How to Power Tune a Device Running on a Linux Kernel for Better Suspend Battery Life

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Introduction

- Based on a true story!
- Started with 2 weeks of focused effort hardening suspend to ram and use cases.
- Ended with 1 extra week at the ODM re-working hardware and doing more measurements
- Reduced suspend power from “way-too-high” to “not-too-bad”
- Identified HW issues to be fixed
- ASK QUESTIONS!!!
  - Only got 17 slides.
Acknowledgments

- Veneesh K K ("destroyer of boards")
  - Experimental power measurement to isolate what device and driver is causing higher power loads
- German Monroy ("designated adult")
  - Drove priorities:
    - Disciplined tracking of issues and power.
- A number of others:
  - Vishwish, Youvdeep, Yanmin, Fengwei, Jack, Aswhar, and others participated in the activity
Outline

- The power BOM
- Suspend to Ram Hardening
- Measuring
- Locating Easy leakages
- Locating Harder leakages
- Getting line of site to spec power
Power BOM-1

- Start with schematic
- ID all peripherals
  - Spec sheets
  - Driver source code
  - Data bus
  - Voltage rails
  - Connectors
  - High, typical, low power ratings
Power BOM-2

- Understand the SOC
  - IP blocks
  - Voltage rails
  - Data buses
- Understand clock and power controls
  - What rails can be gated and how
  - What clocks can be gated
- Understand what platform states are available
Power BOM-3

- Derive board level power target from BOM
  - for this board it was 25mW
- Have an idea what rails have what power going though them
  - Locate extra LDO's
  - Know what rails can be gated from SW.
- Estimate power per connector
- Look for obvious leakages
  - LED's
  - Strong pull up / down resistors
Suspend to RAM Hardening

- Review drivers for suspend/resume functions
  - Check specs for going into and coming out of low power states.
- Turn on linux pm debugging
- Use sys/power/pm_test
- Use sys/power/pm_trace
- Follow Documentation/power/basic-pm-debugging.txt
- First get suspend and resume working.
- Second make sure use cases still work after resume.
  - This is hard.
- Stress test
Measuring

- At battery connectors
  - Battery simulators
  - Monsoon device
- Special instrumented measurement boards
  - Only available for reference hardware.
  - Didn't have one for this device so we had to “rough it”
First result

- ~685mW!
  - Yipes!
- Started pulling connectors to isolate power hogs.
  - Sensor hub (245mW)
  - Cameras (30mW)
  - Display (20mW)
  - Touch Screen (10mW)
  - Touch pad (20mW)
  - Extra display (30mW)
- Power gating rails to isolate more:
  - Modem (100mW)
  - WiFi (120mW)
  - BT (25mW)
Start fixing:

- New Sensor hub FW and driver changes
- Camera driver updates
- Display update
- Back light PWM gating
- Touch screen now held in reset
- Extra display driver off/on
- Power gated modem and BT
Second measurement

- 120mW board level
  - Still looking for 25-ish
- Found devices not going to low power
  - Touch screen was still hot
  - Few more driver updates
  - FW update
  - Found a few more clocks needing gating
How to know when done?

• For each connector that can be unplugged while in suspend state:
  • Power meter shows no change after unplug
  • Or power meter shows expected delta after unplug.

• For each power rail that can be gaited from SW:
  • Power meter shows expected delta after gating

• For each peripheral you can pull out while in suspend:
  • Power meter shows expected delta after cut.
3rd measurement

- 80mW from unmodified hardware
  - Pretty good for an early spin of a device that has a bright power LED always on
- Still have higher than expected leakage from 2 connectors (10mw)
- LED (20mw)
- 25mW of unexpected leakage yet to find in board.
Getting Hard Core

• Reworking device to measure and find floor.
  • Do this because we don't have an instrumented platform
  • Need to keep the device booting.
  • Yank parts off device
  • Cut power rails with exact-o-knife
  • Keep in mind what you end up with is no longer the gadget you started with and results are in some ways “academic”

• At the end we saw 40mW
  • We expected <10.
    – Filed a bug for the 30mW with team responsible for S0C
    – Filed bug with board layout team for the 30 MW
Random data

- We had 8 working devices going into power camp.
  - There was a variance of ~20mW suspend power measured across all of them.
  - All no longer fully functional
- Don't know what expected variances should be.
  - Plans to measure units coming off the line are in place
- Numbers most times never added up all the way.
  - Source of frustration when looking for those last few mW
  - Likely caused by per-device variances confusing measurements.
  - Maybe board level power is not as simple as I want to think.
Concluding remarks

• Went from 685mW to < 80mW through SW and FW updates alone

• At the end we had a small set of issues to get fixed for the next HW spin:
  • Identified HW mods needed to save 20mW (LED)
  • Identified 10 mW of leakage with touch pad and prox light sensor
  • Identified 25 mW higher than expected use from SOC + board

• Line of sight to power target was achieved!

• I had fun and I'd do it again.

• Need to do another pass on next spin of hardware.
Questions?