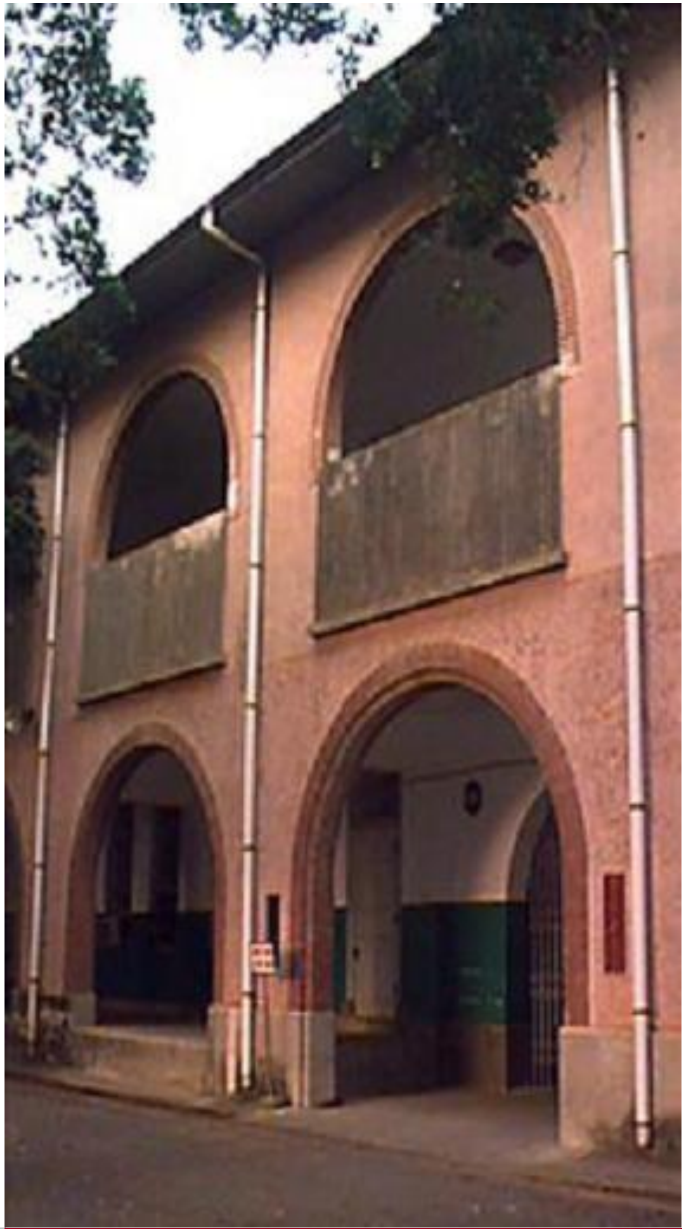
Assembly program for Embedded System

Embedded Systems: Using Assembly and C



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LOOP AND JUMP INSTRUCTIONS

Looping

A loop can be repeated a maximum of 255 times, if R2 is FFH

- Repeating a sequence of instructions a certain number of times is called a *loop*
  - Loop action is performed by
    `DJNZ reg, Label`
    - The register is decremented
    - If it is not zero, it jumps to the target address referred to by the label
    - Prior to the start of loop the register is loaded with the counter for the number of repetitions
    - Counter can be R0 – R7 or RAM location

```
;This program adds value 3 to the ACC ten times
        MOV  A,#0      ;A=0, clear ACC
        MOV  R2,#10    ;load counter R2=10
AGAIN:  ADD  A,#03     ;add 03 to ACC
        DJNZ R2,AGAIN  ;repeat until R2=0,10 times
        MOV  R5,A      ;save A in R5
```

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LOOP AND JUMP INSTRUCTIONS

Nested Loop

- If we want to repeat an action more times than 256, we use a loop inside a loop, which is called *nested loop*
  - We use multiple registers to hold the count

Write a program to (a) load the accumulator with the value 55H, and (b) complement the ACC 700 times

```
       MOV  A,#55H    ;A=55H
       MOV  R3,#10    ;R3=10, outer loop count
NEXT:  MOV  R2,#70    ;R2=70, inner loop count
AGAIN: CPL  A         ;complement A register
       DJNZ R2,AGAIN  ;repeat it 70 times
       DJNZ R3,NEXT
```

- Jump only if a certain condition is met

JZ label ;jump if A=0

```
        MOV   A,R0      ;A=R0
        JZ    OVER      ;jump if A = 0
        MOV   A,R1      ;A=R1
        JZ    OVER      ;jump if A = 0
        ...
OVER:
```

Can be used only for register A, not any other register

Determine if R5 contains the value 0. If so, put 55H in it.

```
        MOV   A,R5      ;copy R5 to A
        JNZ   NEXT      ;jump if A is not zero
        MOV   R5,#55H
NEXT:   ...
```

LOOP AND JUMP INSTRUCTIONS

Conditional Jumps (cont')

- (cont')

JNC label ;jump if no carry, CY=0

- If CY = 0, the CPU starts to fetch and execute instruction from the address of the label
- If CY = 1, it will not jump but will execute the next instruction below JNC

Find the sum of the values 79H, F5H, E2H. Put the sum in registers R0 (low byte) and R5 (high byte).

MOV R5,#0

```
        MOV   A,#0      ;A=0
        MOV     R5,A    ;clear R5
        ADD   A,#79H    ;A=0+79H=79H
;   JNC  N_1            ;if CY=0, add next number
;       INC   R5        ;if CY=1, increment R5
N_1:    ADD   A,#0F5H   ;A=79+F5=6E and CY=1
        JNC   N_2       ;jump if CY=0
        INC   R5        ;if CY=1,increment R5 (R5=1)
N_2:    ADD   A,#0E2H   ;A=6E+E2=50 and CY=1
        JNC   OVER      ;jump if CY=0
        INC     R5      ;if CY=1, increment 5
OVER:   MOV   R0,A      ;now R0=50H, and R5=02
```

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8051 conditional jump instructions

Instructions	Actions
JZ	Jump if A = 0
JNZ	Jump if A ≠ 0
DJNZ	Decrement and Jump if A ≠ 0
CJNE A,byte	Jump if A ≠ byte
CJNE reg,#data	Jump if byte ≠ #data
JC	Jump if CY = 1
JNC	Jump if CY = 0
JB	Jump if bit = 1
JNB	Jump if bit = 0
JBC	Jump if bit = 1 and clear bit

- All conditional jumps are short jumps
  - The address of the target must within -128 to +127 bytes of the contents of PC

LOOP AND JUMP INSTRUCTIONS

Unconditional Jumps

- The unconditional jump is a jump in which control is transferred unconditionally to the target location

`LJMP` (long jump)

- 3-byte instruction
  - First byte is the opcode
  - Second and third bytes represent the 16-bit target address
    - Any memory location from 0000 to FFFFH

`SJMP` (short jump)

- 2-byte instruction
  - First byte is the opcode
  - Second byte is the relative target address
    - 00 to FFH (forward +127 and backward -128 bytes from the current PC)

LOOP AND JUMP INSTRUCTIONS

Calculating Short Jump Address

- To calculate the target address of a short jump (`SJMP, JNC, JZ, DJNZ,` etc.)
  - The second byte is added to the PC of the instruction immediately below the jump
- If the target address is more than -128 to +127 bytes from the address below the short jump instruction
  - The assembler will generate an error stating the jump is out of range

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LOOP AND JUMP INSTRUCTIONS

Calculating Short Jump Address (cont')

Line	PC	Opcode		Mnemonic	Operand
01	0000			ORG	0000
02	0000	7800		MOV	R0,#0
03	0002	7455		MOV	A,#55H
04	0004	6003		JZ	NEXT
05	0006	08		INC	R0
06	0007	04	AGAIN:	INC	A
07	0008	04		INC	A
08	0009	2477	NEXT:	ADD	A,#77H
09	000B	5005		JNC	OVER
10	000D	E4		CLR	A
11	000E	F8		MOV	R0,A
12	000F	F9		MOV	R1,A
13	0010	FA		MOV	R2,A
14	0011	FB		MOV	R3,A
15	0012	2B	OVER:	ADD	A,R3
16	0013	50F2		JNC	AGAIN
17	0015	80FE	HERE:	SJMP	HERE
18	0017			END	

CALL INSTRUCTIONS

- Call instruction is used to call subroutine
  - Subroutines are often used to perform tasks that need to be performed frequently
  - This makes a program more structured in addition to saving memory space

LCALL (long call)

- 3-byte instruction
  - First byte is the opcode
  - Second and third bytes are used for address of target subroutine
    - Subroutine is located anywhere within 64K byte address space

ACALL (absolute call)

- 2-byte instruction
  - 11 bits are used for address within 2K-byte range

CALL INSTRUCTIONS

LCALL

- When a subroutine is called, control is transferred to that subroutine, the processor
  - Saves on the stack the the address of the instruction immediately below the LCALL
  - Begins to fetch instructions form the new location
- After finishing execution of the subroutine
  - The instruction RET transfers control back to the caller
    - Every subroutine needs RET as the last instruction

CALL INSTRUCTIONS

LCALL (cont')

```
        ORG   0
BACK:   MOV   A,#55H     ;load A with 55H
        MOV   P1,A       ;send 55H to port 1
        LCALL DELAY      ;time delay
        MOV   A,#0AAH    ;load A with AA (in hex)
        MOV   P1,A       ;send AAH to port 1
        LCALL DELAY
        SJMP  BACK       ;keep doing this indefinitely

;---------- this is delay subroutine ------------
        ORG   300H       ;put DELAY at address 300H
DELAY:  MOV   R5,#0FFH   ;R5=255 (FF in hex), counter
AGAIN:  DJNZ  R5,AGAIN   ;stay here until R5 become 0
        RET              ;return to caller (when R5 =0)
        END
```

Upon executing "LCALL DELAY", the address of instruction below it, "MOV A,#0AAH" is pushed onto stack, and the 8051 starts to execute at 300H.

The counter R5 is set to FFH; so loop is repeated 255 times.

When R5 becomes 0, control falls to the RET which pops the address from the stack into the PC and resumes executing the instructions after the CALL.

The amount of time delay depends on the frequency of the 8051

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CALL INSTRUCTIONS

CALL Instruction and Stack

```
0000                ORG   0
0000 7455   BACK:   MOV   A,#55H    ;load A with 55H
0002 F590           MOV   P1,A      ;send 55H to p1
0004 120300         LCALL DELAY     ;time delay
0007 74AA           MOV   A,#0AAH   ;load A with AAH
0009 F590           MOV   P1,A      ;send AAH to p1
000B 120300         LCALL DELAY
000E 80F0           SJMP  BACK      ;keep doing this
0010
0010 ;-------this is the delay subroutine------
0300                ORG   300H
0300        DELAY:
0300 7DFF           MOV   R5,#0FFH  ;R5=255
0302 DDFE   AGAIN:  DJNZ  R5,AGAIN  ;stay here
0304 22             RET              ;return to caller
0305                END               ;end of asm file
```

Stack frame after the first LCALL

0A	
09	00
08	07

SP = 09

Low byte goes first and high byte is last

CALL INSTRUCTIONS

Use PUSH/POP in Subroutine

```
0000                      ORG   0
0000 7455      BACK:      MOV   A,#55H    ;load A with 55H
0002 F590                 MOV   P1,A      ;send 55H to p1
0004 7C99                 MOV   R4,#99H
0006 7D67                 MOV   R5,#67H
0008 120300               LCALL DELAY     ;time delay
000B 74AA                 MOV   A,#0AAH   ;load A with AA
000D F590                 MOV   P1,A      ;send AAH to p1
000F 120300               LCALL DELAY
0012 80EC                 SJMP  BACK      ;keeping doing
 this
0014 ;-------this is the delay subroutine------
0300                      ORG   300H
0300 C004      DELAY:     PUSH  4         ;push R4
0302 C005                 PUSH  5         ;push R5
0304 7CFF                 MOV   R4,#0FFH;R4=FFH
0306 7DFF      NEXT:      MOV   R5,#0FFH;R5=FFH
0308 DDFE      AGAIN:     DJNZ  R5,AGAIN
030A DCFA                 DJNZ  R4,NEXT
030C D005                 POP   5         ;POP into R5
030E D004                 POP   4         ;POP into R4
0310 22                   RET             ;return to caller
031                                          e
```

Normally, the number of PUSH and POP instructions must always match in any called subroutine

After first LCALL

0B		
0A		
09	00	PCH
08	0B	PCL

After PUSH 4

0B		
0A	99	R4
09	00	PCH
08	0B	PCL

After PUSH 5

0B	67	R5
0A	99	R4
09	00	PCH
08	0B	PCL

CALL INSTRUCTIONS

Calling Subroutines

```
;MAIN program calling subroutines
        ORG   0
MAIN:   LCALL           SUBR_1
        LCALL           SUBR_2
        LCALL           SUBR_3

HERE:   SJMP            HERE
;-----------end of MAIN

SUBR_1: ...
        ...
        RET
;-----------end of subroutine1

SUBR_2: ...
        ...
        RET
;-----------end of subroutine2

SUBR_3: ...
        ...
        RET
;-----------end of subroutine3
        END             ;end of the asm file
```

It is common to have one main program and many subroutines that are called from the main program

This allows you to make each subroutine into a separate module

-Each module can be tested separately and then brought together with main program

-In a large program, the module can be assigned to different programmers

CALL INSTRUCTIONS

ACALL

- The only difference between `ACALL` and `LCALL` is
  - The target address for `LCALL` can be anywhere within the 64K byte address
  - The target address of `ACALL` must be within a 2K-byte range
- The use of `ACALL` instead of `LCALL` can save a number of bytes of program ROM space

CALL INSTRUCTIONS

ACALL (cont')

```
        ORG    0
BACK:   MOV    A,#55H     ;load A with 55H
        MOV    P1,A       ;send 55H to port 1
        LCALL  DELAY      ;time delay
        MOV    A,#0AAH    ;load A with AA (in hex)
        MOV    P1,A       ;send AAH to port 1
        LCALL  DELAY
        SJMP   BACK       ;keep doing this indefinitely
         ...
        END               ;end of asm file
```

A rewritten program which is more efficiently

```
        ORG    0
        MOV    A,#55H     ;load A with 55H
BACK:   MOV    P1,A       ;send 55H to port 1
        ACALL  DELAY      ;time delay
        CPL    A          ;complement reg A
        SJMP   BACK       ;keep doing this indefinitely
         ...
        END               ;end of asm file
```

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TIME DELAY FOR VARIOUS 8051 CHIPS

- CPU executing an instruction takes a certain number of clock cycles
  - These are referred as to as *machine cycles*
- The length of machine cycle depends on the frequency of the crystal oscillator connected to 8051
- In original 8051, one machine cycle lasts 12 oscillator periods

Find the period of the machine cycle for 11.0592 MHz crystal frequency

Solution:

```
11.0592/12 = 921.6 kHz;
   machine cycle is 1/921.6 kHz = 1.085μs
```

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TIME DELAY FOR VARIOUS 8051 CHIPS (cont')

For 8051 system of 11.0592 MHz, find how long it takes to execute each instruction.

```
(a) MOV R3,#55 (b) DEC R3 (c) DJNZ R2 target
(d) LJMP (e) SJMP (f) NOP (g) MUL AB
```

Solution:

	Machine cycles	***Time to execute***
(a)	1	1x1.085μs = 1.085μs
(b)	1	1x1.085μs = 1.085μs
(c)	2	2x1.085μs = 2.17μs
(d)	2	2x1.085μs = 2.17μs
(e)	2	2x1.085μs = 2.17μs
(f)	1	1x1.085μs = 1.085μs
(g)	4	4x1.085μs = 4.34μs

TIME DELAY FOR VARIOUS 8051 CHIPS

Delay Calculation

Find the size of the delay in following program, if the crystal frequency is 11.0592MHz.

```
        MOV   A,#55H
AGAIN:  MOV   P1,A
        ACALL DELAY
        CPL   A
        SJMP  AGAIN
;---time delay-------
DELAY:  MOV   R3,#200
HERE:   DJNZ  R3,HERE
        RET
```

A simple way to short jump to itself in order to keep the microcontroller busy

```
HERE:  SJMP  HERE
```

We can use the following:

```
        SJMP  $
```

Solution:

```
                               Machine cycle
DELAY:  MOV   R3,#200               1
HERE:   DJNZ  R3,HERE               2
        RET                         2
```

Therefore, [(200x2)+1+2]x1.085μs = 436.255μs.

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TIME DELAY FOR VARIOUS 8051 CHIPS

Increasing Delay Using NOP

Find the size of the delay in following program, if the crystal frequency is 11.0592MHz.

```
                                        Machine Cycle
DELAY:  MOV   R3,#250                          1
HERE:   NOP                                    1
        NOP                                    1
        NOP                                    1
        NOP                                    1
        DJNZ  R3,HERE                          2
        RET                                    2
```

Solution:

The time delay inside HERE loop is

[250(1+1+1+1+2)]x1.085μs = 1627.5μs.

Adding the two instructions outside loop we

have 1627.5μs + 3 x 1.085μs = 1630.755μs

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TIME DELAY FOR VARIOUS 8051 CHIPS

Large Delay Using Nested Loop

Find the size of the delay in following program, if the crystal frequency is 11.0592MHz.

```
                                     Machine Cycle
DELAY: MOV   R2,#200                   1
AGAIN: MOV   R3,#250                   1
HERE:  NOP                             1
       NOP                             1
       DJNZ  R3,HERE                   2
       DJNZ  R2,AGAIN                  2
       RET                             2
```

Notice in nested loop, as in all other time delay loops, the time is approximate since we have ignored the first and last instructions in the subroutine.

Solution:

For HERE loop, we have (4x250)x1.085μs=1085μs. For AGAIN loop repeats HERE loop 200 times, so we have 200x1085μs=217000μs. But "MOV R3,#250" and "DJNZ R2,AGAIN" at the start and end of the AGAIN loop add (3x200x1.805)=651μs. As a result we have 217000+651=217651μs.

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- Two factors can affect the accuracy of the delay
  - Crystal frequency
    - The duration of the clock period of the machine cycle is a function of this crystal frequency
  - 8051 design
    - The original machine cycle duration was set at 12 clocks
    - Advances in both IC technology and CPU design in recent years have made the 1-clock machine cycle a common feature

Clocks per machine cycle for various 8051 versions

Chip/Maker	Clocks per Machine Cycle
AT89C51 Atmel	12
P89C54X2 Philips	6
DS5000 Dallas Semi	4
DS89C420/30/40/50 Dallas Semi	1

TIME DELAY FOR VARIOUS 8051 CHIPS

Delay Calculation for Other 8051 (cont')

Find the period of the machine cycle (MC) for various versions of 8051, if XTAL=11.0592 MHz.

(a) AT89C51 (b) P89C54X2 (c) DS5000 (d) DS89C4x0

```
Solution:
(a) 11.0592MHz/12 = 921.6kHz;
    MC is 1/921.6kHz = 1.085μs =  1085ns
(b) 11.0592MHz/6 = 1.8432MHz;
    MC is 1/1.8432MHz = 0.5425μs  = 542ns
(c) 11.0592MHz/4 = 2.7648MHz ;
    MC is 1/2.7648MHz = 0.36μs =  360ns
(d) 11.0592MHz/1 = 11.0592MHz;
    MC is 1/11.0592MHz = 0.0904μs  = 90ns
```

TIME DELAY FOR VARIOUS 8051 CHIPS

Delay Calculation for Other 8051 (cont')

Instruction	8051	DSC89C4x0
`MOV R3,#55`	1	2
`DEC R3`	1	1
`DJNZ R2 target`	2	4
`LJMP`	2	3
`SJMP`	2	3
`NOP`	1	1
`MUL AB`	4	9

For an AT8051 and DSC89C4x0 system of 11.0592 MHz, find how long it takes to execute each instruction.

```
(a) MOV R3,#55  (b) DEC R3  (c) DJNZ R2 target
(d) LJMP  (e) SJMP  (f) NOP  (g) MUL AB
```

Solution:

```
         AT8051                       DS89C4x0
(a) 1×1085ns = 1085ns        2×90ns = 180ns
(b) 1×1085ns = 1085ns        1×90ns = 90ns
(c) 2×1085ns = 2170ns        4×90ns = 360ns
(d) 2×1085ns = 2170ns        3×90ns = 270ns
(e) 2×1085ns = 2170ns        3×90ns = 270ns
(f) 1×1085ns = 1085ns        1×90ns = 90ns
(g) 4×1085ns = 4340ns        9×90ns = 810ns
```

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