Why do we even need marketing? They just make everything dumb.

Man, you're right! Let's start a company where products are designed, built, and marketed by engineers.

Introducing MAGNA TABLET

"If the user interface is confusing, it's because you're stupid."

smbc-comics.com
EECS 370 Discussion

Topics Today:

– 5-stage Pipeline
  • Basic Design
  • Performance
  • Data Hazards

– Exams
EECS 370 Discussion

Single Cycle

CPI =
Clock Period =
<table>
<thead>
<tr>
<th>Single Cycle</th>
<th>Multi-Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPI = 1</td>
<td>CPI =</td>
</tr>
<tr>
<td>Clock Period = long</td>
<td>Clock Period =</td>
</tr>
<tr>
<td></td>
<td>Single Cycle</td>
</tr>
<tr>
<td>----------------</td>
<td>--------------</td>
</tr>
<tr>
<td>CPI</td>
<td>1</td>
</tr>
<tr>
<td>Clock Period</td>
<td>long</td>
</tr>
</tbody>
</table>
EECS 370 Discussion

<table>
<thead>
<tr>
<th>Single Cycle</th>
<th>Multi-Cycle</th>
<th>Pipelined</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPI = 1</td>
<td>CPI = &gt;1</td>
<td>CPI ≈ 1</td>
</tr>
<tr>
<td>Clock Period = long</td>
<td>Clock Period = short</td>
<td>Clock Period = short</td>
</tr>
</tbody>
</table>
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5-stage Pipeline
EECS 370 Discussion

5-stage Pipeline

Pipeline Example

add  1  2  3
nand 4  5  6
lw  0  4  26
add  2  2  2
nand 1  1  1
5-stage Pipeline

Key Concept

1000 instructions are run on a 5-stage pipeline (no hazards)
How many cycles are needed to complete them?
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5-stage Pipeline

Key Concept

1000 instructions are run on a 5-stage pipeline (no hazards)
How many cycles are needed to complete them?

1004 cycles
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Multi-Cycle Datapath

Timing Example

100 Instructions:

<table>
<thead>
<tr>
<th>Instruction</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>lw</td>
<td>35%</td>
</tr>
<tr>
<td>sw</td>
<td>15%</td>
</tr>
<tr>
<td>add/nand</td>
<td>30%</td>
</tr>
<tr>
<td>beq</td>
<td>20%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operation</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Register Read/Write</td>
<td>5 ns</td>
</tr>
<tr>
<td>ALU Operations</td>
<td>10 ns</td>
</tr>
<tr>
<td>Memory Access</td>
<td>20 ns</td>
</tr>
</tbody>
</table>

What is the total execution time? (No Hazards)

Single Cycle: $100 \times 60 = 6000$ ns

Multi-Cycle: $20 \times (35\times5 + 15\times4 + 30\times4 + 20\times4) = 8700$ ns

Pipelined:
Timing Example

100 Instructions:

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What is the total execution time? (No Hazards)

Single Cycle: \(100 \times 60 = 6000\) ns

Multi-Cycle: \(20 \times (35 \times 5 + 15 \times 4 + 30 \times 4 + 20 \times 4) = 8700\) ns

Pipelined: \(20 \times (4 + 100) = 2080\) ns
Data Hazards

Key Concepts

In what stage is data read from registers?

In what stage is data written to registers?
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Data Hazards

Key Concepts

In what stage is data read from registers?
   Decode

In what stage is data written to registers?
   Writeback
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Data Hazards

The Problem:

\[ x = 5y + 3; \]

\begin{verbatim}
LDR R1 [R0, #wherever y is]
MUL R2 R1 #5
ADD R2 R2 #3
STR R2 [R0, #wherever x is]
\end{verbatim}
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Data Hazards

Solutions:

Avoidance

Detect and Stall

Detect and Forward
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Data Hazards

Pipeline Example

add  1  2  3
nand 3  5  6
lw   0  3  26
add  6  2  4
nand 4  3  1
EECS 370 Discussion

Exam Results

• Answer Keys are posted online

• Exams will be returned now next week

• Regrade Requests:
  – Submit Scantron + written statement to IA/GSI/Professor
  – Before Friday