TI POWER

Choosing the right battery charger topology for low-power applications

Battery Management Deep Dive Training

October 2020

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Low power application examples

Personal Electronics

- Hearables
- True wireless stereo
- Smartwatch
- Activity monitor
- Rechargeable toys

Industrial

- Smart sensors
- Home automation
- Asset tracking
- E-Call
- EPOS

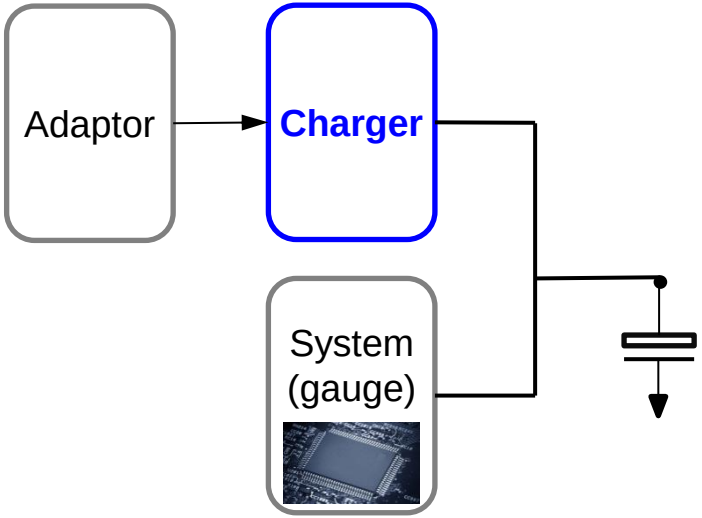
Medical

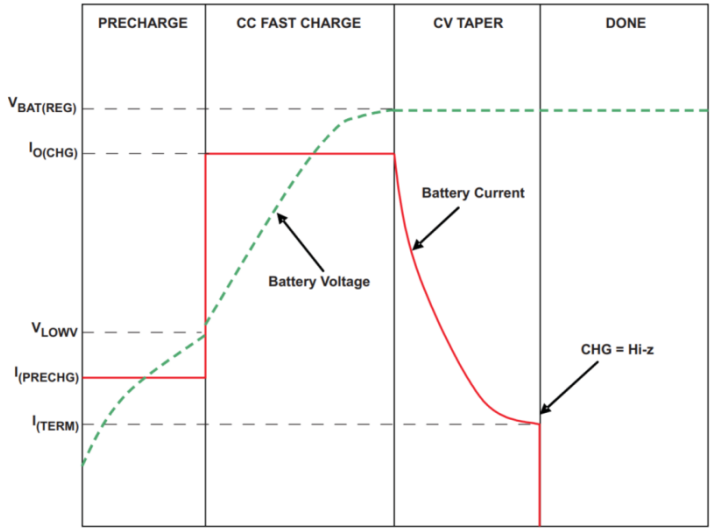
- Hearing aids
- Medical wearable devices
- Blood glucose meters

Considerations for low power design

- **Small board size**
  - Small silicon footprint
  - Low BOM
- **Power requirements**
  - Shipmode
  - Low battery I_Q
  - Low and Accurate termination
  - Input source agnostic
- **Low cost design**

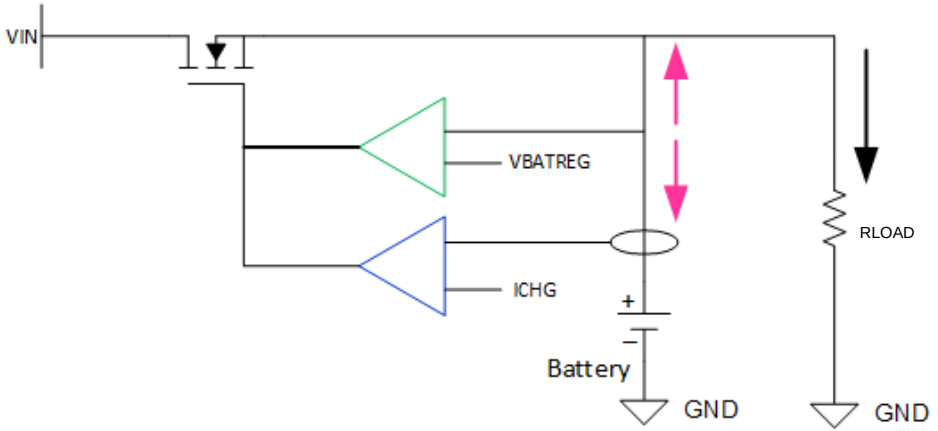
An application with charging system

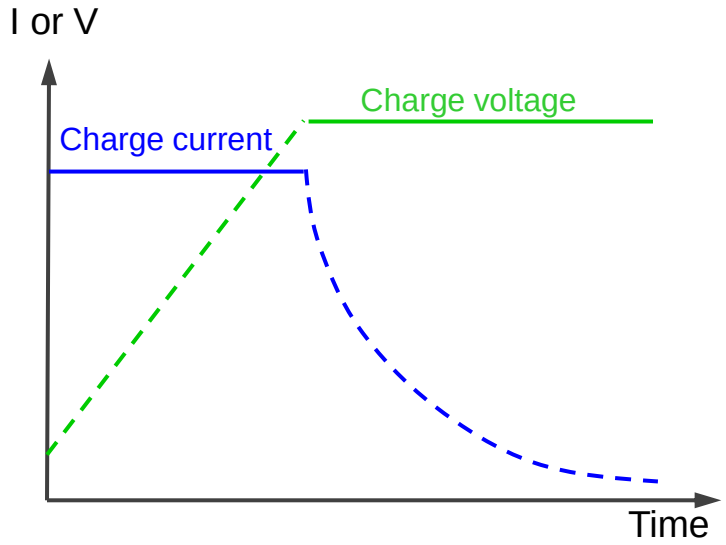




- **Charging system functions**
  - Regulation: constant voltage (CC) and constant current (CV)
  - Safety of charging/discharging and status of charging
  - Features for better customer experience and cost effective dynamic power management

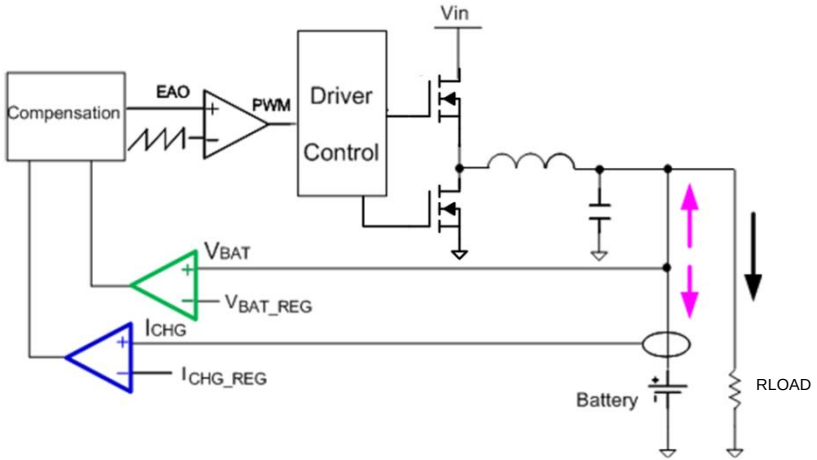
A basic linear battery charger

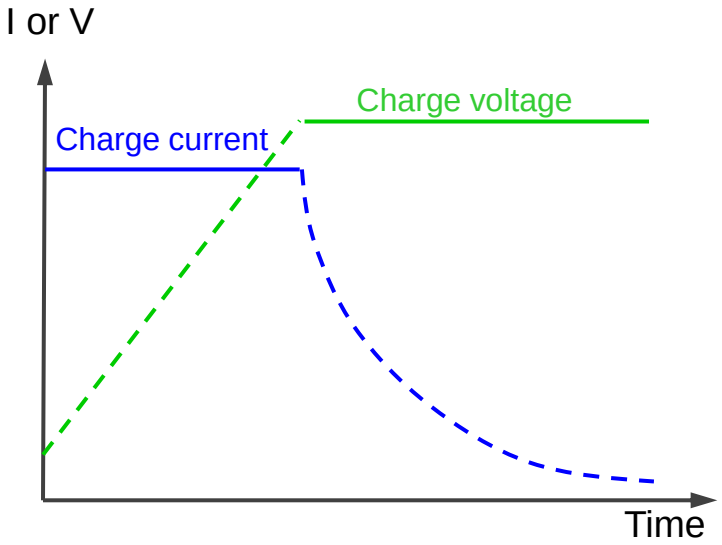




- **Battery charger**
  - Constant current and constant voltage loops for CC and CV
  - Charging occurs using an LDO
  - Input is the adaptor and output is the system and battery
  - Battery can be a ***load*** or a ***source***

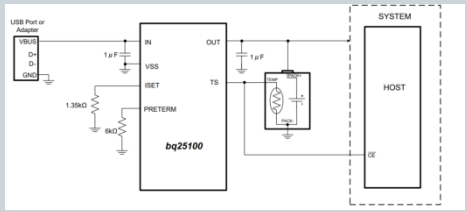
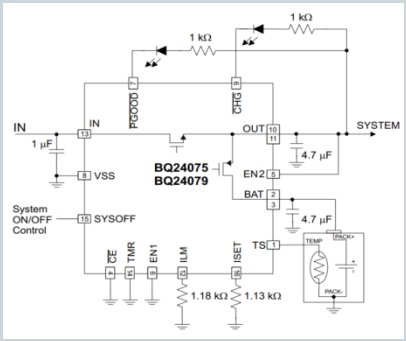
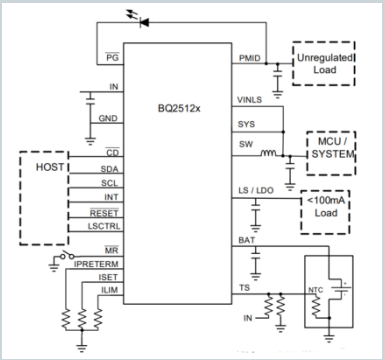
A basic switching battery charger





- **Battery charger**
  - Constant current and constant voltage loops for CC and CV
  - Charging occurs using a buck converter
  - Input is the adaptor and output is the system and battery
  - Battery can be a ***load*** or a ***source***

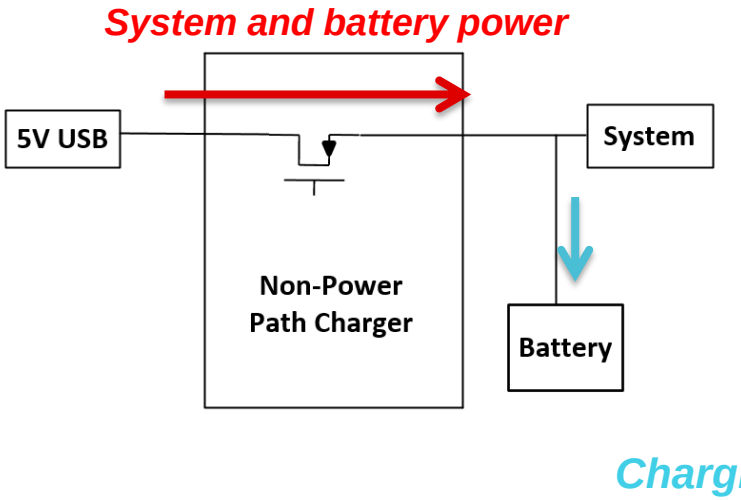
Low power charging topologies

	Non-power path	Power path	Battery management unit
			
I_{CHG}	≤ 1 A	≤ 1.5 A	≤ 0.5 A
Pros	Simple, small size	Instant system power on, accurate termination	High integration, small solution size
Cost	$	$$	$$$

NON-POWER PATH CHARGER

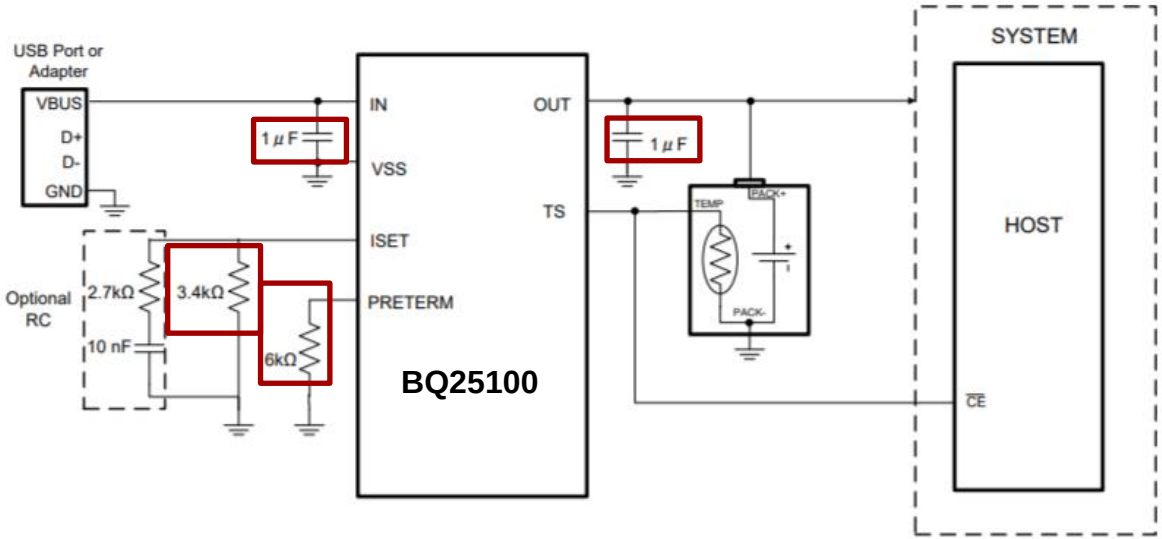
Charger topologies – Non-power path

- Power is supplied from adapter through Q1
- Charge current and load current have same path
- Battery and system will be connected together
- Battery supplements system current directly
- Ideal topology when product won't be charged and used at same time



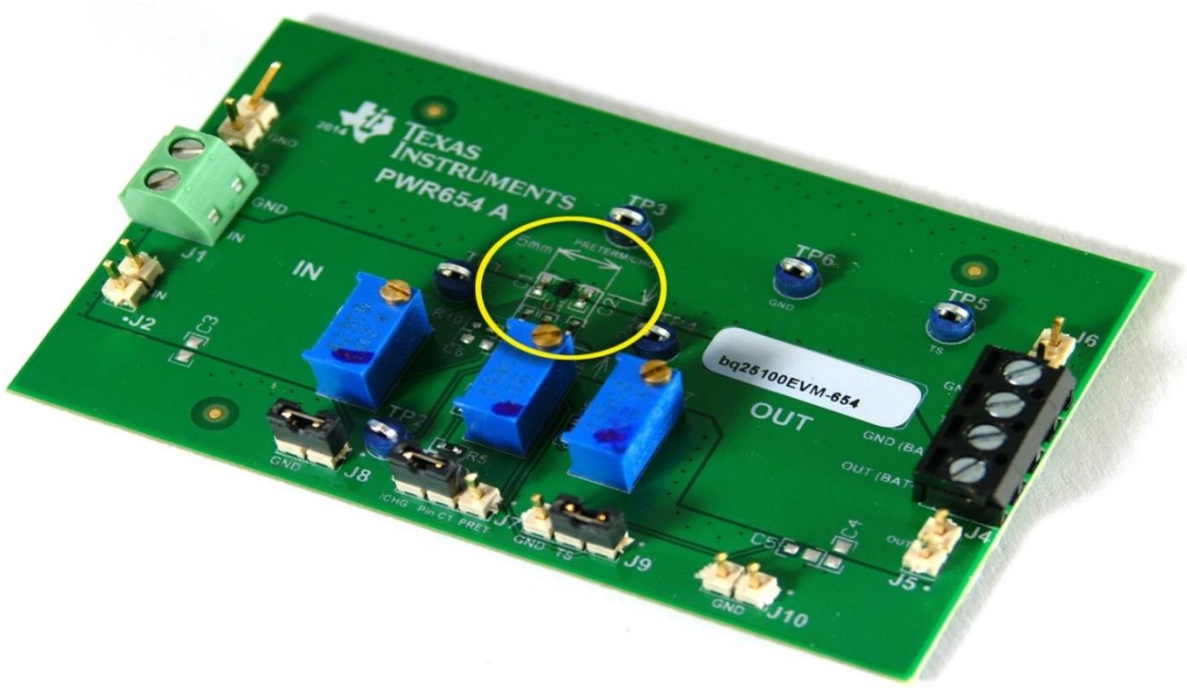
Key Feature: Small Solution Size / Low BOM Count

Passive components – Small solution size



4 passive components

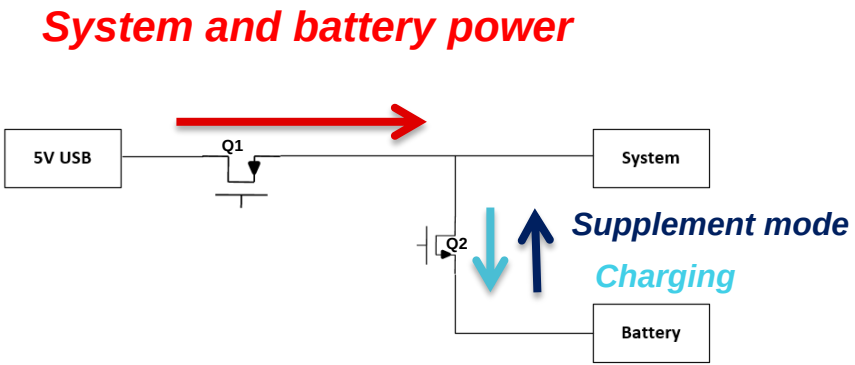
BQ25100 IC actual size –Smaller and thinner than passives



POWER PATH CHARGER

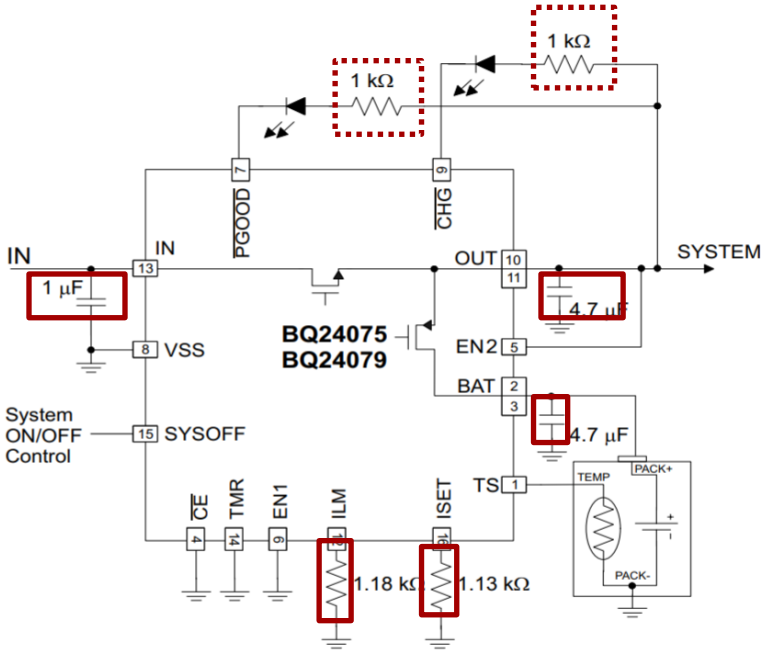
Charger topologies – Power path

- Power is supplied from adapter through Q1; charge current controlled by Q2
- Separates charge current path from system current path with priority given to system current
- Ideal topology when powering system and charging battery simultaneously is a requirement
- System input enables instant system turn on when plugged in, even with a totally discharged battery and enables proper termination
- Supplement mode allows the battery to support the system load when the input current limit is below system requirement



Key Feature: Dynamic Power Management

Passive components – Small solution size

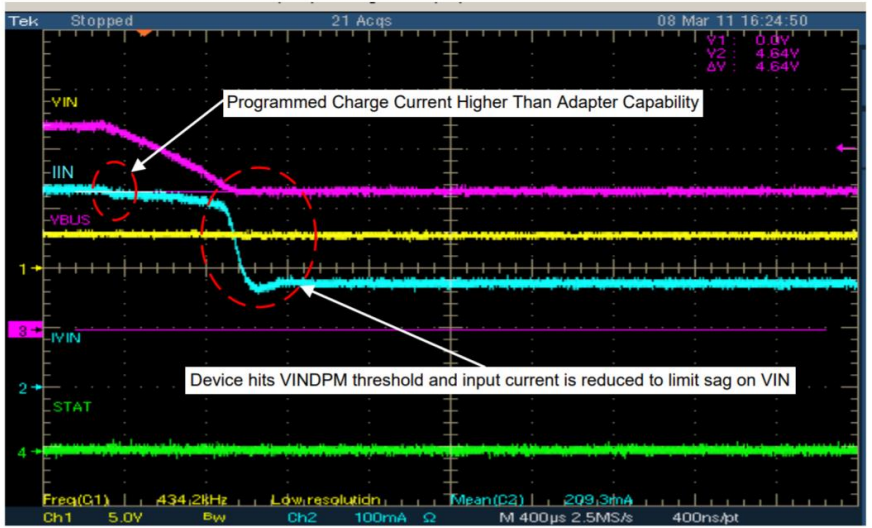


5 passive components

What do you do with a low voltage adapter?

What do you do with a low voltage adapter?

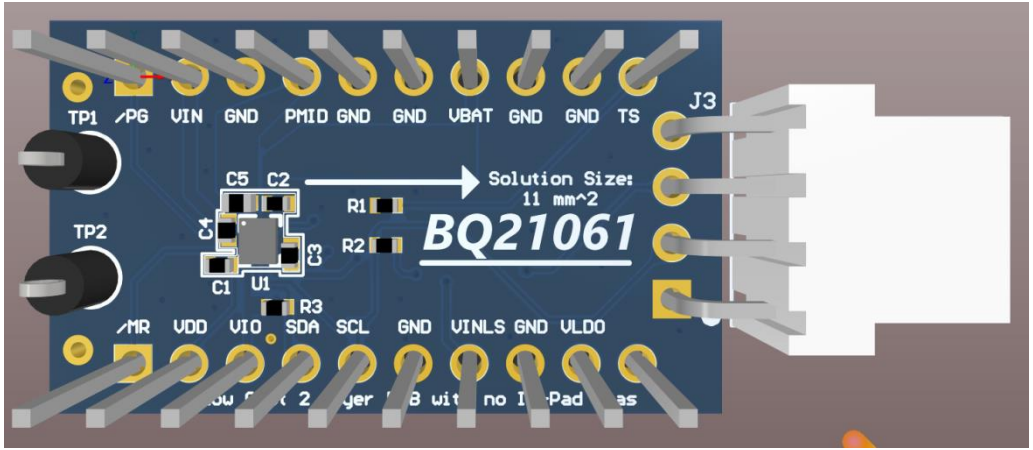
- **VINDPM (VIN Dynamic Power Management)**
  - V_{INDPM} allows charging with low input voltage
  - Input current is reduced to prevent adaptor crash (sag)
  - Enables continuous charging by preventing on/off behavior
- **DPPM (Dynamic Power Path Management**
  - Monitors system voltage
  - Reduces charge current when system voltage drops due to heavy load



DPPM Available in power path chargers

BQ21061 solution size – 11 mm^2

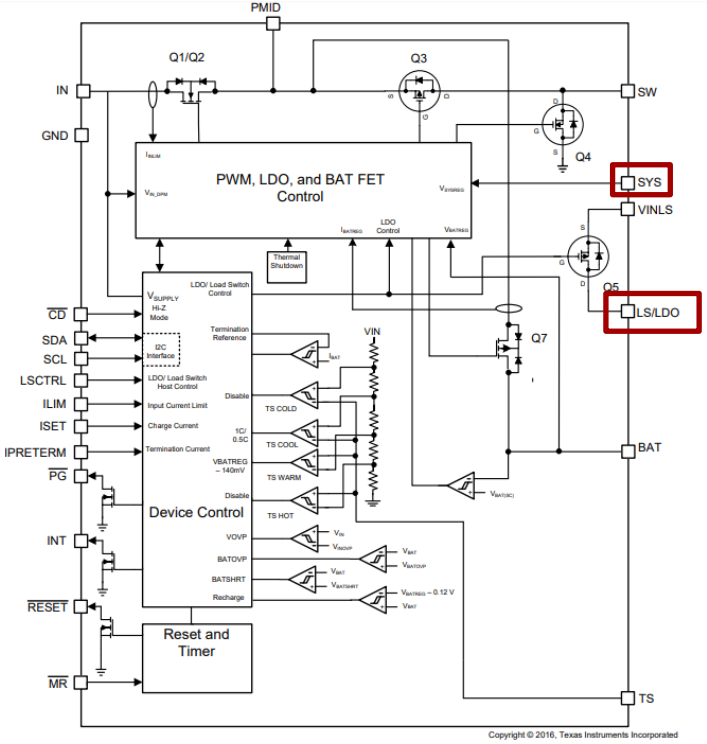
- Battery charger
- Battery undervoltage protection
- Load switch/LDO
- Regulated output
- Shipmode
- Battery Temperature Monitoring
- VINDPM and DPPM



BATTERY MANAGEMENT UNITS (BMU)

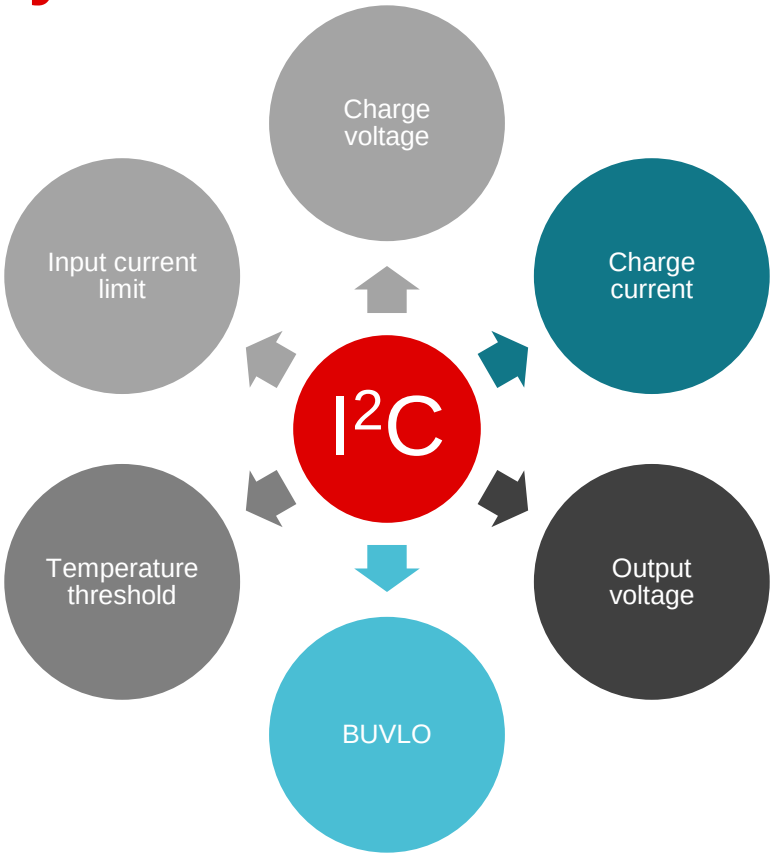
Battery Management Units

- Battery management units are power path chargers with integrated features like
  - Shipmode
  - Power Path Charging
  - LDO
  - DC/DC Converters
  - ADC
  - System level monitoring
  - I^2C communication



Key Features: Configurability, Shipmode and Integration

Design flexibility



I²C communication

Current

- Charge current
- Input current limit
- Termination current
- Pre-charge current

Voltage

- Battery voltage
- Output voltage
- LDO voltage
- DC/DC voltage

Protection

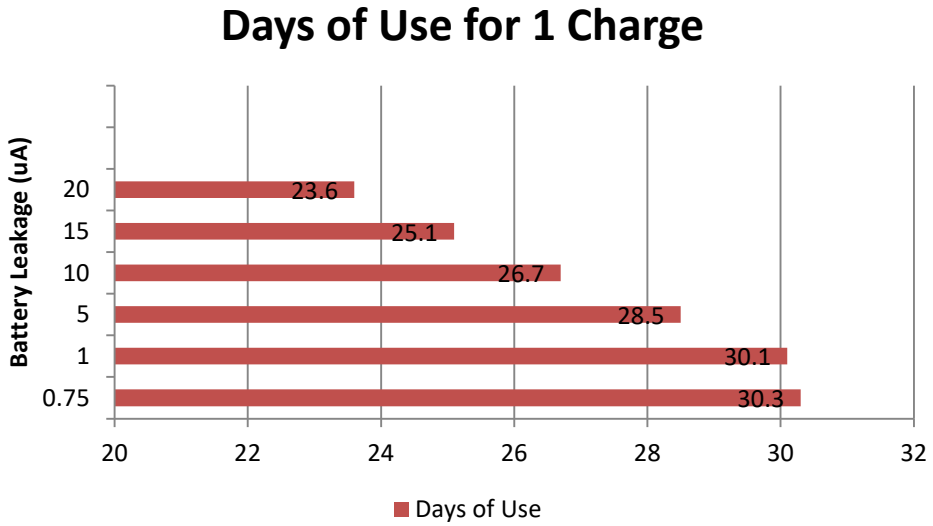
- DPPM
- V_{INDPM}
- TS thresholds
- Battery undervoltage
- Thermal regulation
- Safety timer
- OVP protection
- BUVLO

Features

- ADC readings
- Battery voltage and system monitoring
- LDO control
- Pushbutton control
- Shipmode
- Multi-chemistry charging

Low battery leakage – Significantly improves battery life

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



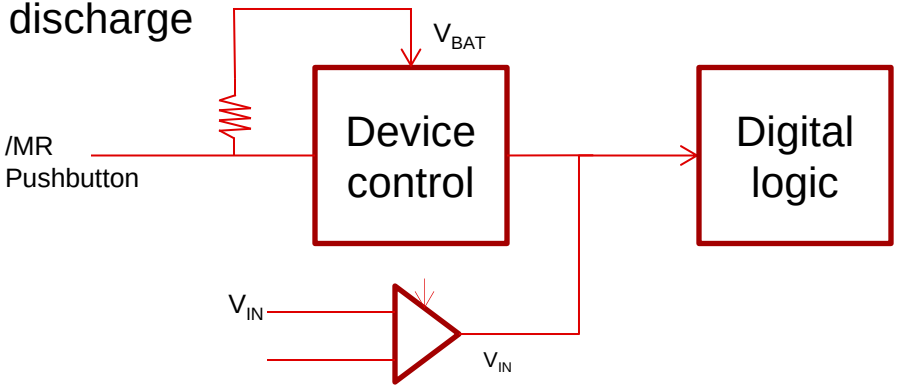
BQ25120
700 nA leakage/quiescent current

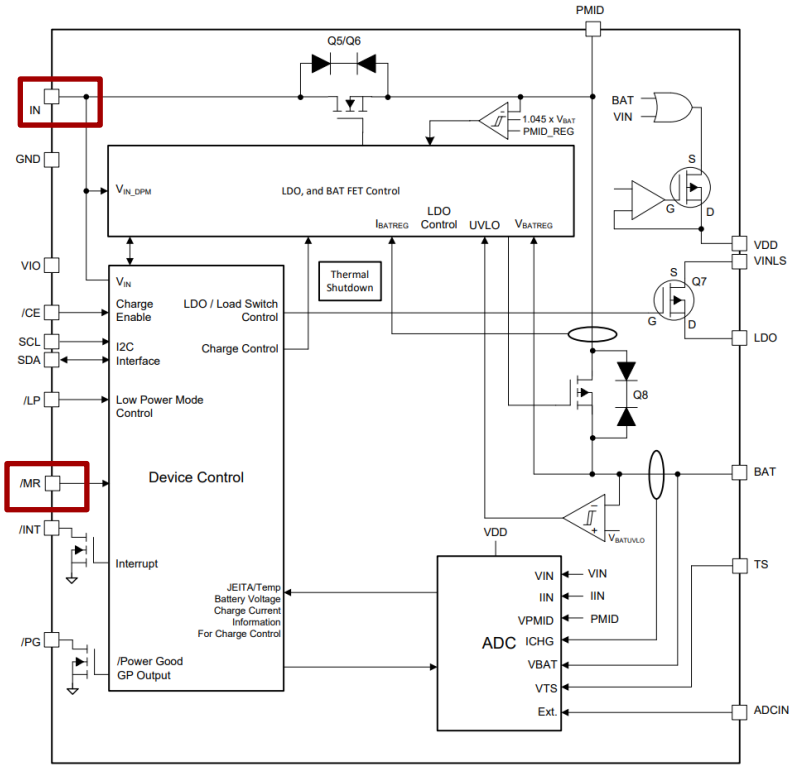
Battery quiescent current states

Parameter	Test conditions	MIN	TYP	MAX	Unit
Input currents					
I_{IN} – Input supply current	PMID_MODE = 01, V_{IN} = 5 V, V_{BAT} = 3.6 V			500	µA
	0ºC<T_J<85ºC, V_{IN} = 5 V, V_{BAT} = 3.6 V Charge disabled			2	mA
I_{BAT_SHIP} – Battery discharge current in shipmode	0ºC<T_J<60ºC, V_{IN} = 0 V, V_{BAT} = 3.6 V		10	150	nA
I_{BAT_LP} – Battery quiescent current in low power mode	0ºC<T_J<60ºC, V_{IN} = 0 V, V_{BAT} = 3.6 V LDO disabled		0.46	1.2	µA
	0ºC<T_J<60ºC, V_{IN} = 0 V, V_{BAT} = 3.6 V LDO enabled		1.7	3.5	µA
I_{BAT_ACTIVE} – Battery quiescent current in active mode	0ºC<T_J<85ºC, V_{IN} = 0 V, V_{BAT} = 3.6 V LDO disabled		18	25	µA
	0ºC<T_J<85ºC, V_{IN} = 0 V, V_{BAT} = 3.6 V LDO enabled		21	27	µA

What is shipmode?

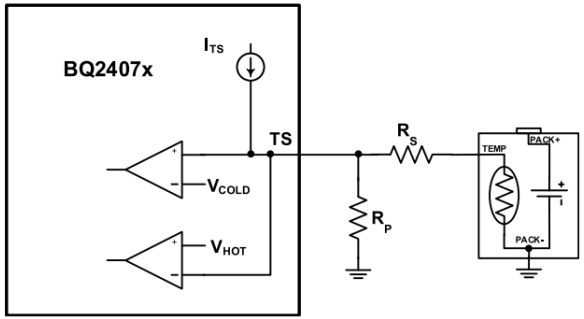
- Lowest I_Q state of device
- Useful to conserve battery life
- The only thing active is the MR comparator and the V_{IN} comparator
- Down to 10 nA quiescent current
- Battery leakage will be dominated by battery self discharge

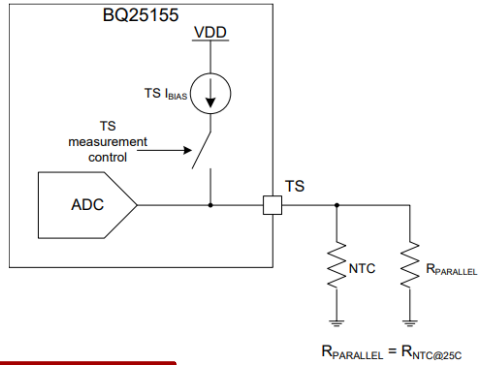




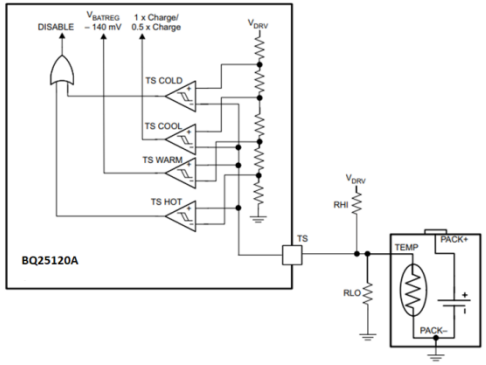
NTC monitoring

- Charging the battery at safe temperatures is very important to improve battery life
- TI chargers have 2 types of NTC monitoring
- Flexibility with voltage based monitoring
- Simplicity with current based monitoring



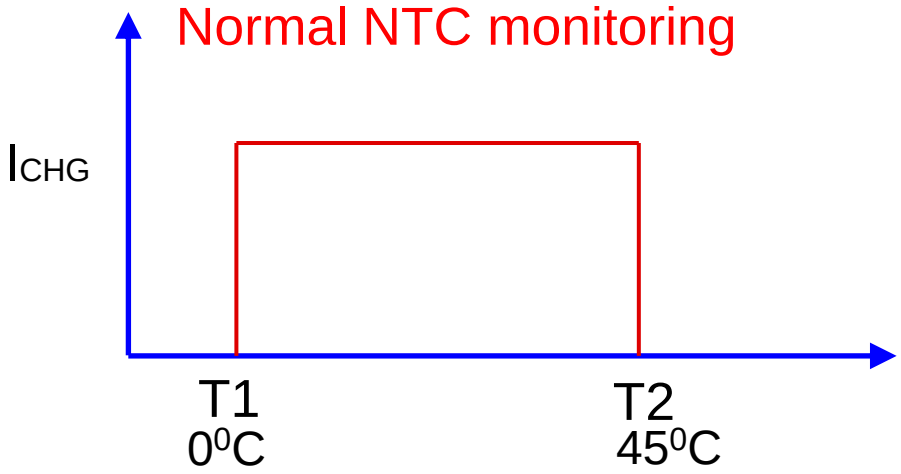


Current based monitoring



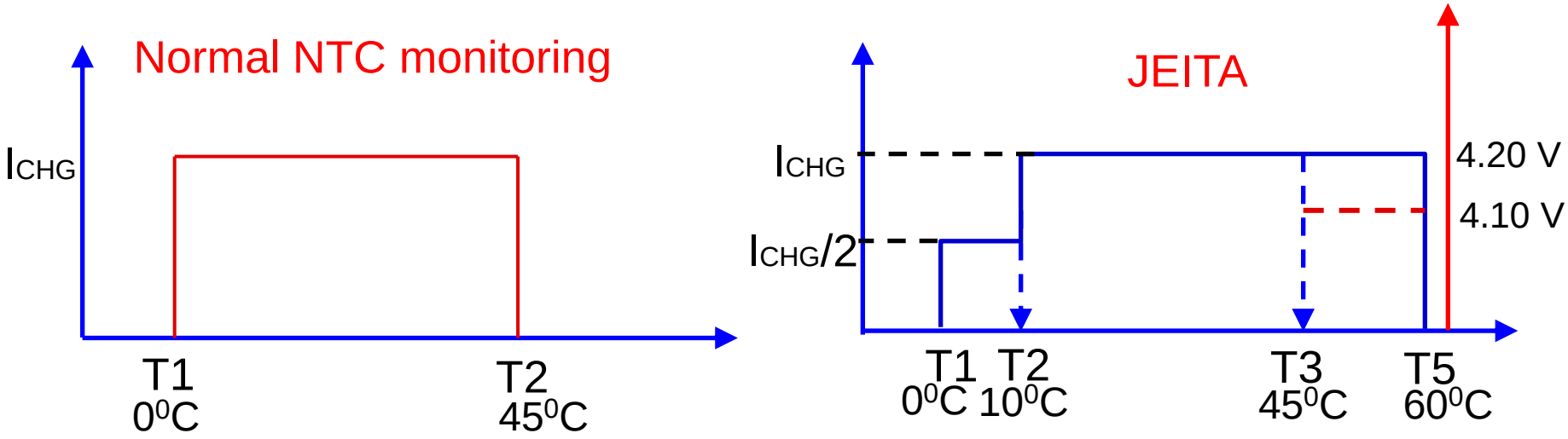
Voltage based monitoring

Battery pack temperature monitoring



- Charge suspended when temperature is below 0°C or above 45°C
- JEITA or non-JEITA standards
- Different charge voltage or current in the temperature window
  - Configurable ranges to accommodate device parameters
  - Low charge current @ low temperature
  - Low charge voltage @ high temperature

Battery pack temperature monitoring



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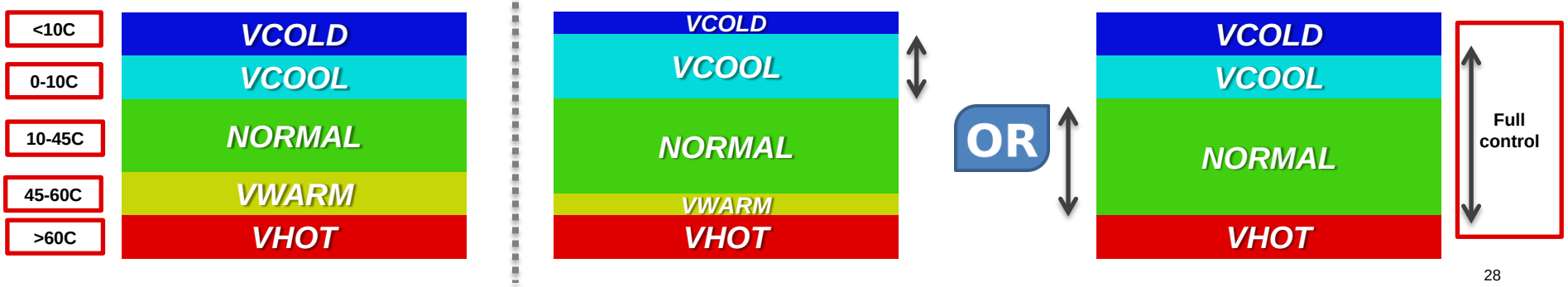
Beyond JEITA – Build your *cool* design

- Applications these days demand operation over wide thermal regions
- Product must work from Siberia to South China
- Often BOM changes or adding R_S and R_P to adjust for JEITA are not possible
- TI offers devices with a completely tangent approach in addressing this problem
- All the cutoffs and actions are completely configurable!

For a given NTC →

Most chargers
Fixed thresholds

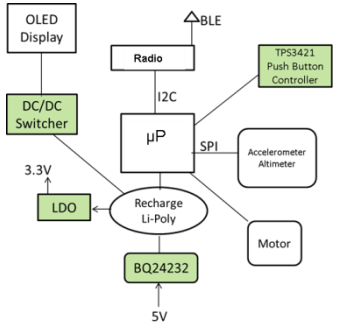
BQ25155
Variable thresholds on software

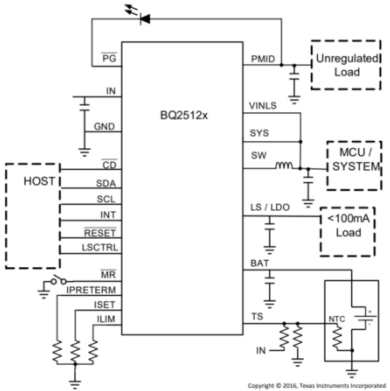


High integration – BQ2512X

Device	Function	I_Q (µA)	Package size (mm²)	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	I_Q (µA)	Package size (mm²)	Other components	Component size
BQ25120	Charger, DC/DC switcher, LDO, push-button controller	1 (typ) 3 (max)	6.25	6	14.375





- Integrated solution is 1/3 the size and has ½ the I_Q

Inbuilt ADC – Know your system!

- Goal: Enable smarter systems to monitor multiple channels without needing external FETS, resistor dividers and MUXes

Input I/V

Monitor input voltage for diagnostics or to alter system/ charge current

Battery I/V

Monitor battery voltage and charge current accurately to derive percentage complete and charging time left

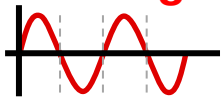
System I/V

Monitor the current consumed by the system load when adapter is plugged in

Thermal monitoring

Monitor the battery temperature to adjust charge profile and monitor the PCB temperature

External signal



Connect an optional external sensor output for monitoring by the ADC

Digital alerts

Use inbuilt comparators to build alerting mechanism to offload MCU processing

Accuracy: V_{BAT} (±0.4%), TS/ADCIN(±1%) over -10ºC to 85ºC

BMU charger

- Typically low BOM cost and easy PCB layout
- High charge current application
- Instant turn on with depleted battery
- High integration
- High level of customization through I^2C

Charger Topologies

Non Power Path	Power Path	BMU
Typically low BOM cost and easy 2-layer PCB layout	Typically low BOM cost and easy PCB layout	Typically low BOM cost and easy PCB layout
Low solution size and small silicon footprint	High charge current application	High charge current application
Low current termination	Instant turn on with depleted battery	Instant turn on with depleted battery
Typically used in applications that don't require charging and operation at same time, like electric razors	Allows for proper termination	High integration
No instant system turn on with depleted battery	Can be charged along with present system load	High level of customization through I^2C
Device might not be able to properly terminate when system load is present		

BQ2510X – Ultra small 250 mA linear charger in 0.9 mm x 1.6 mm WCSP, 75 nA leakage, 1 mA termination

Features

- Ultra small 0.9 mm x 1.6 mm WCSP
- Accurate charge current control down to 10 mA
- Sub 1 mA termination current control
- 75 nA battery quiescent current
- 30 V input voltage rating
- ± 0.5% voltage regulation
- Programmable pre-charge/termination current (BQ25100, BQ25100A,BQ25100H)

Applications

- Fitness accessories
- Smartwatches
- Bluetooth headsets
- Hearing aids

Benefits

- Ideal for space limited applications
- Small battery leakage and accurate termination control maximizes battery run time
- Maximize effective battery capacity
- Allows for extending battery life
- Robust against unstable input signals
- Flexible with different pre-charger/termination needs

Smallest size & maximum battery life!!!

BQ2510x family

Part number	Preterm or /CHG	Battery voltage
BQ25100	Preterm	4.2 V
BQ25100A	Preterm	4.3 V
BQ25100H	Preterm	4.35 V
BQ25101	/CHG	4.2 V
BQ25101H	/CHG	4.35 V

BQ25155 – 500 mA Li-ion charger with power path, regulated PMID, LDO and ADC for battery monitoring

Features

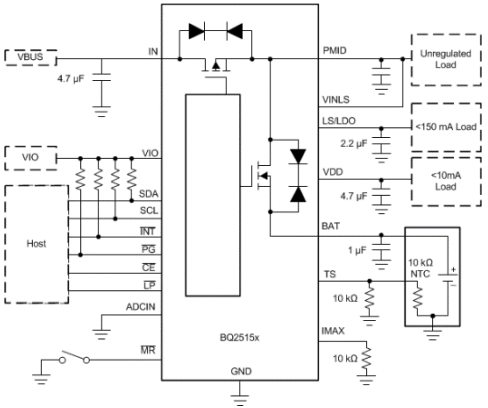
- **10 nA shipmode current for maximum battery shelf life**
- **Button and buttonless options for system power cycle and reset**
- **16-bit ADC** for multipoint monitoring
- **Multi-NTC monitoring** for system temperature monitoring in addition to battery NTC(TS)
- Up to **500 mA** for fast charge current
- **Programmable thermal charging profile** for flexible JEITA support
- **20 V** tolerant input
- /MR button press for shipmode disconnecting system load from battery and/or for system hard reset
- Input operating voltage from 3.4 V to 5.5 V
- I^2C control
- Power path management for supporting input voltage and current based dynamic power management
- LDO with I^2C programmable output voltage
- **2.0 mm x 1.6 mm** CSP-20

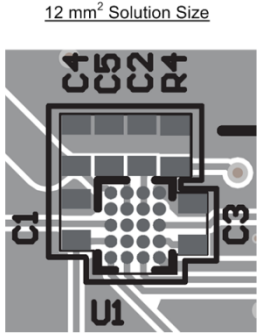
Applications

- True wireless headset (TWS)
- Smartwatches / fitness trackers
- Bluetooth headsets/ hearing aids
- Patient monitors and portable medical equipment

Benefits

- Powers the system while charging the battery for instant system on and system reset
- Supports reset operation for devices with and without button inputs
- ADC provides host with accurate information for battery gauging
- Adjustable charge current down to 1.25 mA for very small battery capacity while maximizing battery run time – critical for small batteries
- Ultra low I_{DDQ} shipmode for longest battery shelf life
- Compatible with JEITA safety standard
- Low BOM cost / solution size





BQ25120A – 300 mA charger low I_Q power path battery management unit

Features

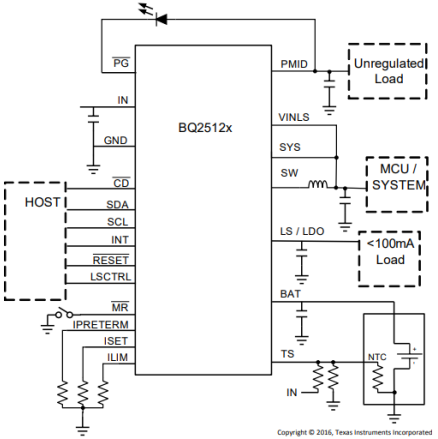
- 700 nA quiescent current with 1.8 V output enabled
- <50 nA shipmode battery quiescent current
- Accurate charger termination down to 500 µA
- High integration with 6 external components for minimal solution: 300 mA buck, 100 mA LDO, pushbutton controller, battery voltage monitor
- I^2C programming interface or standalone
- Tiny 2.5 x 2.5 mm WSCP package, < 15 mm^2

Applications

- Smartwatches and wearable devices
- Wireless headsets
- Fitness accessories
- Health monitoring medical accessories
- Rechargeable toys

Benefits

- Allows always-on without draining the battery
- Allows shipping the device with longest battery shelf life
- Allows the batteries to be fully charged and maximizes the use time between charging cycles
- Low BOM count and reduce total solution cost
- Flexibility to set key parameters
- Small total solution size



Simplified schematic

TWS 2-pin charging + communication

Features

- Single line communication between the earbud and charging case for accurate status of battery charge
- Battery charger in earbud allows for longer battery runtime by using integrated battery monitoring capabilities
- Increased efficiency w/dynamic case output voltage adjustment allowing for more charge cycles

Benefits

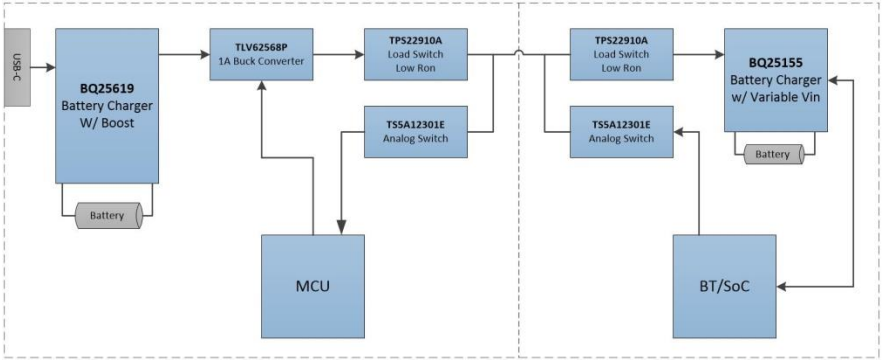
- Increased charging efficiency
- Reduction of pin count between case and earbuds
- BOM size reduction with battery monitoring

Applications

- Earbuds, headphones, hearing aids and headsets

Tools & Resources

- **Device datasheets:**
  - BQ25619
  - BQ25155
  - TLV62568P
  - TPS22910A
  - TS5A12301



Summary

- A very important aspect of selecting the right charger for your low power application is to consider the **cost**, **solution size** and **power requirements**
- Account for safety and charging requirements with features like Battery under voltage lock out, shipmode and battery temperature monitoring
- Understand the type of integration needed to meet system requirements and reduce BOM and PCB costs

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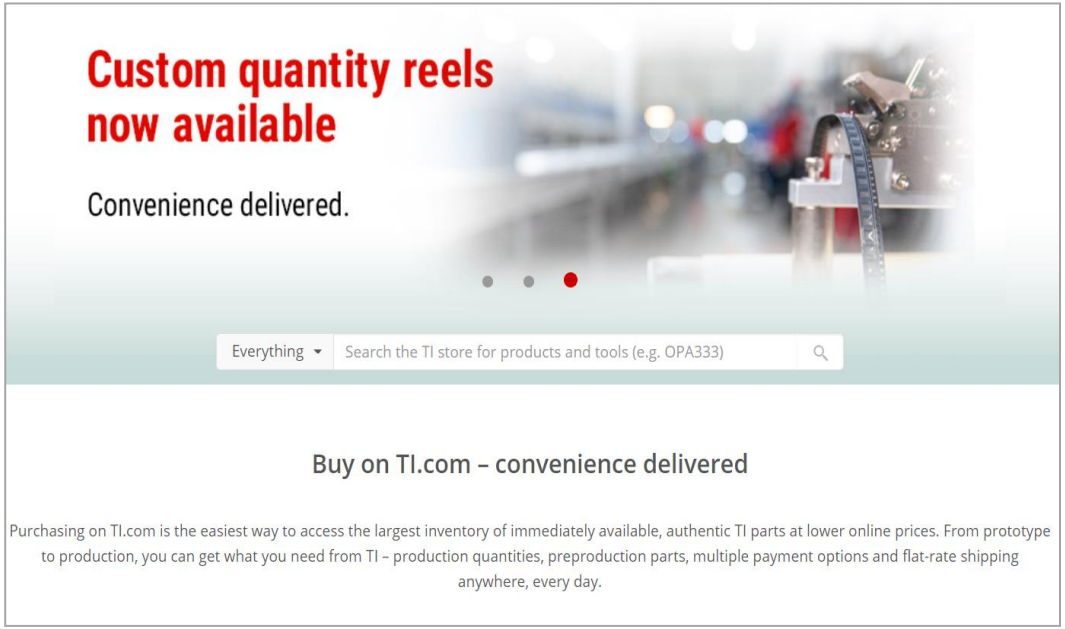

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