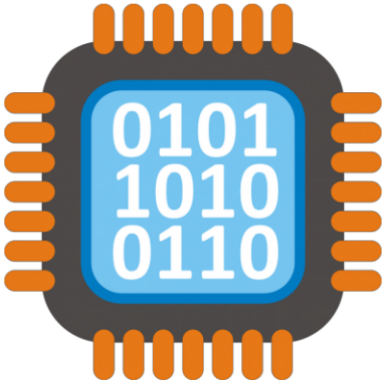
Secure Assembly Coding

Week # 12 Lectures



Dr. Qasem Abu Al-Haija,
Department of Cybersecurity

Addressing Modes

Summary of the addressing modes

Addressing Mode	Operand	Default Segment
Register	Reg	None
Immediate	Data	None
Direct	[offset]	DS
Register Indirect	[BX] [SI] [DI]	DS DS DS
Based Relative	[BX]+disp [BP]+disp	DS SS
Indexed Relative	[DI]+disp [SI]+disp	DS DS
Based Indexed Relative	[BX][SI or DI]+disp [BP][SI or DI]+disp	DS SS

16 bit Segment Register Assignments

Type of Memory Reference	Default Segment	Offset
Instruction Fetch	CS	IP
Stack Operations	SS	SP,BP
General Data	DS	BX, address
String Source	DS	SI, DI, address
String Destination	ES	DI

Example for default segments

- The following registers are used as offsets. Assuming that the default segment used to get the logical address, give the segment register associated?

a) BP b)DI c)IP d)SI, e)SP, f) BX

- Show the contents of the related memory locations after the execution of this instruction

  MOV [BP][SI]+10,DX

  if DS=2000, SS=3000,CS=1000,SI=4000,BP=7000,DX=1299 (all hex)

Assemble: Converting Assembly Language Code To Machine Language Code

Key Benefits of Assembly Language

- There is a one-to-one relationship between the assembly and machine language instructions
- What is found is that a compiled machine code implementation of a program written in high-level language results in inefficient code
  - More machine language instructions than an assembled version of an equivalent handwritten assembly language program
- Two key benefits of assembly language programming
  - It takes up less memory
  - It executes much faster

Languages in terms of applications

- One of the most beneficial uses of assembly language programming is real-time applications.

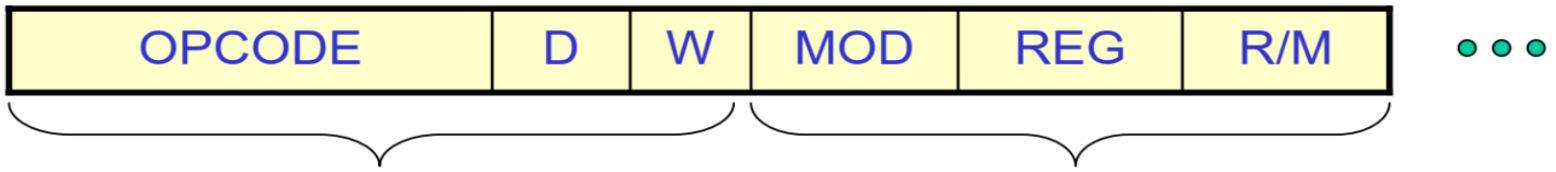
- Real time means the task required by the application must be completed before any other input to the program that will alter its operation can occur.

- For example, the device service routine which controls the operation of the floppy disk drive is a good example that is usually written in assembly language

Languages in terms of applications

- Assembly language is not only good for controlling hardware devices but also for performing pure software operations
  - Searching through a large table of data for a special string of characters
  - Code translation from ASCII to EBCDIC
  - Table sort routines
  - Mathematical routines
- Assembly language: perform real-time operations
- High-level languages: Those operations mostly not critical in time

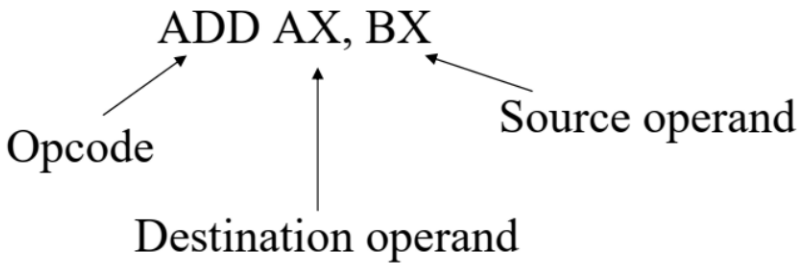
Converting Assembly Language Instructions to Machine Cod



- An instruction can be coded with 1 to 6 bytes
- **Byte 1 contains three kinds of information:**
  - Opcode field (6 bits) specifies the operation such as add, subtract, or move
  - Register Direction Bit (D bit)
    - Tells the register operand in REG field in byte 2 is source or destination operand
      - 1:Data flow to the REG field from R/M
      - 0: Data flow from the REG field to the R/M
  - Data Size Bit (W bit)
    - Specifies whether the operation will be performed on 8-bit or 16-bit data
      - 0: 8 bits
      - 1: 16 bits
- **Byte 2 has two fields:**
  - Mode field (MOD) – 2 bits
  - Register field (REG) - 3 bits
  - Register/memory field (R/M field) – 2 bits

Converting Assembly Language Instructions to Machine Cod

- The sequence of commands used to tell a microcomputer what to do is called a **program**
- Each command in a program is called an **instruction**
- 8086 understands and performs operations for **117 basic instructions**
- The native language of the **IBM PC** is the machine language of 8086/8088
- A program written in machine code is referred to as **machine code**
- In 8086 assembly language, each of the operations is described by alphanumeric symbols instead of just 0s or 1s



Converting Assembly Language Instructions to Machine Cod

- **REG field is used to identify the register for the first operand**

REG	W = 0	W = 1
000	AL	AX
001	CL	CX
010	DL	DX
011	BL	BX
100	AH	SP
101	CH	BP
110	DH	SI
111	BH	DI

Converting Assembly Language Instructions to Machine Cod

- 2-bit MOD field and 3-bit R/M field together specify the second operand

CODE	EXPLANATION
00	Memory Mode, no displacement follows*
01	Memory Mode, 8-bit displacement follows
10	Memory Mode, 16-bit displacement follows
11	Register Mode (no displacement)

*Except when R/M = 110, then 16-bit displacement follows

(a)

MOD = 11			EFFECTIVE ADDRESS CALCULATION			
R/M	W = 0	W = 1	R/M	MOD = 00	MOD = 01	MOD = 10
000	AL	AX	000	(BX) + (SI)	(BX) + (SI) + D8	(BX) + (SI) + D16
001	CL	CX	001	(BX) + (DI)	(BX) + (DI) + D8	(BX) + (DI) + D16
010	DL	DX	010	(BP) + (SI)	(BP) + (SI) + D8	(BP) + (SI) + D16
011	BL	BX	011	(BP) + (DI)	(BP) + (DI) + D8	(BP) + (DI) + D16
100	AH	SP	100	(SI)	(SI) + D8	(SI) + D16
101	CH	BP	101	(DI)	(DI) + D8	(DI) + D16
110	DH	SI	110	DIRECT ADDRESS	(BP) + D8	(BP) + D16
111	BH	DI	111	(BX)	(BX) + D8	(BX) + D16

(b)

Example:

- MOV BL,AL
- Opcode for MOV = 100010
- We'll encode AL so
  - D = 0 (AL source operand)
- W bit = 0 (8-bits)
- MOD = 11 (register mode)
- REG = 000 (code for AL)
- R/M = 011

OPCODE	D	W	MOD	REG	R/M
100010	0	0	11	000	011

MOV BL,AL => 10001000 11000011 = 88 C3h

ADD AX,[SI] => 00000011 00000100 = 03 04 h

ADD [BX][DI] + 1234h, AX => 00000001 10000001 __ __ h

=> 01 81 34 12 h

Disassemble: Converting Machine Language Code To Assembly Language Code

Disassembly of Machine Codes

- Indeed, there's no real difference between machine language and any other programming language; machine language is just a little harder to read.
  - Understanding it requires patience and the right reference.

- Finding the right reference is a large matter of knowing which CPU architecture the machine language was written for as each type of CPU has its own dialect.
  - It can also be important to know what CPU mode the machine language was written for.
  - Modern x86 CPUs, for instance, can be configured to use 16- or 32-bit operands and addressing by default, and the same sequence of machine language bytes may mean different things depending upon the CPU's state.
  - Matters become even more complex when 64-bit instructions are introduced.

Disassembly of Machine Codes

- Since we're looking at a DOS (i.e. x86 real-mode) executable, a good reference is the Instruction Set Reference (ISR) volume from the Intel Architecture Software Developer's Manual.

- This is a formidable volume, but only a few pages are immediately interesting for our purposes. For instance;
  - Pages 1-2 through 2-6 describe the basic layout of x86 machine language instructions. (Note that since we're dealing with real-mode machine language, we're only interested in 16-bit addressing modes.)
  - Pages A-1 through A-8 give the processor's opcode map. (Note that since we're dealing with such an old program, we can assume that it only uses 8086 integer opcodes; this means that we can ignore all two-byte and escape opcodes in the opcode map.)

8086 Instruction Set Opcodes (1)

Operation	Operands	Opcode
ADC	see ADD	ADD opcode + $10, and xx010xxx (ModR/M byte) for $80-$83
ADD	r/m8, reg8	$00
ADD	r/m16, reg16	$01
ADD	reg8, r/m8	$02
ADD	reg16, r/m16	$03
ADD	AL, imm8	$04
ADD	AX, imm16	$05
ADD	r/m8, imm8	$80 xx000xxx (ModR/M byte)
ADD	r/m16, imm16	$81 xx000xxx (ModR/M byte)
ADD	r/m16, imm8	$83 xx000xxx (ModR/M byte)
AND	see ADD	ADD opcode + $20, and xx100xxx (ModR/M byte) for $80, $81,$83
CALL	32-bit displacement	$9A
CALL	16-bit displacement	$E8
CLD		$FC
CMP	See ADD	ADD opcode + $38, and xx111xxx (ModR/M byte) for $80, $81,$83
CMPSB	ES:[DI]==DS:[SI]	$A6
CMPW	ES:[DI]==DS:[SI]	$A7
DEC	r/m8	$FE, xx001xxx (ModR/M byte)
DEC	r/m16	$FF, xx001xxx (ModR/M byte)
DEC	reg16	$48 + reg16 code
DIV	r/m8	$F6, xx110xxx (ModR/M byte)
DIV	r/m16	$F7, xx110xxx (ModR/M byte)
HLT		$F4
IDIV	r/m8	$F6, xx111xxx (ModR/M byte)
IDIV	r/m16	$F7, xx111xxx (ModR/M byte)
IMUL	r/m8	$F6, xx101xxx (ModR/M byte)
IMUL	r/m16	$F7, xx101xxx (ModR/M byte)

8086 Instruction Set Opcodes (2)

Operation	Operands	Opcode
IN	AL, addr8	$E4
IN	AX, addr8	$E5
IN	AL, port[DX]	$EC
IN	AX, port[DX]	$ED
INC	r/m8	$FE, xx000xxx (ModR/M byte)
INC	r/m16	$FF, xx000xxx (ModR/M byte)
INC	reg16	$40 + reg16 code
IRET	48-bit POP	$CF
JA	8-bit relative	$77
JAE	8-bit relative	$73
JB	8-bit relative	$72
JBE	8-bit relative	$76
JE	8-bit relative	$74
JG	8-bit relative	$7F
JGE	8-bit relative	$7D
JL	8-bit relative	$7C
JLE	8-bit relative	$7E
JMP	32-bit displacement	$EA
JNE	8-bit relative	$75
JZ	8-bit relative	$74
LDS	reg16, mem32	$C4
LES	reg16, mem32	$C5
LODSB	AL = DS:[SI]	$AC
LODSW	AX = DS:[SI]	$AD

8086 Instruction Set Opcodes (3)

Operation	Operands	Opcode
LOOP	8-bit relative	$E2
MOV	r/m8, reg8	$88
MOV	r/m16, reg16	$89
MOV	AL, mem8	$A0
MOV	AX, mem16	$A1
MOV	mem8, AL	$A2
MOV	mem16, AX	$A3
MOV	reg8, imm8	$B0 + reg8 code
MOV	reg16,imm16	$B8 + reg16 code
MOV	r/m8, imm8	$C6, xx000xxx(ModR/M byte)
MOV	r/m16, imm16	$C7, xx000xxx(ModR/M byte)
MOV	r/m16,sreg	$8C, xx0 sreg xxx(ModR/M byte)
MOV	sreg, r/m16	$8E, xx0 sreg xxx(ModR/M byte)
MOVSB	ES:[DI] = DS:[SI]	$A4
MOVSW	ES:[DI] = DS:[SI]	$A5
MUL	r/m8	$F6, xx100xxx (ModR/M byte)
MUL	r/m16	$F7, xx100xxx (ModR/M byte)
NEG	r/m8	$F6, xx011xxx (ModR/M byte)
NEG	r/m16	$F7, xx011xxx (ModR/M byte)
NOT	r/m8	$F6, xx010xxx (ModR/M byte)
NOT	r/m16	$F7, xx010xxx (ModR/M byte)
OR	see ADD	ADD opcode + $08, and xx001xxx (ModR/M byte) for $80, $81,$83

8086 Instruction Set Opcodes (4)

Operation	Operands	Opcode
OUT	addr8, AL	$E6
OUT	addr8, AX	$E7
OUT	port[DX], AL	$EE
OUT	port[DX], AX	$EF
POP	r/m16	$8F
POP	reg16	$58 + reg16 code
POP	sreg	$07 + ES = 0, CS = 8, SS = $10, DS = $18
PUSH	r/m16	$FF, xx110xxx (ModR/M byte)
PUSH	reg16	$50 + reg16 code
PUSH	sreg	$06 + ES = 0, CS = 8, SS = $10, DS = $18
REP		$F3
REPNE		$F2
RET	32-bit POP	$CA
RET	16-bit POP	$C2
SBB	see ADD	ADD opcode + $18, and xx011xxx (ModR/M byte) for $80, $81,$83
SCASB	ES:[DI] == AL	$AE
SCASW	ES:[DI] == AX	$AF
STD		$FD
STOSB	ES:[DI] = AL	$AA
STOSW	ES:[DI] = AX	$AB
SUB	see ADD	ADD opcode + $28, and xx101xxx (ModR/M byte) for $80, $81,$83
XOR	see ADD	ADD opcode + $30, and xx110xxx (ModR/M byte) for $80, $81,$83

8086 Instruction Set Opcodes (5)

addr8 = 8-bit address of I/O port
reg8 = AL = 0, CL = 1, DL = 2, BL = 3, AH =4, CH = 5, DH = 6, BH = 7
reg16 = AX = 0, CX =1, DX =2, BX =3, SP = 4, BP = 5, SI = 6, DI = 7
sreg = ES = 0, CS = 1, SS = 2, DS = 3
mem8 = memory byte (direct addressing only)
mem16 = memory word (direct addressing only)
r/m8 = reg8 or mem8
r/m16 = reg16 or mem16
imm8 = 8 bit immediate
imm16 = 16 bit immediate

Example of Code Disassembly

Assume the first bytes of machine language code are located at offset 01000H. They are:

8C C0 05 10 00 0E 1FA3 04 00 03 06 0C 00 8E C0 …

Disassemble this code to obtain an assembly language code?

Example of Code Disassembly

8C C0	MOV AX ES
05 10 00	ADD AX 0010
0E	PUSH CS
1F	POP DS
A3 04 00	MOV [0004], AX
03 06 0C 00	ADD AX , [000C]
8E C0 …	MOV ES AX

Thank you