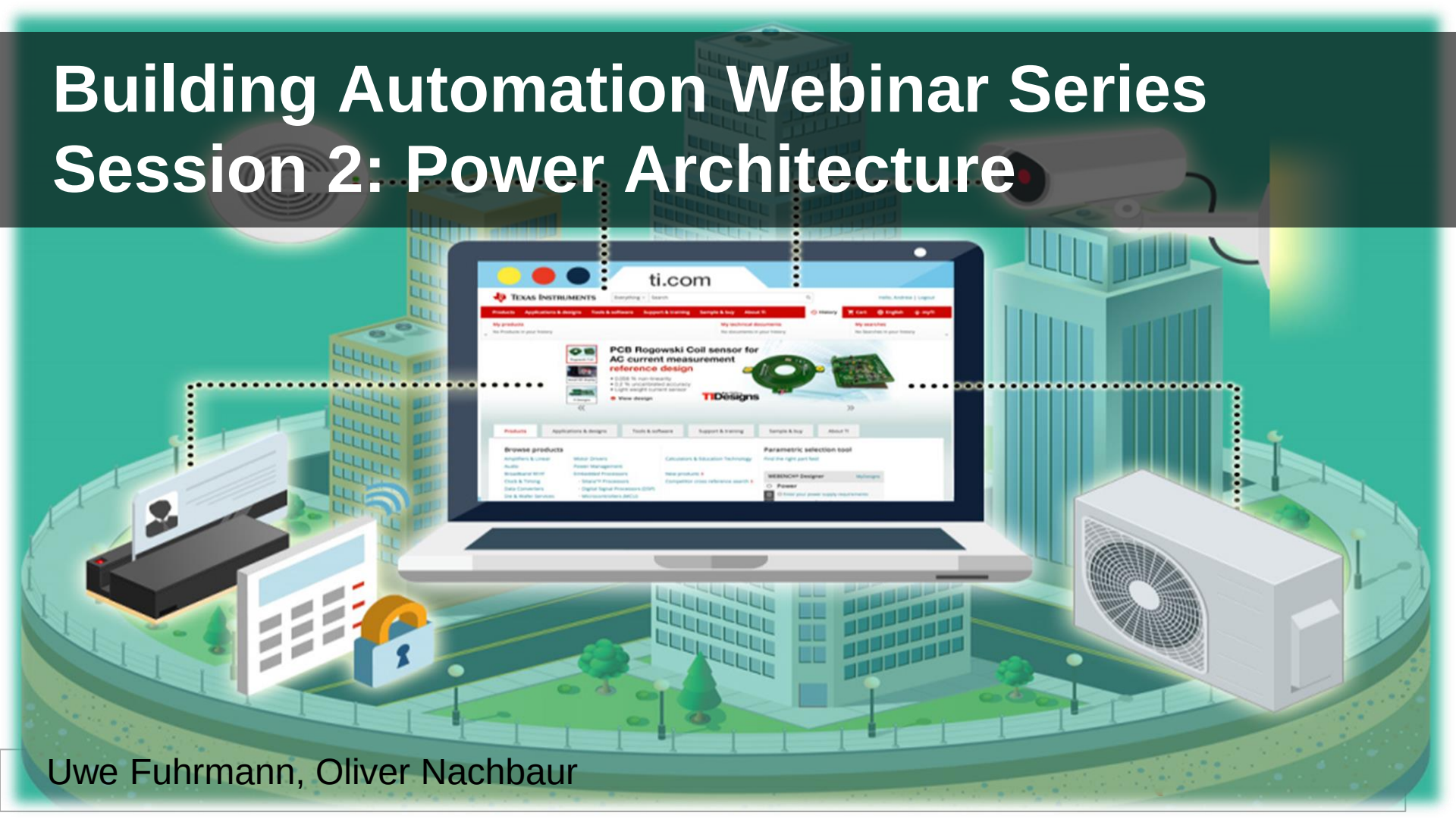
Building Automation Webinar Series
Session 2: Power Architecture



Uwe Fuhrmann, Oliver Nachbaur

Building Automation Webinar Series Session 2: Power Architecture

We take a look at highly efficient power architectures for Smart Door Lock, (battery-less) Light Switch and Wireless Sensors.

As many Building Automation systems become more feature-rich, achieving both long battery run times and low cost poses challenges to the system designer.

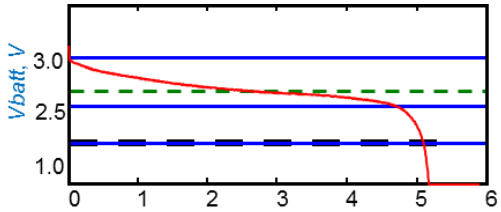
During this webinar, we will discuss real world examples on how easy it can be to extend battery-life (or even eliminate batteries altogether) while still ensuring a reliable system supply.

Agenda

- Introduction to market & system requirements
- Applications & Power Solutions
  - Smart Door Lock
  - Light Switch (battery-less, energy harvesting)
  - Wireless Sensor Node
- Support & More Information
- Q & A

Building Automation – market requests

- Need for more intelligent devices
- Need for extended battery operation time
- Need for cost-effective solutions



Building Automation – system requirements

- Door control
- Light control
- Fire alarm
- Window control
- Security
- Motion sensor
- HVAC control
- Environment sensing
- Smoke detector
- …

HVAC = Heating, Ventilation and Air Conditioning

Building Automation – system requirements
Intelligent devices sense the environment

Humidity

Pressure

Current / power

Position / motion

Biosensing

Temperature

Fluid and gas

Light

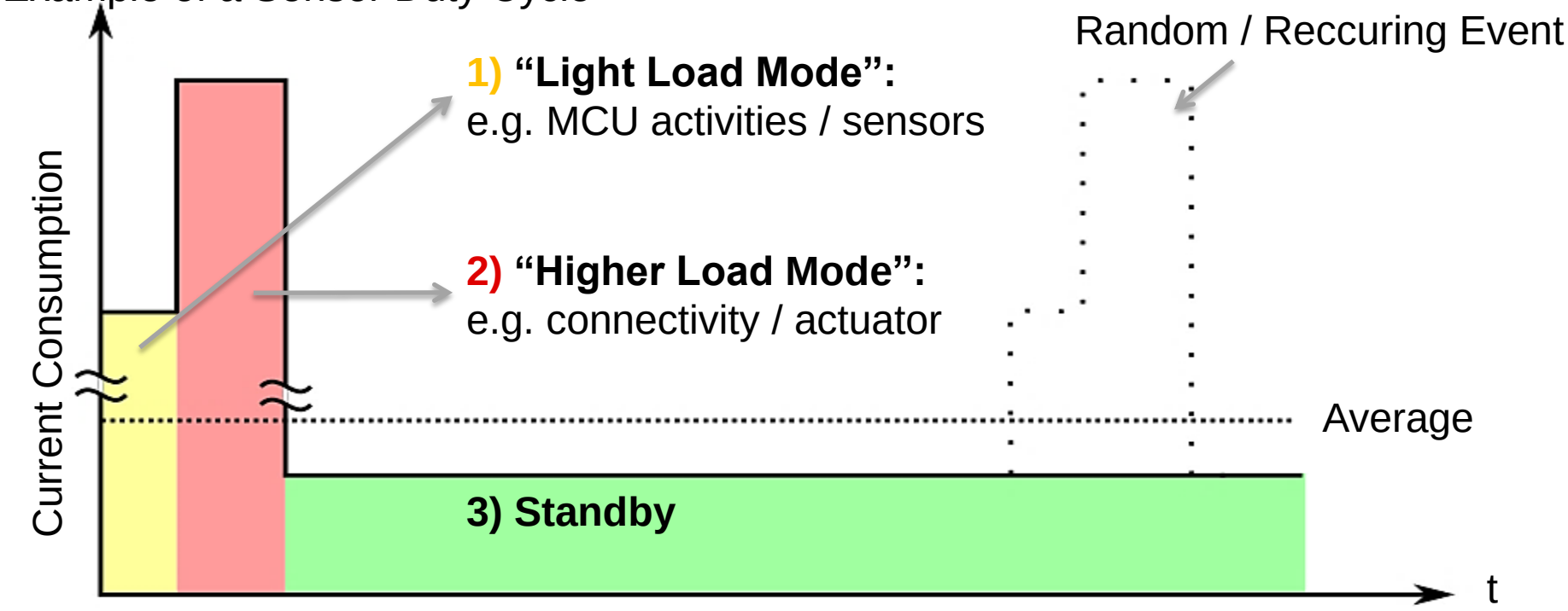
Flow

Level

Proximity

Building Automation – system requirements
Intelligent devices transmit data

Example of a Sensor Duty Cycle



Building Automation – system requirements
Intelligent devices extend battery operating time

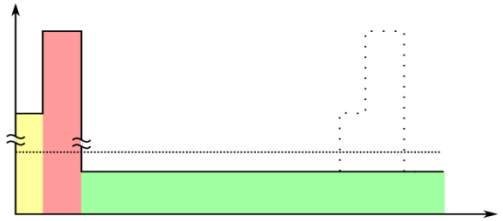
Electrical energy defined by power over time: $E = \int u(t) \cdot i(t)\, dt$

- **Lowering supply voltage**:
  5V → 3.3V lowers energy need by factor 1.5
  5V → 1.8V lowers energy need by factor 2.8
- **Lowering current consumption**:
  10 mA → 1mA lowers energy need by factor 10

Building Automation – system requirements
Intelligent devices extend battery operating time

Example of a Sensor Duty Cycle

- We assume a 1-second operational cycle:
  1) Light Load Mode: 5mA for 10ms
  2) High Load Mode: 25mA for 10ms
  3) Standby: 0.25mA for 980ms



- Electrical Charge $Q = \int I\, dt$:

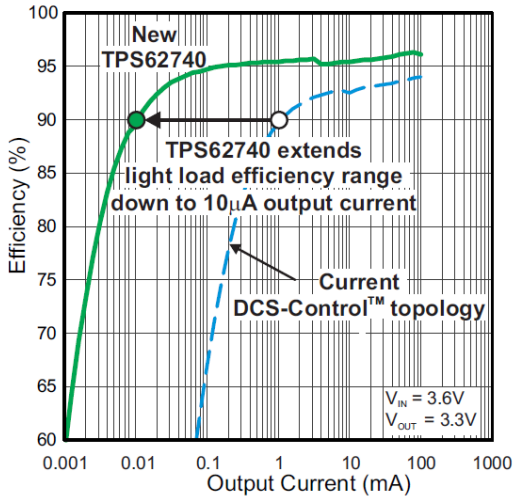
$$Q = I_{LL} \cdot \Delta t_{LL} + I_{HL} \cdot \Delta t_{HL} + I_S \cdot \Delta t_S$$
$$= 5mA \cdot 10ms + 25mA \cdot 10ms + 0.25mA \cdot 980ms$$
$$= 0.05\ mAs + 0.25mAs + 0.245mAs = 0.545mAs$$

- Result:

Standby power consumption is 45% of the total consumption

Building Automation – system requirements
Intelligent devices extend battery operating time

- **Low quiescent current** drives for low standby power consumption
- **High efficiency at light loads** extends operating time >5 years (up to 20 years)

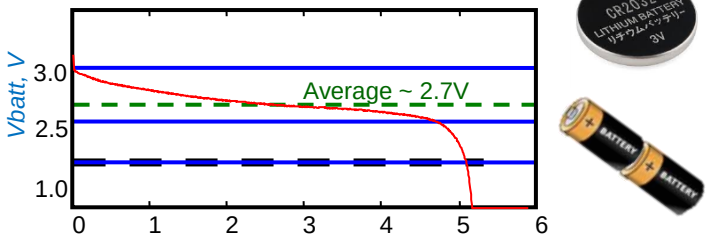


TPS62740
Up to 90% efficiency at 10µA load current

The Simple Power Tree ?

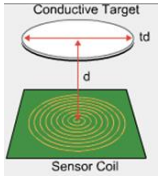
- Example:

  Battery supply (single voltage)



Multiple loads (multiple voltages)

1.8V... 3.3V



2.7V… 3.6V

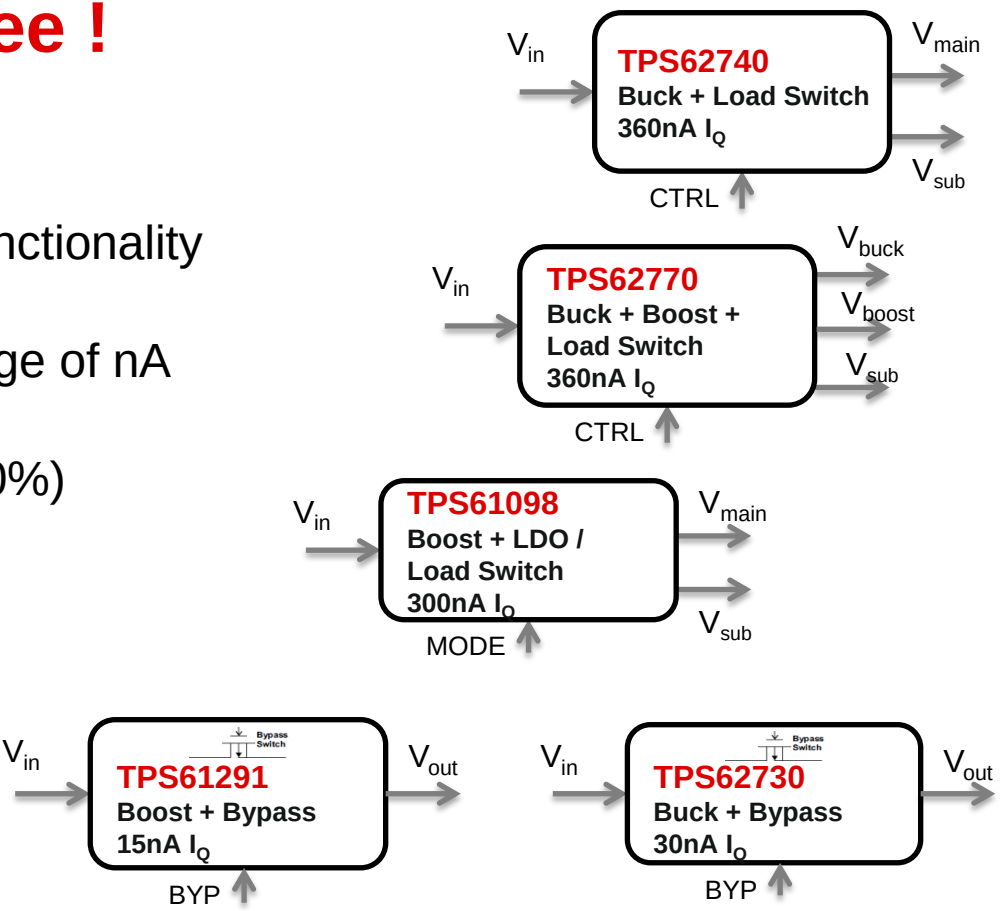
3.0V… >6V

- Question:

  How to design the power tree ?

The Flexible Power Tree !

- Easy-to-use devices with extra functionality
- Low quiescent currents in the range of nA
- High efficiency for light loads (>90%)
- Small solution size

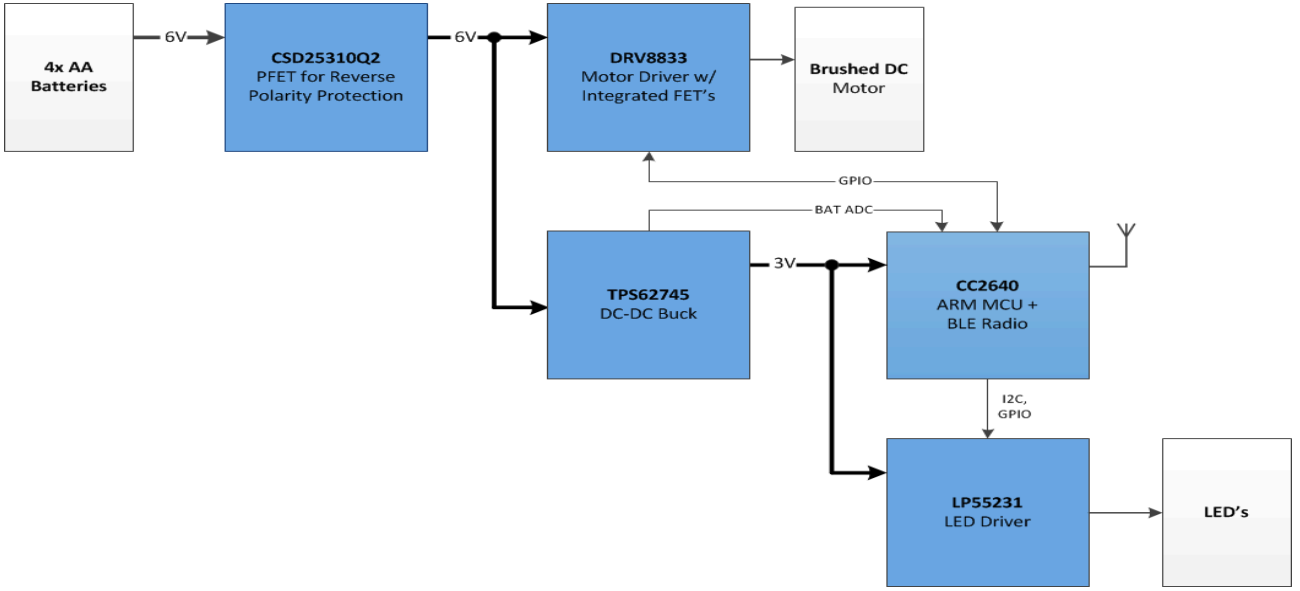


Smart Door Lock

Smart Door Lock
enabling 5+ years of life on 4x AA batteries

TIDesigns
TIDA-00757

- In a smart lock application, the high-current motor and radio often drain the battery quickly, causing battery life to suffer.
- Replacing multiple batteries can be time-consuming and costly, therefore lowering the average current consumption is often a key design consideration.



Texas Instruments

Smart Door Lock
enabling 5+ years of life on 4x AA batteries

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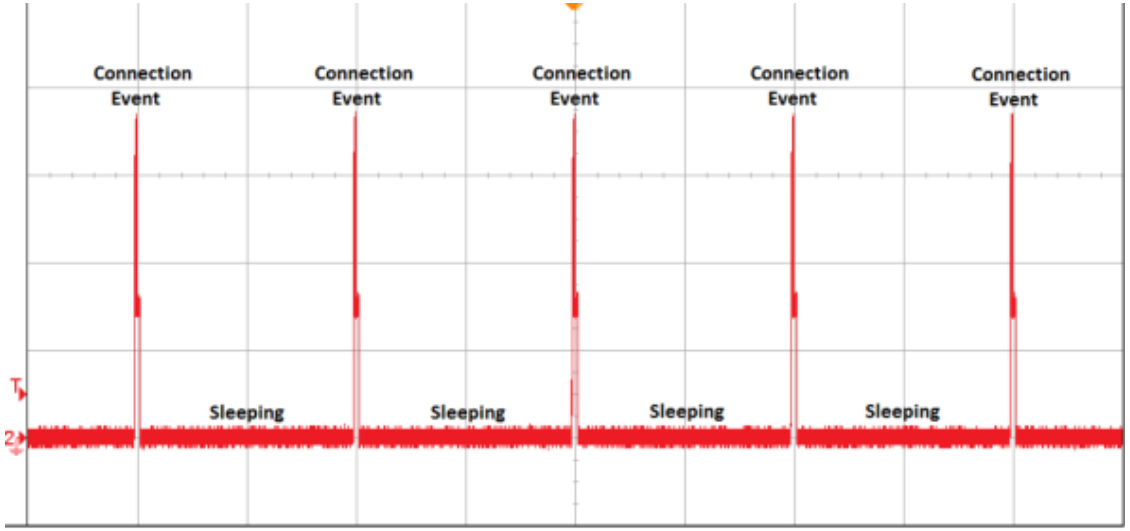
Current consumption depends

- duration of the wireless connection
- number of events per day
- standby current consumption



Current Consumption versus Time during a BLE Connection

Smart Door Lock
enabling 5+ years of life on 4x AA batteries

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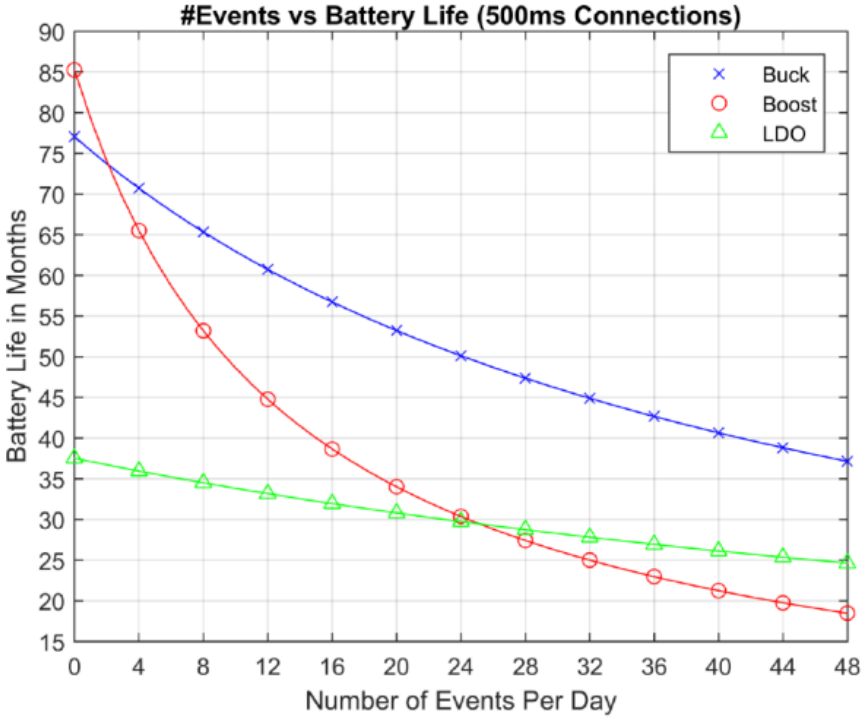
Three main power topologies are possible for this smart lock applications

- Low-dropout regulator (LDO)
  - 35uA Iq
- Step-down converter (Buck)
  - 400nA Iq
- Step-up converter (Boost)
  - 2s2p configuration

- Buck converter gives longest run time (up to >6 years)
- Boost converter gives longer run time vs LDO when # of events is <24/day



TPS62745

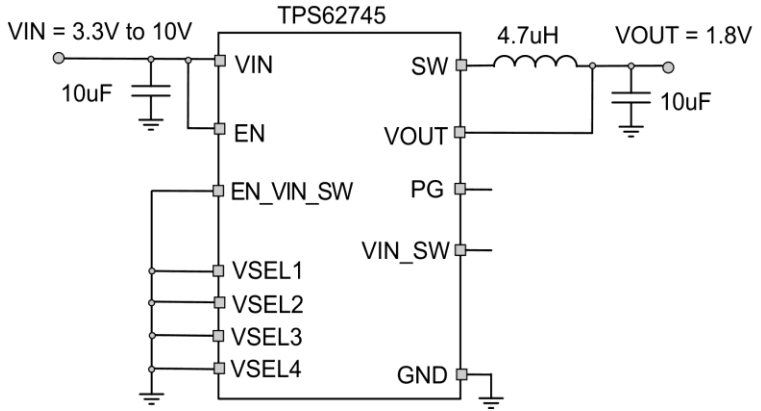
10V_{IN} 300mA Buck Converter with only 400nA I_Q

Features

- **Input Voltage Range: 3.3V to 10V**
- **400nA quiescent current, up to 95% efficiency**
- **Integrated V_{IN}-switch**
- **21 pin-selectable voltage (100mV steps)**
  - → 1.8V to 3.3V (TPS62745)
  - → 1.3V to 2.8V (TPS627451)
- RF friendly DCS-Control™ Topology
- 2x3mm SON package,
  works with small inductor and low ESR caps
- TPS6274x family of 9 different ultra-low power step-down (buck) converter

Benefits

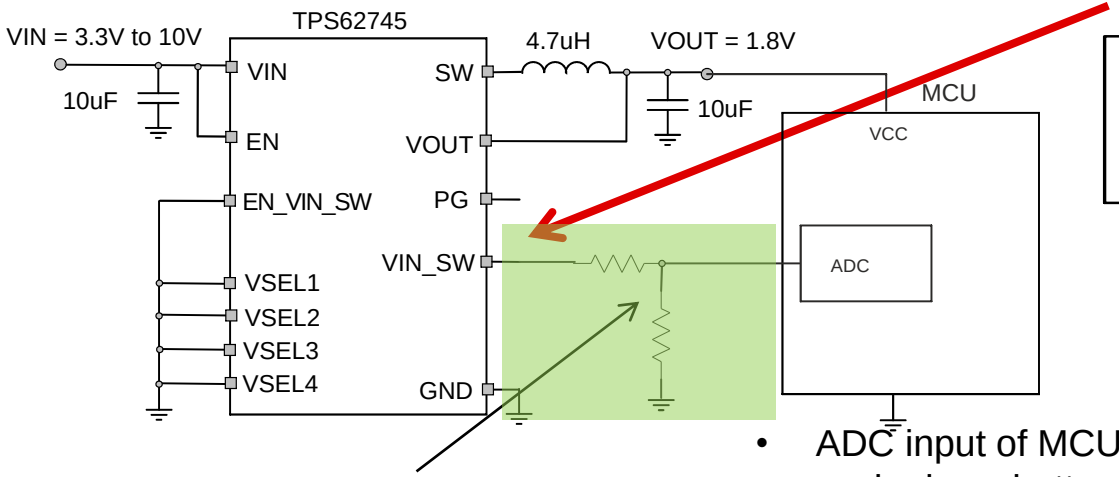
- **Multiple**
- **Reduces battery current, extends application run-time**
- **Easy supervision of V_{IN}, saves board space & cost**
- **Design flexibility & reduces leakage currents during shut down**
- Maintains accurate output voltage at fast AC line and load transients plus a seamless transition between PWM and power save mode
- 31mm^2 solution size with cost efficient components



TPS62745

Integrated VIN Switch saves cost & board space

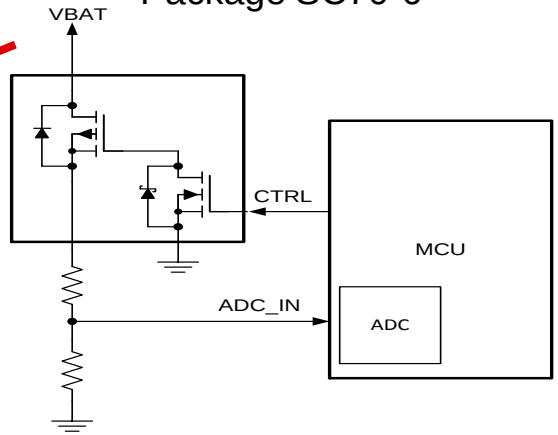
- TPS62745 integrated VIN Switch saves
  - **Cost**
  - **Space** – 4mm² (SC70-6 package)



Matching resistor network for ADC input

Discrete Solution

e.g. SI1865DL
Package SC70-6



- ADC input of MCU requires an external resistor divider to scale down battery voltage
- Discrete solution requires load switch with integrated level shifter (e.g. SI1865DL)

Smart Door Lock
enabling 5+ years of life on 4x AA batteries

TIDesigns
TIDA-00757

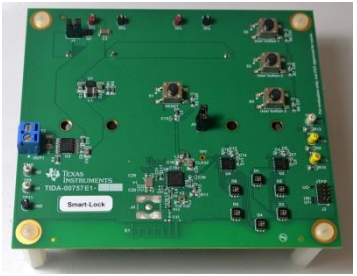
Solution Features

- Low Power Consumption: 58µA average current consumption
  - Ultra-low Power Consumption Radio + MCU
    - 61µA / MHz ARM Cortex M3
    - Very low Rx / Tx current (6mA / 9mA)
  - Low $R_{DS(ON)}$ of 360mΩ from the Motor Driver
- Bluetooth Low Energy (BLE) radio enables seamless connectivity to smart mobile devices for lock and unlock events
- Battery polarity protection using PFET

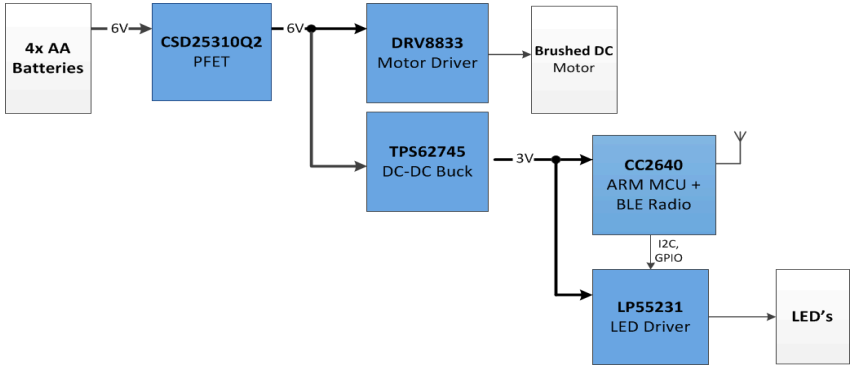
Solution Benefits

- Over 5 years battery life using 4x AA batteries in series
  - 24 lock or unlock events per day
  - 500ms BLE radio connection period
- 6 RGB LED's display power up, lock event, unlock event, and low battery status.
- Voltage-based battery gas gauge integrated in DC-DC converter
- BLE tested using third party BLE iOS application

Tools & Resources



- **TIDA-00757 Tools Folder**
- **User Guide**
- **Device Datasheets**:
  - TPS62745
  - DRV8833
  - CC2640
  - LP55231
  - CSD25310Q2



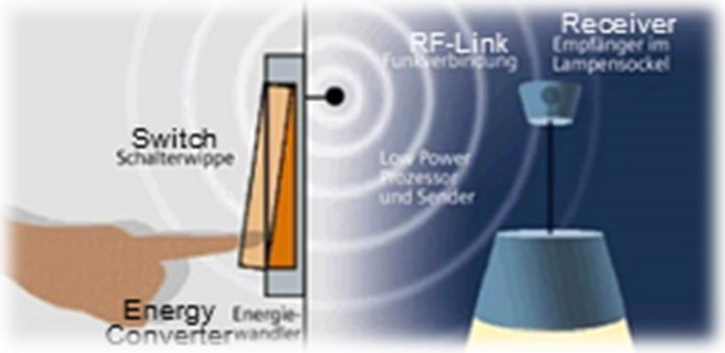
Texas Instruments

Light Switch
battery-less, energy harvesting

Light Switch
Energy harvest for intelligent & energy-efficient light control

Zero power consumption, zero wires

no need for batteries as it operates using kinetic energy – simply through taps from your finger. As a result, it has a remarkable zero watts of power consumption and needs no mains power source. Meaning it's not only smarter, but also free of maintainance.

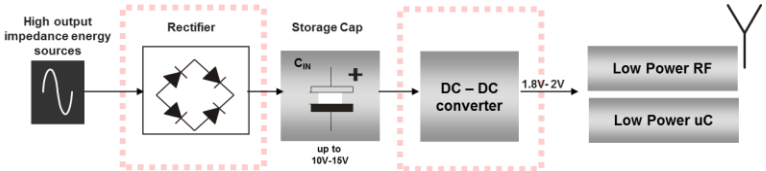


Light Switch
Energy harvest for intelligent & energy-efficient light control

For a proper start-up from a weak energy source and extended application run time it is required to capture most of the available energy from the harvester.

- **Problem: Weak energy source**
- **Storage capacitor buffers the energy**
- **Wide input DCDC regulator (2V to 15V) utilizes the entire energy of the storage buffer capacitor**

Energy Harvesting System



More examples see:

Harnessing wasted energy in 4- to 20-mA current-loop
www.ti.com/lit/SLYT488

Solar-panel MPPT for pulsed-load systems
www.ti.com/SLYT478

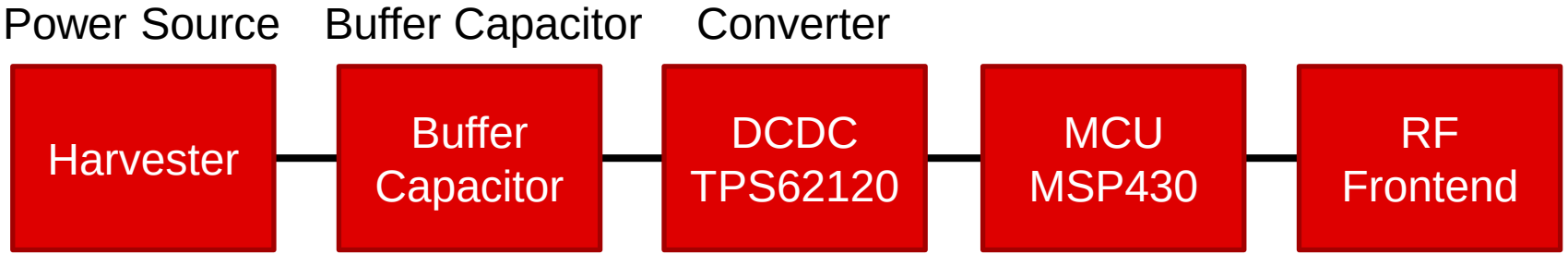
Ultra-Low-Power DC/DC Converter Overview
www.ti.com/lit/SLYT593

Light Switch

Energy harvest for intelligent & energy-efficient light control

Solution:

Wide input voltage, high efficient DCDC regulator with minimum quiescent current → 2V to 15V $V_{IN,}$ 11µA quiescent current, >90% efficient



Available Energy $E = \frac{1}{2} \cdot C \cdot V^2$

$E = E1 - E2$

$E = \frac{1}{2} \cdot C \cdot (V_{max} - V_{min})$

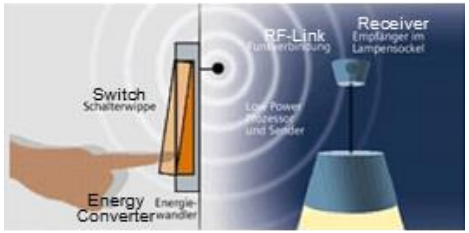
The larger the voltage range of the DCDC Converter the larger the available energy extracted from the buffer capacitor

TPS62120 / 122

2V…15V_{IN}, 75mA I_{OUT}, 96% efficiency Buck Converter

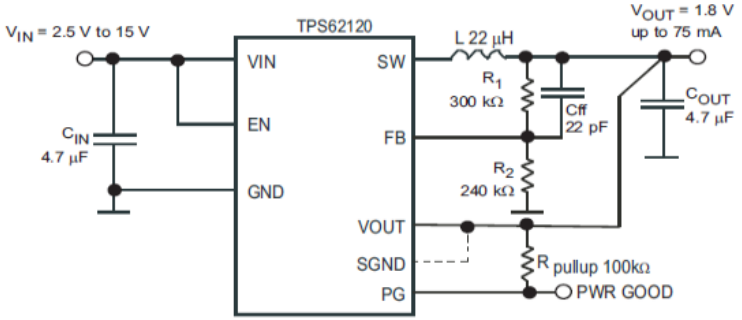
Features

- **2.0V to 15V Input voltage range**
- **High efficiency in PFM mode (>70% @ 100µA load)**
- Active Discharge Capacitor (TPS62120)
- Power Good pin (TPS62120)
- Package
  SOT-23-8 (TPS62120), 2x2 QFN (TPS62122)
- **Application example: battery-less light-switch**



Benefits

- **Wide UVLO hysteresis window allows the storage of energy in C_{IN} until there is enough for the converter to efficiently transfer to the output avoiding short cycling during buck power-up**



Wireless Sensor Node

Wireless Sensor Node
Solar-cell powered sensor for Internet of Things

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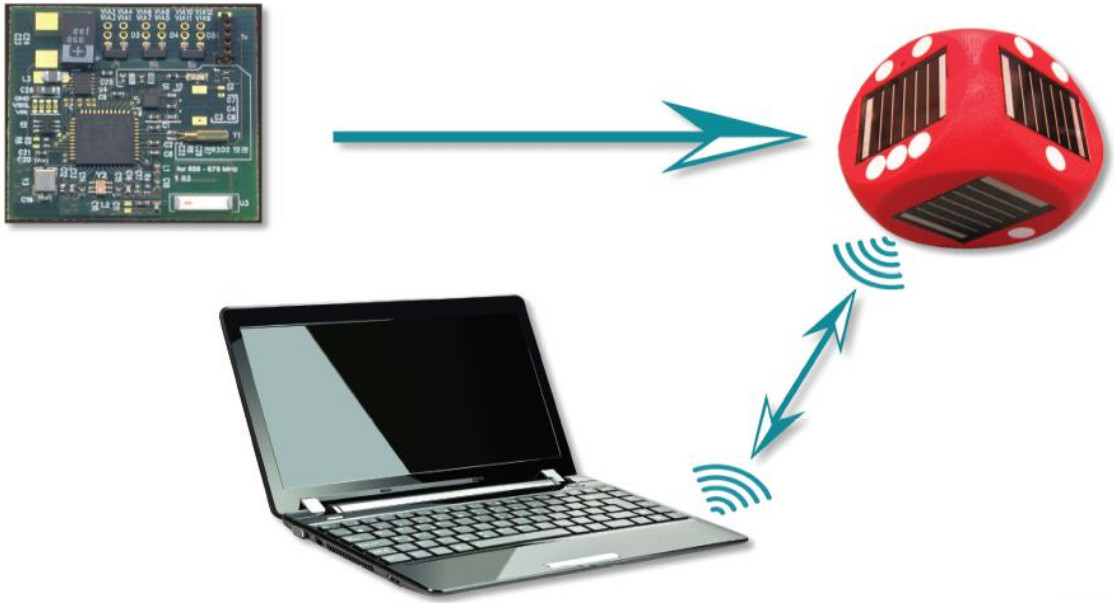
PMP9754

Wireless Sensor Node
Solar-cell powered sensor for Internet of Things

TIDesigns
PMP9754

The wireless dice transmits its position to any computer.

Energy is created from solar panels, and the position is determined by an acceleration sensor.



This same topology enables your sensors to connect to the Internet of Things world.

Wireless Sensor Node
Solar-cell powered sensor for Internet of Things

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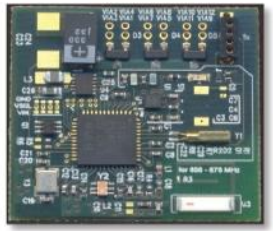
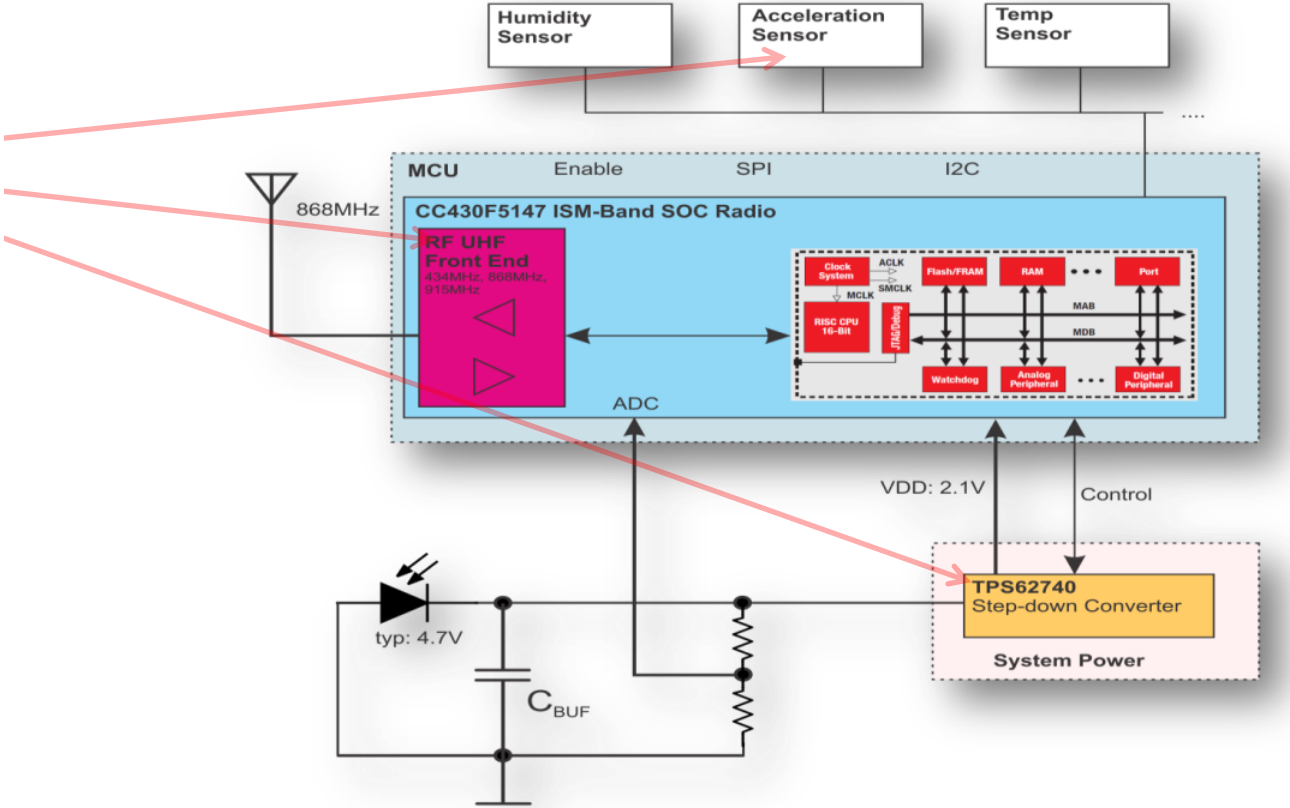
PMP9754





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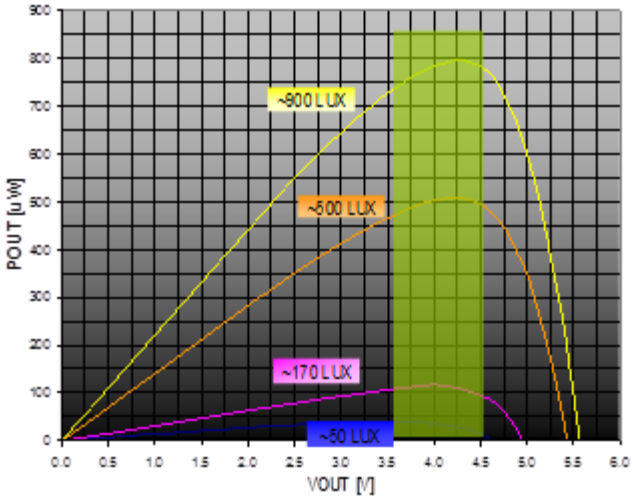
Wireless Sensor Node
Solar-cell powered sensor for Internet of Things

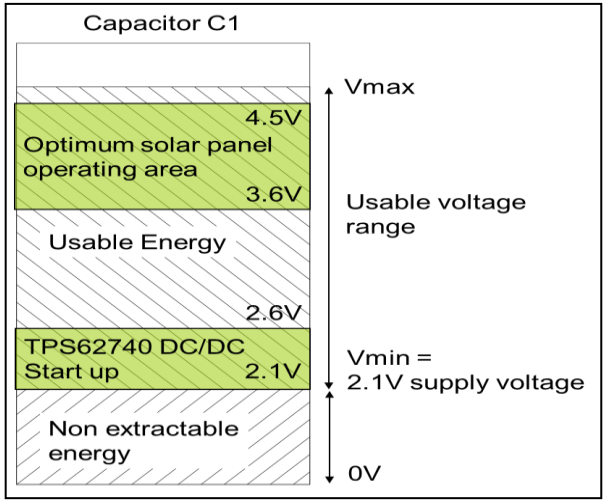
TIDesigns
PMP9754

Power Management Consideration

Power Source



Buffer Capacitor



Available Energy

$$E = \frac{1}{2} \cdot C \cdot V^2$$

$$E = E1 - E2$$

$$E = \frac{1}{2} \cdot C \cdot \left(V_{max} - V_{min}\right)$$

Always-On applications require DCDC converter with high efficiency at light load (90% @10µA) and low quiescent current (360nA).

Wireless Sensor Node
Solar-cell powered sensor for Internet of Things

TIDesigns
PMP9754

DC/DC: TPS62740

- Ultra-low quiescent current: 360nA
- 90% efficiency at 10µA I_{OUT}
- Slew Rate controlled Load Switch
- RF friendly DCS-Control™
- 16 Pin-selectable output voltages between 1.8V – 3.3V

- TPS6274x family of 9 different ultra-low power step-down (buck) converter

MCU+RF: CC430F5147

- Transmission frequency 868MHz IMS and bandwidth 250kBps
- Filter BW 541kHz, 36bit data, 16bit CRC
- RF Protocol length 50Byte total, RF Power level -1dBm
- Software optimized protocol to reduce current consumption

Summary

New high efficient DCDC converter enable low power MCUs and RF frontends

- Microcontroller, sensors and RF frontend power requirements are constantly shrinking
- New innovative low quiescent current DCDC converter can run directly of a harvester or primary battery
- Efficiency levels of 90% and greater with the new generation of ultra low power DCDC converter
- New levels of DCDC quiescent currents of just 360nA in full operation are achieved with the TPS62740 and TPS62745

Power design made easy

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www.ti.com/powerlab

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- Choose your application
- Choose your operating range

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Building Automation design made easy

Daylight Harvester
TIDA-00488 TIDA-00100
TIDA-00758

Gas Detector
TIDA-00056 TIDM-1CHP-
TIDA-00756 TIDA-00378

Automated Window Blinds
TIDA-00757

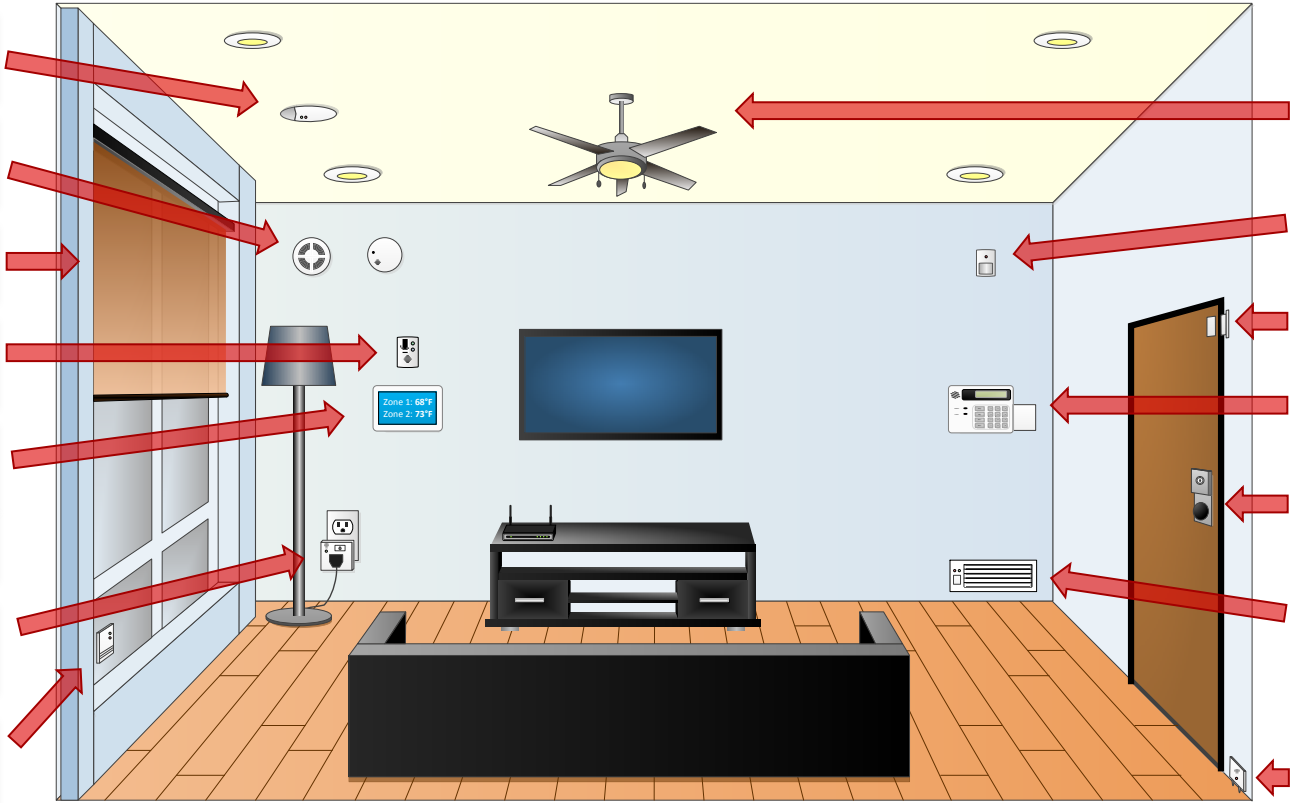
Voice or Speech Recognition
TIDEP0066 CC2650RC
MSP-SR

Thermostat
TIDA-00751 KNX-TSTAT
FRAM-TSTAT TIDA-00754

Environmental Sensor
TIDA-00374 TIDA-00484

Smart Plug
TIDC-CC3200SMARTPLUG
TIDC-SMARTPLUG-WIFI

Glass Break Detector
TIDM-GBD-Robust



Automated Ceiling Fan
TIDA-00386
TIDA-00757

Motion detector
TIDA-00489
TIDA-00759

Door and Window Sensor
slyy058

Intrusion HMI Keypad
TIDEP0015 TIDA-00560
TIDA-00754 TIDA-00509

Electronic Lock
TIDA-00757

Wireless Vent / Damper
TIDA-00757
TIDA-00250

Water Leak Detector
<TIDA-00374>

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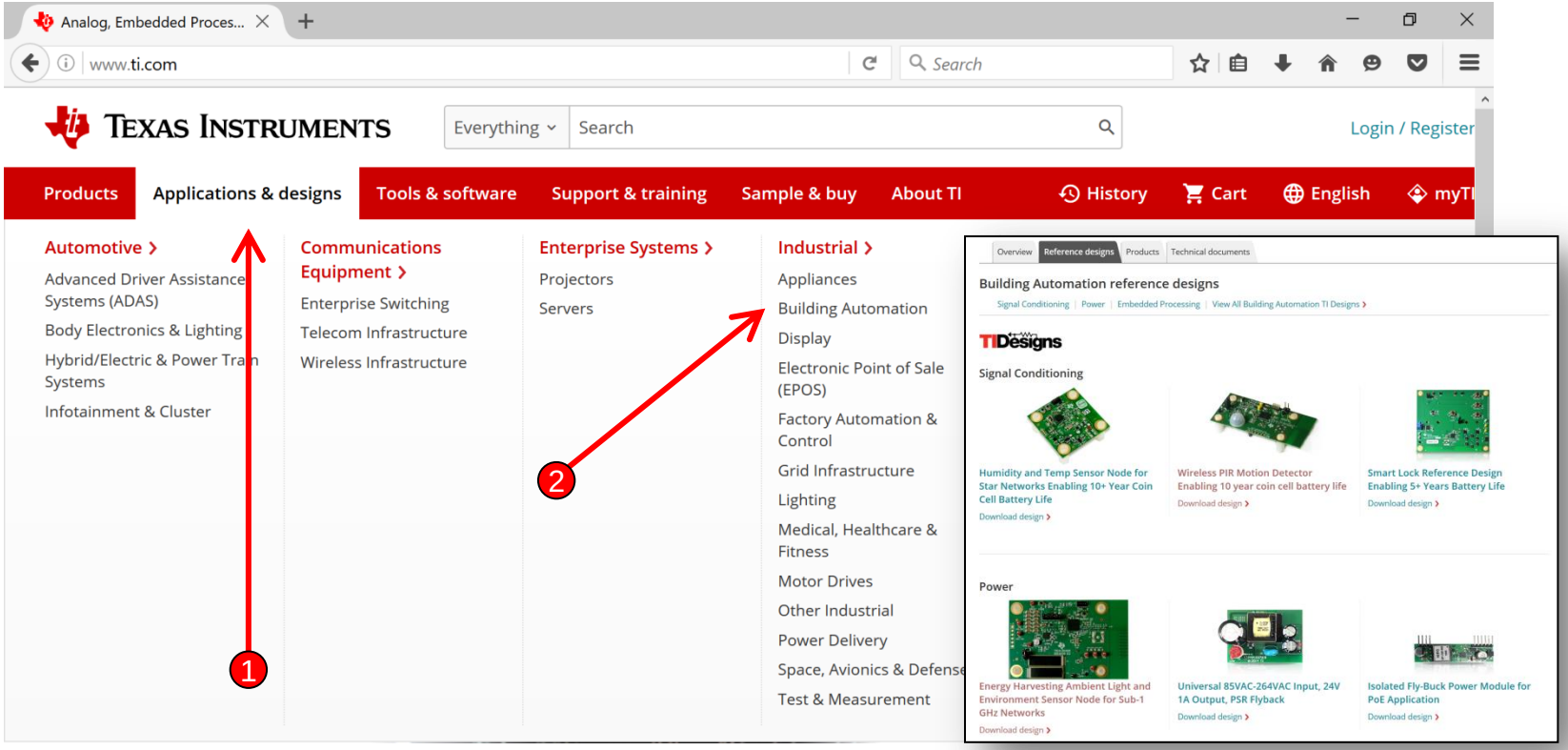

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- Applications & Power Solutions
  - Smart Door Lock
  - Light Switch (battery-less, energy harvesting)
  - Wireless Sensor Node
- Support & More Information
- Q & A

Building Automation Webinar Series
Session 3: HMI interfaces
Oct 6th, 10am German/5pm English CEST