Lecture 4: Assembly Language Programming (1)

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The 80x86 IBM PC and Compatible Computers

Chapter 2

Assembly Language Programming

Programming Languages

- Machine language
  - Binary code, for CPU but not human beings
- Assembly language
  - Mnemonics for machine code instructions
  - *Low-level language:* deals with the internal structure of a CPU
  - Hard to program, poor portability but very efficient
- BASIC, Pascal, C, Fortran, Perl, TCL, BASH,...
  - *High-level languages:* do not have to be concerned with the internal details of a CPU
  - Easy to program, good portability but less efficient

Assembly Language Programs

- A series of *statements*
  - *Assembly language instructions*
    - Perform the real work of the program
  - *Directives (pseudo-instructions)*
    - Give instructions for the *assembler* program about how to translate the program into machine code.
- Consists of multiple segments
  - But CPU can access only one data segment, one code segment, one stack segment and one extra segment (Reason?)

Form of an statement

- [label:] mnemonic [operands] [;comment]
  - *label* is a reference to this statement
    - Rules for names: each label must be unique; letters, 0-9, (?), (.), (@), (_), and ($); first character cannot be a digit; less than 31 characters
  - ":" is needed if it is an instruction otherwise omitted
  - ";" leads a comment, the assembler omits anything on this line following a semicolon

Shell of a Real Program

- Full segment definition (old fashion)
  - See real example
- Simple segment definition

```
;THE FORM OF AN ASSEMBLY LANGUAGE PROGRAM
;NOTE: USING SIMPLIFIED SEGMENT DEFINITION
                .MODEL SMALL
                .STACK 64
                .DATA
DATA1           DB      52H
DATA2           DB      29H
SUM             DB      ?
                .CODE
MAIN            PROC    FAR             ;this is the program entry point
                MOV     AX,@DATA        ;load the data segment address
                MOV     DS,AX           ;assign value to DS
                MOV     AL,DATA1        ;get the first operand
                MOV     BL,DATA2        ;get the second operand
                ADD     AL,BL           ;add the operands
                MOV     SUM,AL          ;store the result in location SUM
                MOV     AH,4CH          ;set up to return to DOS
                INT     21H             ;
MAIN            ENDP
                END     MAIN            ;this is the program exit point
```

Figure 2-1. Simple Assembly Language Program

Model Definition

- The **MODEL** directive
  - Selects the size of the memory model
  - SMALL: code = data <=64KB
  - MEDIUM: data <=64KB, code >64KB
  - COMPACT: code<=64KB, data >64KB
  - LARGE: data>64KB but single set of data<64KB, code>64KB
  - HUGE: data>64KB, code>64KB
  - TINY: code + data<64KB

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MAIN    ENDP
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```

Figure 2-1. Simple Assembly Language Program

Segment Definition

- Simplified segment definition
  - **.CODE**, **.DATA**, **.STACK**
  - Only three segments can be defined
  - Automatically correspond to the CPU's CS, DS, SS

- Full segment definition
  - *label* **SEGMENT**
  - *label* **ENDS**
  - as many as needed
  - Manually load data segments

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```

Figure 2-1. Simple Assembly Language Program

Segments All at a Glance

- Stack segment
- Data segment
  - Data definition
- Code segment
  - Write your statements
  - Procedures definition
    - label **PROC** [**FAR**|**NEAR**]
    - label **ENDP**
  - Entrance proc should be FAR

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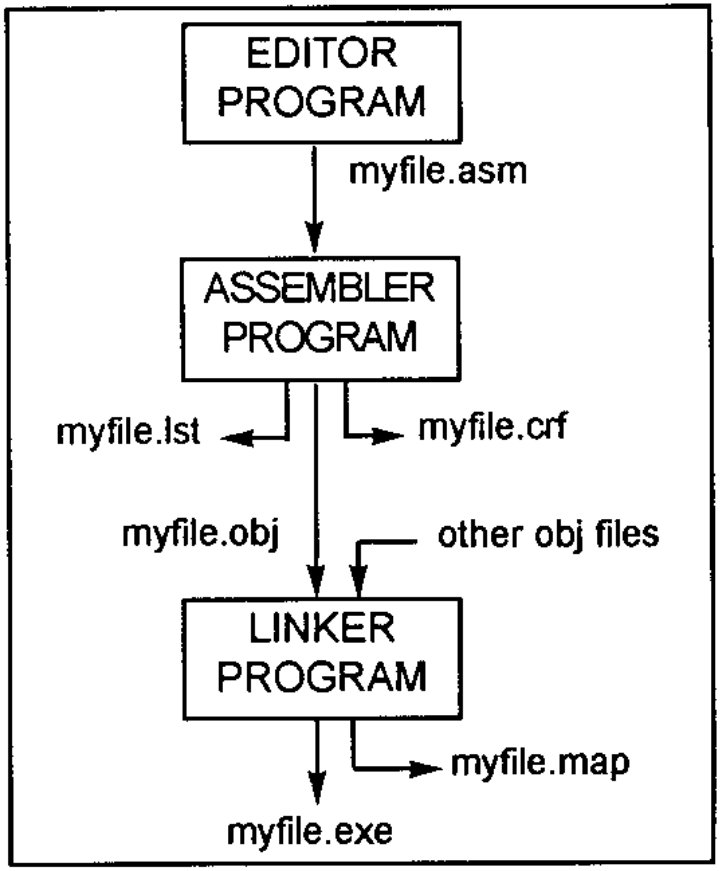
            INT   21H           ;
MAIN        ENDP
            END   MAIN          ;this is the program exit point
```

Figure 2-1. Simple Assembly Language Program

Build up Your Program

C>MASM A:MYFILE.ASM <enter>

C>LINK A:MYFILE.OBJ <enter>



Program Execution

- DOS assigns CS, SS
- Program assigns DS
- Program starts from the entrance
  - Ends whenever calls 21H interruption with AH = 4CH
- Procedure caller and callee
  - **CALL** *procedure*
  - **RET**

```
DaSeg1 segment
    str1 db 'Hello World! $'
DaSeg1 ends

StSeg segment
    dw   128  dup(0)


CoSeg segment
    start   proc far
        assume cs:CoSeg, ss:StSeg

        mov ax, DaSeg1     ; set segment registers:
        mov ds, ax
        mov es, ax

        call subr       ;call subroutine

        mov ah, 1        ; wait for any key....
        int 21h

        mov ah, 4ch      ; exit to operating system.
        int 21h
    start endp

    subr proc

        mov dx, offset str1
        mov ah, 9
        int 21h          ; output string at ds:dx

        ret
    subr endp

CoSeg ends

        end start   ; set entry point and stop the assembler.
```

Control Transfer Instructions

- Range
  - **SHORT**, *intrasegment*
    - IP changed: one-byte range
  - **Near**, *intrasegment*
    - IP changed: two-bytes range
    - If control is transferred within the same code segment
  - **FAR**, *intersegment*
    - CS and IP all changed
    - If control is transferred outside the current code segment
- Jumps
- CALL statement

Conditional Jumps

- Jump according to the value of the flag register
- Short jumps

Mnemonic	Condition Tested	"Jump IF ..."
JA/JNBE	(CF = 0) and (ZF = 0)	above/not below nor zero
JAE/JNB	CF = 0	above or equal/not below
JB/JNAE	CF = 1	below/not above nor equal
JBE/JNA	(CF or ZF) = 1	below or equal/not above
JC	CF = 1	carry
JE/JZ	ZF = 1	equal/zero
JG/JNLE	((SF xor OF) or ZF) = 0	greater/not less nor equal
JGE/JNL	(SF xor OF) = 0	greater or equal/not less
JL/JNGE	(SF xor OR) = 1	less/not greater nor equal
JLE/JNG	((SF xor OF) or ZF) = 1	less or equal/not greater
JNC	CF = 0	not carry
JNE/JNZ	ZF = 0	not equal/not zero
JNO	OF = 0	not overflow
JNP/JPO	PF = 0	not parity/parity odd
JNS	SF = 0	not sign
JO	OF = 1	overflow
JP/JPE	PF = 1	parity/parity equal
JS	SF = 1	sign

Unconditional Jumps

- JMP [SHORT|NEAR|FAR PTR] *label*
- Near by default

Subroutines & CALL Statement

- Range
  - **NEAR**: procedure is defined within the same code segment with the caller
  - **FAR**: procedure is defined outside the current code segment of the caller
- **PROC** & **ENDP** are used to define a subroutine
- **CALL** is used to call a subroutine
  - **RET** is put at the end of a subroutine
  - *Difference between a far and a near call?*

Calling a NEAR proc

- ✓The CALL instruction and the subroutine it calls are in the same segment.
- ✓Save the current value of the IP on the stack.
- ✓load the subroutine's offset into IP (nextinst + offset)

Calling Program	Subroutine	Stack

```
Main proc          sub1 proc
001A: call sub1    0080: mov ax,1
001D: inc ax       …
.                  ret
Main endp          sub1 endp
```

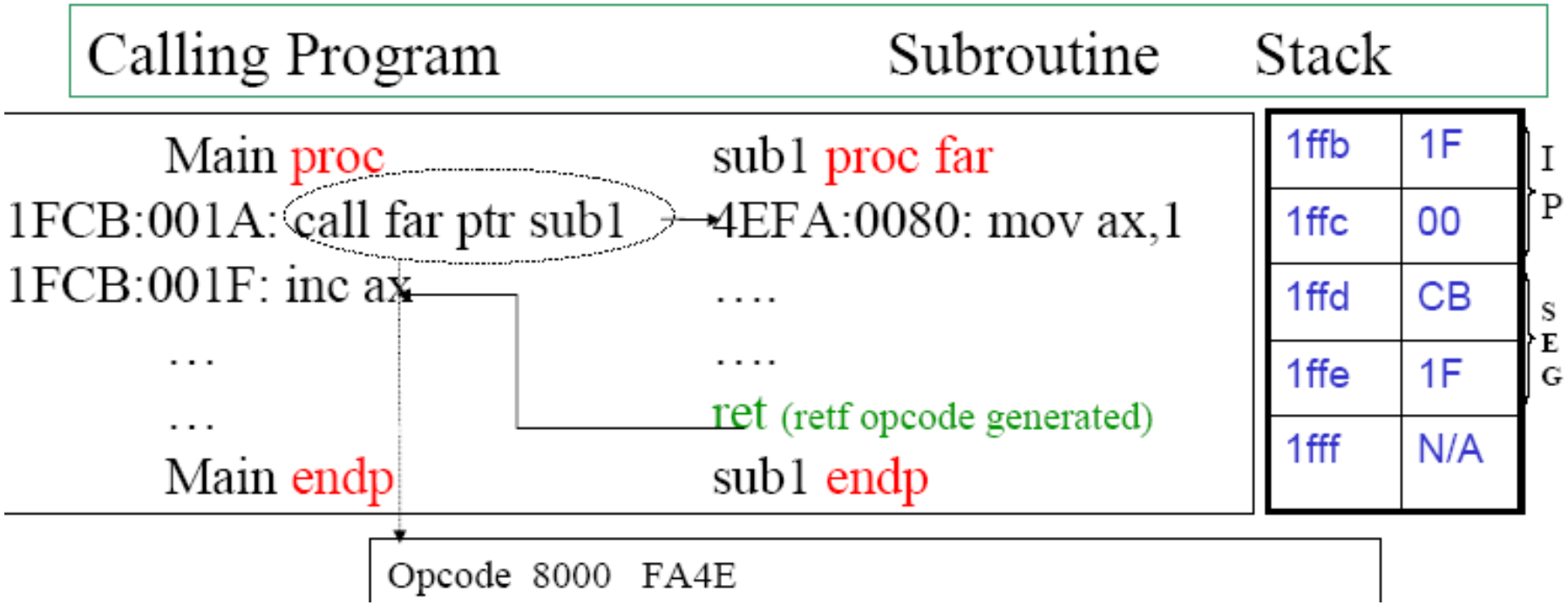
1ffd	1D
1ffe	00
1fff	(not used)

Calling a FAR proc

✓The CALL instruction and the subroutine it calls are in the "Different" segments.

✓Save the current value of the CS and IP on the stack.

✓Then load the subroutine's CS and offset into IP.



Data Types & Definition

- CPU can process either 8-bit or 16 bit ops
  - What if your data is bigger?
- Directives
  - **ORG:** indicates the beginning of the offset address
    - E.g., ORG 10H
  - **DB:** allocate byte-size chunks
    - E.g., x DB 12 | y DB 23H, 48H | Z DB ‘Good Morning!’ | str DB “I’m good!”
  - **DW**, **DD, DQ**
  - **DUP:** duplicate a given number of characters
    - E.g., x DB 6 DUP(23H) | y DW 3 DUP(0FF10H)
  - **EQU:** define a constant
    - E.g., NUM EQU 234

.COM Executable

- One segment in total
  - Put data and code all together
  - Less than 64KB

```
TITLE   PROG2-4 COM PROGRAM TO ADD TWO WORDS
PAGE   60,132
CODSG          SEGMENT
               ORG    100H
               ASSUME  CS:CODSG,DS:CODSG,ES:CODSG
;------THIS IS THE CODE AREA
PROGCODE       PROC   NEAR
               MOV    AX,DATA1        ;move the first word into AX
               MOV    SUM,AX          ;move the sum
               MOV    AH,4CH          ;return to DOS
               INT    21H
PROGCODE       ENDP
;------THIS IS THE DATA AREA
DATA1          DW     2390
DATA2          DW     3456
SUM            DW     ?
;-------------------------------------
CODSG          ENDS
               END    PROGCODE
```

```
TITLE          PROG2-5 COM PROGRAM TO ADD TWO WORDS
PAGE           60,132
CODSG          SEGMENT
               ASSUME  CS:CODSG,DS:CODSG,ES:CODSG
               ORG    100H
START:         JMP    PROGCODE    ;go around the data area
;------THIS IS THE DATA AREA
DATA1          DW     2390
DATA2          DW     3456
SUM            DW     ?
;------THIS IS THE CODE AREA
PROGCODE:      MOV    AX,DATA1    ;move the first word into AX
               ADD    AX,DATA1    ;add the second word
               MOV    SUM,AX      ;move the sum
               MOV    AH,4CH
               INT    21H
;-------------------------------------
CODSB          ENDS
               END    START
```