CSE 210: Computer Organization
Lecture 2: Assembly Language

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Announcements

- Problem set 0 due Friday, Oct. 8 at 23:59
  - Access it via gradescope (link on course website)

How to Speak Computer?

```
10001100011000100000000000000000
10001100111100100000000000000100
10101100111100100000000000000000
10101100011000100000000000000100
```

2

binary → machine language

```
lw $15, 0($2)
lw $16, 4($2)
sw $16, 0($2)
sw $15, 4($2)
```

1

```
temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;
```

3

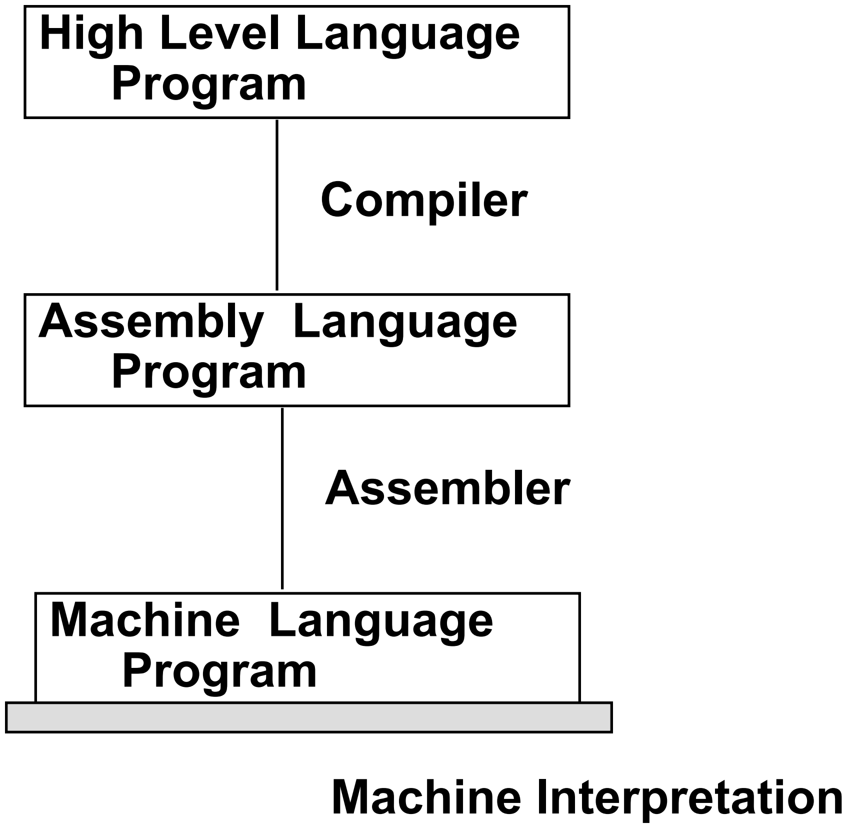
high level

Selection	High Level Language	Assembly	Machine Language
A	3	2	1
B	3	1	2
C	2	1	2
D	1	2	2
E	None of the above		

What Your CPU Understands

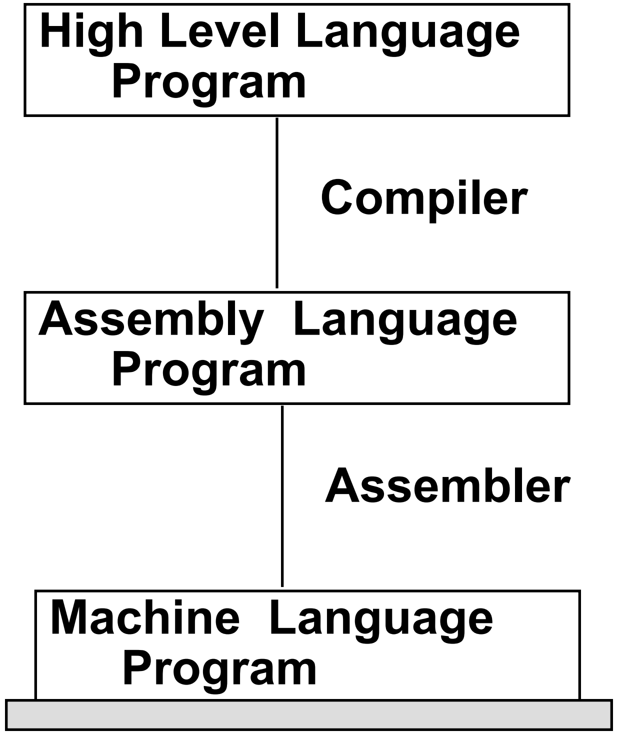
- Electricity
- Ones and zeros
- Problem: People don’t like writing programs in ones and zeros

How to Speak Computer




```
temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;
```

How to Speak Computer

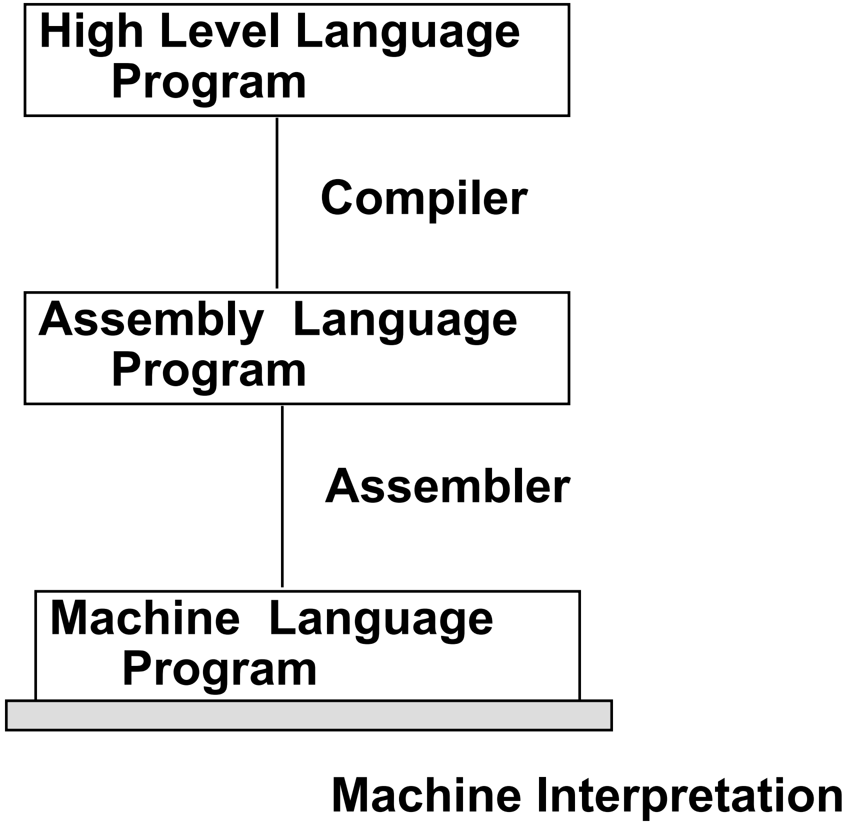


Machine Interpretation

```
temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;
```

```
lw  $15,   0($2)
lw  $16,   4($2)
sw  $16,   0($2)
sw  $15,   4($2)
```

How to Speak Computer

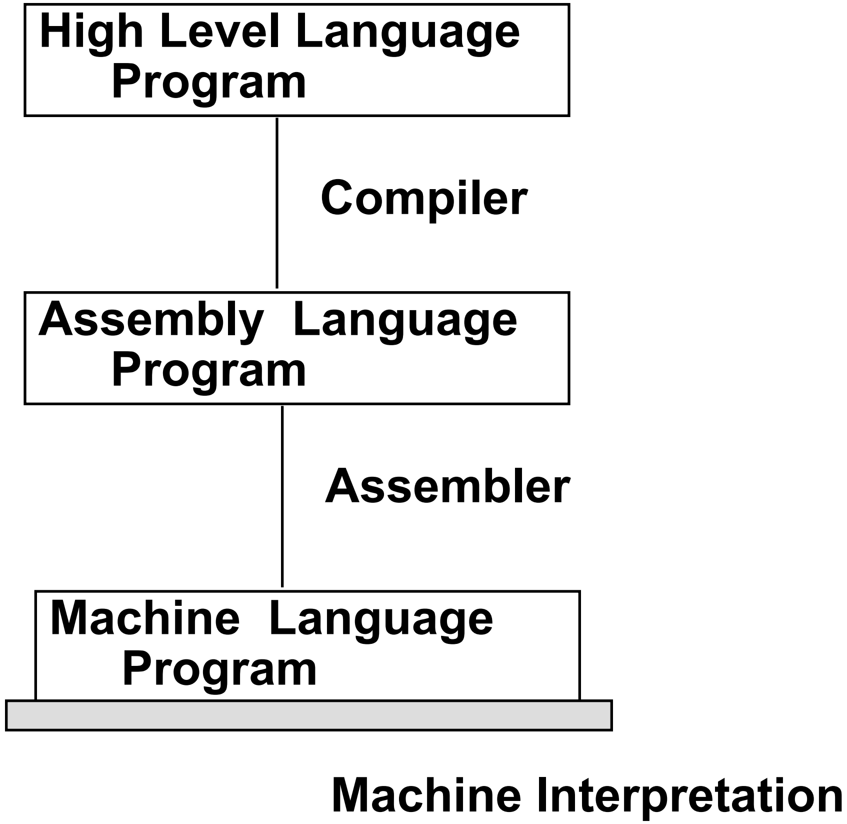



```
temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;
```

```
lw  $15,   0($2)
lw  $16,   4($2)
sw  $16,   0($2)
sw  $15,   4($2)
```

```
10001100011000100000000000000000
10001100111100100000000000000100
10101100111100100000000000000000
10101100011000100000000000000100
```

How to Speak Computer

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temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;
```

```
lw  $15,   0($2)
lw  $16,   4($2)
sw  $16,   0($2)
sw  $15,   4($2)
```

```
10001100011000100000000000000000
10001100111100100000000000000100
10101100111100100000000000000000
10101100011000100000000000000100
```

Machine does something!

How to Speak Computer

High Level Language Program

Compiler

Assembly Language Program

Assembler

Machine Language Program

Machine Interpretation

```
temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;
```

```
lw  $15,   0($2)
lw  $16,   4($2)
sw  $16,   0($2)
sw  $15,   4($2)
```

```
1000110001100010000000000000000
1000110011110010000000000000100
1010110011110010000000000000000
1010110001100010000000000000100
```

Machine does something!

Machine Language

- Actual operations built into hardware.
  - Directly translated to electrical impulses
  - 1 = electricity > .5 V, 0 = electricity < .5V

- Provides direct access to CPU components.

CPU

- Central Processing Unit, or “chip”
- Actually performs instructions

- Contains
  - Mechanism to perform arithmetic instructions
  - Small amount of memory to hold inputs and outputs for these instructions

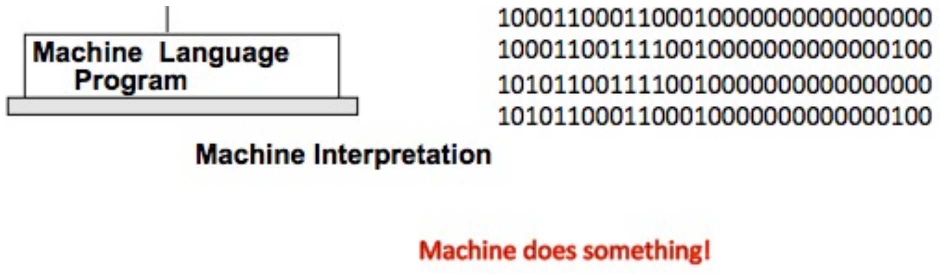
Registers

- (Very) Small amount of memory inside the CPU
- Data is put into a register before it is used in an instruction
- Manipulated data is then stored back in main memory.

Typical Machine Language Operations

- Load a word from memory into a register
- Store the contents of a register into a memory word
- Compute the sum (or difference) of two registers, store the result in a register
- Change which instruction runs next
- Change which instruction runs next based on a register value

Instruction Set Architecture (ISA)



- Abstracts from hardware (voltages) to machine language (1s & 0s)

- Encompasses all the information necessary to write a machine language program, including instructions, registers, memory access, …

- The definition (specification) of the machine language for a particular CPU

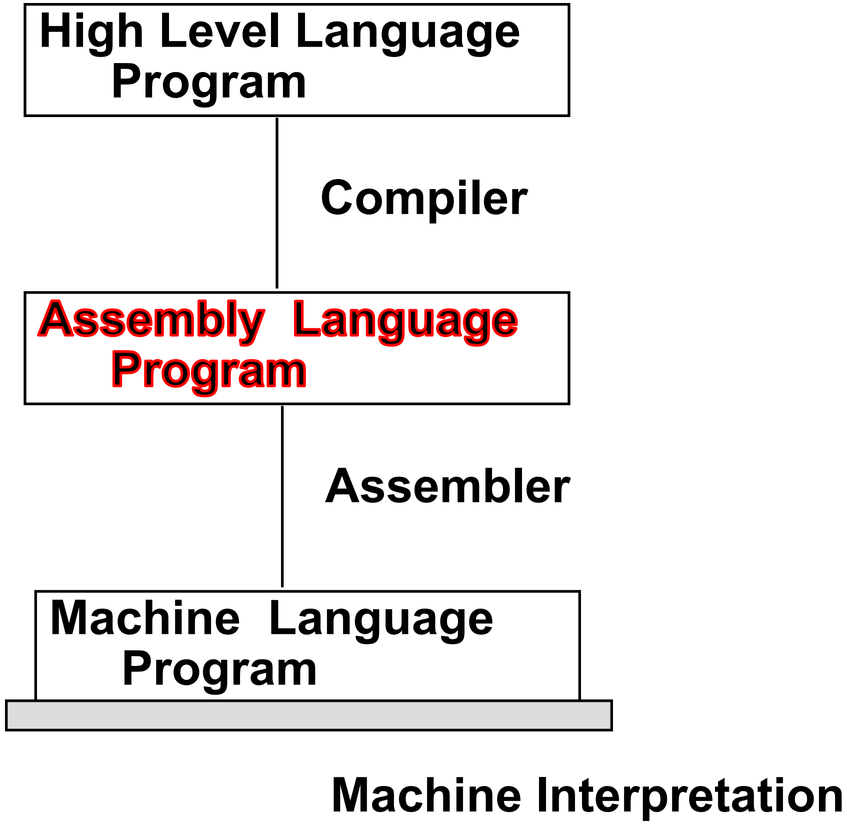
Examples of ISAs

- Intel x86, x86_64
- MIPS
- ARM
- PowerPC

Which of the following statement is generally true about ISAs?

Select	Statement
A	Many models of processors support exactly one ISA.
B	An ISA is unique to one model of processor.
C	Every processor supports multiple ISAs.
D	Each processor manufacturer has its own unique ISA.
E	None of the above

How to Speak Computer




```
temp = v[k];
v[k] = v[k+1];
v[k+1] = temp;
```

```
lw  $15,   0($2)
lw  $16,   4($2)
sw  $16,   0($2)
sw  $15,   4($2)
```

```
10001100011000100000000000000000
10001100111100100000000000000100
10101100111100100000000000000000
10101100011000100000000000000100
```

Machine does something!

Assembly Language

- Abstraction of machine language
  - From 1s & 0s to symbolic names

- Allows direct access to architectural features (registers, memory)

- Symbolic names are used for
  - operations (opcodes) (mnemonics)
  - memory locations (variables, branch labels)

C code

```
x = 4;
y = 5;
x = x + y;
```

MIPS code

```
li  $t0, 4  #load into reg
li  $t1, 5  #load into reg
add $t0, $t0, $t1 #add
```

How to Speak Computer

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10101100011000100000000000000100
```

Machine does something!

Which of these is NOT an advantage of Higher-Level Languages ?

A. Easier to debug.

B. Closer to how humans think about problems.

C. Programs don’t have to be written for a specific machine.

D. These are all advantages of higher-level languages.

Rear Admiral Grace Hopper

- Invented the compiler
- Conceptualized machine-independent programming languages.
- Popularized term “debugging”.

A single program written in a high level language can be compiled into _______ assembly language programs

A. Exactly one

B. Multiple

A single program written in assembly can be assembled into _______ machine language programs

A. Exactly one

B. Multiple

- High-level language program (in C)

```
swap (int v[], int k)
(int temp;
    temp = v[k];
    v[k] = v[k+1];
    v[k+1] = temp;
)
```

one-to-many

C compiler

- Assembly language program (for MIPS)

```
swap:  sll $2, $5, 2
    add $2, $4, $2
    lw  $15, 0($2)
    lw  $16, 4($2)
    sw  $16, 0($2)
    sw  $15, 4($2)
    jr  $31
```

one-to-one

assembler

- Machine (object, binary) code (for MIPS)

```
000000 00000 00101 0001000010000000
000000 00100 00010 0001000000100000
 . . .
```

Reading

- Next lecture: Hardware!
  - Sections 1.5

- Problem set 0 due Friday, Oct. 8 at 23:59