single invention, however, but a development.

Philo of Byzantium and Hero of Alexandria knew of the principle that certain substances, notably air, expand and contract and described a demonstration in which a closed tube partially filled with air had its end in a container of water. The expansion and contraction of the air caused the position of the water/air interface to move along the tube.

Such a mechanism was later used to show the hotness and coldness of the air with a tube in which the water level is controlled by the expansion and contraction of the air. These devices were developed by several European scientists in the 16th and 17th centuries, notably Galileo Galilei.As a result, devices were shown to produce this effect reliably, and the term thermoscope was adopted because it reflected the changes insensible heat (the concept of temperature was yet to arise The difference between a thermoscope and a thermometer is that the latter has a scale Though Galileo is often said to be the inventor of the thermometer, what he produced were thermoscopes.

The first clear diagram of a thermoscope was published in 1617 by Giuseppe Biancani: the first showing a scale and thus constituting a thermometer was by Robert Fludd in 1638. This was a vertical tube, closed by a bulb of air at the top, with the lower end opening into a vessel of water. The water level in the tube is controlled by the expansion and contraction of the air, so it is what we would now call an air thermometer

The first person to put a scale on a thermoscope is variously said to be Francesco Sagredohttp://en.wikipedia.org/wiki/Thermometer - cite_note-6 or Santorio Santorio] in about 1611 to 1613.

The word thermometer (in its French form) first appeared in 1624 in La Récréation Mathématique by J. Leurechon, who describes one with a scale of 8 degrees.The above instruments suffered from the disadvantage that they were also barometers, i.e. sensitive to air pressure. In about 1654 Ferdinando II de' Medici, Grand Duke of Tuscany, made sealed tubes part filled with alcohol, with a bulb and stem, the first modern-style thermometer, depending on the expansion of a liquid, and independent of air pressure.[8]Many other scientists experimented with various liquids and designs of thermometer.

However, each inventor and each thermometer was unique—there was no standard scale. In 1665 Christiaan Huygens suggested using the melting and boiling points of water as standards, and in 1694 Carlo Renaldini proposed using them as fixed points on a universal scale. In 1701 Isaac Newton proposed a scale of 12 degrees between the melting point of ice and body temperature. Finally in 1724 Daniel Gabriel Fahrenheit produced a temperature scale which now (slightly adjusted) bears his name. He could do this because he manufactured thermometers, using mercury (which has a high coefficient of expansion) for the first time and the quality of his production could provide a finer scale and greater reproducibility, leading to its general adoption. In 1742 Anders Celsius proposed a scale with zero at the boiling point and 100 degrees at the freezing point of water, though the scale which now bears his name has them the other way around.

In 1866 Sir Thomas Clifford Allbutt invented a clinical thermometer that produced a body temperature reading in five minutes as opposed to twenty. In 1999 Dr. Francesco Pompei of the Exergen Corporation introduced the world's first temporal artery thermometer, a non-invasive temperature sensor which scans the forehead in about two seconds and provides a medically accurate body temperature

Old thermometers were all non-registering thermometers. That is, the thermometer did not hold the temperature after it was moved to a place with a different temperature. Determining the temperature of a pot of hot liquid required the user to leave the thermometer in the hot liquid until after reading it. If the non-registering thermometer was removed from the hot liquid, then the temperature indicated on the thermometer would immediately begin changing to reflect the temperature of its new conditions (in this case, the air temperature). Registering thermometers are designed to hold the temperature indefinitely, so that the thermometer can be removed and read at a later time or in a more convenient place. The first registering thermometer was designed and built by James Six in 1782, and the design, known as Six's thermometer is still in wide use today. Mechanical registering thermometers hold either the highest or lowest temperature recorded, until manually re-set, e.g., by shaking down a mercury-in-glass thermometer, or until an even more extreme temperature is experienced. Electronic registering thermometers may be designed to remember the highest or lowest temperature, or to remember whatever temperature was present at a specified point in time.

Thermometers increasingly use electronic means to provide a digital display or input to a computer.

1.4.Physical principles of thermometry

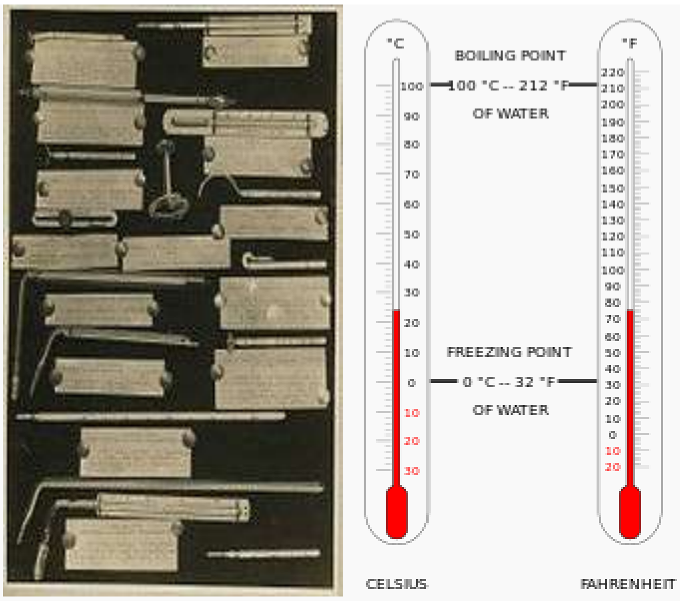


Figure 1 -Comparison of the Celsius and Fahrenheit scales

Thermometers may be described as empirical or absolute. Absolute thermometers are calibrated numerically by the thermodynamic absolute temperature scale. Empirical thermometers are not in general necessarily in exact agreement with absolute thermometers as to their numerical scale readings, but to qualify as thermometers at all they must agree with absolute thermometers and with each other in the following way: given any two bodies isolated in their separate respective thermodynamic equilibrium states, all thermometers agree as to which of the two has the higher temperature, or that the two have equal temperatures. For any two empirical thermometers, this does not require that the relation between their numerical scale readings be linear, but it does require that relation to be strictly monotonic This is a fundamental character of temperature and thermometers.

As it is customarily stated in textbooks, taken alone, the so-called "zeroth law of thermodynamics" fails to deliver this information, but the statement of the zeroth law of thermodynamics by James Serrin in 1977, though rather mathematically abstract, is more informative for thermometry: "Zeroth Law – There exists a topological line M which serves as a coordinate manifold of material behaviour. The points L of the manifold M are called 'hotness levels', and M is called the 'universal hotness manifold'." To this information there needs to be added a sense of greater hotness; this sense can be had, independently of calorimetry, of thermodynamics, and of properties of particular materials, from Wien's displacement law of thermal radiation: the temperature of a bath of thermal radiation is proportional, by a universal constant, to the frequency of the maximum of its frequency spectrum; this frequency is always positive, but can have values that tend to zero.

There are several principles on which empirical thermometers are built. Several such principles are essentially based on the constitutive relation between the state of a suitably selected particular material and its temperature. Only some materials are suitable for this purpose, and they may be considered as "thermometric materials". Radiometric thermometry, in contrast, can be only very slightly dependent on the constitutive relations of materials. In a sense then, radiometric thermometry might be thought of as "universal". This is because it rests mainly on a universality character of thermodynamic equilibrium, that it has the universal property of producing blackbody radiation.

Figure1.2 Bi-metallic thermometer for cooking and baking in an oven

There are various kinds of empirical thermometer based on material properties.

Many empirical thermometers rely on the constitutive relation between pressure, volume and temperature of their thermometric material. For example, mercury expands when heated.

If it is used for its relation between pressure and volume and temperature, a thermometric material must have three properties:

(1) its heating and cooling must be rapid. That is to say, when a quantity of heat enters or leaves a body of the material, the material must expand or contract to its final volume or reach its final pressure and must reach its final temperature with practically no delay; some of the heat that enters can be considered to change the volume of the body at constant temperature, and is called the latent heat of expansion at constant temperature; and the rest of it can be considered to change the temperature of the body at constant volume, and is called the specific heat at constant volume. Some materials do not have this property, and take some time to distribute the heat between temperature and volume change.

(2) its heating and cooling must be reversible. That is to say, the material must be able to be heated and cooled indefinitely often by the same increment and decrement of heat, and still return to its original pressure, volume and temperature every time. Some plastics do not have this property;

(3) its heating and cooling must be monotonic. That is to say, throughout the range of temperatures for which it is intended to work, (a) at a given fixed pressure, either (α) the volume increases when the temperature increases, or else (β) the volume decreases when the temperature increases; not (α) for some temperatures and (β) for others; or (b) at a given fixed volume, either (α) the pressure increases when the temperature increases, or else (β) the pressure decreases when the temperature increases; not (α) for some temperatures and (β) for others.

At temperatures around about 4 °C, water does not have the property (3), and is said to behave anomalously in this respect; thus water cannot be used as a material for this kind of thermometry for temperature ranges near 4 °C.Gases, on the other hand, all have the properties (1), (2), and (3)(a)(α) and (3)(b)(α). Consequently, they are suitable thermometric materials, and that is why they were important in the development of thermometry.

1.5.Calibrating a thermometer

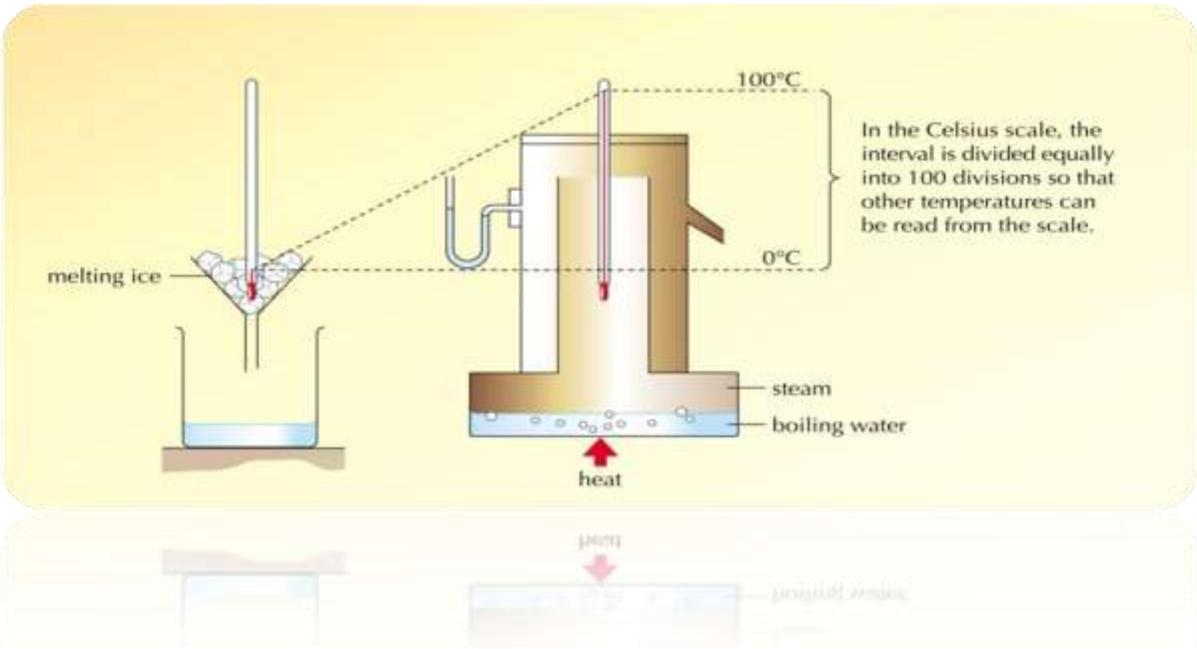


Figure 1.3

Thermometers can be calibrated either by comparing them with other calibrated thermometers or by checking them against known fixed points on the temperature scale. The best known of these fixed points are the melting andboiling points of pure water. (Note that the boiling point of water varies with pressure, so this must be controlled.)

The traditional method of putting a scale on a liquid-in-glass or liquid-in-metal thermometer was in three stages:

1. Immerse the sensing portion in a stirred mixture of pure ice and water at 1 Standard atmosphere (101.325 kPa; 760.0 mmHg) and mark the point indicated when it had come to thermal equilibrium.
2. Immerse the sensing portion in a steam bath at 1 Standard atmosphere (101.325 kPa; 760.0 mmHg) and again mark the point indicated.
3. Divide the distance between these marks into equal portions according to the temperature scale being used.

Other fixed points used in the past are the body temperature (of a healthy adult male) which was originally used by Fahrenheit as his upper fixed point (96 °F (36 °C) to be a number divisible by 12) and the lowest temperature given by a mixture of salt and ice, which was originally the definition of 0 °F (−18 °C).[29] (This is an example of a Frigorific mixture). As body temperature varies, the Fahrenheit scale was later changed to use an upper fixed point of boiling water at 212 °F (100 °C).

These have now been replaced by the defining points in the International Temperature Scale of 1990, though in practice the melting point of water is more commonly used than its triple point, the latter being more difficult to manage and thus restricted to critical standard measurement. Nowadays manufacturers will often use a thermostat bath or solid block where the temperature is held constant relative to a calibrated thermometer. Other thermometers to be calibrated are put into the same bath or block and allowed to come to equilibrium, then the scale marked, or any deviation from the instrument scale recorded. For many modern devices calibration will be stating some value to be used in processing an electronic signal to convert it to a temperature.

1.6. Types of Thermometer

There are two standard units used for measuring temperature, viz. Celsius and Fahrenheit. When we think of a thermometer, a mercury-filled glass tube comes to our mind.

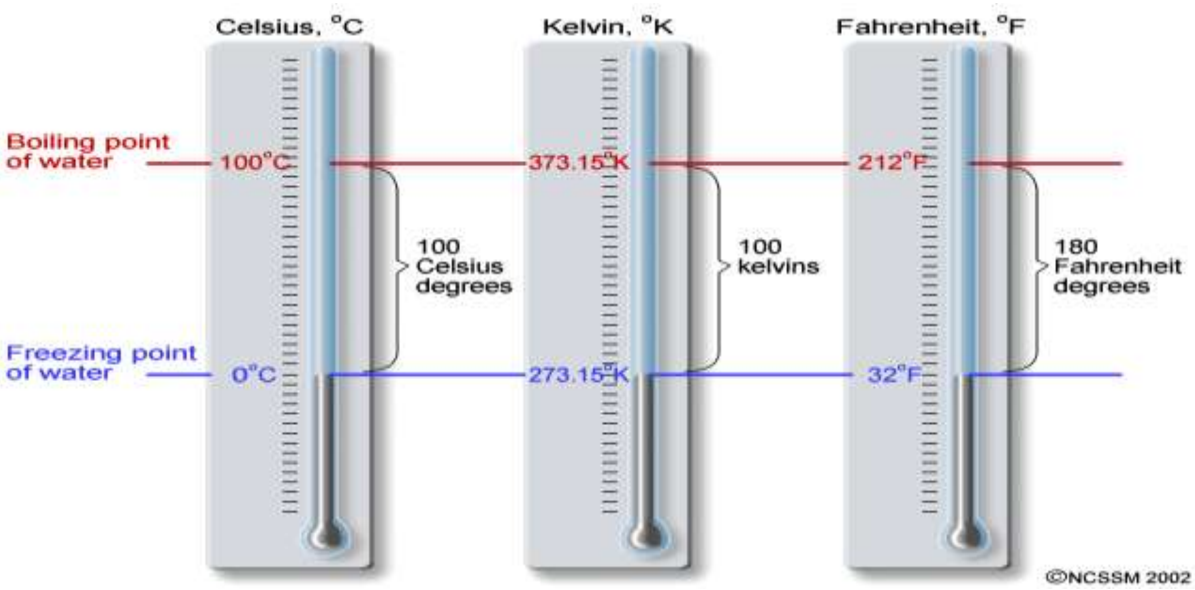
1.6.1. Types of temperature

Fahrenheit Scale - Daniel Gabriel Fahrenheit

What can be considered the first modern thermometer, the mercury thermometer with a standardized scale, was invented by Daniel Gabriel Fahrenheit in 1714.

Daniel Gabriel Fahrenheit was the German physicist who invented a alcohol thermometer in 1709, and the mercury thermometer in 1714. In 1724, he introduced the standard temperature scale that bears his name - Fahrenheit Scale - that was used to record changes in temperature in an accurate fashion.

The Fahrenheit scale divided the freezing and boiling points of water into 180 degrees. 32°F was the freezing pint of water and 212°F was the boiling point of water. 0°F was based on the temperature of an equal mixture of water, ice, and salt. Fahrenheit based his temperature scale on the temperature of the human body. Originally, the human body temperature was 100° F on the Fahrenheit scale, but it has since been adjusted to 98.6°F.



Centigrade Scale - Anders Celsius

The Celsius temperature scale is also referred to as the "centigrade" scale. Centigrade means "consisting of or divided into 100 degrees". In 1742, the Celsius scale was invented by Swedish Astronomer Anders Celsius. The Celsius scale has 100 degrees between the freezing point (0°C) and boiling point (100°C) of pure water at sea level air pressure. The term "Celsius" was adopted in 1948 by an international conference on weights and measures.

Kelvin Scale - Lord Kelvin

Lord Kelvin took the whole process one step further with his invention of the Kelvin Scale in 1848. The Kelvin Scale measures the ultimate extremes of hot and cold. Kelvin developed the idea of absolute temperature, what is called the "Second Law of Thermodynamics", and developed the dynamical theory of heat.

In the 19th century, scientists were researching what was the lowest temperature possible. The Kelvin scale uses the same units as the Celcius scale, but it starts at ABSOLUTE ZERO, the temperature at which everything including air freezes solid. Absolute zero is O K, which is -273°C degrees Celsius.

1.6.2. Applications of Different Thermometers

Clinical Thermometers

The clinical thermometers are used to measure the body temperature of the patient. There are again three types of clinical thermometers depending on the body part used to measure the temperature.

Ear (Tympanic) thermometers

Human ear is located near the brain. This makes it an accurate point to measure the body temperature. The temperature of the eardrum is measured by the ear thermometers. However, the eardrum is most fragile and delicate body part. Therefore, the body temperature cannot be measured by touching the eardrum. For temperature measurement, infrared sensors are used to remotely sense the temperature of the eardrum. Thermopile, an infrared sensor, is commonly used in ear thermometer.

Pacifier Thermometers

The pacifier thermometers are used to check the body temperature of babies or infants. They help measure the body temperature without irritating the baby. The thermometer is held in the mouth of the baby and the baby's natural sucking instinct is used to check its body temperature. The pacifier thermometers are very safe for checking the body.

Underarm or Oral Thermometers

The underarm thermometers are kept in the underarms to measure the body temperature of the patient. Likewise, the oral thermometers are held in the mouth for temperature .

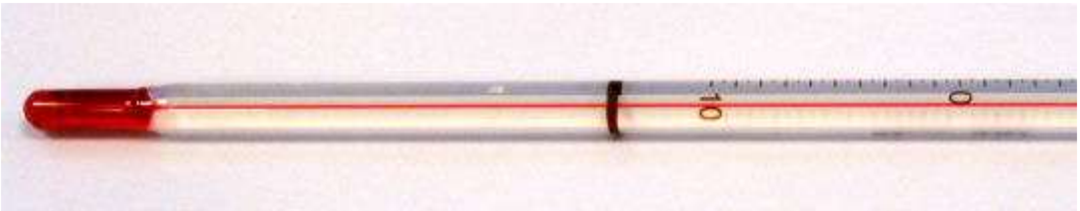
Food Thermometers

There are many food thermometers like the dial oven-safe thermometers, digital instant thermometers, pop-up thermometers and disposable thermometers. The dial oven-safe thermometers are used for thick foods and can be placed in the food while you are cooking the food. However, the dial oven-safe thermometers are not suitable for thin and watery foodstuffs. The digital instant thermometers cannot be kept in the food while cooking. These thermometers read the temperature within 10 seconds. The pop-up thermometers are used to measure the temperatures of turkey and chicken. The disposable thermometer strips are used to measure the temperature of food after they are cooked and they change the color according to the temperature. The color of these thermometer strips can be matched to a chart, which gives the corresponding temperature.

Outdoor Thermometers

The outdoor thermometers are used to measure the temperature of the surrounding air. Wireless outdoor thermometers are very popular these days.

Mercury and Alcohol Thermometers



Mercury thermometers have mercury filled in a glass tube and has a glass bulb at the bottom. As the temperature increases, the mercury rises in the glass tube. The glass tube is calibrated in Celsius, Fahrenheit or both. The rise in mercury determines the temperature according to the calibration. Alcohol thermometers have ethanol or toluene instead of mercury in the glass tube. All the other mechanism of the thermometer are same as that of the mercury thermometer. They are used as clinical thermometers.

Digital Thermometers

Digital thermometers use thermocouples or thermistors to sense the change in temperature and display the temperature on a digital display. They are widely used as clinical, outdoor and food thermometers. Infrared thermometers use the infrared sensors to determine the temperature and have a digital display.

Various types of thermometers are available today, instead of the traditional mercury thermometers. They are all used to measure temperature.

1.7. How Do I Use a Digital Thermometer?

A digital thermometer offers the quickest, most accurate way to take your child's temperature and can be used in the mouth, armpit, or rectum. Before you use this device, read the directions thoroughly. You need to know how the thermometer signals that the reading is complete (usually, it's a beep or a series of beeps or the temperature flashes in the digital window on the front side of the thermometer). Then, turn on the thermometer and make sure the screen is clear of any old readings. If your thermometer uses disposable plastic sleeves or covers, put one on according to the manufacturer's instructions. Remember to discard the sleeve after each use and to clean the thermometer according to the manufacturer's instructions before putting it back in its case.

To take a rectal temperature: Before becoming parents, most people cringe at the thought of taking a rectal temperature. But don't worry - it's a simple process:

1. Lubricate the tip of the thermometer with a water-soluble lubricating jelly (talk with your pharmacist or child's doctor).
2. Place your child face down across your lap while supporting the head, or lay the child down on a firm, flat surface, such as a changing table.
3. Place one hand firmly on your child's lower back to hold him or her still.
4. With your other hand, insert the lubricated thermometer through the anal opening, about half an inch to 1 inch (about 1.25 to 2.5 centimeters) into the rectum. Stop if you feel any resistance.
5. Steady the thermometer between your second and third fingers as you cup your hand against your baby's bottom. Soothe your child and speak quietly as you hold the thermometer in place.
6. Wait until you hear the appropriate number of beeps or other signal that the temperature is ready to be read. If you'd like to keep a record, write down the temperature, noting the time of day.

To take an oral temperature: This process is easy in an older, cooperative child.

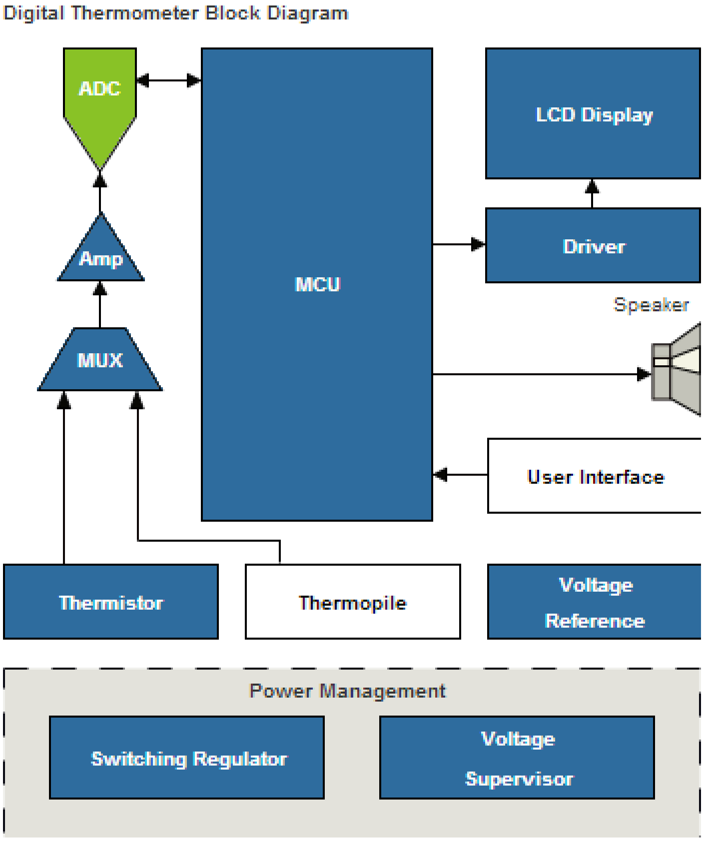
1. Wait 20 to 30 minutes after your child finishes eating or drinking to take an oral temperature, and make sure there's no gum or candy in your child's mouth.
2. Place the tip of the thermometer under the tongue and ask your child to close his or her lips around it. Remind your child not to bite down or talk and ask him or her to relax and breathe normally through the nose.
3. Wait until you hear the appropriate number of beeps or other signal that the temperature is ready to be read. Read and write down the number on the screen, noting the time of day that you took the reading.

To take an axillary temperature: This is a convenient way to take your child's temperature. Although not as accurate as a rectal or oral temperature in a cooperative child, some parents may prefer to take an axillary temperature, especially if your child can't hold a thermometer in his or her mouth.

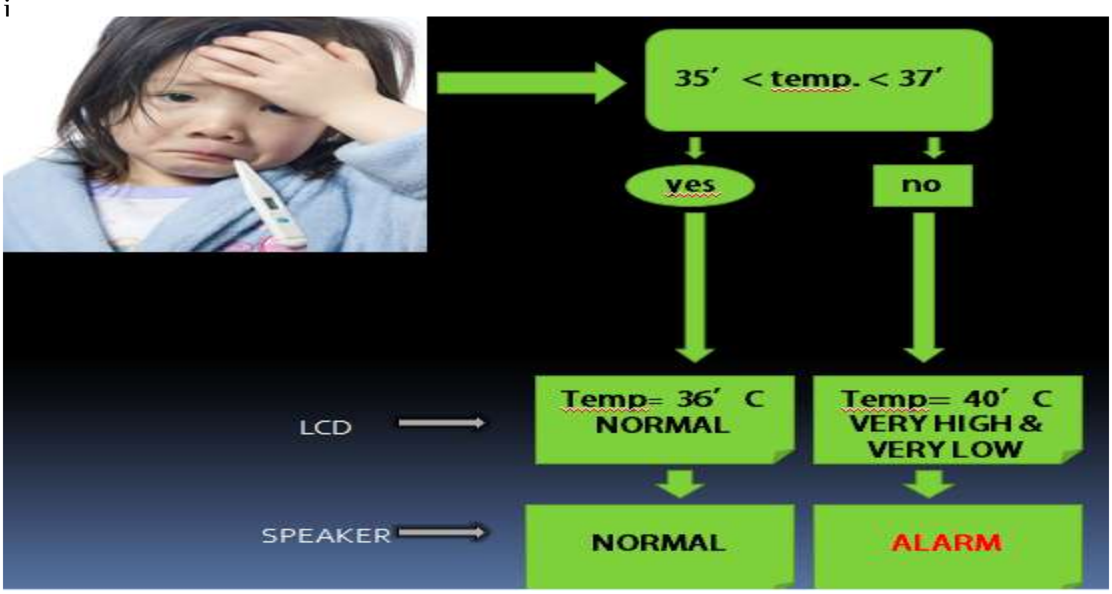
1. Remove your child's shirt and undershirt, and place the thermometer under your child's armpit (it must be touching skin only, not clothing).
2. Fold your child's arm across his or her chest to hold the thermometer in place.
3. Wait until you hear the appropriate number of beeps or other signal that the temperature is ready to be read. Read and write down the number on the screen, noting the time of day that you took the reading.

Whatever method you choose, here are some additional tips to keep in mind:

- Never take your child's temperature right after a bath or if he or she has been bundled tightly for a while - this can affect the temperature reading.
- Never leave a child unattended while taking a temperature.



Before, the analog signal that comes from sensor, converted into digital form via microprocessor. That digital signal is usable. It transfered to the user via speaker and d
i

- 

The reference values are between 35 and 37 C. If the temperature comes from the patient is above the 37 and below 35, system gives us alarm.And writing temp=x , very high and very low at lcd.else towards writing temp=x , normal at lcd.

CHAPTER 2

CIRCUIT ELEMENTS

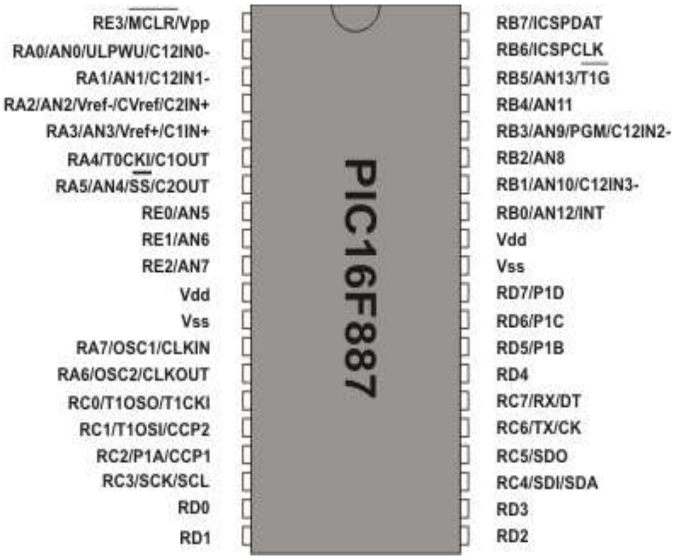
- PIC 16F887
- LM35
- Screen module
- Capacitor
- Resistor
- Easy buzz

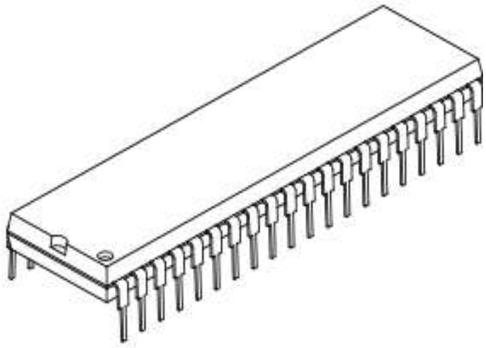
2.1. PIC 16F877

The PIC16F887 is one of the latest products from *Microchip*. It features all the components which modern microcontrollers normally have. For its low price, wide range of application, high quality and easy availability, it is an ideal solution in applications such as: the control of different processes in industry, machine control devices, measurement of different values etc. Some of its main features are listed below.

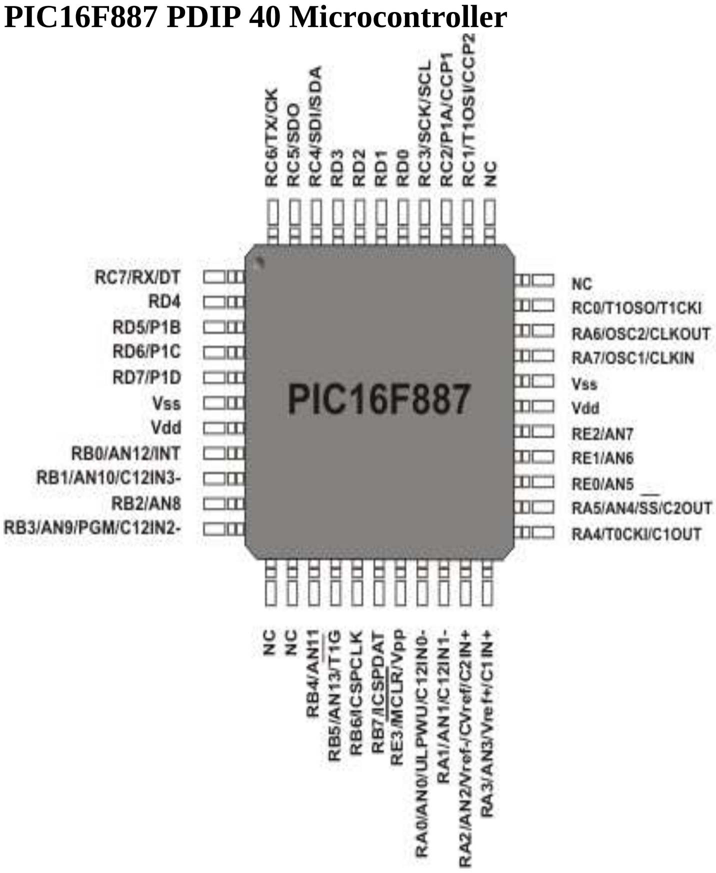
- **RISC architecture**
  - Only 35 instructions to learn
  - All single-cycle instructions except branches
- **Operating frequency 0-20 MHz**
- **Precision internal oscillator**
  - Factory calibrated
  - Software selectable frequency range of 8MHz to 31KHz
- **Power supply voltage 2.0-5.5V**
  - Consumption: 220uA (2.0V, 4MHz), 11uA (2.0 V, 32 KHz) 50nA (stand-by mode)
- **Power-Saving Sleep Mode**
- **Brown-out Reset (BOR) with software control option**

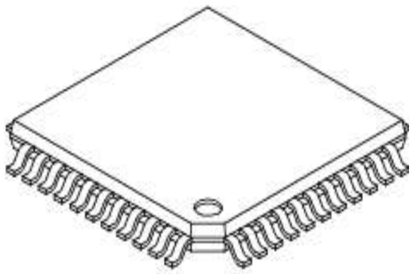
- **35 input/output pins**
  - High current source/sink for direct LED drive
  - software and individually programmable *pull-up* resistor
  - Interrupt-on-Change pin
- **8K ROM memory in FLASH technology**
  - Chip can be reprogrammed up to 100.000 times
- ***In-Circuit Serial Programming* Option**
  - Chip can be programmed even embedded in the target device
- **256 bytes EEPROM memory**
  - Data can be written more than 1.000.000 times
- **368 bytes RAM memory**
- **A/D converter:**
  - 14-channels
  - 10-bit resolution
- **3 independent timers/counters**
- **Watch-dog timer**
- **Analogue comparator module with**
  - Two analogue comparators
  - Fixed voltage reference (0.6V)
  - Programmable on-chip voltage reference
- **PWM output steering control**
- **Enhanced USART module**
  - Supports RS-485, RS-232 and LIN2.0
  - Auto-Baud Detect
- **Master Synchronous Serial Port (MSSP)**
  - supports SPI and I2C mode



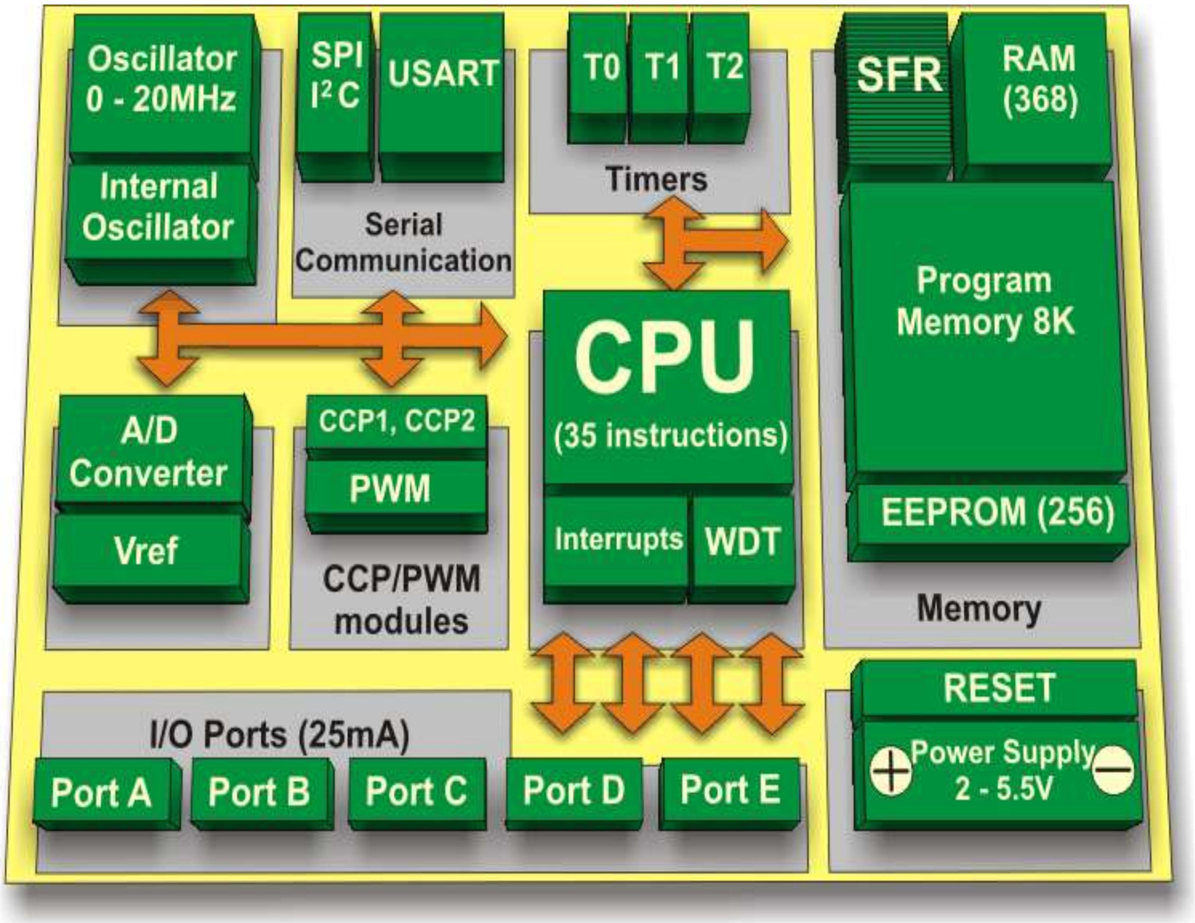


PIC16F887 PDIP 40 Microcontroller





PIC16F887 QFN 44 Microcontroller



PIC16F887 Block Diagram

Pin Description

As seen in Fig. 1-1 above, the most pins are multi-functional. For example, designator RA3/AN3/Vref+/C1IN+ for the fifth pin specifies the following functions:

- RA3 Port A third digital input/output
- AN3 Third analog input
- Vref+ Positive voltage reference
- C1IN+ Comparator C1positive input

This small trick is often used because it makes the microcontroller package more compact without affecting its functionality. These various pin functions cannot be used simultaneously, but can be changed at any point during operation.

The following tables, refer to the PDIP 40 microcontroller.

Name	Number (DIP 40)	Function	Description
RE3/MCLR/Vpp	1	RE3	General purpose input Port E
		MCLR	Reset pin. Low logic level on this pin resets microcontroller.
		Vpp	Programming voltage
RA0/AN0/ULPWU/C12IN0-	2	RA0	General purpose I/O port A
		AN0	A/D Channel 0 input
		ULPWU	Stand-by mode deactivation input
		C12IN0-	Comparator C1 or C2 negative input
RA1/AN1/C12IN1-	3	RA1	General purpose I/O port A
		AN1	A/D Channel 1
		C12IN1-	Comparator C1 or C2 negative input
RA2/AN2/Vref-/CVref/C2IN+	4	RA2	General purpose I/O port A
		AN2	A/D Channel 2
		Vref-	A/D Negative Voltage Reference input
		CVref	Comparator Voltage Reference Output
		C2IN+	Comparator C2 Positive Input
RA3/AN3/Vref+/C1IN+	5	RA3	General purpose I/O port A
		AN3	A/D Channel 3
		Vref+	A/D Positive Voltage Reference Input
		C1IN+	Comparator C1 Positive Input
RA4/T0CKI/C1OUT	6	RA4	General purpose I/O port A
		T0CKI	Timer T0 Clock Input
		C1OUT	Comparator C1 Output
RA5/AN4/SS/C2OUT	7	RA5	General purpose I/O port A
		AN4	A/D Channel 4
		SS	SPI module Input (*Slave Select*)
		C2OUT	Comparator C2 Output
RE0/AN5	8	RE0	General purpose I/O port E
		AN5	A/D Channel 5
RE1/AN6	9	RE1	General purpose I/O port E
		AN6	A/D Channel 6
RE2/AN7	10	RE2	General purpose I/O port E
		AN7	A/D Channel 7
Vdd	11	+	Positive supply
Vss	12	-	Ground (GND)

Pin Assignment

Name	Number (DIP 40)	Function	Description
RA7/OSC1/CLKIN	13	RA7	General purpose I/O port A
		OSC1	Crystal Oscillator Input
		CLKIN	External Clock Input
RA6/OSC2/CLKOUT	14	OSC2	Crystal Oscillator Output
		CLKO	Fosc/4 Output
		RA6	General purpose I/O port A
RC0/T1OSO/T1CKI	15	RC0	General purpose I/O port C
		T1OSO	Timer T1 Oscillator Output
		T1CKI	Timer T1 Clock Input
RC1/T1OSO/T1CKI	16	RC1	General purpose I/O port C
		T1OSI	Timer T1 Oscillator Input
		CCP2	CCP1 and PWM1 module I/O
RC2/P1A/CCP1	17	RC2	General purpose I/O port C
		P1A	PWM Module Output
		CCP1	CCP1 and PWM1 module I/O
RC3/SCK/SCL	18	RC3	General purpose I/O port C
		SCK	MSSP module Clock I/O in SPI mode
		SCL	MSSP module Clock I/O in I^2C mode
RD0	19	RD0	General purpose I/O port D
RD1	20	RD1	General purpose I/O port D
RD2	21	RD2	General purpose I/O port D
RD3	22	RD3	General purpose I/O port D
RC4/SDI/SDA	23	RC4	General purpose I/O port A
		SDI	MSSP module *Data* input in SPI mode
		SDA	MSSP module *Data* I/O in I^2C mode
RC5/SDO	24	RC5	General purpose I/O port C
		SDO	MSSP module *Data* output in SPI mode
RC6/TX/CK	25	RC6	General purpose I/O port C
		TX	USART Asynchronous Output
		CK	USART Synchronous Clock
RC7/RX/DT	26	RC7	General purpose I/O port C
		RX	USART Asynchronous Input
		DT	USART Synchronous Data

cont. Pin Assignment

Name	Number (DIP 40)	Function	Description
RD4	27	RD4	General purpose I/O port D
RD5/P1B	28	RD5	General purpose I/O port D
		P1B	PWM Output
RD6/P1C	29	RD6	General purpose I/O port D
		P1C	PWM Output
RD7/P1D	30	RD7	General purpose I/O port D
		P1D	PWM Output
Vss	31	-	Ground (GND)
Vdd	32	+	Positive Supply
RB0/AN12/INT	33	RB0	General purpose I/O port B
		AN12	A/D Channel 12
		INT	External Interrupt
RB1/AN10/C12INT3-	34	RB1	General purpose I/O port B
		AN10	A/D Channel 10
		C12INT3-	Comparator C1 or C2 Negative Input
RB2/AN8	35	RB2	General purpose I/O port B
		AN8	A/D Channel 8
RB3/AN9/PGM/C12IN2-	36	RB3	General purpose I/O port B
		AN9	A/D Channel 9
		PGM	Programming enable pin
		C12IN2-	Comparator C1 or C2 Negative Input
RB4/AN11	37	RB4	General purpose I/O port B
		AN11	A/D Channel 11
RB5/AN13/T1G	38	RB5	General purpose I/O port B
		AN13	A/D Channel 13
		T1G	Timer T1 External Input
RB6/ICSPCLK	39	RB6	General purpose I/O port B
		ICSPCLK	Serial programming Clock
RB7/ICSPDAT	40	RB7	General purpose I/O port B
		ICSPDAT	Programming enable pin

cont. Pin Assignment
Central Processor Unit (CPU)

I’m not going to bore you with the operation of the CPU at this stage, however it is important to state that the CPU is manufactured with in RISC technology an important factor when deciding which microprocessor to use.

RISC *Reduced Instruction Set Computer*, gives the PIC16F887 two great advantages:

- The CPU can recognizes only 35 simple instructions (In order to program some other microcontrollers it is necessary to know more than 200 instructions by heart).

- The execution time is the same for all instructions except two and lasts 4 clock cycles (oscillator frequency is stabilized by a quartz crystal). The Jump and Branch instructions execution time is 2 clock cycles. It means that if the microcontroller's operating speed is 20MHz, execution time of each instruc tion will be 200nS, i.e. the program will be executed at the speed of 5 million instructions per second!

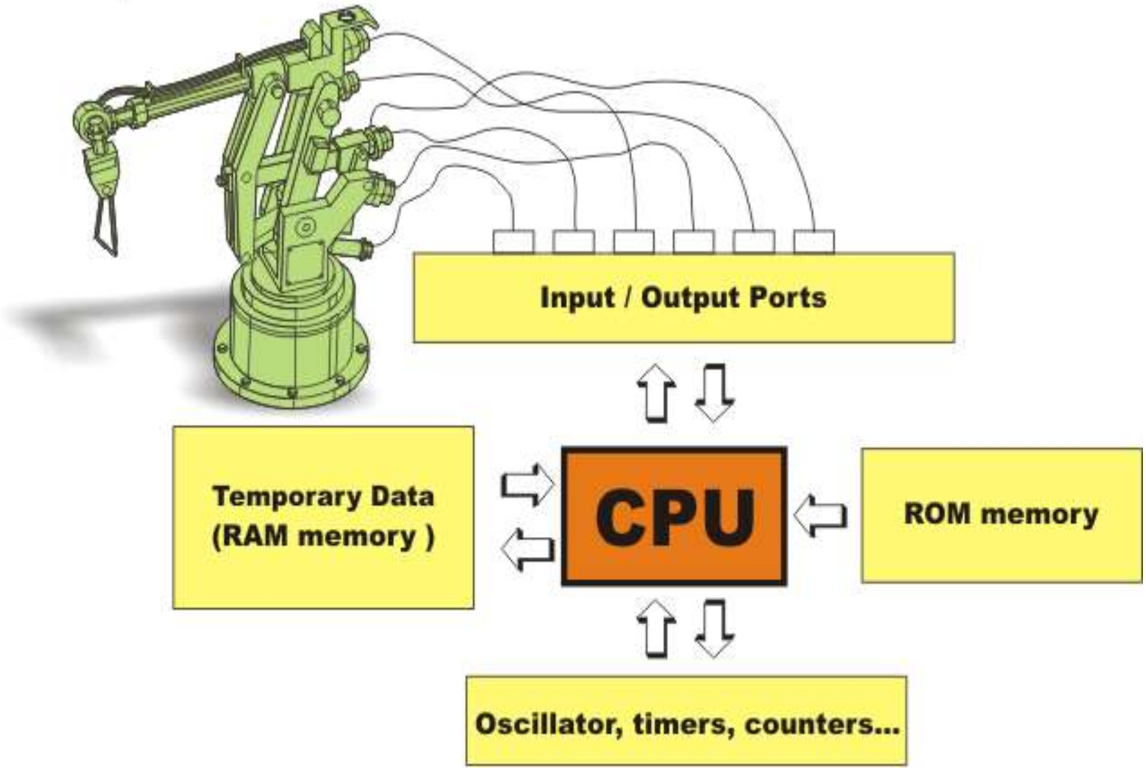


Fig. 1-4 CPU Memory

Memory

This microcontroller has three types of memory- ROM, RAM and EEPROM. All of them will be separately discussed since each has specific functions, features and organization.

ROM Memory

ROM memory is used to permanently save the program being executed. This is why it is often called "program memory". The PIC16F887 has 8Kb of ROM (in total of 8192 locations). Since this ROM is made with FLASH technology, its contents can be changed by providing a special programming voltage (13V).

Anyway, there is no need to explain it in detail because it is automatically performed by means of a special program on the PC and a simple electronic device called the Programmer.

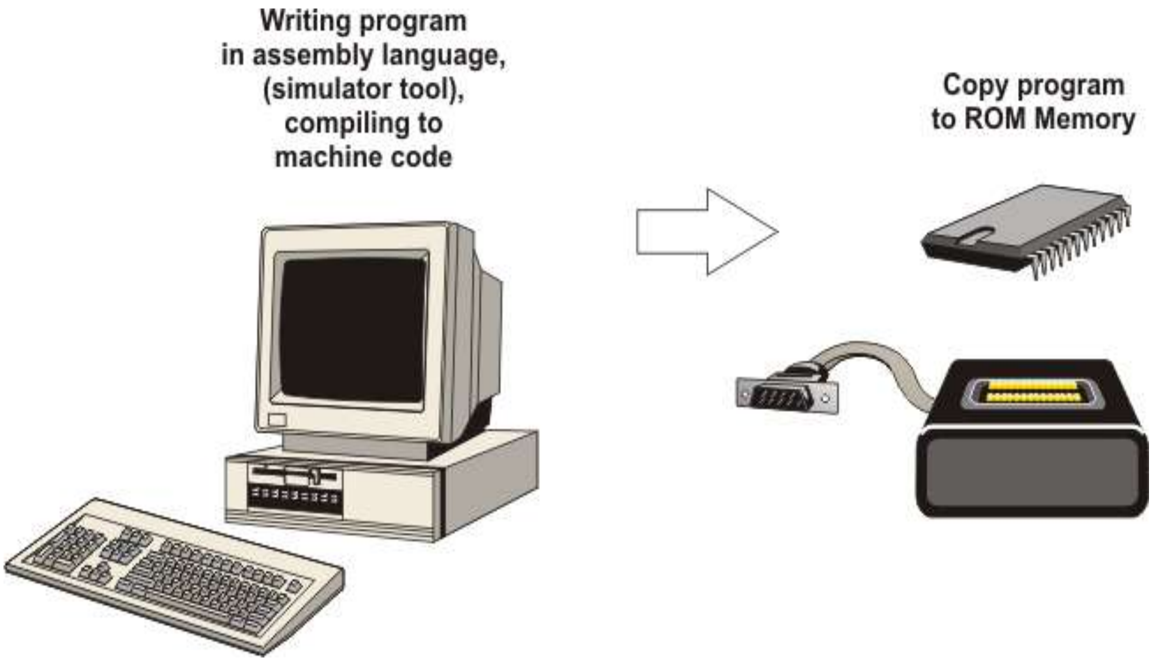


Fig. 1-5 ROM Memory Consept

EEPROM Memory

Similar to program memory, the contents of EEPROM is permanently saved, even the power goes off. However, unlike ROM, the contents of the EEPROM can be changed during operation of the microcontroller. That is why this memory (256 locations) is a perfect one for permanently saving results created and used during the operation.

RAM Memory

This is the third and the most complex part of microcontroller memory. In this case, it consists of two parts: general-purpose registers and special-function registers (SFR).

Even though both groups of registers are cleared when power goes off and even though they are manufactured in the same way and act in the similar way, their functions do not have many things in common.

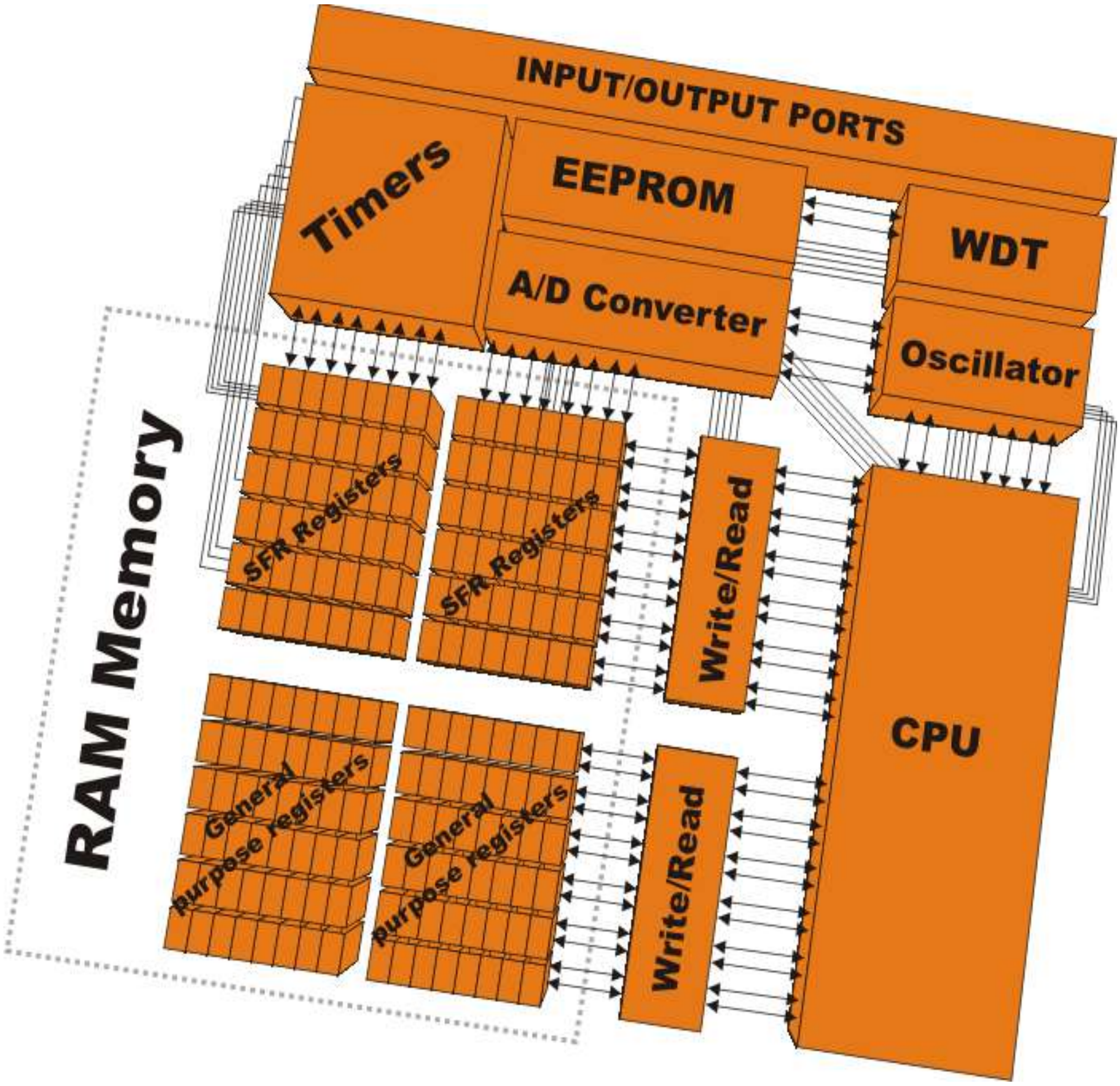


Fig. 1-6 SFR and General Purpose Registers

General-Purpose Registers

General-Purpose registers are used for storing temporary data and results created during operation. For example, if the program performs a counting (for example, counting products on the assembly line), it is necessary to have a register which stands for what we in everyday life call “sum”. Since the microcontroller is not creative at all, it is necessary to specify the address of some general purpose register and assign it a new function. A simple program to increment the value of this register by 1, after each product passes through a sensor, should be created.

Therefore, the microcontroller can execute that program because it now knows what and where the sum which must be incremented is. Similarly to this simple example, each program variable must be preassigned some of general-purpose register.

SFR Registers

Special-Function registers are also RAM memory locations, but unlike general-purpose registers, their purpose is predetermined during manufacturing process and cannot be changed. Since their bits are physically connected to particular circuits on the chip (A/D converter, serial communication module, etc.), any change of their contents directly affects the operation of the microcontroller or some of its circuits. For example, by changing the TRISA register, the function of each port A pin can be changed in a way it acts as input or output. Another feature of these memory locations is that they have their names (registers and their bits), which considerably facilitates program writing. Since high-level programming language can use the list of all registers with their exact addresses, it is enough to specify the register's name in order to read or change its contents.

RAM Memory Banks

The data memory is partitioned into four banks. Prior to accessing some register during program writing (in order to read or change its contents), it is necessary to select the bank which contains that register. Two bits of the STATUS register are used for bank selecting, which will be discussed later. In order to facilitate operation, the most commonly used SFRs have the same address in all banks which enables them to be easily accessed.

Addr.	Name	Addr.	Name	Addr.	Name	Addr.	Name
00h	INDF	80h	INDF	100h	INDF	180h	INDF
01h	TMR0	81h	OPTION_REG	101h	TMR0	181h	OPTION_REG
02h	PCL	82h	PCL	102h	PCL	182h	PCL
03h	STATUS	83h	STATUS	103h	STATUS	183h	STATUS
04h	FSR	84h	FSR	104h	FSR	184h	FSR
05h	PORTA	85h	TRISA	105h	WDTCON	185h	SRCON
06h	PORTB	86h	TRISB	106h	PORTB	186h	TRISB
07h	PORTC	87h	TRISC	107h	CM1CON0	187h	BAUDCTL
08h	PORTD	88h	TRISD	108h	CM2CON0	188h	ANSEL
09h	PORTE	89h	TRISE	109h	CM2CON1	189h	ANSELH
0Ah	PCLATH	8Ah	PCLATH	10Ah	PCLATH	18Ah	PCLATH
0Bh	INTCON	8Bh	INTCON	10Bh	INTCON	18Bh	INTCON
0Ch	PIR1	8Ch	PIE1	10Ch	EEDAT	18Ch	EECON1
0Dh	PIR2	8Dh	PIE2	10Dh	EEADR	18Dh	EECON2
0Eh	TMR1L	8Eh	PCON	10Eh	EEDATH	18Eh	Not Used
0Fh	TMR1H	8Fh	OSCCON	10Fh	EEADRH	18Fh	Not Used
10h	T1CON	90h	OSCTUNE	110h	General Purpose Registers 96 bytes	190h	General Purpose Registers 96 bytes
11h	TMR2	91h	SSPCON2				
12h	T2CON	92h	PR2				
13h	SSPBUF	93h	SSPADD				
14h	SSPCON	94h	SSPSTAT				
15h	CCPR1L	95h	WPUB				
16h	CCPR1H	96h	IOCB				
17h	CCP1CON	97h	VRCON				
18h	RCSTA	98h	TXSTA				
19h	TXREG	99h	SPBRG				
1Ah	RCREG	9Ah	SPBRGH				
1Bh	CCPR2L	9Bh	PWM1CON				
1Ch	CCPR2H	9Ch	ECCPAS				
1Dh	CCP2CON	9Dh	PSTRCON				
1Eh	ADRESH	9Eh	ADRESL				
1Fh	ADCON0	9Fh	ADCON1				
20h	General Purpose Registers 96 bytes	A0h	General Purpose Registers 80 bytes				
7Fh		FFh		17Fh		1EFh	
	Bank 0		**Bank 1**		**Bank 2**		**Bank 3**

Address Banks

SFRs bank 0

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
00h	INDF	Indirect register							
01h	TMR0	Timer T0 Register							
02h	PCL	Least Significant Byte of Program Counter							
03h	STATUS	IRP	RP1	RP0	TO	PD	Z	DC	C
04h	FSR	Indirect Data Memory Address Pointer							
05h	PORTA	RA7	RA6	RA5	RA4	RA3	RA2	RA1	RA0
06h	PORTB	RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0
07h	PORTC	RC7	RC6	RC5	RC4	RC3	RC2	RC1	RC0
08h	PORTD	RD7	RD6	RD5	RD4	RD3	RD2	RD1	RD0
09h	PORTE	-	-	-	-	RE3	RE2	RE1	RE0
0Ah	PCLATH	-	-	-	Upper 5 bits of Program Counter				
0Bh	INTCON	GIE	PEIE	T0IE	INTE	RBIE	T0IF	INTF	RBIF
0Ch	PIR1	-	ADIF	RCIF	TXIF	SSPIF	CCP1IF	TMR2IF	TMR1IF
0Dh	PIR2	OSFIF	C2IF	C1IF	EEIF	BCLIF	ULPWUIF	-	CCP2IF
0Eh	TMR1L	Least Significant Byte of the 16-bit Timer TMR0							
0Fh	TMR1H	Most Significant Byte of the 16-bit Timer TMR0							
10h	T1CON	T1GINV	TMR1GE	T1CKPS1	T1CKPS0	T1OSCEN	T1SYNC	TMR1CS	TMR1ON
11h	TMR2	Timer T2 Register							
12h	T2CON	-	TOUTPS3	TOUTPS2	TOUTPS1	TOUTPS0	TMR2ON	T2CKPS1	T2CKPS0
13h	SSPBUF	Synchronous Serial Port Receive Buffer/Transmit Register							
14h	SSPCON	WCOL	SSPOV	SSPEN	CKP	SSPM3	SSPM2	SSPM1	SSPM0
15h	CCPR1L	Capture/ComparePWM Register 1 Low Byte (LSB)							
16h	CCPR1H	Capture/ComparePWM Register 1 High Byte (LSB)							
17h	CCP1CON	P1M1	P1M0	DC1B1	DC1B0	CCP1M3	CCP1M2	CCP1M1	CCP1M0
18h	RCSTA	SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D
19h	TXREG	EUSART Transmit Data Register							
1Ah	RCREG	EUSART Receive Data Register							
1Bh	CCPR2L	Capture/Compare PWM Register 1 Low Byte (LSB)							
1Ch	CCPR2H	Capture/Compare PWM Register 1 High Byte (LSB)							
1Dh	CCP2CON	-	-	DC2B1	DC2B0	CCP2M3	CCP2M2	CCP2M1	CCP2M0
1Eh	ADRESH	A/D Result Register High Byte							
1Fh	ADCON0	ADCS1	ADCS0	CHS3	CHS2	CHS1	CHS0	GO/DONE	ADON

SFRs bank 1

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
80h	INDF	Indirect Register							
81h	OPTION_REG	RBPU	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0
82h	PCL	Least Significant Byte of Program Counter							
83h	STATUS	IRP	RP1	RP0	TO	PD	Z	DC	C
84h	FSR	Indirect Data Memory Address Pointer							
85h	TRISA	TRISA7	TRISA6	TRISA5	TRISA4	TRISA3	TRISA2	TRISA1	TRISA0
86h	TRISB	TRISB7	TRISB6	TRISB5	TRISB4	TRISB3	TRISB2	TRISB1	TRISB0
87h	TRISC	TRISC7	TRISC6	TRISC5	TRISC4	TRISC3	TRISC2	TRISC1	TRISC0
88h	TRISD	TRISD7	TRISD6	TRISD5	TRISD4	TRISD3	TRISD2	TRISD1	TRISD0
89h	TRISE	-	-	-	-	TRISE3	TRISE2	TRISE1	TRISE0
8Ah	PCLATH	-	-	-	Upper 5 bits of the Ptogram Counter				
8Bh	INTCON	GIE	PEIE	T0IE	INTE	RBIE	T0IF	INTF	RBIF
8Ch	PIE1	-	ADIE	RCIE	TXIE	SSPIE	CCP1IE	TMR2IE	TMR1IE
8Dh	PIE2	OSFIE	C2IE	C1IE	EEIE	BCLIE	ULPWUIE	-	CCP2IE
8Eh	PCON	-	-	ULPWUE	SBOREN	-	-	POR	BOR
8Fh	OSCCON	-	IRCF2	IRCF1	IRCF0	OSTS	HTS	LTS	SCS
90h	OSCTUNE	-	-	-	TUN4	TUN3	TUN2	TUN1	TUN0
91h	SSPCON2	GCEN	ACKSTAT	ACKDT	ACKEN	RCEN	PEN	RSEN	SEN
92h	PR2	Timer T2 Period Register							
93h	SSPADD	Synchronous Serial Port (I^2 C mode) Address Register							
93h	SSPMSK	MSK7	MSK6	MSK5	MSK4	MSK3	MSK2	MSK1	MSK0
94h	SSPSTAT	SMP	CKE	D/A	P	S	R/W	UA	BF
95h	WPUB	WPUB7	WPUB6	WPUB5	WPUB4	WPUB3	WPUB2	WPUB1	WPUB0
96h	IOCB	IOCB7	IOCB6	IOCB5	IOCB4	IOCB3	IOCB2	IOCB1	IOCB0
97h	VRCON	VREN	VROE	VRR	VRSS	VR3	VR2	VR1	VR0
98h	TXSTA	CSRC	TX9	TXEN	SYNC	SENDB	BRGH	TRMT	TX9D
99h	SPBRG	BRG7	BRG6	BRG5	BRG4	BRG3	BRG2	BRG1	BRG0
9Ah	SPBRGH	BRG15	BRG14	BRG13	BRG12	BRG11	BRG10	BRG9	BRG8
9Bh	PWM1CON	PRSEN	PDC6	PDC5	PDC4	PDC3	PDC2	PDC1	PDC0
9Ch	ECCPAS	ECCPASE	ECCPAS2	ECCPAS1	ECCPAS0	PSSAC1	PSSAC0	PSSBD1	PSSBD0
9Dh	PSTRCON	-	-	-	STRSYNC	STRD	STRC	STRB	STRA
9Eh	ADRESL	A/D Result Register Low Byte							
9Fh	ADCON1	ADFM	-	VCFG1	VCFG0	-	-	-	-

SFRs bank 2

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
100h	INDF	Indirect register							
101h	TMR0	Timer T0 Register							
102h	PCL	Least Significant Byte of the Program Counter							
103h	STATUS	IRP	RP1	RP0	TO	PD	Z	DC	C
104h	FSR	Indirect Data Memory Address Pointer							
105h	WDTCON	-	-	-	WDTPS3	WDTPS2	WDTPS1	WDTPS0	SWDTEN
106h	PORTB	RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0
107h	CM1CON0	C1ON	C1OUT	C1OE	C1POL	-	C1R	C1CH1	C1CH0
108h	CM2CON0	C2ON	C2OUT	C2OE	C2POL	-	C2R	C2CH1	C2CH0
109h	CM2CON1	MC1OUT	MC2OUT	C1RSEL	C2RSEL	-	-	T1GSS	C2SYNC
10Ah	PCLATH	-	-	-	Upper 5 bits of the Program Counter				
10Bh	INTCON	GIE	PEIE	T0IE	INTE	RBIE	T0IF	INTF	RBIF
10Ch	EEDAT	EEDAT7	EEDAT6	EEDAT5	EED AT4	EEDAT3	EEDAT2	EEDAT1	EEDAT0
10Dh	EEADR	EEADR7	EEADR6	EEADR5	EEADR4	EEADR3	EEADR2	EEADR1	EEADR0
10Eh	EEDATH	-	-	EEDATH5	EEDATH4	EEDATH3	EEDATH2	EEDATH1	EEDATH0
10Fh	EEADRH	-	-	-	EEADRH4	EEADRH3	EEADRH2	EEADRH1	EEADRH0

SFRs bank 3

Address	Name	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1	Bit0
180h	INDF	Indirect Register							
181h	OPTION_REG	RBPU	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0
182h	PCL	Least Significan Byte of the Program Counter							
183h	STATUS	IRP	RP1	RP0	TO	PD	Z	DC	C
184h	FSR	Indirect Data Memory Address Pointer							
185h	SRCON	SR1	SR0	C1SEN	C2REN	PULSS	PULSR	-	FVREN
186h	TRISB	TRISB7	TRISB6	TRISB5	TRISB4	TRISB3	TRISB2	TRISB1	TRISB0
187h	BAUDCTL	ABDOVF	RCIDL	-	SCKP	BRG16	-	WUE	ABDEN
188h	ANSEL	ANS7	ANS6	ANS5	ANS4	ANS3	ANS2	ANS1	ANS0
189h	ANSELH	-	-	ANS13	ANS12	ANS11	ANS10	ANS9	ANS8
19Ah	PCLATH	-	-	-	Upper 5 bits of the Program Counter				
19Bh	INTCON	GIE	PEIE	T0IE	INTE	RBIE	T0IF	INTF	RBIF
19Ch	EECON1	EEPGD	-	-	-	WRERR	WREN	WR	RD
19Dh	EECON2	EEPROM Control Register 2							

STACK

A part of the RAM used for the stack consists of eight 13-bit registers. Before the microcontroller starts to execute a subroutine (CALLinstruction) or when an interrupt occurs, the address of first next instruction being currently executed is pushed onto the stack, i.e. onto one of its registers. In that way, upon subroutine or interrupt execution, the microcontroller knows from where to continue regular program execution. This address is cleared upon return to the main program because there is no need to save it any longer, and one location of the stack is automatically available for further use.
It is important to understand that data is always circularly pushed onto the stack. It means that after the stack has been pushed eight times, the ninth push overwrites the value that was stored with the first push. The tenth push overwrites the second push and so on. Data overwritten in this way is not recoverable. In addition, the programmer cannot access these registers for write or read and there is no Status bit to indicate stack overflow or stack underflow conditions. For that reason, one should take special care of it during program writing.

Interrupt System

The first thing that the microcontroller does when an interrupt request arrives is to execute the current instruction and then stop regular program execution. Immediately after that, the current program memory address is automatically pushed onto the stack and the default address (predefined by the manufacturer) is written to the program counter. That location from where the program continues execution is called the interrupt vector. For the PIC16F887 microcontroller, this address is 0004h. As seen in Fig. 1-7 below, the location containing interrupt vector is passed over during regular program execution.

Part of the program being activated when an interrupt request arrives is called the interrupt routine. Its first instruction is located at the interrupt vector. How long this subroutine will be and what it will be like depends on the skills of the programmer as well as the interrupt source itself. Some microcontrollers have more interrupt vectors (every interrupt request has its vector), but in this case there is only one. Consequently, the first part of the interrupt routine consists in interrupt source recognition.

Finally, when the interrupt source is recognized and interrupt routine is executed, the microcontroller reaches the RETFIE instruction, pops the address from the stack and continues program execution from where it left off.

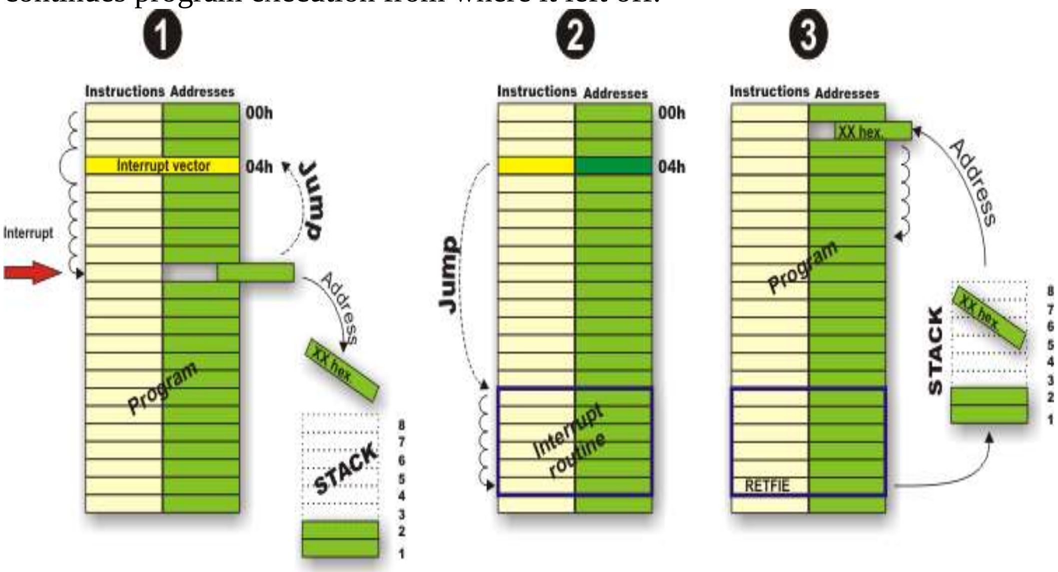


Fig.1-7 Interrupt System

2.2. LM35

Precision Centigrade Temperature Sensors

General Description

The LM35 series are precision integrated-circuit temperaturesensors, whose output voltage is linearly proportional to theCelsius (Centigrade) temperature. The LM35 thus has anadvantage over linear temperature sensors calibrated in° Kelvin, as the user is not required to subtract a largeconstant voltage from its output to obtain convenient Centigradescaling. The LM35 does not require any externalcalibration or trimming to provide typical accuracies of ±1⁄4°Cat room temperature and ±3⁄4°C over a full −55 to +150°Ctemperature range. Low cost is assured by trimming andcalibration at the wafer level. The LM35's low output impedance,linear output, and precise inherent calibration makeinterfacing to readout or control circuitry especially easy. Itcan be used with single power supplies, or with plus andminus supplies. As it draws

only 60 µA from its supply, it hasvery low self-heating, less than 0.1°C in still air. The LM35 israted to operate over a −55° to +150°C temperature range,while the LM35C is rated for a −40° to +110°C range (−10°with improved accuracy). The LM35 series is available packagedin hermetic TO-46 transistor packages, while the
LM35C, LM35CA, and LM35D are also available in theplastic TO-92 transistor package. The LM35D is also availablein an 8-lead surface mount small outline package and aplastic TO-220 package.

Features

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

Typical Applications

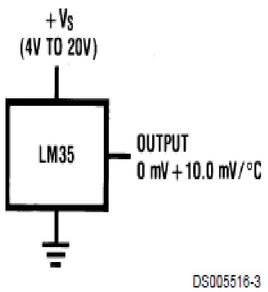
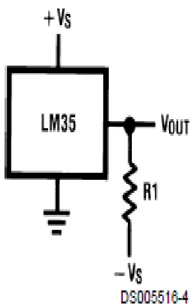


FIGURE 1. Basic Centigrade Temperature Sensor (+2°C to +150°C)

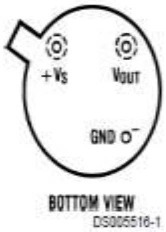


Choose $R_1 = -V_S/50\ \mu A$
V_{OUT}=+1,500 mV at +150°C
= +250 mV at +25°C
= −550 mV at −55°C

FIGURE 2. Full-Range Centigrade Temperature Sensor

Connectin Pin Diagram

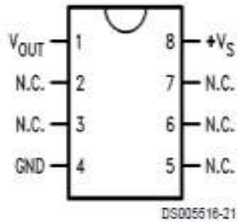
TO-46
Metal Can Package*



*Case is connected to negative pin (GND)

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

SO-8
Small Outline Molded Package



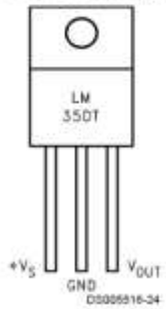
N.C. = No Connection

Top View
Order Number LM35DM
See NS Package Number M08A

TO-92
Plastic Package

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

TO-220
Plastic Package*



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

Order Number LM35DT
See NS Package Number TA03F

Absolute Maximum Ratings

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

-Supply Voltage +35V to −0.2V
-Output Voltage +6V to −1.0V
-Output Current 10 mA
-Storage Temp.;
-TO-46 Package, −60°C to +180°C
-TO-92 Package, −60°C to +150°C
-SO-8 Package, −65°C to +150°C
-TO-220 Package, −65°C to +150°C
-Lead Temp.:
-TO-46 Package,
-(Soldering, 10 seconds) 300°C
-TO-92 and TO-220 Package,
-(Soldering, 10 seconds) 260°C

-SO Package (Note 12)
-Vapor Phase (60 seconds) 215°C
-Infrared (15 seconds) 220°C
-ESD Susceptibility (Note 11) 2500V
-Specified Operating Temperature Range: TMIN to T MAX
-(Note 2)
-LM35, LM35A −55°C to +150°C
-LM35C, LM35CA −40°C to +110°C
-LM35D 0°C to +100°C

Electrical Characteristics

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

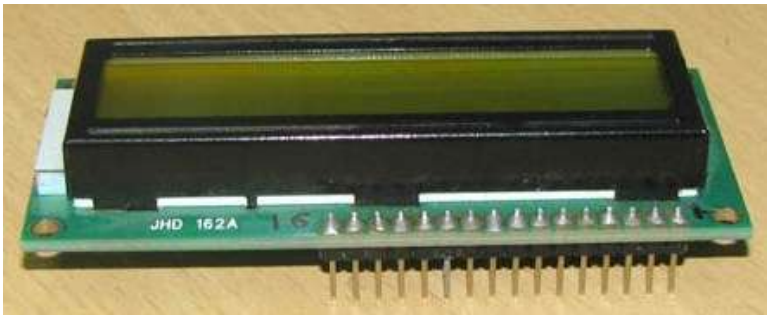
Parameter	Conditions	LM35 Typical	LM35 Tested Limit (Note 4)	LM35 Design Limit (Note 5)	LM35C, LM35D Typical	LM35C, LM35D Tested Limit (Note 4)	LM35C, LM35D Design Limit (Note 5)	Units (Max.)
Accuracy, LM35, LM35C (Note 7)	T_A=+25°C	±0.4	±1.0		±0.4	±1.0		°C
	T_A=−10°C	±0.5			±0.5		±1.5	°C
	$T_A=T_{MAX}$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

Note 1: Unless otherwise noted, these specifications apply: −55°C£TJ£+150°C for the LM35 and LM35A; −40°£TJ£+110°C for the LM35C and LM35CA; and0°£TJ£+100°C for the LM35D. VS=+5Vdc and ILOAD=50 μA, in the circuit of Figure 2. These specifications also apply from +2°C to TMAX in the circuit of Figure 1.
Specifications in **boldface** apply over the full rated temperature range.
Note 2: Thermal resistance of the TO-46 package is 400°C/W, junction to ambient, and 24°C/W junction to case. Thermal resistance of the TO-92 package is180°C/W junction to ambient. Thermal resistance of the small outline molded package is 220°/W junction to ambient. Thermal resistance of the TO-220 packageis 90°C/W junction to ambient. For additional thermal resistance information see table in the Applications section.
Note 3: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can becomputed by multiplying the internal dissipation by the thermal resistance.
Note 4: Tested Limits are guaranteed and 100% tested in production.
Note 5: Design Limits are guaranteed (but not 100% production tested) over theindicated temperature and supply voltage ranges. These limits are not used to

calculate outgoing quality levels.
Note 6: Specifications in **boldface** apply over the full rated temperature range.
Note 7: Accuracy is defined as the error between the output voltage and 10mv/°C times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in °C).
Note 8: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device's rated temperature range.
Note 9: Quiescent current is defined in the circuit of Figure 1.
Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.
Note 11: Human body model, 100 pF discharged through a 1.5 kW resistor.
Note 12: See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" or the section titled "Surface Mount" found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

2.3. Screen Module

The LCD module helps us to display output from our programs. Both text and numeric data can be displayed on the LCD screen .

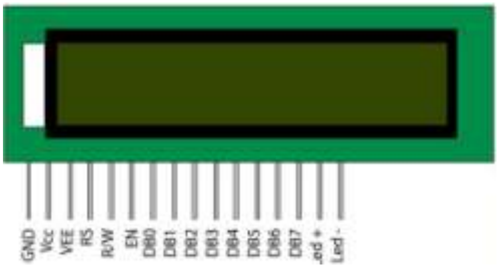


LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being: LCDs are economical; easily programmable; have no limitation of displaying special & even custom characters (unlike in seven segments), animations and so on.

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data.

The command register stores the command instructions given to the LCD. A command is an instruction given to LCD to do a predefined task like initializing it, clearing its screen, setting the cursor position, controlling display etc. The data register stores the data to be displayed on the LCD. The data is the ASCII value of the character to be displayed on the LCD. Click to learn more about internal structure of a LCD.

Pin Diagram of LM016



Pin No	Function	Name
1	Ground (0V)	Ground
2	Supply voltage; 5V (4.7V – 5.3V)	Vcc
3	Contrast adjustment; through a variable resistor	V_{EE}
4	Selects command register when low; and data register when high	Register Select
5	Low to write to the register; High to read from the register	Read/write
6	Sends data to data pins when a high to low pulse is given	Enable
7	8-bit data pins	DB0
8		DB1
9		DB2
10		DB3
11		DB4
12		DB5
13		DB6
14		DB7
15	Backlight V_{CC} (5V)	Led+
16	Backlight Ground (0V)	Led-

2.4. Capacitor

A capacitor (originally known as condenser) is a passive two-terminal electrical component used to store energy in an electric field. The forms of practical capacitors vary widely, but all contain at least two electrical conductors separated by a dielectric(insulator); for example, one common construction consists of metal foils separated by a thin layer of insulating film. Capacitors are widely used as parts of electrical circuits in many common electrical devices.

When there is a potential difference (voltage) across the conductors, a static electric field develops across the dielectric, causing positive charge to collect on one plate and negative charge on the other plate. Energy is stored in the electrostatic field. An ideal capacitor is characterized by a single constant value, capacitance, measured in farads. This is the ratio of the electric charge on each conductor to the potential difference between them.

The capacitance is greatest when there is a narrow separation between large areas of conductor, hence capacitor conductors are often called plates, referring to an early means of construction. In practice, the dielectric between the plates passes a small amount of leakage current and also has an electric field strength limit, resulting in a breakdown voltage, while the conductors and leadsintroduce an undesired inductance and resistance.

Capacitors are widely used in electronic circuits for blocking direct current while allowing alternating current to pass, in filter networks, for smoothing the output of power supplies, in the resonant circuits that tune radios to particular frequencies, in electric power transmission systems for stabilizing voltage and power flow, and for many other purposes.

2.5. Resistor

A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element.

The current through a resistor is in direct proportion to the voltage across the resistor's terminals. This relationship is represented byOhm's law:

$$I = \frac{V}{R}$$

where I is the current through the conductor in units of amperes, V is the potential difference measured across the conductor in units ofvolts, and R is the resistance of the conductor in units of ohms.

The ratio of the voltage applied across a resistor's terminals to the intensity of current in the circuit is called its resistance, and this can be assumed to be a constant (independent of the voltage) for ordinary resistors working within their ratings.

Resistors are common elements of electrical networks and electronic circuits and are ubiquitous in electronic equipment. Practical resistors can be made of various compounds and films, as well as resistance wire (wire made of a high-resistivity alloy, such as nickel-chrome). Resistors are also implemented within integrated circuits, particularly analog devices, and can also be integrated into hybridand printed circuits.

The electrical functionality of a resistor is specified by its resistance: common commercial resistors are manufactured over a range of more than nine orders of magnitude. When specifying that resistance in an electronic design, the required precision of the resistance may require attention to the manufacturing tolerance of the chosen resistor, according to its specific application. The temperature coefficient of the resistance may also be of concern in some precision applications. Practical resistors are also specified as having a maximum power rating which must exceed the anticipated power dissipation of that resistor in a particular circuit: this is mainly of concern in power electronics applications. Resistors with higher power ratings are physically larger and may require heat sinks. In a high-voltage circuit, attention must sometimes be paid to the rated maximum working voltage of the resistor.

Practical resistors have a series inductance and a small parallel capacitance; these specifications can be important in high-frequency applications. In a low-noise amplifier or pre-amp, the noise characteristics of a resistor may be an issue. The unwanted inductance, excess noise, and temperature coefficient are mainly dependent on the technology used in manufacturing the resistor. They are not normally specified individually for a particular family of resistors manufactured using a particular technology.[1] A family of discrete resistors is also characterized according to its form factor, that is, the size of the device and the position of its leads (or terminals) which is relevant in the practical manufacturing of circuits using them.

2.6 EasyBuzz

The EasyBuzz additional board is used to emit audio signals by using a piezo buzzer supplied on the board.

Key features:

- 3.8kHz resonant frequency;
- Low power consumption;
- 3.3 or 5V DC power supply voltage.

EasyBuzz additional board

Howto connect the board?

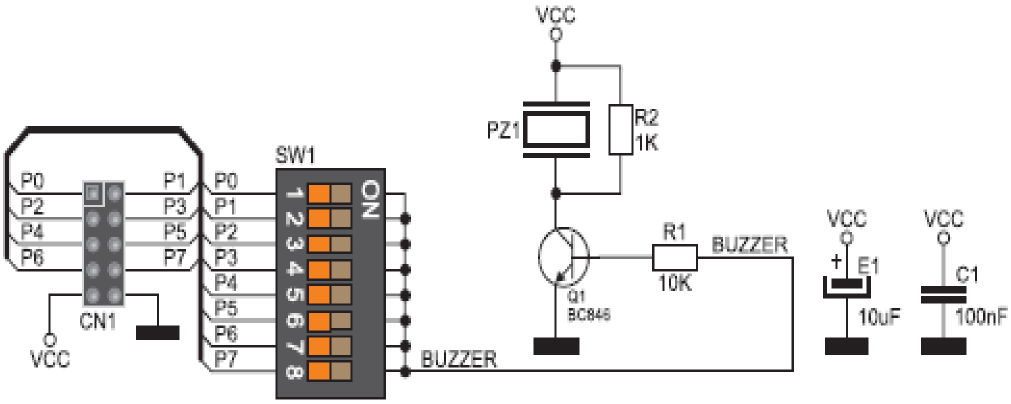
The EasyBuzz additional board can be easily connected to a development system via a 2x5 connector CN1 on the additional board.

How to use the board?

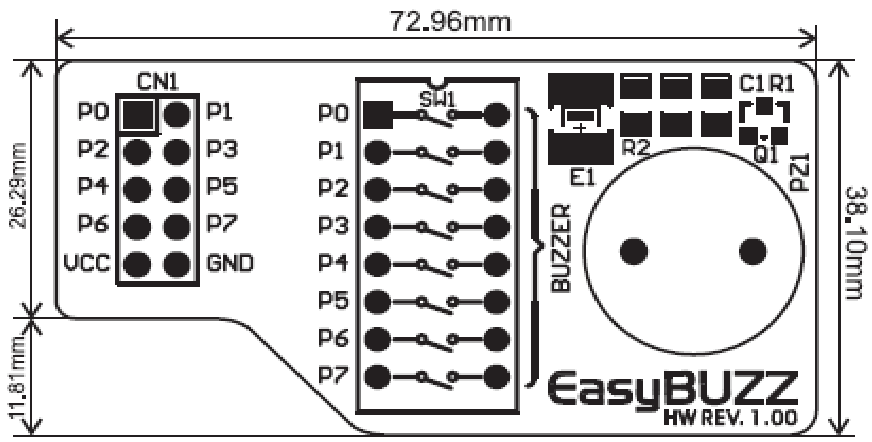
In order to enable the EasyBuzz board to emit audio signals, it is necessary to connect it to a development system and write the appropriate program to be loaded into the microcontroller. The program should define which of the microcontroller pins will be used to generate a voltage signal of specific frequency. Resonant frequency is 3.8kHz, whereas frequencies in a range between 20Hz and 20kHz may also be used. The best sound quality is achieved when using frequencies between 2 and 4kHz.

In order to connect the board to the microcontoller on the development system, it is necessary to set the appropriate switch on DIP switch SW1 to the ON position. It depends on the microcontroller pin, used to emit voltage signal, which one of these switches will be set ON.

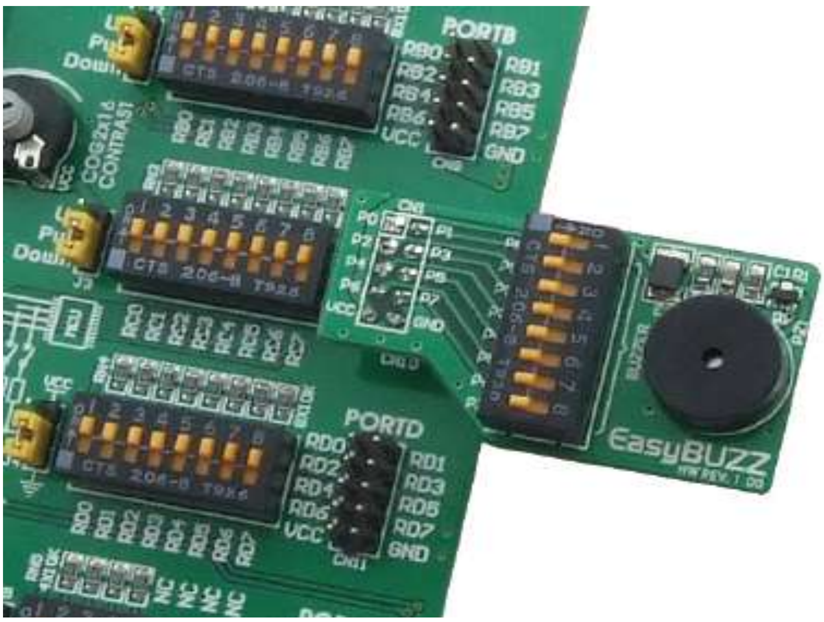
EasyBuzz additional board connection schematic



Dimensions of the EasyBuzz additional board



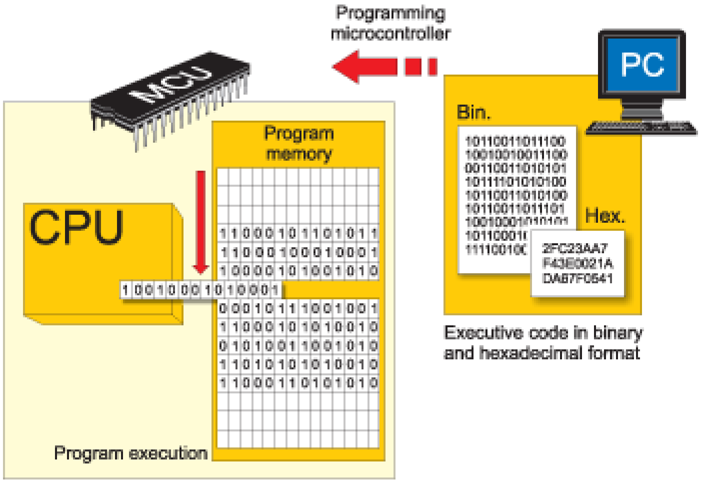
Addition Board Connected to a Development System



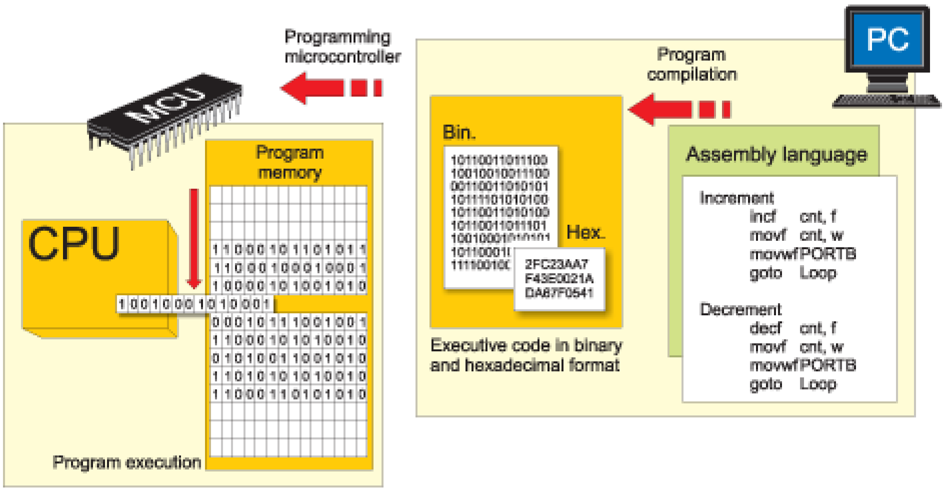
CHAPTER 3

PROGRAMMING MICROCONTROLERS

You certainly know that it is not enough just to connect the microcontroller to other components and turn the power supply on to make it work, don't you? There is something else that must be done. The microcontroller needs to be programmed to be capable of performing anything useful. If you think that it is complicated, then you are mistaken. The whole procedure is very simple. Just read the following text and you will change your mind.

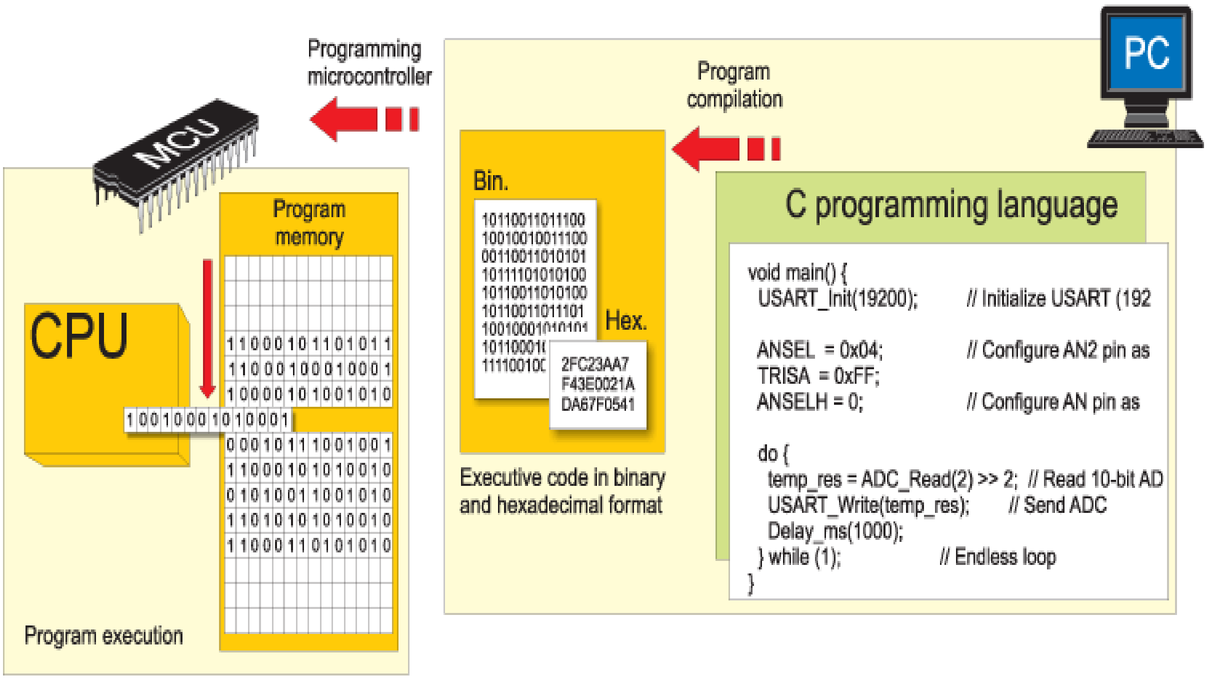


The microcontroller executes the program loaded in its Flash memory. This is the so called executable code comprised of seemingly meaningless sequence of zeros and ones. It is organized in 12-, 14- or 16-bit wide words, depending on the microcontroller's architecture. Every word is considered by the CPU as a command being executed during the operation of the microcontroller. For practical reasons, as it is much easier for us to deal with hexadecimal number system, the executable code is often represented as a sequence of hexadecimal numbers called a Hex code. It used to be written by the programmer. All instructions that the microcontroller can recognize are together called the Instruction set. As for PIC microcontrollers the programming words of which are comprised of 14 bits, the instruction set has 35 different instructions in total.

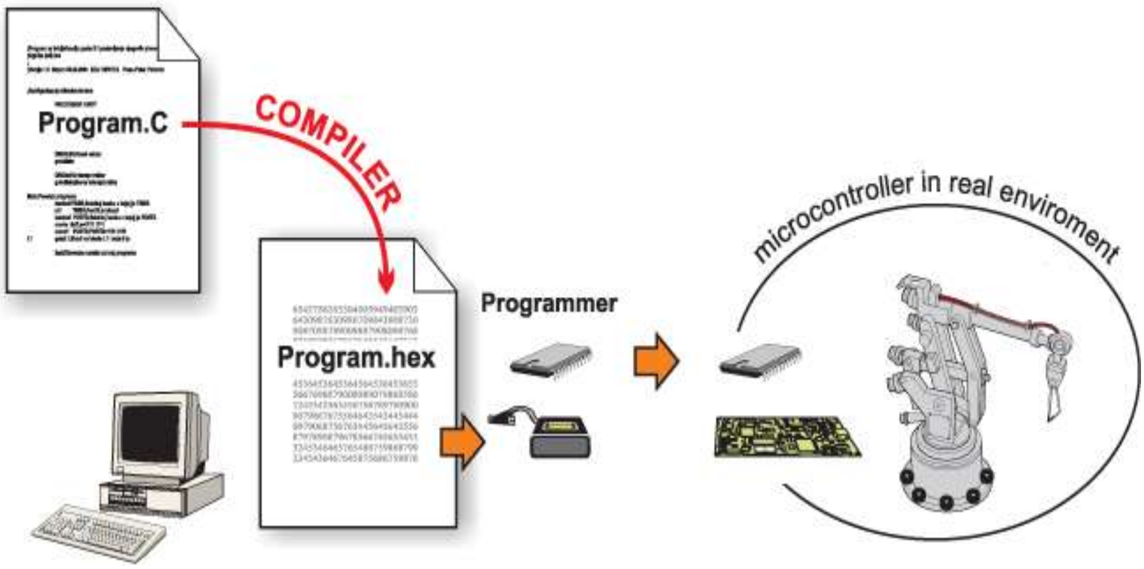


As the process of writing executable code was endlessly tiring, the first ‘higher’ programming language called assembly language was created. The truth is that it made the process of programming more complicated, but on the other hand the process of writing program stopped being a nightmare. Instructions in assembly language are represented in the form of meaningful abbreviations, and the process of their compiling into executable code is left over to a special program on a PC called compiler. The main advantage of this programming language is its simplicity, i.e. each program instruction corresponds to one memory location in the microcontroller. It enables a complete control of what is going on within the chip, thus making this language commonly used today.

However, programmers have always needed a programming language close to the language being used in everyday life. As a result, the higher programming languages have been created. One of them is C. The main advantageof these languages is simplicity of program writing. It is no longer possible to know exactly how each command executes, but it is no longer of interest anyway. In case it is, a sequence written in assembly language can always be inserted in the program, thus enabling it.

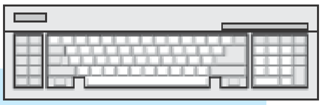


Similar to assembly language, a specialized program in a PC called compiler is in charge of compiling program into machine language. Unlike assembly compilers, these create an executable code which is not always the shortest possible.



Figures above give a rough illustration of what is going on during the process of compiling the program from higher to lower programming language.

Here is an example of a simple program written in C language:



```
void main() {

   TRISB = 0;                // All port B pins are configured as
                             // outputs
   PORTB = 0b01010101;       // Logic state on port B pins
}
```

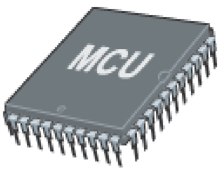
Program written in C

```
; ADDRESS     OPCODE        ASM
; ----------------------------------------------
$0000         $2804         GOTO    _main
$0004         $      _main:
;Test.c,1 :: void main() {
;Test.c,3 :: TRISB = 0;             // All port B pins
$0004         $1303         BCF     STATUS, RP1
$0005         $1683         BSF     STATUS, RP0
$0006         $0186         CLRF    TRISB, 1
;Test.c,4 :: PORTB = 0b01010101; // Logic state
$0007         $3055         MOVLW   85
$0008         $1283         BCF     STATUS, RP0
$0009         $0086         MOVWF   PORTB
;Test.c,5 :: }
$000A         $280A         GOTO    $
```

Compiled Program

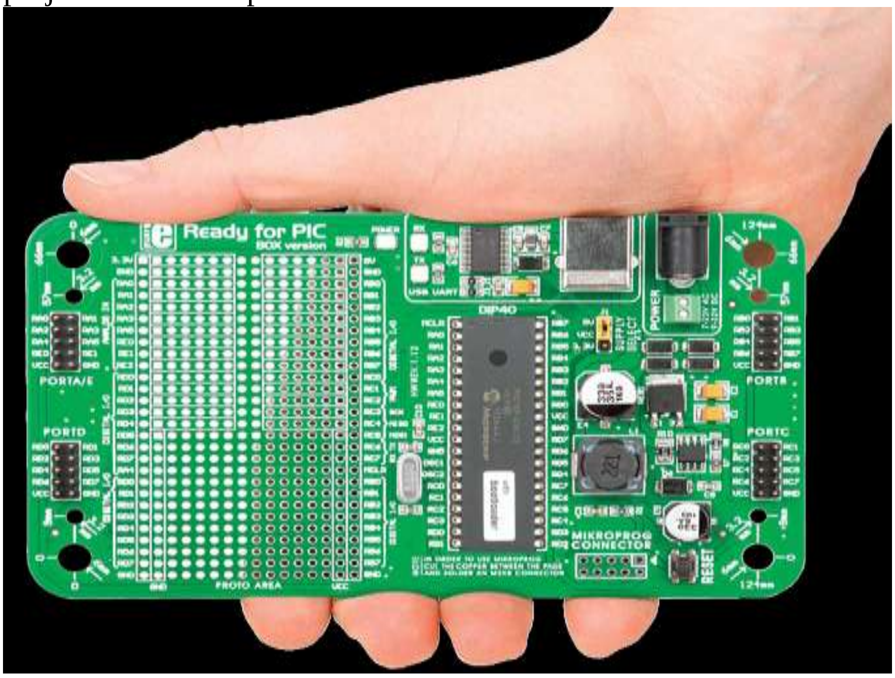
```
:100000000428FF3FFF3FFF3F031383168601553004F
:10001000831286000A28FF3FFF3FFF3FFF3FFF3F5D
:04400E00F22FFFFF8F
:00000001FF
```

Executable Code of the program (HEX code)



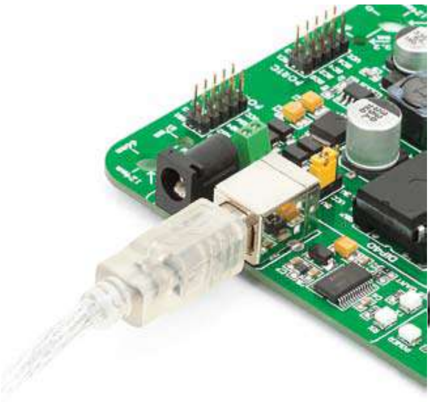
3.1.READY FOR PIC

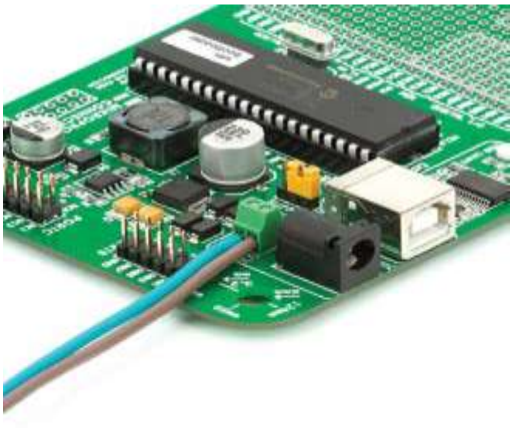
Ready for PIC® Board is the best solutionfor fast and simple development of various microcontroller applications. The boardis equipped with the **PIC16F887**MCU that is placed in DIP 40 socket andcontains male headers and connectionpads for all available microcontroller ports.The pins are grouped according to theirfunctions, which is clearly indicated on thesilkscreen. The MCU comes pre programmed with mikroBootloader, but it can also beprogrammed with mikroProg™ programmer.
The board also contains USB-UART module,prototyping area and a power supply circuit.It is specially designed to fit into the specialwhite plastic casing so that you can turnyour PIC project into a final product.

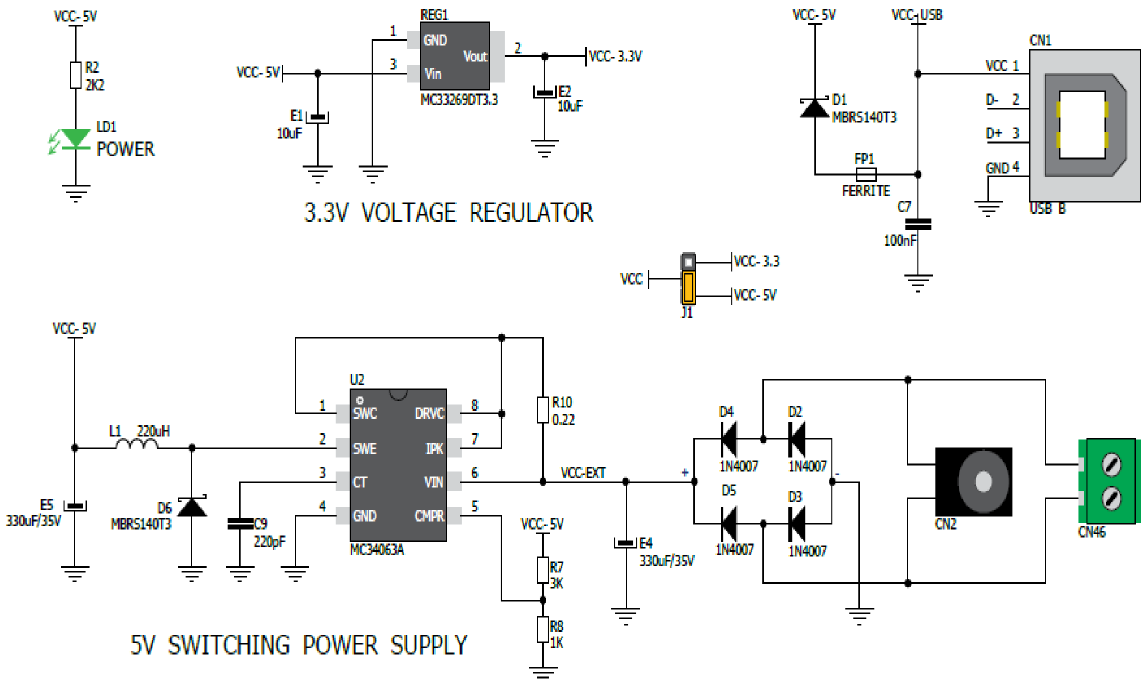


Power supply

Ready for PIC® board can be powered in three different ways: via USB connector **(CN1)**, via adapter connector using external adapters **(CN2)** orvia additional screw terminals **(CN46)**. The USB connection can provide up to 500mA of current which is more than enough for the operationof every on-board module and the microcontroller as well. If you decide to use external power supply, voltage values must be within **7-23V AC**or **9-32V DC** range. **Power LED ON (GREEN)** indicates the presence of power supply. Use only one of suggested methods for powering theboard. If you use MCU with a 5V power supply place jumper J1 in the 5V position. Otherwise, it should be placed in the 3.3V position.





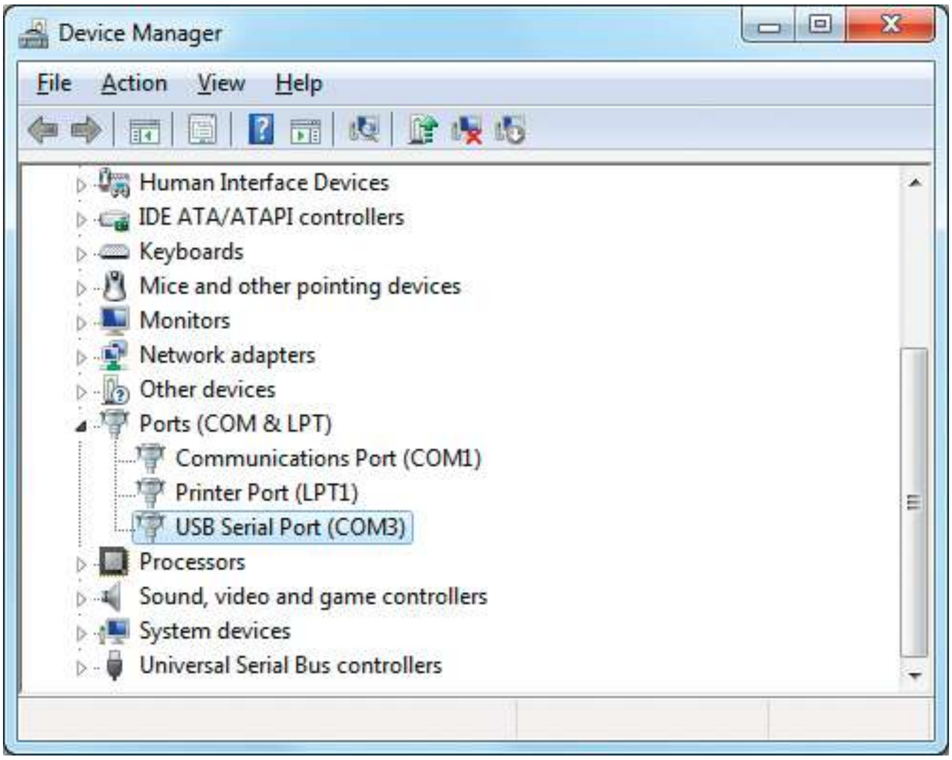

VCC-5V
R2
2K2
LD1
POWER
REG1
GND
Vout
Vin
MC33269DT3.3
VCC-5V
VCC-3.3V
E1
10uF
E2
10uF
3.3V VOLTAGE REGULATOR
VCC-5V
VCC-USB
D1
MBRS140T3
FP1
FERRITE
C7
100nF
CN1
VCC 1
D- 2
D+ 3
GND 4
USB B
VCC
VCC-3.3
VCC-5V
J1
VCC-5V
L1 220uH
E5
330uF/35V
D6
MBRS140T3
C9
220pF
U2
SWC
SWE
CT
GND
DRVC
IPK
VIN
CMPR
MC34063A
R10
0.22
VCC-EXT
VCC-5V
R7
3K
R8
1K
E4
330uF/35V
D4
D2
D5
D3
1N4007
CN2
CN46
5V SWITCHING POWER SUPPLY

Programming with mikroBootloader

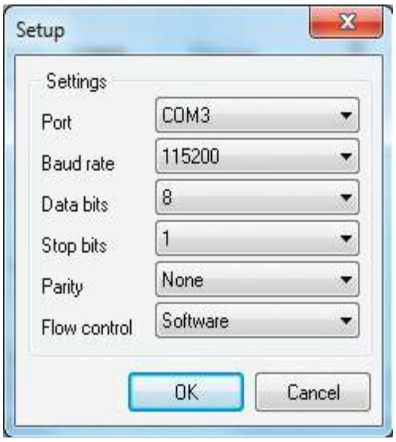
You can program the microcontroller with bootloader which is preprogrammed by default. To transfer .hex file from a PC to the MCUyou need a bootloader software (**mikroBootloader**) which canbe downloaded from:

mikroBootloader software

Identifying device COM port



step 1 – Choosing COM port

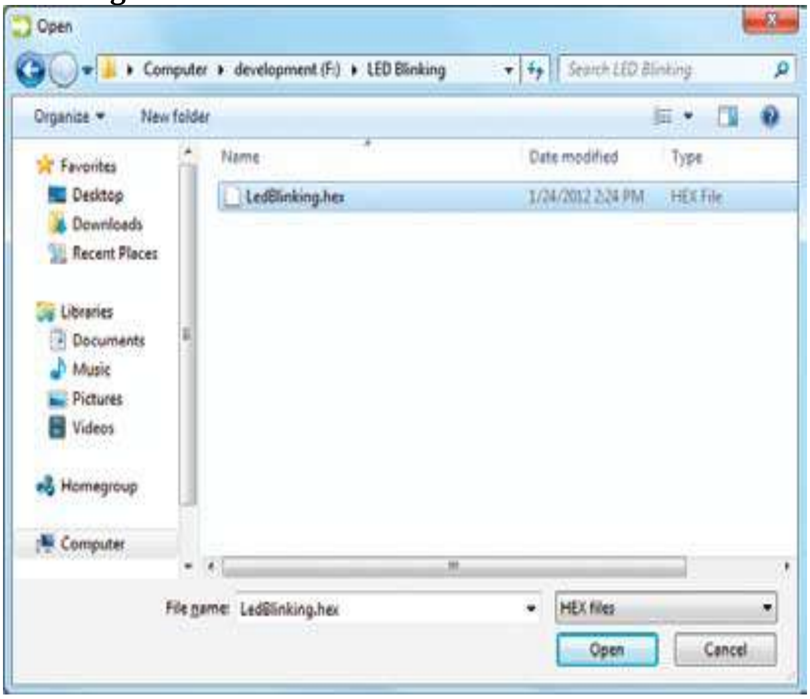


01Click the **Change Settings** button
02From the drop down list, select appropriate COM**port** (in this case it is COM3)
03Click **OK**

Establishing Connection

Browsing for .HEX file

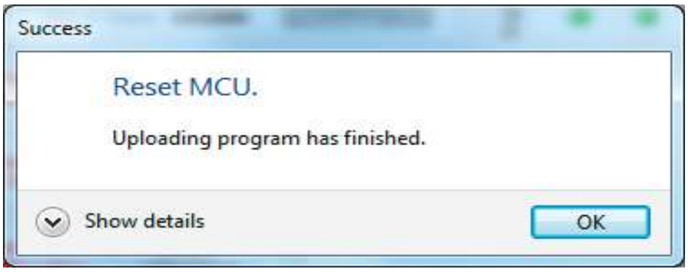
Selecting .HEX file



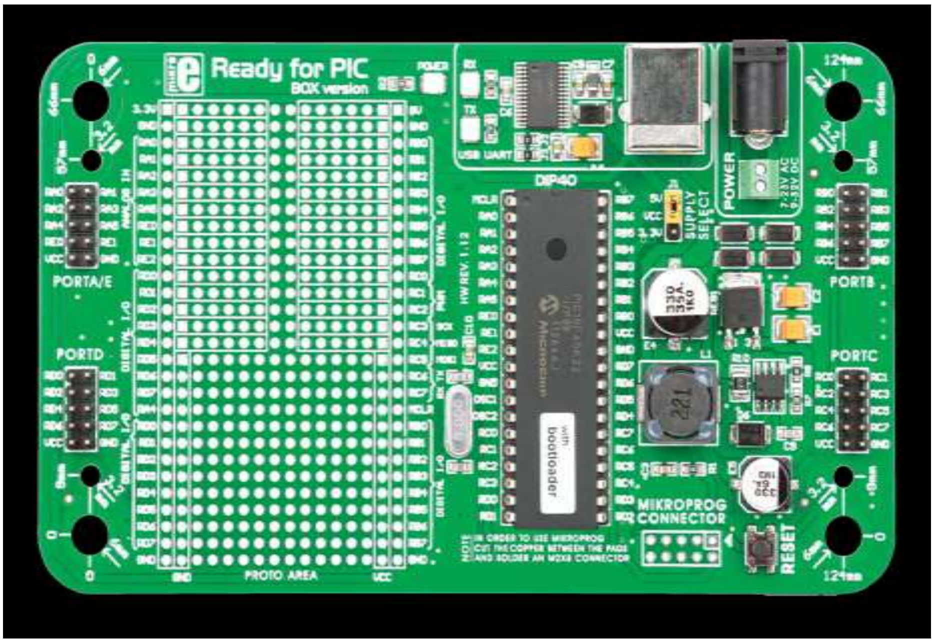
Uploading .HEX file

Progress bar

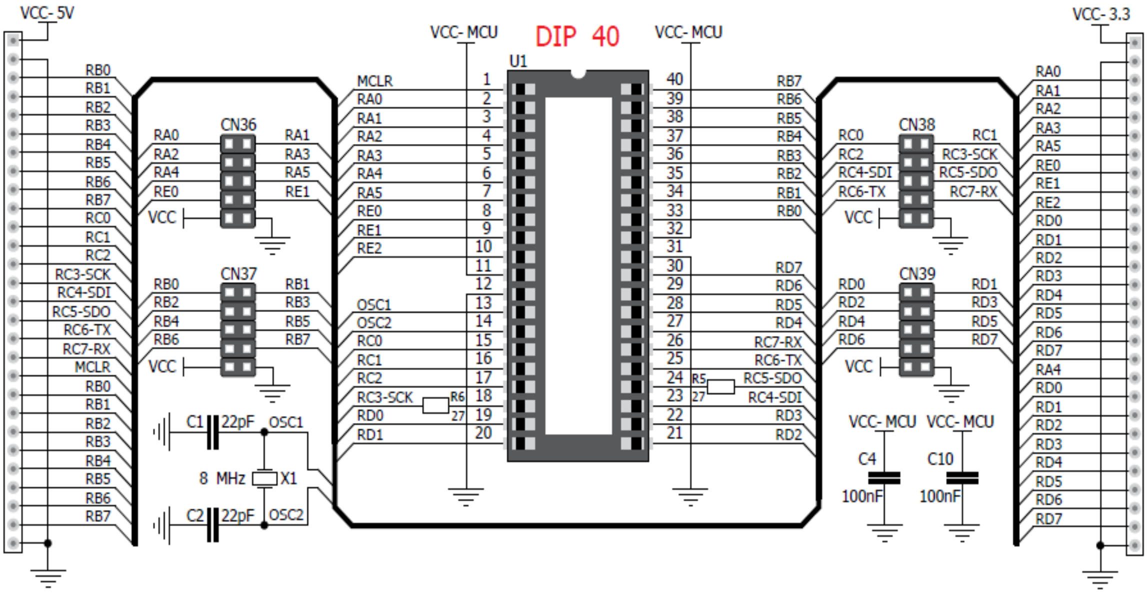
Finishing upload



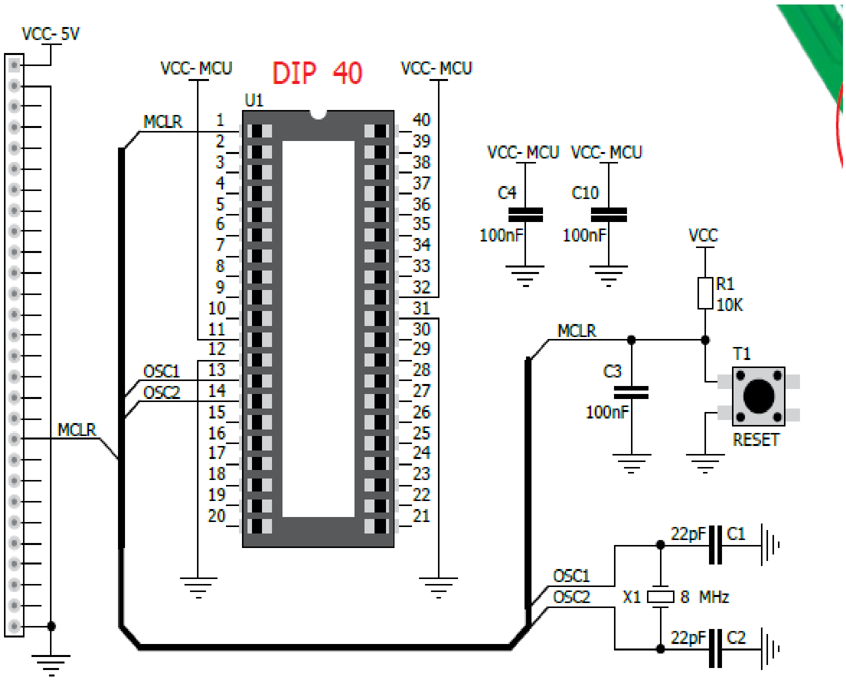
Pin headers and connection pads

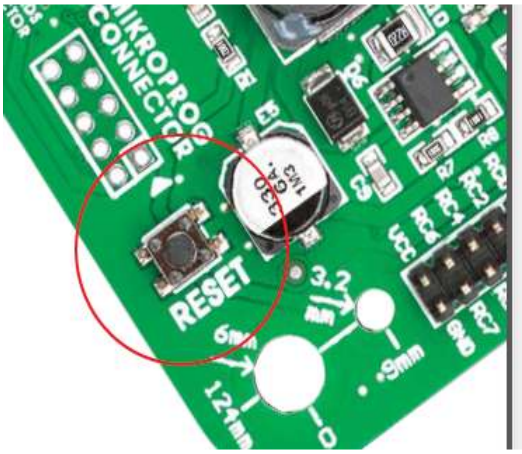


Each microcontroller pin is available for further connections through four on-board 2x5 connection headers and two 1x28 connection pads.Pins are grouped in four PORT groups (2x5 male headers) as well as per their functions (1x28 connection pads), which makes developmentand connections much easier. Everything is printed on the silkscreen, so that there will be no need of using microcontroller data sheet whiledeveloping. Before using the pins, it is necessary to solder **2x5 male headers** (1-4) on the board pads.



Reset button





Ready for PIC® board has a specialized reset circuit with high-quality reset button which can be used to reset the program execution of themicrocontroller. If you want to reset the circuit, press on-board RESET button. It will generate low voltage level on the microcontroller reset pin(input). In addition, a reset can be externally generated through **MCLR pin** on 1x28 connection pads.

3.2.Program Codes

```
sbit LCD_RS at RB2_bit;

sbit LCD_EN at RB3_bit;

sbit LCD_D4 at RB4_bit;

sbit LCD_D5 at RB5_bit;

sbit LCD_D6 at RB6_bit;

sbit LCD_D7 at RB7_bit;


sbit LCD_RS_Direction at TRISB2_bit;

sbit LCD_EN_Direction at TRISB3_bit;

sbit LCD_D4_Direction at TRISB4_bit;

sbit LCD_D5_Direction at TRISB5_bit;

sbit LCD_D6_Direction at TRISB6_bit;

sbit LCD_D7_Direction at TRISB7_bit;
```

```
void main()
{
  unsigned int Temp;
  char Txt[7];
  char Cnt;

  ANSEL = 1;
  ANSELH = 0;
  LCD_Init();                          // Initialize LCD
  ADC_Init();                          // Initialize ADC
  Sound_Init(&PORTC, 2);               // Initialize sound

  Lcd_Cmd(_LCD_CLEAR);                 // Clear LCD
  Lcd_Cmd(_LCD_CURSOR_OFF);
  Lcd_Out(1,1, " Digital");            // Send a startup message
  Lcd_Out(2,1, "Thermometer");         // Send a message
  Sound_Play(1000, 2000);              // Play a startup sound
  Delay_Ms(2000);                      // Wait 2 seconds

  TRISA = 1;                           // RA0 is input
//
// Start of Main loop. Read temperature and display on the LCD
//
    Lcd_Out(1,1,"Waiting...");
    Delay_Ms(20000);                   // wait 20 second
```

```
Cnt = 0;
for(;;)
{
  Temp = ADC_Get_Sample(0);                // Read temperature
  Temp = Temp / 2;                         // convert to degrees C
  IntToStr(Temp, Txt);                     // Convert to string
  Lcd_Cmd(_LCD_CLEAR);                     // Clear LCD
  Lcd_Out(1,1, "Sicaklik:");               // Display heading
  Lcd_Out(2,1, Txt);                       // Display temperature
  Delay_Ms(1000);
  Cnt++;

  if(Cnt == 30)
  {
    if(Temp > 37)                          // If temperature is > 37C
    {
      Lcd_Out(2,2, "High Temperature");
      Sound_Play(1000, 2000);
      while(1);
    }
    else if(Temp < 34)
    {
      Lcd_Out(2,2, "Low Temperature");
      Sound_Play(1000, 2000);
      while(1);
    }
    else
```

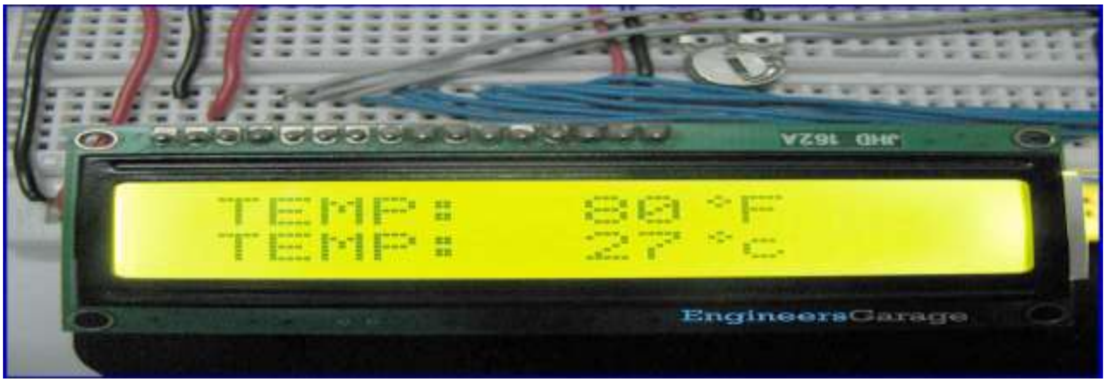
```
        {
          Lcd_Out(2,2,"Normal");
          while(1);
        }
      }
    }

}
```

CHAPTER 4

CONCLUSION

A Digital Thermometer can be easily constructed using a PIC Microcontroller and LM35 Temperature Sensor. LM35 series is a low cost and precision Integrated Circuit Temperature Sensor whose output voltage is proportional to Centigrade temperature scale. Thus LM35 has an advantage over other temperature sensors calibrated in Kelvin as the users don't require subtraction of large constant voltage to obtain the required Centigrade temperature. It doesn't requires any external calibration. It is produced by National Semiconductor and can operate over a -55 °C to 150 °C temperature range



5. REFERENCES

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12. http://www.datasheetarchive.com/
13. http://www.mikroe.com/downloads/get/1690/ready_for_pic_manual_v112.pdf
14. http://www.4dsystems.com.au/downloads/Audio-Sound-Modules/SOMO-14D/Docs/SOMO-14D-Datasheet-REV1.pdf
15. http://www.datasheetcatalog.org/datasheet/nationalsemiconductor/DS005516.PDF
16. http://extremeelectronics.co.in/avr-tutorials/using-lcd-module-with-avrs/
17. http://www.technologystudent.com/pics/picgen1.html
18. http://320volt.com/pic-16f877-ds-18b20-lcd-dijital-termometre/