CS 271
Computer Architecture & Assembly Language

Lecture 3

MASM Syntax and First MASM Program

1/11/22, Tuesday

Oregon State University

Odds and Ends

- My office hours are confirmed:
  - M 11-12, W 12-1 @ KEC 3114, R 3:30-5:30 @ KEC 3057
- From now on, you will have access to lecture recordings from W21 on Canvas
  - I will make a class announcement once I’ve done so
- Assignment 1 clarifications
- Questions?

Lecture Topics:

- Introduction to MASM assembly language
- Writing a MASM program

Introduction to MASM assembly language

MASM Program Template

```
TITLE Program Template (template.asm)
; Author:
; Course/project ID                                   Date:
; Description:

INCLUDE Irvine32.inc
        <insert constant definitions here>
.data
        <insert variable definitions here>

.code
main PROC
        <insert executable instructions here>
        exit                        ; exit to operating system
main ENDP
        <insert additional procedures here>
END main
```

MASM syntax and style

- MASM is **not** case-sensitive!!
  - Constants usually ALL CAPS
- Segments start with `.`
  - `main` should be the first procedure in the `.code` segment
  - Beginning of next segment (or `END main`) is end of segment
- Comments start with `;`
  - Can start anywhere in a line
  - Remainder of line is ignored by the assembler
  - End of line is end of comment
- Use indentation and sufficient white space to make sections easy to find and identify

MASM identifier syntax

- Identifiers: Names for variables, constants, procedures, and labels
- 1 to 247 characters (no spaces)
  - Use concise, meaningful names
- Not case sensitive!
- Start with letter, _, @, or $
  - For now, start with letter only
- Remaining characters are letters, digits, or _
- Cannot be a reserved word
  - E.g.: proc, main, eax, … etc.

Memory Locations

- May be named
  - Name can refer to a variable name or a program label
- Interpretation of contents **depends on program instructions**
  - Numeric data
    - Integer, floating point
  - Non-numeric data
    - Character, string
  - Instruction
  - Address
  - etc.

constant

MASM data types syntax

Type	Used for:
BYTE	Character, string, 1-byte integer
WORD	2-byte integer, address
DWORD	4-byte unsigned integer, address
FWORD	6-byte integer
QWORD	8-byte integer
TBYTE	10-byte integer
REAL4	4-byte floating-point
REAL8	8-byte floating-point
REAL10	10-byte floating-point

int

MASM Data definition syntax

- In the `.data` segment
- General form is

```
label     data_type     initializer     ;comment
```

  - `label` is the "variable name"
  - `data_type` is one of (see previous slides)
  - At least one `initializer` is required
    - May be `?` (value to be assigned later)
- Examples:

```
size      DWORD 100              ;class size
celsius   WORD  -10              ;current Celsius temp
response  BYTE  'Y'              ;positive answer
myName    BYTE  ”Wile E. Coyote”,0
gpa       REAL4 ?                ;my GPA
```

Data in Memory

- “variables” are laid out in memory <u>in the order declared</u>
- Example:

```
.data
size        DWORD   100                ;class size
celsius     WORD    -10                ;current Celsius
response    BYTE    'Y'                ;positive answer
myName      BYTE    "Wile E. Coyote",0
gpa         REAL4   ?                  ;my GPA
```

  - Suppose that the data segment starts at memory address 1000

size	is address 1000	(DWORD uses 4 bytes)
celsius	is address 1004	(WORD uses 2 bytes)
Response	is address 1006	(BYTE uses 1 byte)
myName	is address 1007	(Each character uses 1 byte)
		(Blank spaces and the terminating 0 are characters too!)
gpa	is address 1022	

Data in Memory

`size`	is address 1000	(DWORD uses 4 bytes)
`celsius`	is address 1004	(WORD uses 2 bytes)
`Response`	is address 1006	(BYTE uses 1 byte)
`myName`	is address 1007	(Each character uses 1 byte)
		(Blank spaces and the terminating 0 are characters too!)
`gpa`	is address 1022	

- Note:
- Each **name** is a **constant**
  - i.e. the system substitutes the memory address for each occurrence of a name
- The **contents** of a memory location may be **variable**.

Literals

- Actual values, named constants
  - Integer
  - Floating point
  - Character
  - String (only in `.data` segment or named constant)
- Used for:
  - Initializing variables (in the `.data` segment)
  - Defining constants
  - Assigning contents of registers
  - Assigning contents of memory (in the `.code` segment)

MASM Literals syntax

- Integer
  - Optional radix: b, q/o, d, h
    - Digits must be consistent with radix (e.g., 1011b, 235q, 2012d, 30h)
    - Hex values that start with a letter must have a leading 0 (e.g., 0A3h)
      - Or use the 0x prefix instead of the radix (e.g., 0xA3)
  - Default is <u>decimal</u>
- Floating-point (decimal real)
  - Optional sign
  - Standard notation (e.g., -3.5 +5. 7.2345)
  - Exponent notation (e.g., -3.5E2 6.15E-3)
  - <u>Must have a decimal point</u>

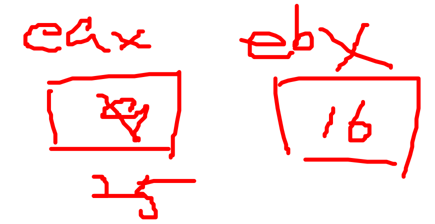
MASM Literals syntax

- Character
  - Single character in quotes
    - ‘a’ 97 “*” 42 ‘3’ 51
    - Single quotes recommended
- String
  - 2 or more characters in quotes
    - “always”, 0
    - ‘123 * 456’, 0
    - Double quotes recommended
    - Embedded quotes must be different
      - “It’s”, 0 ‘Title: “MASM”’, 0
  - String must be null-terminated
    - Always end with zero-byte

MASM Instruction syntax

- Each instruction line has 4 fields:
  - Label
  - Opcode
  - Operands
  - Comments
- Depending on the opcode, one or more operands may be required
  - Otherwise, any field may be empty
  - If empty opcode field, operand field must be empty

MASM Instruction syntax



- Opcode (specifies what to do)
  - Mnemonic (e.g., ADD, MOV, CALL, etc.)
- Zero, one, or two Operands (specify the opcode's target)
  - Different number of operands for different opcodes

```
opcode
opcode      destination
opcode      destination, source
```

MASM Addressing modes

Specific “addressing modes” are permitted for the operands associated with each opcode.

- Basic (used in first programming assignment)
  - Immediate — Constant, literal, absolute address — cannot be dest.
  - Register — Contents of register
  - Direct — Contents of referenced memory address
  - Offset — Memory address; may be calculated
- Advanced (used in later assignments)
  - Register indirect — Access memory through address in a register
  - Indexed — “array” element, using offset in register
  - Base-indexed — start address in one register; offset in another, add and access memory
  - Stack — Memory area specified and maintained as a stack; stack pointer in ESP register

See the MASM list of instructions

Writing a MASM program

- Rules & Regulations
- Syntax and semantics

MASM Instructions

- For now, know how to use
  - mov, add, sub, mul, div, call
- Some instructions use implied operands
- See textbook (Appendix) or on-line instructions

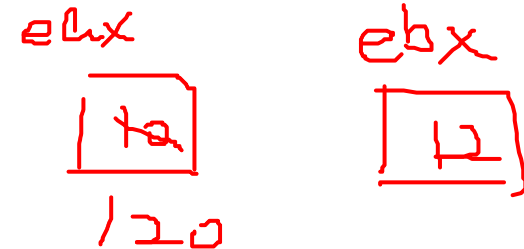
Easy Instructions

- For 2-operand instructions, the 1st operand is the destination, and the 2nd operand is the source
- 2-operand instructions require at least one of the operands to be a register (or op2 must be literal).
  - Note: op1 cannot be a literal

```
mov     op1, op2     ;op2 is copied to op1
add     op1, op2     ;op2 is added to op1
sub     op1, op2     ;op2 is subtracted from op1
inc     op1          ; add 1 to op1
dec     op1          ; subtract 1 from op1
```

Instructions with implied operands

- mul implied operand must be in EAX
- mul   op2   ; result is in EDX:EAX
- Example:

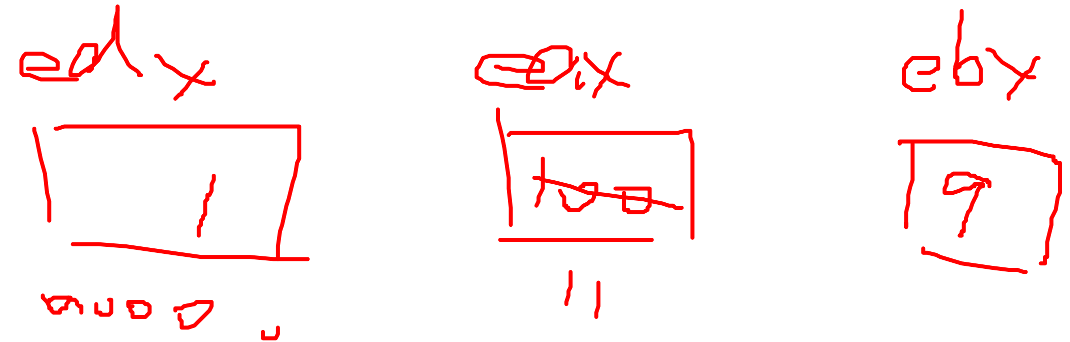


```
mov      eax, 10
mov      ebx, 12
mul      ebx              ; result is in eax (120)
                          ; with possible overflow in edx
                          ; edx is changed!
```

Instructions with implied operands

- div implied operand is in EDX:EAX
- So extend EAX into EDX before division
- div   op2   ; quotient is in EAX

  ; remainder is in EDX



- Example:

```
mov     eax, 100
cdq                     ; extend the sign into edx
mov     ebx, 9
div     ebx             ; quotient is in eax (11)
                        ; remainder is in edx (1)
```

Operand notation (See Instruction list)

Operand	Description
r8	8-bit general-purpose register: AL, AH, BL, BH, CL, CH, DL, DH
r16	16-bit general-purpose or multi-purpose register: AX, BX, CX, DX, SI, DI, BP, SP
r32	32-bit general-purpose or multi-purpose register: EAX, EBX, ECX, EDX, ESI, EDI, EBP, ESP
reg	any general-purpose or multi-purpose register
accum	AL, AX, or EAX (depending on operand size)
mem	8-bit, 16-bit, or 32-bit memory location (depending on operand size)
segreg	16-bit segment register: SS, CS, DS, ES, FS, GS
r/m8	8-bit register or memory location
r/m16	16-bit register or memory location
r/m32	32-bit register or memory location
imm8	8-bit literal value
imm16	16-bit literal value
imm32	32-bit literal value
imm	8-bit, 16-bit, or 32-bit literal value (depending on operand size)

Examples

Syntax	Examples
MOV *mem,accum*	`mov total,eax` `mov response,al`
MOV *accum,mem*	`mov al,char` `mov eax,size`

Syntax	Examples
MOV *mem,imm*	`mov color,7` `mov response,'y'`

Syntax	Examples
MOV *reg,imm*	`mov ecx,256` `mov edx,OFFSET myString`

Notes:

accum means "eax or some valid part of eax"

imm means "a literal or constant"

Examples

Syntax	Examples

MOV *reg,reg*	`mov dh,bh`
	`mov edx,ecx`
	`mov ebp,esp`

MOV *mem,reg*	`mov count,ecx` `mov num1,bx`
MOV *reg,mem*	`mov ebx,pointer` `mov al,response`

Syntax	Examples
MOV *sreg,reg16*	`mov ds,ax`
MOV *sreg,mem16*	`mov es,pos1`
MOV *reg16,sreg*	`mov ax,ds`
MOV *mem16,sreg*	`mov stack_save,ss`

Notes:

mem8 means "BYTE"

mem16 means "WORD"

mem32 means "DWORD"

sreg means CS, DS, ES, FS, GS, or SS

Invalid MOV statements

```
.data
bVal   BYTE    100
bVal2  BYTE    ?
wVal   WORD    2
dVal   DWORD   5

.code
   mov ds,45          immediate move to DS not permitted
   mov esi,wVal       size mismatch
   mov eip,dVal       EIP cannot be the destination
   mov 25,bVal        immediate value cannot be destination
   mov bVal2,bVal     memory-to-memory move not permitted
```

25 = bval

Libraries

- We will use Irvine's library (for now) to handle the really awful stuff
  - Input/output
  - Screen control
  - Timing
  - etc.
- Check IrvineLibHelp, or find the descriptions in your textbook.

Library Procedures – Overview 1

- Clrscr – clear the screen
  - Preconditions: none
  - Postconditions: screen cleared, and cursor is at upper left corner

- Crlf – New line
  - Preconditions: none
  - Postconditions: cursor is at beginning of next new line

Library Procedures – Overview 2

- ReadInt – Reads an integer from keyboard, terminated by the Enter key
  - Preconditions: none
  - Postconditions: value entered is in EAX

- ReadString – Reads a string from keyboard, terminated by the Enter key
  - Preconditions: OFFSET of memory destination in EDX
    Size of memory destination in ECX
  - Postconditions: String entered is in memory
    Length of string entered is in EAX

Library Procedures – Overview 3

- WriteInt, WriteDec – Writes an integer to the screen
  - Preconditions: value in EAX
  - Postconditions: value displayed
  - WriteInt displays +/-

- WriteString – Writes a null-terminated string to the screen
  - Preconditions: OFFSET of memory location in EDX
  - Postconditions: String displayed

Calling a Library Procedure

- The INCLUDE directive copies the procedure prototypes (declarations) into the program source code.

- Call a library procedure using the CALL instruction.

In-line Comments

- Start with ;
- May be on separate line or at the end of a line
- Use comments to clarify lines or sections
- Preferred …

```
; Calculate the number of students on-line today.
          mov     eax,size
          sub     eax,absent
          mov     present,eax
```

- OK …

```
          mov     eax,size        ;start with class size
          sub     eax,absent      ;subtract absentees
          mov     present,eax     ;number present
```

- Terrible …

```
          mov     eax,size        ;move size into eax
          sub     eax,absent      ;subtract absent from eax
          mov     present,eax     ;move eax to present
```

Example Problem Definition

Write a MASM program to perform the following tasks:

1. Introduce yourself to the user.
2. Get the user’s name and number of yards.
3. Greet the user, and report the yards in inches.
4. Say good-bye to the user.

Requirements:

1. The user’s name and yards must be entered by the user, and must be stored and accessed as data segment variables.
2. The “yard-to-inch factor” (36) must be defined as a constant.

Program Design

- Decide what the program should do
- Define algorithm(s)
- Decide what the output should show
- Determine what variables/constants are required

Implementing a MASM program

- Open project
- Start with template, “save as” <.asm file in the program directory>
    - This is the source code file
- Fill in identification block information
- Create comment outline for algorithms
- Define constants
    - Test/fix (syntax check, nothing happens)
- Declare variables (.data section)
    - Test/fix (syntax check, nothing happens)
- Enter the output code
    - Test/fix (no calculations, usually everything show 0)
- Enter the input code
    - Test/fix (no calculations, echo input)
- Enter the calculation code
    - Test/fix (logic check, verify)

*First try Debug, Start Without Debugging (more later on using the debug system)

Writing a MASM program

- Demo