Power Management on State-of-the-Art Mobile Processors

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Abstract

While mobile devices are growing in processing power and increasing in popularity, they continue to face major limitations in battery life and power consumption. Especially when running high performance tasks such as playing games with 3D graphics, the CPU and GPU consume significant power which can quickly drain battery life. To find ways to manage power more efficiently, we first profiled and analyzed performance and power characteristics of real life workloads. Using two Android devices, one being the Odroid XU3 board with an ARM big.LITTLE multi-core heterogeneous computing architecture, the other being the Inforce 6410 board with a homogeneous multi-core processor, we wrote BASH shell scripts to gather various energy and performance metrics. Based on our profiling reults, we plan to extend our results to manage power through an Android app and OS-level CPU management policy that dynamically changes CPU settings to adjust to user's performance needs.

Methodology

- Target Platforms:
  - HardKernel Odroid XU3[1]: Samsung Exynos 5422 Heterogeneous Octa-Core CPU at 2.0 Ghz with Mali-T628 and power sensors
  - Inforce 6410[2]: Qualcomm Snapdragon 600 Homogeneous Quad-Core CPU at 1.7 GHz with Adreno 320 GPU

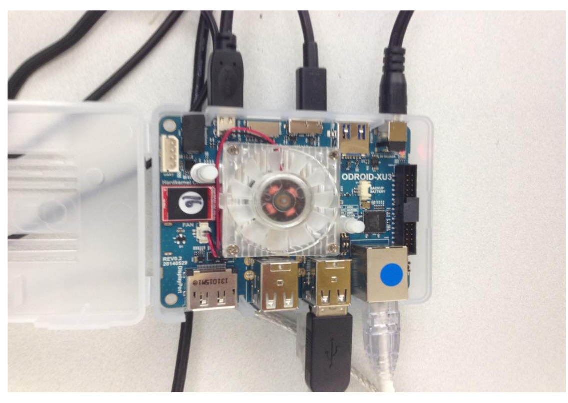

Figure 1. Odroid XU3 board with ARM big.LITTLE

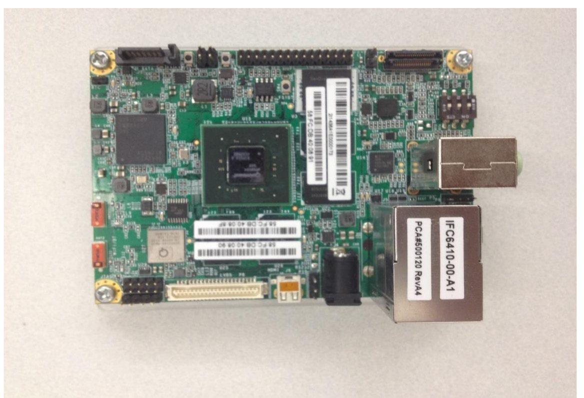

Figure 2. Inforce 6410 board with homogeneous CPU

- Workloads:
  - Games: Hearthstone, Angry Birds, 8-Ball Pool
  - Mobile benchmark tests: Antutu, GFX Bench
  - Full HD YouTube videos running at max frame rate

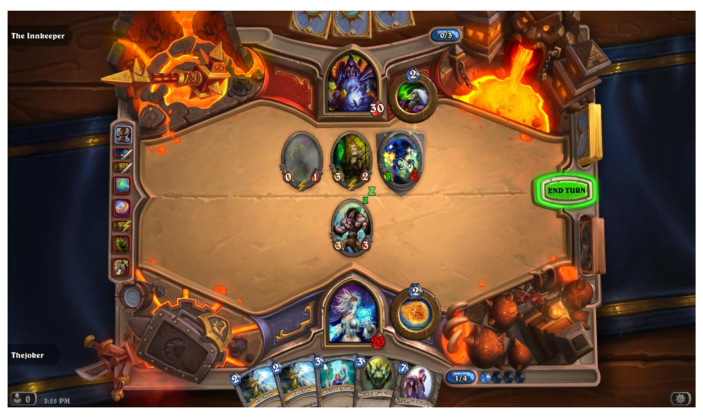

Figure 3. Hearthstone, a CPU and GPU demanding game

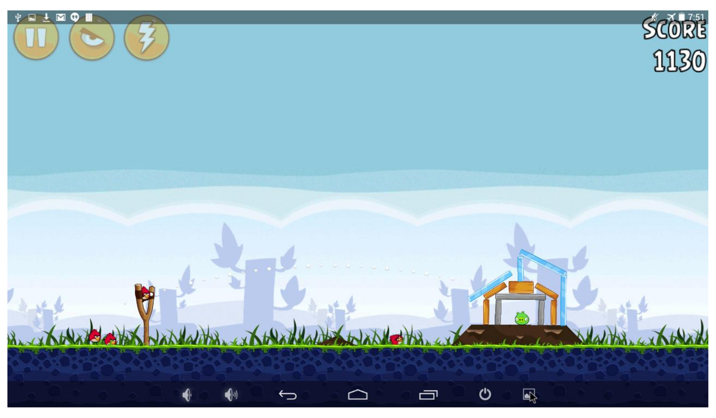

Figure 4. Angry Birds game

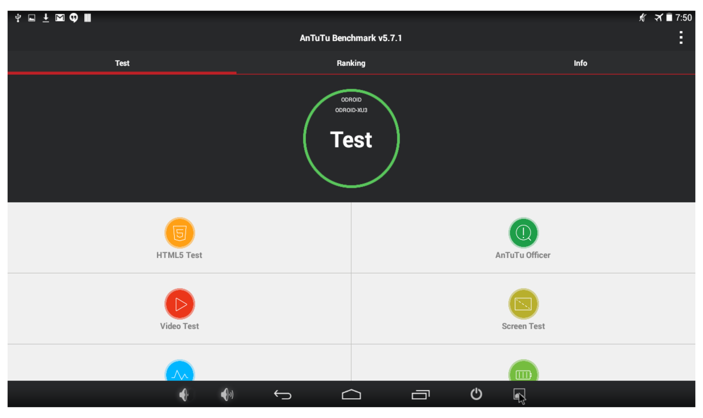

Figure 5. Antutu, a mobile benchmark test for CPU and GPU

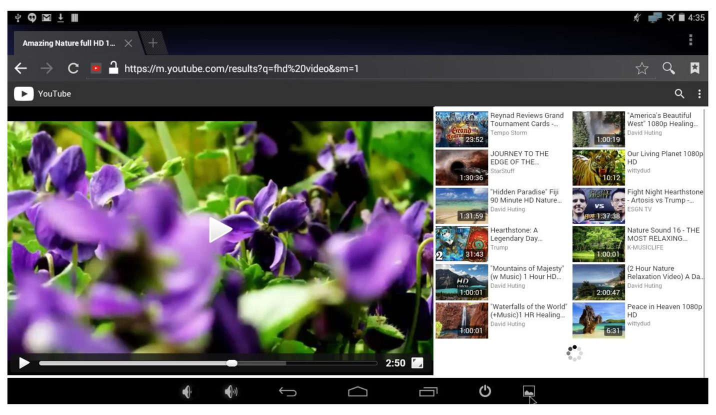

Figure 6. FHD YouTube video

- Profiling methods:
  - Used RERAN[3] event replay software to reproduce same actions
  - Wrote BASH scripts to retrieve on-hardware performance metrics
  - Frames Per Second: SurfaceFlinger, Android system service, to measure FPS
  - Power Consumption: Odroid Power Sensors and Agilent 34401A 6 ½ Digital Multimeter with KeySight BenchVue software
  - Temperature and CPU Utilization: read OS system file
  - Tested various configurations for the userspace and ondemand CPU governors
  - Based on results and current CPU governors, began working on CPU management policy that adjusts the parameters of ondemand governor to optimize power and performance
- Important skills/knowledge gained:
  - computing architecture
  - BASH scripting
  - Android programming
  - CPU/thermal management policies
  - Linux OS

Conclusion

- Power profiling with Inforce 6410 and Odroid Xu3 show power management is still inefficient with default management policy
- ARM big.LITTLE has significantly better energy efficiency than traditional homogenous CPU
- Results can be used to dynamically manage power and allow user to view device performance statistics

Introduction

- Mobile devices require more optimal power management strategies
  - Only few hours on-screen time
- Modern processors beginning to implement more cores and heterogeneous computing architecture
  - i.e. ARM big.LITTLE architecture
  - "big" Cortex-A15 cores for high performance tasks
  - "small" Cortex-A7 cores simpler tasks to conserve power
- Experiment with different computing architectures, CPU governors, CPU frequency etc. to profile power usage and find optimal way to save power

Results and Discussion

Inforce 6410

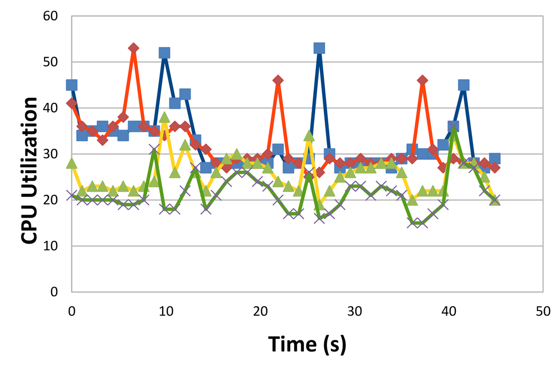

Figure 7. CPU Utilization vs. Time while running Antutu 3D Graphics test at 4 frequencies on Inforce 6410

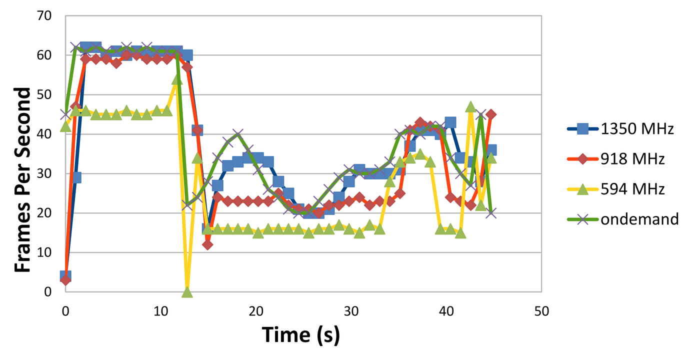

Figure 8. FPS vs. Time while running Antutu 3D Graphics test at 3 static frequency settings and ondemand governor on Inforce 6410

- Medium frequency can produce similar performance to high frequency for Antutu benchmark test
- Temperature increase steadily throughout test
- Taking a short break while gaming could lower temperature and save power

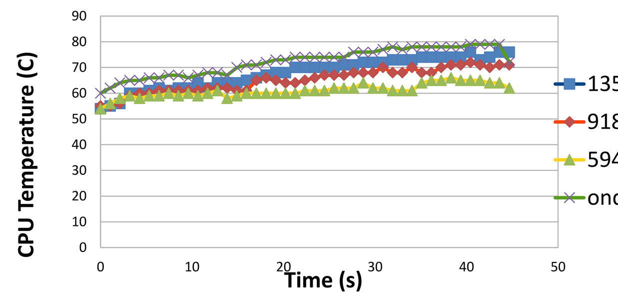

Figure 9. CPU Temperature Antutu 3D Graphics test at3 static frequency settings and ondemand governorvs Time while running

Odroid XU3

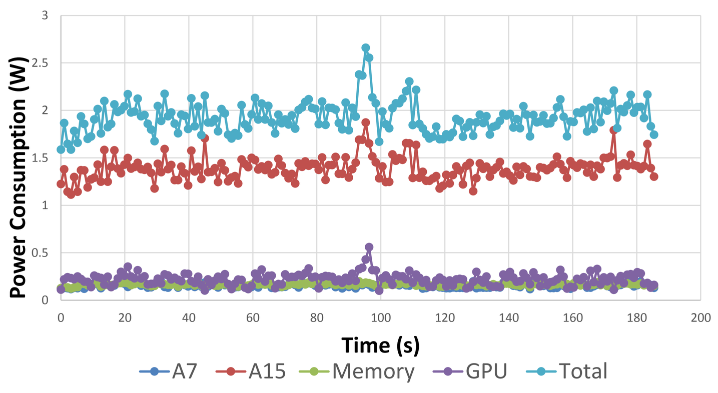

Figure 10. Power Consumption vs Time while playing Hearthstone with 1 A7 core at 1.4 GHz and 1 A15 core at 2.0 GHz on Odroid XU3

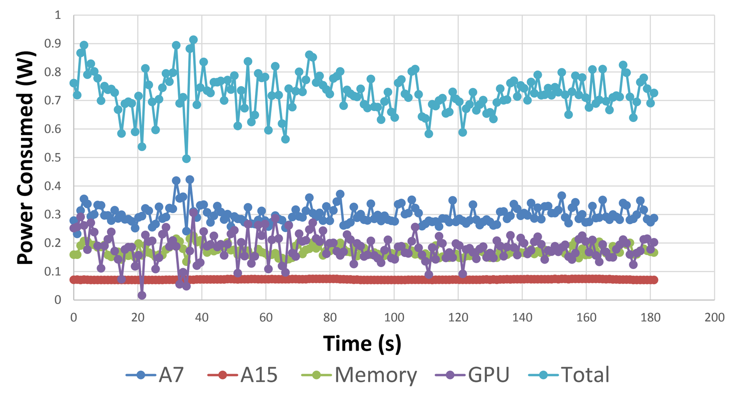

Figure 11. Power Consumption vs Time while playing Hearthstone with 4 1.4 GHz A7 cores and A15 cores idle on Odroid XU3

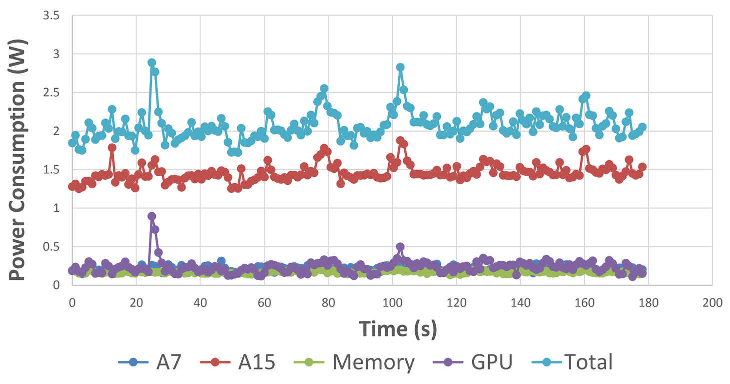

Figure 12. Power Consumption vs Time while playing Hearthstone with ondemand governor and MP decision on Odroid XU3

Confi-guration	A7 Power (W)	A15 Power (W)	Memory Power (W)	GPU Power (W)	Total Output Power (W)	Average FPS
1 A7, 1 A15	0.156	1.388	0.164	0.221	1.93	44.32
4 A7	0.299	0.072	0.171	0.182	0.725	41.54
On-demand	0.209	1.456	0.170	0.237	2.073	45.30

Figure 13. Table with Average Power and FPS for each configuration on Odroid XU3

- A15 cores resulted in minimal performance boost, measured by FPS, and consumed significantly more power than A7 cores, even for intensive gaming
- More efficient to run many cores at low frequency than few cores at high frequency
- Memory and GPU consume minimal power

Odroid XU3 vs Inforce 6410

- Odroid consumed less power, produced better performance measured by FPS on same workload
- ARM big.LITTLE multi-core more efficient than homogeneous CPU
- Odroid heats up less, likely due to more efficient processor, heat sink, and/or better thermal management policy

Device	Average Total Input Power (W)	Peak Temper-ature (°C)	Average FPS
Odroid Xu3	3.144	54	35.44
Inforce 6410	3.570	67	31.00

Figure 14. Power, Peak Temperature, and FPS for devices using default ondemand governor while playing FHD YouTube video

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