Texas Instruments

TI POWER

TI *Live!* BATTERY MANAGEMENT SYSTEMS SEMINAR

ARELIS GUERRERO

CHARGING TRENDS IN LOW POWER INDUSTRIAL SYSTEMS

Agenda

- Battery management solutions overview
- System design considerations
  - Charger parameters
  - Battery chemistries
  - Charger topologies
  - Control interfaces
  - Charger features
- Low power trends and applications examples
  - Building automation
  - Portable medical devices
  - Industrial transport
  - Electronic point of sale

Battery management solutions overview

Personal electronics

Automotive

Industrial

- Battery management solutions are integrated mainly on Personal Electronics, Automotive and Industrial systems.
- Trends shows more rechargeable batteries on Industrial systems.
- Applications requirements will vary greatly by product, size, power, among others.
- Focus today on Low Power Industrial Systems applications.

Aerospace and Defense

Appliances

Building Automation

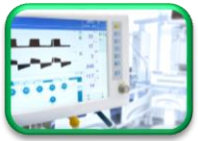
Electronic Point of Sale

Factory Automation and Control

Grid Infrastructure

Industrial Transport

Lighting



Medical

Motor Drives

Power Delivery

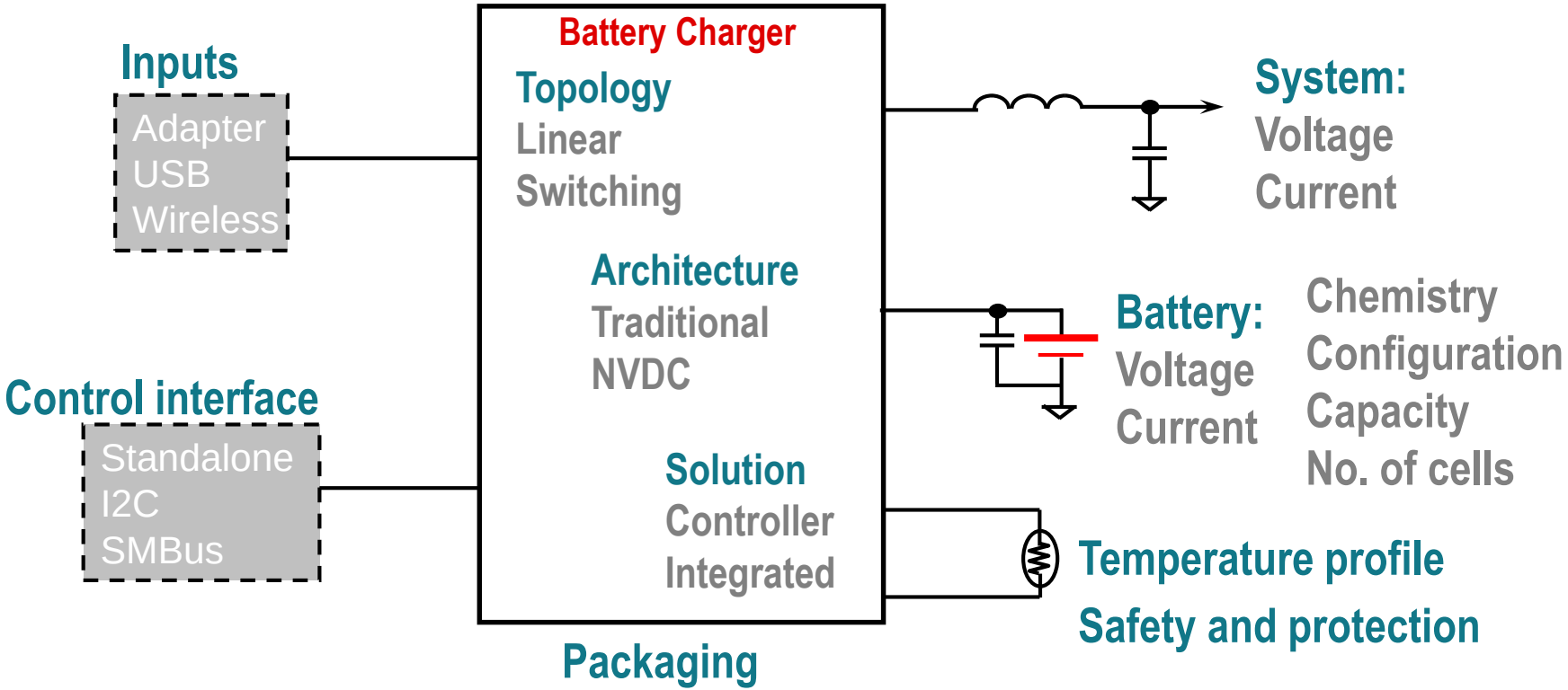
Pro audio, video & signage

Test & Measurement

System design considerations

Includes: power requirements, charger’s topology, battery chemistry, configuration mechanisms, and safety features.

Design considerations | Key charger parameters

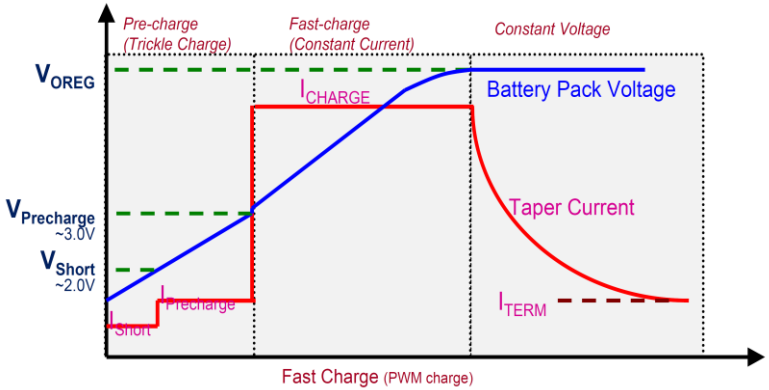


Design considerations | Battery chemistry

- Common battery types found in low-power industrial applications:
  - **Lithium-ion (Li-ion)** – most widely used battery chemistry. Light weight with high energy density.
  - **Lithium iron phosphate battery ($LiFePO_4$)** – relatively new technology, similar to Li-ion. Advantage over Li-ion is longer life and higher peak current, but lower energy density vs. weight volume.
  - **Nickel-metal hydride (NiMH)** – mature technology. Good in industrial applications with a wide temperature range, high peak current and fast charge options.
  - **Supercapacitor** – a new option for power storage. Fewer shipping or transport restrictions. Wider temperature range. Supports high peak currents. But low energy density and wide voltage variation.

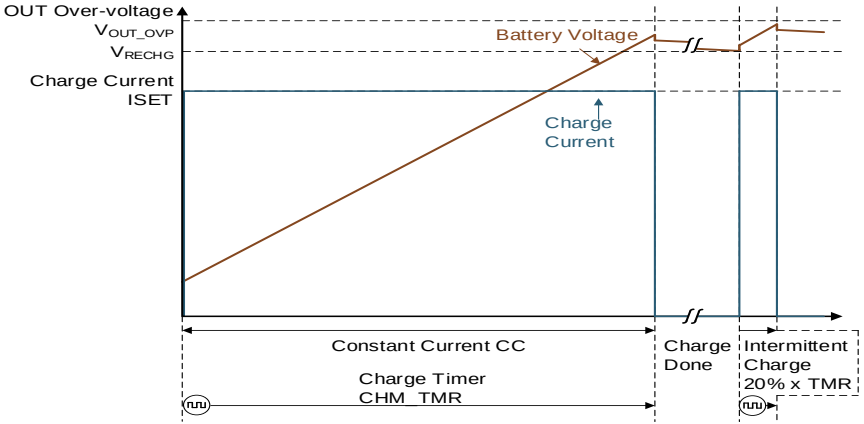
Design considerations | Battery chemistry

Li-ion charging profile



- **Typical specs:**
  - Nominal voltage: 3.6 V
- **Benefits:**
  - High energy density
  - Long lifetime; typically 500 charge cycles.
- **Limitations:**
  - Protection circuit required and risk of thermal runaway.
  - Number of shipping restrictions.

NiMH charging profile (timer-based)

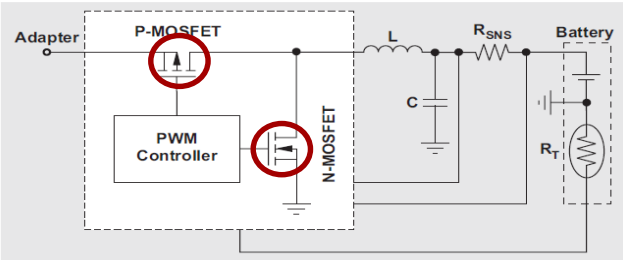


- **Typical specs:**
  - Nominal voltage: 1.2 V
- **Benefits:**
  - Safe: overcharge and discharge do not create high temperatures.
  - Lowest cost solutions.
- **Limitations:**
  - Low cell voltage, require three cells in series to match Li-ion.
  - Quick self-discharge limits storage times.

Design considerations | Charger topology

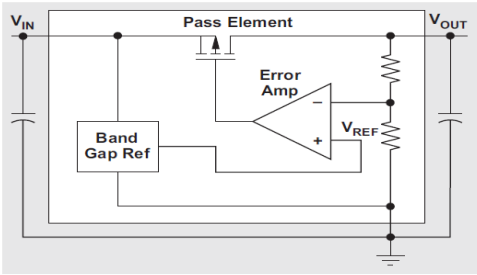
Switch-mode

- **Mainly for high power applications**
  - High side and low side FETs used to control current through the inductor
  - Better for applications with higher charge currents (>1 A)
  - Provides better efficiency therefore better thermal performance
- **Require larger application layer and BOM count**
  - External inductor and additional capacitors
- **EMI considerations**



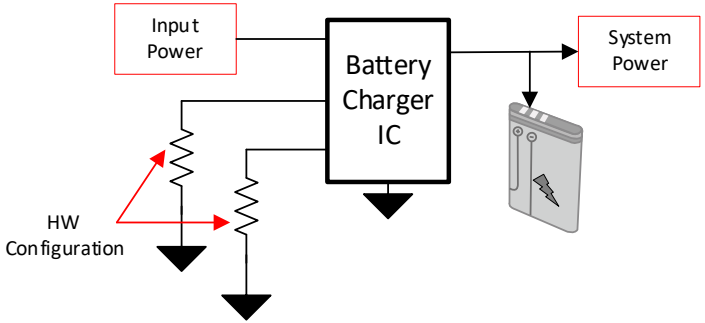
Linear

- **Good for low power applications**
  - Pass transistor used to drop the adapter voltage to battery voltage (current is continuous)
  - Efficiency decreases with higher power applications
- **Small application area and low BOM count**
  - A few capacitors and resistors
  - Good for small size and low cost applications

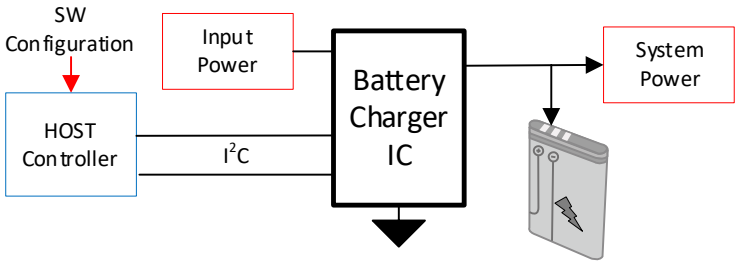


Design considerations | Control interface

Standalone charger



Host-controlled charger



- **Hardware**
  - Parameters are fixed with resistors
  - Simple HI/LO logic to enable device
  - Faster development time, no firmware needed
  - Typically, less options to configure with limited diagnostics
- **Host controlled (I^2C)**
  - Can adjust configuration “on the fly” with software
  - Allows for flexibility for different batteries types or applications needs
  - Rich status and fault reporting and interrupts
  - Requires extra investment at systems level and firmware development

Design considerations | Charger features

High accuracy	• **Accurate charging cycle** – prevents overcharging and maximize battery life. • **Low termination current** – maximize battery capacity and cycle life.
Power saving	• **Low operation IQ** – extend battery runtime life. • **Low leakage modes –** shipmode and shutdown modes to optimize shelf life. • **High efficiency** – provides short charging cycle.
Integration	• **Small form factor –** solution size with less components, cost effective. • **Integrated diagnostic –** reduces firmware development cost.
Safety	• **Integrated Protection –** Over/under voltage/current, system short, DPPM, etc. • **Fault detection and status reporting –** real time fault monitoring and charging status reports.

Low power industrial trends & applications examples

Includes: building automation, medical, industrial transport, and electronic point of sale examples.

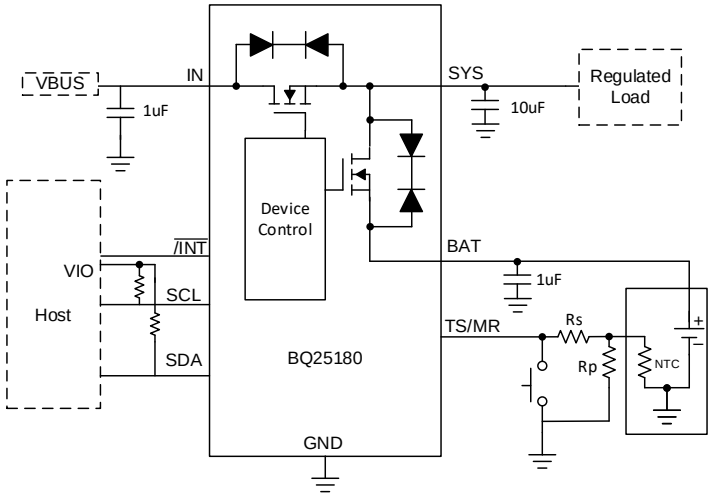
Application example | Building automation

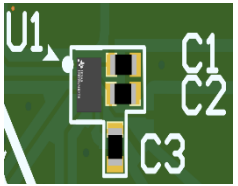
- **Application : Video surveillance**
- **Industry trends:**
  - Internet of Things (IoT) driving battery-operated appliances.
  - Video surveillance has been on the rise driven by home automation.
  - Movement to affordable wireless ‘mini’ cameras.

- **System’s benefits:**
  - Battery operated cameras (main or backup) allow for major flexibility during power outage.
- **Charger’s design challenges:**
  - Typically ‘larger’ capacities batteries for longer operation on single charge.
  - Requires a higher fast charge current.
  - Need a small charger for ‘mini’ cameras trends

Application example | Building automation

- **Application : Video surveillance**
- **Charger Solution: BQ25180**
  - I²C controlled, 1-A linear battery charger with power path and ship mode in CSP package.
- **Advantages:**
  - Up to 1-A charge current with 7-mm² small solution size.
  - Ultra low IQ Modes: 15-nA shutdown, 3.2-uA ship mode, and 4-uA battery only mode. Maximum battery runtime when operating on a power outage scenario.
  - Power path allows for powering the systems while charging the battery, eliminating down time.





7-mm² solution size

https://www.ti.com/product/BQ25180

Application example | Building automation

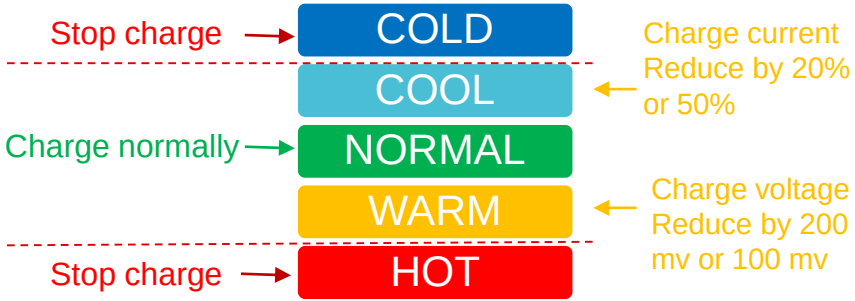
- **Application: Video surveillance, charger solution: BQ25180**
- **Highlight Features:** Host controlled
  - I²C highly configurable, host-control flexibility with systems monitoring and built-in diagnostics.

Battery regulation and thresholds	Charging currents	SYS regulation voltage and mode	Input current limit	Temperature monitoring with flexible JEITA	Battery overcurrent and overvoltage thresholds
Low power modes, DPPM settings	Push button duration and reset modes	Safety, watchdog, and wake timers	Reset and wakeup times	Thermal regulation	Interrupts, faults and status

  - Configure all the registers with additional design tools (temperature monitoring calculator):
    - *TI chargers GUI* - *https://www.ti.com/tool/TI-CHARGER-GUI*

Application example | Building automation

- **Application : Video surveillance, charger solution: BQ25180**
- **Safety considerations:** Li-ion batteries safe charge temperature is from 0 °C to 45 °C, JEITA guarantee charging only inside those ranges.
  - Flexible JEITA: extra configurability for the charger to react at different battery temperatures.



T_{COLD} (°C)	T_{WARM} (°C)
-3, 0, 3, 5 C	45 C, disable
T_{COOL} (°C)	T_{HOT} (°C)
10 C, disable	45, 50, 60, 65 C

- **Design Resources:** Flexible and small solution size charger for space-limited systems.
  - *BQ25180 and BQ25181 I2C Controlled Linear Battery Chargers Small Form Factor Design Application Note* - *https://www.ti.com/lit/an/sluaag6/sluaag6.pdf*

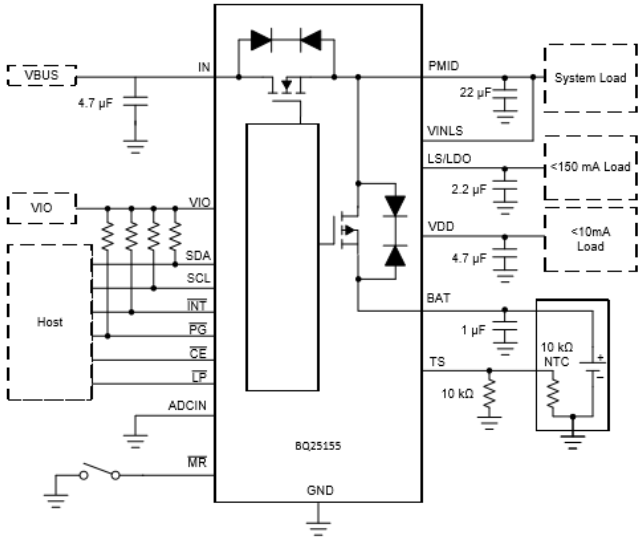
BQ2518x small form factor boards

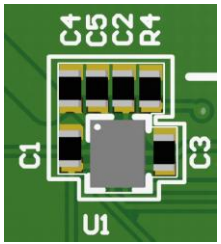
Application example | Medical

- **Application: Hearing aids**
- **Industry trends:**
  - In the past, predominant battery type was zinc-air (non-rechargeable).
  - Nowadays, we see about 50% of hearing aids moving towards rechargeable batteries.
- **System's benefits:**
  - Traditional hearing aids batteries are difficult to replace, and often needed a replaced by a doctor.
  - Rechargeable batteries are easier and more flexible for users.
- **Charger's design challenges:**
  - Size constrains – Need small integrated solution.
  - Small batteries – Shorter runtime between charge.

Application example | Medical

- **Application: Hearing aids**
- **Charger solution: BQ25155**
  - I²C controlled, 500 mA highly integrated power path battery management unit with LS/LDO and ADC.
- **Advantages:**
  - Only 12-mm² solution size, ideal for small integrated applications with needs of additional power rails.
  - Ultra low IQ and adjustable charge down to 1.25 mA, to optimize small batteries run time.
  - Integrated protection and temperature monitoring, for safety and reliability control.
  - Integrated ADC for battery monitoring, can be used to provide State of Charge (SOC).



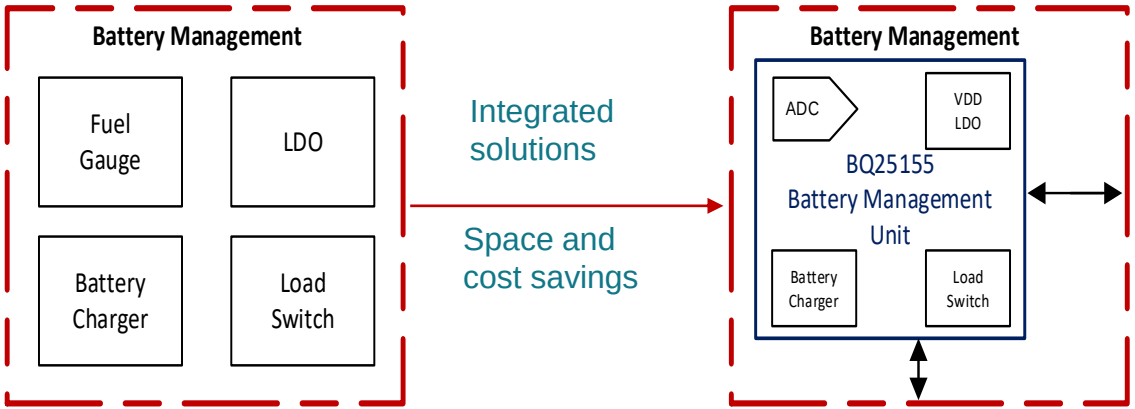


12-mm² solution size

https://www.ti.com/product/BQ25155

Application example | Medical

- **Application: Hearing aids, charger solution: BQ25155**
- **Highlight features:** Integrated solution
  - Battery management unit with integrated rails and ADC.
  - Reduction of additional ICs in your systems, providing space and cost savings.



Application example | Medical

- **Application: Hearing aids, charger solution: BQ25155**
- **Safety considerations:** Need robust system with extensive monitoring and safety features.
  - Integrated protections for battery, adapter, temperature, and systems.
  - ADC for systems monitoring:
    - **Input I/V :** Diagnostic and alter charging
    - **Battery I/V :** Monitor battery charge / discharge
    - **System I/V :** Monitor system consumption
    - **Thermal :** Safe charging profile
    - **External signals :** Connect to ADC
    - **Internal comparators :** Trigger MCU actions

- **Design resources:** Using integrated ADCs to obtain estimated capacity – State of Charge (SOC).
  - *State of Charge Estimation Using Smart Battery Charger App Note* - *https://www.ti.com/lit/an/sluaaa1/sluaaa1.pdf*

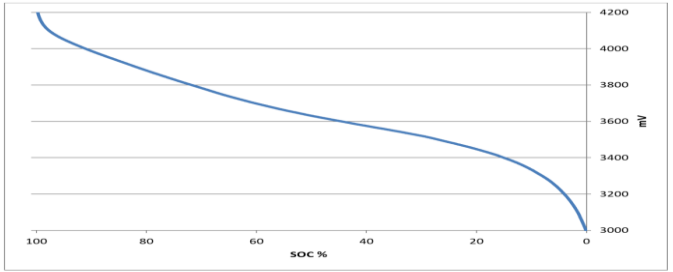


Figure 3-1. Vbat vs SOC

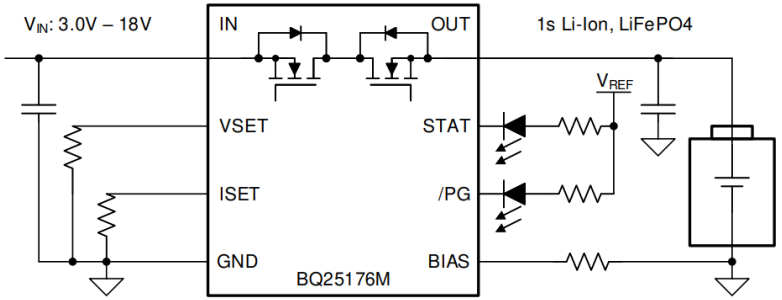
Application example | Industrial transport

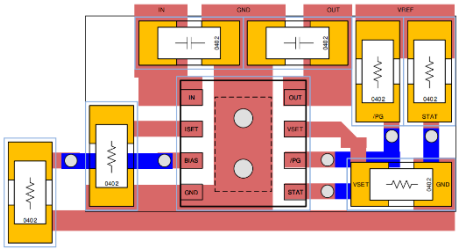
- **Application:** Asset tracker

- **Industry Trends:**
  - Fleet management systems are moving from barcode and RFID asset trackers towards GPS-based ones.
  - Allows to real-time communication across distance to protect assets.
- **System's benefits:**
  - Having a main or back-up battery provides an always 'on' tracking
- **Charger's design challenges:**
  - Prolong battery life alternating between standby mode and GPS reporting.
  - Commonly use different battery chemistries with solar charging inputs.
  - Low complexity, needs to be cost effective and easy to deploy.

Application example | Industrial transport

- **Application:** Asset tracker
- **Charger Solution:** BQ25176M
  - Standalone controlled, 800-mA multi-chemistry linear solar battery charger for harvesting applications.
- **Advantages:**
  - Non-power path standalone charger, cost effective with easy configuration.
  - Battery tracking VINDPM for solar charging.
  - Multi-chemistry : Li-ion, Li-Polymer and $LiFePO_4$.
  - Automatic sleep mode maximize battery runtime.
  - STAT and PG pins for charging and fault status.



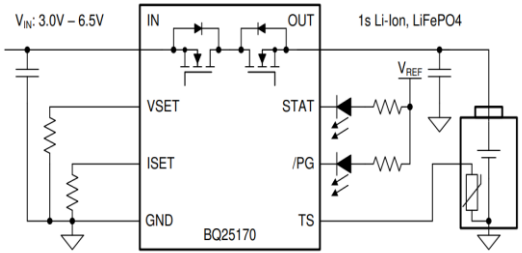


Sample PCB layout

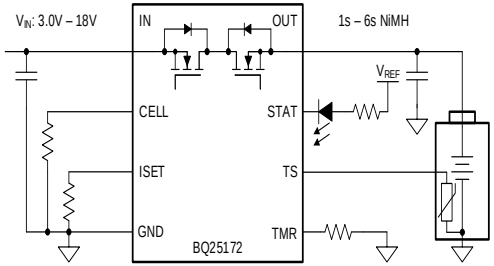
https://www.ti.com/product/BQ25176M

Application example | Industrial transport

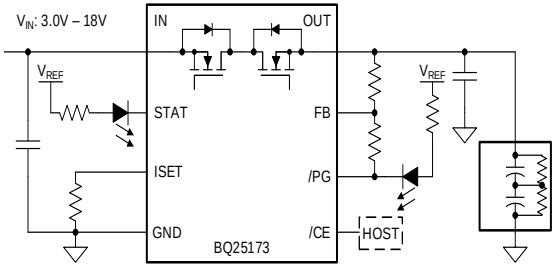
- **Application: Asset tracker, charger solution: BQ25176M**
- **Highlight features:** Multi-chemistry and multi-cell
  - BQ2517x are a multi-cell and multi-chemistry family, all on 2x2-mm^2 8-pin QFN package.



BQ25170
1-cell Li-ion/$LiFePO_4$



BQ25172
1-6 cells NiMH



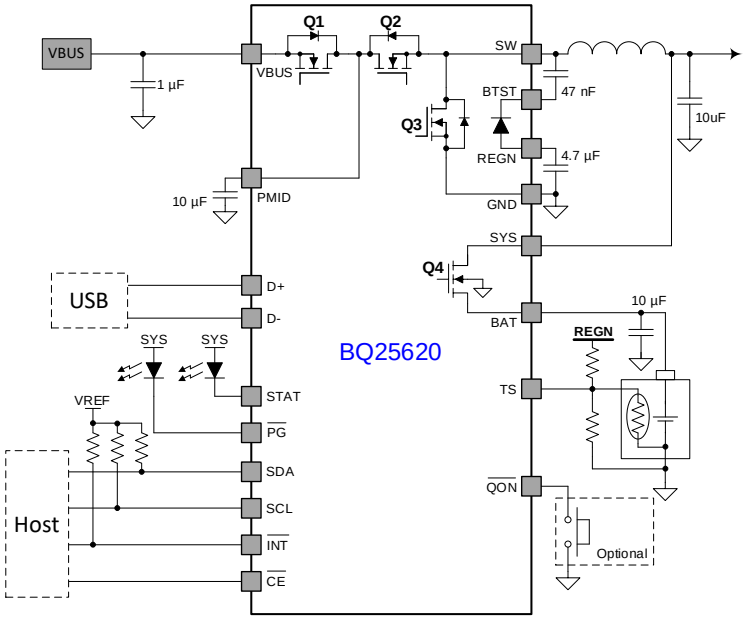
BQ25173
1-4 cells super capacitors

Application example | Electronic point of sale

- **Application: Mobile point of sale (mPoS)**
- **Industry trends:**
  - Shift from traditional EPOS to portable solutions with rechargeable batteries.
  - Cost-effective and secure for small businesses moving to cash-less options.
  - Big retailers with self-checkout increasing demand for mPOS.
- **System's benefits:**
  - Provides a highly flexible, low cost, and low maintenance solution.
- **Charger's design challenges:**
  - Large number of transactions, needs low leakage from battery and power saving modes.
  - Reduce downtime with efficient fast charging and allowing to use systems while charging.

Application example | Electronic point of sale

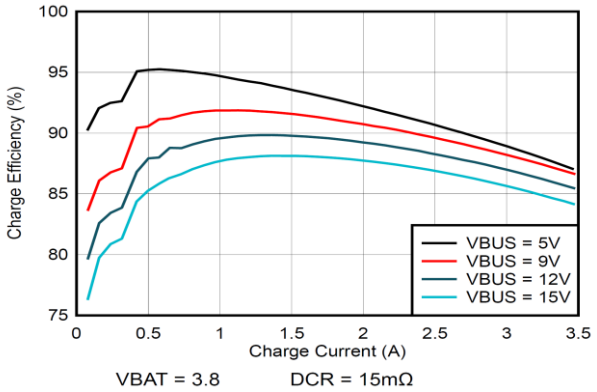
- **Application: Mobile point of sale (mPoS)**
- **Charger Solution: BQ25620**
  - I²C controlled, 3.5-A switching battery charger with NVDC power path, OTG output, and integrated ADC.
- **Advantages:**
  - High-efficiency >90%, fast charge and good thermal performance.
  - USB D+/D- Input Detection for optimizing charge current.
  - Low IQ: 100-nA shutdown, 150-nA shipmode, 1.5-uA battery only mode, for maximum battery runtime.
  - Power path permits powering the systems while charging eliminating down time.

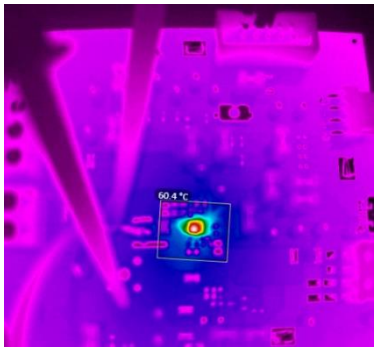


https://www.ti.com/product/BQ25620

Application example | Electronic point of sale

- **Application: Mobile point of sale (mPoS), charger solution: BQ25620**
- **Highlight features:** Switching charger
  - Synchronous switching mode buck charger with >90% efficiency with 5-V input in a QFN package will provide best thermal performance, while charging with high power dissipation.





Power loss = 1 W, $R_{\Theta JA}$ = 60.1 °C/W

  - At 90%+ efficiency, a 2.5% improvement can represent a 27% increase in charging current with same loss budget, resulting in a shorter charging cycle.

Application example | Electronic point of sale

- **Application: Mobile point of sale (mPoS), charger solution: BQ25620**
- **Reliability considerations:**
  - Battery runtime is the key challenge on mobile solutions. Low power consumption modes allow for a longer shelf-time and maximum runtime on battery.
  - BQ25620 low power modes:
    - 1.5-µA quiescent current in battery-only.
    - 0.15-µA battery leakage current in ship mode.
    - 0.1-µA battery leakage current in shutdown.

BAT leakage current	1 µA	5 µA	10 µA	20 µA	50 µA
Lost battery capacity (mAh) 3-month shelf time	0.9%	4.4%	8.8%	17.5%	43.8%
Lost battery capacity (mAh) 6-month shelf time	1.8%	8.8%	17.5%	35.0%	87.6%
Lost battery capacity (mAh) 12-month shelf time	3.5%	17.5%	35.0%	70.1%	100.0%

Battery capacity % lost for a 250mAh battery for different shelf-life durations

Summary

- Industrial systems are all around us and power trends are moving towards more battery-operated applications.
  - All systems are different - therefore TI has a great low-power portfolio of battery chargers to fit the diversity of battery management systems.
  - Understanding the chargers features - will allow you to optimize your battery management solution and build more robust systems.
- TI.com has multiple collateral on-line that could be access to find the best implementation for your applications need.
  - Battery Management ICs – https://www.ti.com/power-management/battery-management/overview.html
  - Battery Chargers Selection Guide - https://www.ti.com/power-management/battery-management/charger-ics/overview.html
  - TI E2E Forum Support - https://e2e.ti.com/support/power-management-group/power-management/

Questions

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