Nano power for IoT
And medical wearables applications

ARROW KOREA

Agenda

- **Common Charging Requirements**
- **Charging Solutions**
  - Energy Sources
  - Simple Linear Charger vs High Integration Linear Chargers (BMU)
  - Low Power Application for Wearable

    (Medical / Healthcare / Fitness)
  - Wireless charger
  - Energy Harvesting
- **Summary**

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

Small solution size

Wireless Power

Water Proof

Energy Harvesting

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”)
- Due to large number of sensor integration, less PCB space is available for battery solution these days.

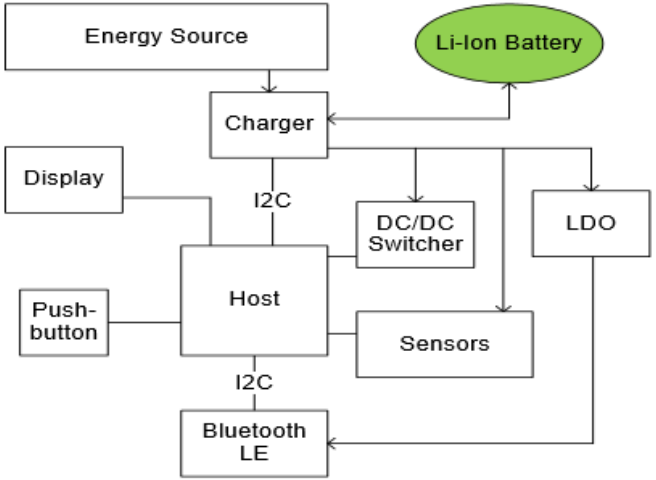
Batteries for Wearables

- The Battery Compromise
  - Capacity - Typical is 30mAh to 300mAh
  - Energy Density – State of the Art is ~150mAh/cm3
- Most popular Batteries for Wearables
  - Primary Li-Metal – Standard CR2032, highest energy density, but must be replaced by user

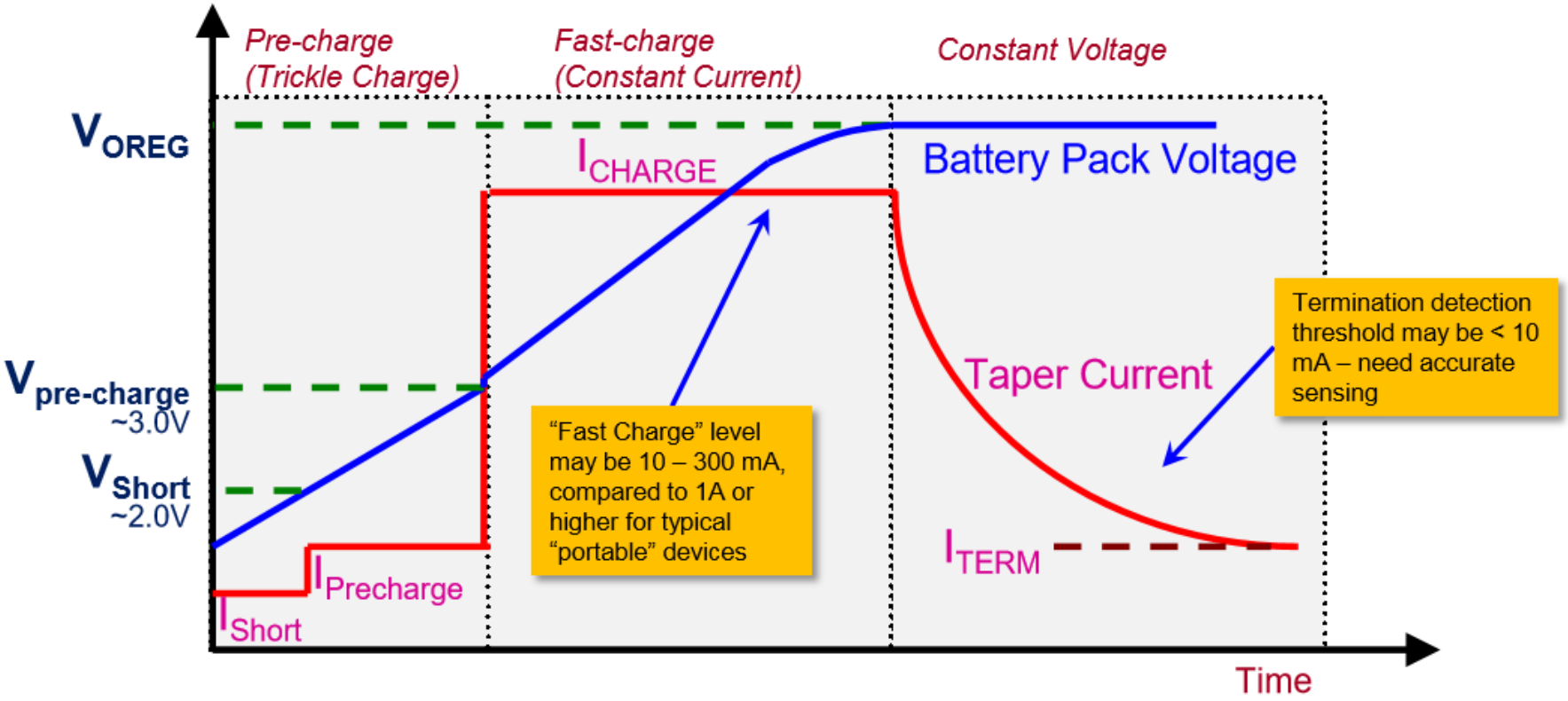
  - Rechargeable Li-Ion – Most popular, able to get in various sizes, shapes, and capacities

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

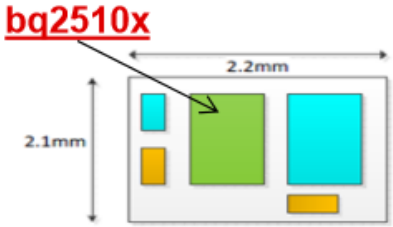
Solution size is critical for Wearables

Very limited space available for the charger IC & components

Capacitor
WCSP IC
Resistor

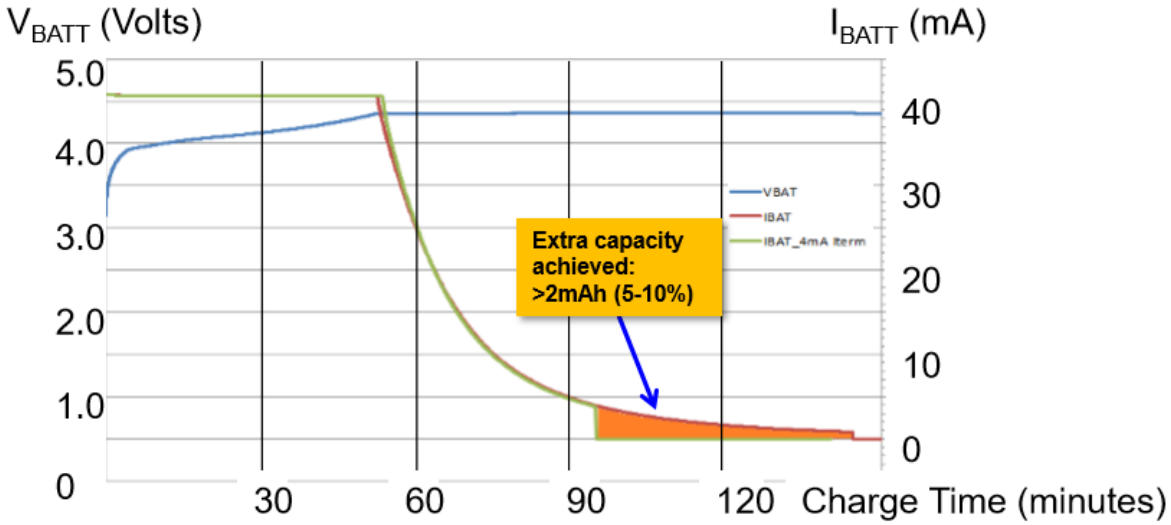
- *Power path function*
- *Up to 500mA charge rate*

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



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

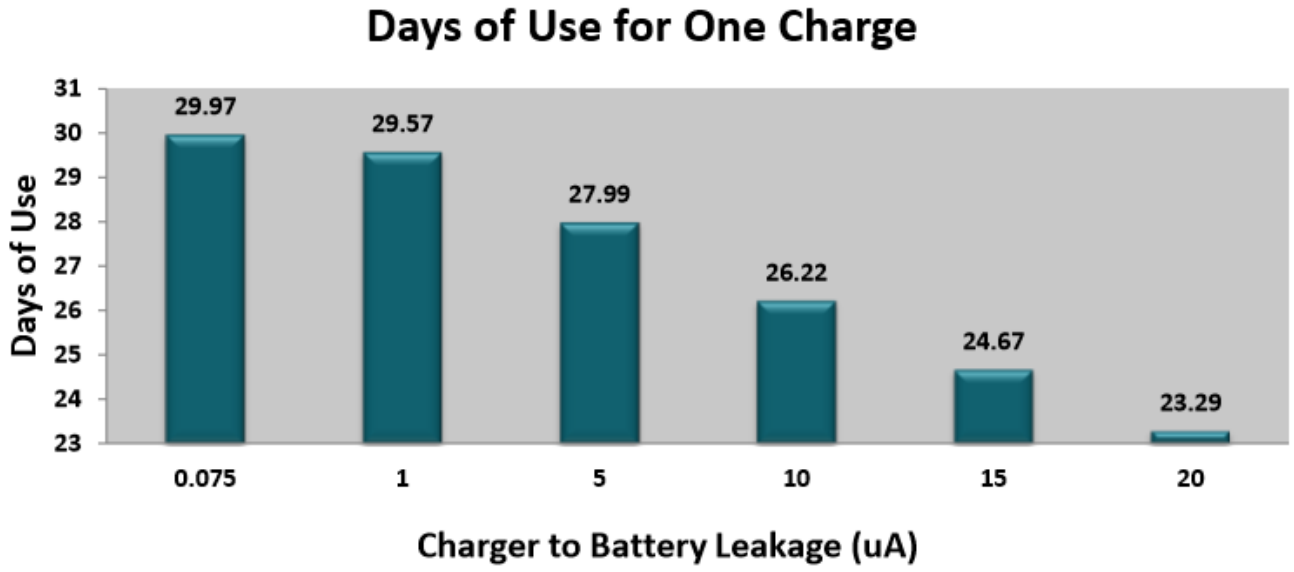
Accurate Small Cell Charge Termination



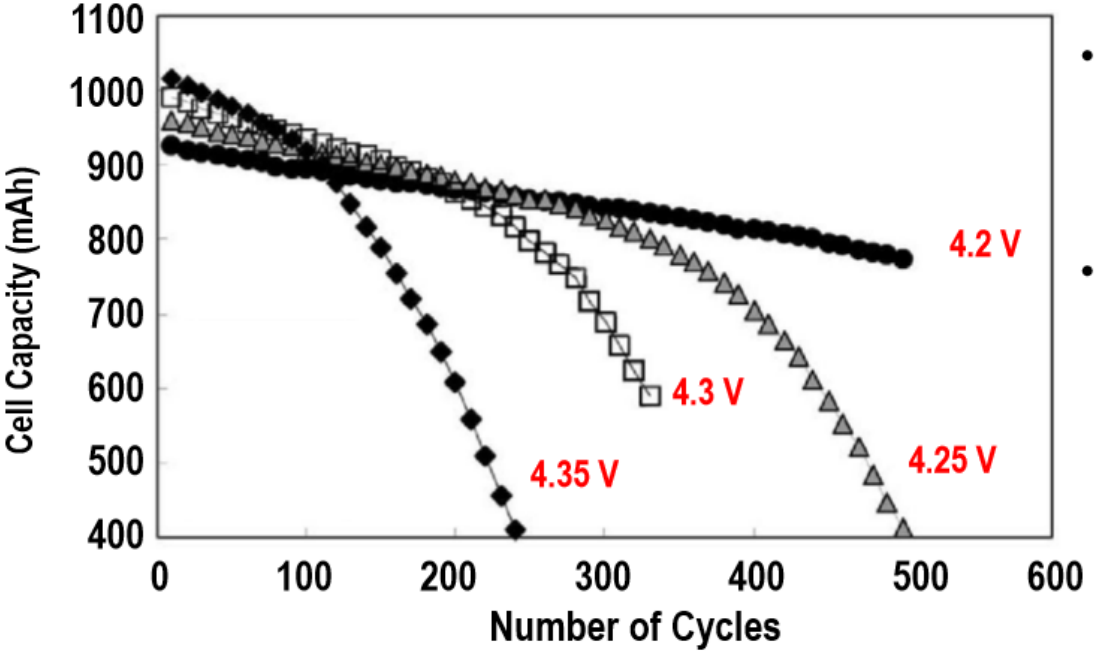
- Charged 41mAh battery at 40 mA fast charge current (1C)
- Termination at 1 mA or 10%
- Shaded area represents additional 5 – 10% capacity restored on each charge

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

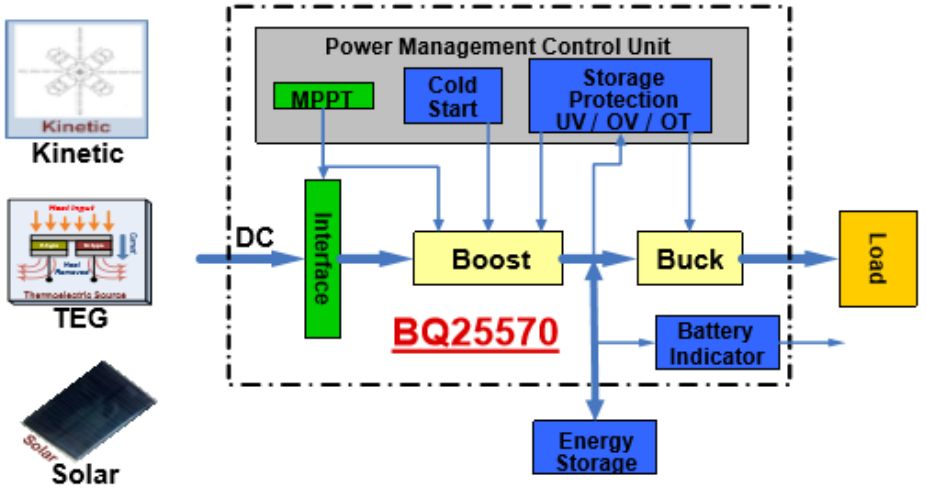
Charging Solutions

- Energy Sources
- Simple Linear Charger vs. High Integration Linear Chargers (BMU)
- Low Power Application for Wearable

  (Medical / Healthcare / Fitness)
- Wireless charger
- Energy Harvesting

Energy Sources for Wearables

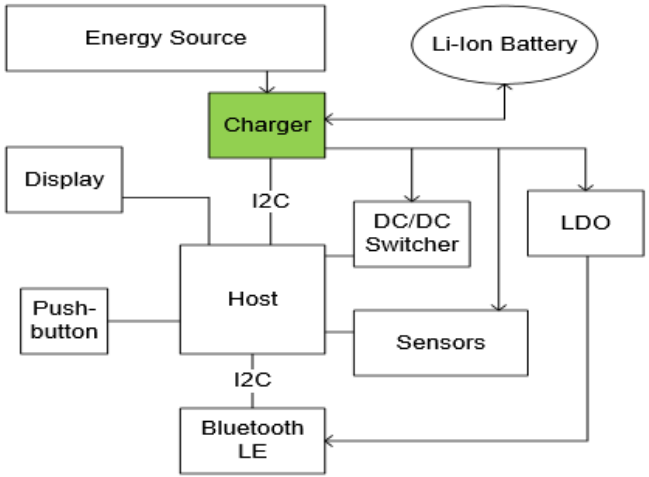
- **USB** – Most Common Today
- **Wireless Power** – Most Benefits for Wearables
  - Allows for Water-Proof and DustProof Designs
  - Eliminates Wires and Connectors
  - Simplifies User Experience for Recharging
- **Alternative Energy Sources** – Most Flexibility for Power



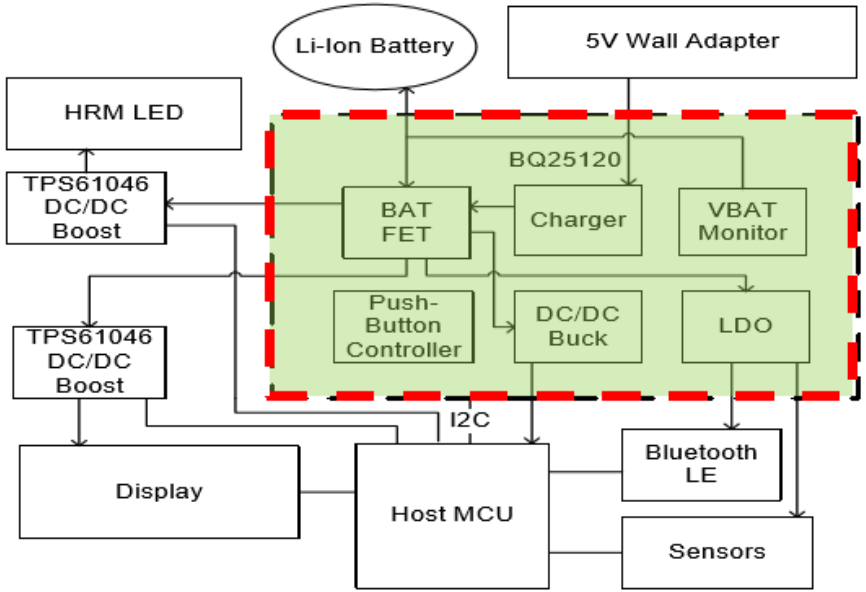
- Energy Sources
- **Simple Linear Charger vs. High Integration Linear Chargers (BMU)**
- Low power for Wearable Solution
- Wireless charger
- Energy Harvesting

Chargers Optimized for Small Batteries

BQ25100 Linear Charger



BQ25120 Battery Management Unit (BMU)



bq25120A: Battery Management for Wearables

Low Iq Linear Charger with Power Path Management, PWM Output, Load Switch, Voltage Based Battery Monitor, and Push-Button Reset

Features

1. Low battery current draw (Iq)

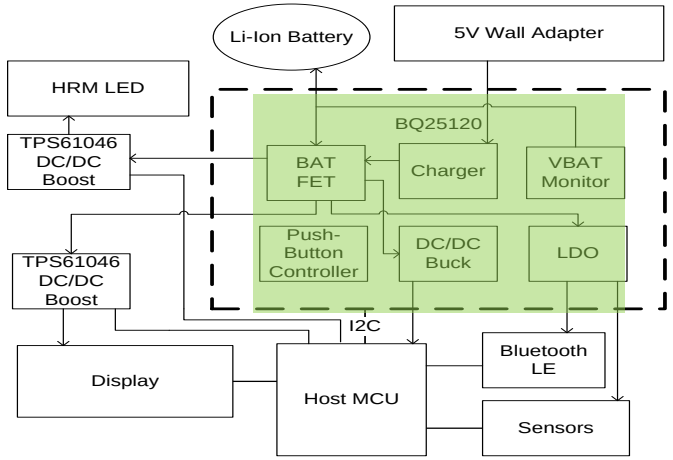
< 750nA (typ) BAT Iq with 1.8V Output Enabled
< 50nA (typ) BAT Iq in Ship mode

2. Small size

2.5mm x 2.5mm WCSP Package
15 mm² solution size (components)

3. Integration

Linear Charger: 300mA, 3.4V-5.5V input, 20V max
LDO: 100mA
Buck Converter: 300mA, 2.2V- 6.6V input
Power path (switcher)
Load switch
pushbutton control
battery voltage monitor: Accurate 2% VBATREG

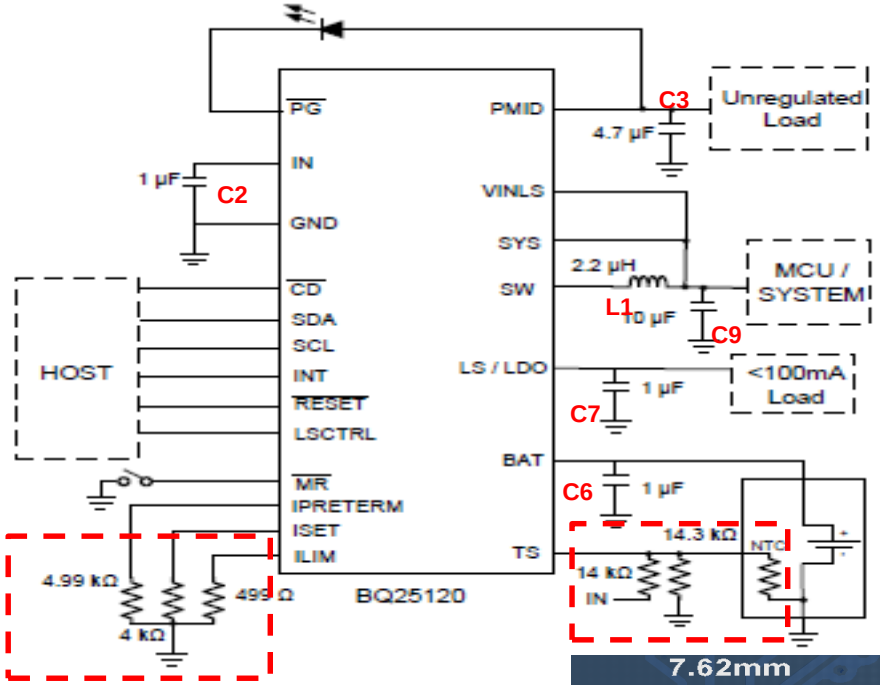


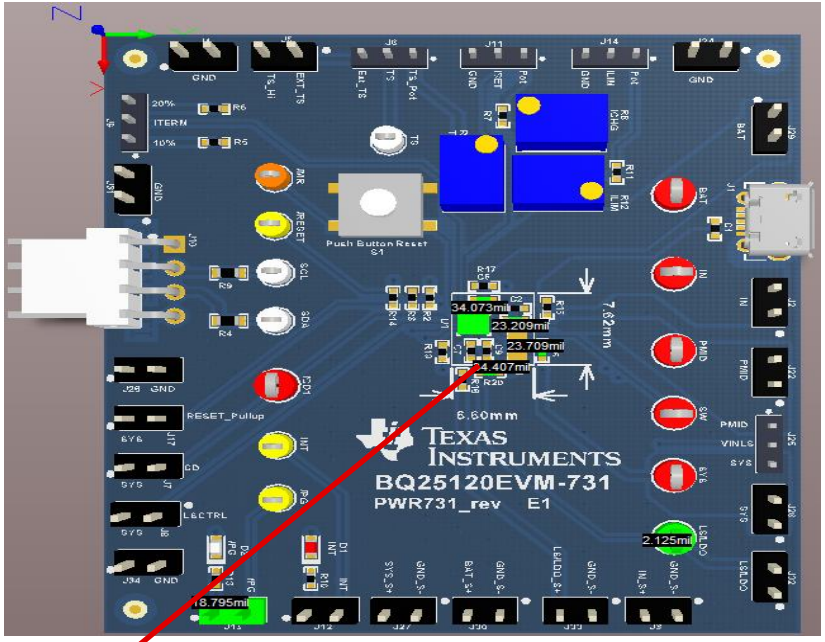
bq2512xA default settings

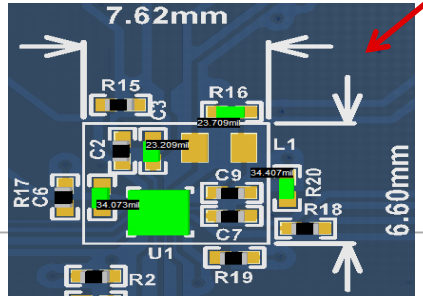
Part Number	VSYS	VBREG	LDO Output
bq25120A	1.8V	4.2V	Load Switch

*Preview, not released yet

EVM







Minimum BOM needed:
C2, C3, C6, C7, C9 and L1

Application size on EVM is 50 sqmm
(can be smaller with smaller passives)

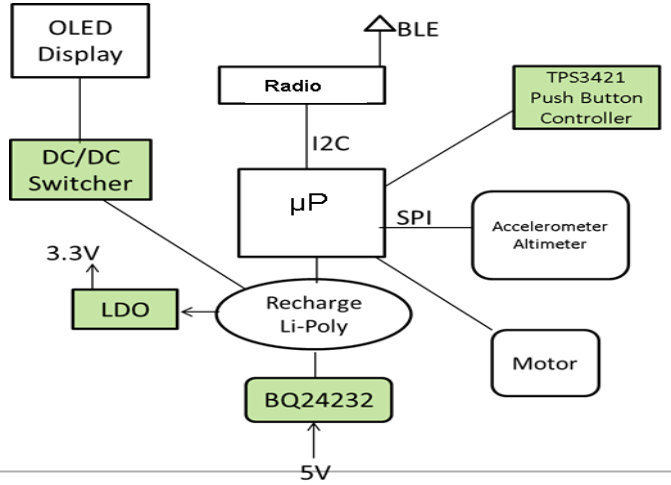
bq25120A – Solution Size and Iq Comparison

Device	Function	Iq (uA)	Package Size (mm^2)	Other Components	Component Size
TPS3421	Push Button Controller	0.35	1.45	1	2.8175
BQ24232	Charger	6.5	9	3	13.8
TPS62740	DC/DC Switcher	0.5	4	5	10.35
TPS780x	LDO	0.5	4	1	5.75
Total		7.85	18.45	10	32.7175

Device	Function	Iq (uA)	Package Size (mm^2)	Other Components	Component Size
bq25120A	Charger, DC/DC Switcher, LDO, Push-Button Controller	1 (typ) 3 (max)	6.25	6.5	14.375

Typical Application Block Diagram

Items in Green Included in BQLinLP



1/3 the Iq
1/2 the size

- Energy Sources
- Simple Linear Charger vs. High Integration Linear Chargers (BMU)
- **Low power for Wearable Solution**

  Medical / Healthcare / Fitness
- Wireless charger
- Energy Harvesting

Wearables Solutions

Audio Devices

- **BQ510x**
  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)

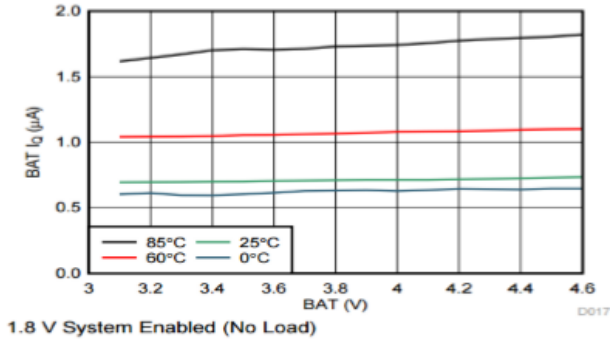
Activity Monitor With Display and Additional Features

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

Most Flexible Solution

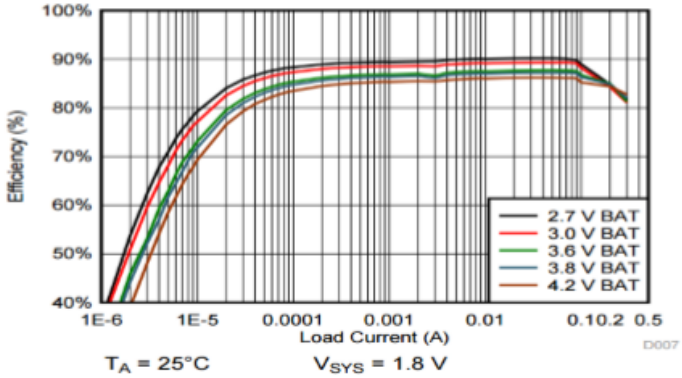
Low Iq vs. Smart Power Management

- **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

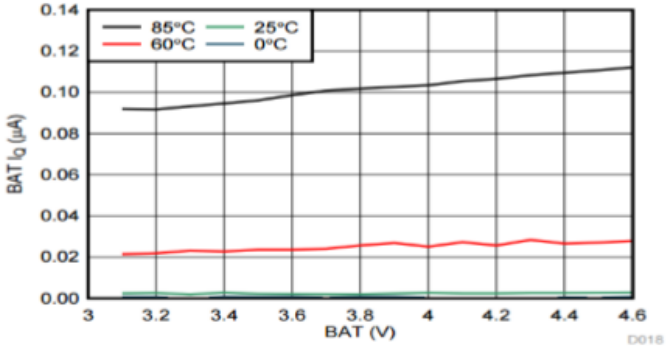
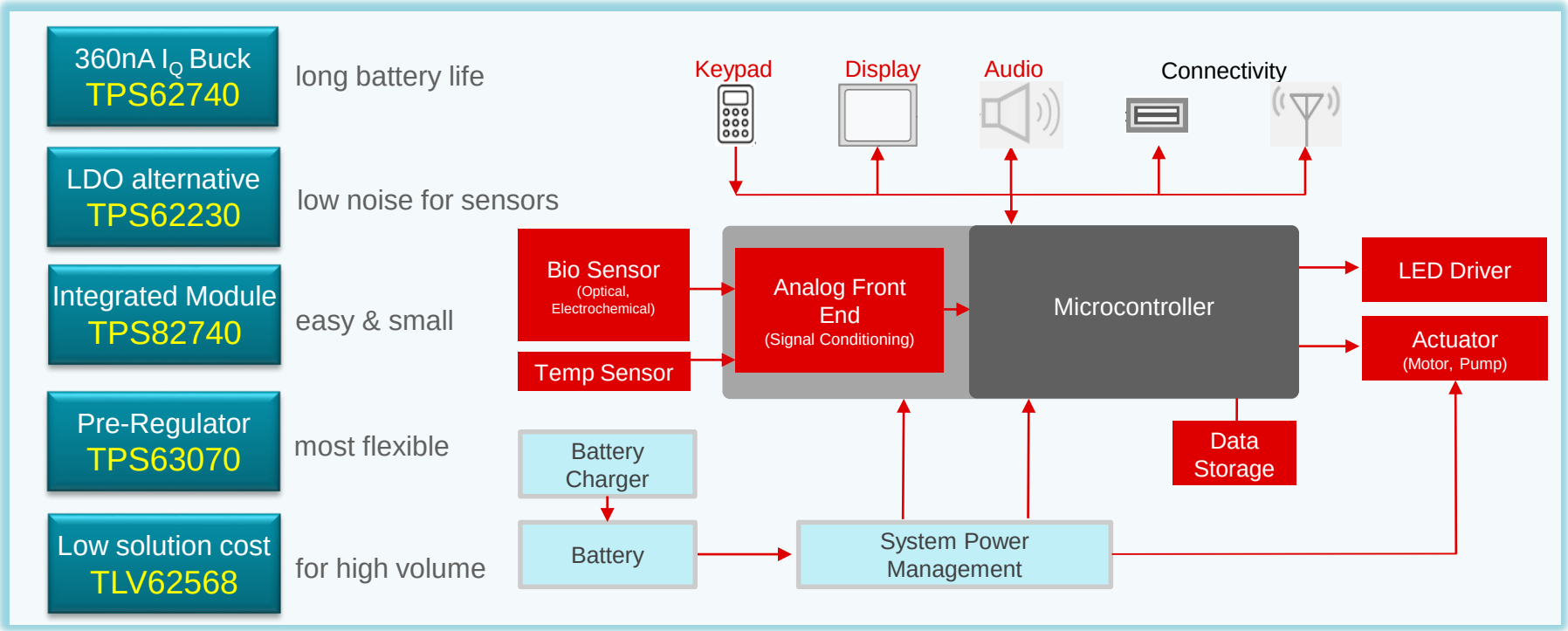


Figure 5. Ship Mode BAT, I_Q

Medical / Healthcare / Fitness
Focus on Battery powered devices

Consumer Medical / Patient Monitor needs:	TPS62-series offers:
• **Ultra-low power**	
Extended run time / long stand-by time	I_Q down to 360nA (30nA in bypass)
Low quiescent current / high efficiency @ light loads	up to 97% efficiency (90% at 10µA load)
• **Reliable and accurate supply voltage**	
Low EMI / RF-friendly IC topology	DCS-Control™ topology
High accuracy of output voltage	1% accuracy (over full temperature)
•**Small solution size**	
Small package / few & small external components	QFN, SOT563, WCSP (3 externals)
High switching frequency (up to 6 MHz)	Fully integrated Modules (0 externals)

Medical / Healthcare / Fitness
Highlights



TPS62740

Ultra-Low Power Buck Converter with Load Switch

Features

- 360nA quiescent current, up to 95% efficiency
- Slew rate controlled, integrated Load Switch
- 16 pin-selectable voltages (100mV steps)
- RF friendly DCS-Control™ Topology
- 2x3mm SON package,
  works with small inductor and low ESR caps
- Power Good Output and Capacitor Discharge

TPS62740 I_{OUT} = 300mA

TPS62742 I_{OUT} = 400mA

TPS62743 in 1.5mm² WCSP, V_{OUT} down to 1.2V

TPS627431 in 1.5mm² WCSP, set of 8 different V_{OUT} options

TPS62745 with V_{IN} up to 10V

TPS62746 with integrated V_{IN}-Switch for V_{BATT} supervision

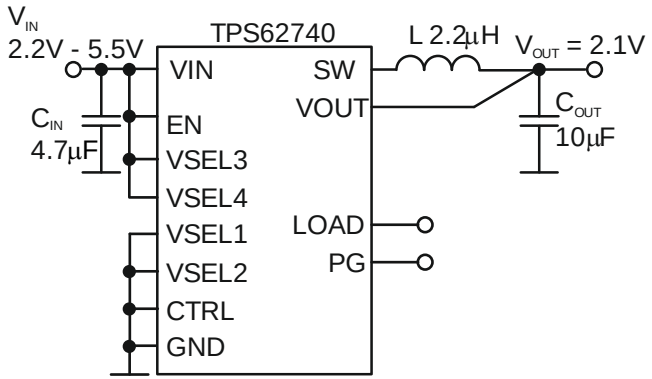
TPS62748 with integrated load switch in 1.5mm² WCSP

TPS62770 with integrated Boost converter

TPS82740 MicroSiP™ Module with integrated C_{IN}, C_{OUT}, L

Benefits

- Reduces battery current, extends application run-time
- Disconnects additional circuitry during shut-down / sleep mode
- 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
- 31mm² solution size with cost efficient components
- Provides design flexibility and active system communication



Heart Rate Monitor / Patient Monitor

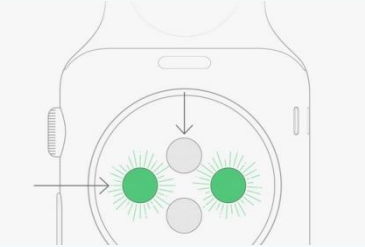
Driving Green LED for HRM

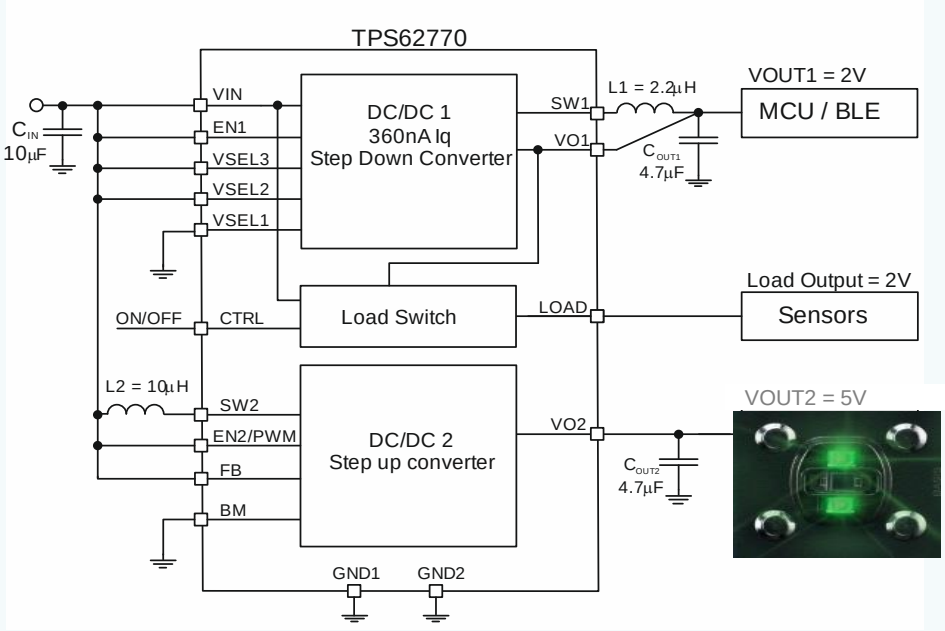
Heart Rate Monitor

..relies on green LED

- blood absorbs green light
- each pulse brings a spike in blood flow

measure the changes in light absorption with photodiodes

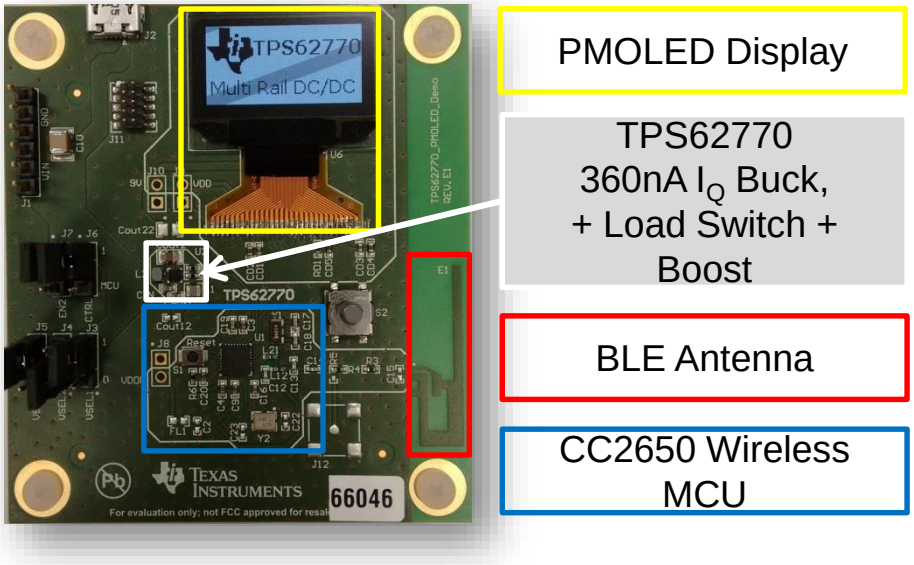




TPS62770

PMP9792 (www.ti.com/tool/pmp9792)

TIDesigns Size and power savings in **Wearable, Fitness and Patient Monitor** Triple Power Solution (Buck + Load Switch + Boost) at <27mm^2



PMOLED Display

TPS62770
360nA I_Q Buck,
+ Load Switch +
Boost

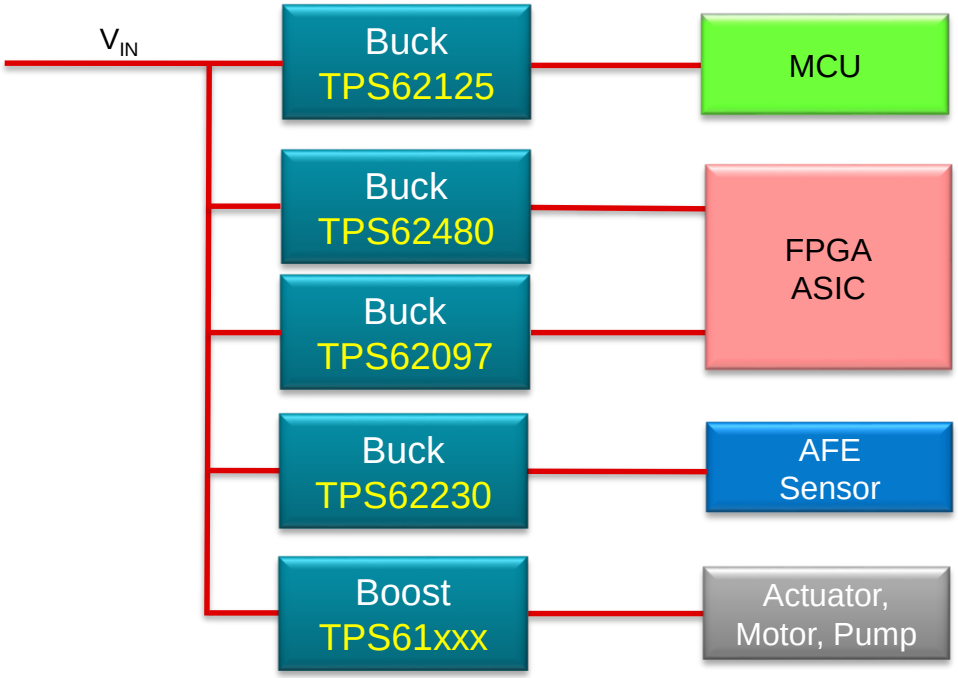
BLE Antenna

CC2650 Wireless MCU

- 360nA I_Q Buck Converter (300mA)
  - Selectable Output Voltage from 1.0V to 3.0V
- Slew rate controlled Load Switch
- Dual mode Boost Converter
  - LED current driver (PWM to current conversion)
  - Adjustable constant output voltage up to 15V
- Tiny 16-pin CSP package
  1.65mm x 1.65mm x 0.5mm

Power Solutions for Medical portable devices

Point-of-Load Regulator: *precision, easy-to-use*



Alternative solution depending on Load requirements
(*for more options see power.ti.com*)

TPS62125: 3-17V_{IN}, 1.2-10V/0.3A_{OUT}
TPS62150: 3-17V_{IN}, 0.9-6.0V/1A_{OUT}

TPS62480: 2.4-5.5V_{IN}, 0.6-5.5V/6A_{OUT}
TPS62085: 2.5-6.0V_{IN}, 0.8-V_{IN}/3A_{OUT}
TPS62097: 2.5-6.0V_{IN}, 0.8-V_{IN}/2A_{OUT}
TPS62135: 3.0-17V_{IN}, 0.8-12V/4A_{OUT} New

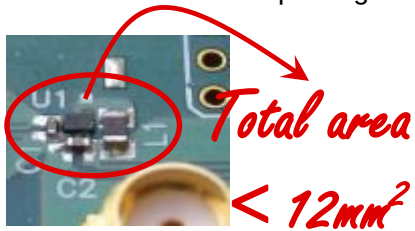
TPS62230: 2.0-6.0V_{IN}, 1.0-3.3V/0.5A_{OUT}

TPS62230

“The Tiny & Simple LDO alternative”

Features

- **Low noise, 90dB PSRR, 10mV V_{OUT} ripple**
- **94% efficiency, 22µA quiescent current**
- RF friendly DCS-Control™ topology
- Selectable forced PWM or automatic Power Save Mode
- 1 x 1.5 x 0.6mm SON package

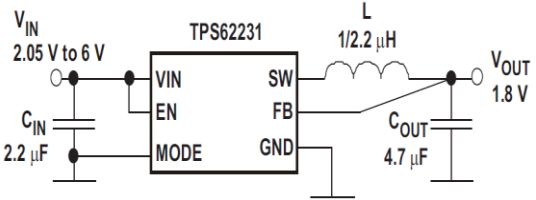


- 19 different options available (1.0V – 3.3V) / 500mA$_{OUT}$

V_{out} (fixed by factory)	VOUT (V)	1.0	1.1	1.15	1.2	1.2	1.25	1.3	1.5	1.8	1.85	2.0	2.1	2.25	2.3	2.5	2.7	2.9	3.0	3.3
	f (MHz)	3	2	2	2	3	3	3	3	3	2	3	3	3	3	3	3	3	3	2
	Device	TPS62239	TPS622311	TPS622315	TPS62235	TPS62232	TPS622318	TPS622313	TPS622314	TPS62231	TPS62236	TPS622312	TPS62234	TPS62238	TPS622310	TPS62230	TPS622316	TPS622317	TPS62233	TPS62237

Benefits

- **Makes the part an alternative solution to linear regulators with higher efficiency**
- **Extends application run-time / standby-time and reduces system temperature for improved reliability**
- Maintains an accurate output voltage at fast AC line and load transients plus a seamless transition between PWM and PSM
- Allows to choose between high efficiency over entire load range (PSM) or regulated fixed frequency (PWM)
- Supports a total solution size of 12mm² and allows selection of cost efficient components



TPS62097

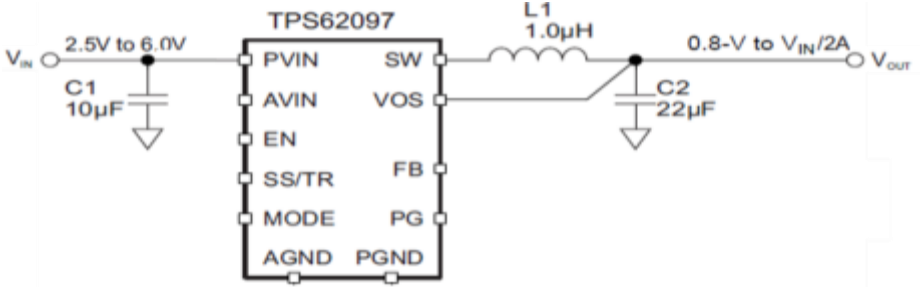
6V_{IN},2A high-efficient Buck with fixed and selectable f_{SW}

Features

- **iDCS-Control™ with Forced-PWM mode and adjustable switching frequency (1.5-2.5 MHz)**
- 1% V_{OUT} accuracy (V_{OUT} = 0.8V – VIN)
- Adjustable and Fixed V_{OUT} (3.3V and 1.8V)
- Adjustable Soft-Start and Voltage Tracking
- V_{IN}: 2.5V to 6V
- 100% duty cycle mode for lowest dropout
- 40µA quiescent current in Power Save Mode
- Output voltage discharge
- T_J=-40 to +125ºC
- Package 2x2mm QFN

Benefits

- **RF-friendly DC/DC converter for noise-sensitive, precision industrial applications**
- Voltage tracking ideally for MCU, CPU, DSP and FPGA sequencing
- Small solution size 28mm^2



Industry 6V/2A BUCK with flexible feature-set and small solution size:
Adjustable Softstart + Tracking + PowerGood + Enable + Mode in 2x2mm QFN

TPS62480

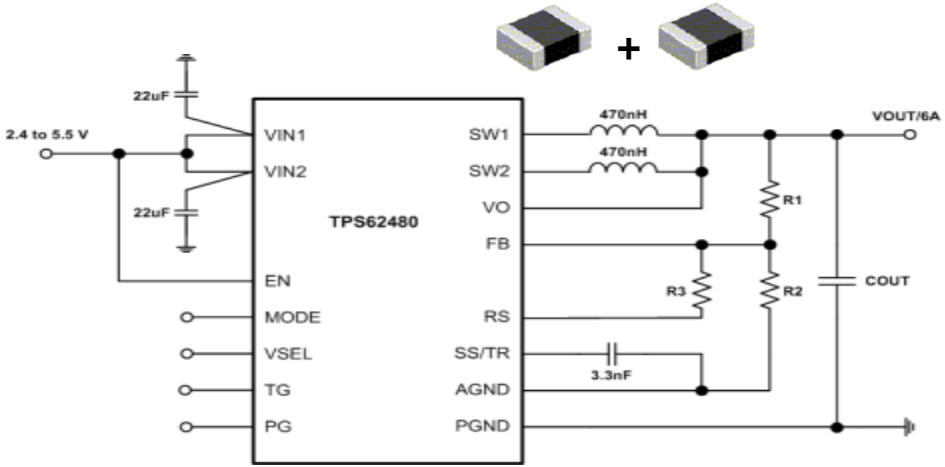
6A$_{OUT}$, 5.5V$_{IN}$, high accuracy, high efficiency, very small Buck

Features

- V_{IN} range: 2.4V to 5.5V
- V_{OUT} range: 0.6V to 5.5V
- **Output Current up to 6A**
  - phase shifted operation, phase adding/shedding
- ±1% Feedback Voltage Accuracy (PWM)
- 23µA Quiescent Current
- Forced-PWM Operation
- **Output Voltage Select**
- Adjustable Soft-Start
- Power Good
- **Thermal Good**
- T_J=-40˚C to +125˚C
- 2.5 x 3mm HotRodTM QFN Package
- **TPSM82480** Power Module (3.7 x 8mm) New
- **TPS62180**: V_{IN} = 4 – 15V, **TPS62184**: V_{IN} = 4 – 17V

Benefits

- **Small solution size (<80mm²)**
- **Ultra-low height solution (1mm)**
- **Selectable output voltage for e.g. power save modes**
- **Thermal Good prevents from excessive heat**



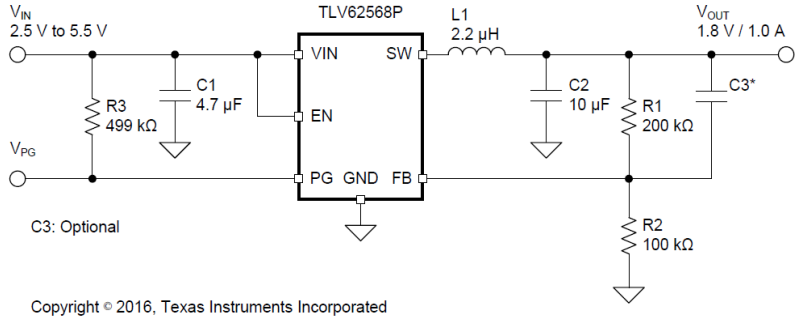
TLV62568 / TLV62569

1A / 2A **Step-Down Converter in SOT23 / SOT563 Package**

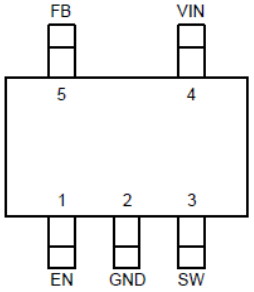
NEW

Features

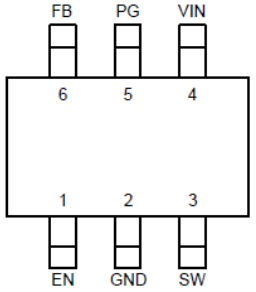
- 2.5V to 5.5V Input Voltage Range
- 35µA Quiescent Current
- Power Save Mode for Light Load Efficiency
- 100% Duty Cycle for Lowest Dropout
- 0.6-V to V_{IN} Adjustable Output Voltage
- Internal Soft Startup
- Thermal Shutdown
- PG (Power Good) for TLV62568P / 569P
- SOT23 and SOT563



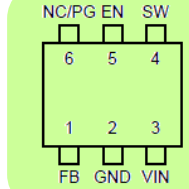
SOT23-5
DBV Package
(Top View)



SOT23-6
DDC Package
(Top View)



SOT563-6
DRL Package
(Top View)



- Energy Sources
- Simple Linear Charger vs. High Integration Linear Chargers (BMU)
- Low power for Wearable Solution

  Medical / Healthcare / Fitness
- **Wireless charger**
- Energy Harvesting

Benefit of Wireless Power

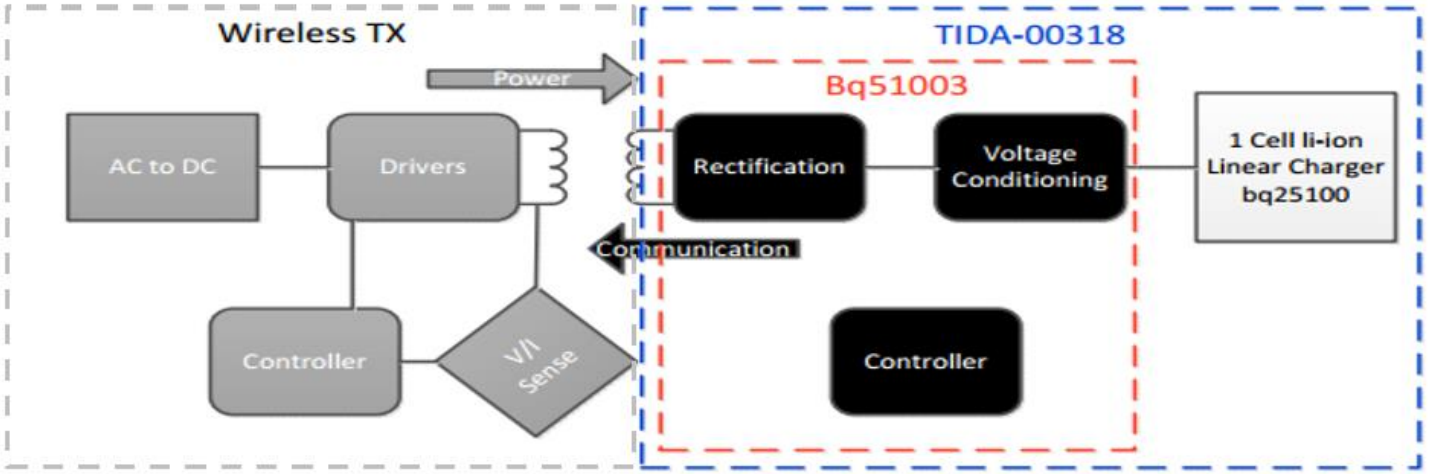
Convenience

Water Proof

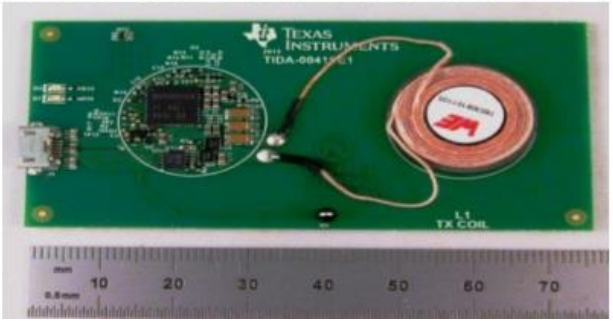
No Cables or Connectors

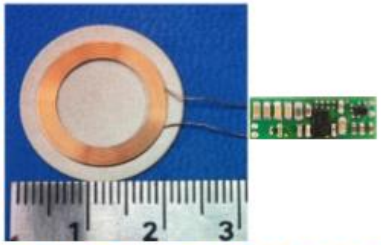
Rugged Industrial Design

Wireless power for wearables



TIDA-00415
20mm, 1W

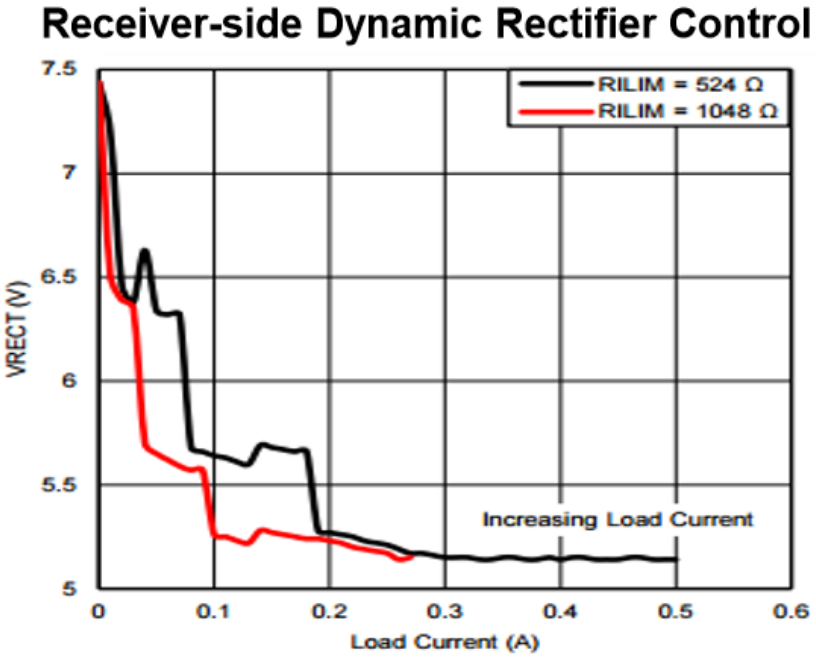


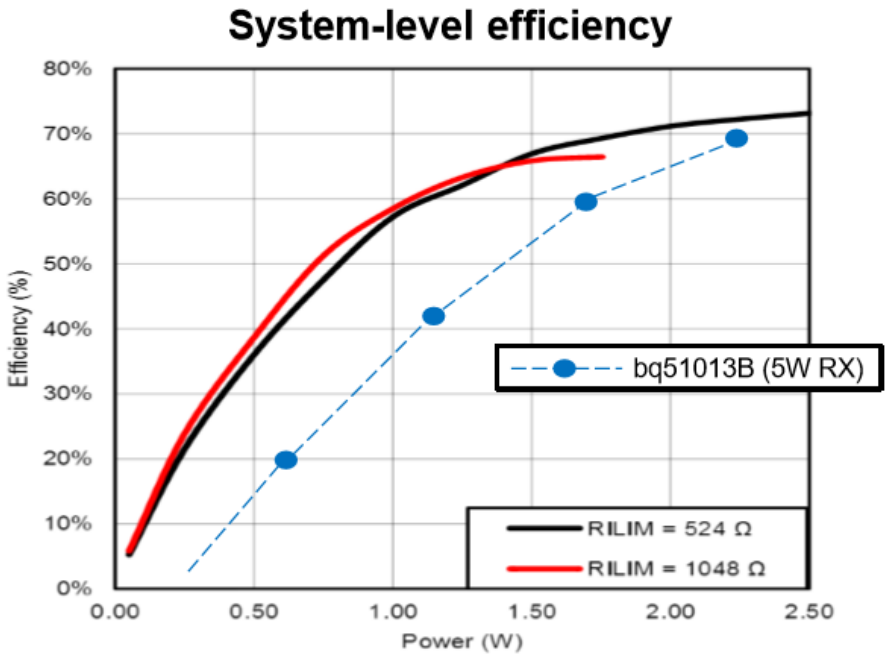


TIDA-00318
10mm, 1W

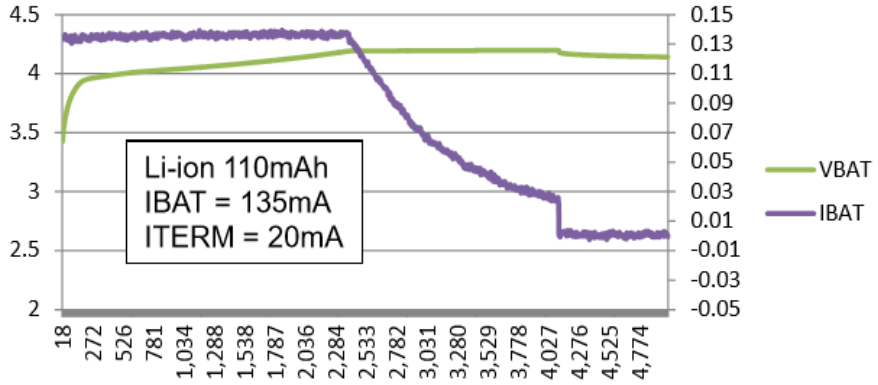
bq51003 2.5W Optimized Receiver

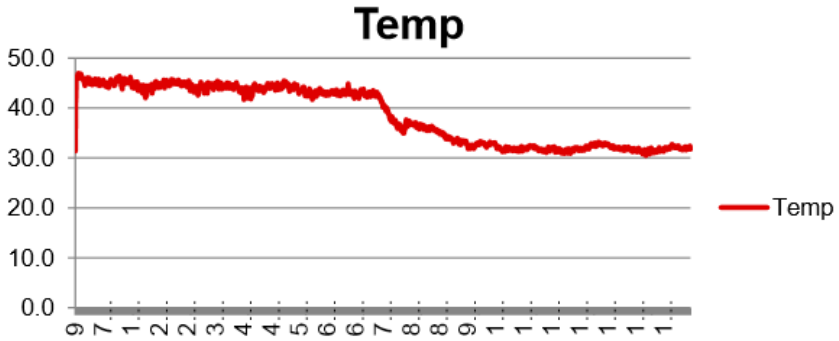
10 – 15% efficiency improvement at 1W output power vs. standard (5W-rated) receiver

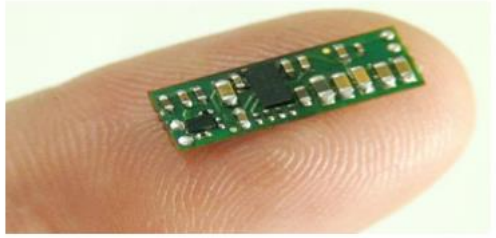




TIDA-00318: Charging Performance







- Small Size: 5x15(mm2)
- 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)
- Low power for Wearable Solution

  Medical / Healthcare / Fitness
- Wireless charger
- **Energy Harvesting**

Energy harvesting applications

Convenience

Home

Wearables

Remotes

Extended battery life

Hard to Reach

Implantables

Oil Rig

Pipelines

Environmental Awareness

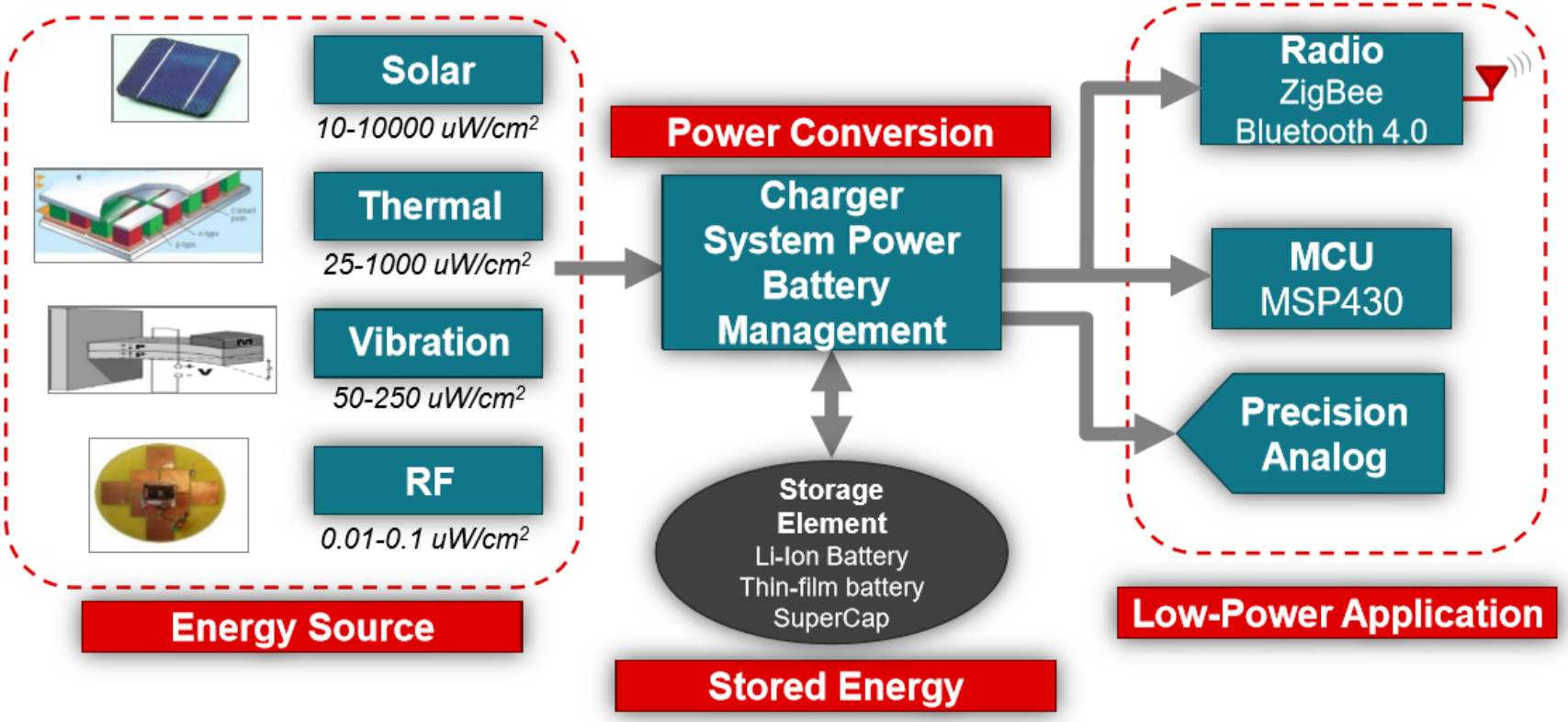
Industrial

Smoke Detectors

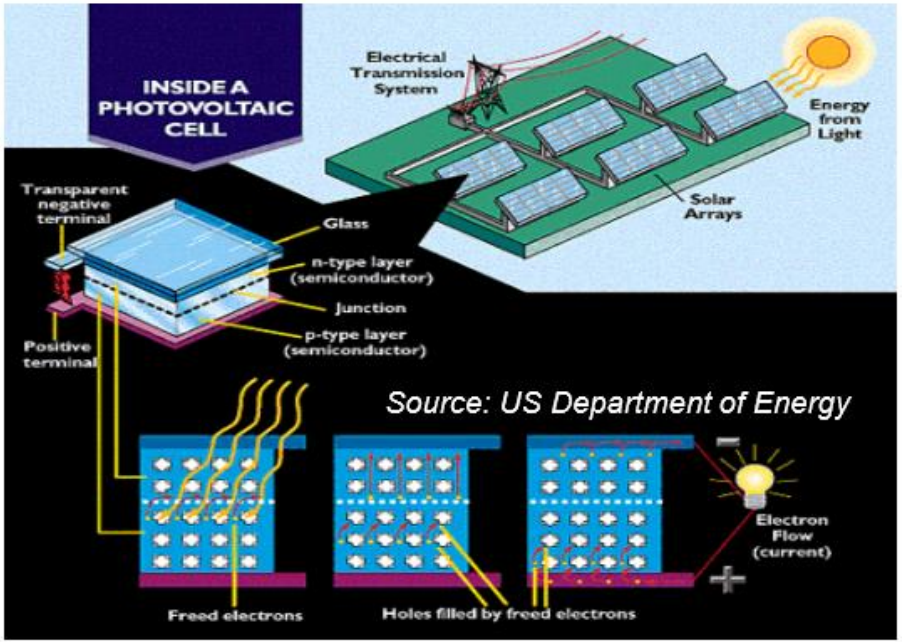
Automotive

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

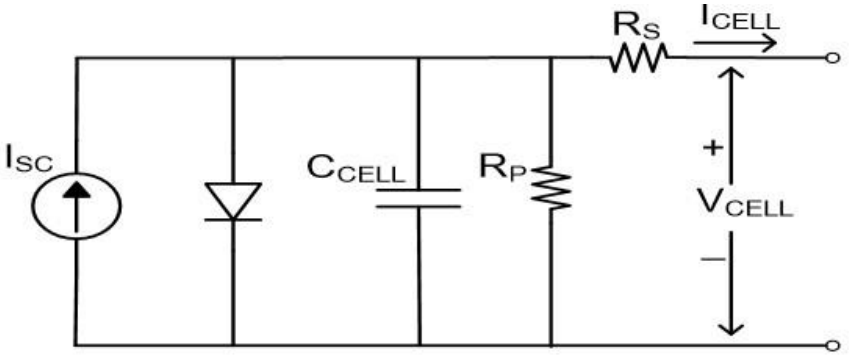
Enabling efficient use of energy harvesting



Harvesting Light Energy

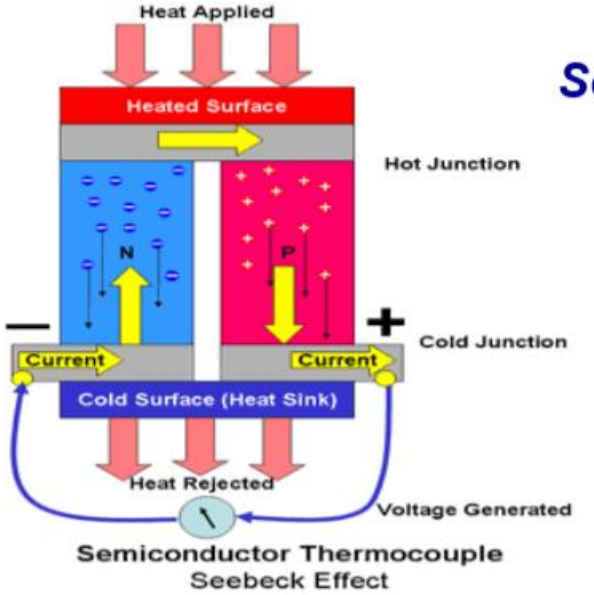


- Incident light generates electron-hole pairs
- Isc proportional to light intensity



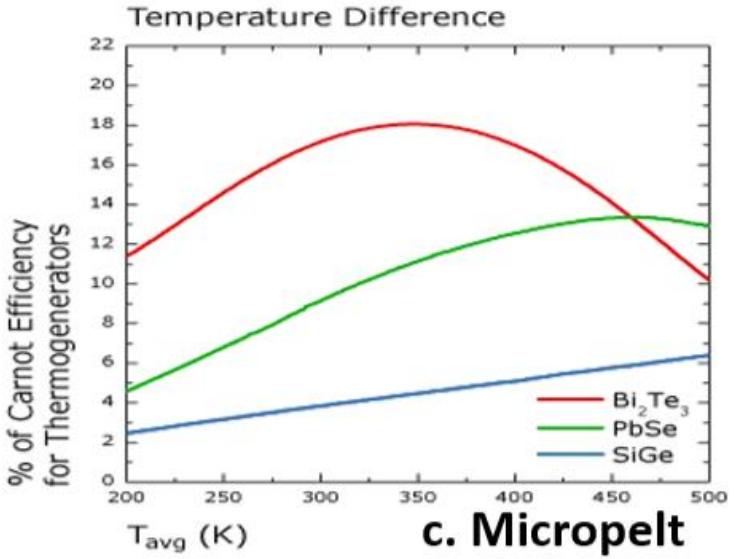
- **Series Solar Cells**
  - Higher Voltage
  - Shading of one cell decreases η of string
- **Parallel Solar Cells**
  - Lower Voltage – Must boost
  - Shading only effect that cell

Thermoelectric Energy Harvesters



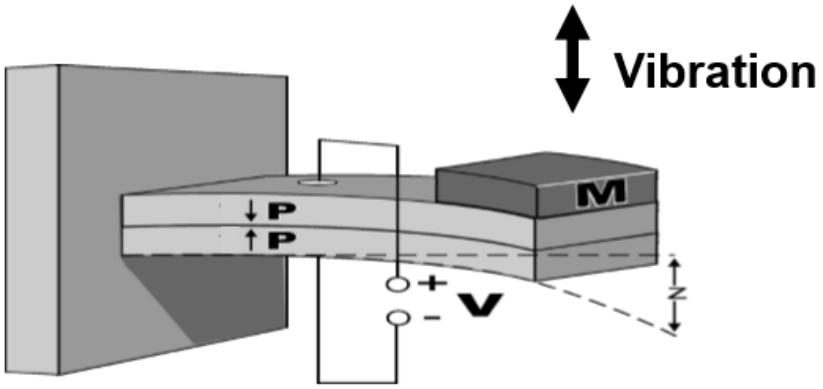
Seebeck Effect (1821)

$$V = \alpha \Delta T$$



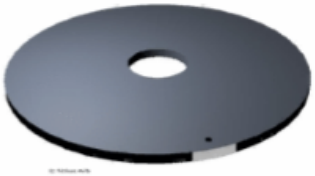
- Convert heat energy to electrical energy
- One p-n leg generates ~ 0.2mV/K

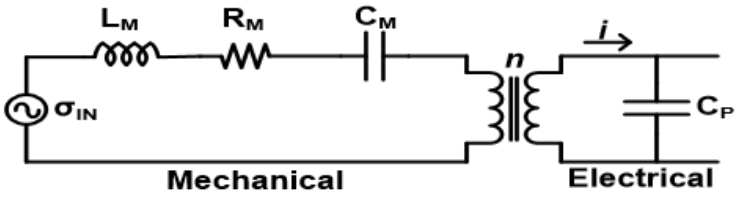
Harvesting Vibration Energy

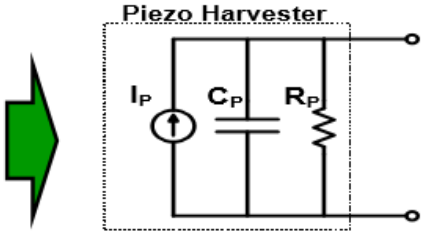


Roundy, Pervasive Computing, 2005

- Strain related to input vibration
- Rm takes into account mechanical losses

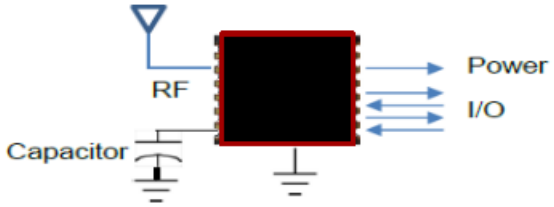






RF Harvesting

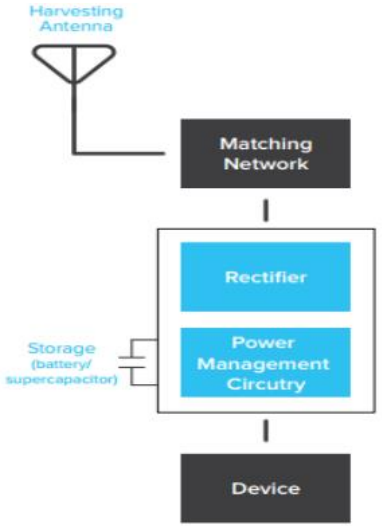
- **Intentional**
  - RFID
  - Similar concept as wireless battery charging

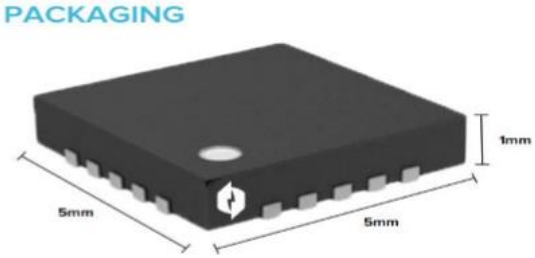


- **Ambient**
  - Known frequency and/or distance (Cell phone, Wifi)
  - Various frequencies (CB radio, AM radio, walkie talkie)
- **Commercially available transducers include rectifier+dc/dc converter**
- **Challenging to develop in-house**

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

ARROW KOREA

Thank You