Nano power for medical wearables and IoT applications

Battery Management Solutions

January 25th, 2017

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Agenda

- Common Charging Requirements
- Charging Solutions
- Summary

Texas Instruments

Wearable Charging Requirements

- Wearable Battery Size
- Charging Voltage, Current
- Quiescent Current, Termination Current
- Ship Mode
- Solution Size

System-level approach to power is required

CHALLENGE

Power is critical

WHAT IS NEEDED

The lowest power solutions for any application

TI DELIVERS

Technology for billions of battery- or harvested-powered devices

Traditional chargers and Integration	Wireless Power	Energy Harvesting
Small solution size	Water Proof	Stretching battery life

Charging System Architecture - Considerations

- Solution Size: Needs to be small
- Charging: Charge with micro USB.
- Battery: Support small to medium capacity Li-Ion batteries (50 mAh to 300 mAh)
- Protection: Provide a safety net to ensure battery does not overheat and explode
- Power consumption: Extend run time between charges
- Low battery alert: Should be able to notify user about the battery conditions (preferably % charge remaining instead of “bars”)

- Smartwatch system design poses unique challenges.
- Due to large number of sensor integration, less PCB space is available for battery solution these days.

Batteries for Wearables

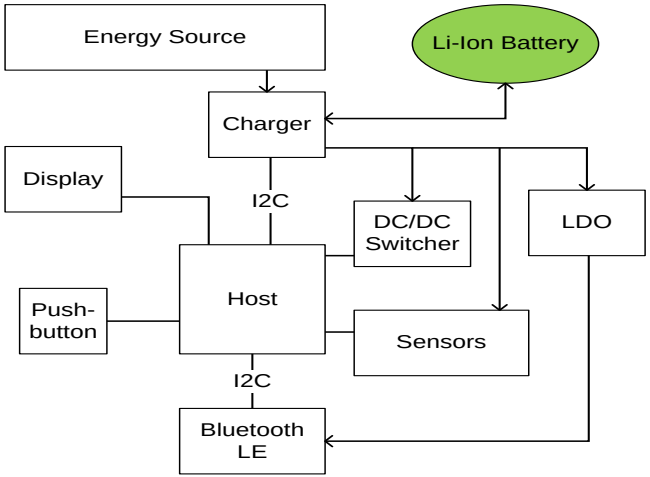
- The Battery Compromise
  - Capacity - Typical is 30mAh to 300mAh
  - Energy Density – State of the Art is ~150mAh/cm^3
- Most popular Batteries for Wearables
  - Primary Li-Metal – Standard CR2032, highest energy density, but must be replaced by user

+ = 240mAh

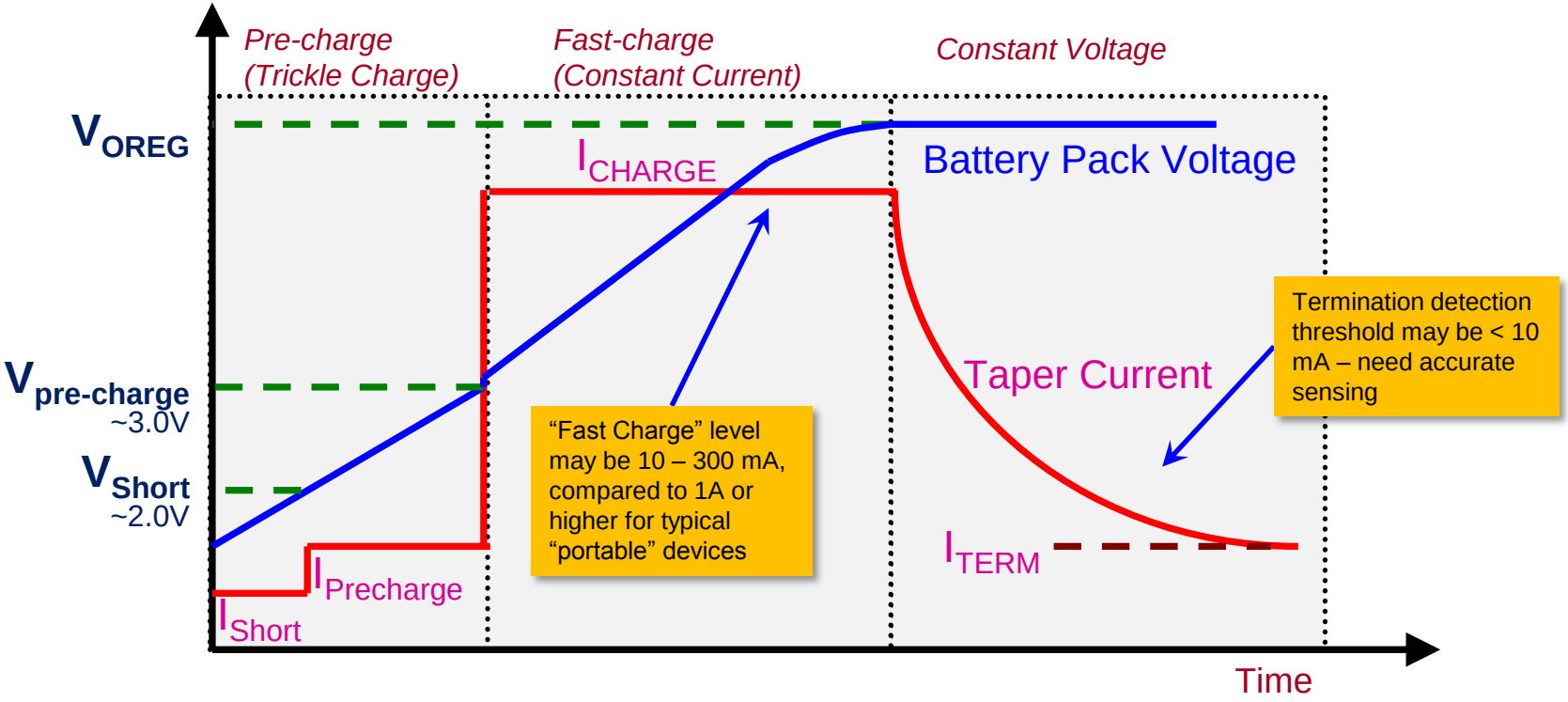
  - Rechargeable Li-Ion – Most popular, able to get in various sizes, shapes, and capacities

110mAh

41mAh



Li-Ion Charging – Challenges at Ultra-Low Power



What is an ideal charger for IoT applications?

High Accuracy in Current & Voltage

Maximize battery life by preventing over charging

Low Termination Current

Maximize battery run time by preventing early termination

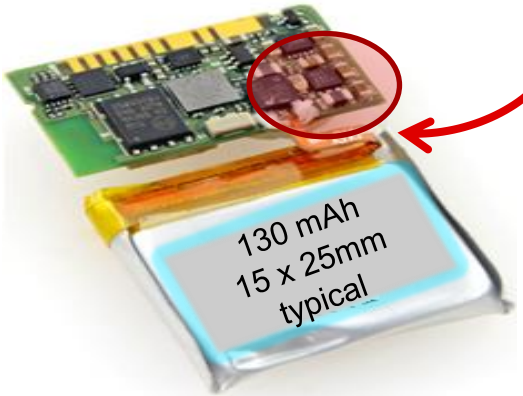
Low Battery leakage

Longer stand by time

Small Size

Smaller total solution size

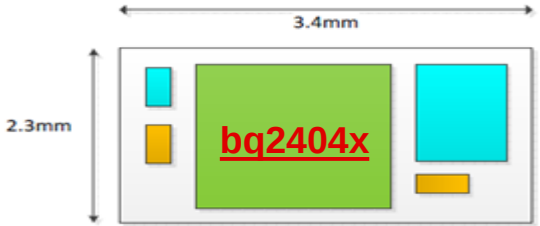
Solution size is critical for Wearables



Very limited space available for the charger IC & components

Capacitor
WCSP IC
Resistor

- *Power path function*
- *Up to 500mA charge rate*

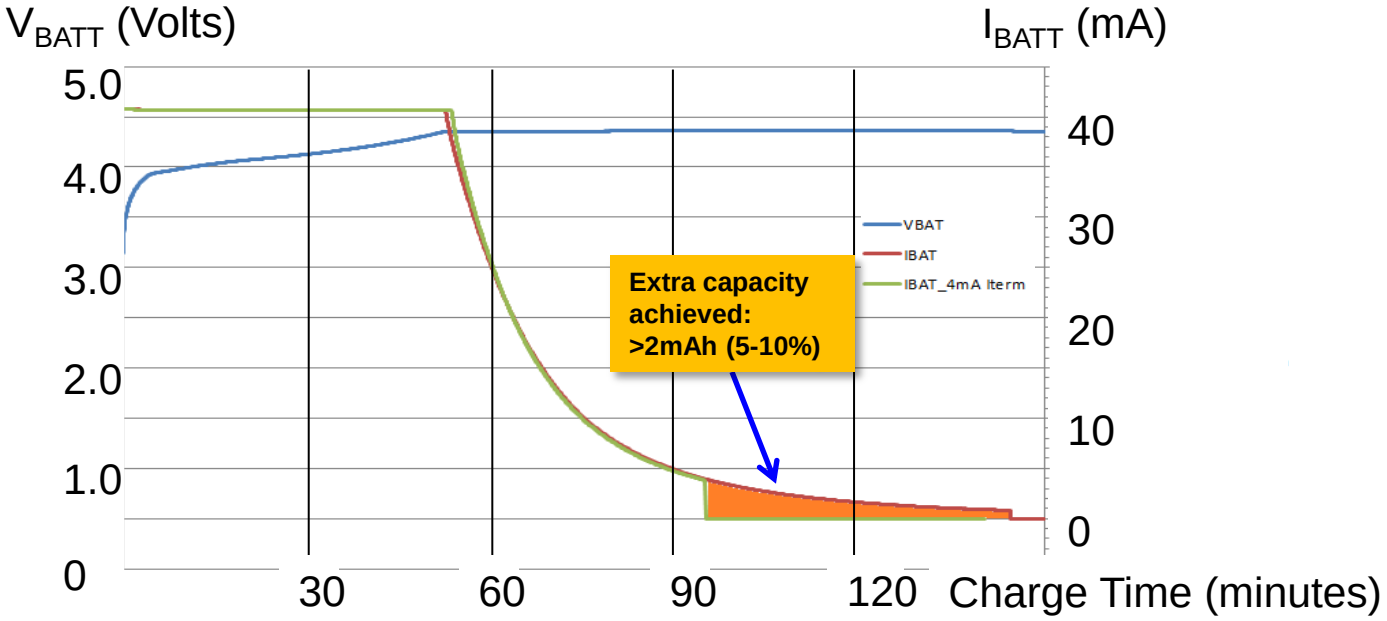


- *Up to 1000mA charge rate*
- *Termination to 5 ~ 10mA*

bq2510x

- *Up to 250mA charge rate*
- *Termination control to 1mA*
- *< 75nA battery pin leakage*

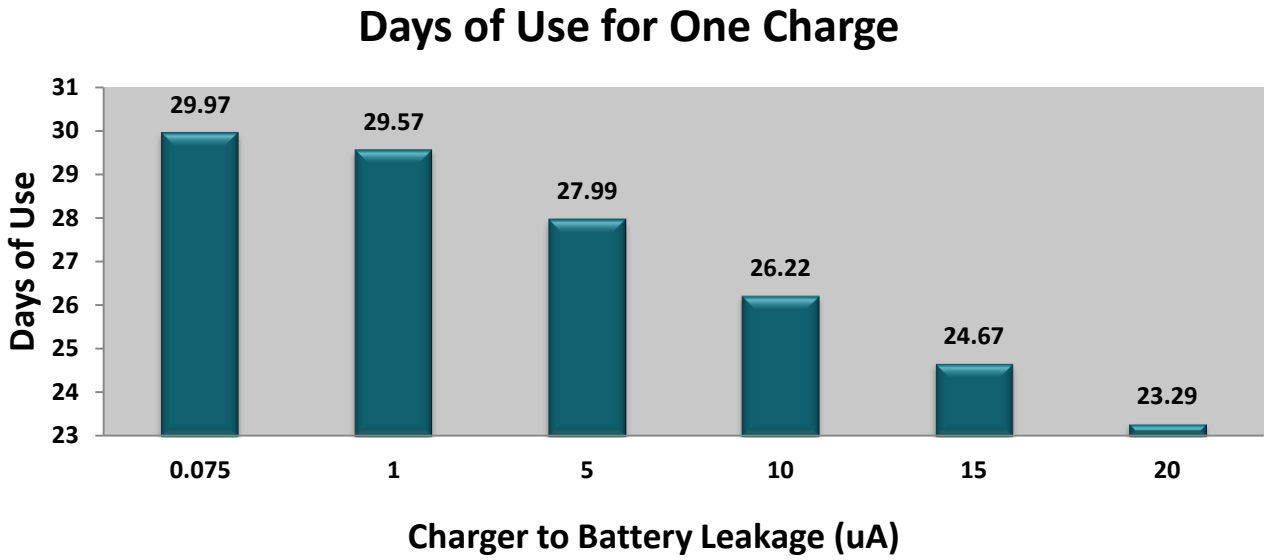
Accurate Small Cell Charge Termination



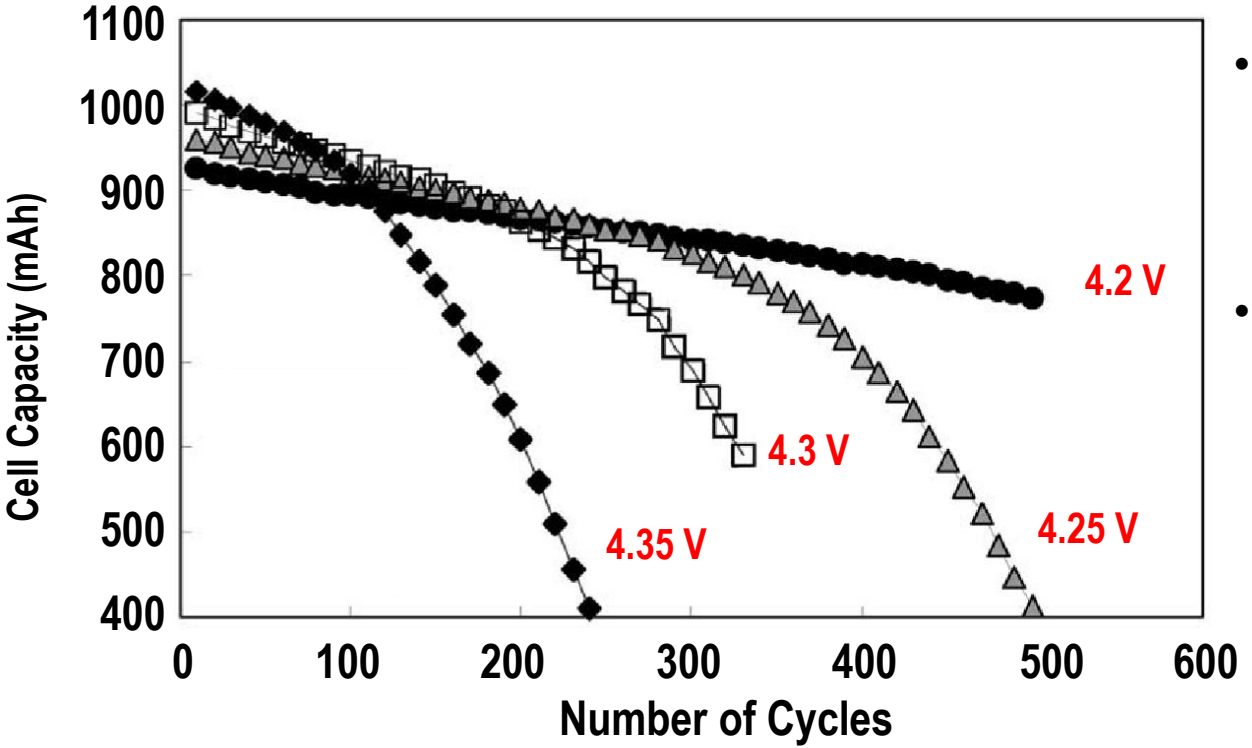
- Charged 41mAh battery at 40 mA fast charge current (1C)
- Termination at 4 mA (10%) or 1 mA
- Shaded area represents additional 5 – 10% capacity restored on each charge

Low Battery Leakage

For a wristband that uses 50mAh battery and supports 30 days of normal use, how critical is the battery leakage?



Li-Ion needs high accuracy charge control



- The higher the voltage, the higher the initial capacity
- Overcharging shortens battery cycle life

Source: "Factors that affect cycle-life and possible degradation mechanisms of a Li-Ion cell based on $LiCoO_2$," Journal of Power Sources 111 (2002) 130-136

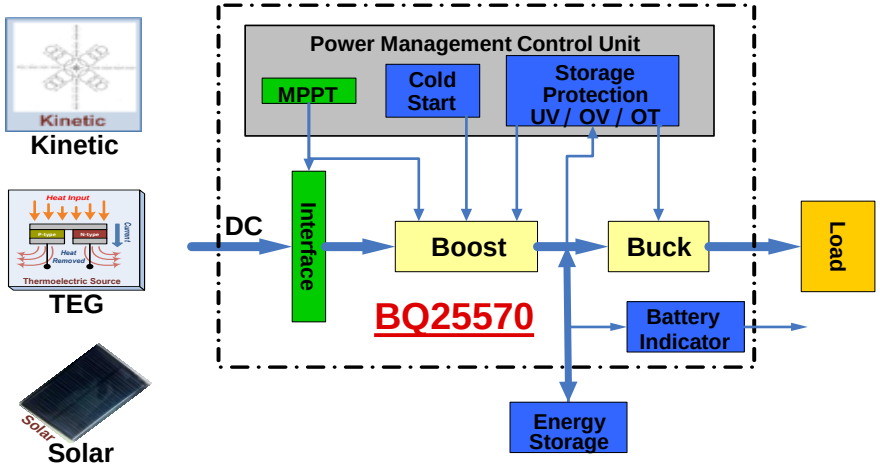
Charging Solutions

- Energy Sources
- Simple Linear Charger vs. High Integration Linear Chargers (BMU)
- Wireless charger
- Energy Harvesting

- **Energy Sources**
- Simple Linear charger vs. High Integration Linear Chargers (BMU)
- Wireless charger
- Energy Harvesting

Energy Sources for Wearables

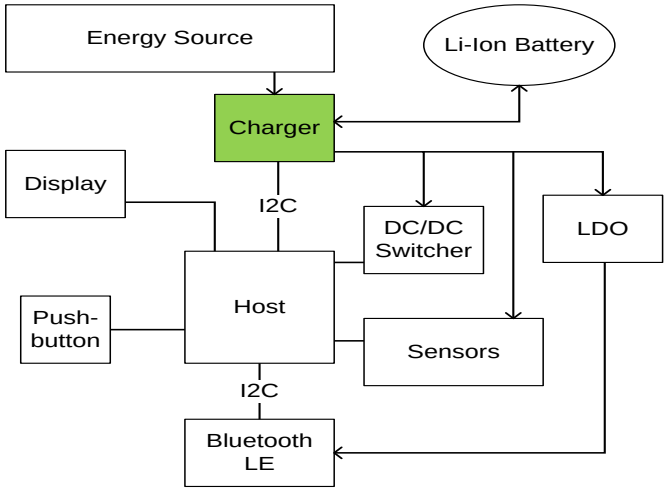
- **USB** – Most Common Today
- **Wireless Power** – Most Benefits for Wearables
  - Allows for Water-Proof and Dust-Proof Designs
  - Eliminates Wires and Connectors
  - Simplifies User Experience for Recharging
- **Alternative Energy Sources** – Most Flexibility for Power



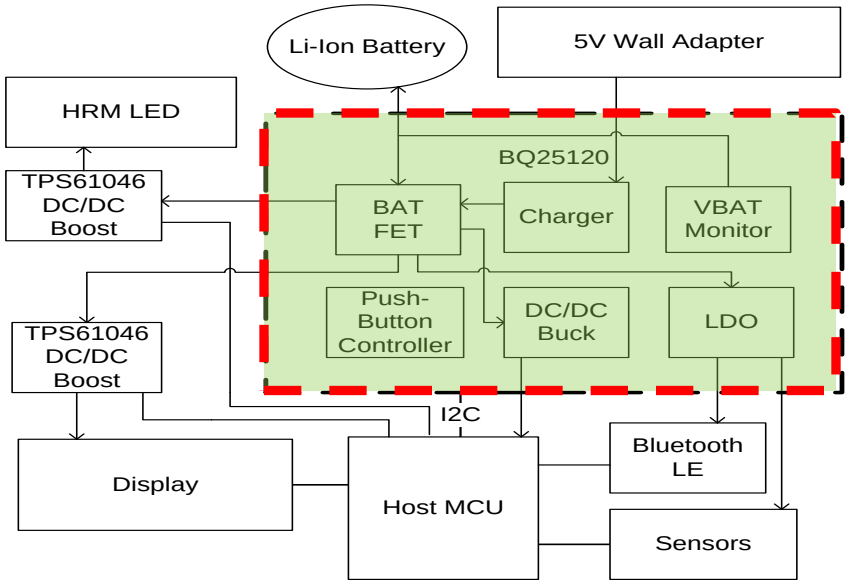
- Energy Sources
- **Simple Linear Charger vs. High Integration Linear Chargers (BMU)**
- Wireless charger
- Energy Harvesting

Chargers Optimized for Small Batteries

bq25100 Linear Charger



bq25120 Battery Management Unit (BMU)



Texas Instruments

Wearables Solutions

Audio Devices

- **BQ2510x**
  Smallest Linear Charger
- **TPS62743**
  Smallest Low Iq DC/DC

Smallest Solution
(If power path and I2C configurability is not needed)

Simple Activity Monitor

- **BQ25120**
  Meets all basic functional requirements

Smallest Solution Size and Lowest Power Consumption
(power path and I2C)

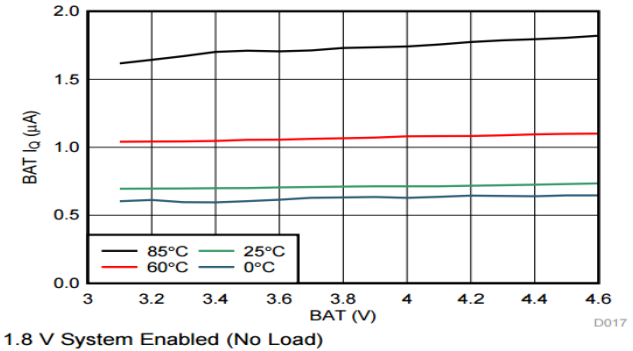
Activity Monitor With Display and Additional Features

- **BQ25120**
- **TPS61046** boost for OLED display
- **TPS61240** boost for HRM or LCD display
- **TPS62743** buck if needed

Most Flexible Solution

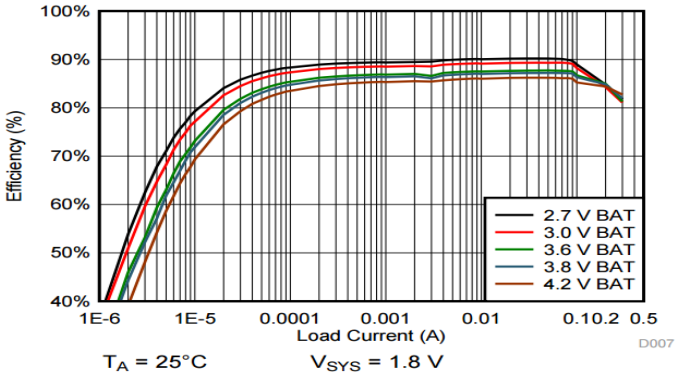
Low Iq vs. Smart Power Management

- **Low Iq**
  - Enables high efficiency for components that need to be powered all the time at low loads
  - MCU, some sensors
- **Smart Power Management**
  - Ability to turn off devices that are used sometimes
  - Radios, some sensors, displays
  - Disconnect the battery for long shelf life



1.8 V System Enabled (No Load)

Figure 4. Hi-Z BAT, I_Q



T_A = 25°C V_{SYS} = 1.8 V

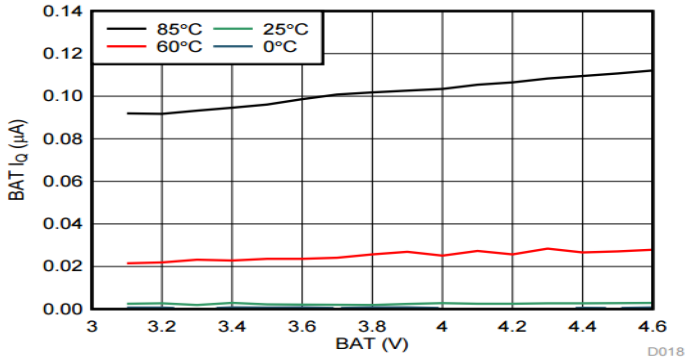


Figure 5. Ship Mode BAT, I_Q

- Energy Sources
- Simple Linear charger vs. High Integration Linear Chargers (BMU)
- **Wireless charger**
- Energy Harvesting

Benefit of Wireless Power

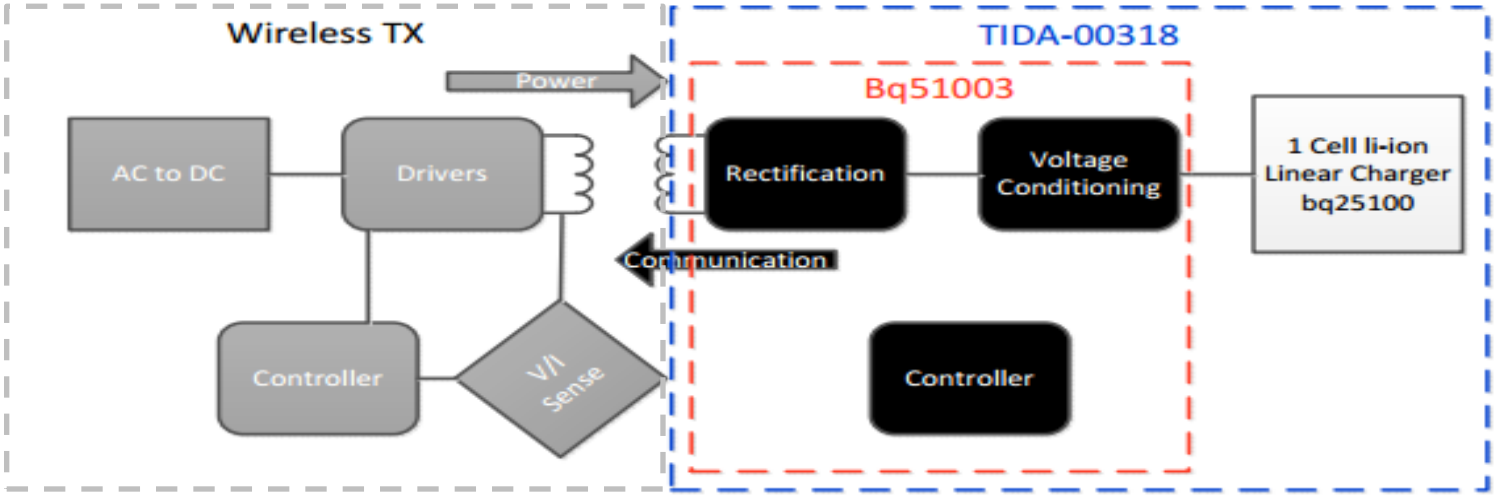
Convenience

Water Proof

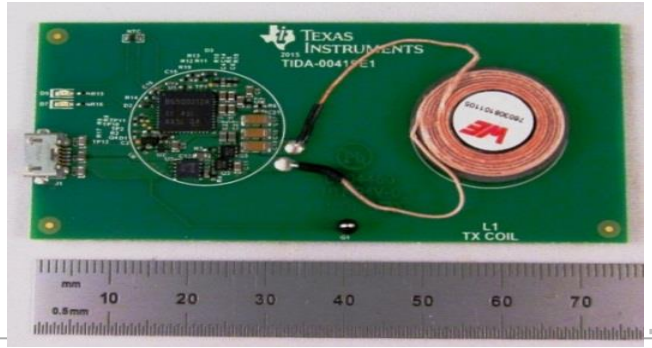
No Cables or Connectors

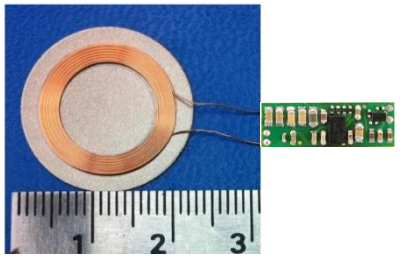
Rugged Industrial Design

Wireless power for wearables



TIDA-00415
20mm, 1W



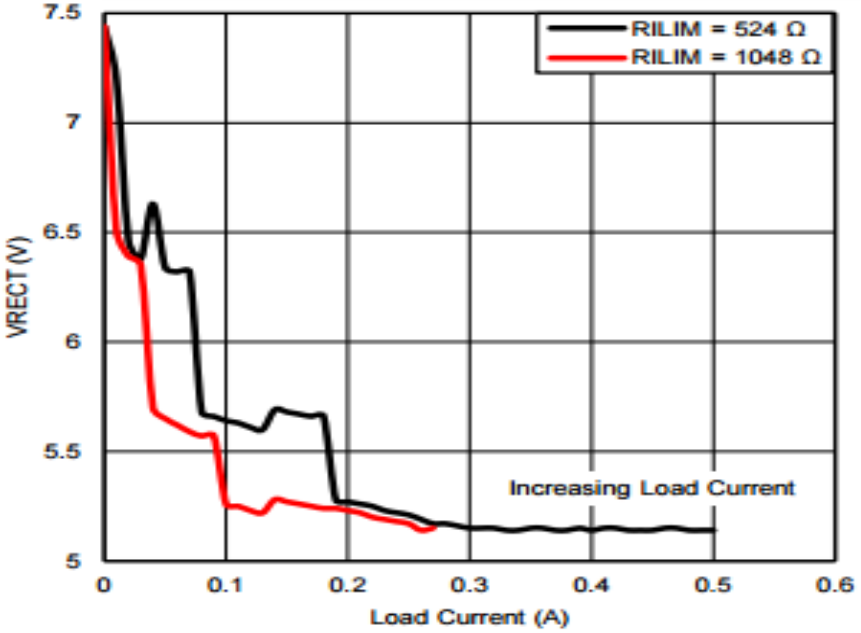


TIDA-00318
10mm, 1W

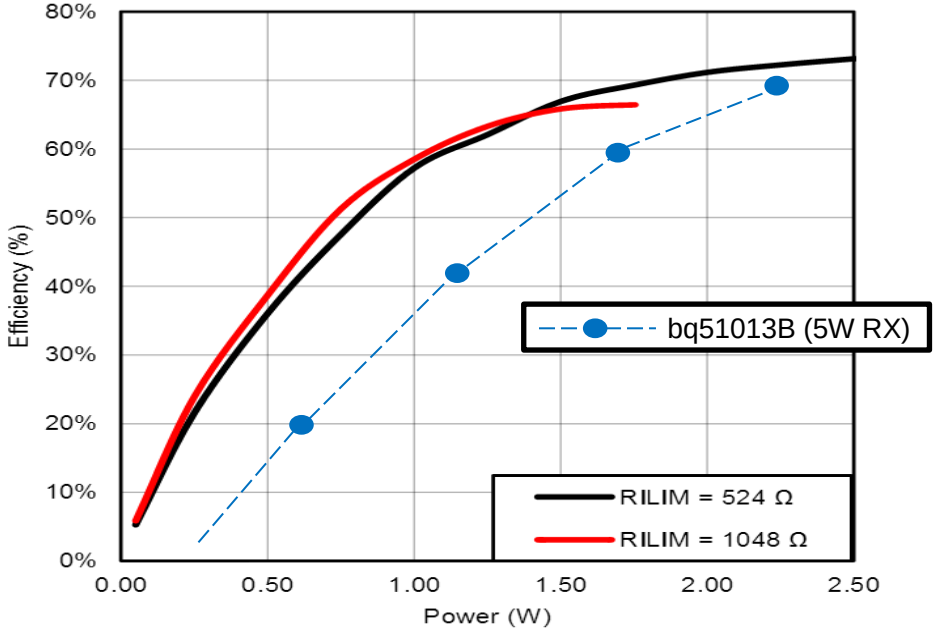
bq51003 2.5W Optimized Receiver

10 – 15% efficiency improvement at 1W output power vs. standard (5W-rated) receiver

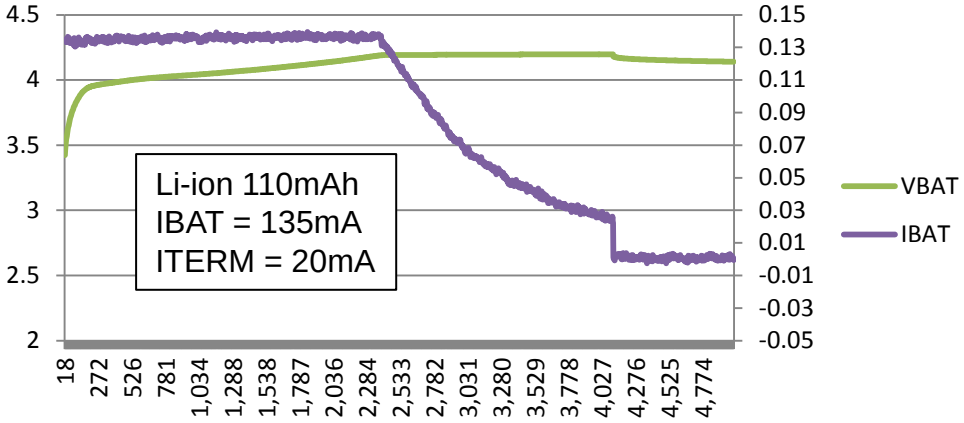
Receiver-side Dynamic Rectifier Control

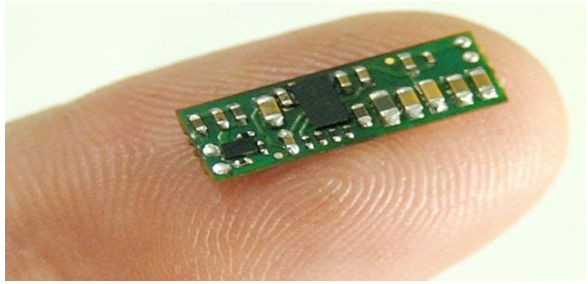


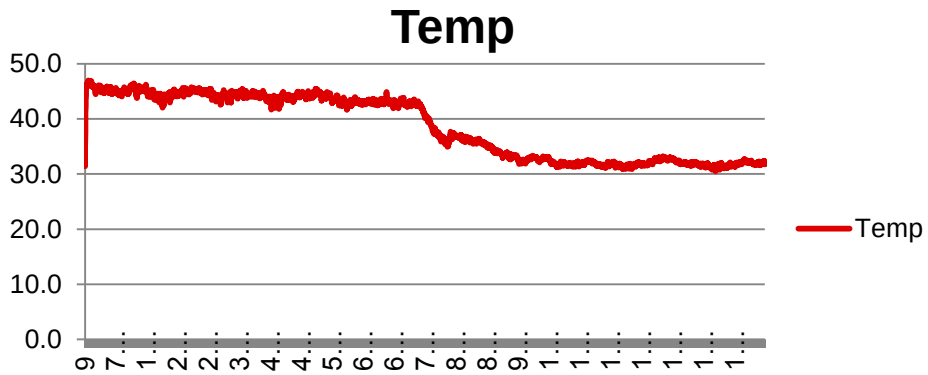
System-level efficiency



TIDA-00318: Charging Performance







- Small Size: **5x15**(mm^2)
- Adjustable charging current: **10~250** (mA)
- Supports **1mA** Charge Termination Currents
- **<75nA** battery leakage current.
- TI design: http://www.ti.com/tool/TIDA-00318

- Energy Sources
- Simple Linear charger vs. High Integration Linear Chargers (BMU)
- Wireless charger
- **Energy Harvesting**

Energy harvesting applications

Convenience

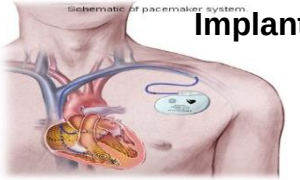
Home

Wearables

Remotes

Extended battery life

Hard to Reach



Implantables

Oil Rig

Pipelines

Environmental Awareness

Industrial

Smoke Detectors

Automotive

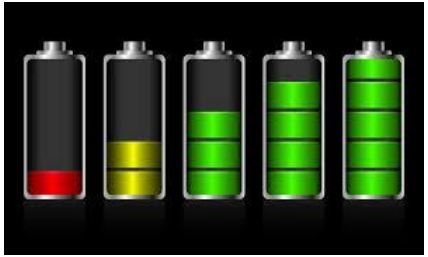
Designs with low data rate, low duty cycle, ultra-low power

When does energy harvesting make sense?

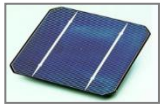
Hard wire Power not available

Battery replacement not practical

Battery Life needs to be extended

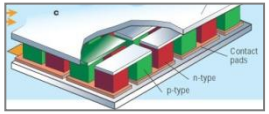


Enabling efficient use of energy harvesting



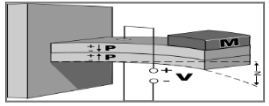
Solar

10-10000 uW/cm²



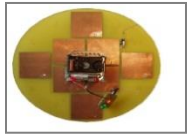
Thermal

25-1000 uW/cm²



Vibration

50-250 uW/cm²



RF

0.01-0.1 uW/cm²

Energy Source

Power Conversion

Charger
System Power
Battery
Management

Storage Element
Li-Ion Battery
Thin-film battery
SuperCap

Stored Energy

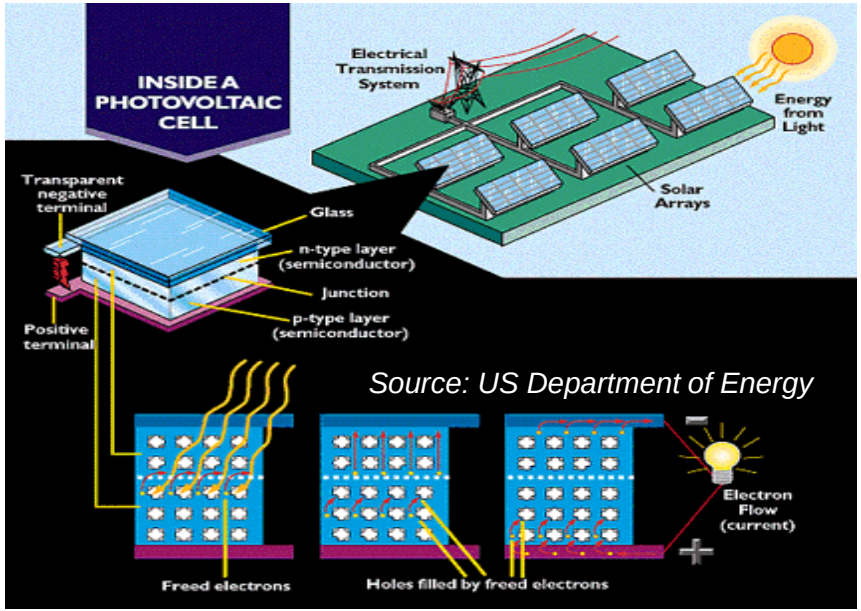
Radio
ZigBee
Bluetooth 4.0

MCU
MSP430

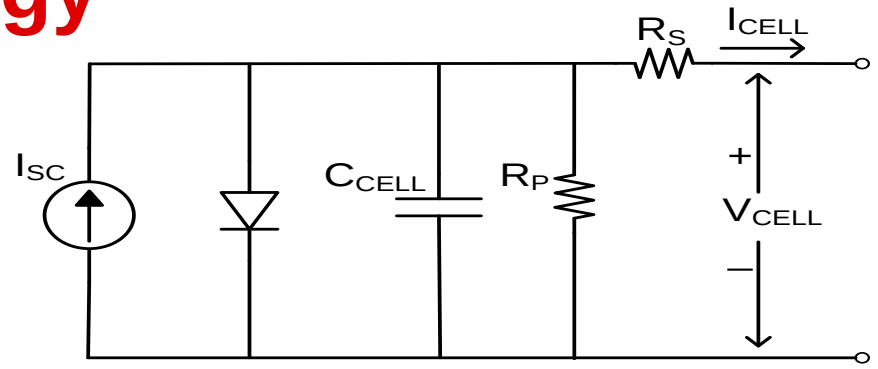
Precision Analog

Low-Power Application

Harvesting Light Energy

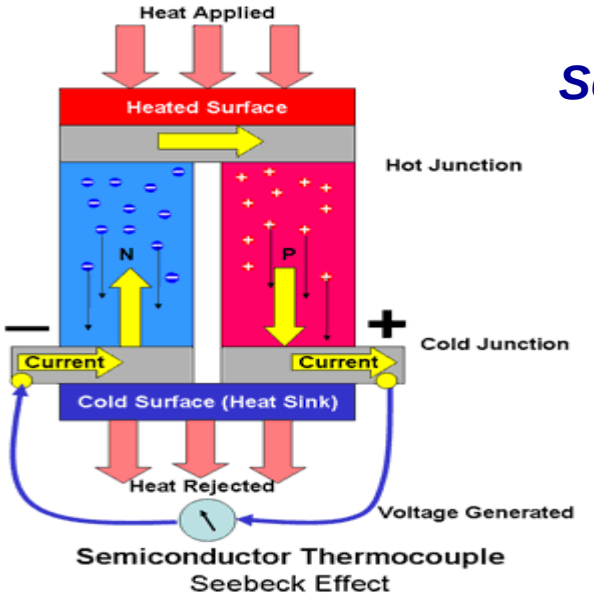


- Incident light generates electron-hole pairs
- I_{SC} proportional to light intensity



- **Series Solar Cells**
  - Higher Voltage
  - Shading of one cell decreases η of string
- **Parallel Solar Cells**
  - Lower Voltage – Must boost
  - Shading only effect that cell

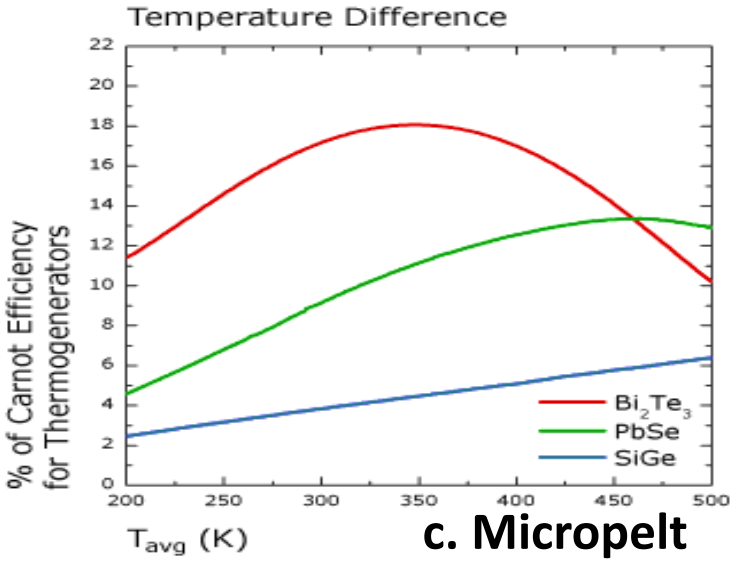
Thermoelectric Energy Harvesters



Semiconductor Thermocouple
Seebeck Effect

Seebeck Effect (1821)

$$V = \alpha \Delta T$$

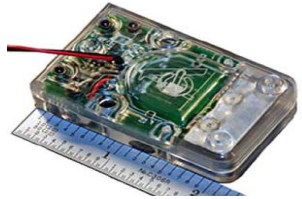


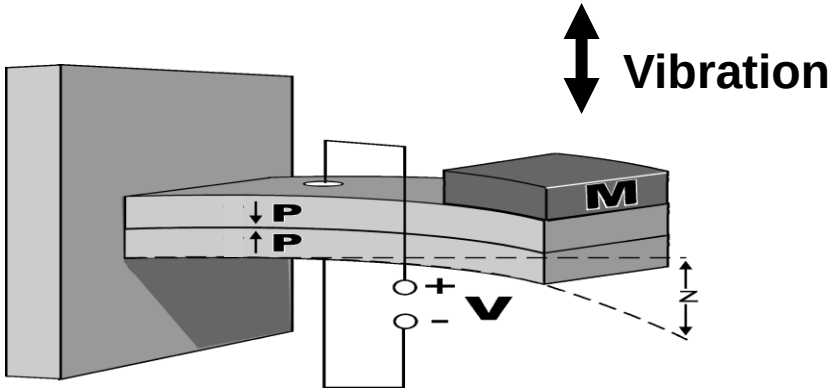
c. Micropelt

- Convert heat energy to electrical energy
- One p-n leg generates ~ 0.2mV/K

Nature 413, Oct. 2001

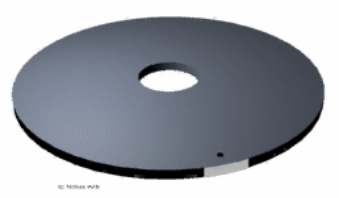
Harvesting Vibration Energy

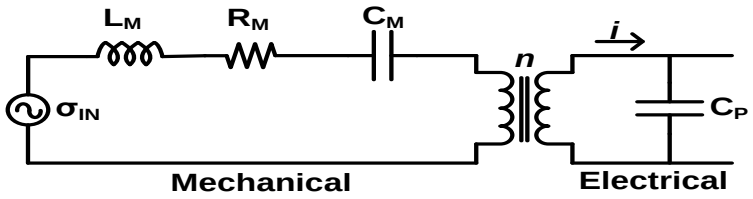


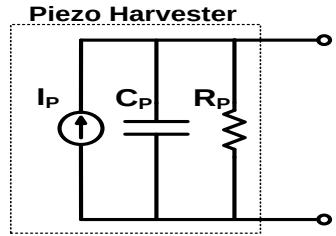


Roundy, Pervasive Computing, 2005

- Strain related to input vibration
- L_M, C_M are the mechanical mass and stiffness
- R_M takes into account mechanical losses

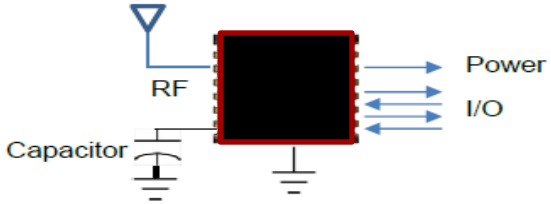






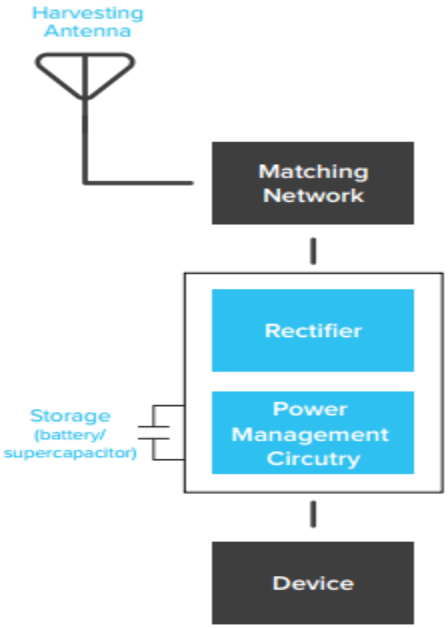
RF Harvesting

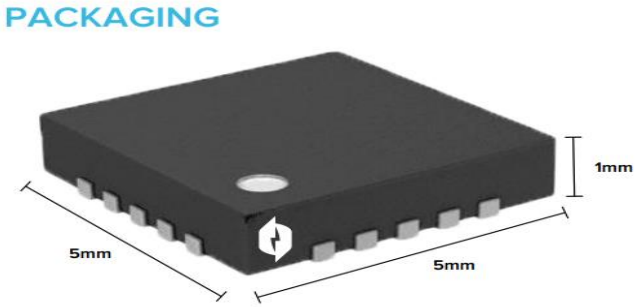
- **Intentional**
  - Known transmitter sends to waiting receiver
  - Similar concept as wireless battery charging
  - RFID
- **Ambient**
  - Known frequency and/or distance (Cell phone, Wifi)
  - Various frequencies (CB radio, AM radio, walkie talkie)
- Commercially available transducers include rectifier+dc/dc converter
- Challenging to develop in-house



Future Development- New Technology

- **Nikola Labs and Skyworks partnership**
- **Develop an easy to integrate harvesting solution**
- **RF to DC**
- **Custom Antenna + SIP = System power**
- **Nikola- Antenna provider/ Design integration**
- **Skyworks- Packaging + RF expertise**
- **Complete Energy Harvesting solution**





NIKOLA LABS

SKYWORKS

TI Energy Harvesting bq255xx Comparison

	bq25504	bq25505	bq25570
Description	Boost Battery Charger	Boost Battery Charger w/ Dual Source Support (primary and secondary storage)	Boost Battery Charger w/ regulated system rail
Cold start Voltage	330mV	330mV	330mV
Continuous Energy Harvesting from Vin	80mV	100mV	100mV
Quiescent Current	330nA	325nA	488nA
Charge Current Max	< 300mA	285mA	285mA
Buck Output Current	-	-	110mA
Package	3mm x 3mm QFN	3.5mm x 3.5mm QFN	3.5mm x 3.5mm QFN

Summary

- IoT applications are divers and are a growing market with specialized battery charging requirements
- High integration battery management unit demand is increasing
- Wireless charging is becoming more popular for wearables
- Energy harvesting will be needed for longer run time
- TI has solutions for simple low power medical devices, activity trackers, and sensor nodes with battery management needs