8051 Assembly Language Programming [Part-2]

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8051 DATA TYPES AND DIRECTIVES

Assembler Directives (cont')

- `ORG` (origin)
  - The `ORG` directive is used to indicate the beginning of the address
  - The number that comes after `ORG` can be either in hex and decimal
    - If the number is not followed by H, it is decimal and the assembler will convert it to hex
- `END`
  - This indicates to the assembler the end of the source (asm) file
  - The `END` directive is the last line of an 8051 program
    - Mean that in the code anything after the `END` directive is ignored by the assembler

8051 DATA TYPES AND DIRECTIVES

Assembler directives (cont')

- `EQU` (equate)
  - This is used to define a constant without occupying a memory location
  - The `EQU` directive does not set aside storage for a data item but associates a constant value with a data label
    - When the label appears in the program, its constant value will be substituted for the label

8051 DATA TYPES AND DIRECTIVES

Assembler directives (cont')

❑ EQU (equate) (cont')

- Assume that there is a constant used in many different places in the program, and the programmer wants to change its value throughout
  - By the use of EQU, one can change it once and the assembler will change all of its occurrences

Use EQU for the counter constant

```
COUNT  EQU 25
...    ....
MOV    R3, #COUNT
```

The constant is used to load the R3 register

FLAG BITS AND PSW REGISTER

Program Status Word

- The program status word (PSW) register, also referred to as the *flag register*, is an 8 bit register
  - Only 6 bits are used
    - These four are CY (*carry*), AC (*auxiliary carry*), P (*parity*), and OV (*overflow*)
      - They are called *conditional flags*, meaning that they indicate some conditions that resulted after an instruction was executed
    - The PSW3 and PSW4 are designed as RS0 and RS1, and are used to change the bank
  - The two unused bits are user-definable

FLAG BITS AND PSW REGISTER

Program Status Word (cont')

CY	AC	F0	RS1	RS0	OV	--	P

A carry from D3 to D4

Carry out from the d7 bit

CY PSW.7 Carry flag.

AC PSW.6 Auxiliary carry flag.

-- PSW.5 Available to the user for general purpose

RS1 PSW.4 Register Bank selector bit 1.

RS0 PSW.3 Register Bank selector bit 0.

OV PSW.2 Overflow flag.

-- PSW.1 User definable bit.

P PSW.0 Parity flag. Set/cleared by hardware each instruction cycle to indicate an odd/even number of 1 bits in the accumulator.

Reflect the number of 1s in register A

The result of signed number operation is too large, causing the high-order bit to overflow into the sign bit

RS1	RS0	Register Bank	Address
0	0	0	00H – 07H
0	1	1	08H – 0FH
1	0	2	10H – 17H
1	1	3	18H – 1FH

FLAG BITS AND PSW REGISTER

ADD Instruction And PSW (cont')

- The flag bits affected by the ADD instruction are CY, P, AC, and OV

Example 2-2

Show the status of the CY, AC and P flag after the addition of 38H and 2FH in the following instructions.

```
MOV A, #38H
ADD A, #2FH ;after the addition A=67H, CY=0
```

Solution:

38	00111000
+ 2F	00101111

FLAG BITS AND PSW REGISTER

ADD Instruction And PSW (cont')

- The flag bits affected by the ADD instruction are CY, P, AC, and OV

Example 2-2

Show the status of the CY, AC and P flag after the addition of 38H and 2FH in the following instructions.

```
MOV A, #38H
ADD A, #2FH ;after the addition A=67H, CY=0
```

Solution:

	38	00111000
+	2F	00101111
	67	01100111

CY = 0 since there is no carry beyond the D7 bit

AC = 1 since there is a carry from the D3 to the D4 bi

P = 1 since the accumulator has an odd number of 1s (it has five 1s)

FLAG BITS AND PSW REGISTER

ADD Instruction And PSW (cont')

Example 2-3

Show the status of the CY, AC and P flag after the addition of 9CH and 64H in the following instructions.

```
MOV A, #9CH
ADD A, #64H  ;after the addition A=00H, CY=1
```

Solution:

	9C	10011100
+	64	01100100

FLAG BITS AND PSW REGISTER

ADD Instruction And PSW (cont')

Example 2-3

Show the status of the CY, AC and P flag after the addition of 9CH and 64H in the following instructions.

```
MOV A, #9CH
ADD A, #64H  ;after the addition A=00H, CY=1
```

Solution:

	9C	10011100
+	64	01100100
	100	00000000

CY = 1 since there is a carry beyond the D7 bit

AC = 1 since there is a carry from the D3 to the D4 bi

P = 0 since the accumulator has an even number of 1s (it has zero 1s)

FLAG BITS AND PSW REGISTER

ADD Instruction And PSW (cont')

Example 2-4

Show the status of the CY, AC and P flag after the addition of 88H and 93H in the following instructions.

```
MOV A, #88H
ADD A, #93H  ;after the addition A=1BH, CY=1
```

Solution:

	88	10001000
+	93	10010011

FLAG BITS AND PSW REGISTER

ADD Instruction And PSW (cont')

<u>Example 2-4</u>

Show the status of the CY, AC and P flag after the addition of 88H and 93H in the following instructions.

```
MOV A, #88H
ADD A, #93H   ;after the addition A=1BH, CY=1
```

Solution:

	88	10001000
+	93	10010011
	11B	00011011

CY = 1 since there is a carry beyond the D7 bit

AC = 0 since there is no carry from the D3 to the D4 bi

P = 0 since the accumulator has an even number of 1s (it has four 1s)

REGISTER BANKS AND STACK

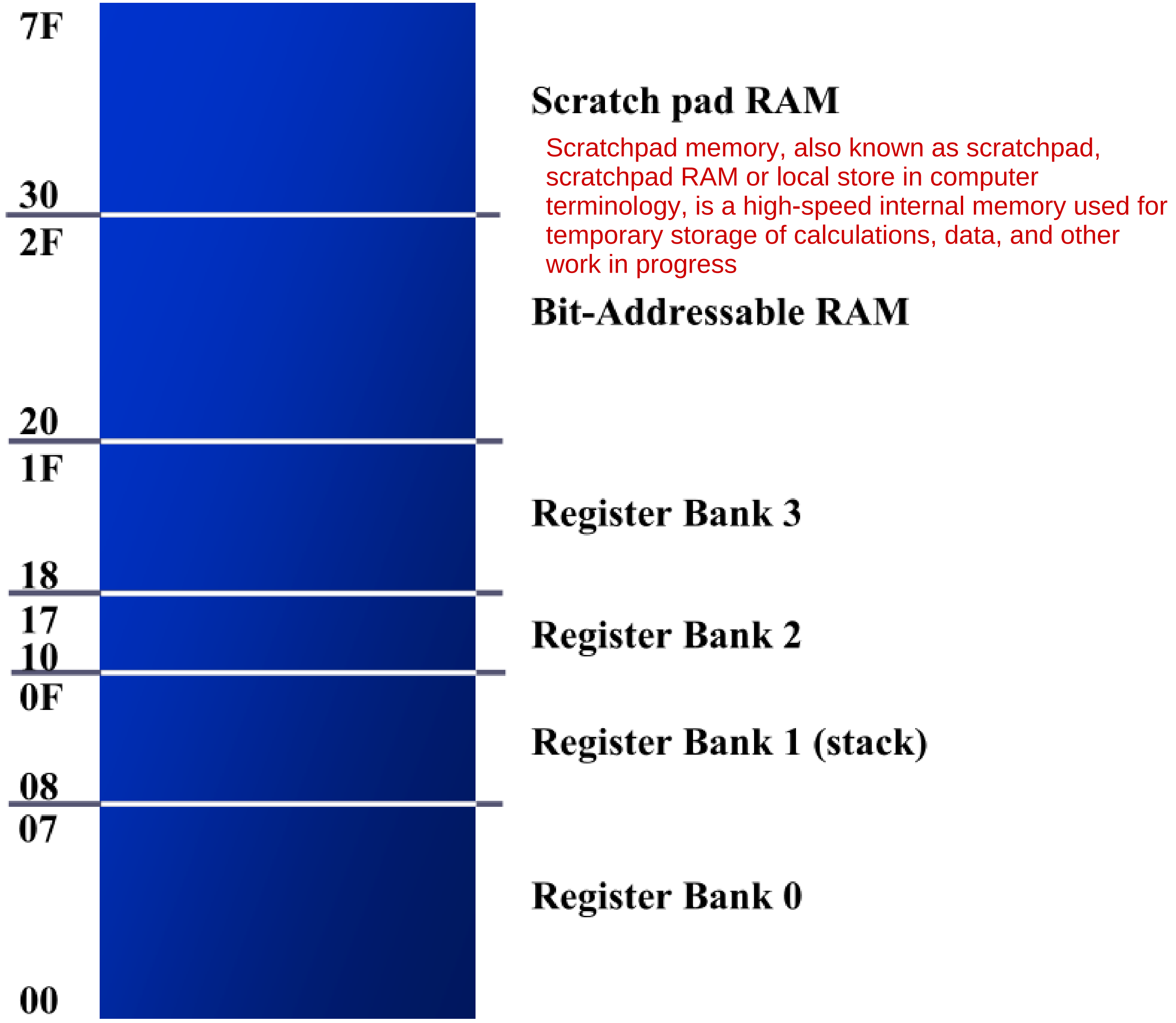
RAM Memory Space Allocation

- There are 128 bytes of RAM in the 8051
  - Assigned addresses 00 to 7FH
- The 128 bytes are divided into three different groups as follows:
  1) A total of 32 bytes from locations 00 to 1F hex are set aside for register banks and the stack
  2) A total of 16 bytes from locations 20H to 2FH are set aside for bit-addressable read/write memory
  3) A total of 80 bytes from locations 30H to 7FH are used for read and write storage, called *scratch pad*

8051 REGISTER BANKS AND STACK

RAM Memory Space Allocation (cont')

RAM Allocation in 8051



8051 REGISTER BANKS AND STACK

Register Banks

- These 32 bytes are divided into 4 banks of registers in which each bank has 8 registers, R0-R7
  - RAM location from 0 to 7 are set aside for bank 0 of R0-R7 where R0 is RAM location 0, R1 is RAM location 1, R2 is RAM location 2, and so on, until memory location 7 which belongs to R7 of bank 0
  - It is much easier to refer to these RAM locations with names such as R0, R1, and so on, than by their memory locations
- Register bank 0 is the default when 8051 is powered up

8051 REGISTER BANKS AND STACK

Register Banks (cont')

Register banks and their RAM address

Bank 0		Bank 1		Bank 2		Bank 3	
7	R7	F	R7	17	R7	1F	R7
6	R6	E	R6	16	R6	1E	R6
5	R5	D	R5	15	R5	1D	R5
4	R4	C	R4	14	R4	1C	R4
3	R3	B	R3	13	R3	1B	R3
2	R2	A	R2	12	R2	1A	R2
1	R1	9	R1	11	R1	19	R1
0	R0	8	R0	10	R0	18	R0

8051 REGISTER BANKS AND STACK

Register Banks (cont')

- We can switch to other banks by use of the PSW register
  - Bits D4 and D3 of the PSW are used to select the desired register bank
  - Use the bit-addressable instructions SETB and CLR to access PSW.4 and PSW.3

PSW bank selection

	RS1(PSW.4)	**RS0(PSW.3)**
Bank 0	0	0
Bank 1	0	1
Bank 2	1	0
Bank 3	1	1

Micro-Processor Based System Design

Datatypes, Loops and masking

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Slides are adapted from Chung-Ping Young lectures

- The unsigned int is a 16-bit data type
  - Takes a value in the range of 0 to 65535 (0000 – FFFFH)
  - Define 16-bit variables such as memory addresses
  - Set counter values of more than 256
  - Since registers and memory accesses are in 8-bit chunks, the misuse of int variables will result in a larger hex file
- Signed int is a 16-bit data type
  - Use the MSB D15 to represent – or +
  - We have 15 bits for the magnitude of the number from –32768 to +32767

Write an 8051 C program to toggle bit D0 of the port P1 (P1.0) 50,000 times.

Solution:

sbit keyword allows access to the single bits of the SFR registers

```
#include <reg51.h>
sbit MYBIT=P1^0;

void main(void)
  {
    unsigned int z;
    for (z=0;z<=50000;z++)
      {
        MYBIT=0;
        MYBIT=1;
      }
  }
```

DATA TYPES

Bit and sfr

- The bit data type allows access to single bits of bit-addressable memory spaces 20 – 2FH
- To access the byte-size SFR registers, we use the sfr data type

Data Type	Size in Bits	Data Range/Usage
unsigned char	8-bit	0 to 255
(signed) char	8-bit	-128 to +127
unsigned int	16-bit	0 to 65535
(signed) int	16-bit	-32768 to +32767
sbit	1-bit	SFR bit-addressable only
bit	1-bit	RAM bit-addressable only
sfr	8-bit	RAM addresses 80 – FFH only

Delay using Loops

Write an 8051 C program to toggle bits of P1 continuously forever with some delay.

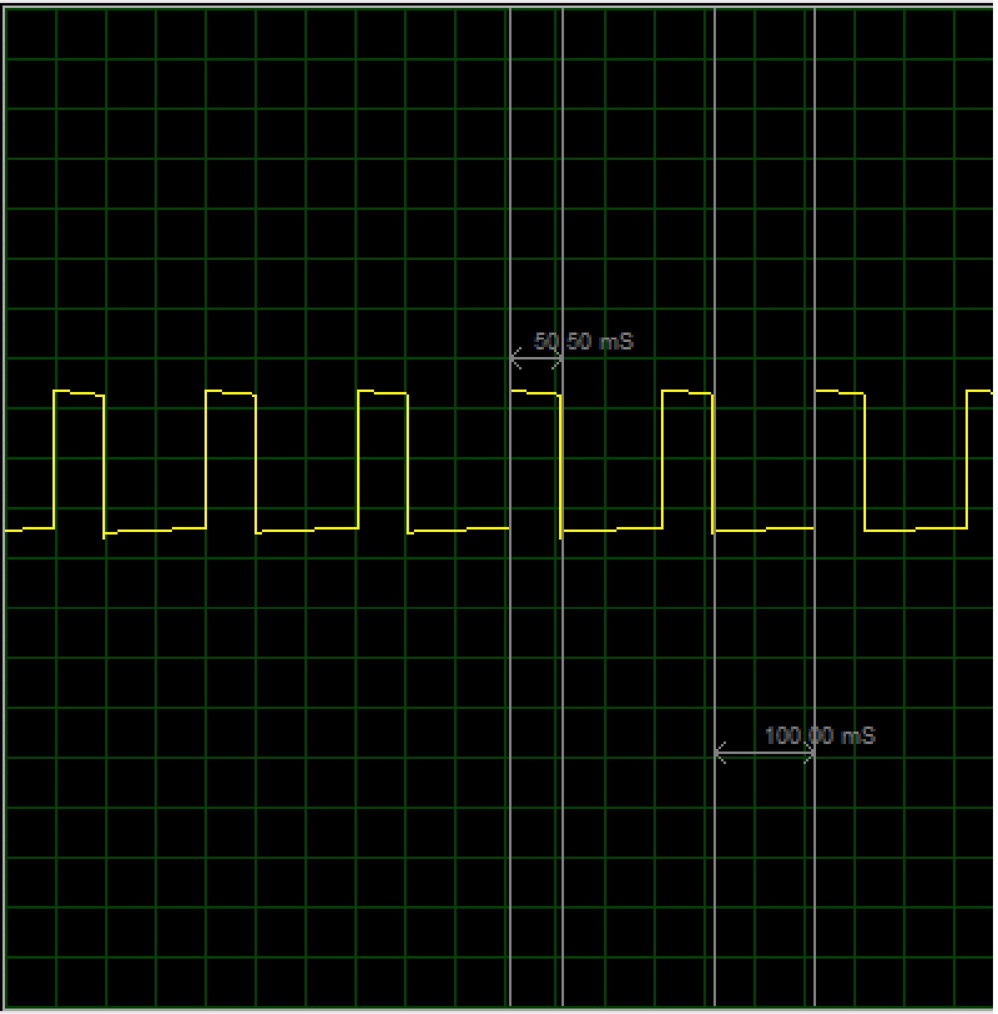
Solution:

```
//Toggle P1 forever with some delay in between
//"on" and "off"
#include <reg51.h>
void main(void)
  {
    unsigned int x;
    for (;;)                    //repeat forever
      {
        p1=0x55;
        for (x=0;x<40000;x++);  //delay size
                                //unknown
        p1=0xAA;
        for (x=0;x<40000;x++);
      }
  }
```

We must use the oscilloscope to measure the exact duration

Millisecond delay

Digital Oscilloscope




```
#include <reg51.h>
#include <stdio.h>
void MS_delay(unsigned int);
void main(void)
 {
        while(1)
        {
            P1 = 0x01;       //    0000 0001...ON
            MS_delay(50);
            P1 = 0x00;       //   0000 0000...Off
            MS_delay(100);
        }
 }

void MS_delay(unsigned int itime)
{
    unsigned int i,j;
    for (i=0;i<itime;i++)
        for (j=0;j<125;j++);
}
```

LOGIC OPERATIONS

Bit-wise Operators in C

- Logical operators
  - AND (&&), OR (||), and NOT (!)
- Bit-wise operators
  - AND (&), OR (|), EX-OR (^), Inverter (~), Shift Right (>>), and Shift Left (<<)
    - These operators are widely used in software engineering for embedded systems and control

Bit-wise Logic Operators for C

		AND	OR	EX-OR	Inverter
A	B	A&B	A|B	A^B	~B
0	0	0	0	0	1
0	1	0	1	1	0
1	0	0	1	1	
1	1	1	1	0	

LOGIC OPERATIONS

Bit-wise Operators in C (cont')

Run the following program on your simulator and examine the results.

Solution:

```
#include <reg51.h>

void main(void)
  {
    P0=0x35 & 0x0F;          //ANDing
    P1=0x04 | 0x68;          //ORing
    P2=0x54 ^ 0x78;          //XORing
    P0=~0x55;                //inversing
    P1=0x9A >> 3;            //shifting right 3
    P2=0x77 >> 4;            //shifting right 4
    P0=0x6 << 4;             //shifting left 4
  }
```

LOGIC OPERATIONS

Bit-wise Operators in C (cont')

Write an 8051 C program to get bit P1.0 and send it to P2.7 after inverting it.

Solution:

```
#include <reg51.h>
sbit inbit=P1^0;
sbit outbit=P2^7;
bit membit;

void main(void)
  {
    while (1)
        {
          membit=inbit;    //get a bit from P1.0
          outbit=~membit; //invert it and send
                           //it to P2.7
        }
  }
```