12 – ASSEMBLY LANGUAGE

COMP256 – COMPUTING ABSTRACTIONS

DICKINSON COLLEGE

ASSEMBLY LANGUAGE PROGRAMMING

- A thought before we begin…
  - "He who hasn't hacked assembly language as a youth has no heart. He who does as an adult has no brain."

    John Moore

ASSEMBLY LANGUAGE PROGRAMMS

- An assembly language is an abstraction for a machine language.
  - Assembly language instructions:
    - Are mnemonic (human readable, easier to remember text) version of machine language instructions.
    - Usually have a 1-to-1 correspondence to machine language instructions.

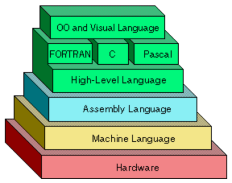


Image from: https://www.codetips.co.uk/translation-and-types/

Machine Language	Meaning	Assembly Language
1000 0001 0 10 00101	R0 = MM[5]	LOAD R2 5
1010 0001 00 11 00 01	R3 = R0 + R1	ADD R3 R0 R1

ASSEMBLY LANGUAGES

- *Assembly Languages* are low level translated languages.
  - A program called an *assembler* translates the assembly source code program into an equivalent executable machine language program for the target machine.
  - Assembly language source code is specific to the target machine.
- Used in applications that require:
  - Precise control of the system
  - Highly optimized performance
  - E.g. Operating systems, device drivers, real-time control systems, game engines

Intel x86, IA-32, x86-64
ARM, MIPS, SPARC, DEC, IBM360,
Motorola 6800, etc …

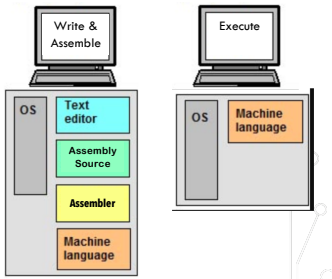
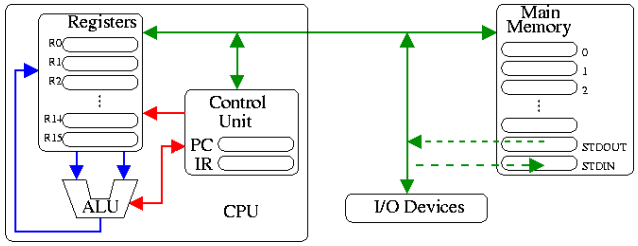


Image adapted from: https://encyclopedia2.thefreedictionary.com/interpreter

OUR ASSEMBLY LANGUAGE: THE MACHINE

- Simplified MIPS machine and assembly language

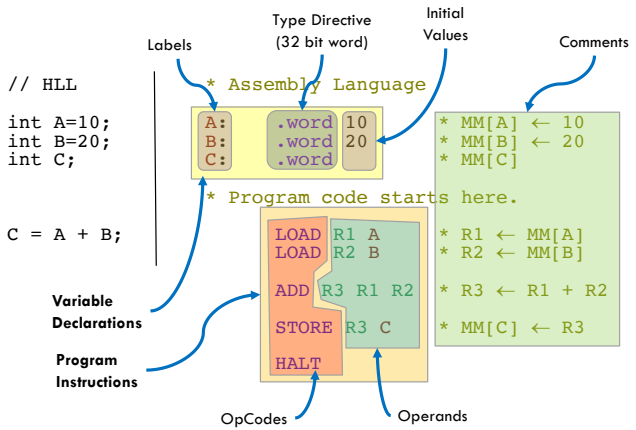


- 16 Registers (R0-R15)
  - 32 bits each
  - R0-R11 General Purpose
  - R12-R15 Reserved
- Two special memory addresses
  - STDOUT
    - STORE to here to display to console.
  - STDIN
    - LOAD from here to read from user.

OUR ASSEMBLY LANGUAGE: FIRST EXAMPLE

```
// HLL                    * Assembly Language

int A=10;                 A:    .word 10      * MM[A] ← 10
int B=20;                 B:    .word 20      * MM[B] ← 20
int C;                    C:    .word         * MM[C]

                          * Program code starts here.

C = A + B;                      LOAD R1 A     * R1 ← MM[A]
                                LOAD R2 B     * R2 ← MM[B]

                                ADD R3 R1 R2  * R3 ← R1 + R2

                                STORE R3 C    * MM[C] ← R3

                                HALT
```

OUR ASSEMBLY LANGUAGE: TERMINOLOGY



OUR ASSEMBLY LANGUAGE: ASSEMBLING

- Make `COMP256Machine` folder
- Download `Assembler.jar` to `COMP256Machine` folder
- In terminal `cd COMP256Machine` folder
- Assemble source code program to machine language program
  - Syntax: `java -jar Assembler.jar <assembly> <executable>`
    - `<assembly>`: Filename of assembly language source code program to assemble.
    - `<executable>`: Filename for executable machine language program to create.
  - Example: `java -jar Assembler.jar example1.asm example1.exe`
    - Assembles the assembly language program in the file `example1.asm` into machine language and stores the result in the file `example1.exe`.
      - Note: `example1.asm` must be in the same folder as `Assembler.jar`

OUR ASSEMBLY LANGUAGE: RUNNING

- Download `Machine.jar` to `COMP256Machine` folder
- In terminal `cd COMP256Machine` folder
- Run machine language program
  - Syntax: `java -jar Machine.jar <executable>`
    - `<executable>`: Filename for machine language program to run.
  - Example: `java -jar Machine.jar example1.exe`
    - Loads the machine language program in the file `example1.exe` into the machine simulator.
      - Note: `example1.exe` must be in the same folder as `Machine.jar`

REGISTER TO REGISTER INSTRUCTIONS

- A **register to register instruction** operates on values from the registers and stores the result into a register.

Instruction	Example	Meaning	Comments
ADD R R R	ADD R1 R2 R3	R1 ← R2 + R3	
SUB R R R	SUB R1 R2 R3	R1 ← R2 - R3	
AND R R R	AND R1 R2 R3	R1 ← R2 & R3	Bitwise AND
OR R R R	OR R1 R2 R3	R1 ← R2 | R3	Bitwise OR
NOT R R	NOT R1 R2	R1 ← ~R2	Bitwise NOT
SHL R R	SHL R1 R2	R1 ← R2 << 1	LSb = 0
SHR R R	SHR R1 R2	R1 ← R2 >>> 1	MSb = 0
MOV R R	MOV R1 R2	R1 ← R2	Copy

DIRECT ADDRESSING MODE INSTRUCTIONS

- In a **direct addressing mode** instruction the label is used (directly) as a memory address.
  - A label is a mnemonic name for a memory address assigned by the assembler.

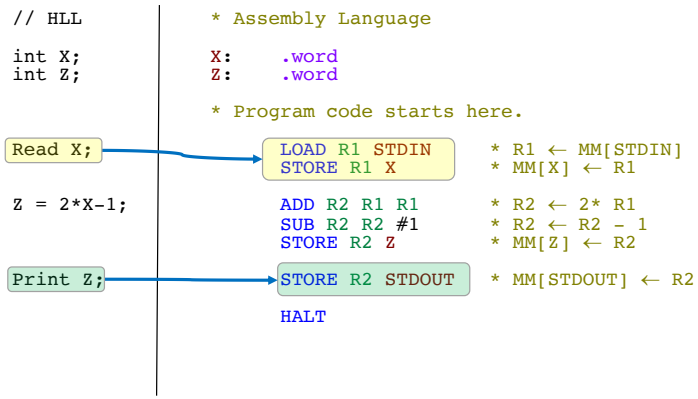
Instruction	Example	Meaning	Comments
LOAD R L	LOAD R1 X	R1 ← MM[X]	Direct Mode
STORE R L	STORE R1 X	MM[X] ← R1	Direct Mode

IMMEDIATE ADDRESSING MODE INSTRUCTIONS

- In an **immediate addressing mode** instruction the value of the operand preceded by a # is used as is (i.e. "immediately").
  - The value of an immediate mode operand can be given in decimal, hexadecimal or binary.

Instruction	Example	Meaning	Comments
ADD R R #	ADD R1 R2 #231	R1 ← R2 + 231	Immediate Mode
SUB R R #	SUB R1 R2 #1	R1 ← R2 - 1	Immediate Mode
AND R R #	AND R1 R2 #0xF00F	R1 ← R2 & 0xF00F	Immediate Mode
OR R R #	OR R1 R2 #b1001	R1 ← R2 | b1001	Immediate Mode
LOAD R #	LOAD R1 #27	R1 ← 27	Immediate Mode

OUR ASSEMBLY LANGUAGE: INPUT / OUTPUT



ACTIVITY

- Write assemble and execute an assembly language program that accomplishes the same task as the following HLL program:

```
int A;
int B;
int C;

Read A;
Read B;

C = 2*(A+10) – (B-20);

Print C;
```

ACTIVITY

- Download the Assembler and Machine from the course home page.
- Type the First Example in to a text editor.
  - Save it in the same directory as the Assembler and Machine.
- Assemble the First Example using the Assembler.
- Run the First Example using the Machine.

```
* Assembly Language

A:      .word 10        * MM[A] ← 10
B:      .word 20        * MM[B] ← 20
C:      .word           * MM[C]

* Program code starts here.

        LOAD R1 A       * R1 ← MM[A]
        LOAD R2 B       * R2 ← MM[B]

        ADD R3 R1 R2    * R3 ← R1 + R2

        STORE R3 C      * MM[C] ← R3

        HALT
```