Energy consumption aware software optimization of embedded systems

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Outline

• Energy optimization
• Energy aware software optimization
• Measuring instruction level energy consumption: case Atmega8515
• Results and verification
• Future work
Energy optimization

- Energy consumption of embedded systems is reaching the limits of batteries
- Energy consumption reduction methods
  - Lower operating voltage
  - Lower operating frequency
  - Sleep modes
  - Low power electronics
  => Not always possible

Energy aware software optimization

- Try to choose instructions which consume as little energy as possible => minimized energy consumption
- Try to balance difference between consecutive instructions => maximize energy available from batteries
- Speed optimization is not always energy optimization.
  - What to do with saved time?
- + No changes to existing hardware
Measuring instruction level energy

- Testing AT90S8515 and Atmega8515
- Energy of every instruction must be measured
- Pipelining makes measuring difficult
- Simple measurement system utilizes oscilloscope

Example measurement

![Current vs. Clock Graph](image)
Results

- Zeros in the opcode are more expensive than ones
- In data ones are more expensive than zeros
- Configuration of unused IOs is important
- Instruction memory (flash) is divided to pages. Activation of new page is expensive
- Usage of some registers is more expensive than usage of other registers

Results verification

- Simple program, counts an average of eight eight bit integer
- Average current of whole measurement system is measured

<table>
<thead>
<tr>
<th>Cheaper registers</th>
<th>Data near $00$</th>
<th>Data near $FF$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Looped inside one page</td>
<td>5,209</td>
<td>5,350</td>
</tr>
<tr>
<td>Looping over page border</td>
<td>5,251</td>
<td>5,393</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expensive registers</th>
<th>Data near $00$</th>
<th>Data near $FF$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Looped inside one page</td>
<td>5,282</td>
<td>5,449</td>
</tr>
<tr>
<td>Looping over page border</td>
<td>5,323</td>
<td>5,492</td>
</tr>
</tbody>
</table>

- Result confirm that energy consumption can be decreased with energy aware software optimization
Future work

- Implementation of an automatic measurement system
- Writing of a compiler, which can automatically optimize the written software according to the energy consumption

Thank you

Questions?