In the following branches, the first is filled in for the following branches. The first is filled in for each of.

How would the ALU be used to help with each of?

Review Problem 12

on an outcome, the top bit is a 1 times wrong.
NOTE: Each bit of partial products is just an AND operation.

Compute partial product, shift, and add.

Repeat n times:

Multiplier:

Multiplicand:

Example:

Multiplication.
Comparing a 500MHz PowerBook G4 to an 800MHz Pentium III-based portable computers

* Based on Adobe Photoshop tests

The PowerBook G4 outperforms Pentium III-based notebooks by up to 30 percent.

Measuring "best" in a computer

Throughput (jobs/seconds) vs. Latency (time to complete a job)

BIPS (Billions Instructions Per Second) vs. GHz (Giga Cycles Per Second)

Readings: 1.6-1.8
<table>
<thead>
<tr>
<th>House Option</th>
<th>House Type</th>
<th>Time Per House</th>
<th>Prepaid Contractor</th>
<th>Self-Build</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000</td>
<td>100</td>
<td>3 months</td>
<td></td>
<td>24 months</td>
</tr>
<tr>
<td>200,000</td>
<td>24</td>
<td>24 months</td>
<td>24 months</td>
<td></td>
</tr>
<tr>
<td>250,000</td>
<td>100</td>
<td>6 months</td>
<td>6 months</td>
<td>24 months</td>
</tr>
</tbody>
</table>

Moving to wilds of Alaska?
Rebuilding Haiti?
Which is the best home builder?
Orange is twice times faster than Grape.

\[ \frac{x}{2} = \frac{5}{10} = \frac{500}{1000} = \frac{50}{100} \]

Orange takes 5 seconds, Grape takes 10 seconds.

Example: Machine Orange and Grape run a program.

\[ \frac{\text{Execution Time}_x}{\text{Performance}_x} = \frac{\text{Execution Time}_y}{\text{Performance}_y} = n \]

To compare machines, we say "x is n times faster than y."

Primary goal: execution time (time from program start to program completion)
Time spent executing the lines of code that are "in" our program.

Our focus: user CPU time.

Example: Unix "time" command.

Can be broken up into system time, and user time.

CPU time doesn't count I/O or time spent running other programs.

A useful number, but often not good for comparison purposes.

Counts everything (disk and memory accesses, I/O, etc.),

Elapsed time.

Execution time.
to run the program in 6 seconds, how fast must the clock rate be?

6 Seconds = \frac{6}{1.2 \times \text{cycles}} \times \text{cycles}

6 seconds = \text{clock cycles} \times 1.2

10 seconds = \text{clock cycles} \times \frac{0.4 \times 10^9}{1}

A program takes 10 seconds on computer Orange, with a 400 MHz clock.

Application example:

<table>
<thead>
<tr>
<th>Clock Rate</th>
<th>For a Program</th>
<th>CPU Clock Cycles</th>
<th>For a Program</th>
<th>CPU Execution Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>\times</td>
<td></td>
<td>\times</td>
<td></td>
</tr>
<tr>
<td>Clock Period</td>
<td>For a Program</td>
<td>CPU Clock Cycles</td>
<td>For a Program</td>
<td>CPU Execution Time</td>
</tr>
</tbody>
</table>

CPU Time

\[
\begin{align*}
\text{CPU Time} & = \frac{6}{10^9} \\
& = 6 \times 10^{-9}
\end{align*}
\]
\[
\text{CPI} = \frac{\text{Clock Rate}}{\text{CPU execution time}} \times \frac{\text{CPI}}{\text{Instructions}} = \frac{\text{CPI}}{\text{CPU clock cycles}}
\]

(\text{CPI})
\text{Cycles per Instruction}
\text{Average Clock}

\text{How do the # of instructions in a program relate to the execution time?}

\text{CPI of last issued} \#