Assembly Language Wrap-up

Assembly language is the medium for directly programming the ISA. It reveals the beauty and the quirks of the computer’s design.

Addressing Modes

Immediate

<table>
<thead>
<tr>
<th>op</th>
<th>rs</th>
<th>rt</th>
<th>immediate</th>
</tr>
</thead>
</table>

Register Addressing

<table>
<thead>
<tr>
<th>op</th>
<th>rs</th>
<th>rt</th>
<th>rd</th>
<th>shamt</th>
<th>funct</th>
</tr>
</thead>
</table>

Base Addressing

<table>
<thead>
<tr>
<th>op</th>
<th>rs</th>
<th>rt</th>
<th>address</th>
</tr>
</thead>
</table>

Effective Address (byte)

Effective Address (word)

Addressing Modes (Continued)

PC-relative Addressing

<table>
<thead>
<tr>
<th>op</th>
<th>rs</th>
<th>rt</th>
<th>address</th>
</tr>
</thead>
</table>

Effective Address (word)

Pseudo-direct Addressing

<table>
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<th>op</th>
<th>address</th>
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Effective Address (word)

Signed Arithmetic

- Most operations involving integers are signed
- When a number is loaded into a larger field, it is sign extended, which preserves its sign

Signed operations:

\[
\begin{align*}
0000 0011 & \quad \text{3 as byte} \\
0000 0000 0000 0000 0000 0000 0000 0011 & \quad \text{3 as word}
\end{align*}
\]

\[
\begin{align*}
\text{1111 1101} & \quad \text{-3 as byte} \\
\text{1111 1111 1111 1111 1111 1111 1111 1101} & \quad \text{-3 as word}
\end{align*}
\]

Unsigned Operations

- Sometimes, the bit sequences are not numbers, and then an unsigned load is desired
  - lbu: load byte unsigned
  - There are unsigned arithmetic operations
    - addu: add unsigned
    - subu: subtract unsigned
    - addiu: add immediate unsigned
    - sltu: set less than unsigned
    - sltiu: set less than immediate unsigned

ASCII

- American Standard Code for Information Interchange -- now known redundantly as “US-ASCII”
- A 7-bit code for the keyboard characters and certain “control characters”
- When bytes became 8-bits, the coding became extended or 8-bit ASCII

<table>
<thead>
<tr>
<th>op</th>
<th>address</th>
</tr>
</thead>
</table>

| 0000 0011 | 3 as byte |
| 0000 0000 0000 0000 0000 0000 0000 0011 | 3 as word |
| 1111 1101 | -3 as byte |
| 1111 1111 1111 1111 1111 1111 1111 1101 | -3 as word |
8-bit ASCII

<table>
<thead>
<tr>
<th>8-bit ASCII</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>12345</td>
<td>6</td>
</tr>
<tr>
<td>67890</td>
<td></td>
</tr>
</tbody>
</table>

Program Forms

- C Program
- Assembly Language Program
- Object (machine language) module
- Library routines (machine lang)
- Executable: Machine language program

Diagram:
- Compiler
- Assembler
- Linker
- Loader
- Memory