

CSCI 210: Computer Organization

Lecture 2: Assembly Language

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Announcements

- Problem set 0 due this Friday at 23:59
 - Access it via Gradescope (link on course website)

How to Speak Computer?

```
10001100011000100000000000000000
100011001111001000000000000000100
101011001111001000000000000000000
101011000110001000000000000000100
```

lw \$15, 0(\$2)

lw \$16, 4(\$2)

sw \$16, 0(\$2)

sw \$15, 4(\$2)

1

2

temp = v[k];

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

v[k+1] = temp;

3

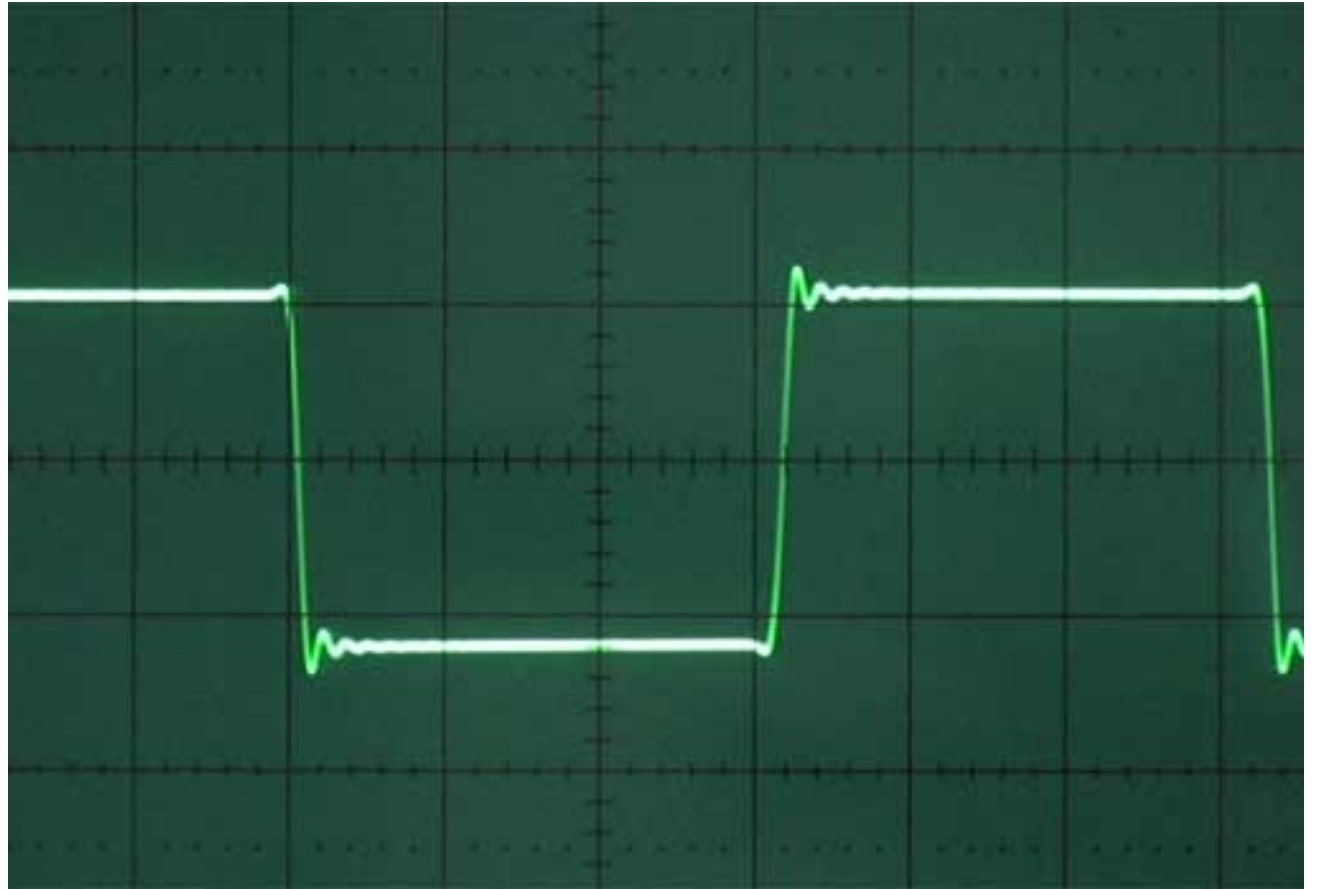
Selection	High Level Language	Assembly	Machine Language
A	3	2	1
B	3	1	2
C	2	1	2
D	1	2	2
E	None of the above		

What Your CPU Understands

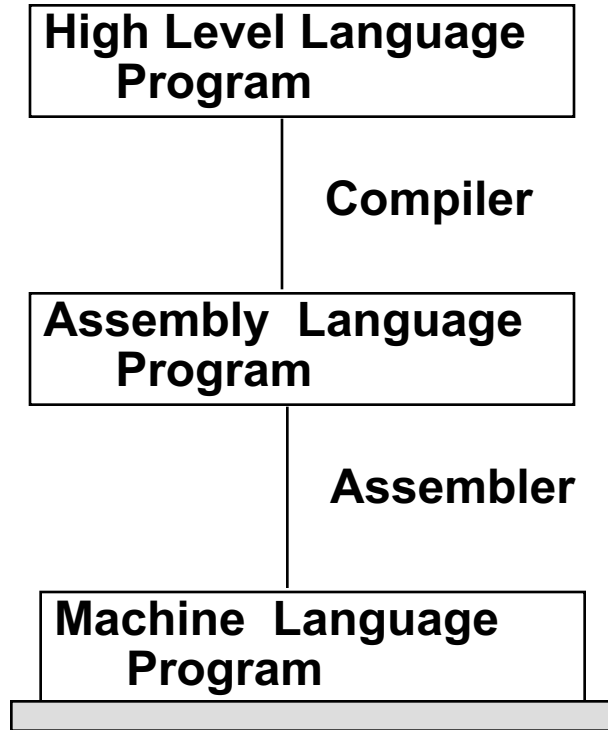
Electricity

Ones and zeros

Problem: People don't
like writing programs in
ones and zeros



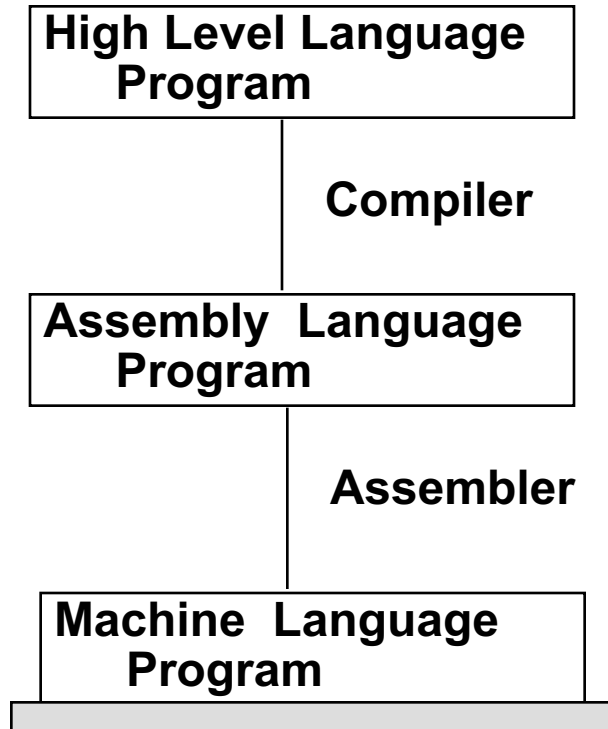
How to Speak Computer



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

Machine Interpretation

How to Speak Computer

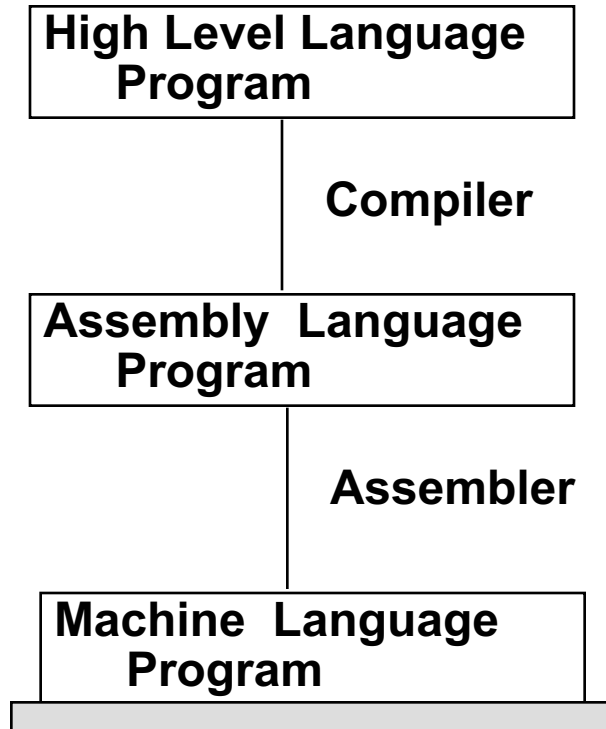


```
temp = v[k];  
v[k] = v[k+1];  
v[k+1] = temp;
```

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

Machine Interpretation

How to Speak Computer



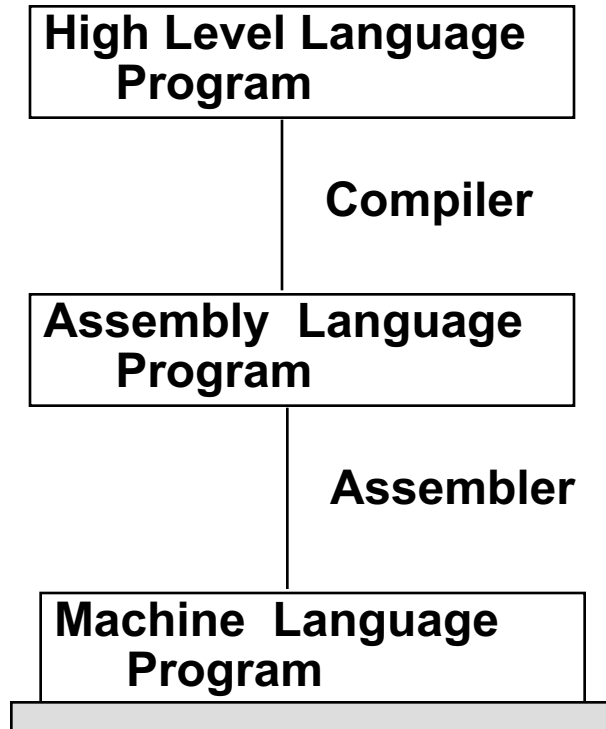
```
temp = v[k];  
v[k] = v[k+1];  
v[k+1] = temp;
```

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

```
10001100011000100000000000000000  
10001100111100100000000000000100  
10101100111100100000000000000000  
10101100011000100000000000000100
```

Machine Interpretation

How to Speak Computer



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

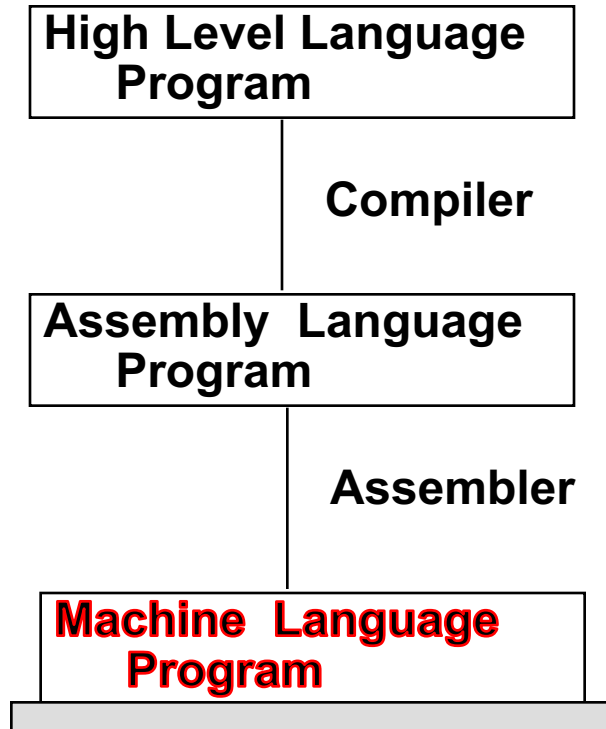
```
lw $15, 0($2)  
lw $16, 4($2)  
sw $16, 0($2)  
sw $15, 4($2)
```

```
10001100011000100000000000000000  
10001100111100100000000000000100  
10101100111100100000000000000000  
10101100011000100000000000000100
```

Machine Interpretation

Machine does something!

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)
```

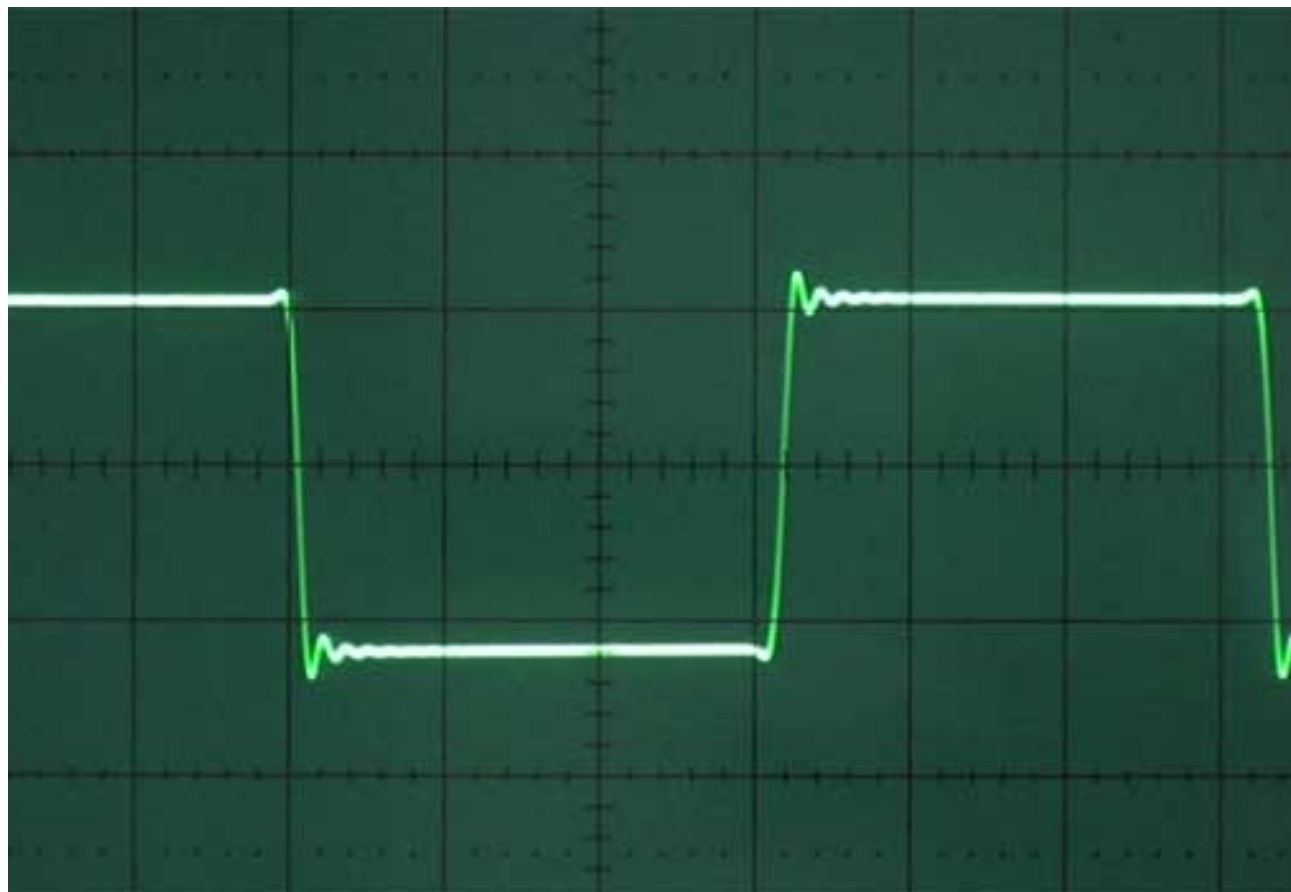
```
10001100011000100000000000000000  
10001100111100100000000000000100  
10101100111100100000000000000000  
10101100011000100000000000000100
```

Machine Interpretation

Machine does something!

Machine Language

- Actual operations built into hardware.
 - Translated to electrical impulses
 - 1: voltage $> .5\text{ V}$
 - 0: voltage $< .5\text{V}$
- Provides direct access to CPU components.



CPU

- Central Processing Unit, or “chip”
- Performs operations by executing instructions
- Contains
 - Mechanism to perform arithmetic operations
 - Small amount of memory to hold inputs and outputs for these instructions

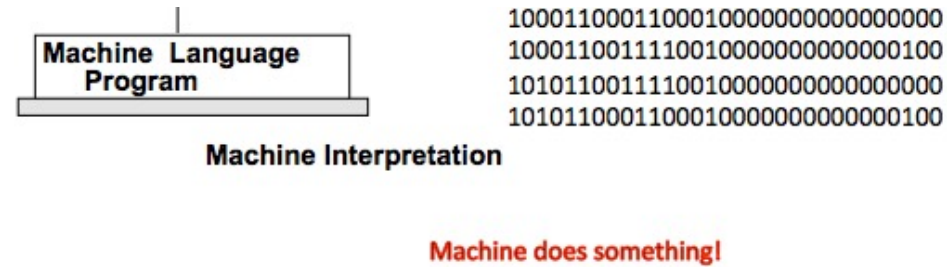
Registers

- (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

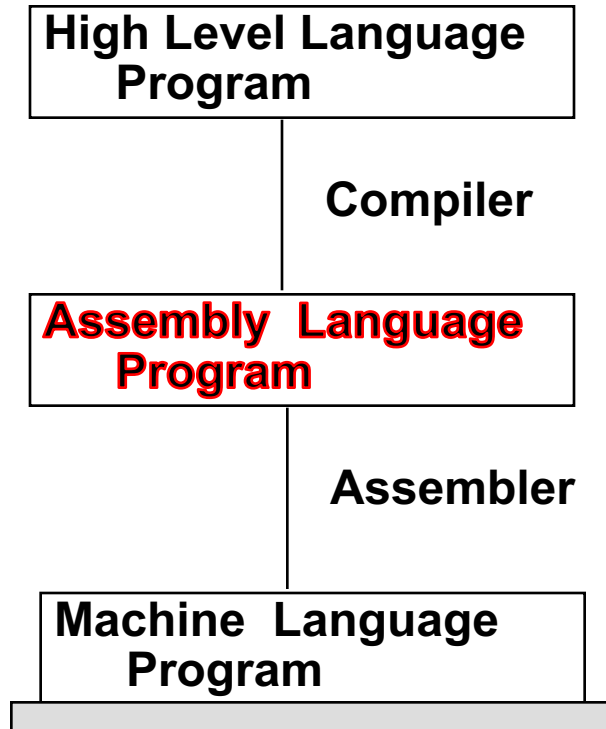
Examples of ISAs

- Intel x86, x86_64
- MIPS
- ARM: A32 (32-bit ARM), A64 (64-bit ARM), T32 (Thumb)
- Power ISA (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 Interpretation

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 (mnemonics)
 - memory locations (variables, branch labels)

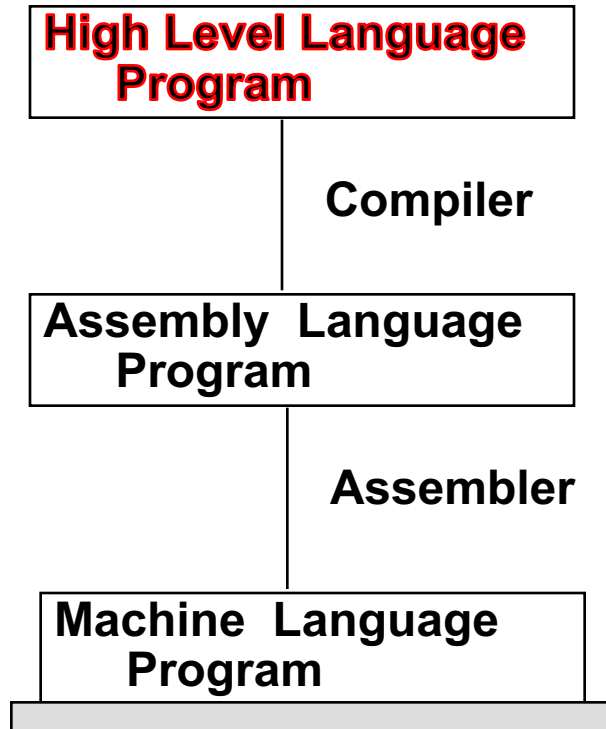
C code

```
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



```
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 Interpretation

Machine does something!

What are some advantages to a high-level language?



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
- C. At most three

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

A. Exactly one

B. Multiple

C. At most two

High-level language program (in C)

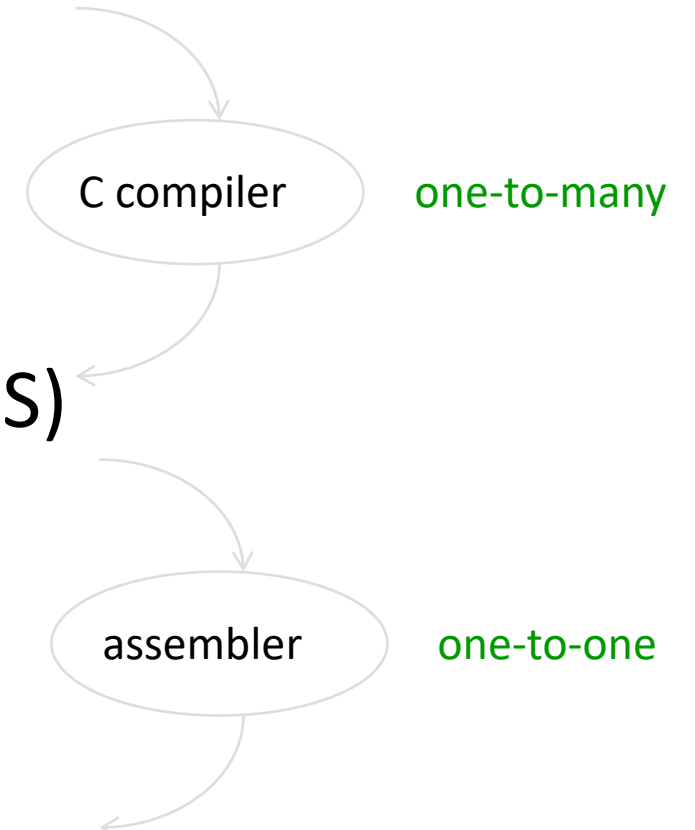
```
swap (int v[], int k)
(int temp;
    temp = v[k];
    v[k] = v[k+1];
    v[k+1] = temp;
)
```

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
```

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 at 23:59