Optimizing Embedded Software Energy Consumption

- Find the program part causing the highest energy consumption
- Locate unexpected power peaks
- Check if power-saving modes are used efficiently
Optimizing Embedded Software Energy Consumption

Motivation

- Requirements
- Solution
- Example
Energy = Current x Voltage x Time

In microprocessor-controlled applications each of this parameters can be influenced by the software

- Dynamic use of power-saving modes
- Dynamic change of CPU frequency
- Dynamic change of target voltage

- Dynamic use of chip internal and external resources (RAM, Flash)
- Dynamic function run-times (cached, non-cached)
Tasks of Energy Profiling

Software developers have to constantly search for optimal settings of these three parameters

Energy = Current × Voltage × Time

- Detect power-hungry hardware parts
- Detect power-hungry software parts
- Detect wrong usage of power-saving modes
- Detect unexpected power peaks

- Calculation of energy consumption (overall, task, function ...)

- How program changes affect power consumption
Motivation

Program chart

Voltage waveform

Current waveform

Energy statistics

Program flow
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Requirements

Debugger + Real-time Trace

- Debug control and run-time measurement

Logic Analyzer + Analog Probe

- Current and voltage measurement

- Time-correlated measurement of program flow, current and voltage
- Cross-trigger capability
- Tool control integrated in debug user interface
Analog Probe

- V[3..0] voltage inputs (0..5 V, 1 MOhm)
- I[2..0] current inputs (requires shunt resistance)

- 12 bit resolution
- 625 KHz sampling rate (one channel)

Sampling rate = 625 KHz / number-of-enabled-channels
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Voltage Measurement

Target

Chip

GND

Voltage channel

GND

Analog Probe
Current Measurement

- **Chip**
- **Target**
- **Shunt resistor**
- **Drilled pair of wires**
- **Analog Probe**
- **VDD**
- **GND**
Current Measurement

- Chip
- Target
- VDD
- GND
- Shunt resistor
- Analog Probe
- GND
Shunt Resistance

Calculation of shunt resistance

Max-current at 125mV voltage drop

\[ R = \frac{U}{I} \]

e.g. 125mV/4A = 0.03125 \rightarrow 0.025 Ohm
e.g. 125mV/2A = 0.0625 \rightarrow 0.050 Ohm

Many dev boards are equipped with shunt resistors and provide pins either side
## Configuration

*4 voltage channels*

<table>
<thead>
<tr>
<th>Channel</th>
<th>Max Value</th>
<th>Res Value</th>
<th>Compress</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>V0</td>
<td>1.131591</td>
<td>4.999V</td>
<td>0.001220V</td>
<td>4/1</td>
</tr>
<tr>
<td>V1</td>
<td>2.106933</td>
<td>4.999V</td>
<td>0.001220V</td>
<td>64/1</td>
</tr>
<tr>
<td>V2</td>
<td>0.994873</td>
<td>4.999V</td>
<td>0.001220V</td>
<td>256/1</td>
</tr>
<tr>
<td>V3</td>
<td>4.296875</td>
<td>4.999V</td>
<td>0.001220V</td>
<td>1/1</td>
</tr>
</tbody>
</table>

*3 current channels*

<table>
<thead>
<tr>
<th>Channel</th>
<th>Max Value</th>
<th>Res Value</th>
<th>Compress</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>I0</td>
<td>0.000305</td>
<td>1.250A</td>
<td>0.000305A</td>
<td>0.100</td>
</tr>
<tr>
<td>I1</td>
<td>0.000610</td>
<td>2.499A</td>
<td>0.000610A</td>
<td>0.050</td>
</tr>
<tr>
<td>I2</td>
<td>0.000610</td>
<td>2.499A</td>
<td>0.000610A</td>
<td>0.050</td>
</tr>
</tbody>
</table>

*3 power channels (virtual channels)*

<table>
<thead>
<tr>
<th>Channel</th>
<th>Max Value</th>
<th>Res Value</th>
<th>Compress</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>P0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>0.002014</td>
<td>8.240W</td>
<td>0.002014W</td>
<td>3.300</td>
</tr>
<tr>
<td>P2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Shunt resistance
- Voltage

Channel enable
User Interface
User Interface

Trigger on voltage, current and power
Data Save / Export / Offline Analysis

TRACE32 off-line analysis
• Save recording:  i.SAVE <filename> <recordrange>
• Load to simulator:  t.LOAD <filename> /Config

Data export (as text file)
• Select printer type: PRinTer.FILE <filename>
• Open i.List window with the analog channels of interest
• Scroll cursor to the first record of interest
• Left mouse click to i.List icon, click to Print all
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Demo Application

Target Board

Ports

VCC

0.5 Ohm

BUFFER

220 Ohm

GND

GND

I+ I-

GND

220 Ohm

GND

GND
Example

Cached/non-cached program flow

Memory interface current

Core current
Thank You!

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Questions?