Lecture 19: 80x86 Assembly Programming I

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Based on the slides by Hongzi Zhu

Review

- 80x86 memory organization
  - Memory segments
- Addressing modes

Outline

- Assembly statement
- Model definition
- Segments definition
- Building programs
- Control transfer instructions
  - Short, near and far
- Data types and definition

Assembly Language Programs

- A series of *statements* (lines)
  - *Assembly language instructions* (ADD, MOV, etc.)
    - 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
  - CPU can access only one data segment, one code segment, one stack segment and one extra segment (*Why?*)

Form of a 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
- Mnemonic and the operands perform the real work of the program.
- ";" leads a comment, the assembler omits anything on this line following a semicolon

Example of an Assembly Program

- Full segment definition
  - See an example later
- Simple segment definition

```
;THE FORM OF AN ASSEMBLY LANGUAGE PROGRAM
;
                .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
```

Model Definition

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

```
;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
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                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
```


Simplified Segment Definition

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

```
;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
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                MOV     AH,4CH          ;set up to return to DOS
                INT     21H             ;
MAIN            ENDP
                END     MAIN            ;this is the program exit point
```

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

```
;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
```

Note: On program start, the OS assigns CS and SS, the program must initialize DS.

Sample Shell of an Assembly Program

```
;THE FORM OF AN ASSEMBLY LANGUAGE PROGRAM
; USING SIMPLIFIED SEGMENT DEFINITION
                .MODEL SMALL
                .STACK 64
                .DATA
                ;
                ;place data definitions here
                ;
                .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
                ;
                ;place code here
                ;
                MOV   AH,4CH        ;set up to
                INT   21H           ;return to DOS
MAIN            ENDP
                END   MAIN          ;this is the program exit point
```

Full Segment Definition

- Full segment definition
  - *label* **SEGMENT**
  - *label* **ENDS**
  - You name those labels
  - as many as needed
  - DOS assigns CS, SS
  - Program assigns DS (manually load data segments) and ES

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

StSeg segment
    dw   128  dup(0)
StSeg ends

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.
```


Program Execution

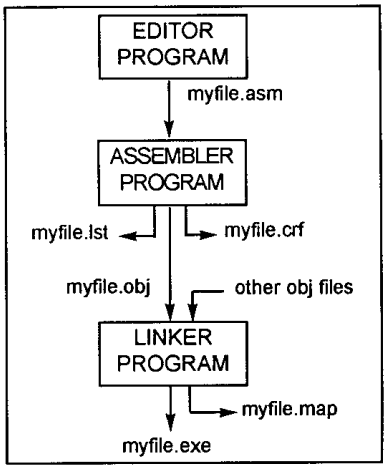
- Program starts from the entrance
  - Ends whenever calls 21H interrupt with AH = 4CH
- Procedure caller and callee
  - **CALL** *procedure*
  - **RET**

```
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.
```

Build up Your Program

- .asm: the source file
- .obj: object file created by assembler
- .lst: lists opcodes, offset addresses and detected errors
- .crf: cross reference file lists references and lables and their addresses
- .map: name of the segments, their address and size

C>MASM A:MYFILE.ASM <enter>
C>LINK A:MYFILE.OBJ <enter>



Control Transfer Instructions

- Range
  - **SHORT**, *intrasegment*
    - IP changed: one-byte range (within -128 to + 127 bytes of the IP)
  - **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
- Example:

```
0005  8A 47 02 AGAIN:    MOV   AL,[BX]+2
0008  3C 61               CMP   AL,61H
000A  72 06               JB    NEXT
000C  3C 7A               CMP   AL,7AH
000E  77 02               JA    NEXT
0010  24 DF               AND   AL,ODFH
0012  88 04   NEXT:       MOV   [SI],AL
```

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
- In FAR jump, both IP and CS change

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
```

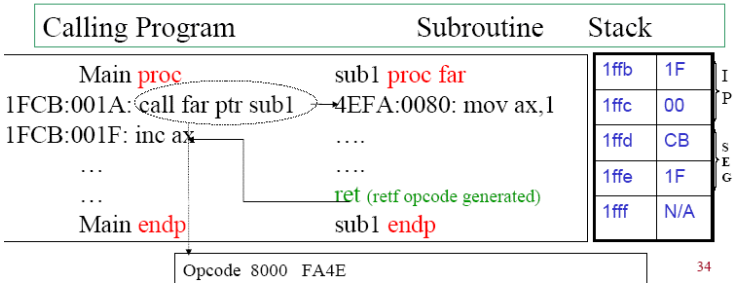
1ffd	1D
1ffe	00
1fff	(not used)

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`
  - Define variables:
    - **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**
  - **EQU:** define a constant
    - E.g., `NUM EQU 234`
  - **DUP:** duplicate a given number of characters
    - E.g., `x DB 6 DUP(23H) |y DW 3 DUP(0FF10H)`

Example

```
0000 19                    DATA1 DB   25                ;DECIMAL
0001 89                    DATA2 DB   10001001B         ;BINARY
0002 12                    DATA3 DB   12H               ;HEX
0010                             ORG  0010H
0010 32 35 39 31           DATA4 DB   '259'             ;ASCII NUMBERS
0018                             ORG  0018H
0018 00                    DATA5 DB   ?                 ;SET ASIDE A BYTE
0020                             ORG  0020H
0020 4D 79 20 6E 61 6D     DATA6 DB   'My name is Joe'  ;ASCII CHARACTERS
     65 20 69 73 20 4A
     6F 65
```

```
0070                       ORG    70H
0070 03BA                  DATA11 DW   954                 ;DECIMAL
0072 0954                  DATA12 DW   100101010100B       ;BINARY
0074 253F                  DATA13 DW   253FH               ;HEX
0078                       ORG    78H
0078 0009 0002 0007 000C   DATA14 DW   9,2,7,0CH,00100000B,5,'HI'   ;MISC. DATA
     0020 0005 4849
0086 0008[                 DATA15 DW   8 DUP (?)           ;SET ASIDE 8 WORDS
          ????             ]
```


More about Variables

- For variables, they may have names
  - E.g., `luckyNum DB 27H, time DW 0FFFFH`
- Variable names have three attributes:
  - **Segment value**
  - **Offset address**

  } Logical address
  - **Type:** how a variable can be accessed (e.g., DB is byte-wise, DW is word-wise)
- Get the segment value of a variable
  - Use **SEG** directive (E.g., `MOV AX, SEG luchyNum`)
- Get the offset address of a variable
  - Use **OFFSET** directive, or **LEA** instruction
  - E.g., `MOV AX, OFFSET time`, or `LEA AX, time`

More about Labels

- Label definition:
  - Implicitly:
    - E.g., `AGAIN: ADD AX, 03423H`
  - Use **LABEL** directive:
    - E.g.,
```
AGAIN LABEL FAR
    ADD AX, 03423H
```
- Labels have three attributes:
  - **Segment value:**
  - **Offset address:**

  } Logical address
  - **Type:** range for jumps, NEAR, FAR

More about the PTR Directive

- Temporarily change the type (range) attribute of a variable (label)
  - To guarantee that both operands in an instruction match
  - To guarantee that the jump can reach a label
- E.g.,
```
DATA1  DB  10H,20H,30H  ;
DATA2  DW  4023H,0A845H
……
MOV  BX, WORD PTR DATA1   ; 2010H -> BX
MOV  AL, BYTE PTR DATA2   ; 23H -> AL
MOV  WORD PTR [BX], 10H ; [BX],[BX+1]←0010H
```
- E.g., `JMP FAR PTR aLabel`

.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
```


Next Lecture

- 8086 Assembly
  - Addition and subtraction
  - Multiplication and division (unsigned)
  - BCD arithmetic
  - Rotate instructions