LECTURE NOTES (E- CONTENTS) for

ELECTRONICS

DSC -1005 D Semester: IV
Paper- IV Advance Communication and Microcontroller 8051

Section II: Microcontroller 8051

Unit- I: Introduction to 8051microcontroller:

Prepared and Circulated
For B.Sc.II Electronics Students

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Chapter 1
Introduction to 8051 Microcontroller

INTRODUCTION TO 8051

A by-product of microprocessor development was microcontroller. The Intel 8051 is Harvard architecture, single chip microcontroller that was developed by Intel in 1980 for use in embedded systems. It is one of the most popular 8-bit widely used microcontroller. There are many reasons for this including the existence of multiple producers and its simple architecture. It can address 64KB of external memory and has a basic instruction time of 1μs. The fixed amount of on-chip ROM, RAM and number of I/O ports in microcontrollers makes them ideal for many applications in which cost and space are critical.

The purpose of this chapter is to introduce the concept of a microcontroller, overview of its family, architecture and internal memory organization.

FEATURES OF 8051:-

1) 8 bit CPU optimized for control applications.
2) 4KB of on-chip program memory (ROM).
3) 128 bytes of on-chip data memory (RAM).
4) 64KB programmable external ROM & 64KB external RAM address ability.
5) 32 bidirectional and individually addressable I/O lines arranged as four 8-bit ports. These are P0, P1,P2 and P3.
6) Two 16 - bit timer/ counter.
7) Full duplex serial data transmitter/ receiver.
8) 4 register banks.
9) 8 bit program status word and stack pointer.
10) Interrupt structure with two priority levels.
11) On-chip oscillator and a clock circuit.
12) Direct bit and byte addressability.
13) Binary or decimal arithmetic.

APPLICATIONS OF MICROCONTROLLER:-

1) Telephone
2) Intercom
3) Garage door opener
4) Answering machine
5) Fax machine
6) Home computers - Hard disk controller
   Floppy drive controller
   Keyboard controller
7) Cable TV tuner (set top box)
8) DVD player
9) Camcorder

10) Remote control
11) Video games consol.
12) Cellular phones (mobiles)
13) Musical instruments
14) Sewing machine
15) Toys
16) Security systems, keyless entry

DIFFERENCE BETWEEN MICROPROCESSOR AND MICROCONTROLLER:

Sr. No.	Microprocessor	Microcontroller
1.	A microprocessor is a chip i.e. depends on other chips for main functions.	A microcontroller is a single chip microcomputer that has everything built in.
2.	A microprocessor contains ALU, general purpose registers stack pointer, program counter, timing and control circuit and a interrupt circuit.	A microcontroller contains the circuitry of Microprocessor and has built in RAM, ROM, I/O devices, timers and counter.
3.	It is suited to processing information in a computer system.	It is suited to control I/O devices requiring a minimum component count.
4.	It has one or two bit manipulation instructions.	It has many bit manipulation instructions.
5.	It has less no. of multifunction pins.	It has more number of multifunction pins.
6.	They have large memory address space and more data.	They have relatively small address space and less data.
7.	Design is very flexible.	Design is less flexible.
8.	Microprocessor based system require more hardware.	Microcontroller based system requires less hardware.
9.	Access time for memory and I/O devices are known.	Less access time for memory and I/O devices.
10.	Total power consumption is large	Total power consumption is less

OVERVIEW OF 8051 FAMILY:-

1) **8051:-** This is original member of 8051family. This had 128 bytes of RAM, 4K bytes of on-chip ROM, two timers, one serial port and four ports of each 8-bit wide.

2) **8052:-**

It supports all the standard features of 8051. It has extra 128 bytes of memory (RAM) and an extra timer. 8052 has 3 timers, 256 bytes of internal RAM and 8K bytes of on-chip ROM.

3) **8031 :-**

It is also called as ROM less 8051. This has 0KB of on chip ROM. Hence in order to use 8031 we require external ROM. The extra ROM requires program that 8031 will fetch and execute. The 8031 looses 2 ports if external memory is added.

4) **8751:-**

It has 4KB of on-chip UVPROM. This chip is to be used for development purpose, then a PROM burner and UVEPROM eraser is required. As it supports on chip ROM, it requires approx 20 min to erase 8751 Microcontroller before it can be reprogrammed.

5) **89C51:-**

To eliminate the need of PROM burner, Dallas semiconductors has introduced 89C51 that can be programmed through serial com port and of IBM PC. It has on chip 4KB of flash memory.

6) **OTP version of 8051:-**

OTP version of 8051 is there, they come with NV-RAM. This kind of version is used when the product is fully developed and ready to launch in the market.

PIN DIAGRAM OF 8051 MICROCONTROLLER:-

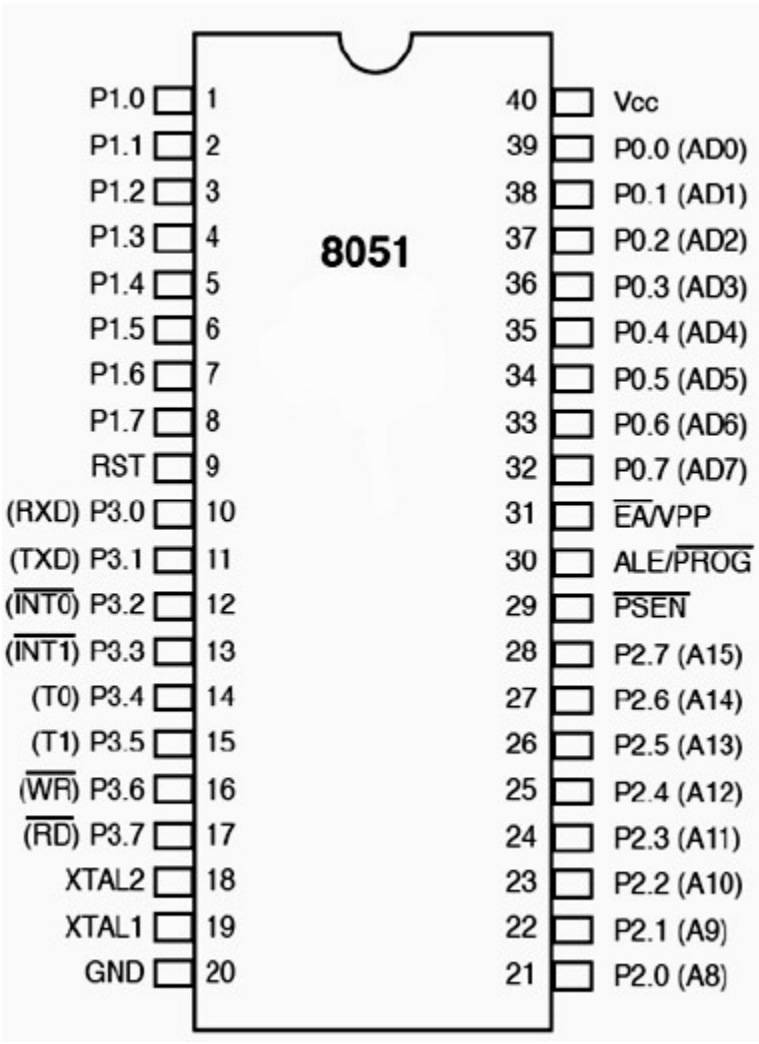


Figure 1.1 Pin Diagram of 8051

1) **V_{CC}: -** Pin no. 40 provides + 5V supply voltage to the chip
2) **GND: -** Pin no. 20 is ground
3) **Port 0:-**

Port 0 is an 8-bit open drain bidirectional I/O port. As an output port each pin can sink 8 TTL inputs. Port 0 may be configured as multiplexed lower order address / data bus during access to external program and data memory. It is also designated as AD0-AD7.

4) **Port 1:-**

Port 1 is 8 bit bidirectional I/O port with internal pull- ups. The port 1 output buffers can sink/ source 8 TTL inputs. When 1's are written to ports 1 pins are pulled high by the internal pull-ups and can used as input port.

5) **Port 2 :-**

Port 2 is 8 bit bidirectional I/O port with internal pull- ups. The port 2 output

buffer can sink/ sources 8 TTL inputs. When 1's are written to port 2 pins they are pulled high by internal pull- ups and can used as inputs. Port 2 works as an address lines (A8-A15) during access to external program or data memory.

6) Port 3 :-

Port 3 is 8 bit bidirectional I/O port with internal pull- ups. The port 3 Output buffer can sink/ source 8 TTL inputs. When 1's are written to port 3 pins they are pulled high by internal pull- ups and can be used as input. Port 3 also has several various other functions.

P3. 0: R x D (serial I/P port)
P3.1: T x D (serial O/P port)
P3.2: INT_0 (external interrupt 0)
P3.3: INT_1 (external interrupt 1)
P3.4: T_0 (Timer / Counter 0 external I/P)
P3.5: T_1 (Timer / Counter 1 external I/P)
P3.6: $\overline{WR}$ (external data memory write strobe)
P3.7: $\overline{RD}$ (external data memory write strobe)

7) RST :-

A high on this reset input pin for 2 machine cycles while the oscillator is running resets the device and terminate all activity.

8) ALE/ PROG:-

ALE (Address latch enable) signal is an output pulse used for latching lower byte of address during communication with external memory.

Second function of this pin is to apply a low program pulse during programming, and then it enters into programming mode.

9) PSEN (Program Store Enable) :-

It is an output signal and must be connected to the OE pin of a ROM containing the program code. When the EA pin is connected to GND, the 8031/51 fetches opcode from external ROM by using PSEN. It is activated twice each machine cycle.

10) EA/Vpp:-

External Access pin (EA) must be connected to the ground innorder to fetch information from external program memory. EA should be connected to Vcc for fetching information from internal program memory.

This pin also receives 12V programming enable voltage during flash programming.

11) XTAL 1, XTAL 2:- Internal oscillator input and output. A quartz crystal which specifies operating frequency is usually connected to these pins. Instead of it, miniature ceramics resonators can also be used for frequency stability.

ARCHITECTURE OF 8051 MICROCONTROLLER:-

The block diagram of the 8051 microcontroller is shown in Figure 4.2 which shows all the features. Explanation of functional block is given below.

1) Accumulation A registers:-

The accumulator is the principal register. It is an 8-bit register. It is most versatile and it holds source operand and receives the result of arithmetic operation including addition, subtraction, integer multiplication, division and Boolean bit manipulation. It is also used for data transfer between 8051 and any external memory. Several function like rotate, swap etc. are applied specifically on accumulator.

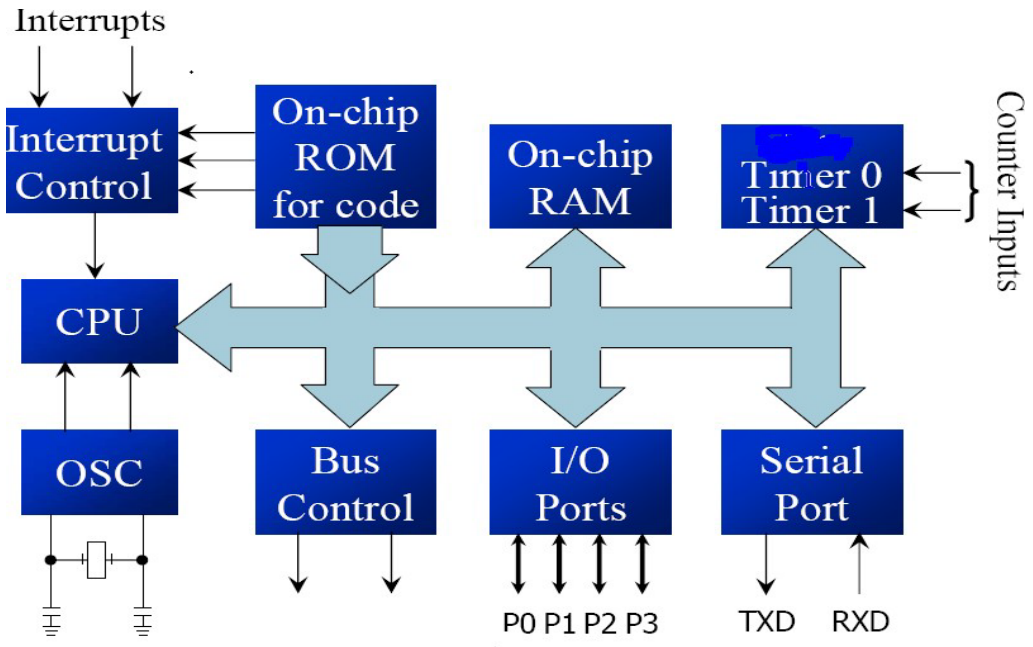


Figure 1.2 Block diagram of 8051

2) B register:-

The B-register is used with the A register for multiplication and division operation and for other instructions it is treated as scratch pad register. In multiplication operation it holds the higher byte of a data and in division operatio n it holds the remainder after division.

3) Arithmetic and logic Unit:-

The ALU can perform arithmetic and logical operations on 8-bit data. It can perform arithmetic operations like additions, subtraction, multiplication, division and logical operations like AND, OR, XOR, Complement, Rotate etc. The ALU also takes care of branching instructions.

4) PSW register:-

Many instructions affect the status flags. Flags are one bit registers provided to store, the status of the result of some instructions. The PSW has 4 flags that includes Carry (CY), Auxiliary (AC), overflow flag (OV) and Parity flag (P). The

PSW has one general purpose flag F0 called as user defined flag and RS0 and RS1 register bank selection bits.

5) Program Counter (PC):-

It is 16-bit register, its function is to hold the address of instruction in the memory and keep the track of the execution of the program.

6) Data Pointer (DPTR):-

The DPTR is 16 bit registers as shown in Figure 4.3. It is used to hold the memory address for external code access and external data accesses. It is used in case of instruction handling look up tables and is under control of program instructions. It can be used as 16-bit data register or 2 independent 8 bit registers as lower 8-bits DPL and higher 8-bits (DPH)

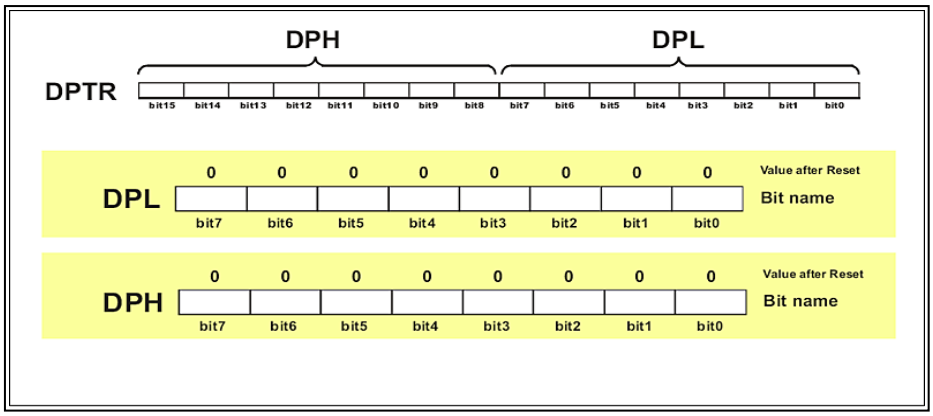


Figure 1.3 DPTR Register of 8051

7) Stack & Stack Pointer:-

The stack is reserved area of memory in a RAM where the temporary information may be stored and 8-bit SP is use to hold the address of the most recent stack entry. This location, which has most recent entry is called as top of the stack. When the information is written on the stack, the operation is called as PUSH. When information is read from stack, the operation is called as POP. The stack works on principal of Last In First Out [LIFO] and First In Last Out [FILO].

Normally the stack is placed at higher location in internal RAM to avoid conflict with the register and bit addressable interval RAM areas. After reset the Stack Pointer is initialized to 07H.

RAM STURECTURE OF 8051

The 8051 has microcontroller 128 bytes internal RAM. This internal RAM is organized in a three distinct area. They are

(1) 4 banks of 8 register each total 32 byte.
(2) Bit addressable area of 16 byte.
(3) General purpose RAM area of 80 byte.

Four register banks

There are 4-register banks which are numbered 0 to 3. Each bank is made up of 8-registers named as R0 to R7. In total 32 bytes or 32 working registers from address 00H to 1FH organized as 4-register banks. For selecting register bank two bits RS0 and RS1 are provided in program status word. If any of the bank is not selected, then the programmer can use the area as general purpose RAM memory. Upon power on or reset by default bank 0 is selected.

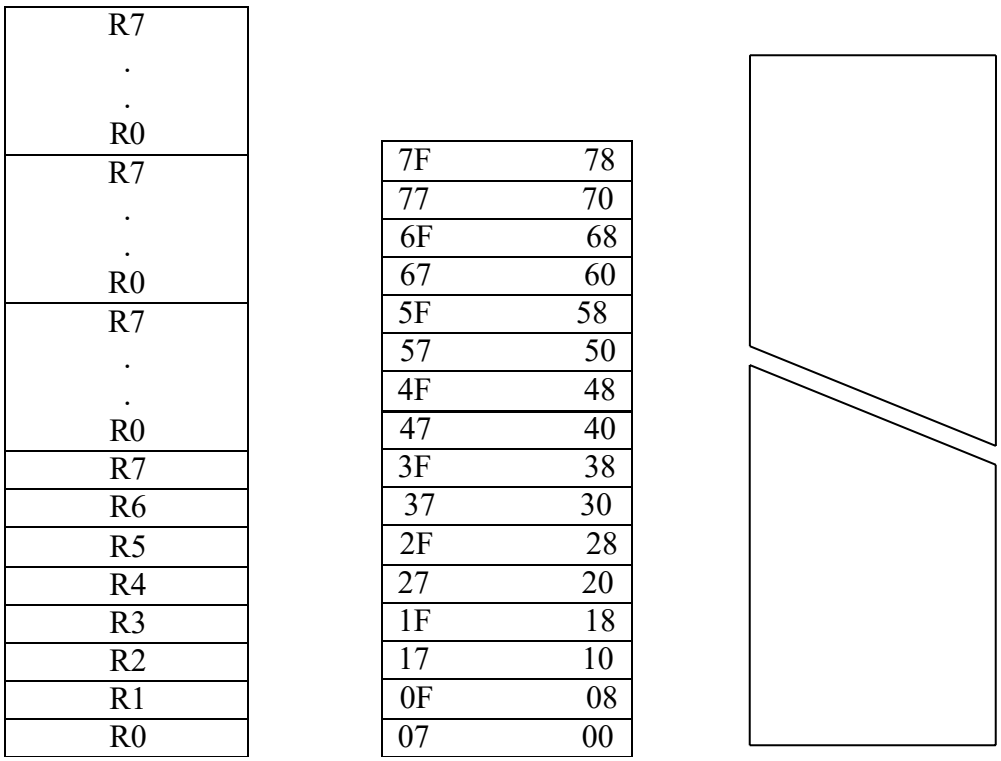


Figure 1.4 RAM Structure of 8051

Bit addressable area of 16-byte

The microcontroller has reserved 16-bytes of bit addressable RAM whose address range is from 20H to 2FH. These 16-bytes provide us 128 addressable bits.

The microcontroller has given addresses to this bits ranging from 00H to 7FH. Hence these locations are called bit addressable locations.

General purpose RAM area

This RAM area is also called as scratch pad area. It lies above the bit addressable area and has address 30H to 7FH. This RAM area can be used as data RAM. The memory in this area is byte addressable. The programmer may declare stack in this area.

ROM MEMORY:-

The ROM is a type of memory that does not lose its contents when the power is turned off. ROM is user programmable memory. The microcontroller 8051 has two physically separate memories; one is data memory and other program memory. These memories have same address ranges. The internal ROM is used to store the program code. It occupies the address space ranging from address 0000H to FFFFH. The program counter (PC) is ordinarily used to address program code bytes from addresses 0000H to FFFFH. Program addresses higher than 0FFFH, which exceeds the internal ROM capacity of 4KB, will cause the 8051 to automatically fetch code bytes from external program memory.

SPECIAL FUNCTION REGISTERS (SFR):-

The 8051 operations are done by a group of specific internal register each called a special function registers, which may be addressed like an internal RAM. The address space is immediately above 128 bytes RAM from address 80H to FFH.

Some SFRs are bit addressable. This feature allows the programmer to change only which bits needs to be altered. The remaining SFRs are byte addressable. SFRs are named in certain opcodes by their functional names, such as A or TCON and are referenced by other opcodes by their addresses, such as E0H or 88H. The SFR memory consist of important registers like accumulator, B register, interrupt control registers, PSW, timer/counter, power control, four I/O parts and serial control. The SFR names and equivalent internal RAM addresses are given in the following table.

Table 1: Special Function Registers

Symbol	Name	Address in HEX
A	Accumulator	E0
B	B register	F0
DPL	Data pointer low byte	83
DPH	Data pointer High byte	82
IE	Interrupt enable control	AB
IP	Interrupt priority control	B8
P0	Port 0	80
P1	Port 1	90
P2	Port 2	A0
P3	Port 3	B0
PCON	Power control	87
PSW	Program status word	D0
SCON	Serial port control	98
SBUF	Serial data buffer	99
SP	Stack pointer	81
TMOD	Timer/counter mode control	89
TCON	Timer/counter control	88
TL0	Timer 0 low byte	8A
TH0	Timer 0 high byte	8C
TL1	Timer 1 low byte	8B
TH1	Timer 1 high byte	8D

The program counter (PC) is not a part of SFR and has no internal RAM address.

PROGRAM STATUS WORD (PSW) REGISTER:-

The flag register in the 8051 is called program status word register. The PSW register is an eight bit register. Flags are one bit registers (flip- flop) provided to store, the status of the result of some instructions. The PSW has 4 math flags that includes Carry (CY), Auxiliary (AC), overflow flag (OV), Parity flag (P), user program flag F0 and register bank select bits. The program status word is shown in Figure 4.5

D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0
CY	**AC**	**F0**	**RS1**	**RS0**	**OV**	**-**	**P**

Figure 4.5 PSW Register of 8051

The explanation of program status word is given below.

The carry (CY) flag

The carry flag is set whenever there is a carry out from the D7 bit. This flag bit is affected after eight bit addition or subtraction. This flag can also set to 1 or 0

directly by an instruction "SETB C" set bit carry and "CLR C" clear bit carry.

The auxiliary Carry (AC) flag

The auxiliary carry is set whenever there is a carry out of lower nibble into a higher nibble or whenever there is borrow from higher nibble to lower nibble i.e. carry from D3 to D4 during an ADD or SUB operation. This flag is used by instructions that perform BCD arithmetic.

The parity (P) flag

The parity flag reflects the number of ones in accumulator (A) register only**.** The parity flag is set when the result has odd parity i.e. odd number of 1s. The parity flag is clear when the result has even number of 1s.

The overflow (OV) flag

The overflow flag will be set whenever the result of a signed number operation is too large, causing the high order bit to overflow into the sign bit. The over flow flag is only used to detect errors in signed arithmetic operations.

The flag F0

The PSW has one general purpose flag F0. This is also called as user defined flag.

The Register bank select bits

The bits D3 and D4 are represented as RS0 and RS1 are used to select bank register from RAM.

RS1	RS0	Register bank
0	0	Bank 0
0	1	Bank 1
1	0	Bank 2
1	1	Bank 3

Bit D_1 of PSW is not used, it reserved for future use.

The 8051 Clock

Typically 1 MHz - 16 MHz crystals are used

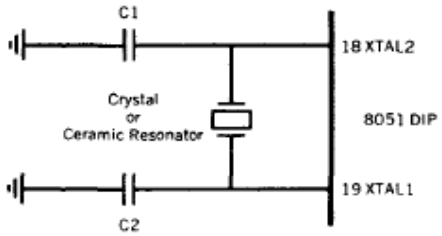
1/f gives the pulse time P

Two oscillator pulses define one state and 6 states define a machine cycle

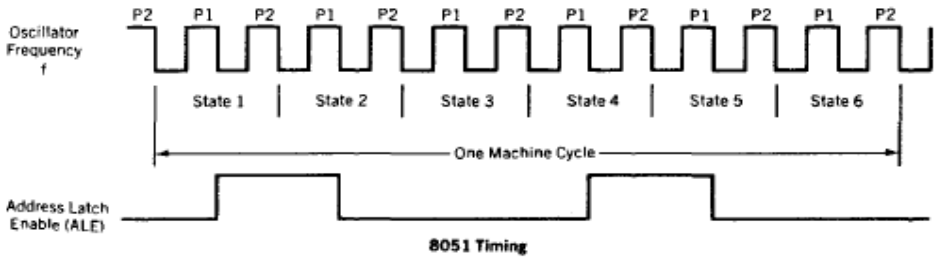
Instructions require 1,2 or 4 machine cycles.

Hence T(inst) = (cycles x 12) / freq

FIGURE 2.3 Oscillator Circuit and Timing

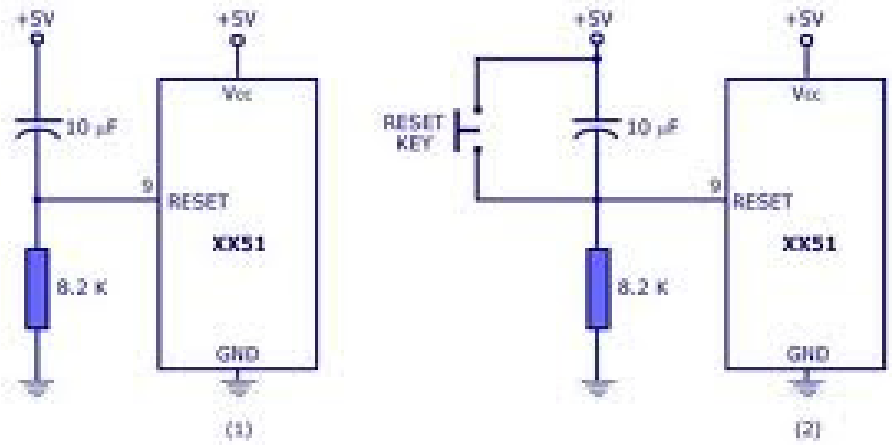


Crystal or Ceramic Resonator Oscillator Circuit



8051 Timing

RESET CIRCUIT OF 8051 CONTROLLER



(1) Power-on Reset Circuit and (2) With Manual Reset Option

Register	Content
Program counter	0000h
Accumulator	00h
B register	00h
PSW	00h
SP	07h
DPTR	0000h
All ports	FFh

EXERCISES

(A) Select Correct Alternative

1) 8051 microcontroller has---------- pins
   a) 20
   b) 40
   c) 80
   d) 16
2) DPTR is a---------bit register
   a) 8
   b) 16
   c) 64K
   d) 2K
3) 8051 has ----------Bytes of internal memory space
   a) 128
   b) 16
   c) 64K
   d) 2K
4) 8051 is a ---------- bit microcontroller
   a) 8
   b) 16
   c) 64
   d) 2
5) To access the external memory---------- pin s used
   a) EA/Vpp
   b) PSEN
   c) ALE/PROG
   d) Vcc

6) 8051 has ----------number of I/O 8 bit ports
   a) 8
   b) 32
   c) 4
   d) 1

7) 8051 has ---------- number of 16 bit timers.
   a) 8
   b) 32
   c) 2
   d) 1

8) 8051 has ---------- number of register banks .
   a) 8
   b) 4
   c) 2
   d) 1

9) 8051 has built internal--------- of ROM.
   a) 8KB
   b) 4KB
   c) 2KB
   d) 1KB

10) 8051 has built internal--------- of RAM.
   a) 0 bytes
   b) 256 bytes
   c) 128 bytes
   d) 4 KB

(B) Solve the following (Long answer type)

1) Explain the pin diagram of 8051.
2) Explain the block diagram / architecture of 8051.
3) Explain the RAM and ROM structure/organization of 8051.

(C) Solve the following (short answer type)

1) Explain the difference between microprocessor and microcontroller.
2) Explain the PSW register of 8051.
3) Explain SFRs of 8051.
4) Explain the working of PSEN and EA/Vpp.
5) Write a short note on DPTR and stack pointer.