Assemblers

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See: P&H Appendix B.1-2

```
    ...
T:  ADDI r4, r0, -1
    BEQ r3, r0, B
    ADDI r4, r4, 1
    LW r3, 0(r3)
    J T
    NOP
B:  ...
```

```
    ...
    JAL L
    nop
    nop
L:  LW r5, 0(r31)
    ADDI r5, r5, 1
    SW r5,  0(r31)
    ...
```

C

```
int x = 10;
x = 2 * x + 15;
```

compiler

MIPS assembly

```
addi r5, r0, 10
muli r5, r5, 2
addi r5, r5, 15
```

assembler

machine code

```
00100000000001010000000000001010
00000000000001010010100001000000
00100000101001010000000000001111
```

CPU

Circuits

Gates

Transistors

Silicon

```
   ...
T: ADDI r4,r0,-1
   BEQ r3, r0, B
   ADDI r4,r4, 1
   LW r3, 0(r3)
   J T
   NOP
B: ...
```

...
001000
000100
001000
100011
000010
00000000000000000000000000000000
...

Q: How to resolve labels into offsets and addresses?

A: Two-pass assembly

- 1st pass: lay out instructions and data, and build a *symbol table* (mapping labels to addresses) as you go
- 2nd pass: encode instructions and data in binary, using symbol table to resolve references

```
   ...
   JAL L
   nop
   nop
L: LW r5, 0(r31)
   ADDI r5,r5,1
   SW r5, 0(r31)
   ...
```

...
00100000001000000000000000000100
00000000000000000000000000000000
00000000000000000000000000000000
10001111111001010000000000000000
00001000101001010000000000000001
00000000000000000000000000000000
...

```
.text 0x00400000 # code segment
    ...
    ORI r4, r0, counter
    LW r5, 0(r4)
    ADDI r5, r5, 1
    SW r5,  0(r4)
    ...
.data 0x10000000 # data segment
counter:
    .word 0
```

Lessons:

- Mixed data and instructions (von Neumann)
- … but best kept in separate *segments*
- Specify layout and data using *assembler directives*
- Use *pseudo-instructions*

Pseudo-Instructions

NOP # do nothing

MOVE reg, reg # copy between regs

LI reg, imm # load immediate (up to 32 bits)

LA reg, label # load address (32 bits)

B label # unconditional branch

BLT reg, reg, label # branch less than

Assembler:

assembly instructions

+ psuedo-instructions

+ data and layout directives

= executable program

Slightly higher level than plain assembly

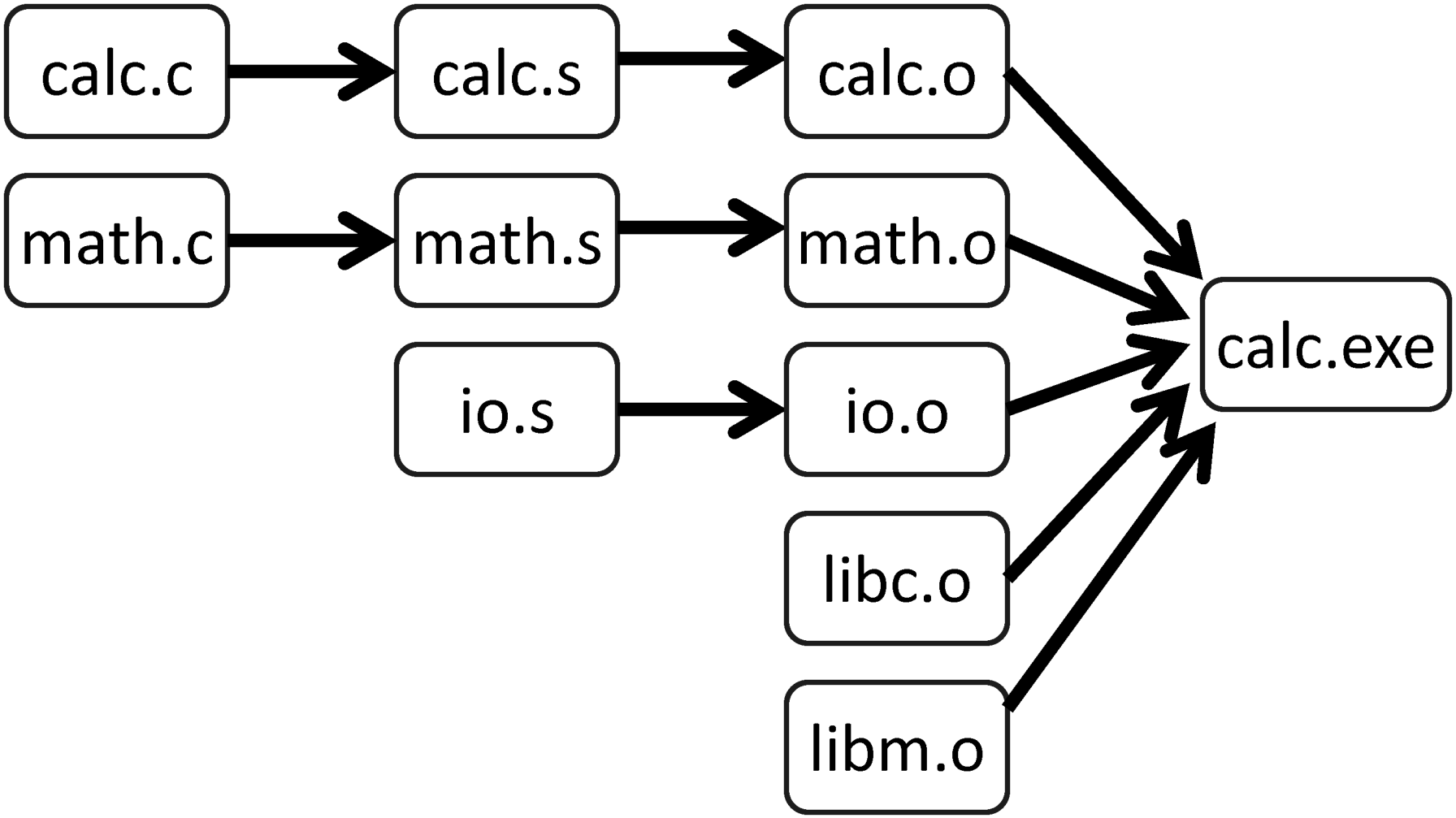
e.g: takes care of delay slots

(will reorder instructions or insert nops)

Q: Will I program in assembly?

A: I do...

- For kernel hacking, device drivers, GPU, etc.
- For performance (but compilers are getting better)
- For highly time critical sections
- For hardware without high level languages
- For new & advanced instructions: rdtsc, debug registers, performance counters, synchronization, ...


calc.c
calc.s
calc.o
math.c
math.s
math.o
io.s
io.o
libc.o
libm.o
calc.exe