Emerging Zero-Standby Solutions for Miscellaneous Electric Loads

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Bio

Bachelor: MIT – Electrical Engineering
PhD: University of California Berkeley – Power Electronics
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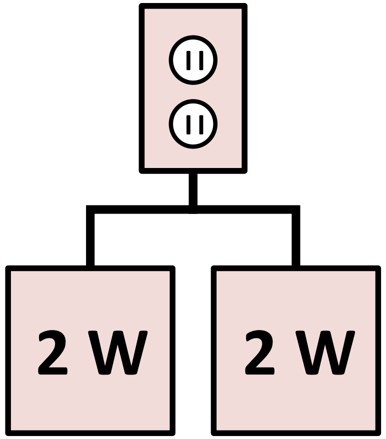
My current field of research is in standby power reduction, DC microgrids, and end-use load electrification.

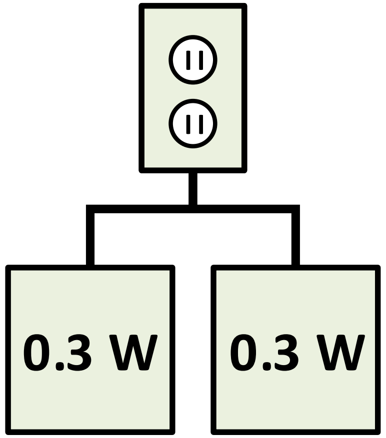
My interest is in rapid prototyping and applications-based research. These topics span power electronics, microgrids, power systems, controls, buildings, and energy.

Motivation for Reduction in Standby Consumption



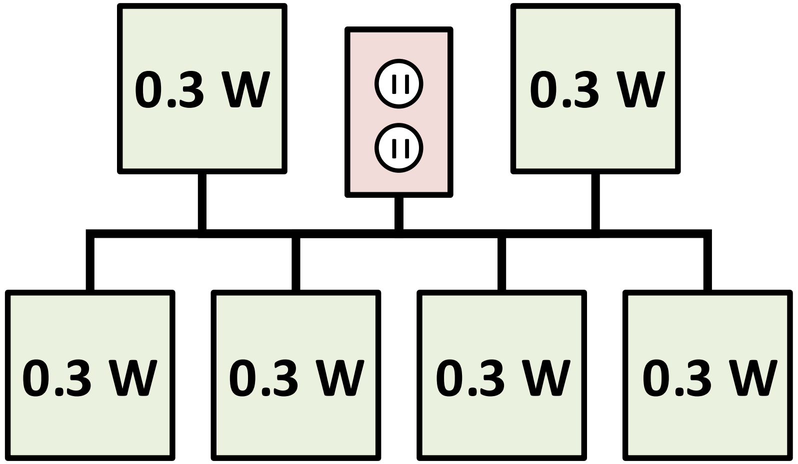
Past

Devices in standby would regularly consume over 2 W.



Present

Considerable progress in reducing standby has been achieved through a variety of policies and technologies.

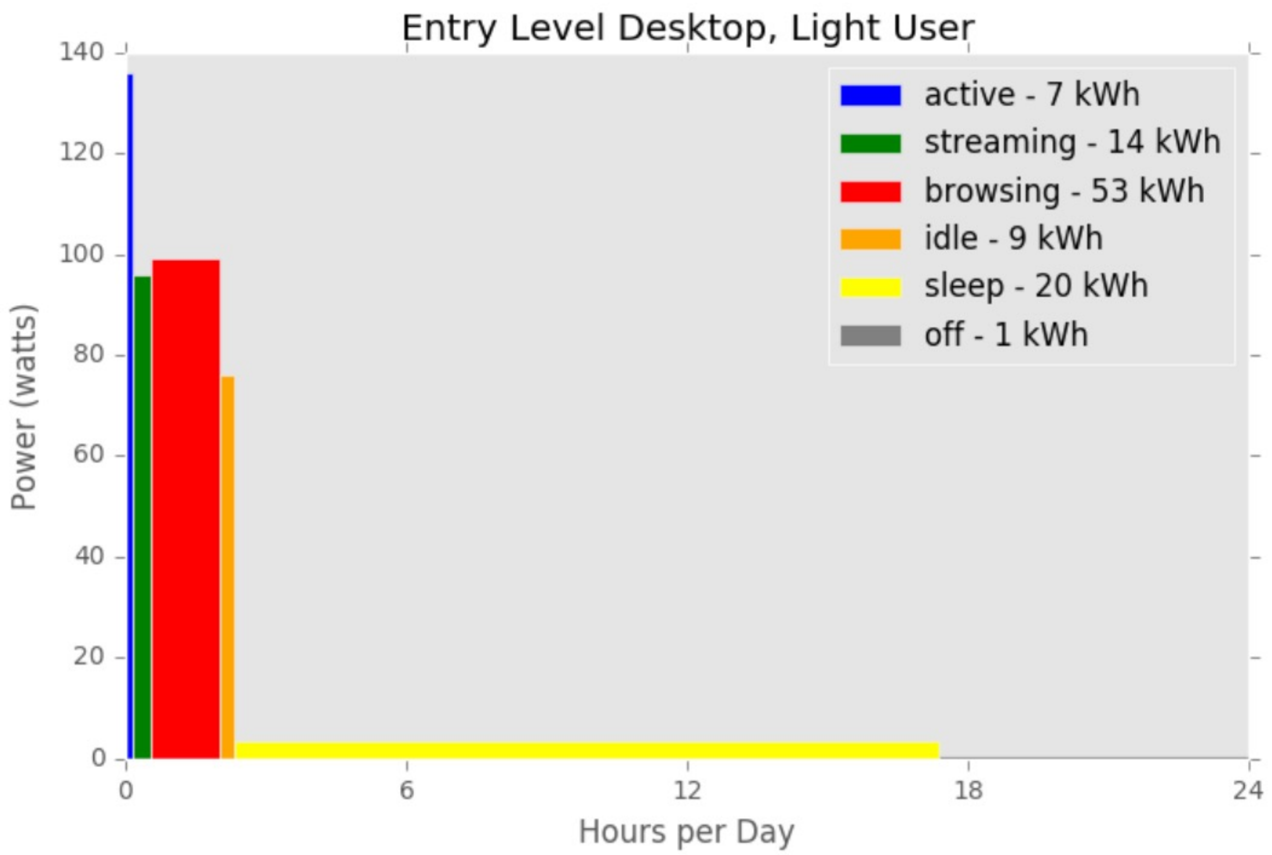


Future

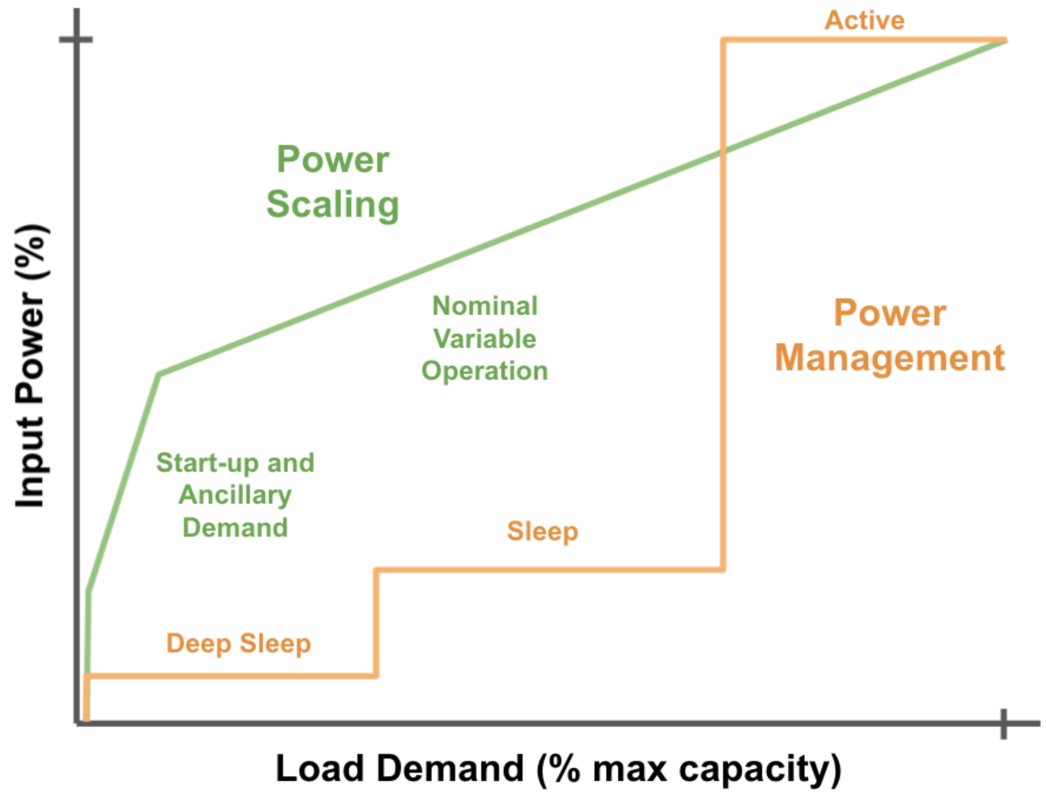
Trends in electronics and the IOT suggest a proliferation of low-power devices with standby modes.

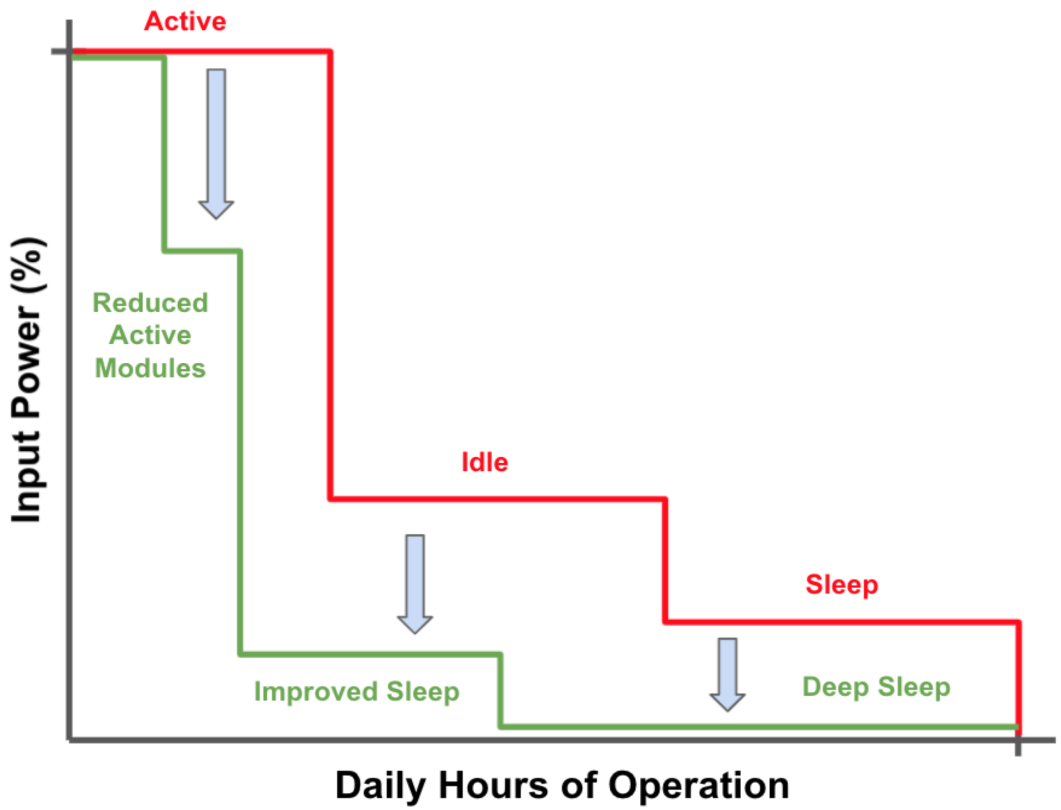
What Causes Standby Consumption?

- Standby consumption has had many definitions
- Our research concerns any consumption that occurs when a load’s primary function is not in an active mode. Includes:
  - Idle – On, but not useful output
  - Sleep – Consumption in an intentional low-power mode (or “ready” mode for appliances)
  - Off – Consumption that occurs while device is officially off



Reducing Standby Consumption

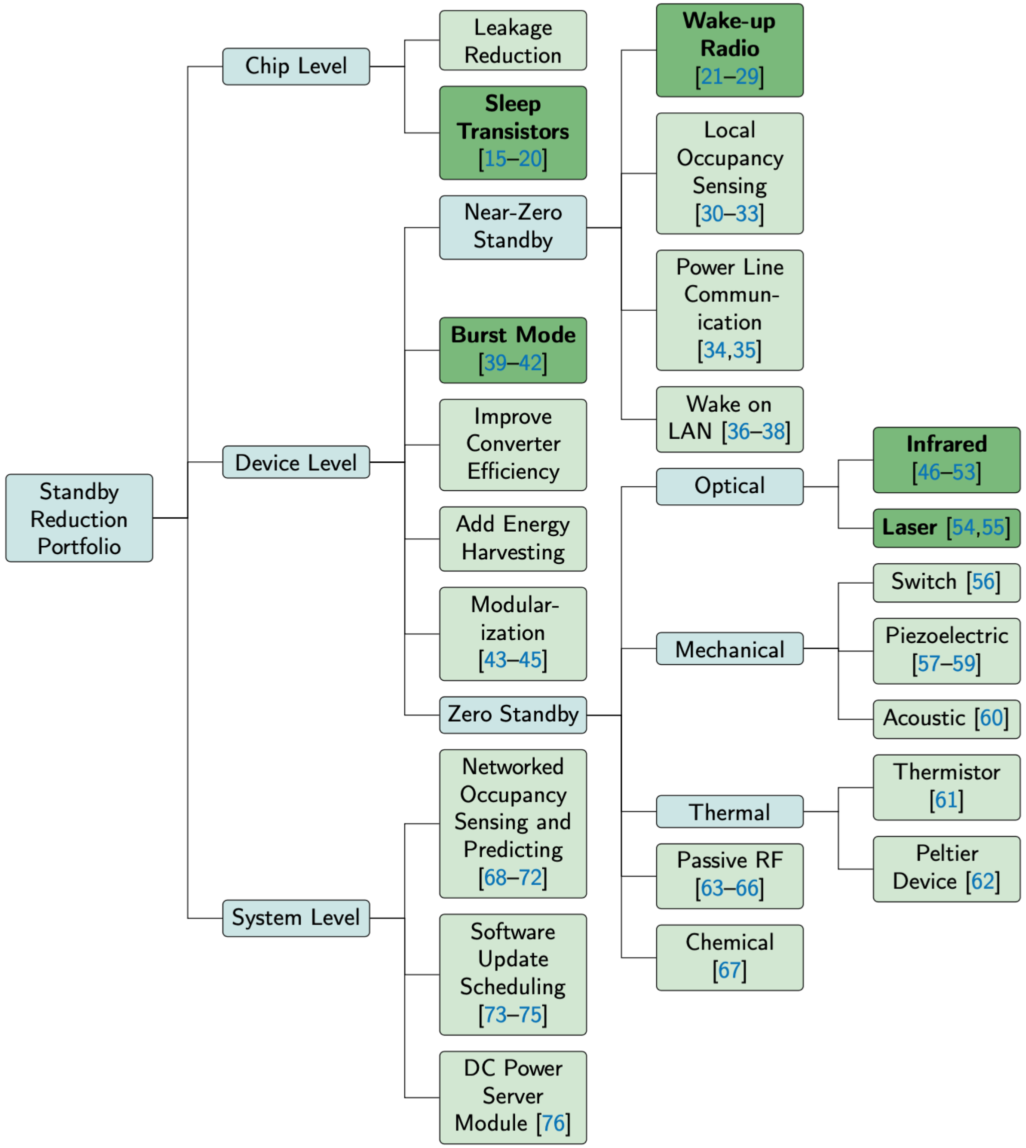




- A device’s consumption, arranged as a histogram, can include power management and power scaling
- How to improve part-load consumption?
- Shrink the staircase
  - Improve efficiency in various modes
  - Eliminate low-power modes: Zero Standby technology

Standby Reduction Portfolio

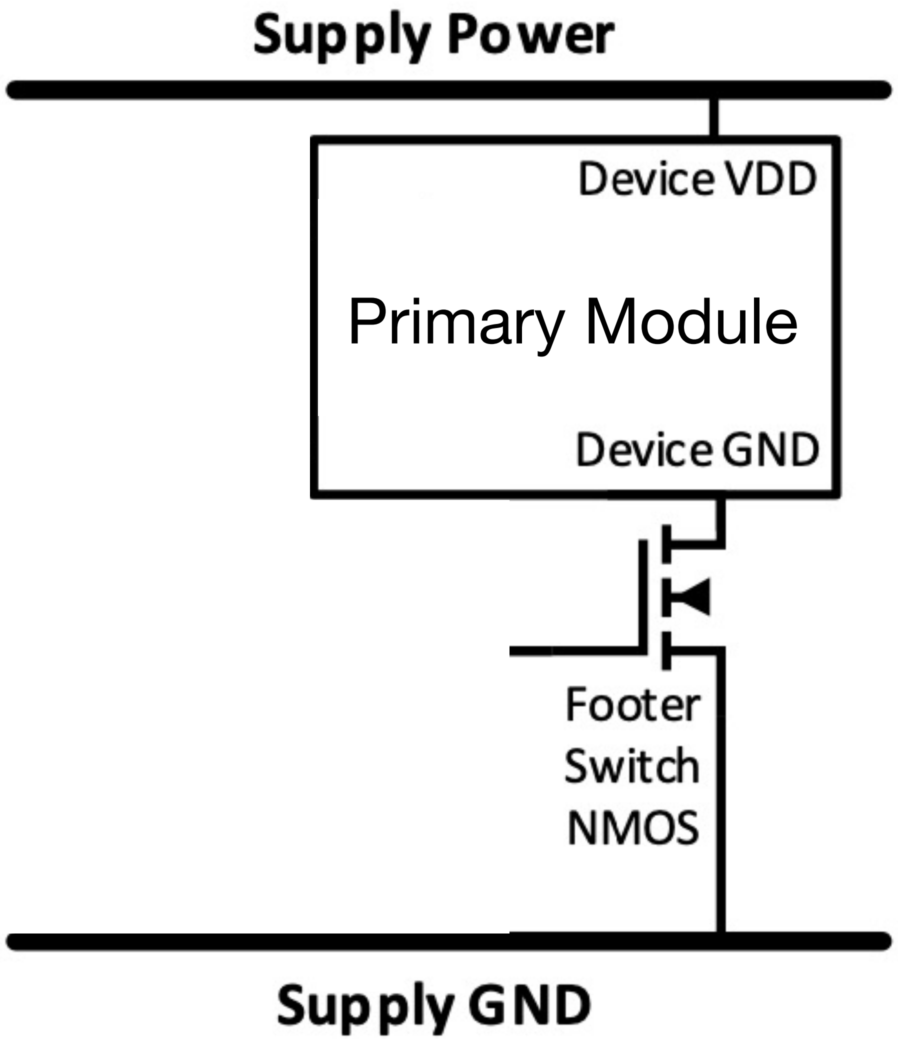
- Many standby reduction techniques, applicable to specific classes of devices
- This presentation describes some examples from each category
- Chip-Level Improvements
  - Leakage
  - Improved Power Management
- Device-Level Improvements
  - Burst Mode
  - Wake-up Radio
- System-Level Improvements
  - Centralized Wake-up Controller
  - Automatic Update Scheduling



Review from a 2018 study: *Emerging Zero-Standby Solutions for Miscellaneous Electric Loads and the Internet of Things*

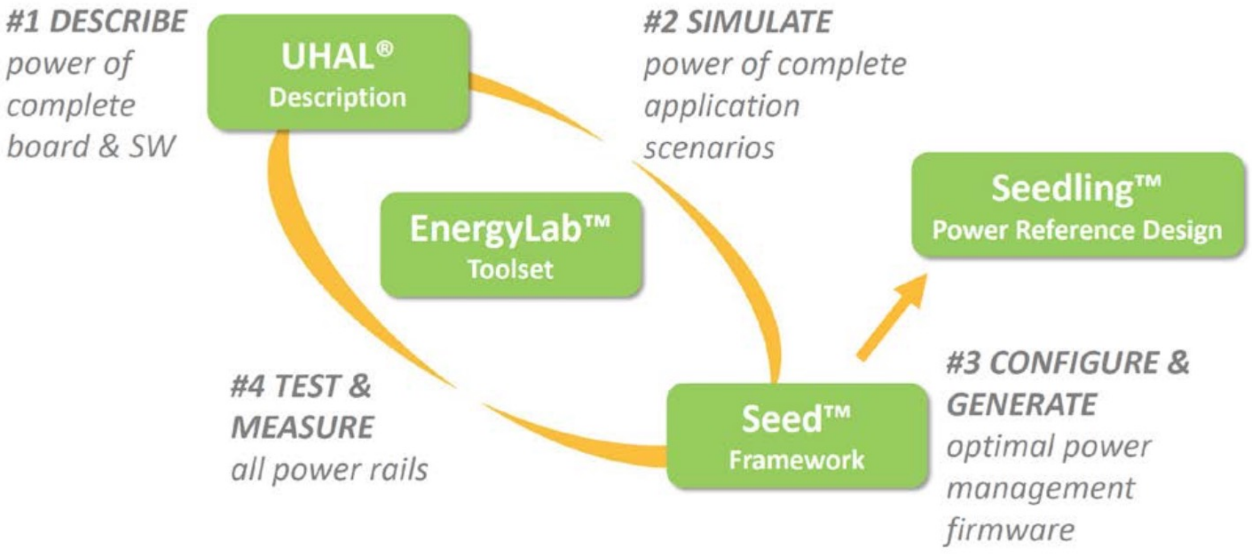
Chip Level – Circuit Improvements

- Leakage – Quiescent current through Rds when off, or CMOS held in state
  - Can occur in primary modules that have been "turned off"; adds up over many CMOS gates
  - Can reduce leakage with footer switches to help turn off main modules
- Switching Loss – Loss during switching due to capacitive and switch overlapping effects
  - Can occur in wake-up logic that must be powered to wake primary modules
  - Can reduce by designing wake-up circuit to reduce loss: low clock frequency, low supply voltage, low gate capacitance, low output resistance



Chip Level – Software Defined Energy Management

- SoC/FPGA power management can often be optimized
- Optimization services can leverage special tools to improve power consumption in standard on-chip processes
- Tool Process Flow
  - Simulate power what-if scenarios
  - Evaluate and select various optimization options
  - Conduct power measurements on the prototyping or custom production board



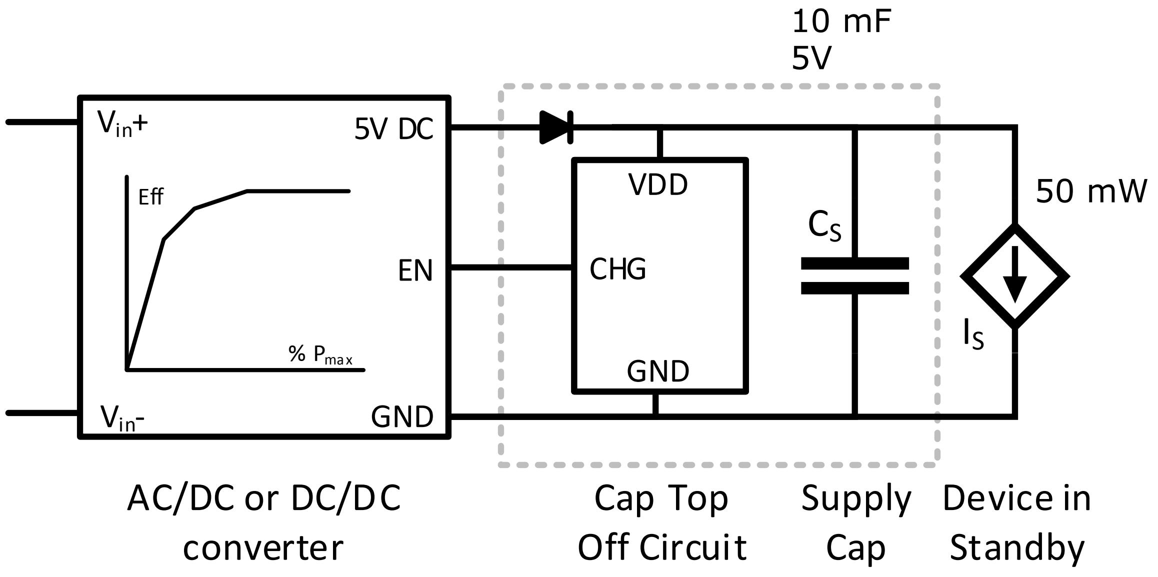
Application	Description	SoC Version	Board	Mode	Xilinx TRD or equivalent	AGGIOS PRD	Difference	Saved
Video	1080p60 streaming	ZU7EV	ZCU106	Active PS and PL	4,559 mW	2,950 mW	- 1,609 mW	35%
Video	Deep Learning - Region of Interest	ZU7EV	ZCU106	Active PS and PL	10,959 mW	4,201 mW	- 6,758 mW	62%
ECC	ECC processing	ZU9EG	ZCU102	Active PS and PL	3,702 mW	1,573 mW	- 2,129 mW	58%
Benchmark	Memory throughput	ZU9EG	ZCU102	Active PS only	1,714 mW	1,031 mW	- 683 mW	40%
SDR	Radio	ZU9EG	ZCU102	Signal Detection APU/Linux only	1,680 mW	535 mW	- 1,145 mW	68%
SDR	Radio	ZU9EG	ZCU102	Signal Detection RPU/RTOS only	350 mW	50 mW	- 300 [illegible]	86%

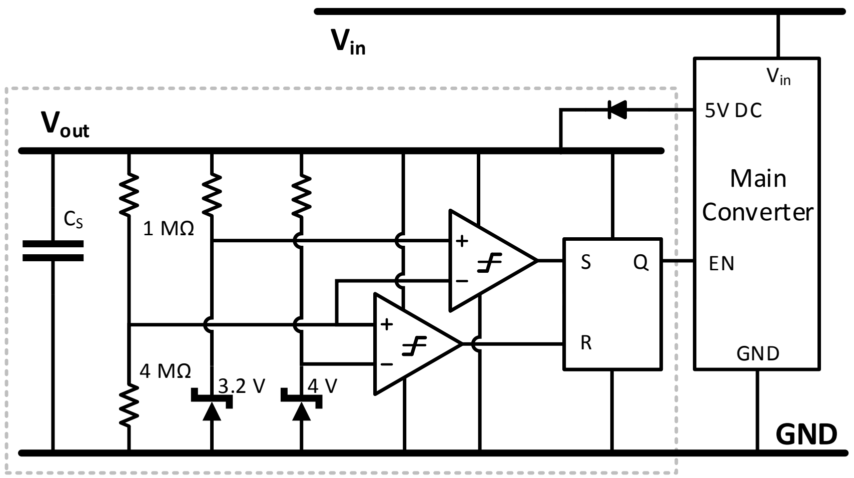
Reference design examples from Aggios' tool EnergyLab. Currently only for Xilinx, but general principles applicable to other chips.

Source: *AGGIOS Seedlings Power Reference Designs: Xilinx Zynq UltraScale+ MPSoC*

Device Level - Burst Mode – Low-power Improvements in Converter

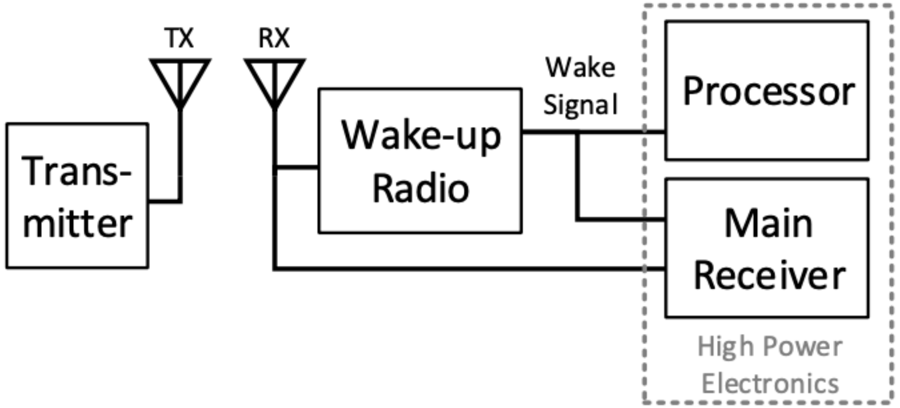
- Converters perform poorly at low load
- Burst Mode is a converter technique that powers light loads by periodically turning on for a short duration
  - Currently only used at extremely light load with a small supply capacitor
  - Does not allow supply cap voltage to sag; requires converter always on
- Extended applications?
  - Many electronics are tolerant to a range of input voltage
  - Allowing supply cap voltage to sag a bit reduces frequency of bursting; allows converter to turn off completely for a few seconds
  - Eliminates no-load consumption of converter while off
  - Can use a super cap to extend off time

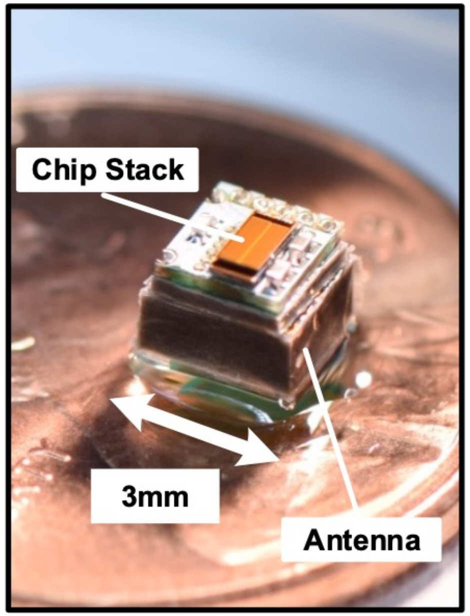




Device Level – Wake-up Radio (WuR) – The Ultimate Standby Killer

- An extremely low-power radio designed solely to wake a main device or module from sleep
- Most appealing type of standby killer
  - RF wake-up signal is fairly universal
  - Most future IoT and smart devices will have an antenna
- Still not available as COTS chips, but promising results in academia. Examples:
  - 578 µW, -91.5 dBm (WiFi) [1]
  - 2.1 mW, -109 dbm (cellular) [2]
- Can optionally use energy harvesting to power WuR in battery applications



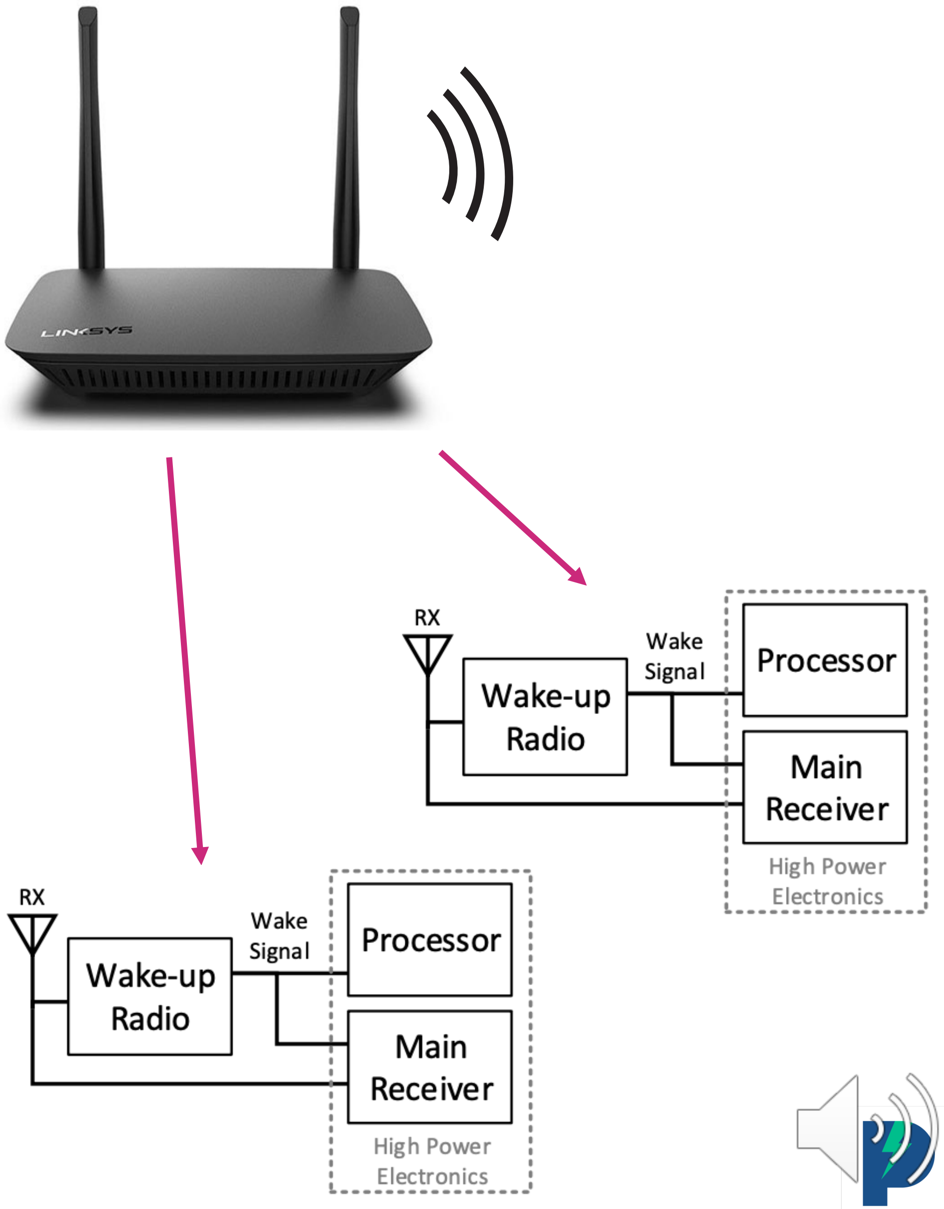


Source: [2]

[1] *A Fully Integrated 0.2V 802.11ba Wake-Up Receiver with -91.5dBm*
[2] *A 2.1mW -109dBm NB-IoT Wake-Up Receiver*

System Level – Network Management

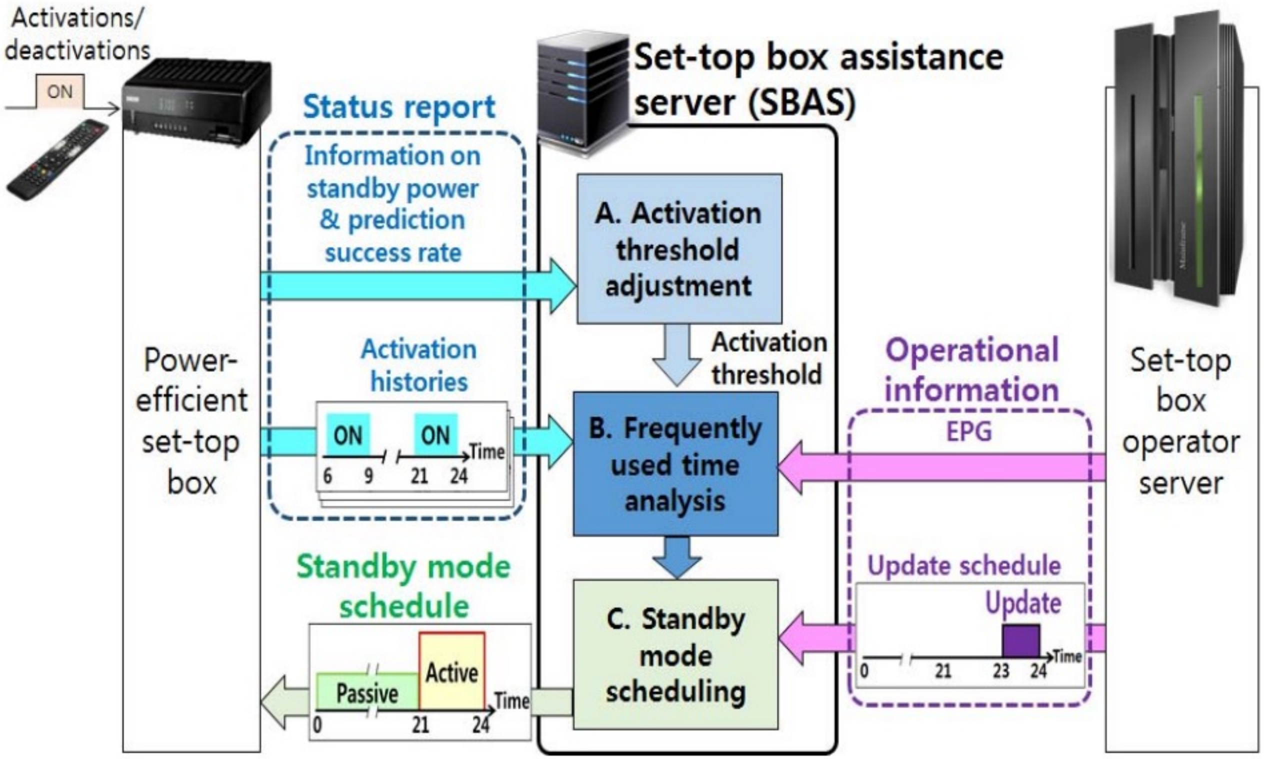
- Integrate home energy management software with WiFi network router
  - Receive wake-up signal input such as remote controller or sensor
  - Send WuR (or other) wake-up command from router
- The challenge – navigating user convenience
  - Some devices take forever to boot [1]
- Can use sensor input and behavioral data to predict device demand and pre-boot when appropriate
  - Weights user convenience and energy savings factors for a performance score
  - Ex. Long-short-term memory based prediction with device grouping and long-term model improvement [1]



[1] Deep Learning Based Prediction Towards Designing A Smart Building Assistant System

System Level – Automatic Update Scheduling

- Many devices are always on in order to listen for software updates
  - Ex. Xbox One draws ~10W when “off”
- Let’s allow the WiFi router to schedule automatic updates
  - Device schedules its wake-up with router
  - Device powers off (with standby killer)
  - Router wakes device at appointed time
  - Device checks internet for appropriate updates
  - Repeat



Source: [1]

[1] *Network-Assisted Management of Power-Efficient Set-Top Boxes for Enhancing User Experience*

Thank you for your interest.

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Are You Throwing Energy Away? Don't, or Recover it!

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