CDX - Chiplet System Power Modeling Example

System Power Model in action

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Thrace Systems

Problem statement

Model chiplet power and thermals

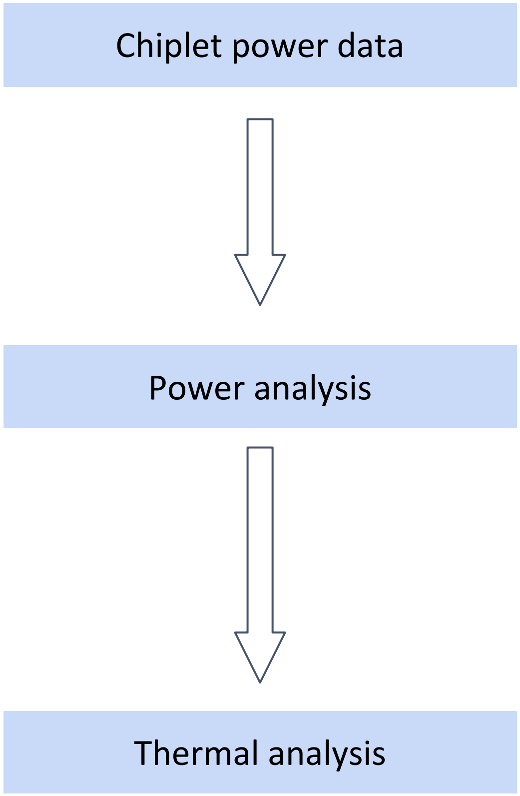
Take existing tools and methodologies

Develop a workflow for power and thermal analysis

Demonstrate how this works for chiplets

- Demonstrate electronic power datasheets
- This focuses on the work done by Thrace Systems using PowerMeter ™

Publish to industry



Agenda

Intro and Overview

Chiplet System - OmniChip Reference design

- Challenges and setup

Power modeling details

- System power model goals
- Modeling details
- Scenarios and results

Summary

Intro and Overview

OSDA CDX workstream

- Focus on flow pipe clean and PoC
- Design data seeded by zGlue - OmniChip Reference Design

Si2 UPM workgroup

- Focus on IEEE2416 “IEEE Standard for Power Modeling to Enable System Level Analysis”, aka UPM

Chiplet power data

- Extract information from datasheet
- Provide UPM, when available

Power analysis

- Provide use scenarios
- Provide system information
- Use PowerMeter™ to perform system-level power analysis
- Generate UPM, if needed
- Generate data for thermal analysis

Thermal analysis

Reference design power analysis

Power data in datasheet

- Can it be converted to machine readable format?
- Can it be understood by tools?

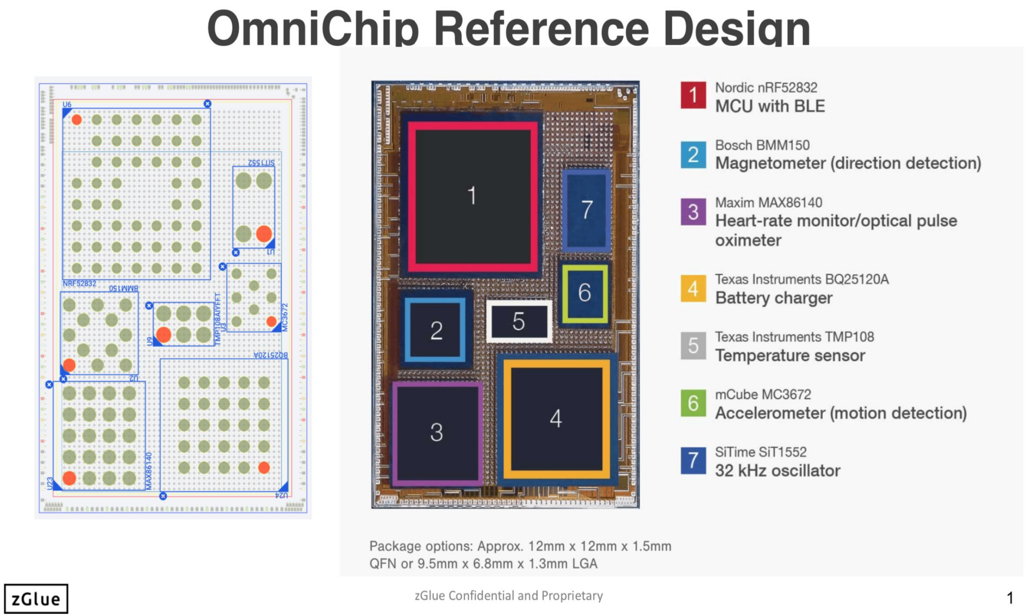
System model?

Scenario definition

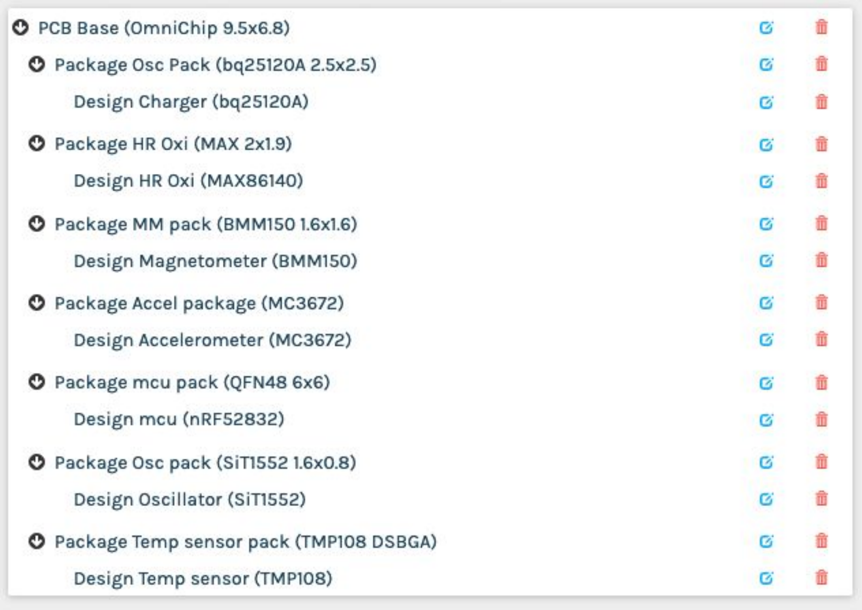
- Choose 2 application scenarios

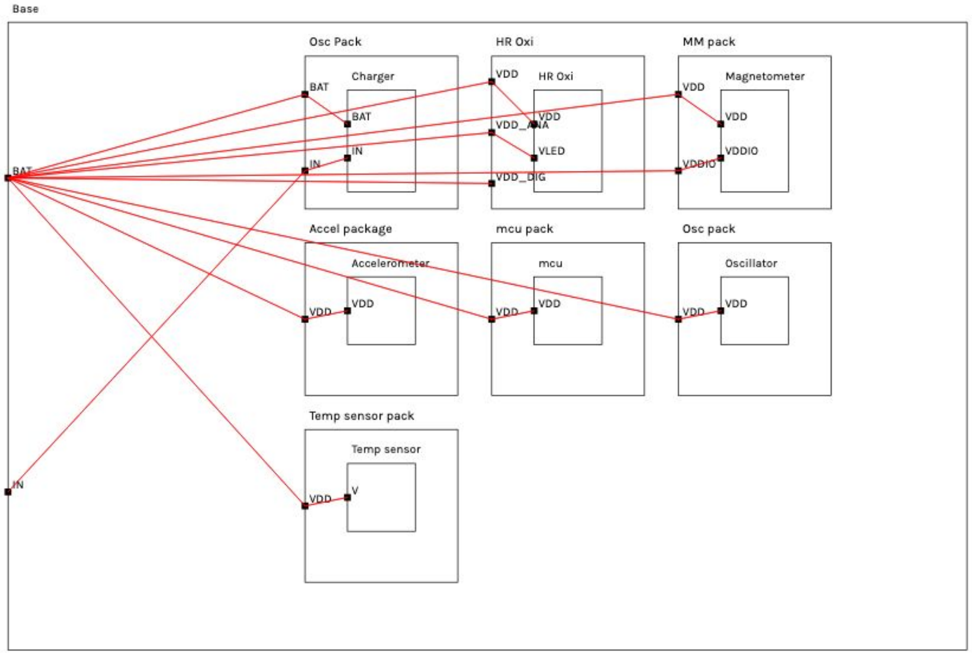
Power analysis

- Power and energy



System Setup Overview





Model LGA, each chiplet package and die individually

Hierarchical supply connectivity

System Power Model Goals

Include and supercede existing data to maintain flow compatibility

- Built on existing Liberty gate-level models

Improve modeling gate-level modeling - IEEE2416

- Power contributors for detailed leakage and energy modeling

Extend to system-level

- States
- Different styles of representing data - equations, tables and waveforms, typically dependent on external parameters
- Combination with gate-level models (the two level modeling aspect of IEEE2416)

Model overview - TI bq25120A

TI bq25120A is Low IQ Highly Integrated Battery Charge Management Solution for Wearables and IoT

Demonstrate table support

- Extract data from graph
- Generate power estimates

Tool automatically handles interpolation and extrapolation

TEXAS INSTRUMENTS

www.ti.com

8.7 Typical Characteristics

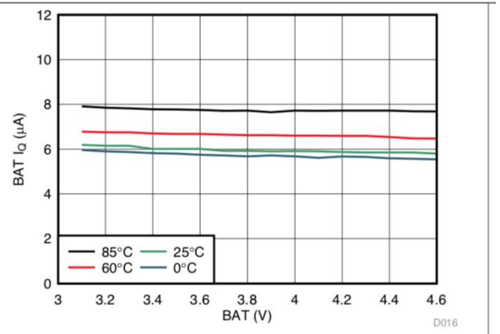


Figure 3. Active BAT, I_Q

Voltage	Temperature	Power
3.1	0	6*1e-3*BAT
3.1	25	6.2*1e-3*BAT
3.1	60	6.8*1e-3*BAT
3.1	85	7.9*1e-3*BAT
4.6	0	5.4*1e-3*BAT
4.6	25	5.8*1e-3*BAT
4.6	60	6.7*1e-3*BAT
4.6	85	7.7*1e-3*BAT

Model overview - TI TMP108

TMP108 Low Power Digital Temperature Sensor With Two-Wire Serial Interface in WCSP

Demonstrate waveform support

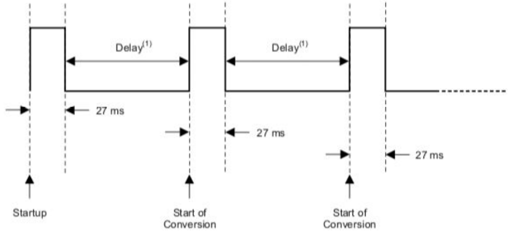
Waveform times and values are equations

TEXAS INSTRUMENTS

TMP108

www.ti.com SBOS663A – APRIL 2013 – REVISED SEPTEMBER 2019

After power-up or a general-call reset, the TMP108 immediately starts a conversion, as shown in Figure 12. The first result is available after 27 ms (typical). The active quiescent current during conversion is 40 µA (typical at +25°C). The quiescent current during delay is 0.7 µA (typical at +25°C).



(1) Delay is set by the CR1 and CR0 bits in the configuration register.

Waveform | Configuration

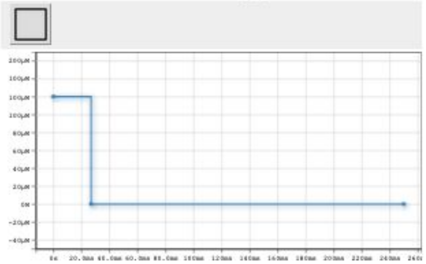
+POWER | AS TEXT

Time	Power	Computed time	Computed power
0	40*1e-3*V	0ns	120µW
27*1e6	0	27000000ns	0W
1/cr*1e9	0	250000000ns	0W

Average power @ 3V 12.96µW

Average current @ 3V 4.32µA

Energy @ 3V 3.24µJ



Nordic nRF52832 model

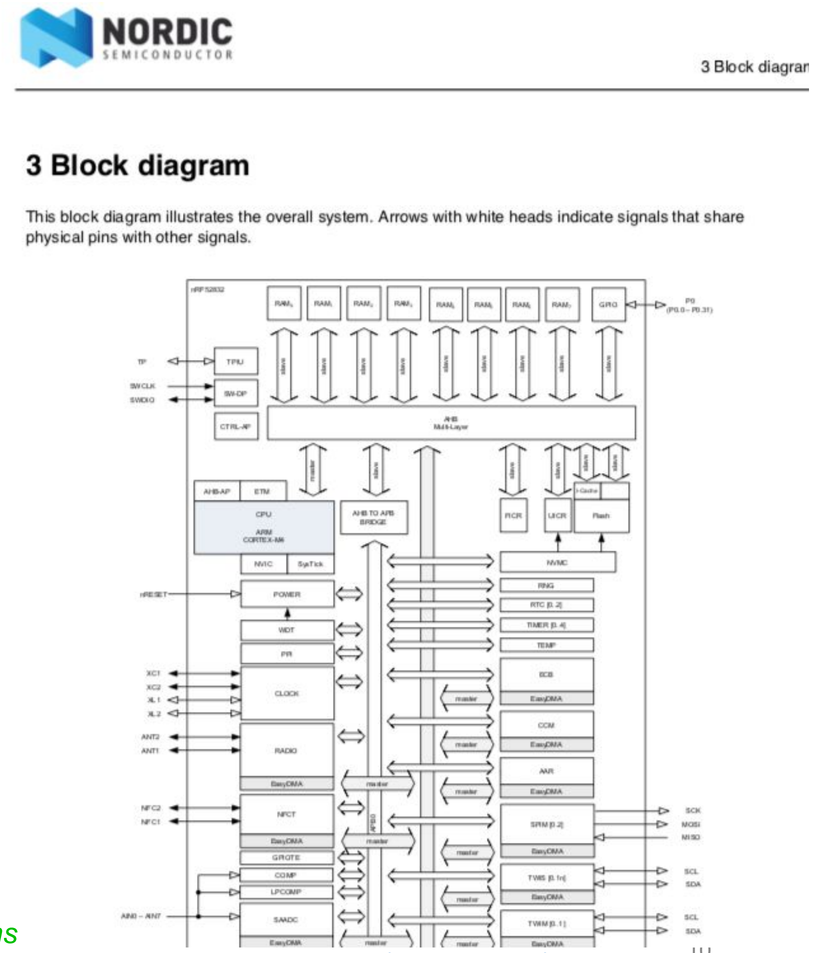
MCU is already a System with 20+ functional blocks

Integrated LDO and DCDC converter

For brevity focus on CPU and RADIO subsystems

- Model integration
- Use for Scenario modeling

Overall MCU model includes the two subsystem models



Source: [Nordic Semiconductor]

nRF52832: CPU subsystem

ARM® Cortex®-M4 core featuring DFS

Datasheet power includes granularity on whether code runs from RAM or Cache, power choice and whether cache is on

There is only one Mode of operation as result

Demonstrate use of equations

Name	Units	Description	Properties
cache		Cache	Choices: Disabled, Enabled Default: 0
frequency	MHz	Frequency	Min: 0 MHz Default: 64 MHz
memory		Memory	Choices: Flash, RAM Default: 1
power		Power	Choices: DCDC, LDO Default: LDO

		VDD
Default default	Total	frequency*((3.7 if cache and memory else 3.9 if cache == 0 and memory else 3.3 if memory == 0 else 0) if power == "DCDC" else (7.4 if cache and memory else 8.0 if cache == 0 and memory else 6.7 if memory == 0 else 0))/64*VDD

nRF 52832 model

Overall MCU modeled with single State and 8 parameters

Parameters are derived from CPU and RADIO subsystems (but are not exact)

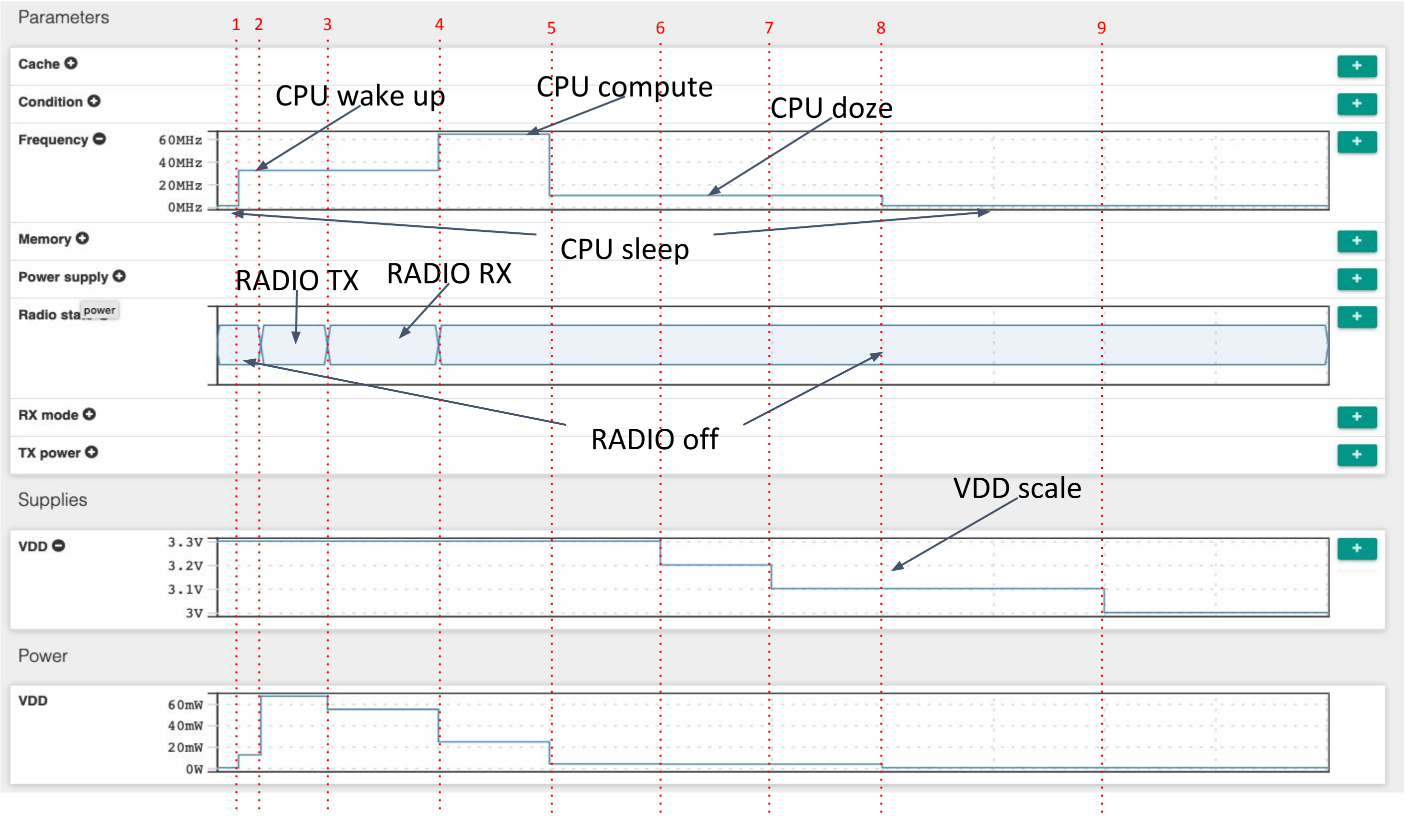
Hierarchical model employed

Parameters + PARAMETER

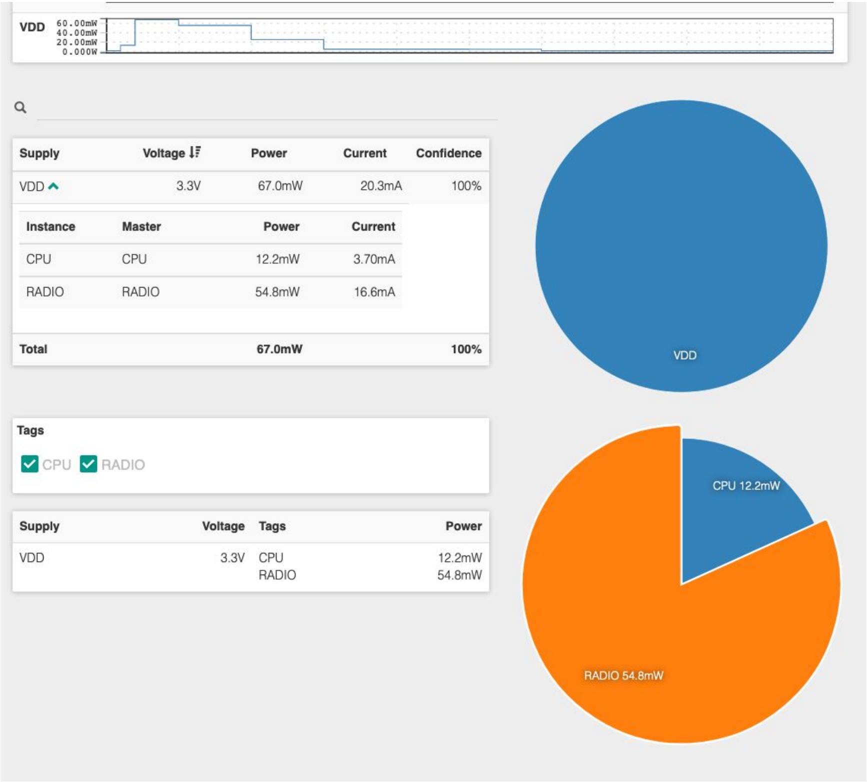
Name	Units	Description	Properties
cache		Cache	Choices: Disabled, Enabled Default: 1
cond		Condition	Choices: Max, Typ Default: max
frequency	MHz	Frequency	Min: 0 MHz Default: 64 MHz
memory		Memory	Choices: Flash, RAM Default: 1
power		Power supply	Choices: DCDC, LDO Default: DCDC
radio		Radio state	Choices: OFF, RX, TX Default: TX
rx_mode		RX mode	Choices: 1 Msps, 2 Msps Default: 2
tx_power		TX power	Choices: -12 dBm, -16 dBm, -20 dBm, -4 dBm, -40 dBm, -8 dBm, 0 dBm, 4 dBm Default: 4

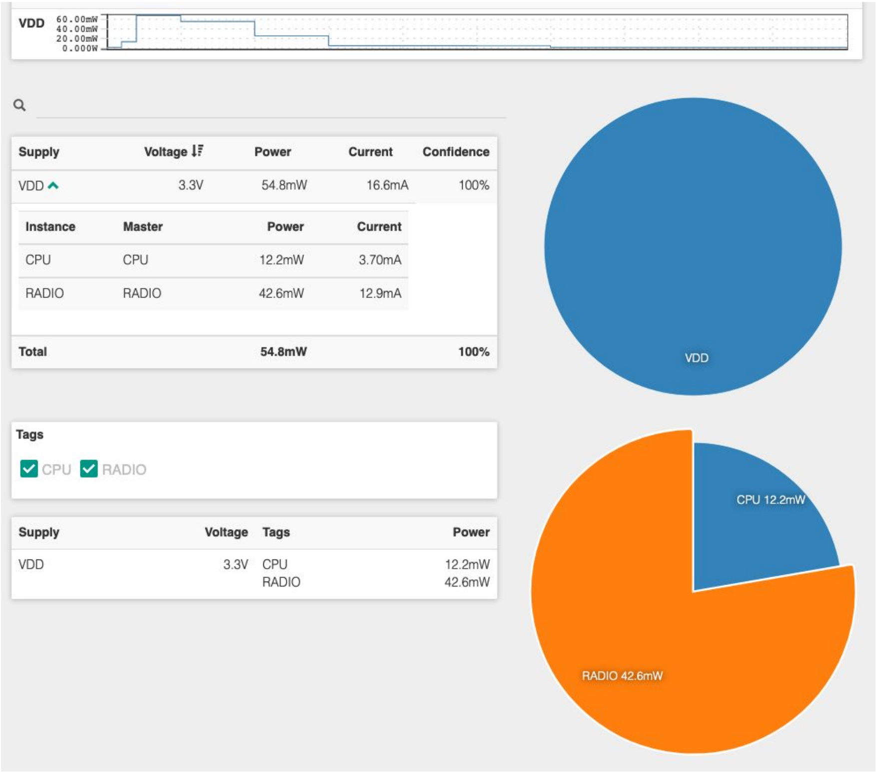
MCU Scenario definition and power analysis

1. CPU wake up for processing
2. Begin TX
3. TX done, begin RX
4. RX done, compute result
5. Doze
6. Lower voltage
7. Lower voltage again
8. CPU sleep
9. Lower voltage again



TX vs RX power





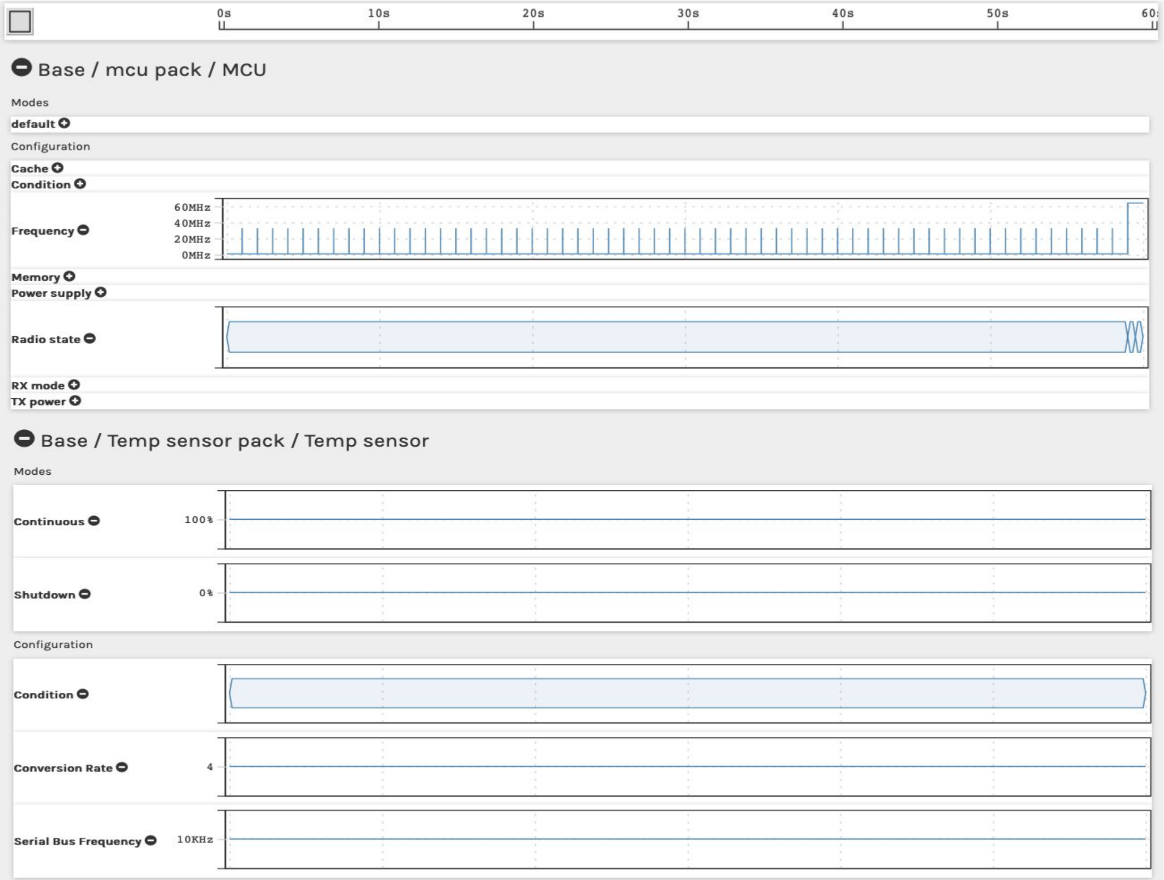
System scenario #1 - Industrial

Industrial temperature sensor
Enabled: Temp sensor, MCU
All other disabled

MCU waking up every second for processing (@ 32MHz) and data TX/RX every minute (2 64MHz)
RADIO:

- OFF @ 0s - 59s
- TX @ 59s
- RX @ 59.5s

Temp sensor running
Continuous measurements



Thrace Systems

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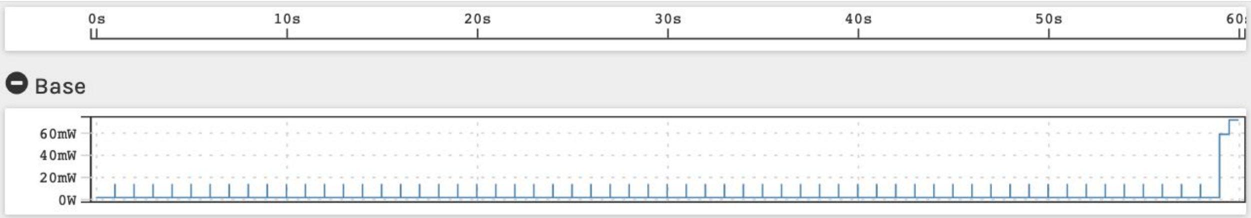
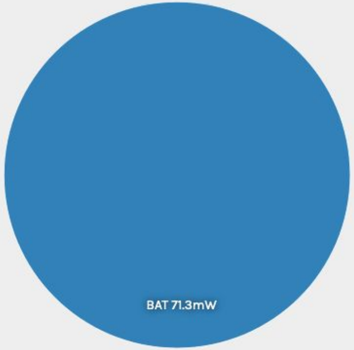
Continuous measurements

Reported power over time, max 71mW after 50s



Supply	Voltage	Power	Current	Confidence
BAT	3.6V	71.3mW	19.81mA	100%
IN	3.6V	0W	0A	0%
Total at 59.67s		**71.3mW**		**100%**



System scenario #2 - Consumer

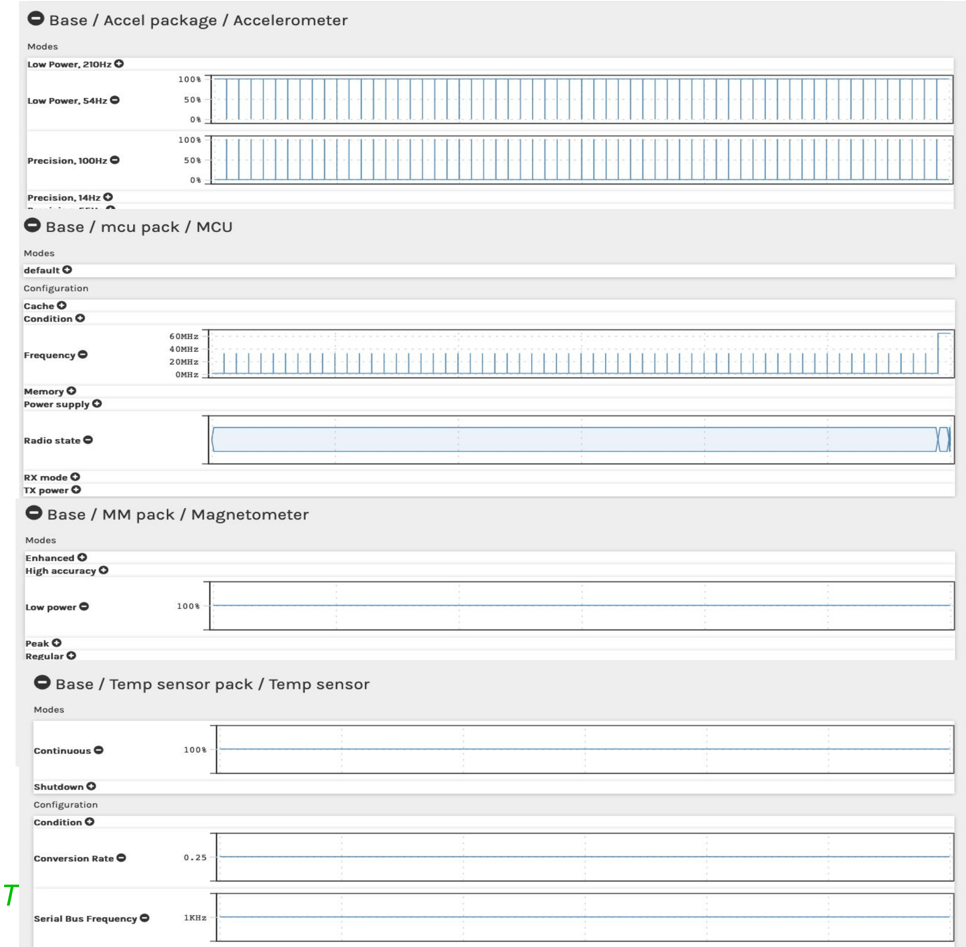
Watch product
Almost all chiplets are on
Accelerometer:

- Running in low power mode
- Switches to Precision every second

MCU

- Wakes up every second to process data @ 32MHz
- Every minute sends the data and receives back data
- TX @ 59s - 59.8s
- RX @ 59.8s

Temp sensor running Continuous measurements



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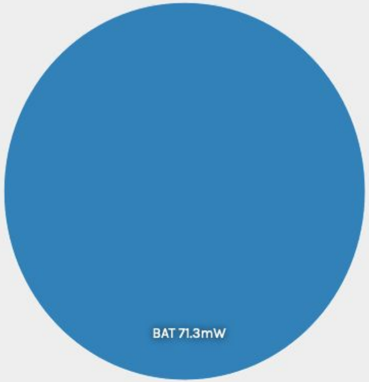
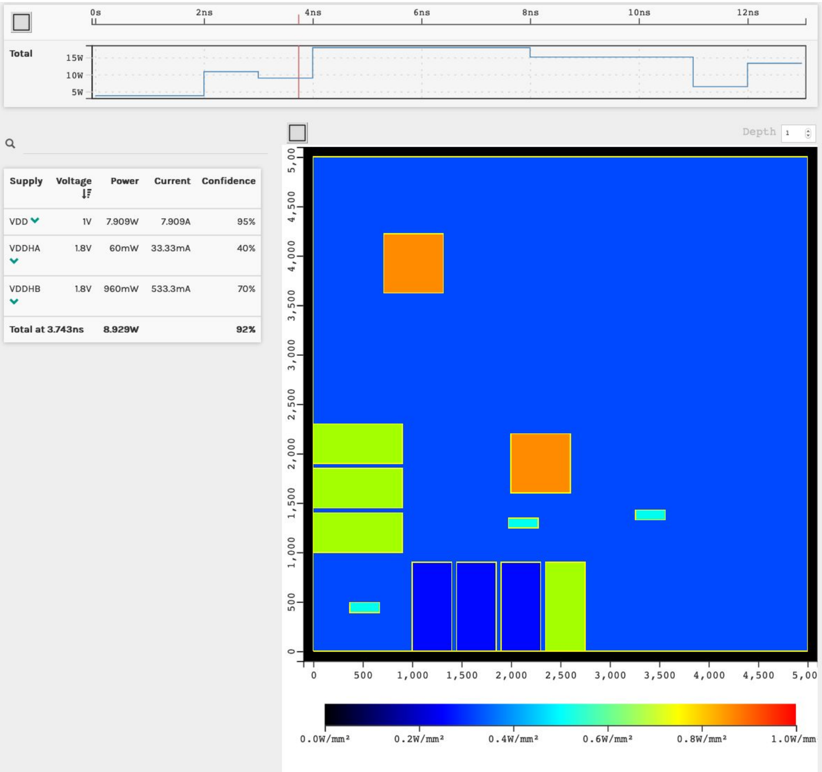
Temp sensor running Continuous measurements

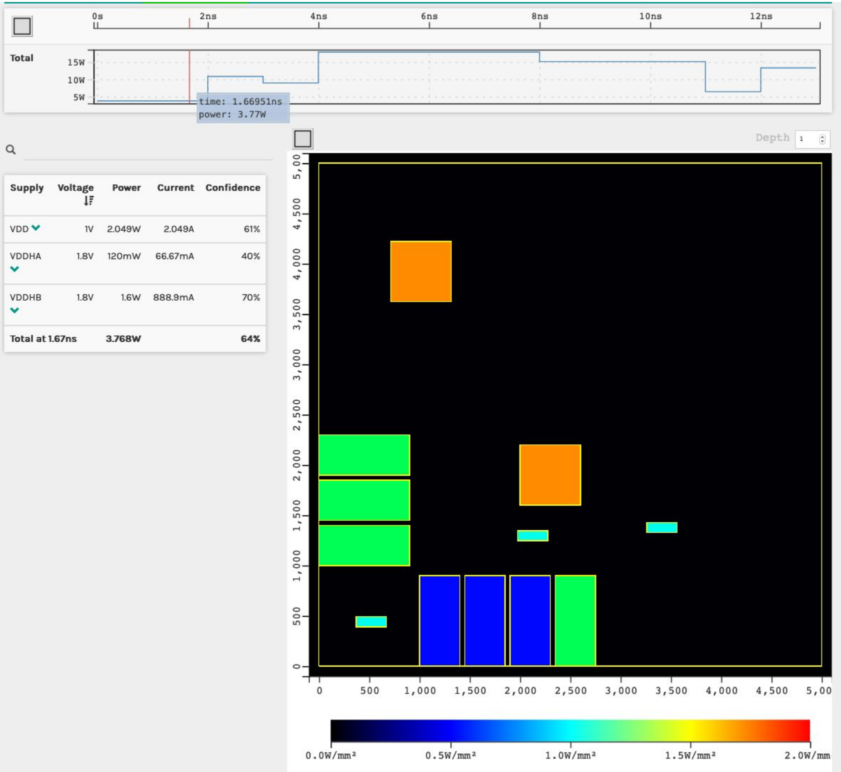
Supply	Voltage	Power	Current	Confidence
BAT	3.6V	71.3mW	19.81mA	100%
IN	3.6V	0W	0A	0%
Total at 59.72s		**71.3mW**		**100%**



Data for thermal analysis

Accurate thermal analysis requires detailed power distribution data at the die level
Example SoC: Case 1: **8.9W** with < **1W/sq.mm** density, Case 2: **3.76W** with < **2W/sq.mm.** density
Which case has worse hot spot temperature?





Summary

Demonstrated power analysis on a 7 chiplet system

System-level Power can be specified in tool readable format such as IEEE2416

- Handles complex data - equations, tables, waveforms
- Extends existing power formats for flow compatibility

PowerMeter™ is ready for chiplet system-level power analysis

- Model complex scenarios, over time, hand-off between chiplet states
- Analyze power and energy
- Generate detailed power distribution data for accurate thermal analysis

Summary

Learnings

- Standardize on IEEE2416 for electronic power datasheet
- Publish white paper with flow results

Next steps

- Continue collaboration
- Hand-off power analysis data to thermal analysis