Passive Thermal Management using Phase Change Materials

Javier Adrian Ruiz

Motivation

• Implementing new and more powerful processors in cellphones is limited by the significant heat generated by their use.
• Typically, the computational power of the processor is limited (by the software) once the temperature exceeds a certain threshold to prevent damage to the device.
• To improve the performance of modern mobile devices, new thermal management strategies are needed.
• Phase change materials (PCMs) absorb thermal energy during melting, while limiting spikes in temperature, and are promising for passive thermal management schemes.

Project Goals

• Develop a thermal management solution based on phase change materials (PCMs) in order to store energy generated by transient and localized hotspots in processors.
• Test which integration method and which PCMs will prove most useful for the use in passive thermal management in cellphones.
• Enable devices to operate at a higher performance level for longer periods of time.

Background & Literature Review

• When a PCM begins to melt, the absorbed energy goes into breaking the intermolecular bonds of the material increasing the internal energy of the material but not raising the temperature.
• This energy storage allows the processor to run at a higher performance level for an extended period of time.

Predicted Thermal Response of Processor with PCM [1]

<table>
<thead>
<tr>
<th>Applied Power Levels</th>
<th>Thermal Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increasing power density</td>
<td>Cooling Bottleneck</td>
</tr>
<tr>
<td>Limited form factor of mobile devices</td>
<td></td>
</tr>
</tbody>
</table>

Experimental Design

• We designed and built a testing fixture to measure the effect of the PCM on the internal and surface temperature of the processor.
• An enclosure filled with PCM is placed directly on the processor of a single board computer (SBC).
• An IR camera and external thermocouples measure the surface temperature of the PCM and built in sensors on the chip monitor the temperature processor.
• To stress the system, a benchmarking app (Linpack) is executed on the processor while temperature data is measured.
• Initial data in the absence of the PCM has been collected to provide a baseline performance metric. Test with PCM are in progress.

Computational Model

A computational model is being developed to visualize what might be expected in our experiments, interrogate the uncertainty of the results, and translate the experimental data to cell phone applications.

Summary & Conclusions

• Preliminary test for the processor without PCM have been conducted, and measurements with the PCM are in progress.
• The impact of the thickness and volume of PCM, as well as different types of PCMs will be interrogated to determine the optimum configuration for thermal management.
• In combination with numerical modeling, these results will determine whether PCMs are effective for thermal management of mobile devices.

References

3. Z. Zhao, SEMITHERM, 2013