MIPS History

- MIPS is a computer family
  - R2000/R3000 (32-bit); R4000/4400 (64-bit); R10000 (64-bit) etc.
- MIPS originated as a Stanford research project under the direction of John Hennessy
  - *Microprocessor without Interlocked Pipe Stages*
- MIPS Co. bought by SGI
- MIPS used in previous generations of DEC (now Compaq) workstations
- Now MIPS Technologies is the embedded systems market
- **MIPS is a RISC**
ISA MIPS Registers

- Thirty-two 32-bit registers $0, $1, …, $31 used for
  - integer arithmetic; address calculation; temporaries; special-purpose functions (stack pointer etc.)
- A 32-bit Program Counter (PC)
- Two 32-bit registers (HI, LO) used for multi. and division
- Thirty-two 32-bit registers $f0, f1, …, f31 used for floating-point arithmetic
  - Often used in pairs: 16 64-bit registers
- Registers are a major part of the “state” of a process
# MIPS Register names and conventions

<table>
<thead>
<tr>
<th>Register</th>
<th>Name</th>
<th>Function</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$0</td>
<td>Zero</td>
<td>Always 0</td>
<td>No-op on write</td>
</tr>
<tr>
<td>$1</td>
<td>$at</td>
<td>Reserved for assembler</td>
<td>Don’t use it</td>
</tr>
<tr>
<td>$2-3</td>
<td>$v0-v1</td>
<td>Expr. Eval/funct. Return</td>
<td></td>
</tr>
<tr>
<td>$4-7</td>
<td>$a0-a3</td>
<td>Proc./func. Call parameters</td>
<td></td>
</tr>
<tr>
<td>$8-15</td>
<td>$t0-t7</td>
<td>Temporaries; volatile</td>
<td>Not saved on proc. Calls</td>
</tr>
<tr>
<td>$16-23</td>
<td>$s0-s7</td>
<td>Temporaries</td>
<td>Should be saved on calls</td>
</tr>
<tr>
<td>$24-25</td>
<td>$t8-t9</td>
<td>Temporaries; volatile</td>
<td>Not saved on proc. Calls</td>
</tr>
<tr>
<td>$26-27</td>
<td>$k0-k1</td>
<td>Reserved for O.S.</td>
<td>Don’t use them</td>
</tr>
<tr>
<td>$28</td>
<td>$gp</td>
<td>Pointer to global static memory</td>
<td></td>
</tr>
<tr>
<td>$29</td>
<td>$sp</td>
<td>Stack pointer</td>
<td></td>
</tr>
<tr>
<td>$30</td>
<td>$fp</td>
<td>Frame pointer</td>
<td></td>
</tr>
<tr>
<td>$31</td>
<td>$ra</td>
<td>Proc./funct return address</td>
<td></td>
</tr>
</tbody>
</table>
MIPS = RISC = Load-Store architecture

- Every operand must be in a register
  - Except for some small integer constants that can be in the instruction itself (see later)
- Variables have to be \textit{loaded} in registers
- Results have to be \textit{stored} in memory
- Explicit Load and Store instructions are needed because there are many more variables than the number of registers
Example

- The HLL statements
  
  $a = b + c$
  
  $d = a + b$
  
- will be “translated” into assembly language as:
  
  load $b$ in register $rx$
  
  load $c$ in register $ry$
  
  $rz \leftarrow rx + ry$
  
  store $rz$ in $a$
  
  $rt \leftarrow rz + rx$
  
  store $rt$ in $d$
MIPS Information units

• Data types and size:
  – Byte
  – Half-word (2 bytes)
  – Word (4 bytes)
  – Float (4 bytes; single precision format)
  – Double (8 bytes; double-precision format)

• Memory is **byte-addressable**

• A data type must start at an address evenly divisible by its size (in bytes)

• In little-endian environment, the address of a data type is the address of its lowest byte
Addressing of Information units

Byte address 0
Half-word address 0
Word address 0
Byte address 8
Half-word address 8
Word address 8

Byte address 2
Half-word address 2
Byte address 5
SPIM Convention

Words listed from left to right but little endians within words

[0x7fffebd0]  0x00400018  0x00000001  0x00000005  0x00010aff

Byte 7fffebd2  Word 7fffebd4  Half-word 7fffebde
Assembly Language programming or
How to be nice to your TAs

• Use lots of detailed comments
• Don’t be too fancy
• Use lots of detailed comments
• Use words (rather than bytes) whenever possible
• Use lots of detailed comments
• Remember: The address of a word is evenly divisible by 4
• Use lots of detailed comments
• The word following the word at address \( i \) is at address \( i+4 \)
• Use lots of detailed comments
MIPS Instruction types

- Few of them (RISC philosophy)
- Arithmetic
  - Integer (signed and unsigned); Floating-point
- Logical and Shift
  - Work on bit strings
- Load and Store
  - For various data types (bytes, words, …)
- Compare (of values in registers)
- Branch and jumps (flow of control)
  - Includes procedure/function calls and returns
Notation for SPIM instructions

- Opcode: rd, rs, rt
- Opcode: rt, rs, immed
- where
  - rd is always a destination register (result)
  - rs is always a source register (read-only)
  - rt can be either a source or a destination (depends on the opcode)
  - immed is a 16-bit constant (signed or unsigned)
Arithmetic instructions in SPIM

- Don’t confuse the SPIM format with the “encoding” of instructions that we’ll see soon

<table>
<thead>
<tr>
<th>Opcode</th>
<th>Operands</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add</td>
<td>rd,rs,rt</td>
<td>#rd = rs + rt</td>
</tr>
<tr>
<td>Addi</td>
<td>rt,rs,immed</td>
<td>#rt = rs + immed</td>
</tr>
<tr>
<td>Sub</td>
<td>rd,rs,rt</td>
<td>#rd = rs - rt</td>
</tr>
</tbody>
</table>
## Examples

<table>
<thead>
<tr>
<th>Operation</th>
<th>Instruction</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add</td>
<td>$8,$9,$10</td>
<td>#$8=$9+$10</td>
</tr>
<tr>
<td>Add</td>
<td>$t0,$t1,$t2</td>
<td>#$t0=$t1+$t2</td>
</tr>
<tr>
<td>Sub</td>
<td>$s2,$s1,$s0</td>
<td>#$s2=$s1-$s0</td>
</tr>
<tr>
<td>Addi</td>
<td>$a0,$t0,20</td>
<td>#$a0=$t0+20</td>
</tr>
<tr>
<td>Addi</td>
<td>$a0,$t0,-20</td>
<td>#$a0=$t0-20</td>
</tr>
<tr>
<td>Addi</td>
<td>$t0,$0,0</td>
<td>#clear $t0</td>
</tr>
<tr>
<td>Sub</td>
<td>$t5,$0,$t5</td>
<td>#$t5 = -$t5</td>
</tr>
</tbody>
</table>
Integer arithmetic

- Numbers can be *signed* or *unsigned*
- Arithmetic instructions (+,-,*,/) exist for both signed and unsigned numbers (differentiated by Opcode)
  - Example: Add and Addu
    - Addi and Addiu
  - Mult and Multu
- Signed numbers are represented in *2’s complement*
- For Add and Subtract, computation is the same but
  - Add, Sub, Addi cause *exceptions* in case of *overflow*
  - Addu, Subu, Addiu don’t
How does the CPU know if the numbers are signed or unsigned?

• It does not!
• **You do** (or the compiler does)
• You have to tell the machine by using the right instruction (e.g. Add or Addu)