INSTRUCTION SET ARCHITECTURE

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Overview

- Homework 2 due on Jan 24th (midnight)
- One more TA added
  - Please check the class webpage for office hours
- This lecture
  - Instruction set architecture (ISA)

Recall: Example MIPS Instruction

- Translate this one

f = (g + h) – (i + j);

- Assembly

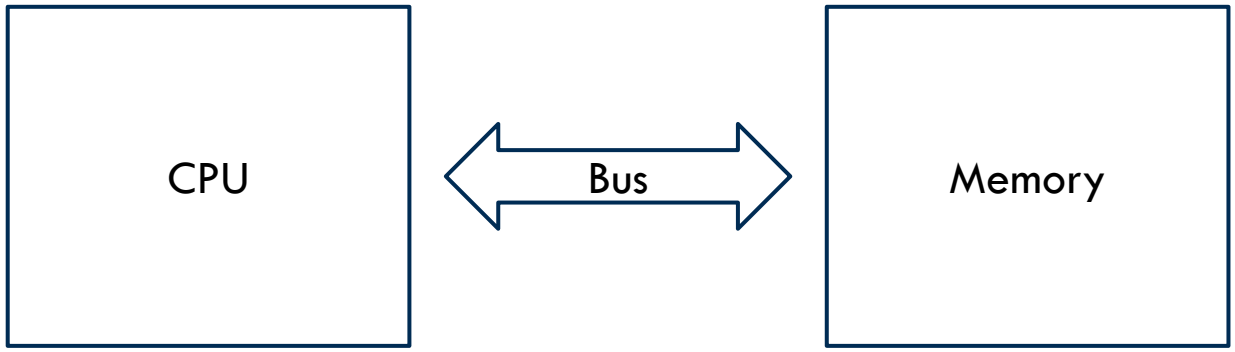
```
add  f, g, h
sub  f, f, i
sub  f, f, j
```

```
add  t0, g, h
add  t1, i, j
sub  f, t0, t1
```

- In summary
  - operations are not necessarily associative and commutative
  - More instructions than C statements
  - Usually fixed number of operands per instruction

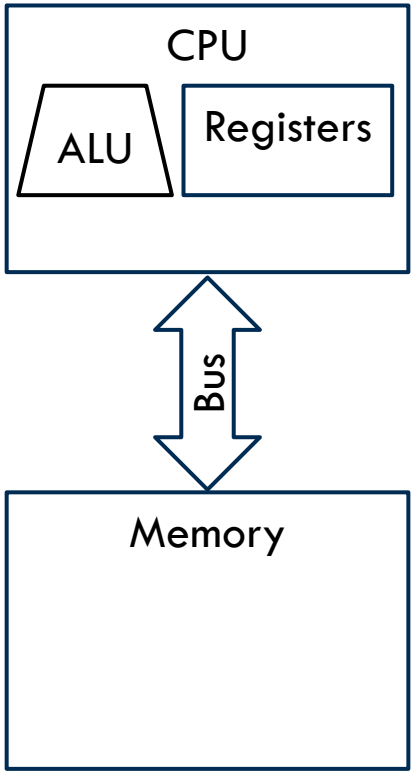
Operands

- In a high level language, each variable is a location in memory
- You may define a large number of operands (variables) in a high-level program
- The number of operands in assembly is fixed (registers)



Registers

- To simplify hardware, let's require each instruction (add, sub) only operate on registers
- For example
  - MIPS ISA has 32 registers
  - x86 has 8 registers
- 32-bit registers
  - Modern 64-bit architectures
- Every 32-bit stores a word



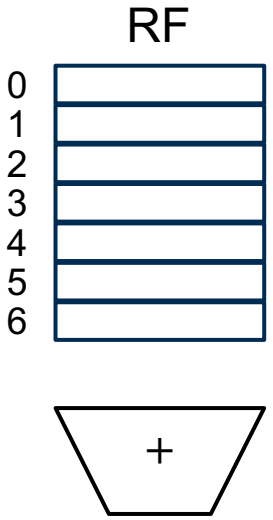
Register File

- A set of registers in the processor core
  - An index is used to identify each register

add a, b, c

add $3, $4, $1

$3 ← $4 + $1

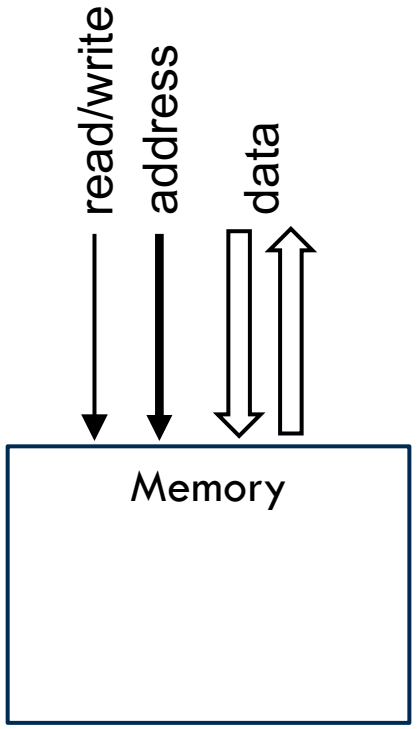


- For more readability
  - registers are partitioned as $s0-$s7 (C/Java variables), $t0-$t9 (temporary variables)…

Memory Access

- Values must be fetched from memory before (add and sub) instructions can operate on them

- Memory operations
  - Read
    - Returns *data* stored at location *address*
  - Write
    - Stores *data* at location *address*



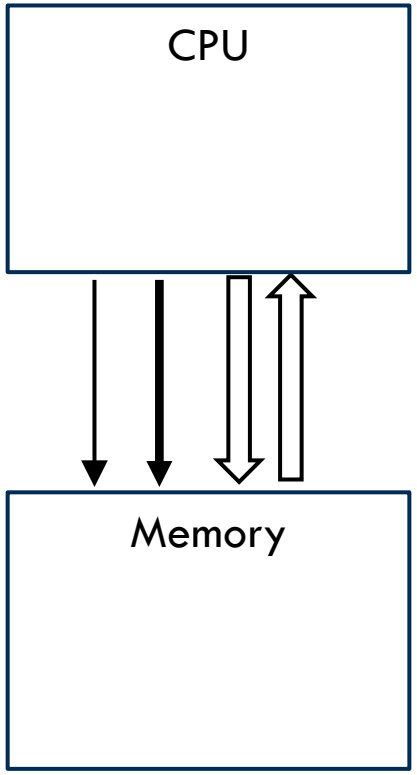
Memory Access

- Values must be fetched from memory before (add and sub) instructions can operate on them

- Load word
  - lw $t0, memory-address

- Store word
  - sw $t0, memory-address

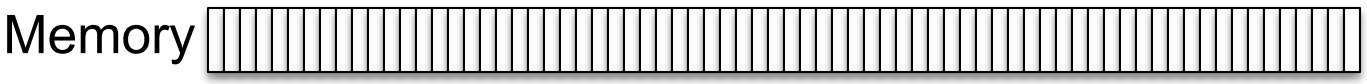
- How is memory-address determined?



Memory Address

- The compiler organizes data in memory… it knows the location of every variable (saved in a table)… it can fill in the appropriate mem-address for load-store instructions

```
int  a, b, c, d[10]
```



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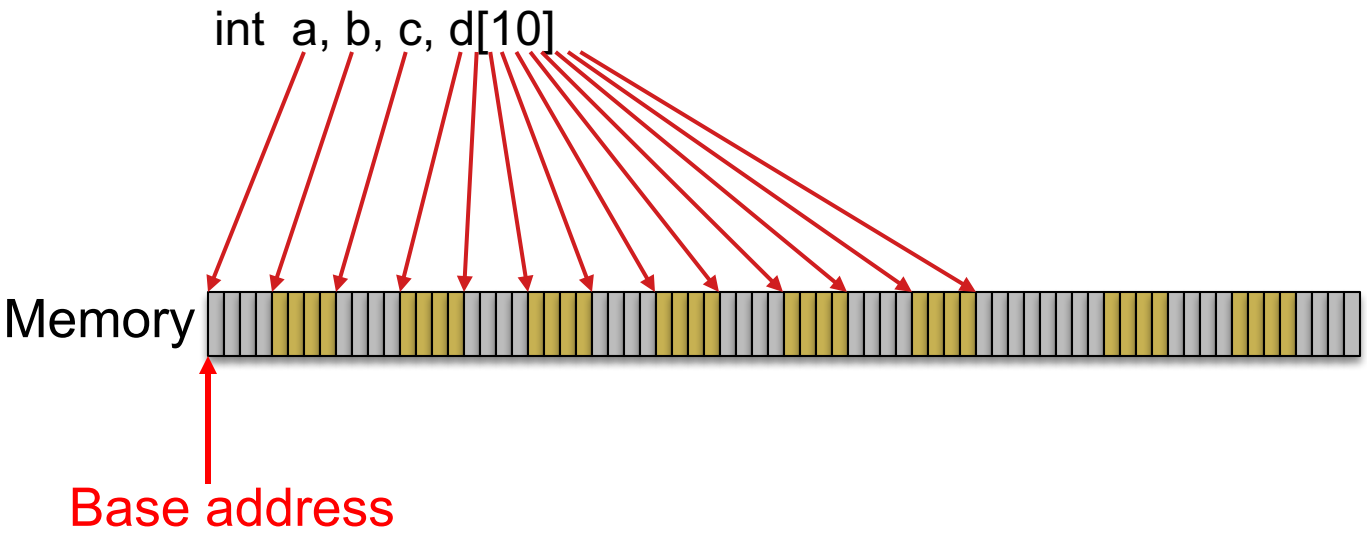
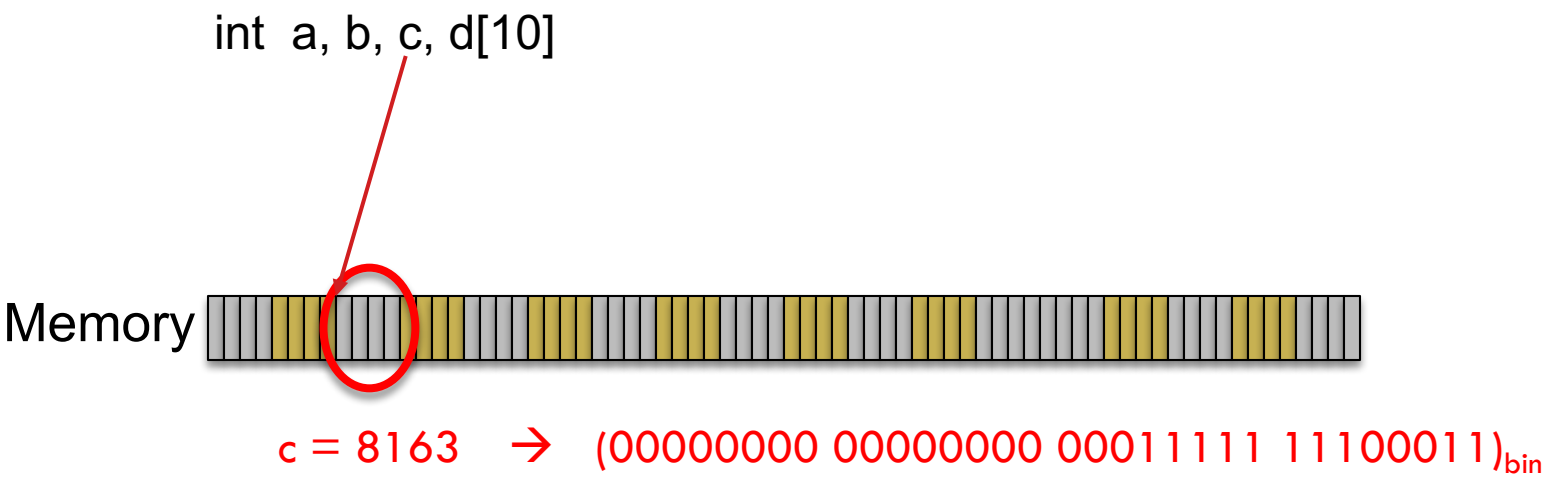


Memory Address

- Each word is referred to with the address of a single byte



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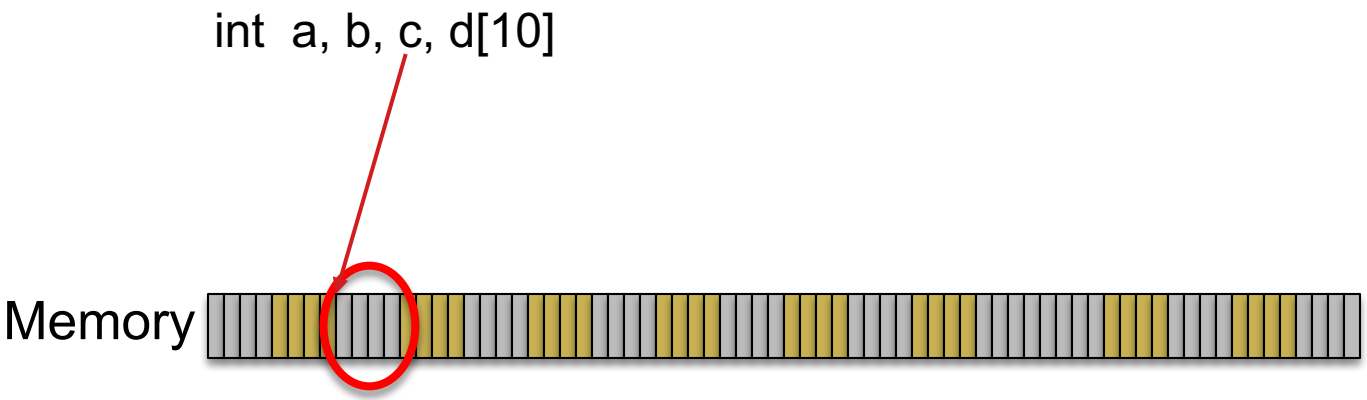
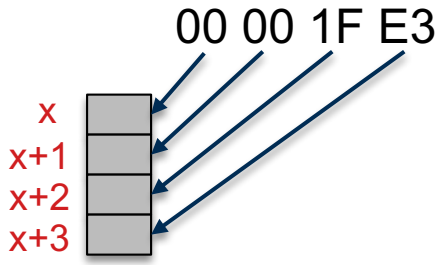


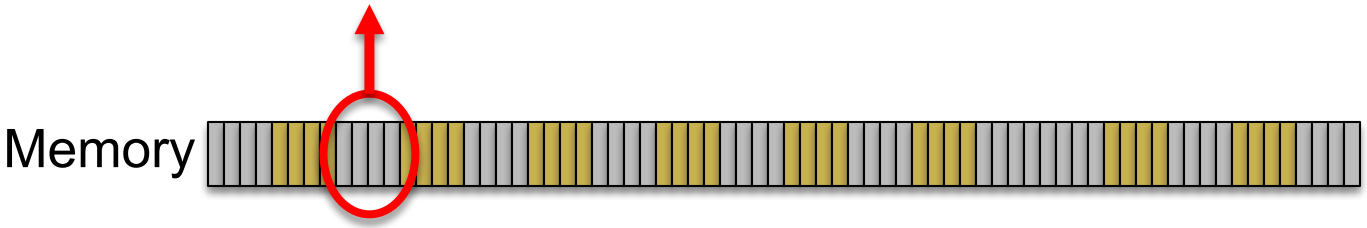
c = 8163 → $(00000000\ 00000000\ 00011111\ 11100011)_{bin}$

→ $(00\ 00\ 1F\ E3)_{hex}$ = 0X00001FE3

Memory Address

- Each word is referred to with the address of a single byte
  - Big Endian
    - MIPS, IBM 360/370,
    - Motorola 68k, Sparc,
    - HP PA, ARMv8





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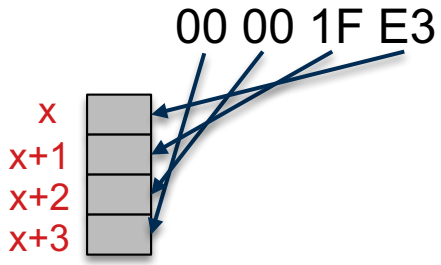
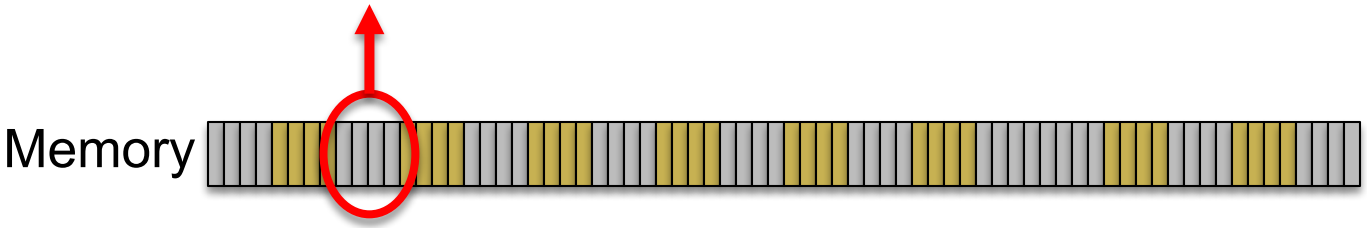
Memory Address

- Each word is referred to with the address of a single byte
  - Little Endian
    - Intel x86, DEC VAX
    - DEC Alpha





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Immediate Operand

- An instruction may require a constant as input
- An immediate instruction uses a constant number as one of the inputs (instead of a register operand)
- Putting a constant in a register requires addition to register $zero (a special register that always has zero in it) -- since every instruction requires at least one operand to be a register
- For example, putting the constant 1000 into a register:
  - addi $s0, $zero, 1000