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" المسيطرات الدقيقـــــــة "

Advanced Digital Controllers

"Microcontroller Course"

INTRODUCTION TO MICROCONTROLLERS

1) Important Notes over Electronics.
2) What is a Microcontroller?
3) Inside Components of the Microcontroller.
4) How does the Microcontroller Work?
5) Microcontroller Vs Microprocessor.
6) Short list of MCU Brands.
7) How to choose your chip?
8) Necessary connections of PIC Microcontroller.
9) Outputting Data / Signals
10) Applications examples.
11) Important Displays Interfacing For PIC MCU

1) Important Notes over Electronics

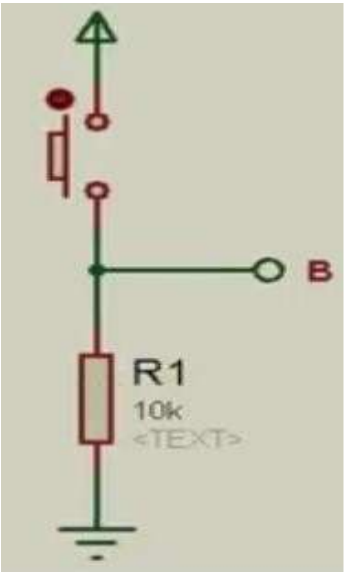
a) Pull Down Resistor Connection.
b) Pull UP Resistor Connection.
c) Relay Driver Circuit.
d) Logic Gates.
e) Test Board.

a) Pull Down Resistor Connection

- We use it to prevent the pin's voltage to be floating due to the noises.

- When the switch is pressed, we get input HIGH on the pin "B".

- When the switch isn't pressed, we get input LOW on the pin "B".

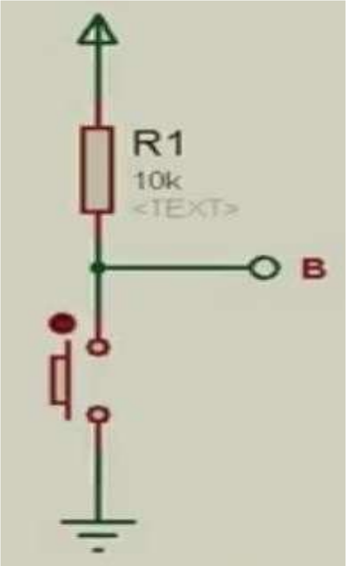


B) PULL UP RESISTOR CONNECTION

- We use it to prevent the pin's voltage to be floating due to the noises

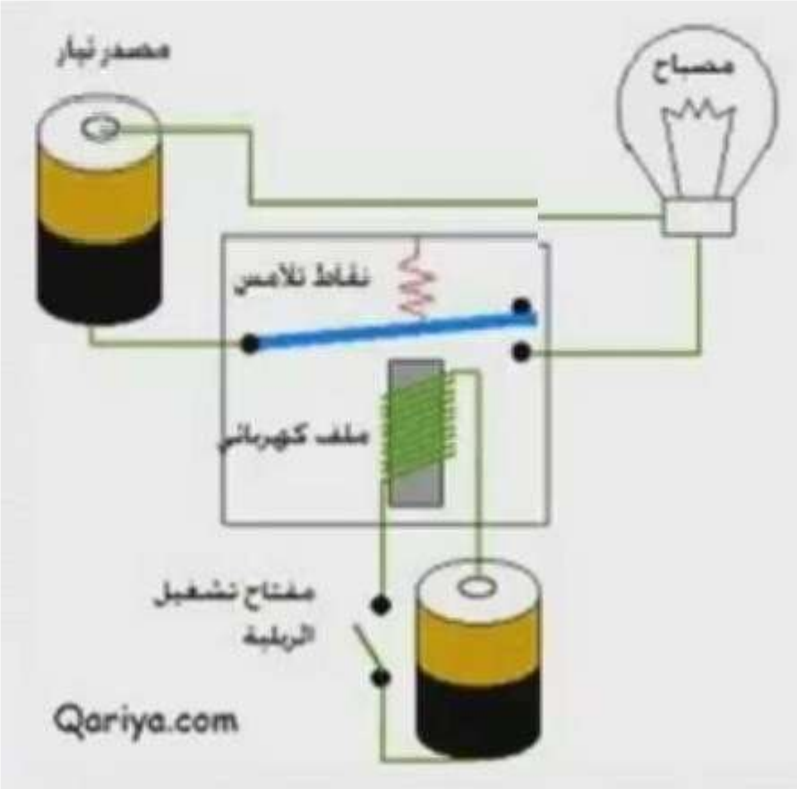
- When the switch is pressed, we get input LOW on the pin "B".

- When the switch isn't pressed, we get input HIGH on the pin "B".



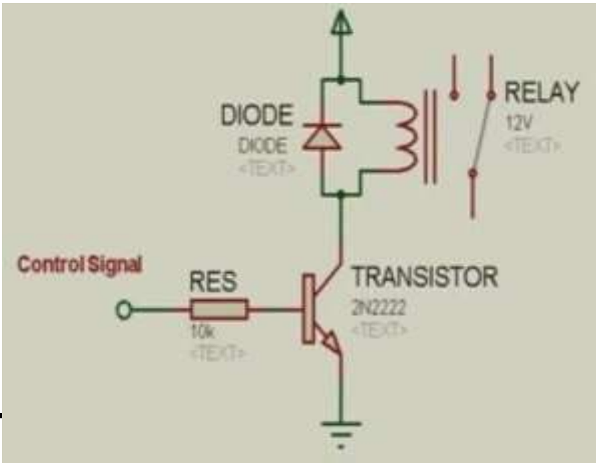
C) RELAY DRIVER CIRCUIT

A Relay is an electromechanical switch, that means that it is a normal switch but it is controlled electrically using a coil.



Relays rating is :

- The value and type of the voltage applied across the coil to energize the electromagnetic field.
- The max current can pass through the contact without having a fault.
- The type and max value of the voltage applied across the contact without having a fault.
- Relay Driver circuit is a circuit used to allow any IC to control any load through a Relay.
- The Relay may require voltage or current that the IC can't afford so we circuit.



USAGE OF EACH COMPONENT:

- **Diode:** to prevent the back EMF of the relay's coil from causing damage to the Transistor.
- **Transistor:** to allow the IC to control the Relay, We use the Transistor in the saturation mode (as a switch) and this makes the IC control the Relay no matter the current or voltage required by its coil.
- **Resistor:** to limit the current passing through the base of the Transistor, so it protects the Transistor.

D) LOGIC GATES

- It is important to be known that 1 in logic or *High* means 5 volt and 0 or *Low* means 0 volts.
- Also you must know that there is different forms for numbering:

1) Binary: consists of 0 and 1 only.

2) Decimal: it is the normal numbering system we are using:

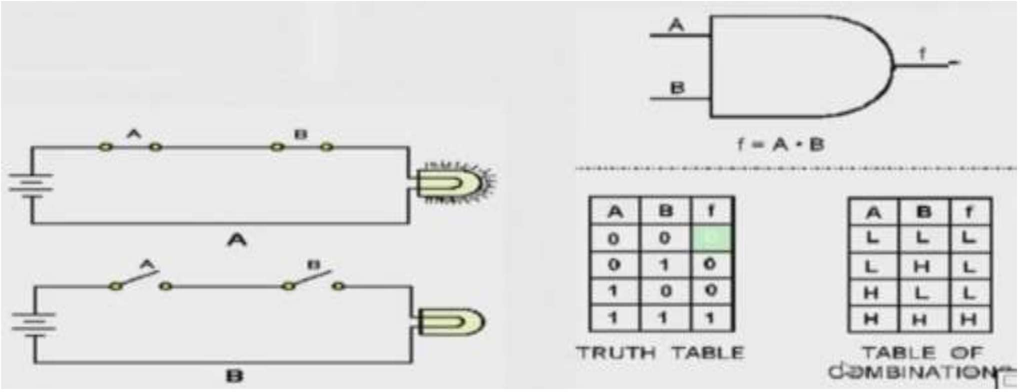
(0, 1, 2, 3, 4, 5, 6, 7, 8, 9)

3) Hex Decimal: consist of (0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F)

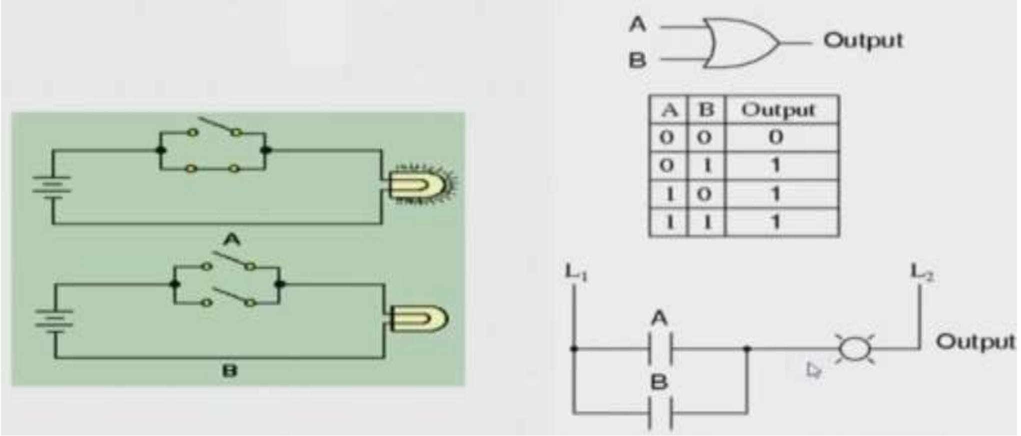
4) Octal: consist of (0, 1, 2, 3, 4, 5, 6, 7)

- **NOT Gate**

- **AND Gate**

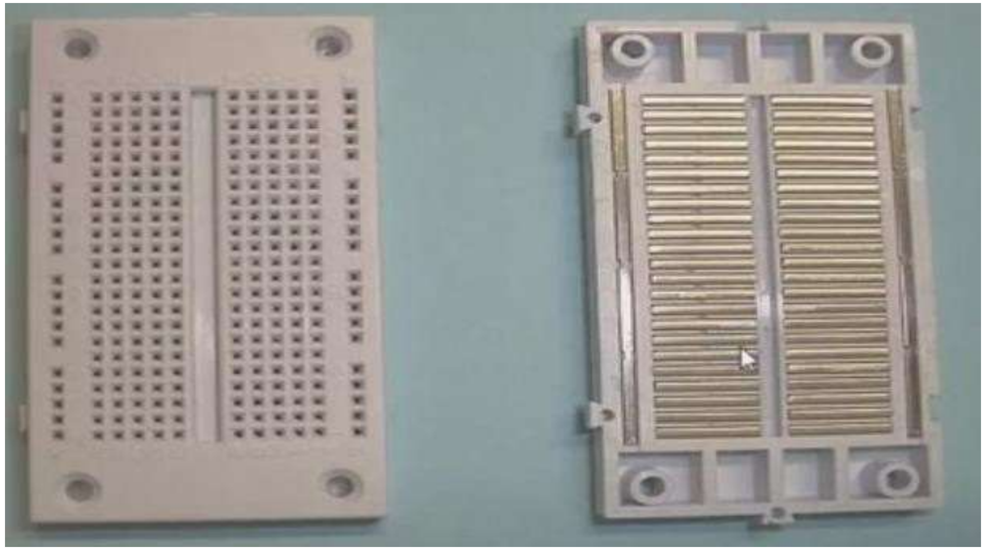


- **OR Gate**



E) TEST BOARDS

- It is a board that can be used several times as the component are fixed and can be replaced from it and its used for prototype design and testing also for practical experimental .



2) WHAT IS A MICROCONTROLLER?

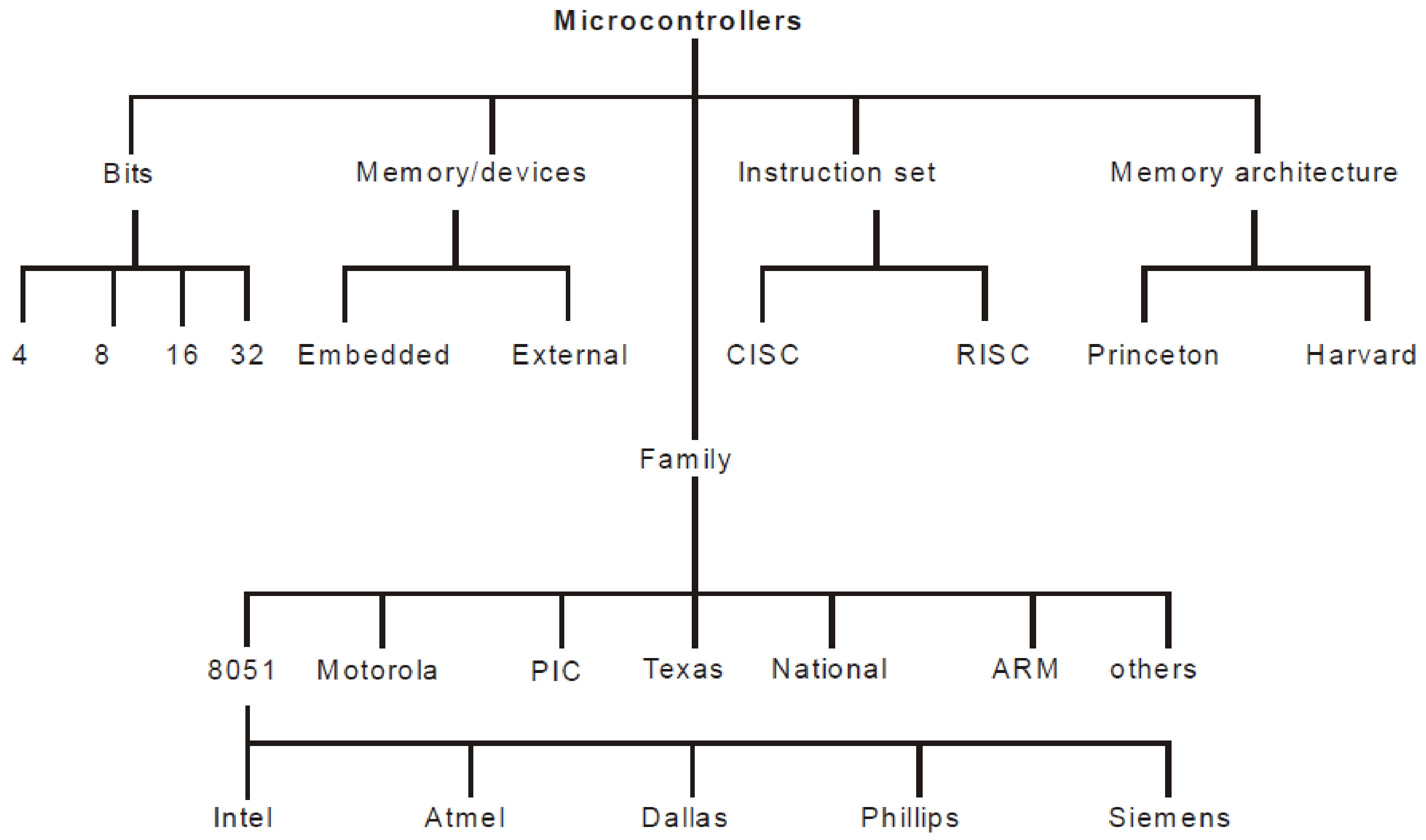
- Embedded Systems
  - An embedded system is a product which uses a computer to run it but the product itself is not a computer.
- Microcontroller (MCU)
  - Integrated electronic computing device or a small computer on a single integrated circuit that includes three major components on a single chip
    - Microprocessor (MPU).
    - Memory.
    - I/O (Input/Output) ports.

Types of Microcontrollers:

Microcontrollers can be classified on the basis of **internal bus width, architecture, memory** and **instruction set.** Figure below shows the various types of microcontrollers.

- When the ALU performs arithmetic and logical operations on a byte **(8- bits) at an instruction**, the microcontroller is an **8-bit microcontroller**. The internal bus width of 8-bit microcontroller is of 8-bit. Examples of 8-bit microcontrollers are **Intel 8051 family and Motorola MC68HC11 family**.
- When the ALU performs arithmetic and logical operations on a word **(16-bits)** at an instruction, the microcontroller is an **16-bit microcontroller. The internal bus width of 16-bit microcontroller is of 16-bit**. Examples of 16-bit microcontroller are **Intel 8096 family and Motorola MC68HC12 and MC68332** families. performance and computing capability of 16 bit microcontrollers are enhanced with greater precision as compared to the 8-bit microcontrollers.
- When the ALU performs arithmetic and logical operations on **a double word (32-bits)** at an instruction, the microcontroller is an 32-bit microcontroller. The internal bus width of 32-bit microcontroller is of 32-bit. Examples of 32-bit microcontrollers are **Intel 80960 family and Motorola M683xx and Intel/Atmel 251 family.**

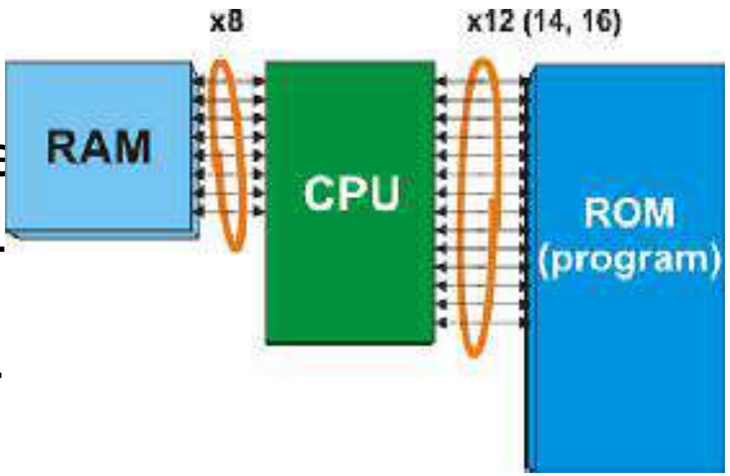
The performance and computing capability of 32 bit microcontrollers are enhanced with greater precision as compared to the 16-bit microcontrollers.



- **Memory Architecture:** All MCs use one of two basic design models

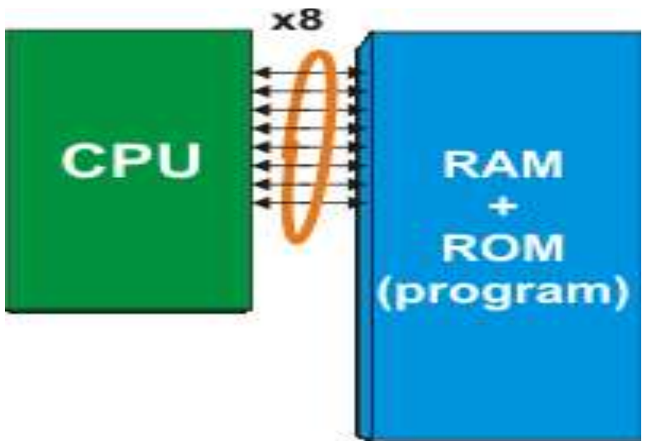
  - **Harvard Architecture**:

    data bus and address bus are separate. Thus a greater flow of data is possible through the CPU, and of course, a greater speed of work.



  - **Von –Neumann (Princeton):**

    This model use share a common bus for data and address bus.



- **Microcontroller Applications:**

These small devices have revolutionized the world of electronics. Today microcontrollers are everywhere, think of a device and you will find a microcontroller somewhere in it. May it be your **remote control**, cell phone air conditioner, microwave oven, DVD player, home monitoring system, environmental control (greenhouse, factory, home) television or all have a microcontroller sitting inside . These small devices can do so much, that only imagination is the limit. Moreover they are very simple to use, you don't need to be an expert in electronics to use them in your next project. A basic understanding of electronics, and digital circuits is all that is required to get started. Once you are in the business, sky is the limit. Think of any logical application and you will find microcontroller handling the job nicely.

Industrial automation including automatic assembly lines, robots and quality control systems all are backed by some kind of microcontroller.

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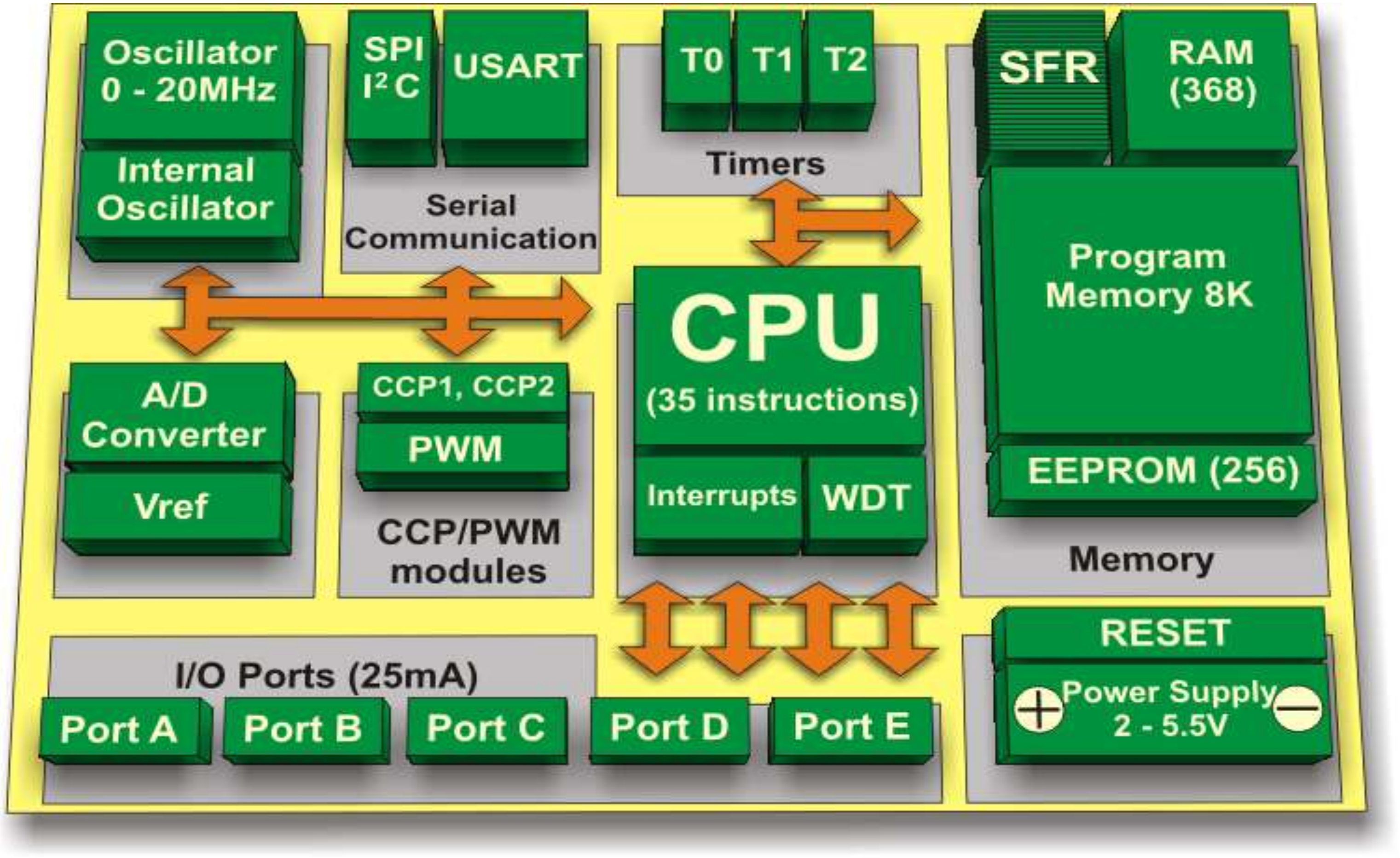
3) INSIDE COMPONENTS OF THE MICROCONTROLLER.



PIC MUC Components

a) Central processing unit (CPU)

b) Read Only Memory (ROM)

c) Random Access Memory (RAM)

d) Special Function Registers (SFR)

e) Input /Output Ports

f) Serial Communication

g) Timers/Counters

h) A/D Converter

i) Power Supply Circuit

j) Oscillator

a) Central processing unit (CPU)

- This is a unit which monitors and controls all processes within the microcontroller and the user cannot affect its work.
- It consists of several smaller subunits, of which the most important are:

a) Instruction decoder
b) Arithmetical Logical Unit (ALU)
c) Accumulator

b) Read Only Memory (ROM)

- Read Only Memory (ROM) is a type of memory used to permanently save the program being executed.
- The size of the program that can be written depends on the size of this memory.
- ROM can be built in the microcontroller or added as external chip, which depends on the type of the microcontroller.
- Today's microcontrollers commonly use 16-bit addressing, which means that they are able to address up to 64 Kb of memory, i.e. 65535 locations. As a novice, your program will rarely exceed the limit of several hundred instructions. There are several types of ROM:-

- MROM (Masked ROM).
- UV Erasable Programmable ROM (UV EPROM).
- EEPROM (Electric erasable programmable ROM).

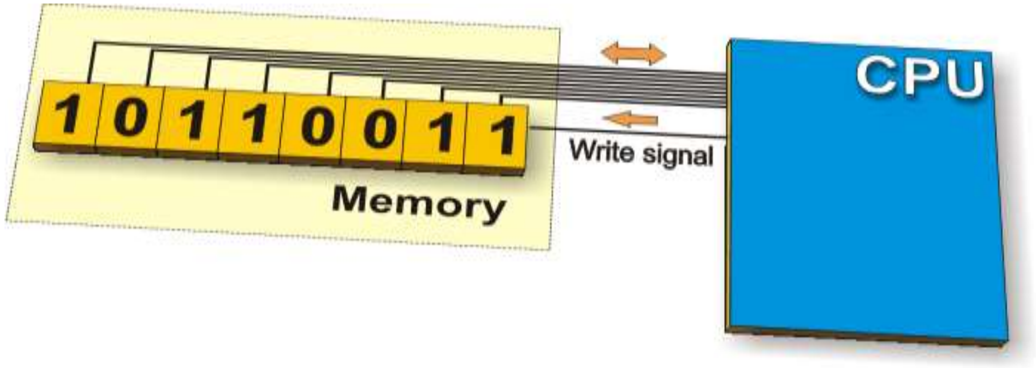
- **Flash Memory:** Flash memory is a non-volatile memory used mainly to store user programs. This type of memory can be programmed electrically while embedded on the board. Some microcontrollers have only 1 KB flash memory, while some others can have 32KB or more. In addition to computers, flash memory is also used in mobile phones and digital cameras.
- This type of memory was invented in the 80s in the laboratories of INTEL and was represented as the successor to the UV EPROM. Since the content of this memory can be written and cleared practically an unlimited number of times, microcontrollers with Flash ROM are ideal for learning, experimentation and small-scale production. Because of its great popularity, most microcontrollers are manufactured in flash technology today. So, if you are going to buy a microcontroller, the type to look for is definitely Flash!

c) Random Access Memory (RAM)

- Random Access Memory (RAM) is a type of memory used for temporary storing data and intermediate results created and used during the operation of the microcontrollers.
- The content of this memory is cleared once the power supply is off.
- **EEPROM Data Memory:** EEPROM-type data memory is also very common in many microcontrollers. The advantage of an EEPROM memory is that the programmer can store nonvolatile data there and change this data whenever required. For example, in a temperature monitoring application, the maximum and minimum temperature readings can be stored in an EEPROM memory. If the power supply is removed for any reason, the values of the latest readings are available in the EEPROM memory. The PIC18F452 microcontroller has 256 bytes of EEPROM memory. Other members of the PIC18F family have more EEPROM memory (e.g., the PIC18F6680 has 1024 bytes). The mikroC language provides special instructions for reading and writing to the EEPROM memory of a PIC microcontroller.

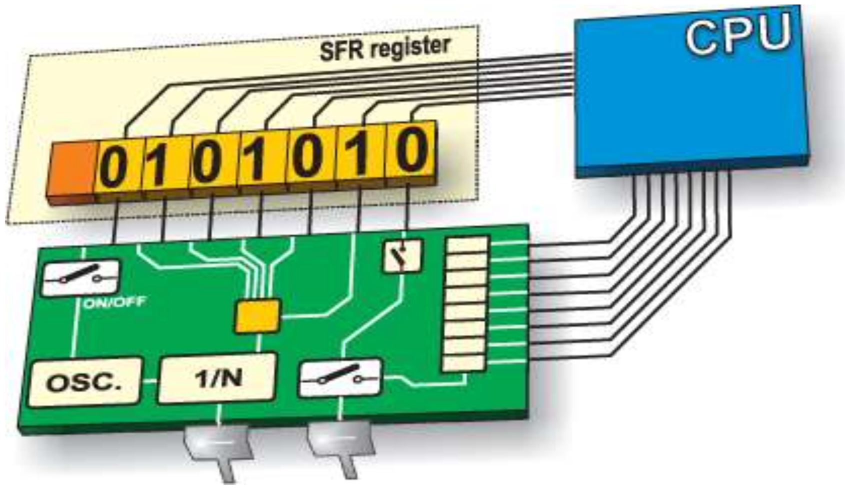
D) REGISTERS & SPECIAL FUNCTION REGISTERS (SFR)

- **Register:** In short, a register or a memory cell is an electronic circuit which can memorize the state of one byte.



- **Special Function Registers (SFR)**
  - Special Function Registers are part of RAM memory.
  - In addition to registers which do not have any special and predetermined function, every microcontroller has a number of registers (SFR) whose function is predetermined by the manufacturer.
  - Their bits are physically connected to particular circuits within the micro-controller such as timers, A/D converter, oscillators etc.,

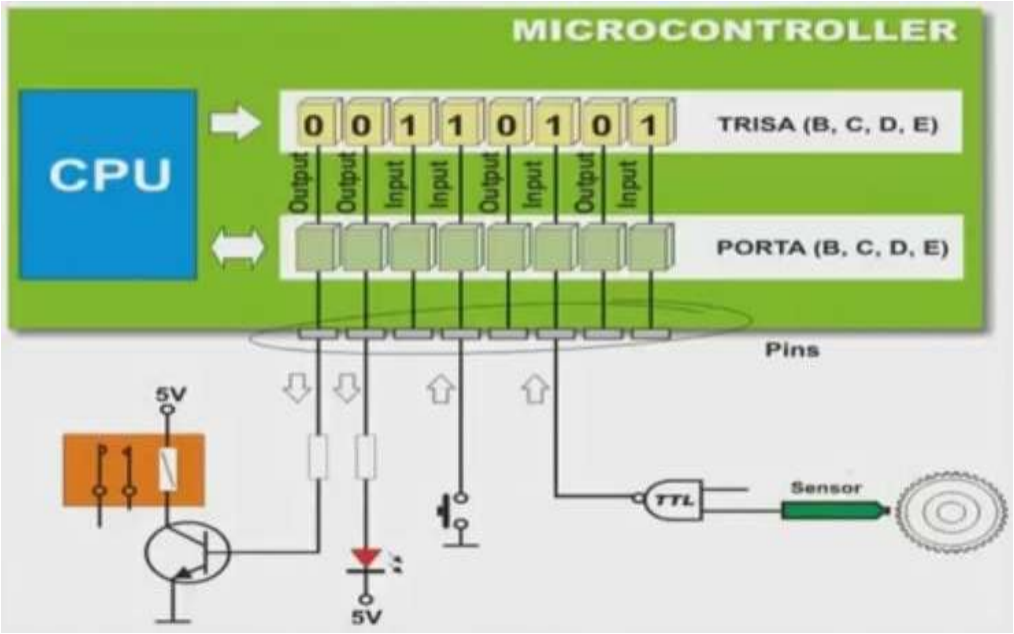
- Any change of their state affects the operation of the microcontroller or some of the circuits



e) Input /Output Ports

- In order to make the microcontroller useful, it has to be connected to additional electronics, i.e. peripherals.
- Each microcontroller has one or more registers (called a port) connected to the microcontroller pins.
- So the microcontroller will be connected to the peripheral devices through the pins connected the port register.
- The port registers are controlled to be input or output using registers called TRIS registers, so each port has its on TRIS register.

- So any bit in a PORTx can be input if the equivalent bit in the TIRSx register is (1) and output if the equivalent bit in the TRISx register is (0).



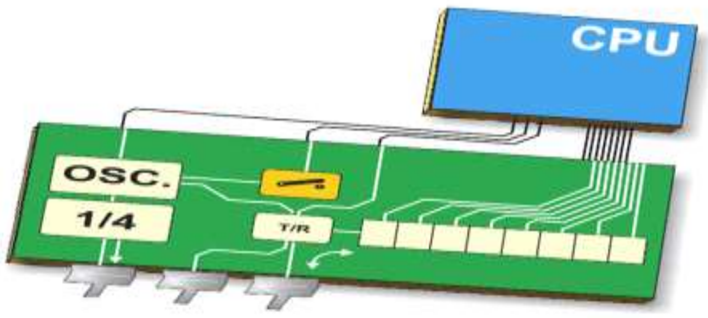
- Current sink/source capability is important if the microcontroller is to be connected to an external device that might draw a large amount of current to operate. PIC microcontrollers can source and sink 25mA of current from each output port pin. This current is usually sufficient to drive LEDs, small lamps, buzzers, small relays, etc. The current capability can be increased by connecting external transistor switching circuits or relays to the output port pins.

F) SERIAL COMMUNICATION

- Parallel connection between the microcontroller and peripherals via input/output ports is the ideal solution on shorter distances up to several meters. However, in other cases when it is necessary to establish communication between two devices on longer distances it is not possible to use parallel connection. Instead, serial communication is used.
- Serial Input-Output or Serial communication (also called RS232 communication) enables a microcontroller to be connected to another microcontroller or to a PC using a serial cable. Some microcontrollers have built-in hardware called USART (universal synchronous asynchronous receiver-transmitter) to implement a serial communication interface.

- Today, most microcontrollers have built in several different systems for serial communication as a standard equipment. Which of these systems will be used depends on many factors of which the most important are:

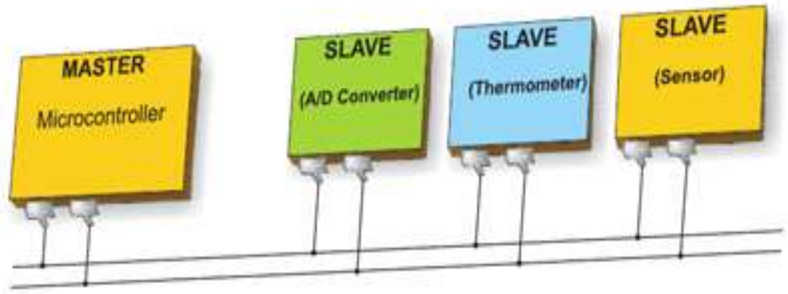
- How many devices the microcontroller has to exchange data with?
- How fast the data exchange has to be?
- What is the distance between devices?
- Is it necessary to send and receive data simultaneously?



- One of the most important things concerning serial communication is the Protocol which should be strictly observed. It is a set of rules which must be applied in order that devices can correctly interpret data they mutually exchange. Fortunately, the microcontroller automatically takes care of this, so that the work of the programmer/user is reduced to simple write (data to be sent) and read (received data).
- **Baud Rate:** The term baud rate is used to denote the number of bits transferred per second [bps]. Note that it refers to bits, not bytes. It is usually required by the protocol that each byte is transferred along with several control bits. It means that one byte in serial data stream may consist of 11 bits. For example, if the baud rate is 300 bps then maximum 37 and minimum 27 bytes may be transferred per second.
- The most commonly used serial communication systems are:

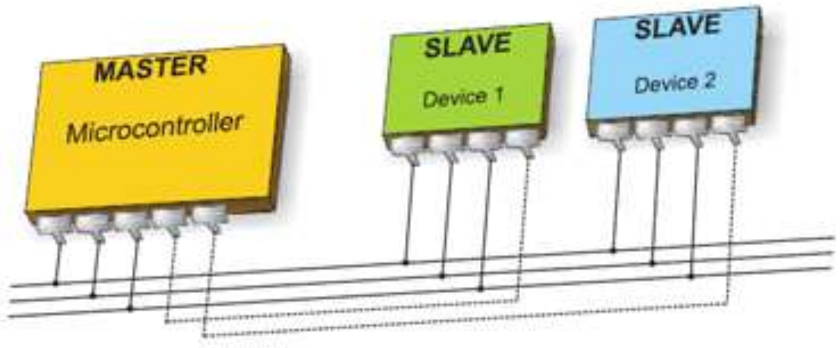
1) I^2C (Inter Integrated Circuit)

Inter-integrated circuit is a system for serial data exchange between the microcontrollers and specialized integrated circuits of a new generation. It is used when the distance between them is short (receiver and transmitter are usually on the same printed board). Connection is established via two conductors. One is used for data transfer, the other is used for synchronization (clock signal). As seen in figure below, one device is always a master. It performs addressing of one slave chip before communication starts. In this way one microcontroller can communicate with 112 different devices. Baud rate is usually 100 Kb/sec (standard mode) or 10 Kb/sec (slow baud rate mode). Systems with the baud rate of 3.4 Mb/sec have recently appeared. The distance between devices which communicate over an I2C bus is limited to several meters.



2) SPI (Serial Peripheral Interface Bus)

A serial peripheral interface (SPI) bus is a system for serial communication which uses up to four conductors, commonly three. One conductor is used for data receiving, one for data sending, one for synchronization and one alternatively for selecting a device to communicate with. It is a full duplex connection, which means that data is sent and received simultaneously. The maximum baud rate is higher than that in the I2C communication system.



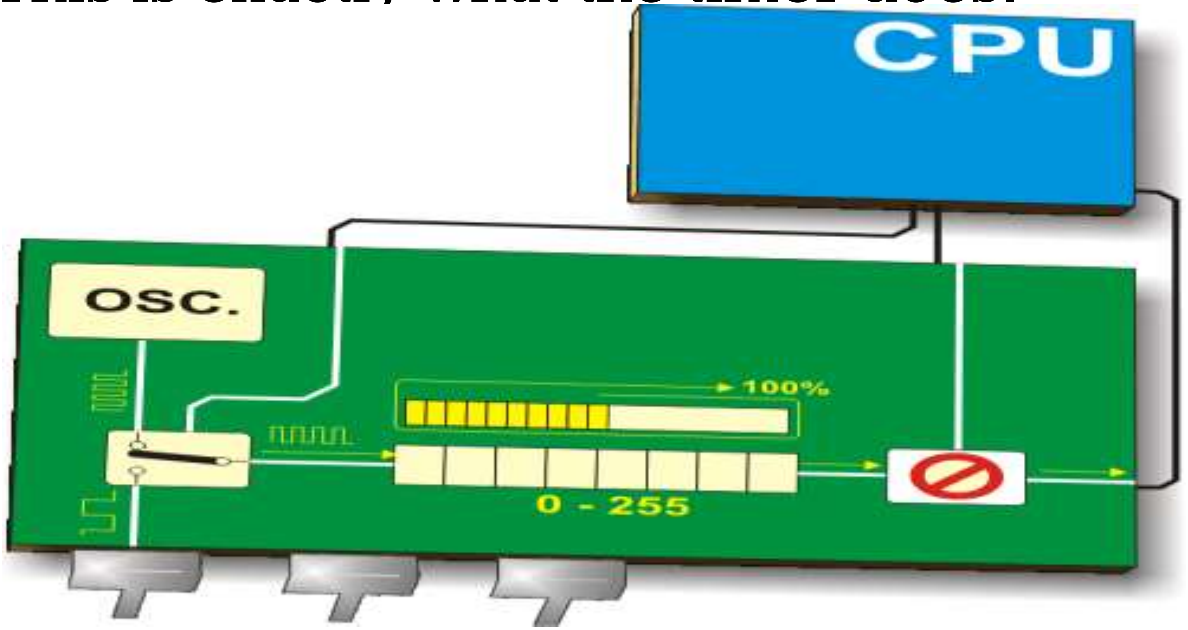
3) UART (UNIVERSAL ASYNCHRONOUS RECEIVER/ TRANSMITTER)

This sort of communication is asynchronous, which means that a special line for transferring clock signal is not used. In some applications, such as radio connection or infrared waves remote control, this feature is crucial. Since only one communication line is used, both receiver and transmitter operate at the same predefined rate in order to maintain necessary synchronization. This is a very simple way of transferring data since it basically represents the conversion of 8-bit data from parallel to serial format. Baud rate is not high, up to 1 Mbit/sec.

g) Timers/Counters

The microcontroller oscillator uses quartz crystal for its operation. Even though it is not the simplest solution, there are many reasons to use it.

The frequency of such oscillator is precisely defined and very stable, so that pulses it generates are always of the same width, which makes them ideal for time measurement. Such oscillators are also used in quartz watches. If it is necessary to measure time between two events, it is sufficient to count up pulses generated by this oscillator. This is exactly what the timer does.

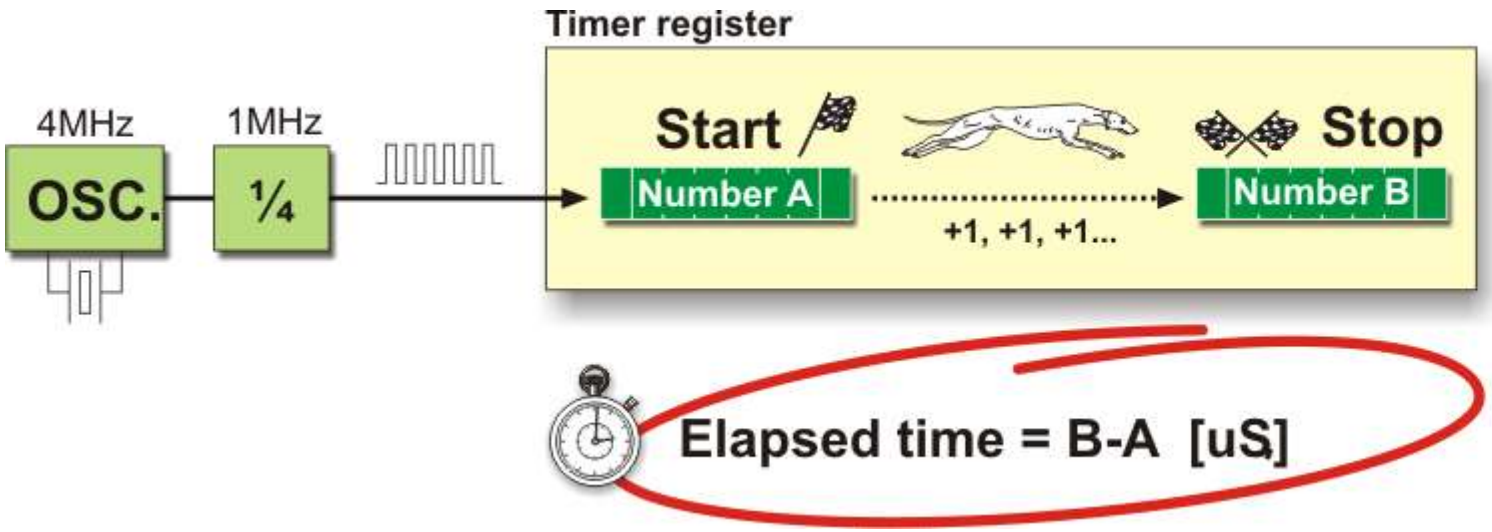


Most programs use these miniature electronic 'stopwatches'. These are commonly 8- or 16-bit SFRs the contents of which is automatically incremented by each coming pulse. Once a register is completely loaded, an interrupt may be generated!. If the timer uses an internal quartz oscillator for its operation then it can be used to measure time between two events (if the register value is T1 at the moment measurement starts, and T2 at the moment it terminates, then the elapsed time is equal to the result of subtraction T2-T1). If registers use pulses coming from external source then such a timer is turned into a counter.

This is only a simple explanation of the operation itself. It is however more complicated in practice.

How Does the Timer Operate?

In practice, pulses generated by the quartz oscillator are once per each machine cycle, directly or via a prescaler, brought to the circuit which increments the number stored in the timer register. If one instruction (one machine cycle) lasts for four quartz oscillator periods then this number will be incremented a million times per second (each microsecond) by embedding quartz with the frequency of 4MHz.



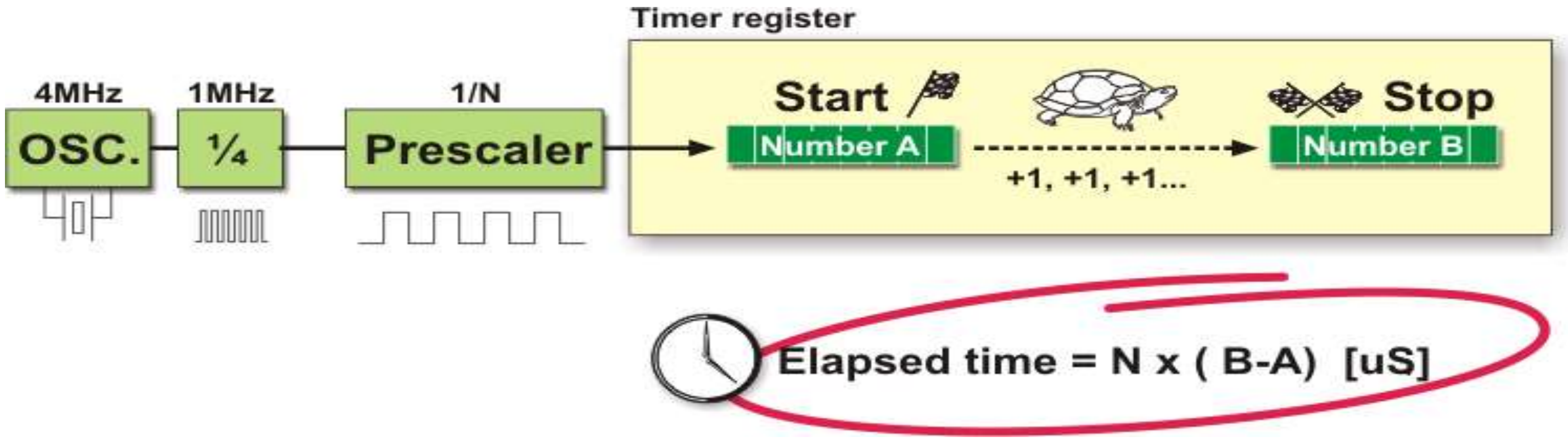
It is easy to measure short time intervals, up to 256 microseconds, in the way described above because it is the largest number that one register can store. This restriction may be easily overcome in several ways such as by using a slower oscillator, registers with more bits, prescaler or interrupts. The first two solutions have some weaknesses so it is more recommended to use prescalers or interrupts.

Using a Prescaler in Timer Operation:

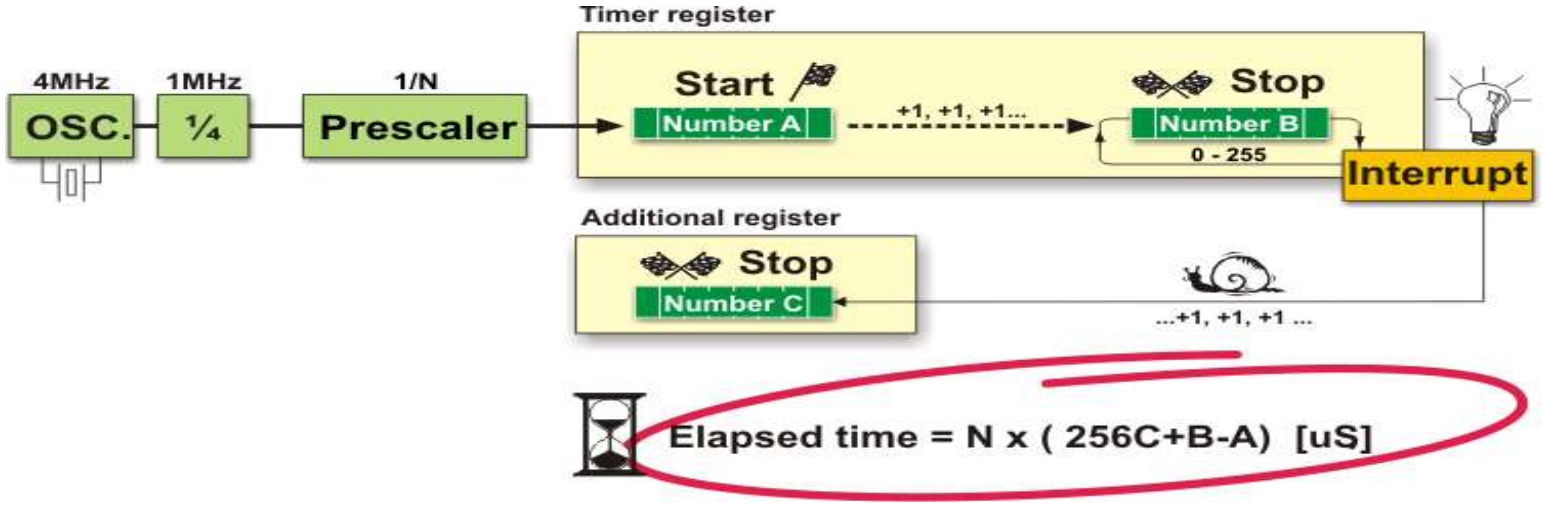
A prescaler is an electronic device used to reduce frequency by a predetermined factor. In order to generate one pulse on its output, it is necessary to bring 1, 2 , 4 or more pulses on its input.

Most microcontrollers have one or more prescalers built in and their division rate may be changed from within the program. The prescaler is used when it is necessary to measure longer periods of time. If one prescaler is shared by timer and watchdog timer, it cannot be used by both of them simultaneously.

Most microcontrollers have one or more prescalers built in and their division rate may be changed from within the program. The prescaler is used when it is necessary to measure longer periods of time. If one prescaler is shared by timer and watchdog timer, it cannot be used by both of them simultaneously.



Using Interrupt in Timer Operation: If the timer register consists of 8 bits, the largest number it can store is 255. As for 16-bit registers it is the number 65.535. If this number is exceeded, the timer will be automatically reset and counting will start at zero again. This condition is called an overflow. If enabled from within the program, the overflow can cause an interrupt, which gives completely new possibilities. For example, the state of registers used for counting seconds, minutes or days can be changed in an interrupt routine. The whole process (except for interrupt routine) is automatically performed behind the scenes, which enables the main circuits of the microcontroller to operate normally.



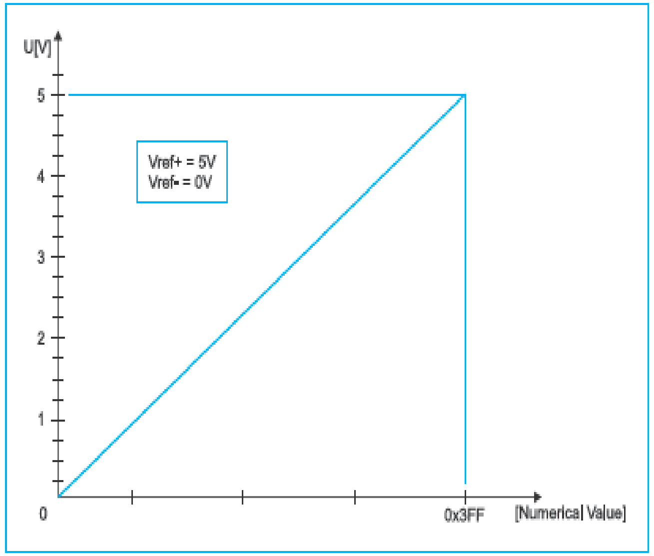
This figure illustrates the use of an interrupt in timer operation. Delays of arbitrary duration, having almost no influence on the main program execution, can be easily obtained by assigning the prescaler to the timer.

Counters: If the timer receives pulses from the microcontroller input pin, then it turns into a counter. Obviously, it is the same electronic circuit able to operate in two different modes. The only difference is that in this case pulses to be counted come over the microcontroller input pin and their duration (width) is mostly undefined.

This is why they cannot be used for time measurement, but for other purposes such as counting products on an assembly line, number of axis rotation, passengers etc. (depending on sensor in use).

h) A/D Converter``

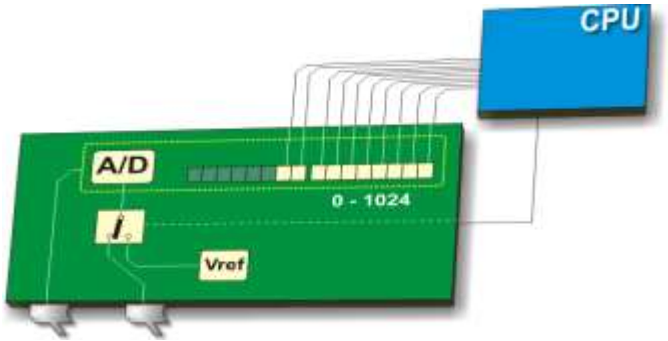
External signals are usually fundamentally different from those the microcontroller understands (ones and zeros) and have to be converted therefore into values understandable for the microcontroller. An analogue to digital converter is an electronic circuit



which converts continuous signals to discrete digital numbers. In other words, this circuit converts an analogue value into a binary number and passes it to the CPU for further processing.

This module is therefore used for input pin voltage measurement (analogue value). The result of measurement is a number (digital value) used and processed later in the program.

A/D converters are especially useful in control and monitoring applications, since most sensors (e.g., temperature sensors, pressure sensors, force sensors, etc.) produce analog output voltages.



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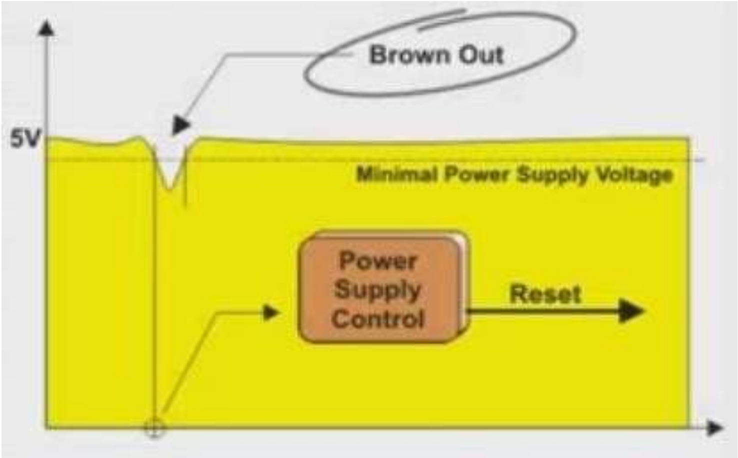
I) POWER SUPPLY CIRCUIT

There are two things worth attention concerning the microcontroller power supply circuit:

- Brown Out
- Reset Pin

Brown Out:

- It is a potentially dangerous state which occurs when the microcontroller is being turned off or when power supply voltage drops to the lowest level due to electric noise.



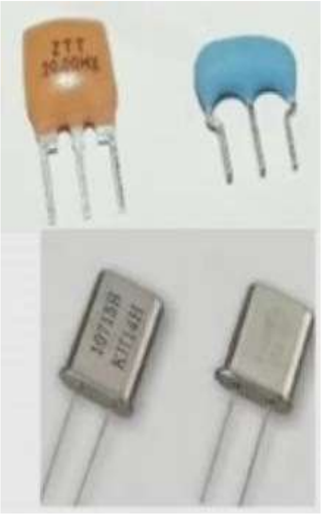
- As the microcontroller consists of several circuits which have different operating voltage levels, this can cause its out of control performance. This circuit immediately resets the whole electronics when the voltage level drops below the lower limit.

Reset Pin

Master Clear Reset (MCLR) serves for external reset of the microcontroller. Reset puts the microcontroller into a known state. Usually, after a reset, the program starting from memory address 0 of the microcontroller is executed.

j) Oscillator

- Even pulses generated by the oscillator enable the operation of all circuits within the microcontroller.
- One of the factors that controls the speed of the microcontroller is the frequency of the oscillator.
- There are different modes of oscillators like:
    - Low Power Crystal (LP)
    - Crystal/Resonator (XT)
    - High Speed Crystal/Resonator (HS)
    - Resistor Capacitor (RC)



- We use capacitors with the oscillators to reduce noises and we chose the capacitors values depending on the oscillator frequency and type.

CERAMIC RESONATORS

Ranges Tested:			
Mode	Freq.	OSC1	OSC2
XT	455 kHz 2.0 MHz 4.0 MHz	68-100 pF 15-68 pF 15-68 pF	68-100 pF 15-68 pF 15-68 pF
HS	8.0 MHz 16.0 MHz	10-68 pF 10-22 pF	10-68 pF 10-22 pF

CAPACITOR SELECTION FOR CRYSTAL OSCILLATOR

Osc Type	Crystal Freq.	Cap. Range C1	Cap. Range C2
LP	32 kHz	33 pF	33 pF
	200 kHz	15 pF	15 pF
XT	200 kHz	47-68 pF	47-68 pF
	1 MHz	15 pF	15 pF
	4 MHz	15 pF	15 pF
HS	4 MHz	15 pF	15 pF
	8 MHz	15-33 pF	15-33 pF
	20 MHz	15-33 pF	15-33 pF

- It is important to say that program instructions are not executed at the rate imposed by the oscillator.
- There are four steps taken by the CPU to do an instruction:
  1. Fetch
  2. Decode
  3. Execute
  4. Transfer

$$F_{internal\text{-}clock} = 1/F_{osc}$$

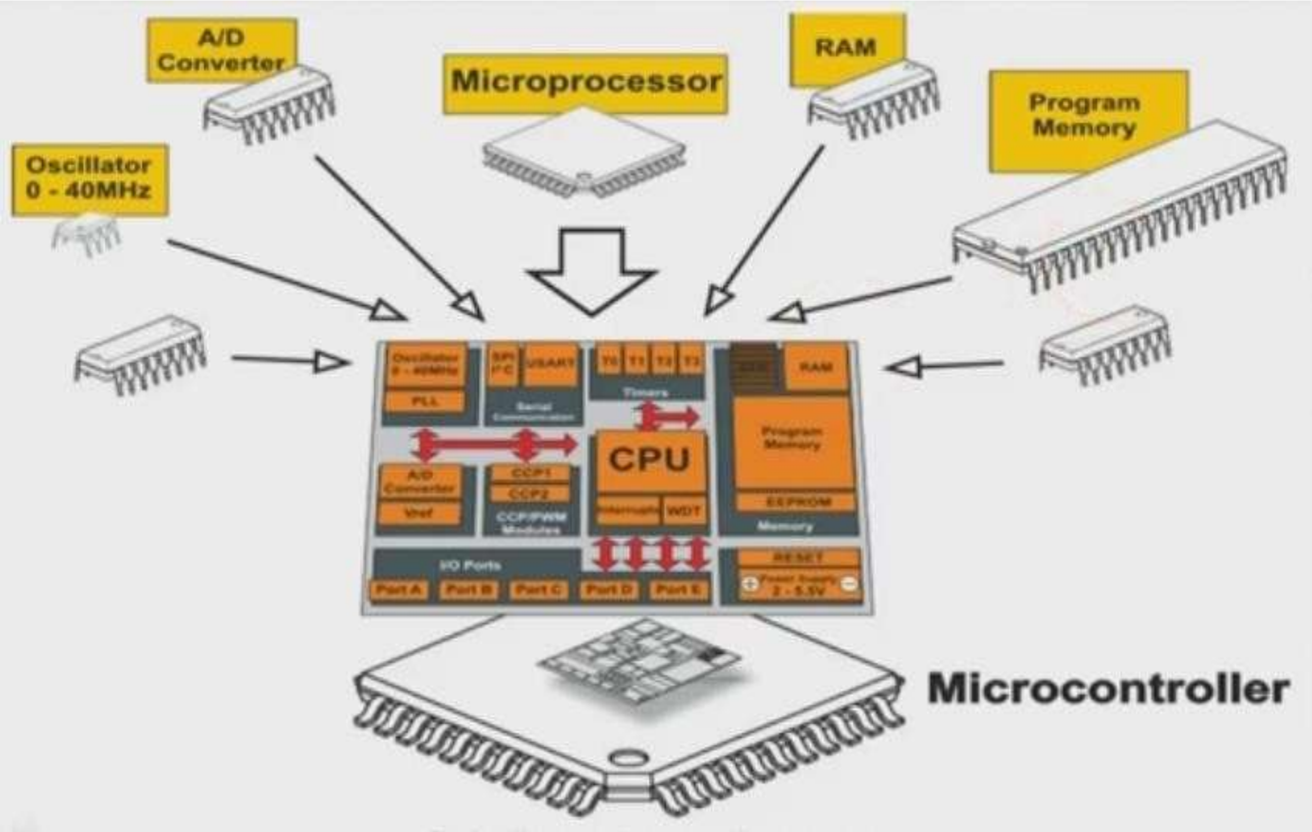
$$T_{cycle} = 4 * T_{osc} = T_{fetch} + T_{decode} + T_{execute} + T_{transfer}$$

4) HOW DOES THE MICROCONTROLLER WORK?

- The program is load into the microcontroller.
- Power supply is turned on, the control logic units disables all other circuits except quartz crystal to operate.
- Power supply voltage reaches its maximum and oscillator frequency becomes stable. SFRs are being filled with bits reflecting the state of all circuits within the microcontroller.
- Program counter is set to zero. Instruction from that address is sent to instruction decoder which recognizes it, after which it is executed with immediate effect.
- The value of the program counter is incremented by (1) and the whole process is repeated several million times per second.

5) MICROCONTROLLER VS MICROPROSSER

- Microcontroller contains a Microprocessor.



- Microprocessor is a single chip CPU, microcontroller contains, a CPU and much of the remaining circuitry of a complete microcomputer system in a single chip.
- Microcontroller includes RAM, ROM, serial and parallel interface, timer, interrupt schedule circuitry (in addition to CPU) in a single chip.
- RAM is smaller than that of even an ordinary microcomputer, but enough for its applications.
- Interrupt system is an important feature, as microcontrollers have to respond to control oriented devices in real time. E.g., opening of microwave oven's door cause an interrupt to stop the operation. (Most microprocessors can also implement powerful interrupt schemes, but external components are usually needed).
- Microprocessors are most commonly used as the CPU in microcomputer systems. Microcontrollers are used in small, minimum component designs performing control-oriented activities.
- Microprocessor instruction sets are processing intensive, implying powerful addressing modes with instructions catering to large volumes of data. Their instructions operate on nibbles, bytes, etc. Microcontrollers have instruction sets catering to the control of inputs and outputs. Their instructions operate also on a single bit. E.g., a motor may be turned ON and OFF by a 1-bit output port.

6) **How to choose your chip?**

Logically:

Decide the type and number of the modules in the microcontroller you will need in your project.

Check up the microcontrollers available in the market.

Look for the data sheet for each of them to get the one that you need (look it up in the library of the software proteus easier than the internet).

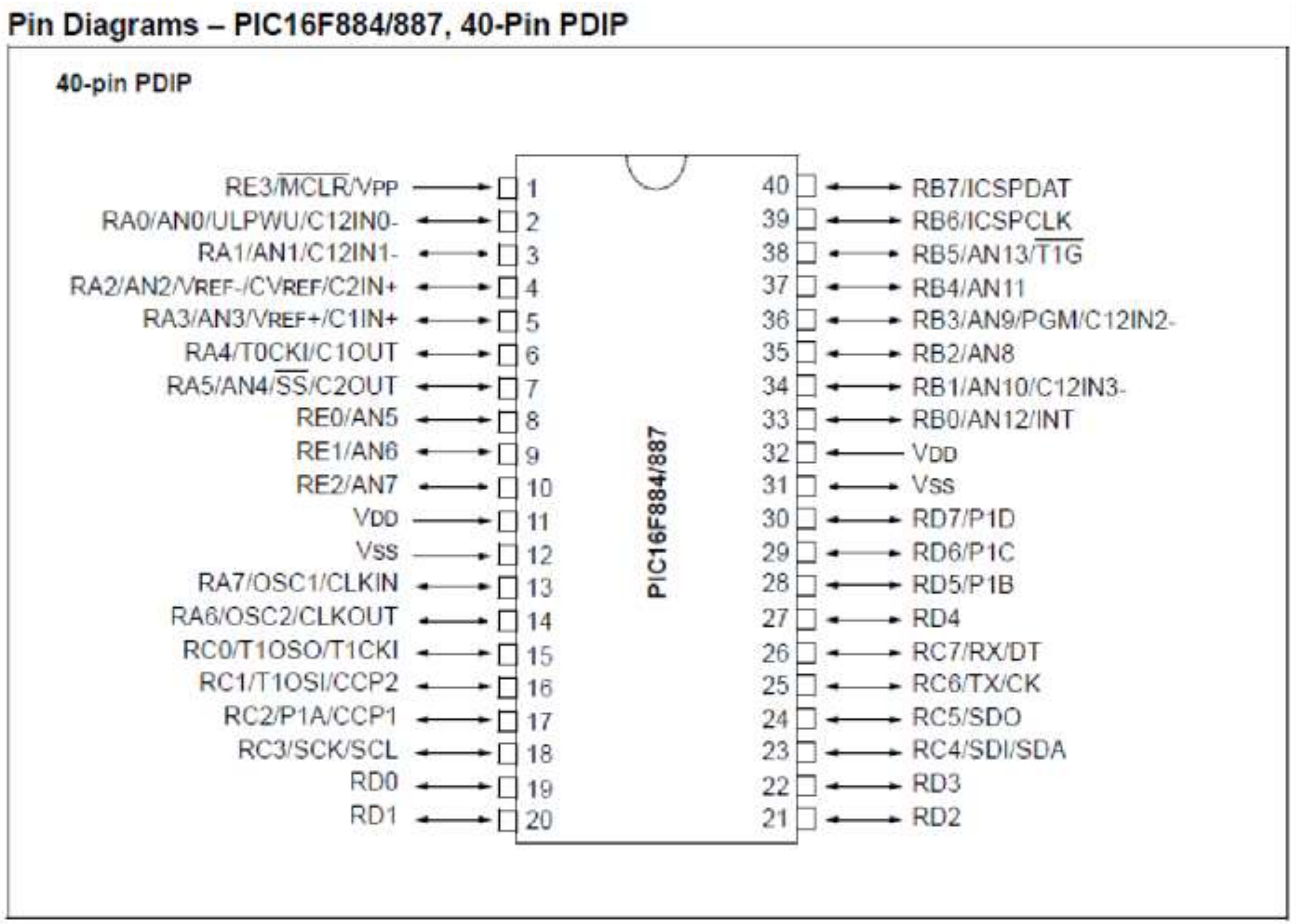
7) SHORT LIST OF MCU BRANDS

- Atmel
- Intel
- ZiLOG
- ***Microchip Technology***
- Toshiba
- Parallax
- Sony
- Fujitsu

- Each Brand has many families of MCUs and we will work with "*Microchip*" Brand , and we will work with "*PIC16F877A*" MCU form the family of "*PIC16F*"

LEC-4

8) PIC16F887 DESCRIPTION



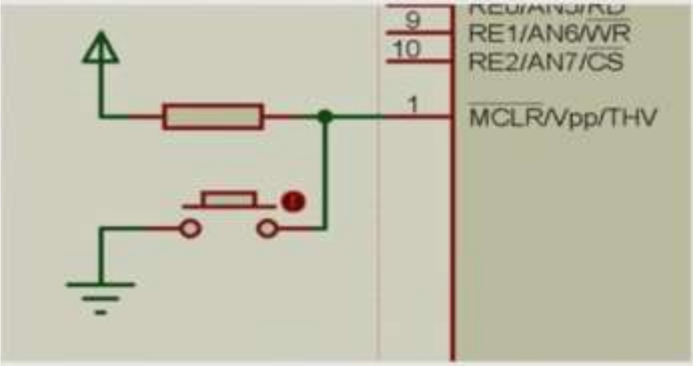
PIC16F887 Pin Configuration

9) NECESSARY CONNECTIONS FOR PIC16F887

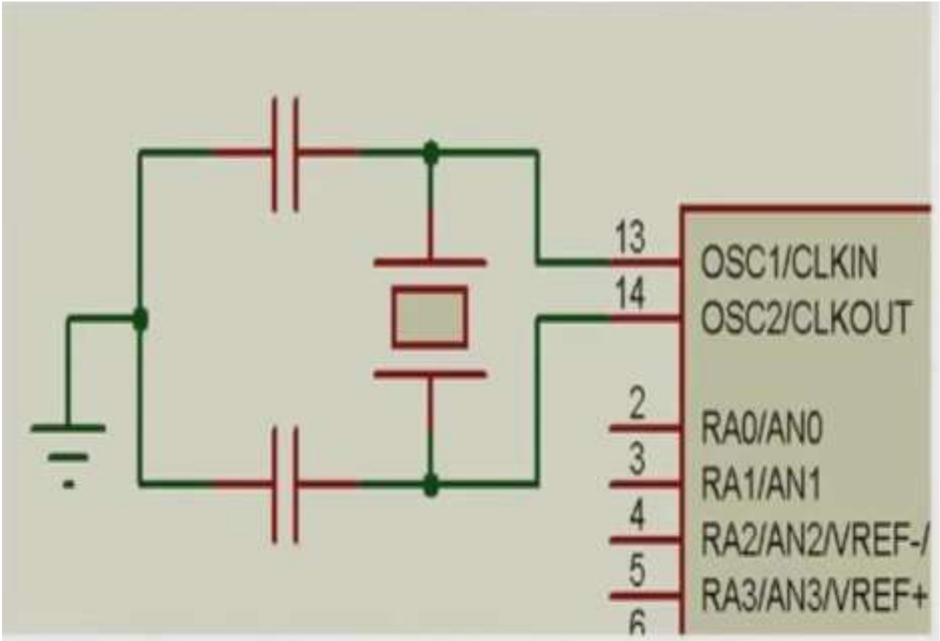
- Connect Pin 11 and 32 to the Vcc and Pin 12 and 31 to the GND.

VCC (+5V)	GND
PIN 11	PIN 12
PIN 32	PIN 31

- Connect Pin 1 (MCLR) to a pull down resistor connection.



- Connect pin 13 and 14 to the oscillator and two capacitors like the figure.

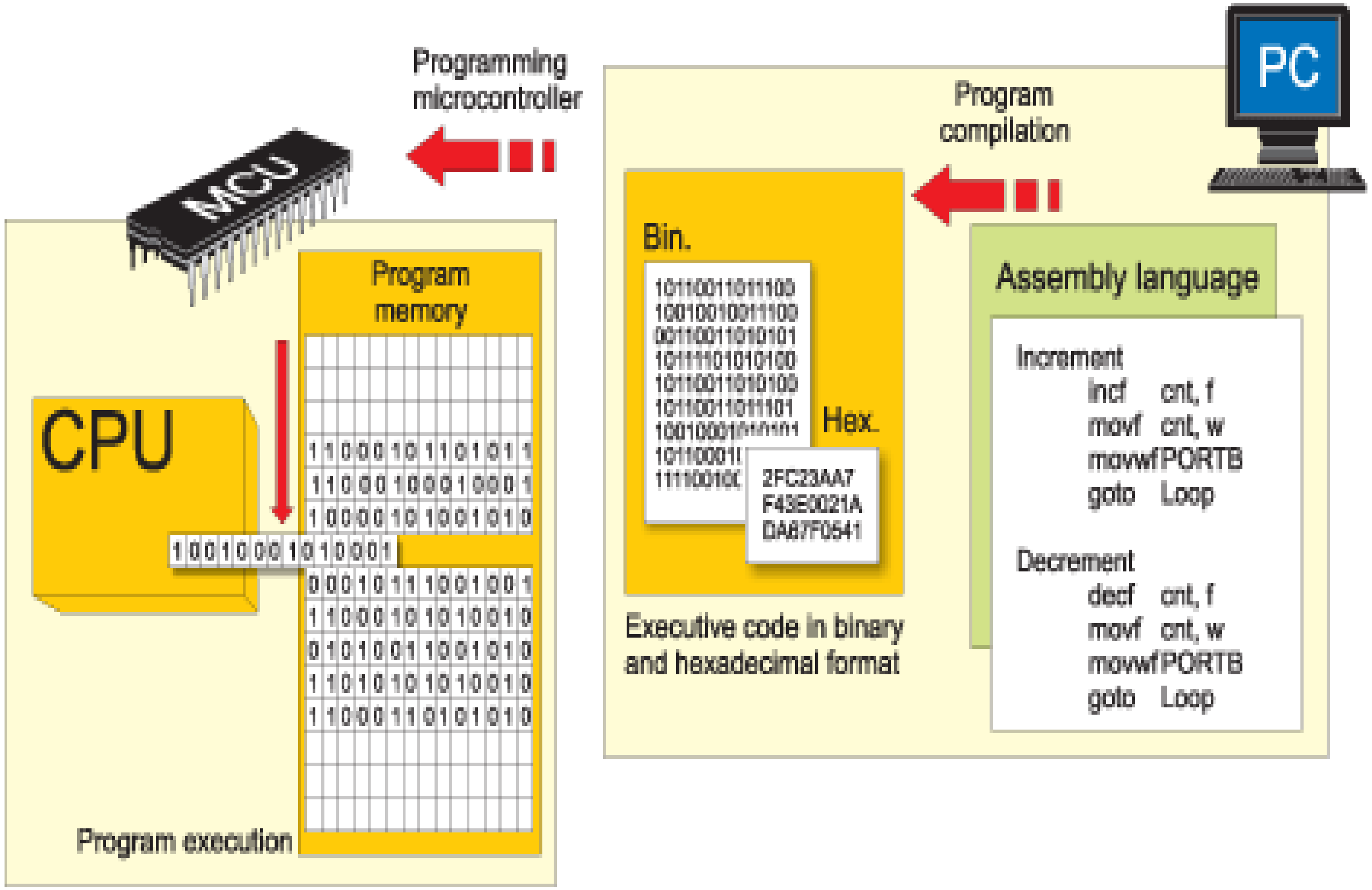


C PROGRAMMING LANGUAGE

1) **Introduction to Programming**
2) **mikroC Compiler**
3) **Structure of a Simple Program**
4) **Variables & Constants**
5) **Arrays**
6) **Operators**
7) **Flow Control**
8) **Functions**
9) **Notes**

1) INTRODUCTION TO PROGRAMMING

- Programming is writing the instruction that the Microprocessor will do.
- At first programs were written in Machine Code (0, 1).
- Then Assembly Language was invented as the hardware became complex and we needed to make an easier language.
- Then the higher level languages were invented, They are much easier than
- assembly Language (C, Java).
- The microcontroller executes the program loaded in its Flash memory. This is so called executable code (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 to gather 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.


Programming microcontroller
MCU
Program memory
CPU
Program execution
PC
Program compilation
Bin.
Hex.
2FC23AA7
F43E0021A
DA67F0541
Executive code in binary and hexadecimal format
Assembly language
Increment
incf cnt, f
movf cnt, w
movwf PORTB
goto Loop
Decrement
decf cnt, f
movf cnt, w
movwf PORTB
goto Loop

2) MikroC Complier

The first thing you need to write a program for the microcontroller is a PC program which understands the programming language you use, C in this case, and provides a window for writing program. Besides, the *software must 'know' the architecture of the microcontroller in use*. In this case, you need a *compiler* for C language.

There is no compiler to be used for only one concrete microcontroller as there is no compiler to be used for all microcontrollers. It's all about software used to program a group of similar microcontrollers of one manufacturer compiler. As the name suggests, the compiler is intended for writing programs for PIC microcontrollers in C language. It is provided with all data on internal architecture of these microcontrollers, operation of particular circuits, instruction set, names of registers, their accurate addresses, pin outs etc. When you start up the compiler, the next thing to do is to select a chip from the list and operating frequency and of course - to write a program in C language.

3) Variables and Constants

a) Why using Variables and Constants?!
b) How to declare a Variable?
c) Variable Types.
d) Variable Name.
e) Examples of Variable declaration.
f) Constants declaration.

a) Why using Variables and Constants?!

- We use Variables and constants to store the data of the program and deal with them like doing mathematical operations or displaying their values.
- Variables are stored in RAM so we can change their values during the program.
- Constants are stored in ROM so we can't change their values during the program.

B) HOW TO DECLARE A VARIABLE?

- To declare a variable we need to describe the following:
  1. Variable Type.
  2. Variable name.
  3. Value of the Variable (not a must).

  And we write the declaration statement like this:

Variable Type Variable name = Variable Value;

C) VARIABLE TYPES

Type	Size in Bytes	Range
(unsigned) char	1	0 ... 255
signed char	1	-128 ... 127
(signed) short (int)	1	-128 ... 127
unsigned short (int)	1	0 ... 255
(signed) int	2	-32768 ... 32767
unsigned (int)	2	0 ... 65535
(signed) long (int)	4	-2147483648 ... 2147483647
unsigned long (int)	4	0 ... 4294967295

- Keywords in parentheses can be (and often are) omitted.
- In int >> automatically considered signed except if we write unsigned .
- In char >> automatically considered unsigned except if we write signed

Type	Size in Bytes	
float	4	$\pm 1.17549435082 * 10^{-38}$ .. $\pm 6.80564774407 * 10^{38}$
double	4	$\pm 1.17549435082 * 10^{-38}$ .. $\pm 6.80564774407 * 10^{38}$
long double	4	$\pm 1.17549435082 * 10^{-38}$ .. $\pm 6.80564774407 * 10^{38}$

- float , double and long double are considered floating-point types. mikroC's implementation of ANSI Standard considers them the same .

D) VARIABLE NAME

- Variable Names must be Unique.
- Variable Names must begin with alphabetical characters (uppercase or lowercase) or Underscore characters.
- It may contain numbers and can contain uppercase or lowercase characters.
- Variable Names must not be like the reserved names of the compiler.
- It must not contain any special characters like ( ) : ; _ " ' & % $ # } [{].
- Examples:
  - Correct Variable Names: (sum, Result, student_1, Student4, _sum).
  - Wrong Variable Names: (5student, 5_student, #sum, if, switch, while, enum, case, else, asm, goto .....

e) Examples of Variable Declaration

- int x ;
- char n = 'A' ;
- float sum = 0 ;
- long z =12 ;
- Int L = 0b110011 ;

F) CONSTANT DECLARATION

- Declaring a constant is just like declaring a variable, we just put the word const before the variable type.
- As we can't change the value of the constants during the program so we must put their value when declaring them.
- Examples:

✓ **const int** x = 5 ;

✓ **const char** ch_1 = 'L' ;

4) Arrays

a) What are Arrays and why using them?

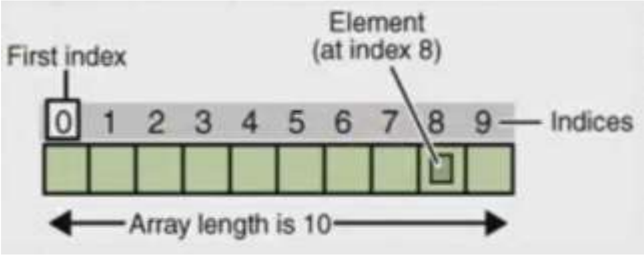
b) How to declare an array?

A) WHAT ARE ARRAYS AND WHY USING THEM?

- Array used to store elements with the same type in memory.
- We may use arrays to one operation to more than a couple of variables like adding three number to an other three numbers in the same time.
- Arrays will help you to store and handle data easily during the program such as in loops and many other uses.

b) How to declare an array?

- Like a variable with declaring name and type but we need to add the number of elements (optional).
- Index of the elements of an array begins from zero.



- char name [ ] = "Ahmed" ;
- int numbers [4] = {1, 2, 3, 4} ;
- char name [ ] = {'A', 'h', 'm', 'e', 'd'} ;

5) OPERATORS

- Arithmetic operators.
- Relational operators.
- Logical operators.
- Bitwise operators.
- Preprocessor operators.

- Arithmetic operators

Operator	Operation
+	Addition
-	Subtraction
*	Multiplication
/	Division
%	Modulus operator returns the remainder of integer division (cannot be used with floating points)
++	Increment adds one to the value of the operand.
--	Decrement subtracts one from the value of the operand.

- Relational operators

Operator	Operation
==	Equal
!=	Not Equal
>	Greater than
<	Less than
>=	Greater than or Equal
<=	Less than or Equal

- Logical operators

Operator	Operation
&&	Logical AND
||	Logical OR
!	Logical NOT

- Bitwise operators

Operator	Operation
&	bitwise AND; compares pairs of bits and returns 1 if both bits are 1, otherwise returns 0
|	bitwise (inclusive) OR; compares pairs of bits and returns 1 if either or both bits are 1, otherwise returns 0
^	bitwise exclusive OR (XOR); compares pairs of bits and returns 1 if the bits are complementary, otherwise returns 0
~	bitwise complement (unary); inverts each bit
>>	bitwise shift right; moves the bits to the right, discards the far right bit and if unsigned assigns 0 to the left most bit, otherwise sign extends
<<	bitwise shift left; moves the bits to the left, discards the far left bit and assigns 0 to the right most bit.

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- **Preprocessor operators**

  - The Preprocessor parts of the code are not compiled.
  - Replace symbols with other symbols or values in the program.
  - Insert text file into a program.
  - The processor operator is the ('#") characters.
  - The semicolon characters (";") is not needed to terminate a preprocessor command.

    ✓ Example1:

    #define value // **global declaration of a value**

    ✓ Example2:

    #include <file.h> // **to include source file (headerfile.h)**

6) Flow Control

- Selection statement:
  - ✓ ***if***
  - ✓ ***switch***
- Interation statement:
  - ✓ ***while***
  - ✓ ***for***
  - ✓ ***do while***
- Unconditional statement:
  - ✓ ***goto***
  - ✓ ***break***

❖ **<u>Selection statment "*if*"</u>**

- *if (condition1)*

```
{
Statement1;
}
else if (condition2)
```

```
  {
    Statement2;
  }
else
    Statement3;
```

- If *condition1* happend do *statement1*.
- If *condition2* happend do *statement2*.
- If *non of them* happend do *statement3*.

- Example:

```
if(x==1)
{
Portb.f0 = 1;
}
else if (x==92&& L==91)
{
        Portb.f1=1;
         }
       else

      Portb.f3=1;
```

❖ Selection statment *"switch"*

- Example:

```
switch(x) {
case condition1:
statement1;
case condition2:
Statement2;
 defult:
  Statement3;
}
```

- Check the variable x.
- If it is equal to *condition1* do *statement1*.
- If it is equal to *condition2* do *statement2*.
- If *condition1* or *condition2* didn't happen do *statement3*.

```
switch (x) {
case 1:
   Portb.f0 = 1;
case 4:
   Portb.
f3 = 1;
defult:
   Portb.f7 = 1;
 }
```

❖ **Iteration statment "*while*"**

- *while (condition1)*

```
     {
        Statement1;
      }
```

If *condition1* occurs, do *statement1* until it changes.

Example:

```
while (L<=4)
{
Portc.f4=1;
L++;
}
```

- **Iteration statment "*for*"**

```
for (initial expression; condition expression; increment expression)
{
Statement1;
}
```

Example:

```
for (i=1; i<4; i++)
    {
     x++;
}
```

- It will ***begin with i = 1*** then it will ***check if it is less than 4*** and ***if this true it will do x++ then increments i with 1*** and then checks ***if the new value of i is less than 4 or not*** if it was ***true it will do x++*** then ***increments i with 1*** and so on until i is equal or ***greater than 4 it will not do the loop and continue the program***.

Iteration statment *"do while"*

- *do*{

Statement1;
}
while(condition1)

- It will do statement 1 then checks if condition 1 is happening it will continue in the loop until condition 1 don't occur.
- Example:

```
do{
    x++;
    }
while(x<10);
```

❖ Unconditional statment "*goto*"

- **start:**

statement1; **goto** **start;**

- **goto** makes the program jump to the label called after it.
- Example:

```
Lamp:
 x++;
goto lamp;
```

Unconditional statment "*break*"

- It breaks the flow of a part in the program.
- In the next example if ***y*** equal to ***5*** the processor ***will not continue the loop and breaks it*** and will do the rest of the program.
- Example:

```
for (x = 4; x < 40; x ++)
{ y++;
if (y == 5)
 break; }
```

7) Functions

- What is a function?
- How to Declare a function?
- Example.

-- What is a function?

- A function is a process which is outside the main function of the program and you can use it in the main function.
- It is similar to a function in Math - but not exactly the same -, it has input values and it does some kind of operations on it then it gives you an output.

-- How to Declare a function?

- To declare a function we must put:

1.The Function's name.

2.What parameters will the function have as input (number of them and their type).

3. What parameters will the function return as an output (Type).

Example

- **int square (int x)**

In this example we here declared:

  - Name of the function as ***square***.
  - It have ***one*** input parameter.
  - The input parameter is ***integer***.
  - Its output is also an ***integer***.

- **int anything (int x, char y)**

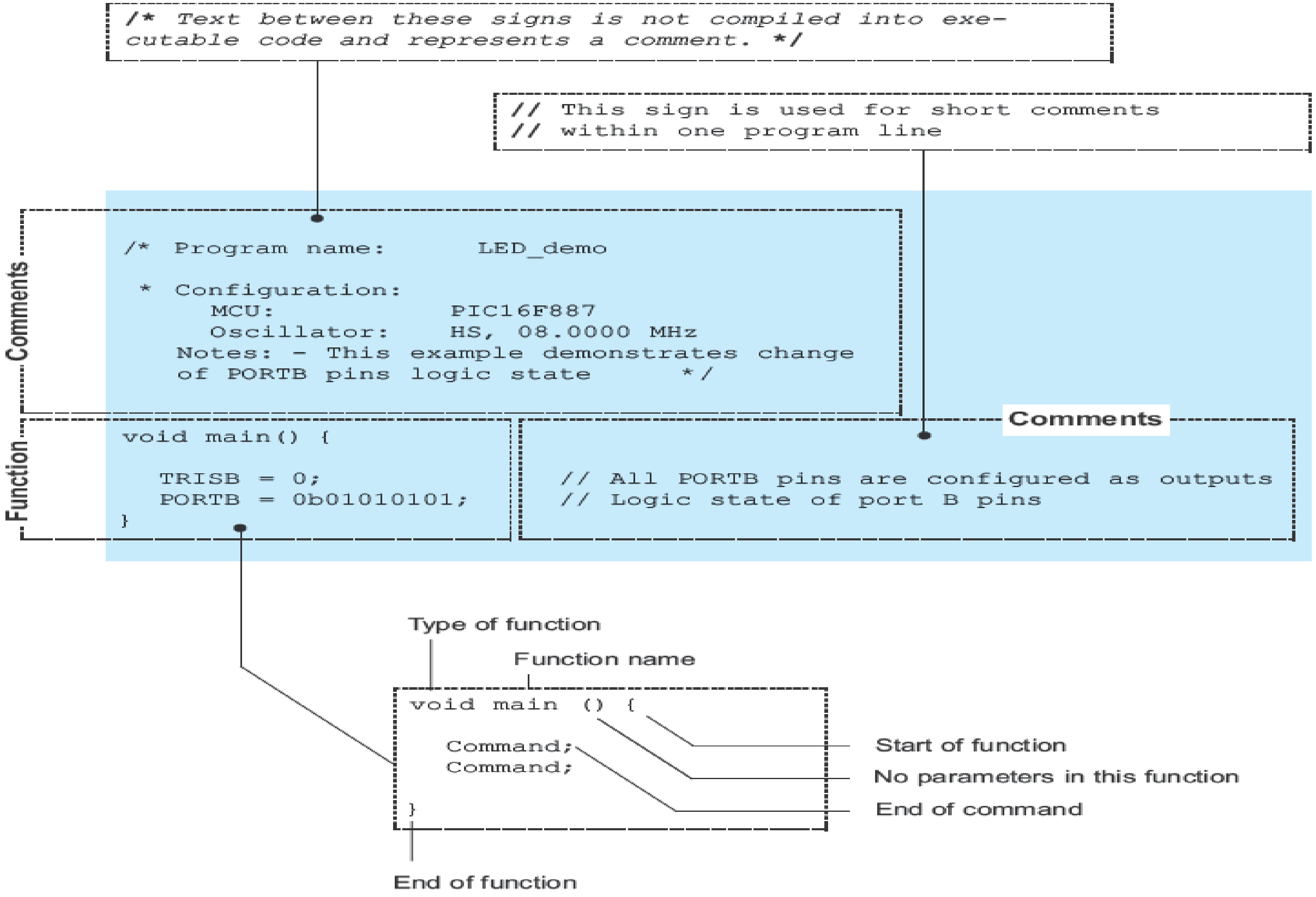
  In this example we here declared:

  - Name of the function as **anything**.
  - It have ***two*** input parameters.
  - The input parameter is ***integer*** and the other one is ***char***.
  - Its output is also an ***integer***.

- **Note that:**
  - If you don't want the function to have any input parameters you should leave the two brackets empty ( ) or write (void) between them.
    - ✓ **Example: int sum ( ), int sum (void).**
  - If you don't want the function to return any parameters you will write void instead of the type that it returns.
    - ✓ **Example: void sum (int x), void sum ( ).**

8) Structure Of Simple Program

Figure below illustrates the structure of a simple program, pointing out the parts.



/* Text between these signs is not compiled into exe-
cutable code and represents a comment. */
// This sign is used for short comments
// within one program line
Comments
/* Program name: LED_demo
* Configuration:
MCU: PIC16F887
Oscillator: HS, 08.0000 MHz
Notes: - This example demonstrates change
of PORTB pins logic state */
Function
void main() {
TRISB = 0;
PORTB = 0b01010101;
}
Comments
// All PORTB pins are configured as outputs
// Logic state of port B pins
Type of function
Function name
void main () {
Command;
Command;
}
Start of function
No parameters in this function
End of command
End of function

9) NOTES

- We will write the main program in a function called main.

  ☒ void **main ( ) {**

  Program!

  }

- Each statement must end with semi colon " **;** ".
- White spaces doesn't matter.

  ☒ **Example: x = 6**; is the same as **x =6;**

- Names are case sensitive (upper case and lower case).

  ☒ **Example: x** *is different from* **X**

- To write comments use // before them for one line comment and for more than one line comment use /* in the beginning and */ at the end of the comment.

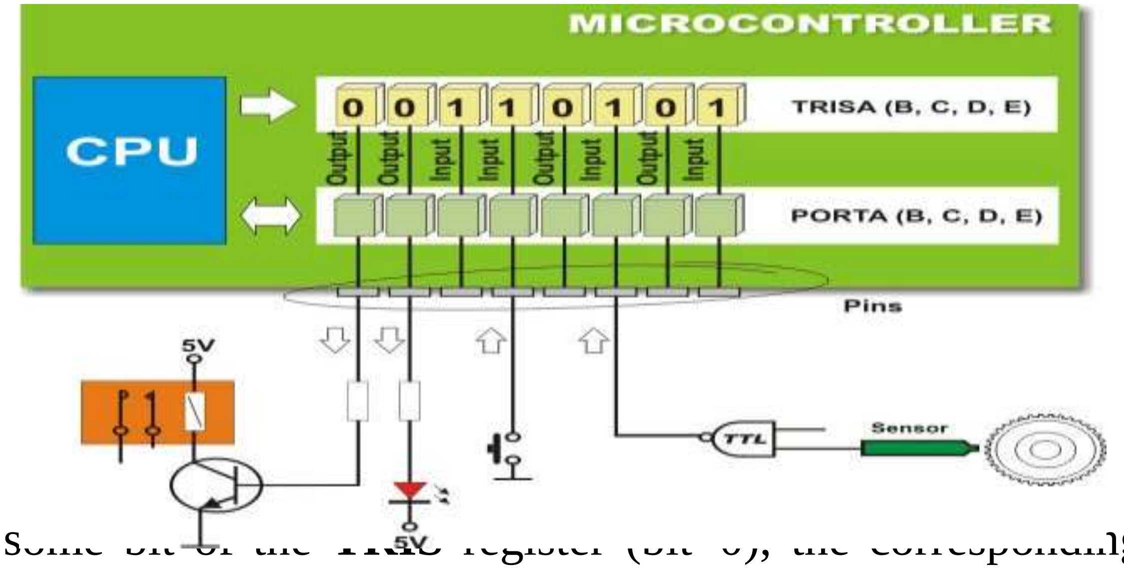
10) OUTPUTTING DATA / SIGNALS

Microcontrollers have dual worlds. An internal world; comprising of registers, timers, CPU and other integrated devices, and an external world, which consists of other devices, like LCD, Keypads, speakers, sensors and what not. In order to communicate with these devices microcontroller uses its pins, also called I/O lines. The number of these I/O lines is one of the major characteristics of a microcontroller.

PIC16F887 microcontroller, which is 40 pin device, it has one MCLR pin, 4 Power supply and two for oscillator. The rest of 33 I/O lines are available for connection to other devices.

In order pins' operation can match internal 8-bit organization, all of them are, similar to registers, grouped into five so called ports denoted by A, B, C, D and E. All of them have several features in common:

- For practical reasons, many I/O pins have two or three functions. In case any of these alternate functions is currently active, that pin may not simultaneously use as a general purpose input/output pin.
- Every port has its "satellite", i.e. the corresponding TRIS register: TRISA, TRISB, TRISC etc. which determines performance, but not the contents of the port bits.



By clearing some bit of the TRIS register (bit=0), the corresponding port pin is configured as output. Similarly, by setting some bit of the TRIS register (bit=1), the corresponding port pin is configured as input. This rule is easy to remember 0 = Output, 1 = Input.

Analog and Digital Pins

PIC16F887 has a number of pins, which can acquire analog data. The same pins however can also be configured as digital, if not to be used as analog.

PORTA and TRISA register

PORTA is an 8-bit wide, bidirectional port. Bits of the TRISA and ANSEL registers control the PORTA pins. All PORTA pins act as digital inputs/outputs. Five of them can also be analog inputs (denoted by AN):

	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	Features
PORTA	RA7	RA6	RA5	RA4	RA3	RA2	RA1	RA0	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	Features
TRISA	TRISA7	TRISA6	TRISA5	TRISA4	TRISA3	TRISA2	TRISA1	TRISA0	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

Legend

R/W	Readable/Writable bit
(x)	After reset, bit is unknown
(1)	After reset, bit is set

- RA0 = AN0 (determined by the ANS0 bit of the ANSELregister)
- RA1 = AN1 (determined by the ANS1 bit of the ANSELregister)
- RA2 = AN2 (determined by the ANS2 bit of the ANSELregister)
- RA3 = AN3 (determined by the ANS3 bit of the ANSELregister)
- RA5 = AN4 (determined by the ANS4 bit of the ANSELregister)

Similar to bits of the TRISA register determine which of the pins are to be configured as inputs and which ones as outputs, the appropriate bits of the ANSEL register determine whether pins are to be configured as analog inputs or digital inputs/outputs.

Let's do it in mikroC...

```
// The PORTA.2 pin is configured as a digital input.
// All other PORTA pins are digital outputs
ANSEL = ANSELH = 0;      // All I/O pins are configured as digital
PORTA = 0;               // All PORTA pins are cleared
TRISA = 0b00000100;      // All PORTA pins except PORTA.2 are configured as outputs
```

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PORTB AND TRISB REGISTER

	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	Features
PORTB	RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	Features
TRISB	TRISB7	TRISB6	TRISB5	TRISB4	TRISB3	TRISB2	TRISB1	TRISB0	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

Legend

-	Bit is unimplemented
R/W	Readable/Writable bit
(x)	After reset, bit is unknown
(1)	After reset, bit is set

Similar to PORTA, a logic one (1) in the TRISB register configures the appropriate PORTB pin as an input and vice versa. Six pins of this port can act as analog inputs (AN). The bits of the ANSELH register determine whether these pins are to be configured as analog inputs or digital inputs/outputs

RB0 = AN12 (determined by the ANS12 bit of the ANSELH register)

RB1 = AN10 (determined by the ANS10 bit of the ANSELH register)

RB2 = AN8 (determined by the ANS8 bit of the ANSELH register)

RB3 = AN9 (determined by the ANS9 bit of the ANSELH register)

RB4 = AN11 (determined by the ANS11 bit of the ANSELH register)

RB5 = AN13 (determined by the ANS13 bit of the ANSELH register)

This port has several features which distinguish it from other ports and make its pins commonly used:

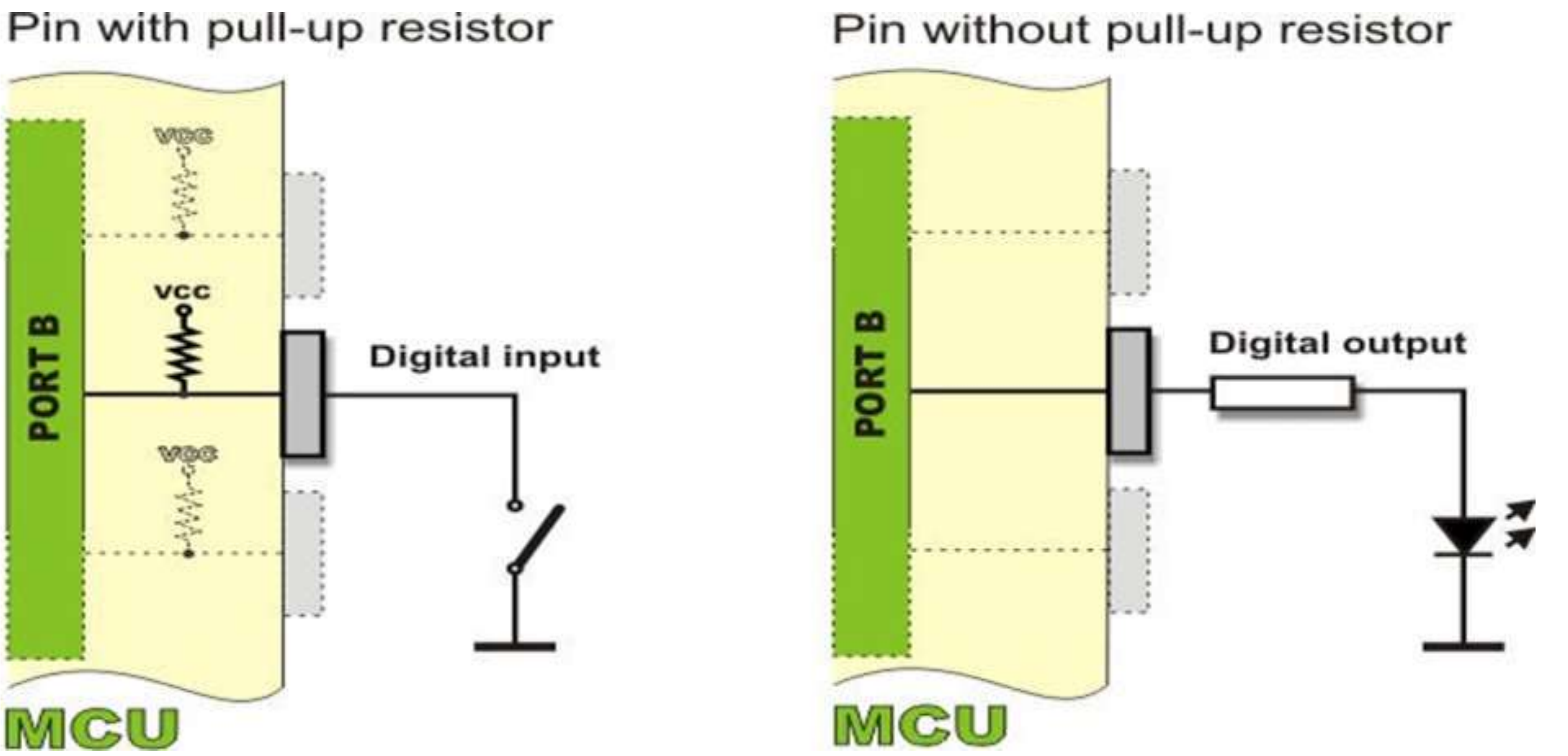
All the PORTB pins have built in pull-up resistors, which make them ideal for connection to push buttons (keyboard), switches and optocouplers. In order to connect these resistors to the microcontroller ports, the appropriate bit of the WPUB register should be set.*

	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	Features
WPUB	WPUB7	WPUB6	WPUB5	WPUB4	WPUB3	WPUB2	WPUB1	WPUB0	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

Legend

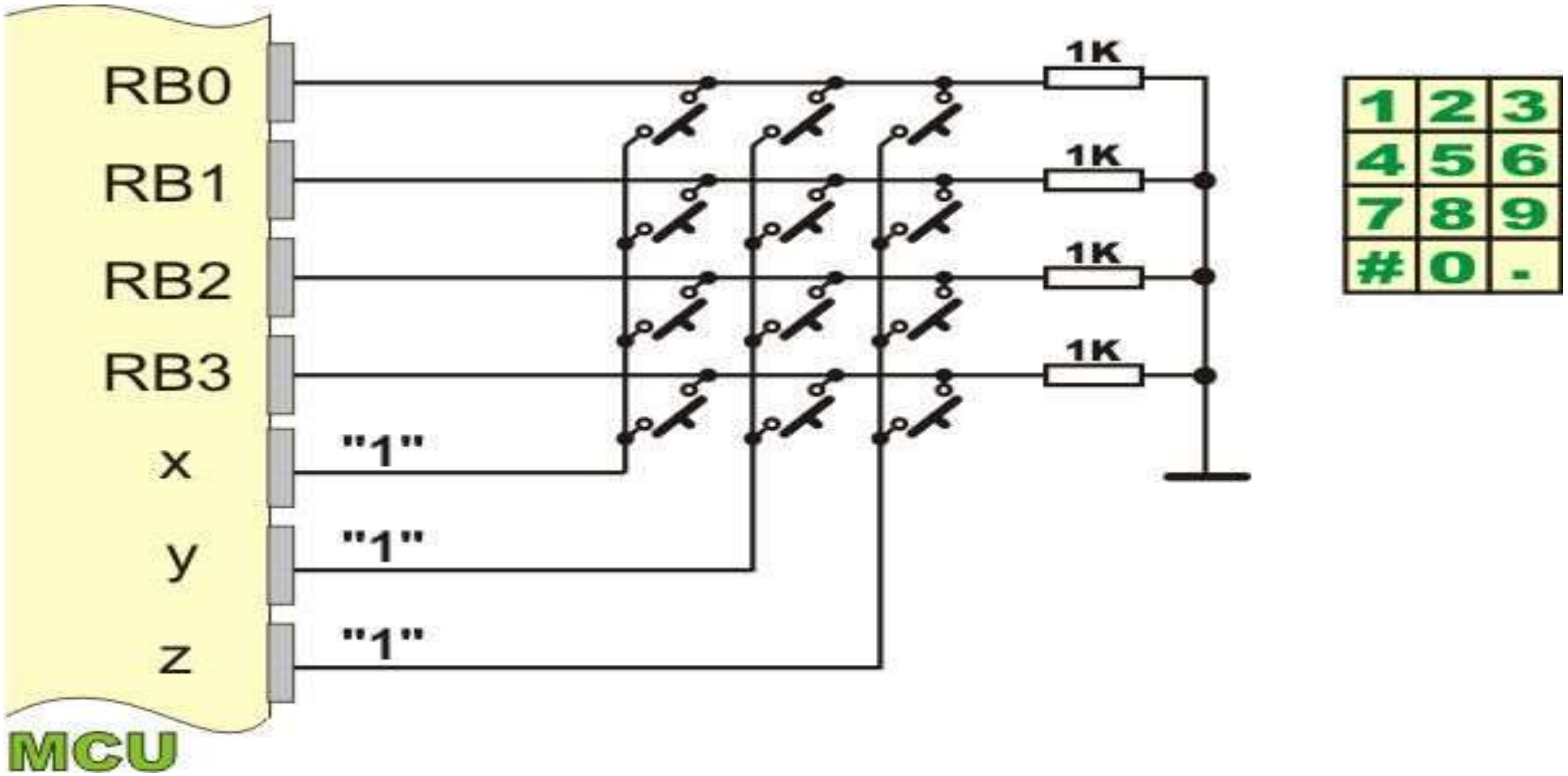
R/W	Readable/Writable bit
(1)	After reset, bit is set

Having a high level of resistance (several tens of kiloohms), these ‘virtual’ resistors do not affect pins configured as outputs, but serves as a useful complement to inputs. As such, they are connected to the inputs of CMOS logic circuits. Otherwise, they would act as if they are floating due to their high input resistance.



*Apart from the bits of the WPUB register, there is another bit affecting the installation of all pull-up resistors. It is the RBPU bit of the OPTION_REG. If enabled, each PORTB bit configured as an input may cause an interrupt by changing its logic state. In order to enable pins to cause an interrupt, the appropriate bit of the IOCB register should be set.

- The PORTB pins are commonly used for checking push buttons on the keyboard because they unerringly register any button press. Thus, there is no need to ‘scan’ these inputs all the time.



When the X, Y and Z pins are configured as outputs set to logic one (1), it is only necessary to wait for an interrupt request which arrives upon any button press. After that, by combining zeros and ones on these outputs it is checked which push button is pressed. **Let's do it in mikroC**...

```
/* The PORTB.1 pin is configured as a digital input. Any change of its logic state will cause
an .i.n.terrupt. It also has a pull-up resistor. All other PORTB pins are digital outputs.*/
ANSEL = ANSELH = 0; // All I/O pins are configured as digital
PORTB = 0; // All PORTB pins are cleared
TRISB = 0b00000010; // All PORTB pins except PORTB.1 are configured as outputs
RBPU = 0; // Pull-up resistors are enabled
WPUB1 = 1; // Pull-up resistor is connected to the PORTB.1 pin
IOCB1 = 1; // The PORTB.1 pin may cause an interrupt on logic state change
RBIE = GIE = 1; // Interrupt is enabled
```

PIN RB0/INT

The RB0/INT pin is the only 'true' external interrupt source. It can be configured to react to signal raising edge (zero-to-one transition) or signal falling edge (one-to-zero transition). The INTEDG bit of the OPTION_REG register selects the appropriate signal.

PORTC and TRISC register

PORTC is an 8-bit wide, bidirectional port. Bits of the TRISC register determine the function of its pins. Similar to other ports, a logic one (1) in the TRISC register configures the appropriate PORTC pin as an input.

	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	Features
PORTC	RC7	RC6	RC5	RC4	RC3	RC2	RC1	RC0	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	Features
TRISC	TRISC7	TRISC6	TRISC5	TRISC4	TRISC3	TRISC2	TRISC1	TRISC0	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

Legend

R/W	Readable/Writable bit
(x)	After reset, bit is unknown
(1)	After reset, bit is set

PORTD and TRISD register

PORTD is an 8-bit wide, bidirectional port. Bits of the TRISD register determine the function of its pins. A logic one (1) in the TRISD register configures the appropriate PORTD pin as an input.

	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	R/W (x)	Features
PORTD	RD7	RD6	RD5	RD4	RD3	RD2	RD1	RD0	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	Features
TRISD	TRISD7	TRISD6	TRISD5	TRISD4	TRISD3	TRISD2	TRISD1	TRISD0	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

Legend

R/W	Readable/Writable bit
(x)	After reset, bit is unknown
(1)	After reset, bit is set

PORTE and TRISE register

Port E is a 4-bit wide, bidirectional port. The TRISE register's bits determine the function of its pins. Similar to other ports, a logic one (1) in the TRISE register configures the appropriate PORTE pin as an input.

The exception is the RE3 pin which is always configured as an input.

					R/W (x)	R/W (x)	R/W (x)	R/W (x)	Features
PORTE	-	-	-	-	RE3	RE2	RE1	RE0	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

					R (1)	R/W (1)	R/W (1)	R/W (1)	Features
TRISE	-	-	-	-	TRISE3	TRISE2	TRISE1	TRISE0	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

Legend

-	Bit is unimplemented
R/W	Readable/Writable bit
R	Readable bit
(x)	After reset, bit is unknown
(1)	After reset, bit is set

Similar to ports A and B, three pins can be configured as analog inputs in this case. The ANSELH register bits determine whether a pin will act as an analog input (AN) or digital input/output:

RE0 = AN5 (determined by the ANS5 bit of the ANSELregister);

RE1 = AN6 (determined by the ANS6 bit of the ANSELregister); and

RE2 = AN7 (determined by the ANS7 bit of the ANSELregister).

ANSEL and ANSELH register

The ANSEL and ANSELH registers are used to configure the input mode of an I/O pin to analog or digital.

	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	Features
ANSEL	ANS7	ANS6	ANS5	ANS4	ANS3	ANS2	ANS1	ANS0	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

			R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	R/W (1)	Features
ANSELH	-	-	ANS13	ANS12	ANS11	ANS10	ANS9	ANS8	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

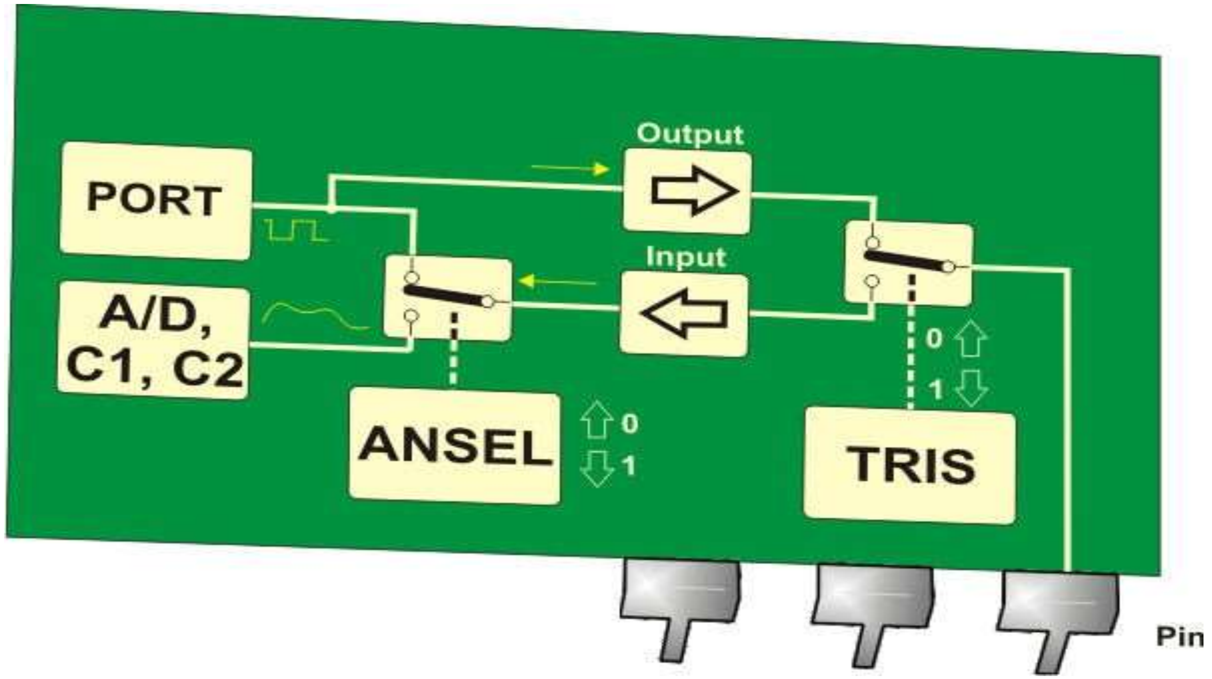
Legend

-	Bit is unimplemented
R/W	Readable/Writable bit
(1)	After reset, bit is set

The rule is:

To configure a pin as an analog input, the appropriate bit of the ANSEL or ANSELH registers must be set (1). To configure a pin as a digital input/output, the appropriate bit must be cleared (0).

The state of the ANSEL bits has no influence on digital output functions. The result of any attempt to read a port pin configured as an analog input will be 0.



In Short

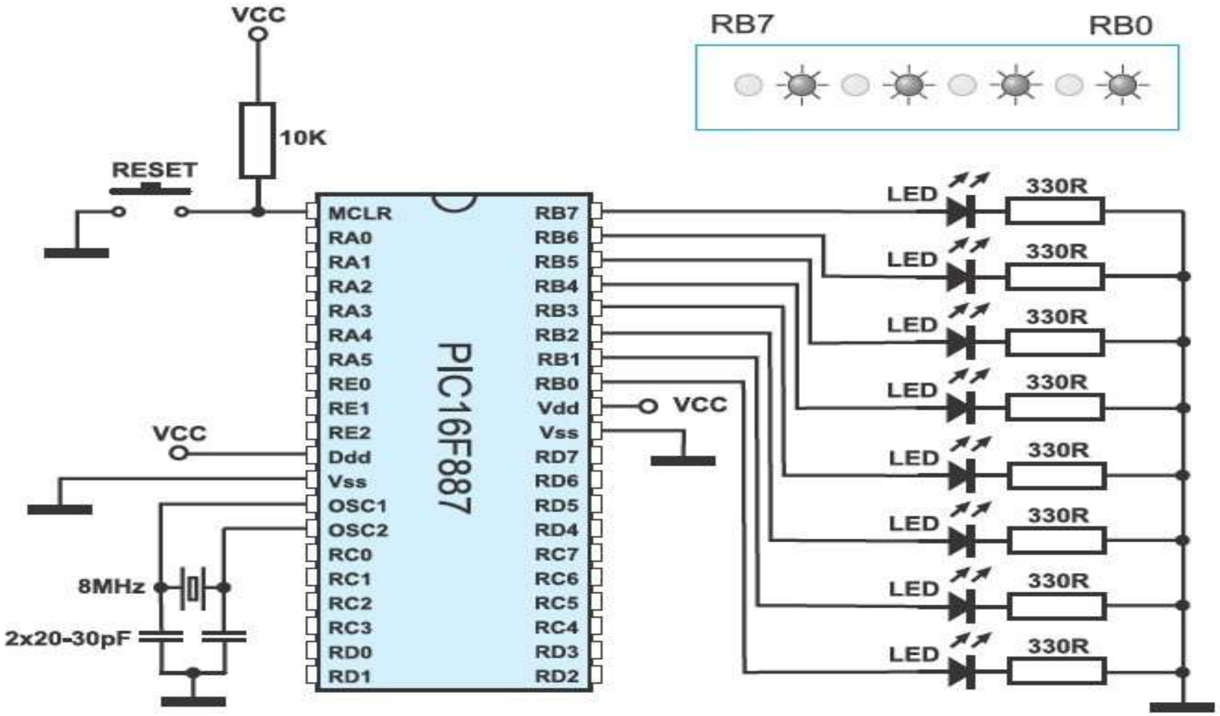
•When designing a device, select a port through which the microcontroller will communicate to peripheral environment. If you use only digital inputs/outputs, select any port you want. If you intend to use some of the analog inputs, select the appropriate ports supporting such a pin configuration (AN0-AN13).

- Each port pin may be configured as either input or output. Bits of the TRISA, TRISB, TRISC, TRISD and TRISE registers determine how the appropriate port pins- PORTA, PORTB, PORTC, PORTD and PORTE will act. Simply...
- If you use some of the analog inputs, it is first necessary to set the appropriate bits of the ANSEL and ANSELH registers at the beginning of the program.
- If you use switches and push buttons as input signal source, connect them to PORTB pins because they have pull-up resistors. The use of these resistors is enabled by the RBPU bit of the OPTION_REG register, whereas the installation of individual resistors is enabled by bits of the WPUB register.
- It is usually necessary to respond as soon as input pins change their logic state.
- However, it is not necessary to write a program for checking pins' logic state. It is far simpler to connect such inputs to the PORTB pins and enable an interrupt to occur on every voltage change. Bits of the IOCB and INTCON registers are in charge of that.

11) APPLICATION EXAMPLES

EXAMPLE 1

Writing header, configuring I/O pins, using delay function and switch operator. The only purpose of this program is to turn on a few LED diodes on port B. Anyway, use this example to study what a real program looks like. Figure below shows connection schematic, while the program is on the next page



When switching on, every other LED diode on the PORTB emits light, which indicates that the microcontroller is properly connected and operates normally.

This example describes a correctly written header. It's the same for all the programs described in this book. To skip repetitiveness, it will not be written in the following examples, but is considered to be at the beg

Example 1

Header

```
/*
 * Program name:
     Example 1
 * Copyright:
     (c) MikroElektronika, 2005-2009
 * Description:
       This is a simple program used to demonstrate the operation of the micro-
       controller. Every second LED on port B is turned on.
 * Configuration:
     Microcontroller: PIC16F887
     Device:          EasyPIC5
     Oscillator:      HS, 08.0000 MHz
     SW:              mikroC PRO v8.0
 * Notes: -
*/
```

Header is placed at the beginning of the program and gives basic information in the form of comments (name of the program, release date etc.). Don't be deluded into thinking that after a few months you will know what that program is about and why you saved it.

Program execution

```
void main() {
  ANSEL  = 0;                    // All I/O are configured as digital
  ANSELH = 0;
  PORTB = 0b01010101;            // Binary combination on port B
  TRISB = 0;                     // Port B pins are configured as outputs
}
```

To make this example more interesting, we will enable LEDs connected to the PORTB to blink. There are several ways to do it:

1. As soon as the microcontroller is turned on, all LEDs will emit light for a second. The Delay function is in charge of it in the program. It's only needed to set delay expressed in milliseconds.

2. After one second, the program enters the for loop and remains there as long as the variable k is less than 20. The variable is incremented by 1 after each iteration. Within the for loop, the switch operation monitors PORTB logic state. If PORTB=0xFF, its state is inverted into 0x00 and vice versa. Any change of these logic states causes all LEDs to blink. Duty Cycle is 5:1 (500mS:100mS).

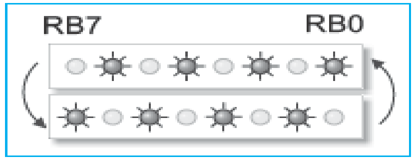
3. When the program exits the for loop, the PORTB logic state changes (0xb 01010101) and the program enters the endless while loop and remains there as long as 1=1. The PORTB logic state is inverted each 200mS.

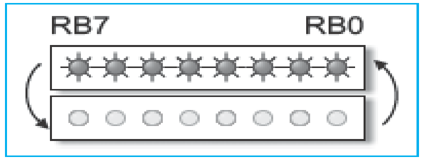
```
/*  Header ***************************************************/

int k;
void main() {
  ANSEL  = 0;            // All I/O pins are configured as digital
  ANSELH = 0;
  PORTB = 0xFF;          // Reset port B
  TRISB = 0;             // Port B pins are configured as outputs

  Delay_ms(1000);        // 1s delay

  PORTB = 0;

for(k=1; k<20; k++)      // Remain in the loop as long as 1<k<20, k is incremented
{                        // by 1 after each iteration

    switch (PORTB) {             // Switch operator monitors port B state

    case 0x00: PORTB = 0xFF;     // If PORTB=0, change its state into 0xFF
    Delay_ms(100);               // and provide 100mS delay
    break;

    case 0xFF: PORTB = 0x00;     // If PORTB=0xFF, change its state into 0
    Delay_ms(500);    }          // and provide 500mS delay

}                                // End of for loop

  PORTB = 0b01010101;            // Binary combination on port B

  while(1) {                     // endless loop
    PORTB =  ~PORTB;             // Invert port B logic state
    Delay_ms(200);               // 200mS delay
  }
}
```

for loop

switch Operator

while loop





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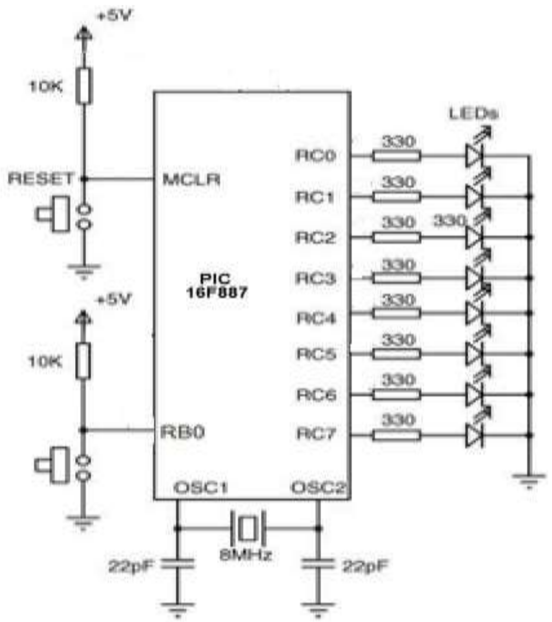
EXAMPLE 2

8 LEDs are connected to PORT C of a PIC microcontroller. In addition, a push- button switch is connected to port pin RB0. Write a program to turn ON the odd numbered LEDs (at bit positions 1, 3, 5 and 7) when the button is pressed and the even numbered LEDs (at bit positions 0, 2, 4 and 6) if the button is not pressed.



```
#define START PORTB.RB0
void main) (
  {
    ANSEL = ANSELH = 0;          // Configure all ports as
    digital TRISB = 0x01;        // RB0 input
    TRISC = 0x00;                // PORTC output
    for ( ; ; )                  // DO FOREVER
     {
       if (START == 0)
        {
          PORTC = 0XAA;
          Delay_Ms(500);         // Delay 500ms
        }
       if (START == 1)
        {
          PORTC = 0X55;
          Delay_Ms(500);
        }
     }
  }
```

12) IMPORTANT DISPLAYS INTERFACING FOR PIC MCU

1) Interfacing 7-Segment Display With Pic MCU.

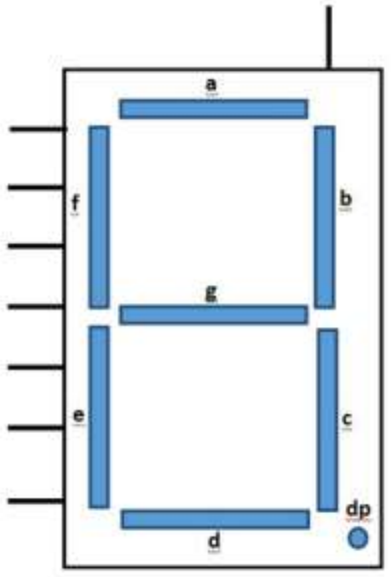
2) Interfacing Character LCD with PIC MCU.

3) Interfacing Graphics LCD (GLCD) With PIC MC

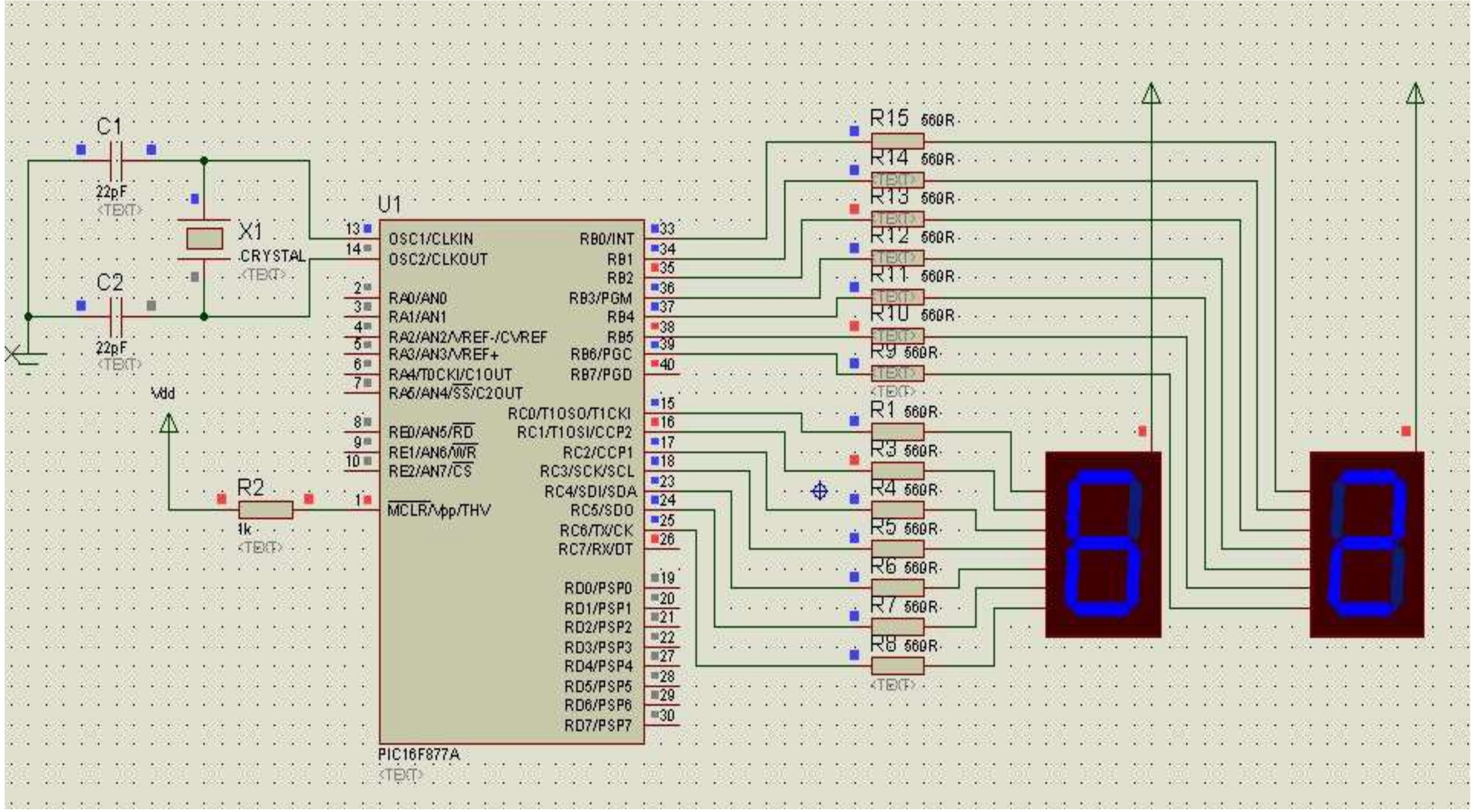
1) Interfacing 7-Segment Display With Pic MCU

A seven segment display is the most basic electronic display device that can display digits from 0-9. The most common configuration has an array of eight LEDs arranged in a special pattern to display these digits. These device are commonly used in digital clocks, electronics meters, counters and signaling.

A common pin is also associated with the 7-segment, which is used to identify the type of 7-segment display; whether it is common anode or common cathode. In common anode display, the positive pins of all the LEDs are tied together to form the common pin which needs to be provided a ‘HIGH’ signal. In common cathode display, all the cathode connections of the LEDs are tied together which forms the common pin that needs to be grounded.



Number	gfedcba	Hexadecimal
0	0111111	3F
1	0000110	06
2	1011011	5B
3	1001111	4F
4	1100110	66
5	1101101	6D
6	1111101	7D
7	0000111	07
8	1111111	7F
9	1101111	6F



C1
22pF
C2
22pF
X1
CRYSTAL
U1
PIC16F877A
Vdd
R2
1k
OSC1/CLKIN
OSC2/CLKOUT
RA0/AN0
RA1/AN1
RA2/AN2/VREF-/CVREF
RA3/AN3/VREF+
RA4/T0CKI/C1OUT
RA5/AN4/SS/C2OUT
RE0/AN5/RD
RE1/AN6/WR
RE2/AN7/CS
MCLR/Vpp/THV
RB0/INT
RB1
RB2
RB3/PGM
RB4
RB5
RB6/PGC
RB7/PGD
RC0/T1OSO/T1CKI
RC1/T1OSI/CCP2
RC2/CCP1
RC3/SCK/SCL
RC4/SDI/SDA
RC5/SDO
RC6/TX/CK
RC7/RX/DT
RD0/PSP0
RD1/PSP1
RD2/PSP2
RD3/PSP3
RD4/PSP4
RD5/PSP5
RD6/PSP6
RD7/PSP7
R15 560R
R14 560R
R13 560R
R12 560R
R11 560R
R10 560R
R9 560R
R1 560R
R3 560R
R4 560R
R5 560R
R6 560R
R7 560R
R8 560R

2) INTERFACING CHARACTER LCD WITH PIC MCU

The Liquid Crystal Display (LCD) is one of the most commonly used displays today. There are basically three types of LCDs as far as the type of data that can be displayed is concerned: Segment LCD, Dot Matrix LCD and Graphic LCD.

Dot Matrix LCD is also known as the character LCD. The most commonly used dot matrix LCD displays are 2 lines of 16 characters. Each character is represented by 5x7 dots (or 5x8 characters including the cursor). Dot matrix LCDs can display alphanumeric data, including a subset of symbols. It can display all the letters of alphabet, Greek letters, punctuation marks, mathematical symbols…etc. It is also possible to display symbols made up by the user. Other useful features include automatic message shift (left and right), cursor appearance, LED backlight etc..

Liquid crystals do not emit light by themselves, like LEDs. Therefore you need light to see them; usually the surrounding light is enough to read the display, yet in case of dark environments it is hard to read the display. Most LCDs therefore contain an optional backlight, to produce sufficient contrast, which makes reading easy in dark environment.

A) LCD HARDWARE

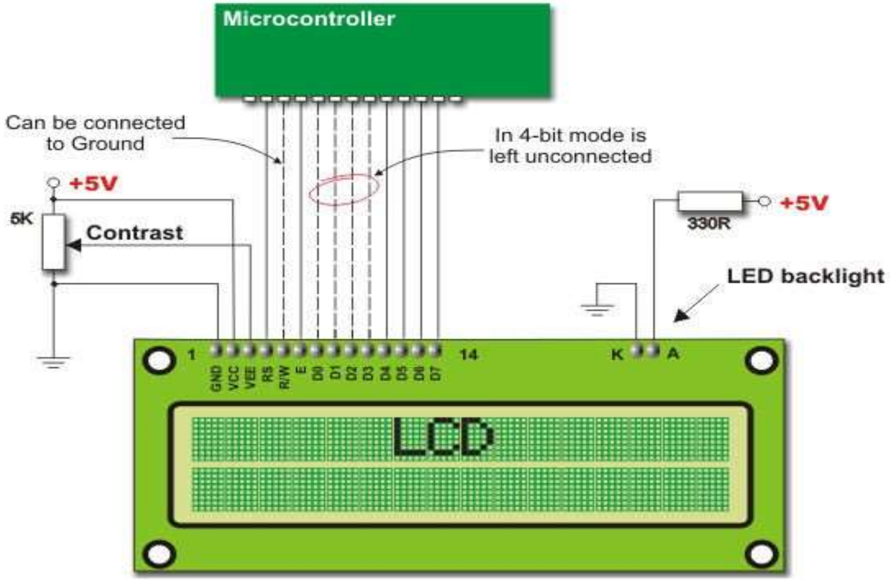
The character LCDs, contain onboard controller, with a connector to communicate with the parent microcontroller. There are usually 14 pins for communication and two pins for a backlight LED, if that is there. Thus a total of 16 pin connector is usually required. It is important to identify various pins of the connector so that they can be sent appropriate date. All 44780 compliant controllers have following pin definitions.

16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
(+)	(-)	D7	D6	D5	D4	D3	D2	D1	D0	E	RW	RS	VEE	VCC	GND

- **VEE** is the contrasts adjust volts, to adjust the visibility of characters.
- **RS** stands for Register Select pin.
- **RW** is for Read/write operation.
- **E** is enable.
- **D0** to **D7** are eight bits of data communication.
- **(-) and (+)** are the Backlight LED connections.

The pins will be referred in programs and discussion by these names. The hardware design only requires a pot to adjust the contrast. A 50K is enough, connected between VCC and GND. The center tape is connected to VEE Pin. The RW pin selects if we want to read in the contents of LCD display. This is rarely required, so this pin is usually permanently connected to GND, which means a Write mode is selected. D0 to D7 are 8 bits of data.

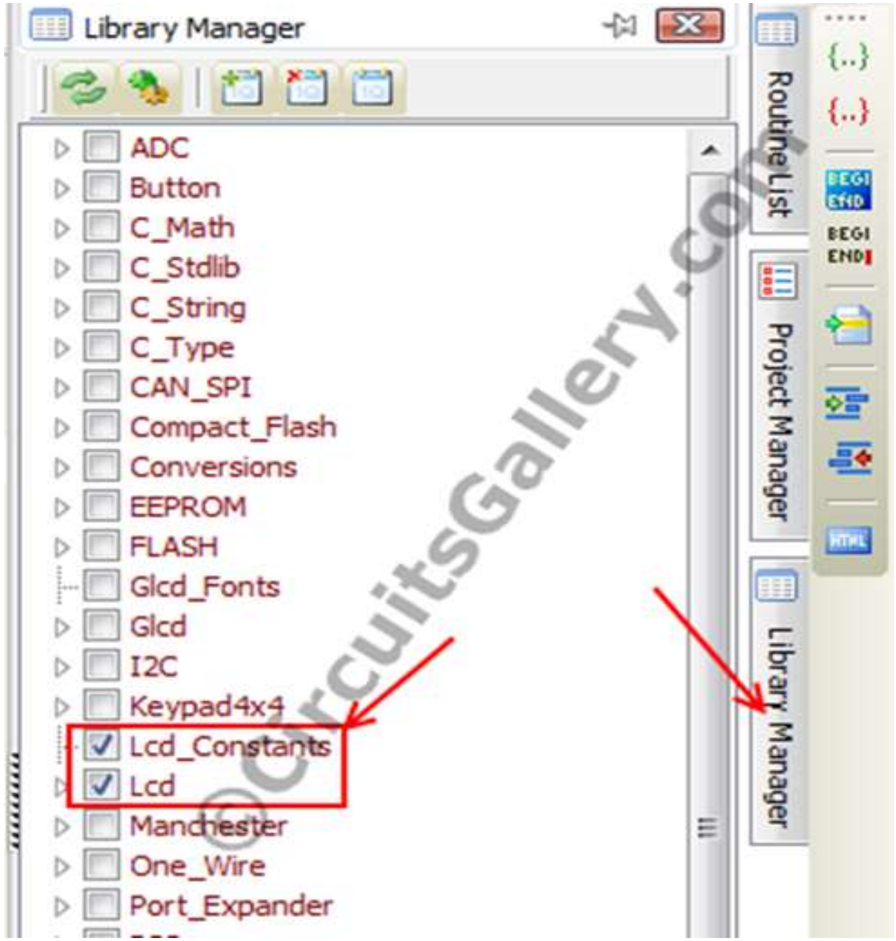
We can operate the display in either 8 bit mode or 4 bit mode. In 8 bit mode all 8 bits are connected to the microcontroller, on a single port. This mode is fast as it sends one byte at a time. However consumes expansive I/O lines. The 4 bit mode connects data pins, D4 to D7 to the microcontroller. The main purpose of the 4-bit LCD mode is to save valuable I/O pins of the microcontroller. The data is sent in two chunks. You can connect the four bits to either the upper or lower 4 bits of the selected port. Other two control pins, RS and E can be connected to free pins of the same port, or some other port. Every compiler has its own default configuration, however you are not bound to follow it, and you can chose any port and pins you want, the compiler can be instructed to use the specified pins.



B)LCD Library

The Mikro C PRO for PIC offers a library for communication with LCDs over the 4-bit interface. For executing LCD commands we should add this LCD Library file to the program code that represent how the pins of LCD are connected to pic microcontroller .

Go to Library Manager → then add Lcd_Constants and Lcd



Below shows the table including all the initialization commands in LCD library of Mikro C.

Mikro C Code	Description
`sbit LCD_RS at RC2_bit;`	Register Select line
`sbit LCD_EN at RC3_bit;`	Enable line
`sbit LCD_D7 at RC7_bit;`	Data 7 line
`sbit LCD_D6 at RC6_bit;`	Data 6 line
`sbit LCD_D5 at RC5_bit;`	Data 5 line
`sbit LCD_D4 at RC4_bit;`	Data 4 line
`sbit LCD_RS_Direction at TRISC2_bit;`	Register Select direction pin
`sbit LCD_EN_Direction at TRISC3_bit;`	Enable direction pin
`sbit LCD_D7_Direction at TRISC7_bit;`	Data 7 direction pin
`sbit LCD_D6_Direction at TRISC6_bit;`	Data 6 direction pin
`sbit LCD_D5_Direction at TRISC5_bit;`	Data 5 direction pin
`sbit LCD_D4_Direction at TRISC4_bit;`	Data 4 direction pin

Important Library Routines for LCD Module

C) LCD Setup

Lcd_Init();

Initializes LCD module to work with PIC Microcontroller.

Lcd_Out(char row, char column, char“Text”);

Writes text on LCD beginning from definite position. Both string variables and literals can be passed as a text. **row**: starting position row number. **column**: starting position column number text: text to be written.

Lcd_Out_Cp(char *text);

This function prints the text (string) in the current cursor position. When we write data to LCD Screen, it automatically increments the cursor position.

Lcd_Cmd(_LCD_CLEAR); LCD clear display.

Lcd_Cmd(_LCD_CURSOR_OFF); LCD Cursor off .

D) Algorithm for LCD to PIC program Steps

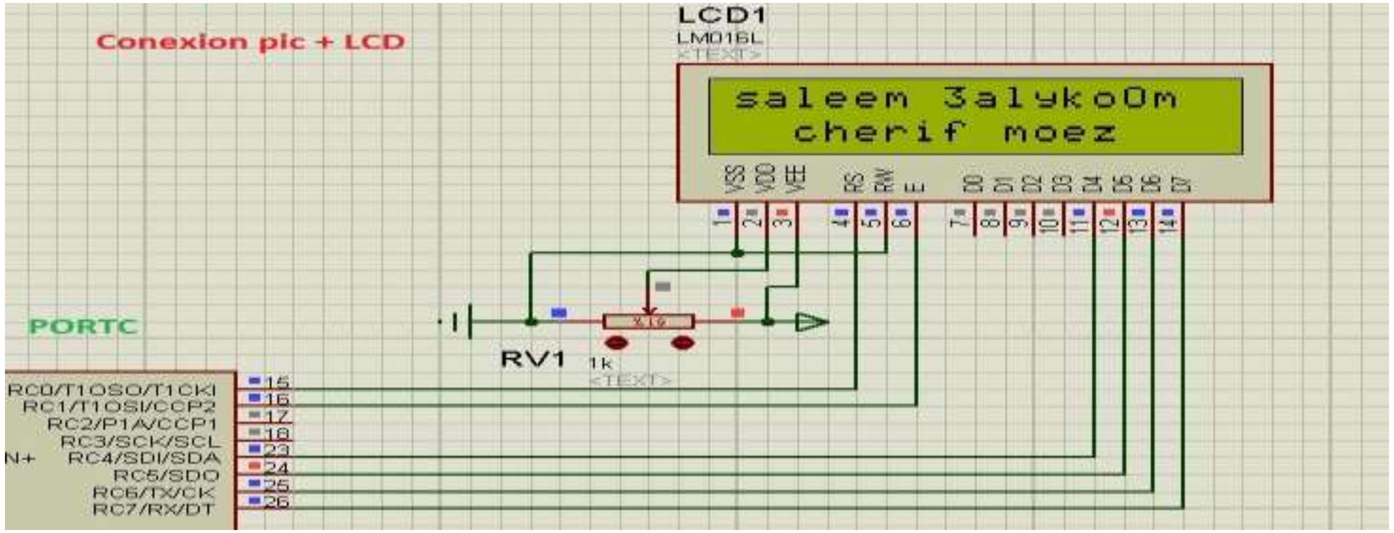
1. Configure LCD module pin connections.
2. Set PORTC as Output port.

3.Setup LCD display.
4. Send data to LCD display.

Example: write mikroC code for monitoring world(saleem 3alyko0m) at the first row and (cherif moez) at the second row for the LCD 16x2 for 4-bit interface mode.

Solution :

Step 1: connect the LCD with the pic microcontroller with port c.



Step 2: Write the program code that represent how the pins of LCD are connected to pic microcontroller . As shown below

```
// LCD module connections
sbit LCD_RS at RC0_bit;
sbit LCD_EN at RC1_bit;
sbit LCD_D4 at RC4_bit;
sbit LCD_D5 at RC5_bit;
sbit LCD_D6 at RC6_bit;
sbit LCD_D7 at RC7_bit;

sbit LCD_RS_Direction at TRISC0_bit;
sbit LCD_EN_Direction at TRISC1_bit;
sbit LCD_D4_Direction at TRISC4_bit;
sbit LCD_D5_Direction at TRISC5_bit;
sbit LCD_D6_Direction at TRISC6_bit;
sbit LCD_D7_Direction at TRISC7_bit;
// End LCD module connections
```

Step 3: write the statements for setup the LCD as shown below

lcd_init(); // Initialize LCD i.e defined pins connection of the LCD to the pic micro.
lcd_cmd(_lcd_clear); // Clear display
lcd_cmd(_LCD_CURSOR_OFF); // Cursor off

Step 4: Write the mikroc code that send the required text at the LCD

monitor.

```
while (1)
{
lcd_out(1,1,"saleem 3alykoOm");          // Write text in first row
lcd_out(2,3,"cherif moez");              // Write text in second row there'd
column

**
```

Complete previous connection program

```
/* essai simple avec pic 16f887 avec afficheur LCD
realise par cherif moez
CLOK = 8MHz
*/
// LCD module connections
sbit LCD_RS at RC0_bit;
sbit LCD_EN at RC1_bit;
sbit LCD_D4 at RC4_bit;
sbit LCD_D5 at RC5_bit;
sbit LCD_D6 at RC6_bit;
sbit LCD_D7 at RC7_bit;

sbit LCD_RS_Direction at TRISC0_bit;
sbit LCD_EN_Direction at TRISC1_bit;
sbit LCD_D4_Direction at TRISC4_bit;
sbit LCD_D5_Direction at TRISC5_bit;
sbit LCD_D6_Direction at TRISC6_bit;
sbit LCD_D7_Direction at TRISC7_bit;
// End LCD module connections
void main()
 {
   trisc = 0;                    // configure PORTC as output
   Portc=0;
   lcd_init();
   lcd_cmd(_lcd_clear);
   lcd_cmd(_LCD_CURSOR_OFF);
     while (1)
       {
         lcd_out(1,1,"saleem 3alykoOm");
         lcd_out(2,3,"cherif moez");
       }
}
```

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EXAMPLE Using LCD display

This example illustrates the use of an alphanumeric LCD display for 4-bit mode . The function libraries simplify this program, which means that the effort made to create software pays off in the end. A message written in two lines appears on the display:

Lcd4bit
example

Two seconds later, the message is changed to:

mikroElektronika

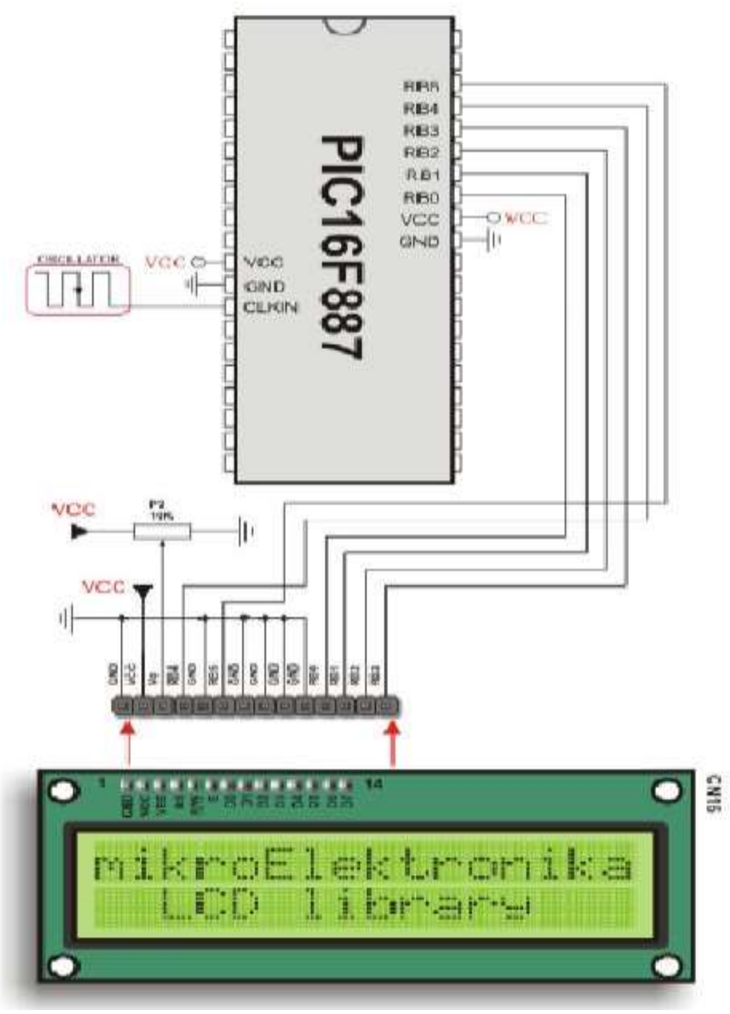
EasyPIC6

Two seconds later, the last message is Moved to the left 7 times then it is Moved to the right 7 times:

```
// LCD module
connections sbit
LCD_RS at RB4_bit;
sbit LCD_EN at
RB5_bit; sbit
LCD_D4 at RB0_bit;
sbit LCD_D5 at
RB1_bit; sbit
LCD_D6 at RB2_bit;
sbit LCD_D7 at
RB3_bit;

sbit   LCD_RS_Direction    at
TRISB4_bit;               sbit
LCD_EN_Direction            at
TRISB5_bit;               sbit
LCD_D4_Direction            at
TRISB0_bit;               sbit
LCD_D5_Direction            at
TRISB1_bit;               sbit
LCD_D6_Direction            at
TRISB2_bit;               sbit
LCD_D7_Direction            at
TRISB3_bit;
// End LCD module connections

char txt1[] =
"mikroElektronika"; char
txt2[] = "EasyPIC6";
char txt3[] =
"Lcd4bit"; char
txt4[] =
"example";

char i;                              // Loop variable

void Move_Delay() {                  // Function used for text moving
  Delay_ms(500);                     // You can change the moving speed here
}
```

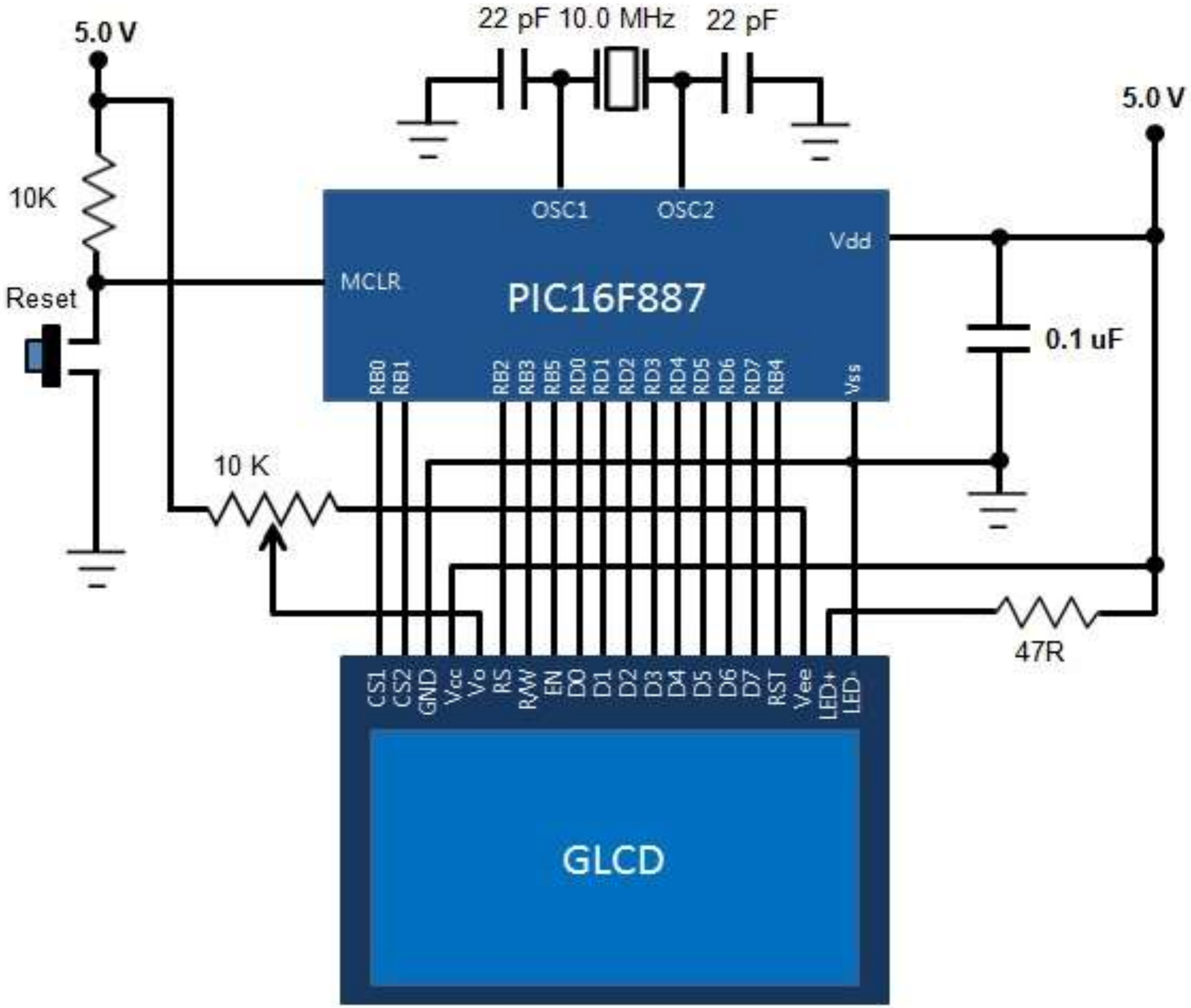
```
void main(){
  ANSEL  = 0;                    // Configure AN pins as digital I/O
  ANSELH = 0;
  C1ON_bit = 0;                  // Disable comparators
  C2ON_bit = 0;
  Lcd_Init();                        // Initialize LCD

  Lcd_Cmd(_LCD_CLEAR);               // Clear display
  Lcd_Cmd(_LCD_CURSOR_OFF);          // Cursor off
  Lcd_Out(1,6,txt3);                 // Write text in first row

  Lcd_Out(2,6,txt4);                 // Write text in second row
  Delay_ms(2000);
  Lcd_Cmd(_LCD_CLEAR);               // Clear display

  Lcd_Out(1,1,txt1);                 // Write text in first row
  Lcd_Out(2,5,txt2);                 // Write text in second row

  Delay_ms(2000);

  // Moving text
  for(i=0; i<4; i++) {               // Move text to the right 4 times
    Lcd_Cmd(_LCD_SHIFT_
    RIGHT);
    Move_Delay();
  }
```

```
  while(1) {                      // Endless loop
    for(i=0; i<8; i++) {          // Move text to the left 7 times
      Lcd_Cmd(_LCD_SHIFT
      _LEFT);
      Move_Delay();
    }

    for(i=0; i<8; i++) {
      Lcd_Cmd(_LCD_SHIFT_
      RIGHT);
      Move_Delay();
    }
  }
}
```



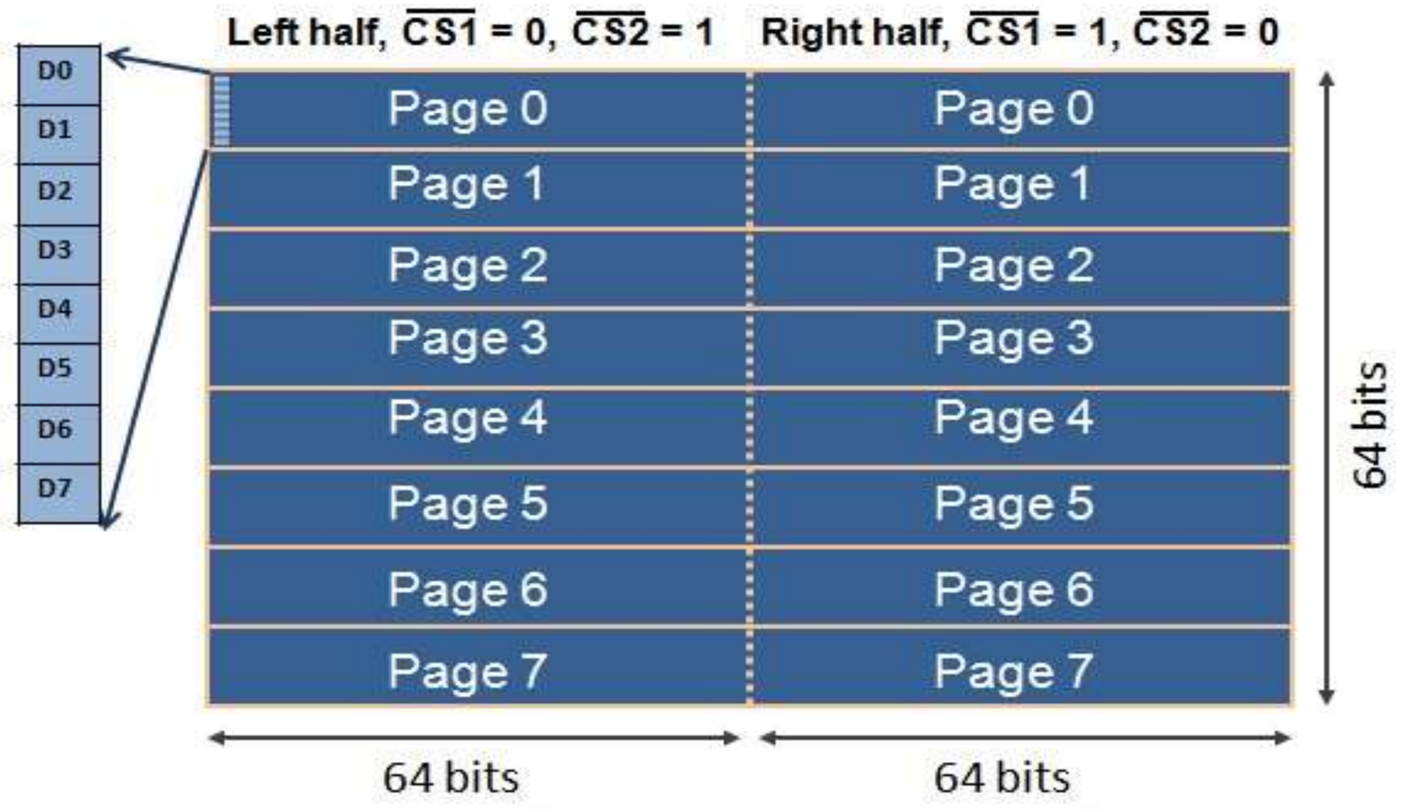
3) Interfacing Graphics LCD (GLCD) With PIC

The use of a graphical LCD (GLCD) drastically changes the look of your design. It provides more freedom for presenting data than the based character LCDs. Because the GLCDs required large number of I/O and memory there for its required a bigger size PIC microcontroller like PIC16F887 which has 36 I/O pins and 14KB flash memory. Also like characters LCD the mikroC Pro for PIC compiler has built-in GLCD Library to display more complex texts and objects. There are different types of GLCD this means the pin diagrams of GLCDs is not standardized and it is therefore, important to read the manufacturer's datasheet for correct wiring of a GLCD module.



5.0 V
22 pF 10.0 MHz
22 pF
5.0 V
10K
OSC1
OSC2
Vdd
MCLR
PIC16F887
Reset
0.1 uF
RB0
RB1
RB2
RB3
RB5
RD0
RD1
RD2
RD3
RD4
RD5
RD6
RD7
RB4
Vss
10 K
47R
CS1
CS2
GND
Vcc
Vo
RS
R/W
EN
D0
D1
D2
D3
D4
D5
D6
D7
RST
Vee
LED+
LED-
GLCD

The GLCD consist of tow halves. The two halves of the display can be individually accessed through the chip select pins (CS1 and CS2). Each half consists of 8 horizontal pages (0-7) which are 8 bits (1 byte) high. This is illustrated in the drawing below.



Starting from page 0 on the left half (/CS1 = 0) if you transmit one data byte, it will appear on the first column of page 0. If you repeat this 64 times, then switch to the second half, and repeat until 128th position is reached, the first 8 display lines will be plotted. The next 8 lines can be plotted similarly by switching to page address 1. The total amount of bytes needed for a complete display frame (128×64 pixels) is, therefore, 2 * 64 pixels * 8 bits = 1024 bytes.

Here’s a brief description of various user-defined function subroutines used in the code.

GLCD_ON() : This function turns the display on. This can be done by sending the command 3Fh to both the controllers. So, while sending this command, both CS1 and CS2 must be pulled low. Similarly the RS pin should be low too as the byte sent is an instruction.

Set_Start_Line() : This function changes the line number to be displayed at the top of the screen. You can set it to be any number between 0 to 63. It does not affect the data in the display RAM, it just scrolls the display up and down.

GOTO_COL() : Moves the cursor to specified column (0-127).

GOTO_ROW() : Moves the cursor to specified row or page number (0-7).

GOTO_XY() : Moves the cursor to specified row and column.

GLCD_Write() : Writes a byte of data to the current location.

GLCD_Read() : Returns a byte read from the current display location. If you see the code for this subroutine, you will see there are two read operations involved. The first one is a dummy read during which the data is fetched from the display RAM is latched in to the output register of KS0108B. In the second read, the microcontroller can get the actual data.

GLCD_Clrln() : Clears a specified row (0-7).

GLCD_CLR() : Clears the whole screen (all 8 pages).

Draw_Point() : Plots a dark or light color point at a specified position.

At the end, the dotted lines are created by plotting too

```
// Glcd module connections
#define GLCD_Data   PORTD
#define GLCD_Dir    TRISD
 sbit GLCD_CS1 at RB0_bit;
sbit GLCD_CS2 at RB1_bit;
sbit GLCD_RS  at RB2_bit;
sbit GLCD_RW  at RB3_bit;
sbit GLCD_RST  at RB4_bit;
sbit GLCD_EN at RB5_bit;
sbit GLCD_CS1_Direction at TRISB0_bit;
sbit GLCD_CS2_Direction at TRISB1_bit;
```

LEC-9

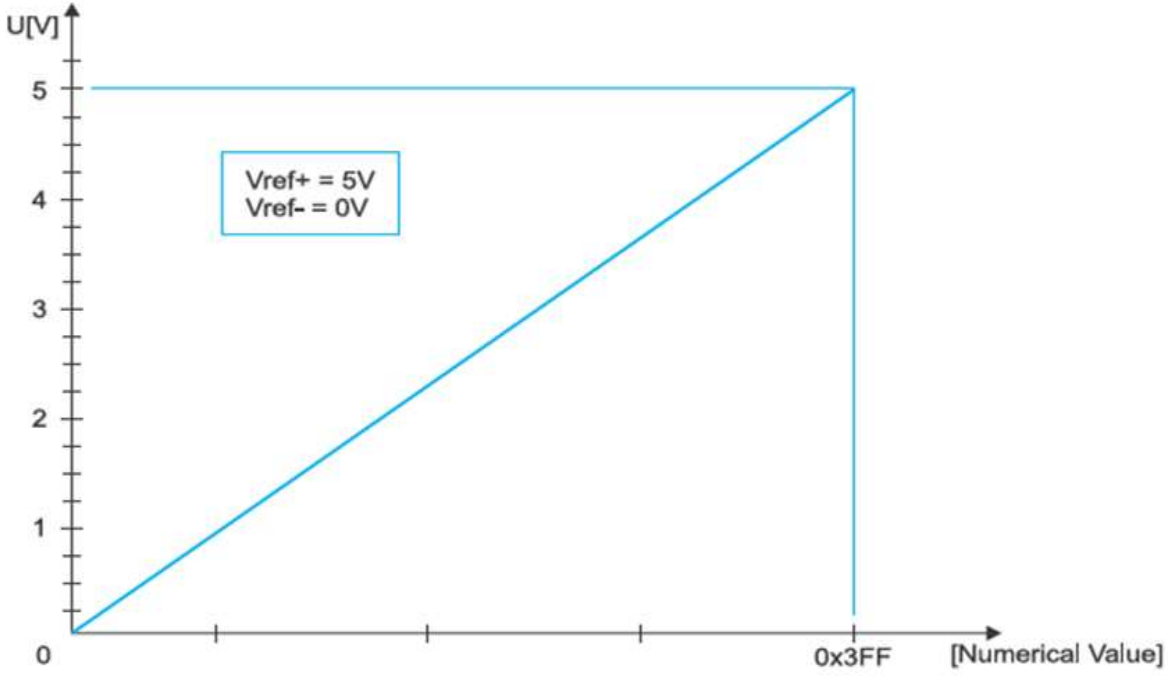
13) A/D CONVERTER & ANALOG MODULES

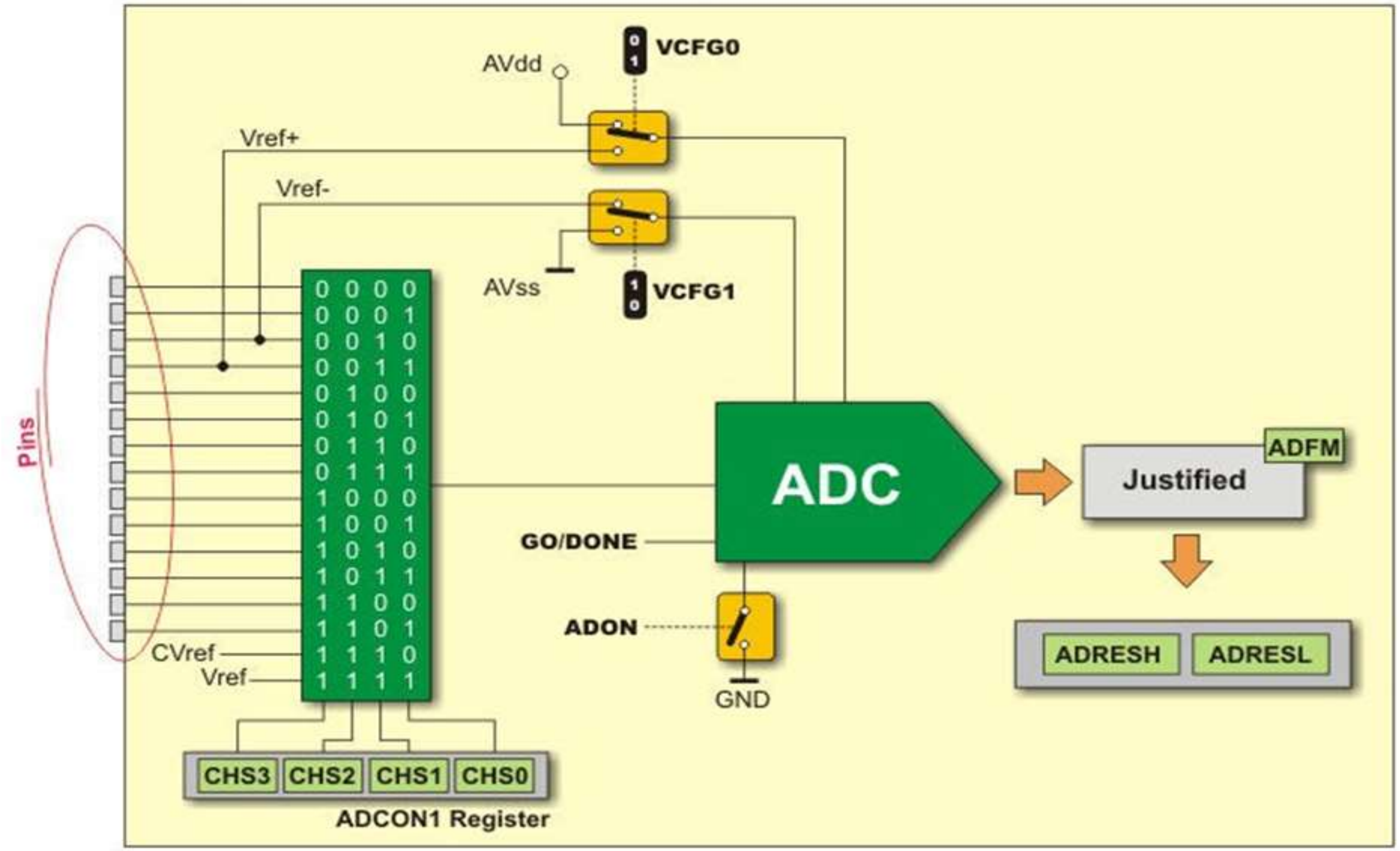
Analogue-to-digital converter (A/D converter) is used to convert an analogue input signal into digital form, so that the signal can be processed within the microcontroller. Most midrange PIC microcontrollers have built-in A/D converter modules. In general purpose and low-speed applications, the A/D converters are 8 to 10 bits, having 256 or 1024 quantisation levels. An A/D converter can either be unipolar or bipolar. Unipolar converters can only handle signals that are always positive. Bipolar converters, on the other hand, can handle both positive and negative signals. The A/D converters implemented in PIC series of microcontrollers are unipolar. The A/D conversion process is started by the user program and the conversion can take tens of processor cycles to complete. The user program has the option of either: polling the conversion status and waiting until the conversion is complete, or alternatively, the A/D converter completion interrupt can be enabled to generate an interrupt as soon as the conversion is complete.

The A/D converter module has the following features:

• The converter generates a 10-bit binary result using the method of successive approximation and stores the conversion results into the ADC registers (ADRESL and ADRESH);

- There are 14 separate analog inputs;
- The A/D converter converts an analog input signal into a 10-bit binary number;
- The minimum resolution or quality of conversion may be adjusted to various needs by selecting voltage references Vref- and Vref+.





VCFG0
AVdd
Vref+
Vref-
AVss
VCFG1
Pins
0 0 0 0
0 0 0 1
0 0 1 0
0 0 1 1
0 1 0 0
0 1 0 1
0 1 1 0
0 1 1 1
1 0 0 0
1 0 0 1
1 0 1 0
1 0 1 1
1 1 0 0
1 1 0 1
1 1 1 0
1 1 1 1
CVref
Vref
ADC
GO/DONE
ADON
GND
Justified
ADFM
ADRESH
ADRESL
CHS3
CHS2
CHS1
CHS0
ADCON1 Register

The operation of A/D converter is in control of the bits of four registers:

- ADRESH Contains high byte of conversion result;
- ADRESL Contains low byte of conversion result;
- ADCON0 Control register 0; and
- ADCON1 Control register 1.

ADRESH and ADRESL Registers

The result obtained after converting an analog value into digital is a10-bit number that is to be stored in the ADRESH and ADRESL registers. There are two ways of handling it - left and right justification which simplifies its use to a great extent. The format of conversion result depends on the ADFM bit of the ADCON1 register. In the event that

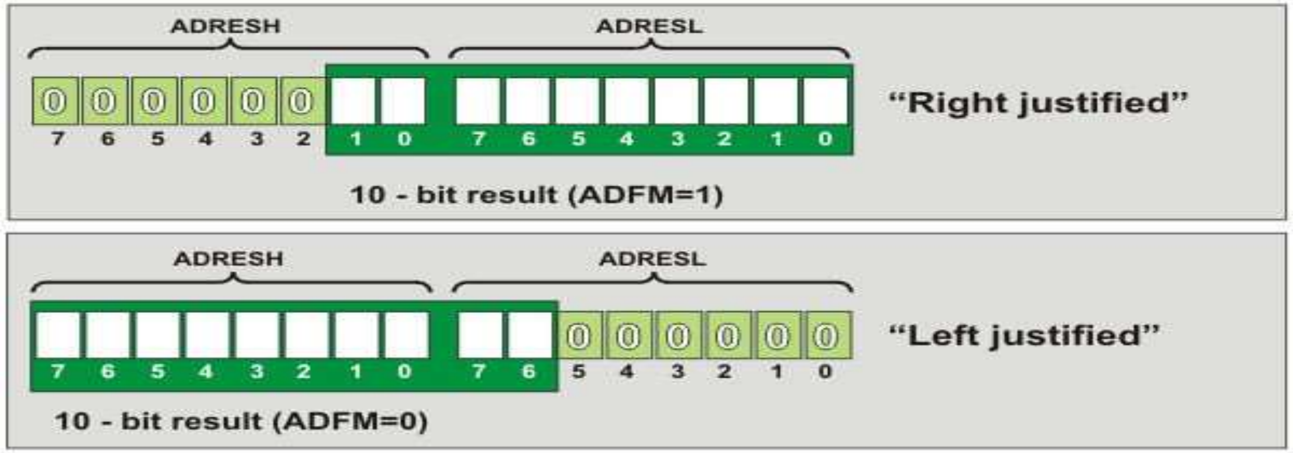
the A/D converter

is not used, these

registers may be

used as general

-purpose registers.



- In order to enable the ADC to meet its specified accuracy, it is necessary to provide a certain time delay between selecting specific analog input and measurement itself. This time is called 'acquisition time' and mainly depends on the source impedance. There is an equation used to calculate this time accurately, which in the worst case amounts to approximately 20µS. So, if you want the conversion to be accurate, don’t forget this important detail.

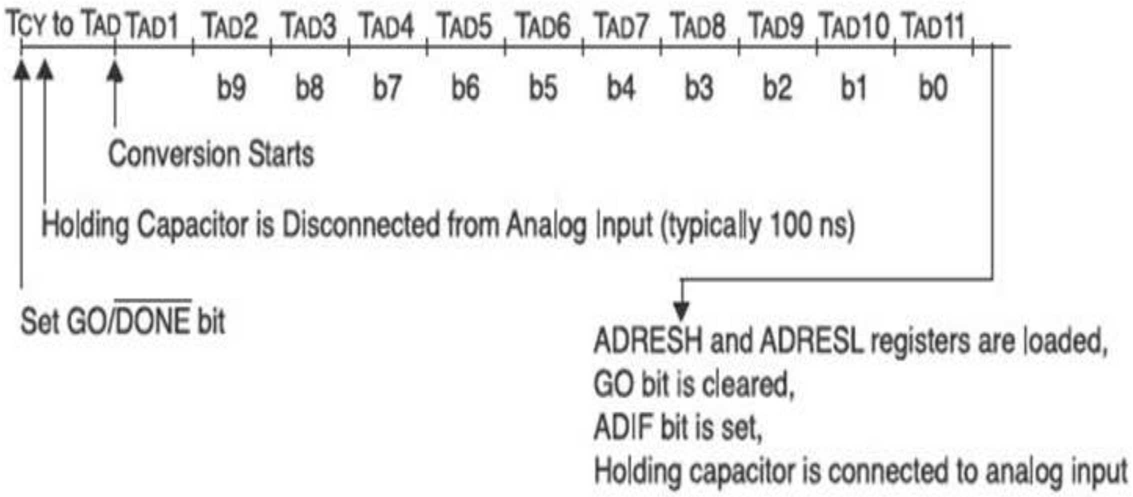
ADC Clock Period

The time needed to complete a one-bit conversion is defined as TAD. It is required to be at least 1.6 µs. One full 10-bit A/D conversion is slightly longer than expected and amounts to 11 TAD periods. Since both clock frequency and source of A/D conversion are specified by software, it is necessary to select one of the available combinations of bits ADCS1 and ADCS0 before the voltage measurement on some of the analog inputs starts. These bits are stored in the ADCON0 register.

ADC Clock Source	ADCS1	ADCS0	Device Frequency (Fosc)			
			20 Mhz	8 Mhz	4 Mhz	1 Mhz
Fosc/2	0	0	100 nS	250 nS	500 nS	2 uS
Fosc/8	0	1	400 nS	1 uS	2 uS	8 uS
Fosc/32	1	0	1.6 uS	4 uS	8 uS	32 uS
Frc	1	1	2 - 6 uS	2 - 6 uS	2 - 6 uS	2 - 6 uS

Any change in the system clock frequency will affect the ADC clock frequency, which may adversely affect the ADC result. Device frequency characteristics are shown in the table above. The values in the shaded cells are outside of the range recommended.

A/D conversion TAD cycles



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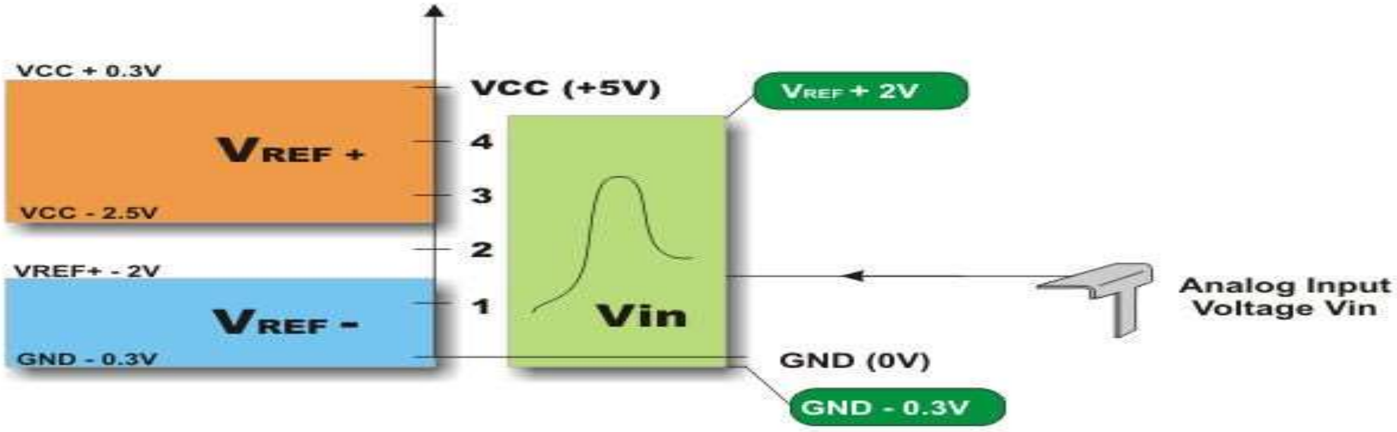
How to use the A/D Converter?

In order to enable the A/D converter to run without problems as well as to avoid unexpected results, it is necessary to consider the following:

- A/D converter does not differ between digital and analog signals. In order to avoid errors in measurement or chip damage, pins should be configured as analog inputs before the process of conversion starts. Bits used for this purpose are stored in the TRIS and ANSEL (ANSELH) registers;
- When reading the port with analog inputs, the state of the corresponding bits will be read as a logic zero (0); and
- Roughly speaking, voltage measurement in the converter is based on comparing input voltage with internal scale which has 1024 marks (2^{10} = 1024). The lowest scale mark stands for the Vref- voltage, whilst its highest mark stands for the Vref+ voltage. Figure below shows selectable voltage references as well as their minimum and maximum values.



ADCON0 Register

	R/W (0)	R/W (0)	R/W (0)	R/W (0)	R/W (0)	R/W (0)	R/W (0)	R/W (0)	Features
ADCON0	ADCS1	ADCS0	CHS3	CHS2	CHS1	CHS0	GO/DONE	ADON	Bit name
	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	

Legend

R/W	Readable/Writable bit
(0)	After reset, bit is cleared

ADCS1, ADCS0 - A/D Conversion Clock Select bits select clock frequency used for internal synchronization of A/D converter. It also affects duration of conversion.

ADCS1	ADCS2	Clock
0	0	Fosc/2
0	1	Fosc/8
1	0	Fosc/32
1	1	RC*

* Clock is generated by internal oscillator which is built in the converter.

CHS3-CHS0 - Analog Channel Select bits select a pin or an analog channel for A/D conversion, i.e. voltage measurement:

- **GO/DONE** - A/D Conversion Status bit determines current status of conversion:
  - 1 - A/D conversion is in progress.
  - 0 - A/D conversion is complete. This bit is automatically cleared by hardware when the A/D conversion is complete.
- **ADON** - A/D On bit enables A/D converter.
  - 1 - A/D converter is enabled.
  - 0 - A/D converter is disabled.

CHS3	CHS2	CHS1	CHS0	Channel	Pin
0	0	0	0	0	RA0/AN0
0	0	0	1	1	RA1/AN1
0	0	1	0	2	RA2/AN2
0	0	1	1	3	RA3/AN3
0	1	0	0	4	RA5/AN4
0	1	0	1	5	RE0/AN5
0	1	1	0	6	RE1/AN6
0	1	1	1	7	RE2/AN7
1	0	0	0	8	RB2/AN8
1	0	0	1	9	RB3/AN9
1	0	1	0	10	RB1/AN10
1	0	1	1	11	RB4/AN11
1	1	0	0	12	RB0/AN12
1	1	0	1	13	RB5/AN13
1	1	1	0	CVref	
1	1	1	1	Vref = 0.6V	

Let's do it in mikroC...

```
/* This example code reads analog value from channel 2 and displays it on
PORTB and PORTC as 10-bit binary number.*/
#include
<built_in.h>
unsigned  int
adc_rd;   void
main()
{
    ANSEL = 0x04;          // Configure AN2 as analog pin
    TRISA = 0xFF;          // PORTA is configured as input
    ANSELH = 0;            // Configure all other AN pins as
    digital I/O TRISC = 0x3F;          // Pins RC7 and RC6 are
    configured as outputs TRISB = 0;          // PORTB is
    configured as an output
    do
        {
         temp_res = ADC_Read(2);        // Get 10-bit result of AD conversion
         PORTB = temp_res;               // Send lower 8 bits to PORTB
         PORTC = temp_res >> 2;          // Send 2 most significant bits to RC7, RC6
         } while(1);                     // Remain in the loop
  }
```

ADCON1 REGISTER

	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	
	R/W (0)		R/W (0)	R/W (0)					Features
ADCON1	ADFM	-	VCFG1	VCFG0	-	-	-	-	Bit name

Legend

-	Bit is unimlemented
R/W	Readable/Writable bit
(0)	After reset, bit is cleared

ADFM - A/D Result Format Select bit

- 1 - Conversion result is right justified. Six most significant bits of the ADRESH are not used.
- 0 - Conversion result is left justified. Six least significant bits of the ADRESL are not used.

VCFG1 - Voltage Reference bit selects negative voltage reference source needed for the operation of A/D converter.

- 1 - Negative voltage reference is applied to the Vref- pin.
- 0 - Power supply voltage Vss is used as negative voltage reference source.

VCFG0 - Voltage Reference bit selects positive voltage reference source needed for the operation of A/D converter.

- 1 - Positive voltage reference is applied to the Vref+ pin.
- 0 - Power supply voltage Vdd is used as positive voltage reference source.

In Short

In order to measure voltage on an input pin by the A/D converter, the following should be done:

Step 1 - Port configuration:

- Write a logic one (1) to a bit of the TRIS register, thus configuring the appropriate pin as an input.
- Write a logic one (1) to a bit of the ANSEL register, thus configuring the appropriate pin as an analog input.

Step 2 - ADC module configuration:

- Configure the voltage reference in the ADCON1 register.
- Select the ADC conversion clock in the ADCON0 register.
- Select one of input channels CH0-CH13 of the ADCON0 register.
- Select data format using the ADFM bit of the ADCON1 register.
- Enable A/D converter by setting the ADON bit of the ADCON0 register.

Step 3 - ADC interrupt configuration (optionally):

- Clear the ADIF bit.
- Set the ADIE, PEIE and GIE bits.

Step 4 - Wait for the required acquisition time to pass (approximately 20µS). **Step 5** - Start conversion by setting the GO/DONE bit of the ADCON0 register. **Step 6** - Wait for ADC conversion to complete.

- It is necessary to check in the program loop whether the GO/DONE pin is cleared or wait for an A/D interrupt (must be previously enabled).

Step 7 - Read ADC results:

- Read the ADRESH and ADRESL registers.

EXAMPLE :

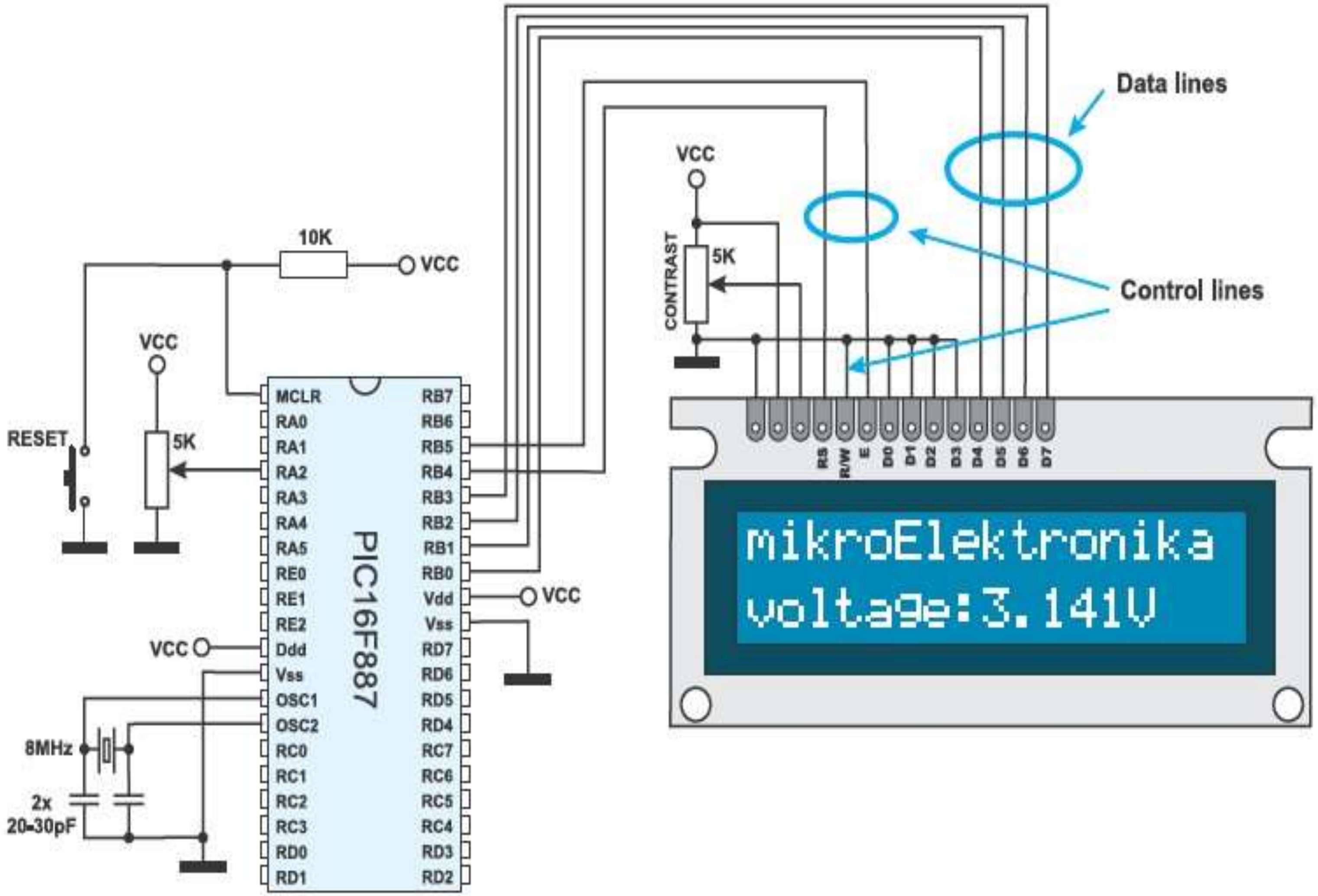
This example illustrates the use of an alphanumeric LCD display. The function libraries simplify this program, which means that the effort made to create software pays off in the end. A message written in two lines appears on the display:

mikroElekt
ronikaLCD
example

Two seconds later, the message in the second line is changed and displays voltage present on the A/D converter input (the RA2 pin). For example:

mikroElekt
ronika
voltage:3.1
41V

In true device, the current temperature or some other measured value can be displayed instead of voltage.



Data lines
Control lines
VCC
10K
VCC
5K
RESET
CONTRAST
MCLR
RA0
RA1
RA2
RA3
RA4
RA5
RE0
RE1
RE2
Ddd
Vss
OSC1
OSC2
RC0
RC1
RC2
RC3
RD0
RD1
RB7
RB6
RB5
RB4
RB3
RB2
RB1
RB0
Vdd
Vss
RD7
RD6
RD5
RD4
RC7
RC6
RC5
RC4
RD3
RD2
PIC16F887
8MHz
2x
20-30pF
RS
R/W
E
D0
D1
D2
D3
D4
D5
D6
D7
mikroElektronika
voltage:3.141V

In order to make this example work properly, it is necessary to tick off the following libraries in the *Library Manager* prior to compiling:

- ADC
- LCD

```
/*Header****************************************
****************/
// LCD module connections
 sbit LCD_RS at RB4_bit;
sbit LCD_EN at RB5_bit;
sbit LCD_D4 at RB0_bit;
sbit LCD_D5 at RB1_bit;
 sbit LCD_D6 at RB2_bit;
 sbit LCD_D7 at RB3_bit;
sbit LCD_RS_Direction at TRISB4_bit;
 sbit LCD_EN_Direction at TRISB5_bit;
 sbit LCD_D4_Direction at TRISB0_bit;
 sbit LCD_D5_Direction at TRISB1_bit;
sbit LCD_D6_Direction at TRISB2_bit;
sbit LCD_D7_Direction at TRISB3_bit;
// End LCD module connections
```

```
unsigned char ch;                              //
unsigned int adc_rd;                           // Declare variables
char *text;                                    //
long tlong;                                    //
void main()
{
    INTCON = 0;                                // All interrupts disabled
    ANSEL = 0x04;                              // Pin RA2 is configured as an analog input
    TRISA = 0x04;
    ANSELH = 0;                                // Rest of pins are configured as digital
    Lcd_Init();                                //      LCD      display
    initialization Lcd_Cmd(_LCD_CURSOR_OFF);   //        LCD
    command (cursor off) Lcd_Cmd(_LCD_CLEAR);  //        LCD
    command (clear LCD)
    text = "mikroElektronika";                 // Define the first message
    Lcd_Out(1,1,text);                         // Write the first message in the first line
    text = "LCD example";                      // Define the second message
    Lcd_Out(2,1,text);                         // Define the first message
    ADCON1 = 0x82;                             // A/D voltage reference is VCC
    TRISA = 0xFF;                              // All port A pins are configured as inputs
    Delay_ms(2000);
    text = "voltage:";                         // Define the third message
    while (1)
```

```
{
  adc_rd = ADC_Read(2);                // A/D conversion. Pin RA2 is an input.
  Lcd_Out(2,1,text);                   // Write result in the
  second line tlong = (long)adc_rd * 5000;//   Convert   the
  result in millivolts tlong = tlong / 1023;       // 0..1023 -
  > 0-5000mV
  ch = tlong / 1000;                   // Extract volts (thousands of millivolts) from result
  Lcd_Chr(2,9,48+ch);                  // Write result in ASCII format
  Lcd_Chr_CP('.');
  ch = (tlong / 100) % 10;             // Extract hundreds of millivolts
  Lcd_Chr_CP(48+ch);                   // Write result in ASCII format
  ch = (tlong / 10) % 10;              // Extract tens of millivolts
  Lcd_Chr_CP(48+ch);                   // Write result in ASCII format
  ch = tlong % 10;                     // Extract digits for millivolts
  Lcd_Chr_CP(48+ch);                   // Write result in ASCII format
  Lcd_Chr
  _CP('V');
  Delay_m
  s(1);
  }
}
```