Title

Emerging Solutions to the Standby Power Problem

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Emerging Solutions to the Standby Power Problem

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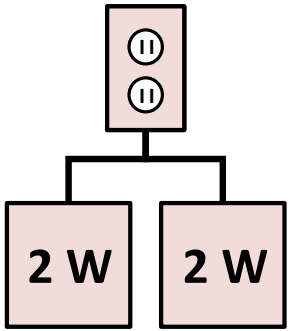
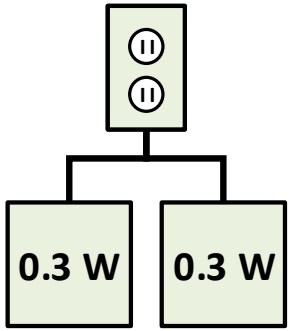
Motivation for Reduction in Standby Consumption



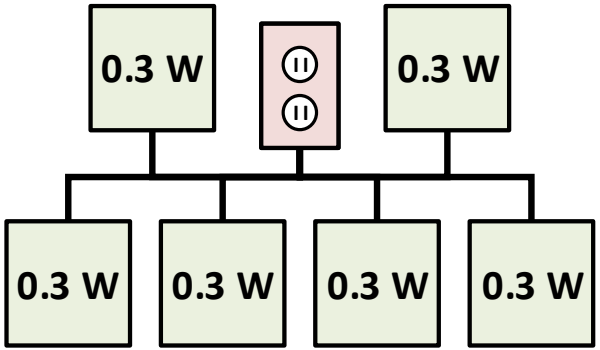
Past

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.

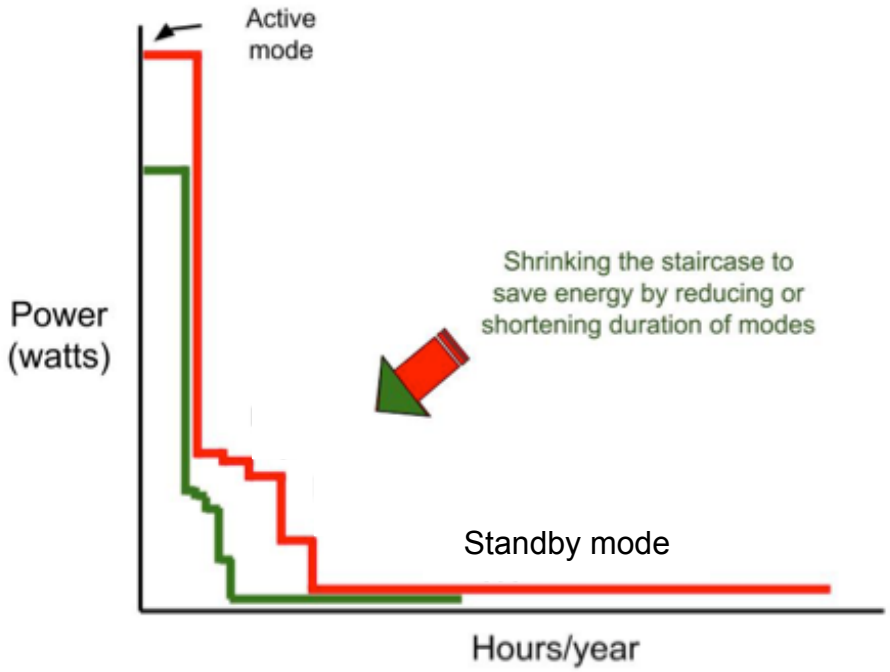


Future

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

Reducing Standby Consumption

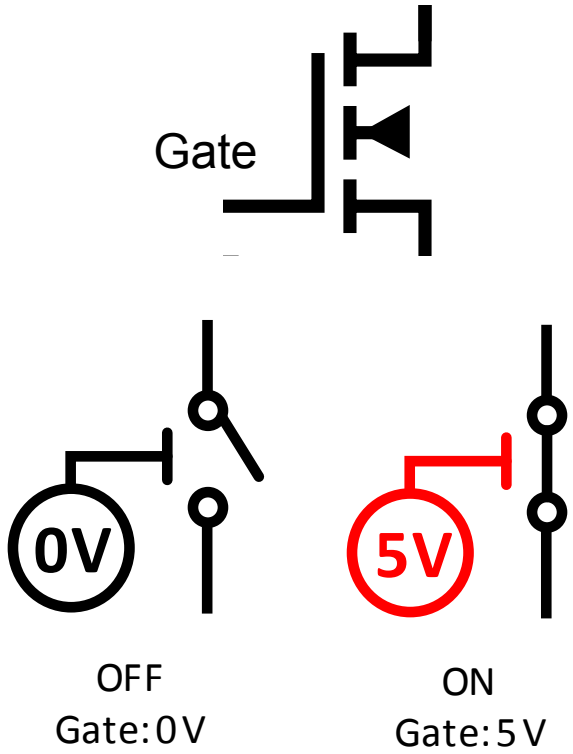
- Devices often have several power modes, ranging from active to standby
- Improvements in device efficiency can reduce consumption in various modes
- Alternatively, low-power standby modes can be eliminated in certain applications: **Zero Standby Technology**



Transistor Switches

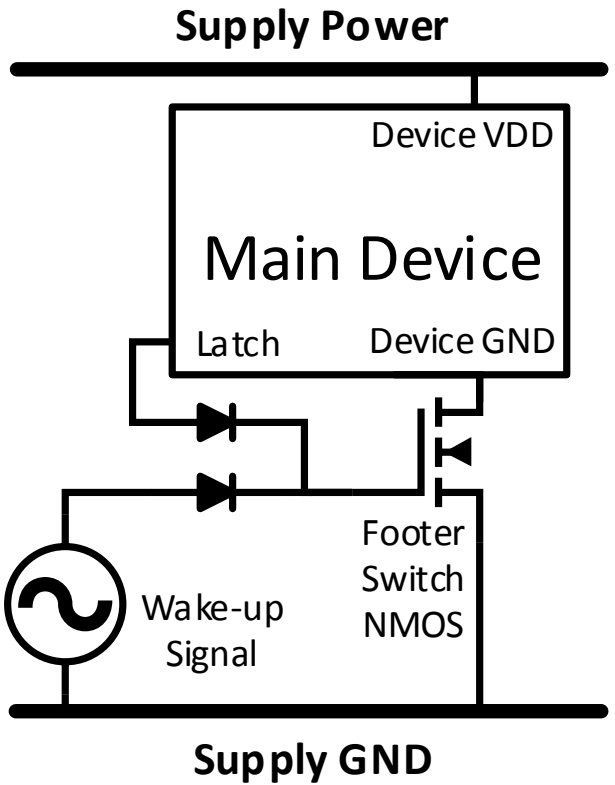
- Can disconnect a device from its power supply
- 3-terminal solid state device
- Switch state is set by gate voltage

- Gate = 0V: switch open (OFF)
- Gate = 5V: switch closed (ON)

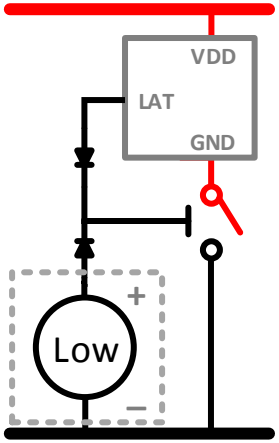


The Footer Switch for Zero Standby

- Connects main device ground to power supply ground
- Allows the main device to completely shut down, resulting in zero standby power consumption
- Requires a wake-up drive signal and a latching mechanism

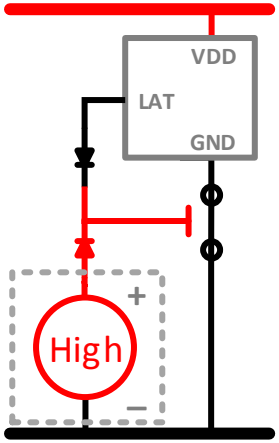


Footer Switch Operation



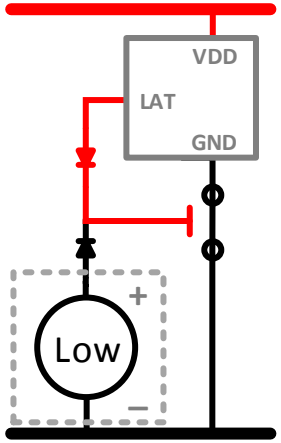
Standby

The device ground is disconnected from supply ground.



Wake-up

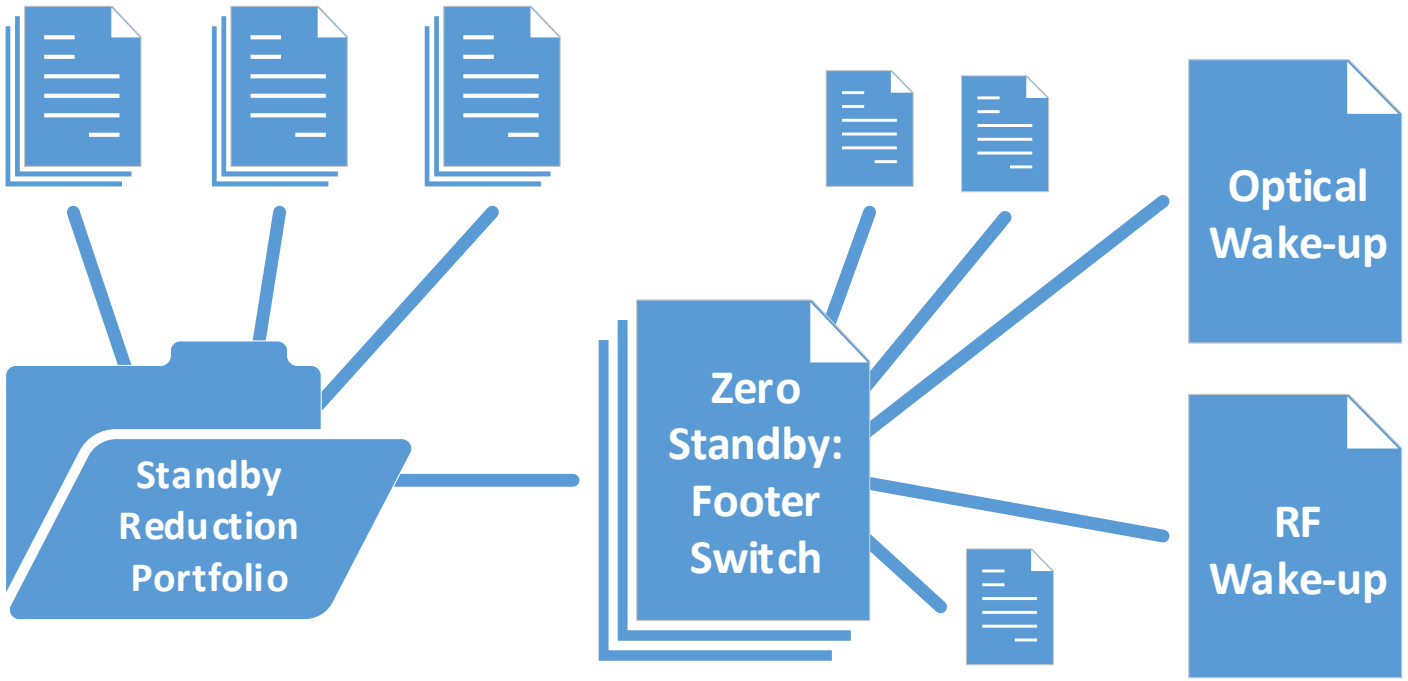
Wake-up signal connects device ground to supply ground. Device receives power.



Latch

The device must latch the gate of the footer switch in order to remain powered.

Applications of a Footer Switch in Zero Standby



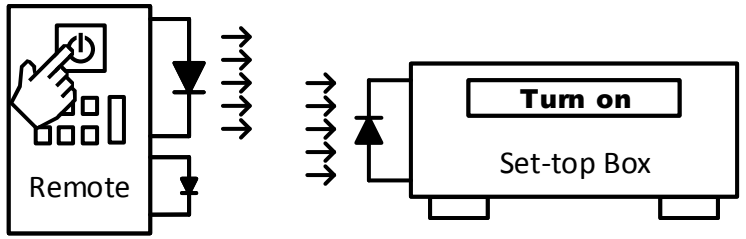
The footer-based technology is determined by the intended wake-up signal.

Optical Wake-up Signal

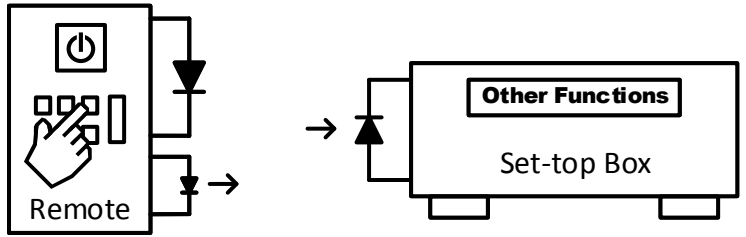
Applicable to DVD players, ceiling fans, lamps, curtains, and other devices that use line-of sight signaling

Two-stage signaling:

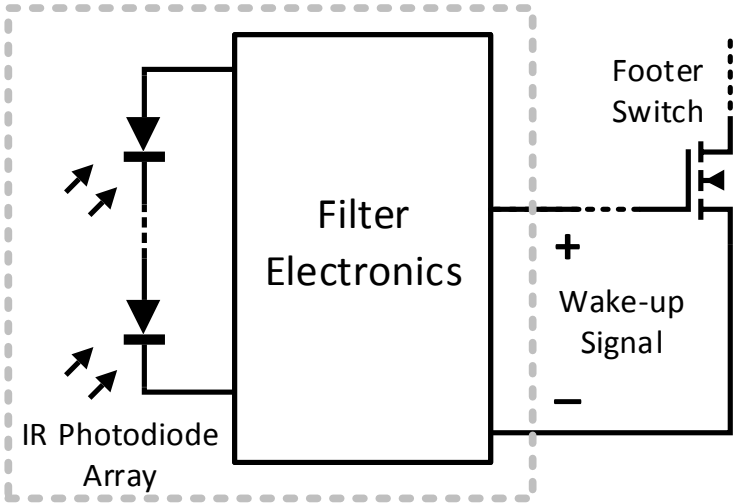
1. To turn on, transmit a high power IR wake-up signal, which gets harvested by a photodiode receiver



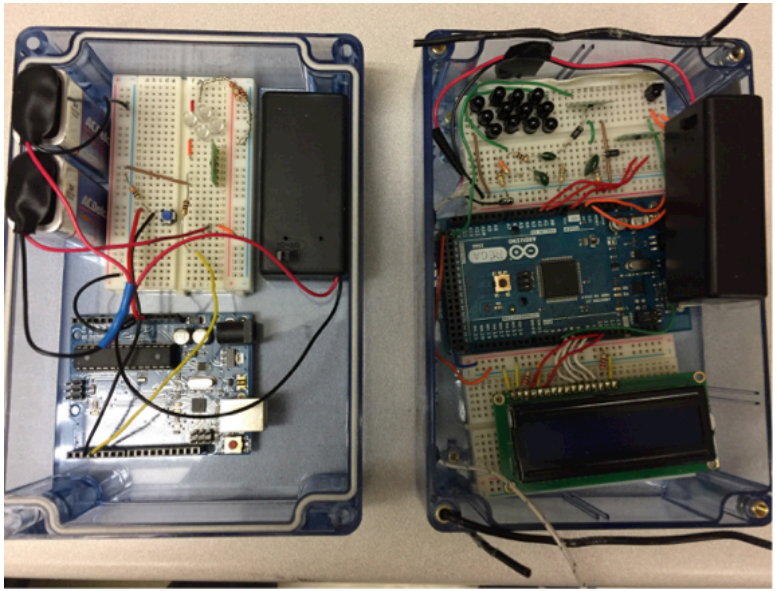
2. Once the DVD player is active, other signals can be low power



IR-Based Wake-up Signal Prototype



Photodiode receiver harvests enough energy to generate a wake-up signal

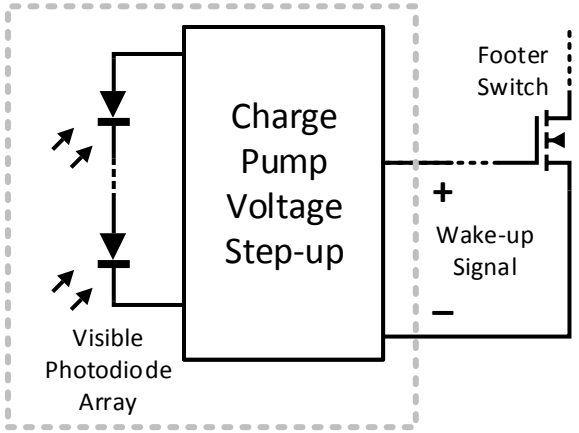


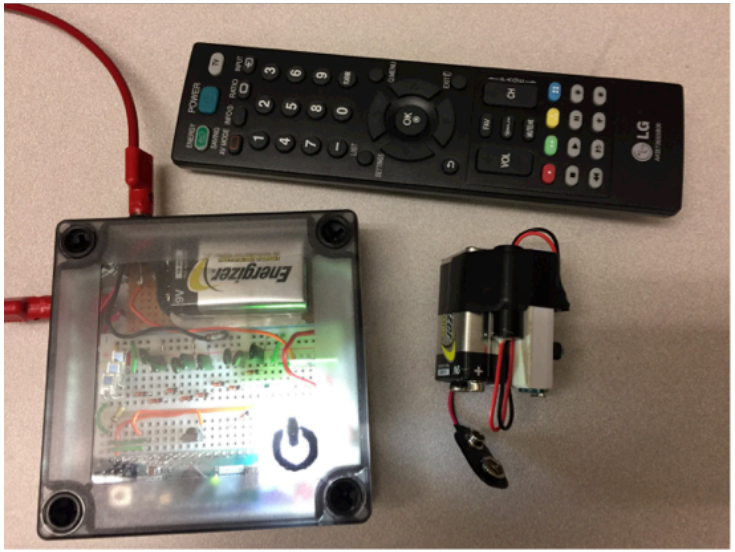
Prototype with an IR transmitter (left), and zero standby receiver (right)

Laser-Based Wake-up Signal

Pros
- Greatly enhances transmission range
- Laser pointers are universal and cheap
- Guaranteed to wake the correct device

Cons
- Harder to aim for people with shaky hands. Can increase beam width or photodiode reception area.

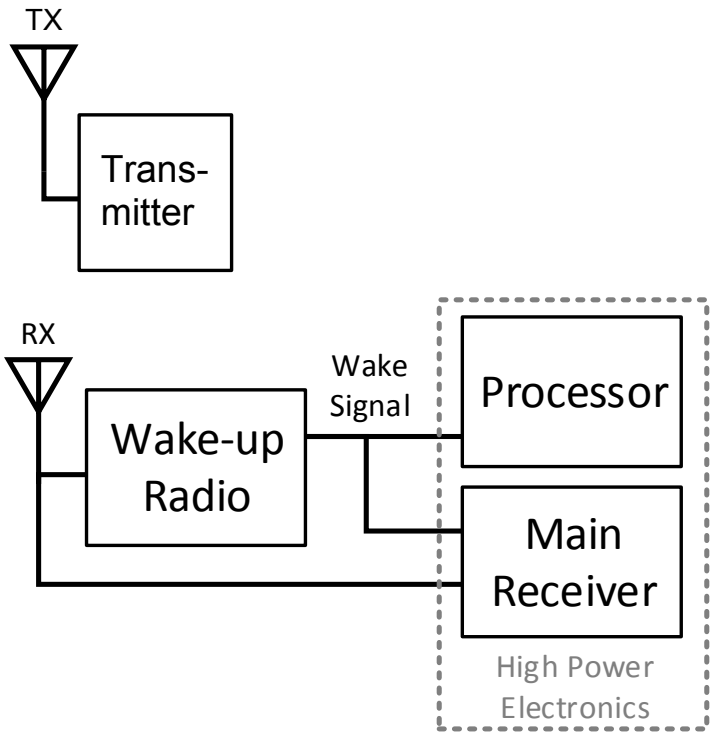




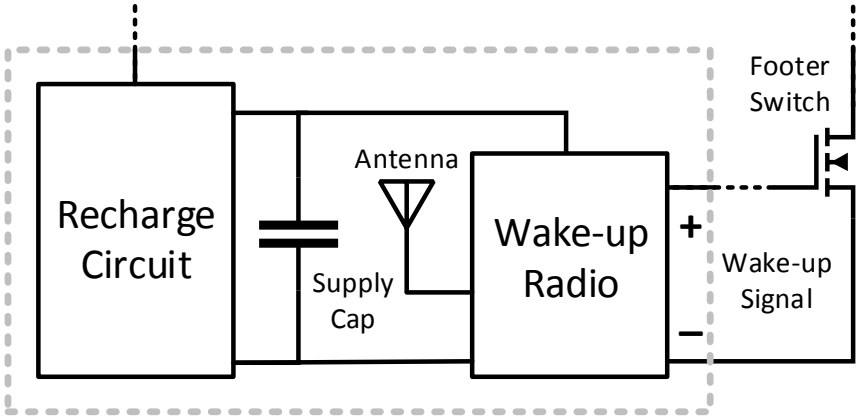
Wake-up Radio Overview

Applicable to IOT devices and network-connected appliances that have an antenna

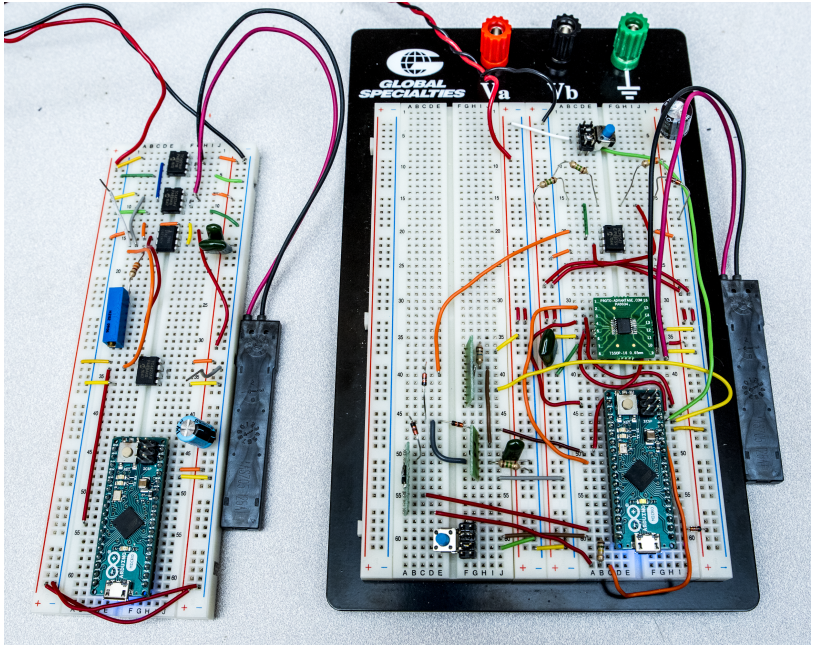
- A family of ultra-low power receivers that are designed solely to wake the main device from standby or sleep mode
- Mainly for battery applications at present
- Wake-up radios can be individually addressable, and have been designed for most frequencies
- Technically not zero standby, but has very low (microwatt) consumption



Wake-up Radio Prototype

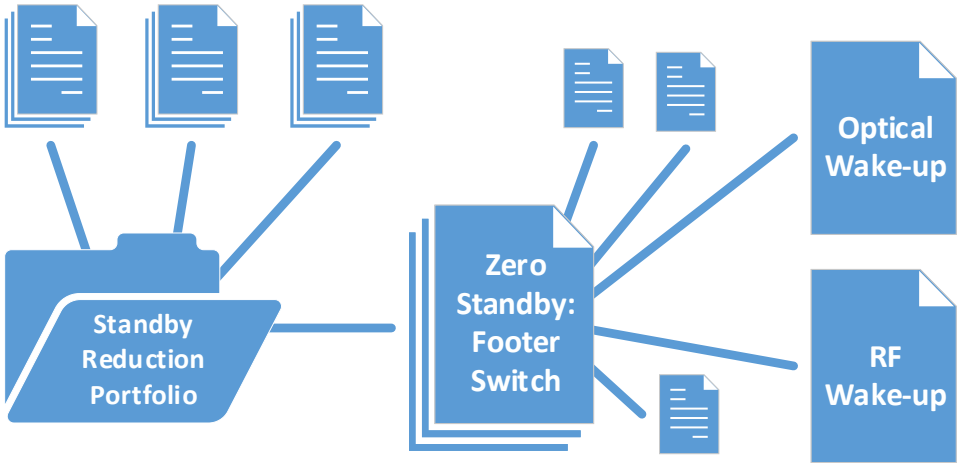


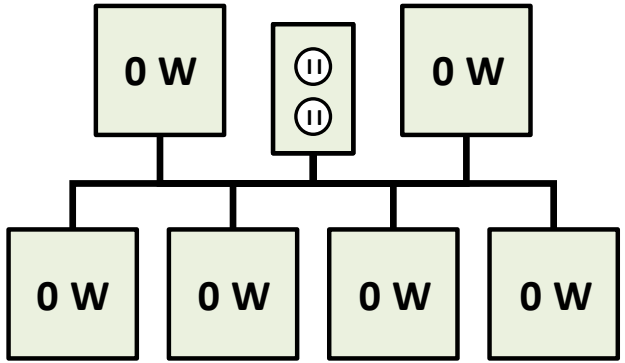
Wake-up radio requires 3 uA to operate. For plug-load applications, it is often useful to use a supply capacitor to power the wake-up radio. The supply capacitor can be efficiently recharged in a way similar to burst mode.



Prototype with an RFID transmitter (left), and wake-up radio zero standby receiver (right)

Future Work: Expanding the Standby Reduction Portfolio





Currently in the works

- Other sleep transistors: header switch
- Applications of burst mode
- Mechanical, thermal, or power-line wake-up
- Routers that can activate wakeup radios
- DC power with intelligent control
- Scheduled software updates

Backup

Applications of a Footer Switch in Zero Standby

When does a footer switch make sense?

- Standby mode has no critical functions
- Standby power is consumed solely by wake-up electronics (i.e. receiver)
- The device can be naturally waken with an external energy input

The footer-based technology is determined by the type of wake-up signal.

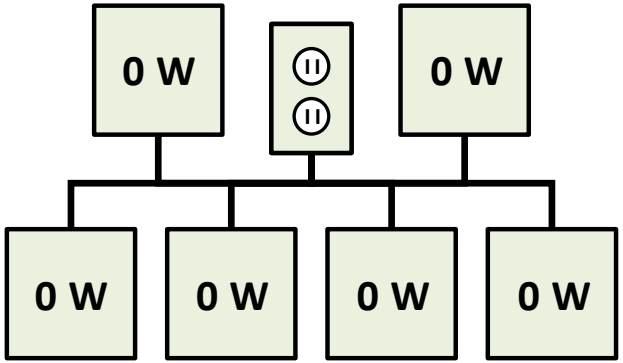
Methods in this presentation

- IR-based and laser-based wake-up signal for devices with remote activation
- Wake-up radio for network-connected devices

Future Work in Standby Reduction

Work that I plan to do

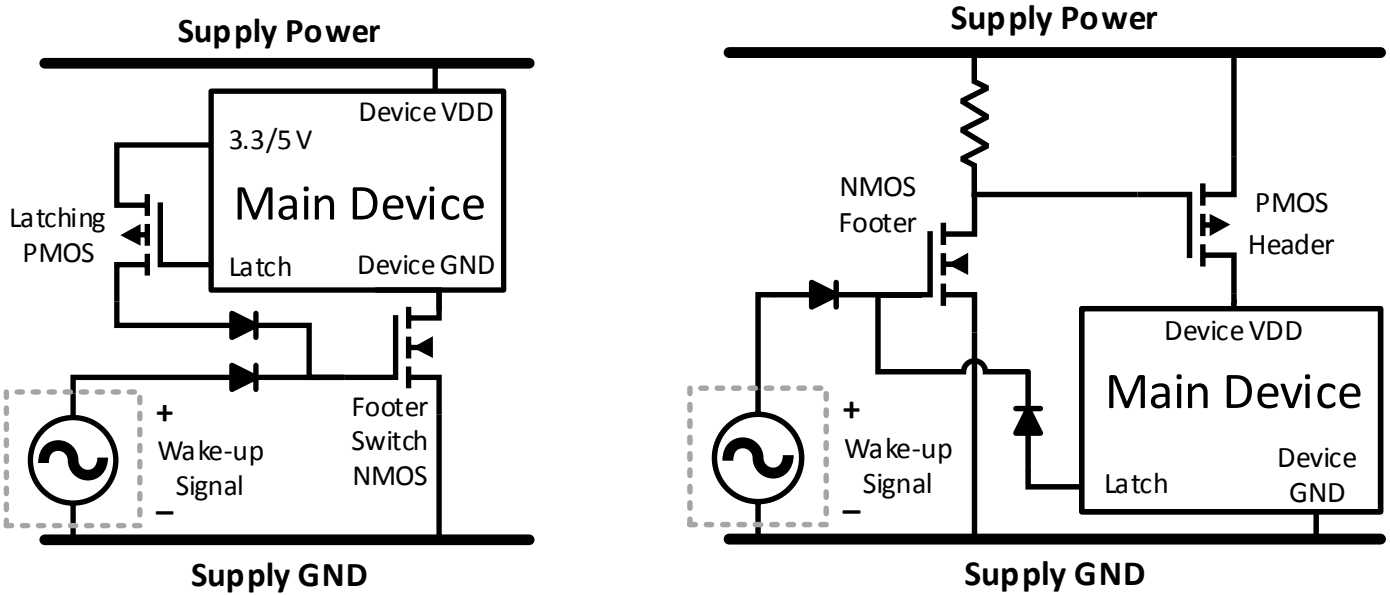
- Prototypes with other types of sleep transistors such as the header switch
- In-depth analysis of burst mode and how much power it can save in standby modes



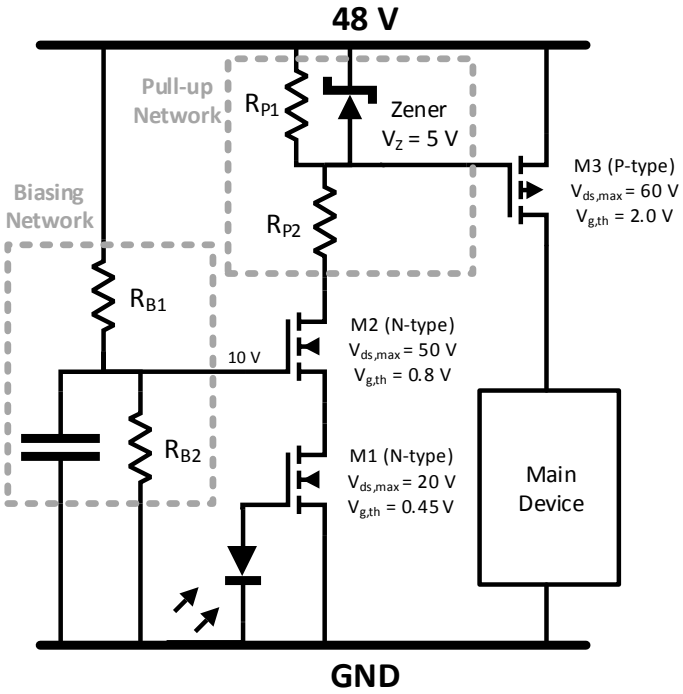
Possible future work in standby reduction

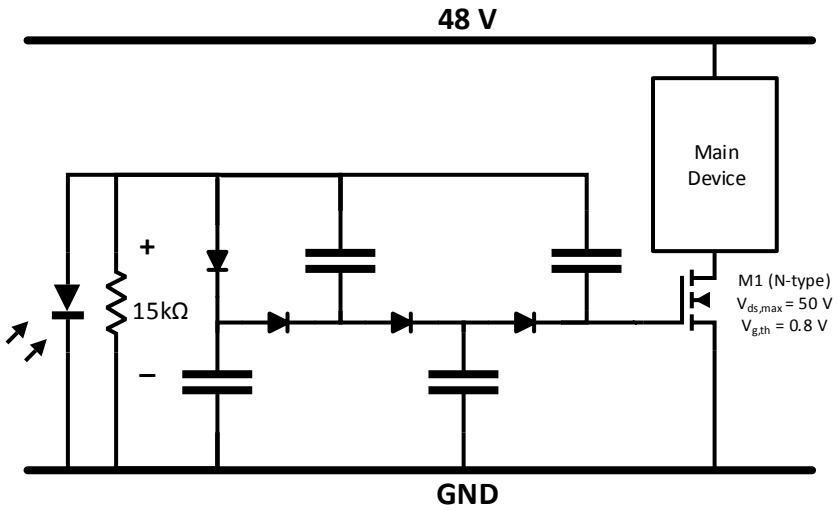
- Other footer switch application areas such as mechanical, thermal, or power-line signals
- Routers that can signal wakeup radios
- Smart DC power servers with intelligent current control
- Scheduled/coordinated software updates to allow internet connected devices to sleep and wake efficiently

Sleep Transistor

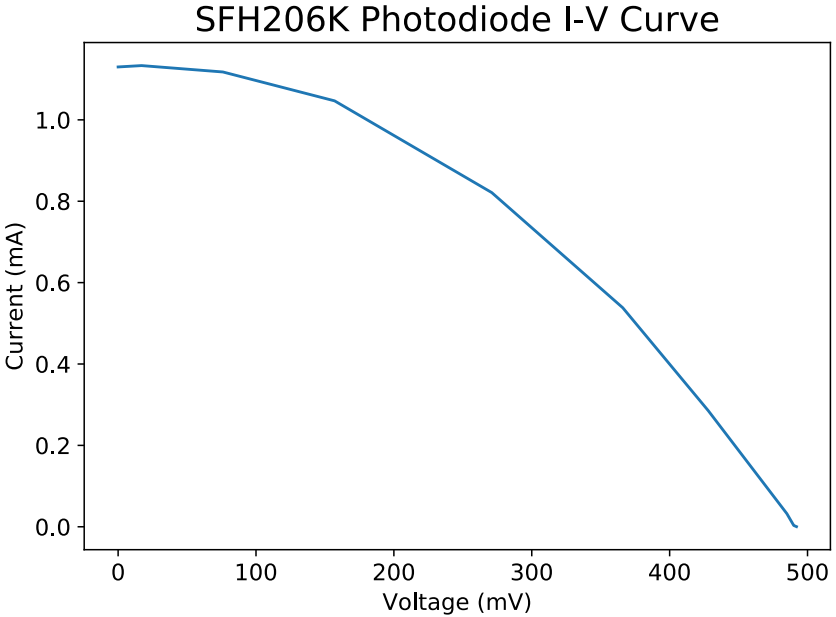


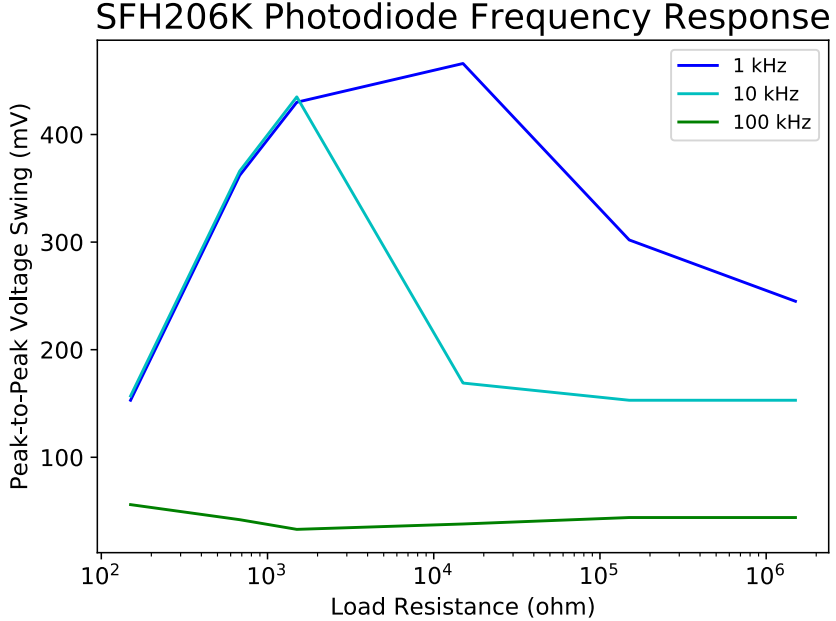
Laser


48 V
Pull-up Network
R_{P1}
Zener
V_Z = 5 V
M3 (P-type)
$V_{ds,max}$ = 60 V
$V_{g,th}$ = 2.0 V
Biasing Network
R_{P2}
R_{B1}
10 V
M2 (N-type)
$V_{ds,max}$ = 50 V
$V_{g,th}$ = 0.8 V
R_{B2}
M1 (N-type)
$V_{ds,max}$ = 20 V
$V_{g,th}$ = 0.45 V
Main Device
GND

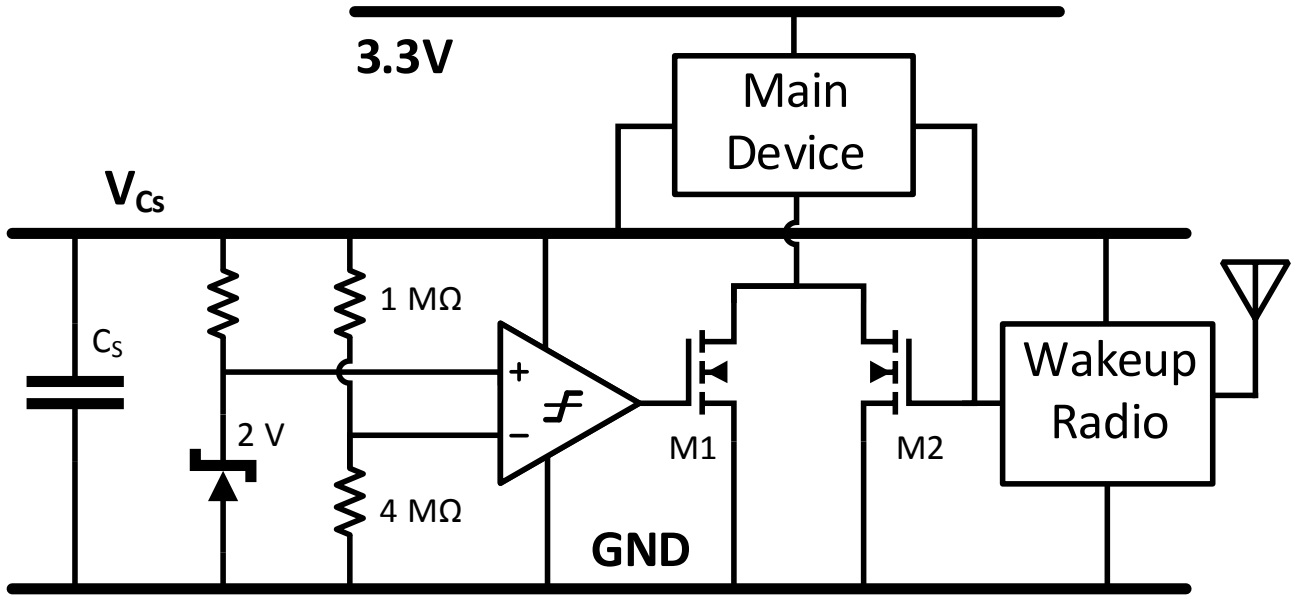

48 V
Main Device
+
15kΩ
–
M1 (N-type)
$V_{ds,max}$ = 50 V
$V_{g,th}$ = 0.8 V
GND

Photodiode

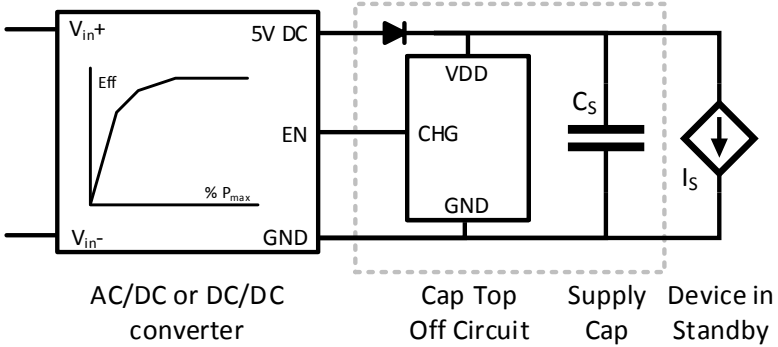

SFH206K Photodiode I-V Curve
Current (mA)
Voltage (mV)
0.0
0.2
0.4
0.6
0.8
1.0
0
100
200
300
400
500

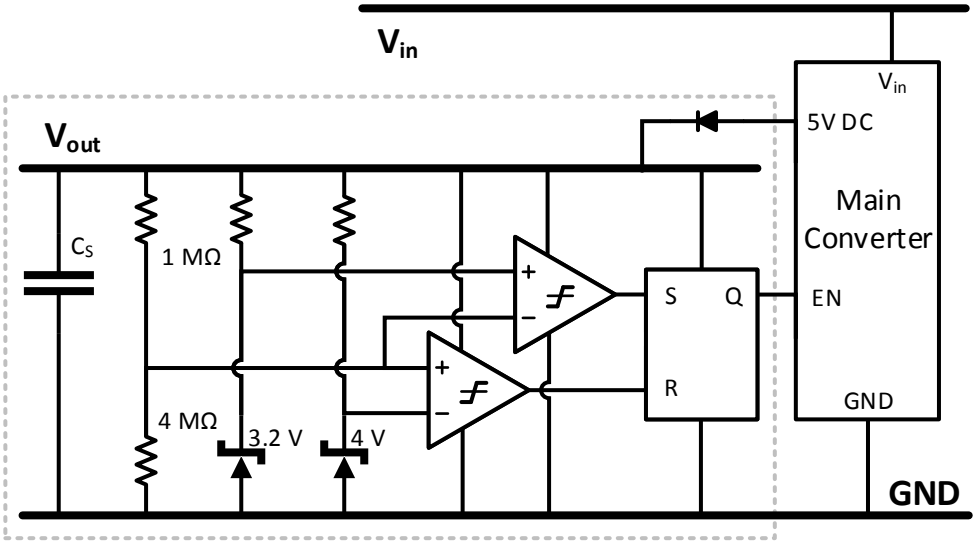

SFH206K Photodiode Frequency Response
Peak-to-Peak Voltage Swing (mV)
Load Resistance (ohm)
1 kHz
10 kHz
100 kHz
100
200
300
400
10^2
10^3
10^4
10^5
10^6

WuR



Burst mode


V_{in}+
5V DC
Eff
EN
% P_{max}
V_{in}-
GND
VDD
CHG
GND
C_S
I_S
AC/DC or DC/DC converter
Cap Top Off Circuit
Supply Cap
Device in Standby


V_{in}
V_{out}
C_S
1 MΩ
4 MΩ
3.2 V
4 V
S
Q
R
V_{in}
5V DC
Main Converter
EN
GND
GND

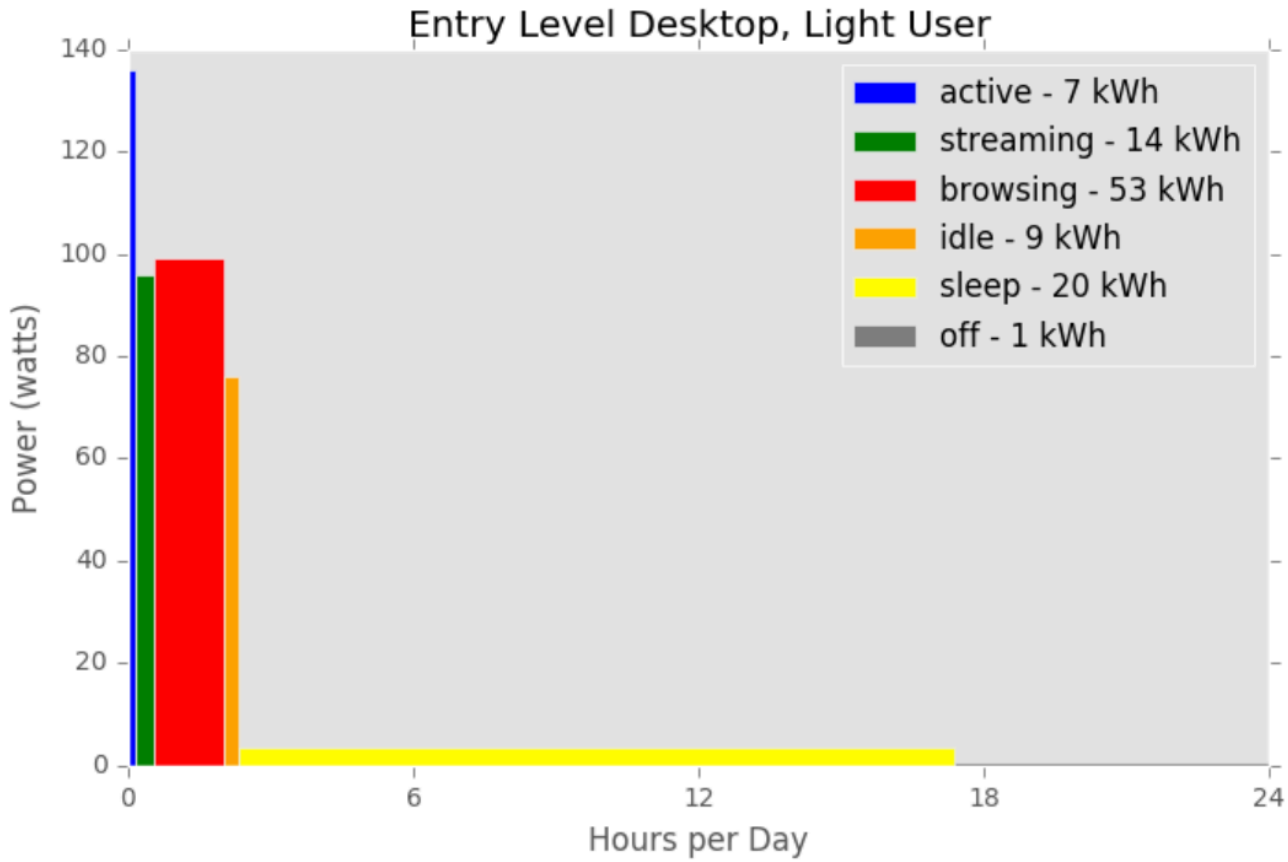


Figure 3. Typical power consumption histogram for a desktop computer. Roughly 20% of the daily energy consumption can be attributed to a standby mode.