TI POWER

Battery charger design considerations for wearables and true wireless stereo (TWS)

Battery Management Deep Dive Training

October 2020

Will Zhou

Agenda

- Market trend
- Common design considerations for wearables and TWS
- Specific challenges for TWS
- Specific challenges for wearables
- Design resources
- Summary

MARKET TREND

Wearables and TWS market trend

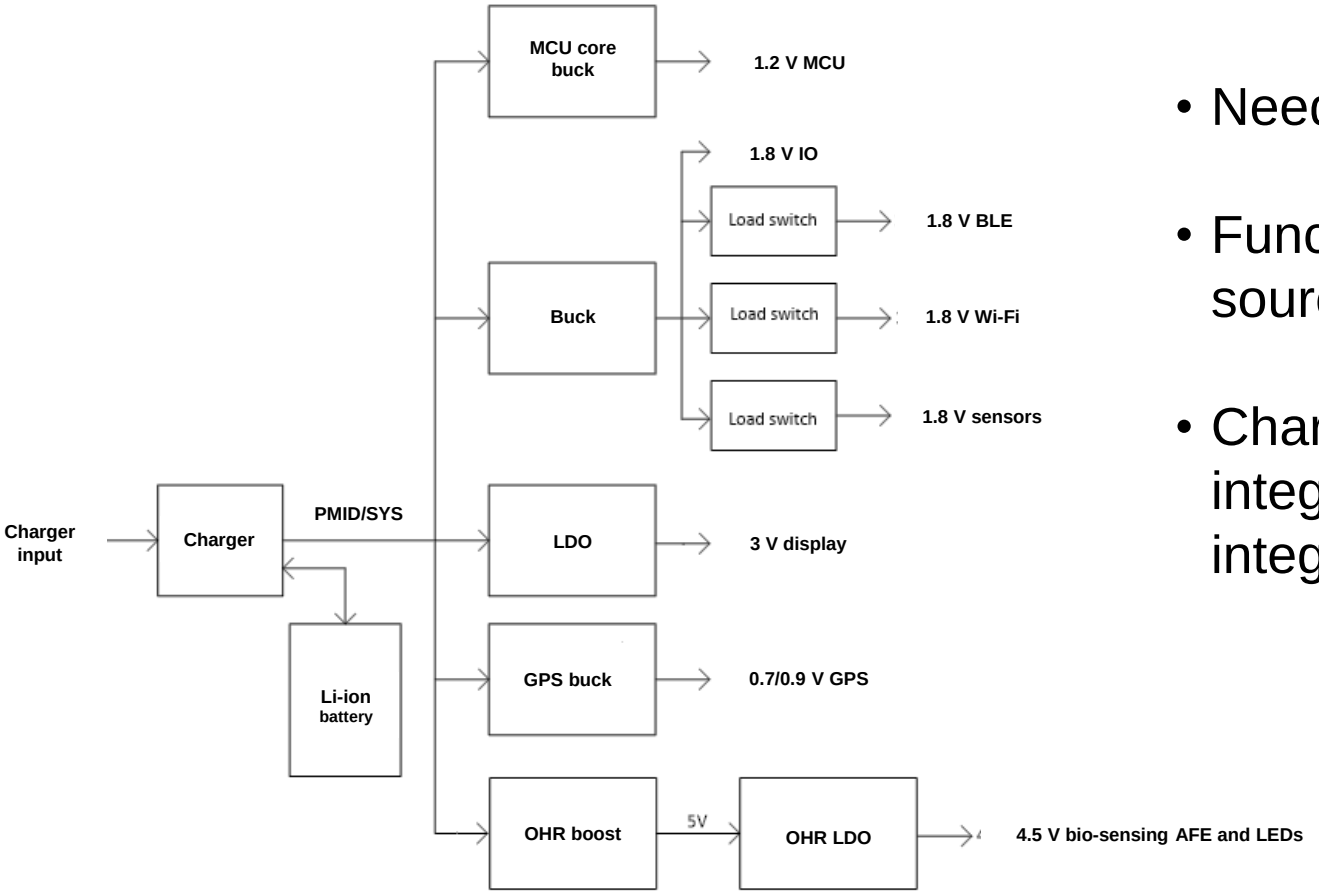
- True Wireless Stereo (TWS) headset market has exploded, growing at an estimated rate of more than 50% every year since the first release of the Apple Airpods in 2016
- 2019 global TWS headset shipments has exceeded 100 million units

- Smart watch and wristband have also been growing at sub 10% speed
- 2019 global smart watch and wristband shipment is almost 150 million units
- New wearable applications like smart clothing, smart eyewear have emerged

- Competition has been fierce. How to differentiate on performance and features to stand out in the market?

COMMON DESIGN CONSIDERATIONS FOR WIRELESS HEADSETS AND WEARABLES

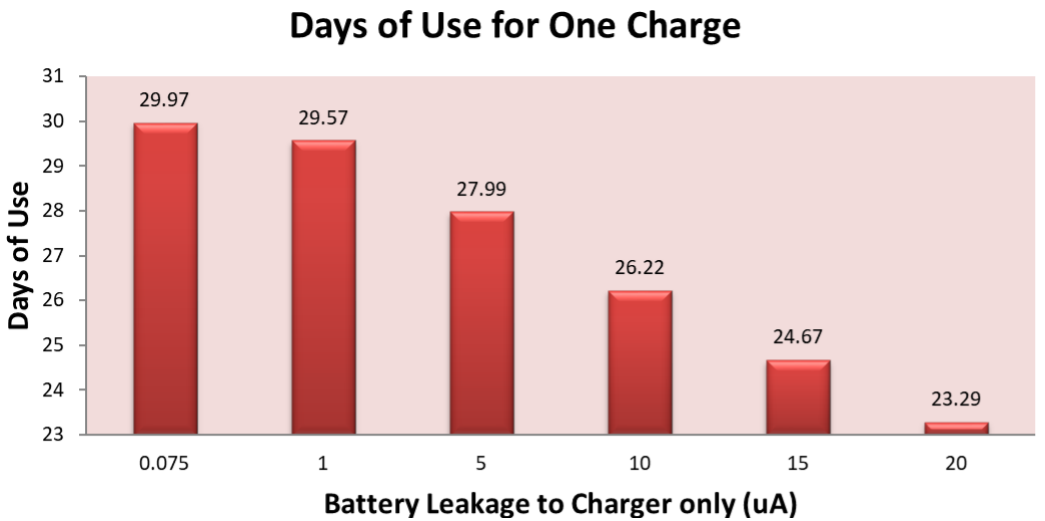
Squeeze on smaller board and have more functions



- Need power integration in small area
- Functional blocks need various power sources
- Chargers with various levels of power integration. Trade-off between integration and flexibility

Get more out of a smaller battery & increase standby time

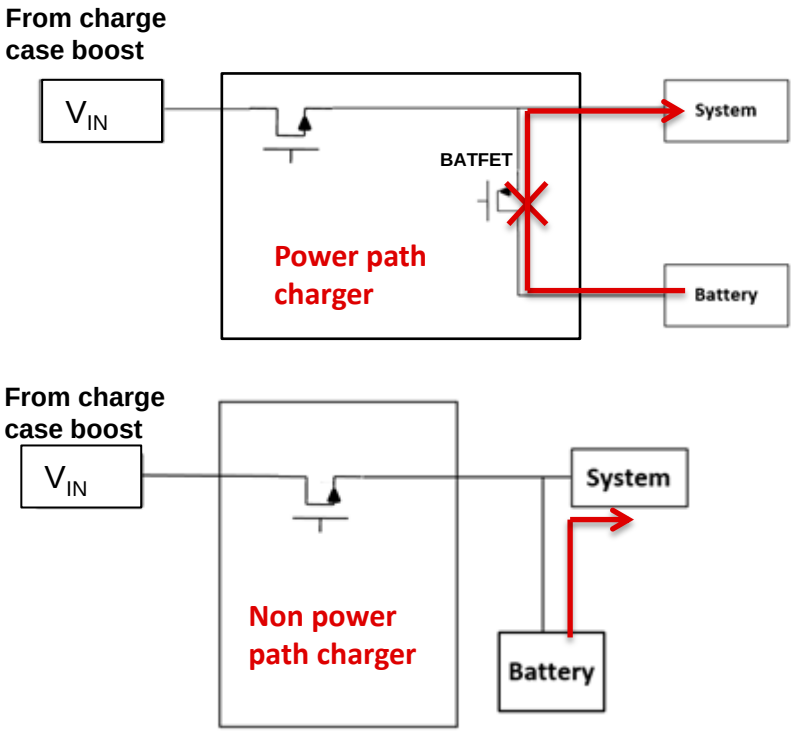
How critical is the battery leakage?



Assuming a smart tracker that uses 50 mAh, 70 µA avg system I_Q

e.g., BQ25100 75 nA battery I_Q

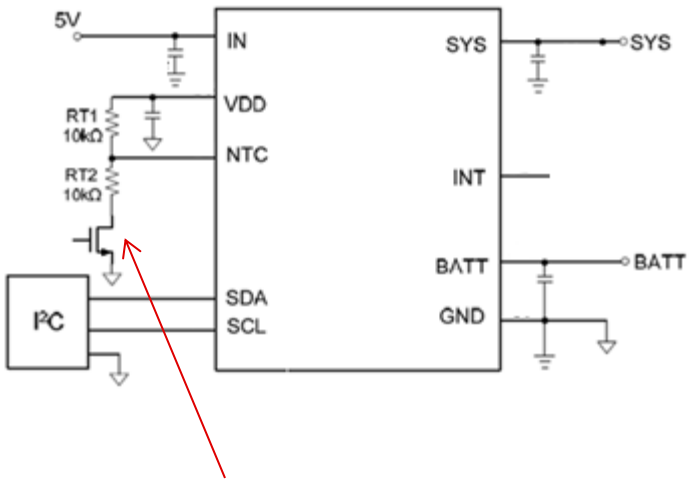
Ship mode and power path



e.g., BQ21061 10 nA ship mode current

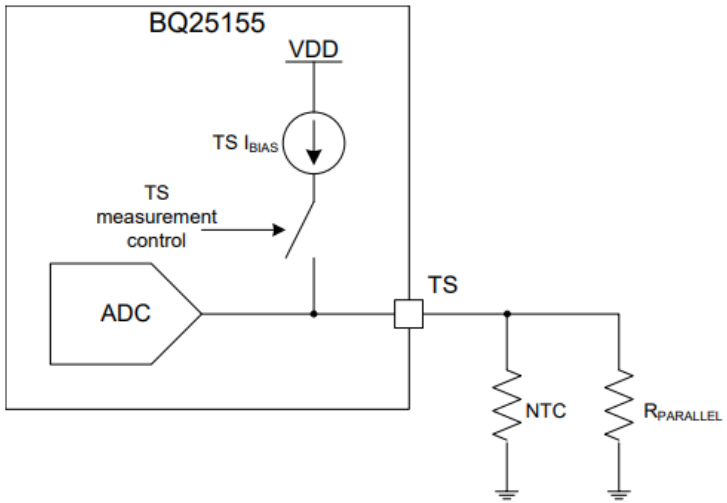
Get more out of a smaller battery & increase standby time – System considerations

System I_Q consideration: extra I_Q or extra components



- Need external FET **($0.03-0.05)** and GPIO to cut off NTC I_Q
- NTC is biased by V_{DD} (V_{IN} or V_{BAT})
- NTC bias I_Q is large (~ 200 µA) from battery (including ship mode) w/o external FET and GPIO

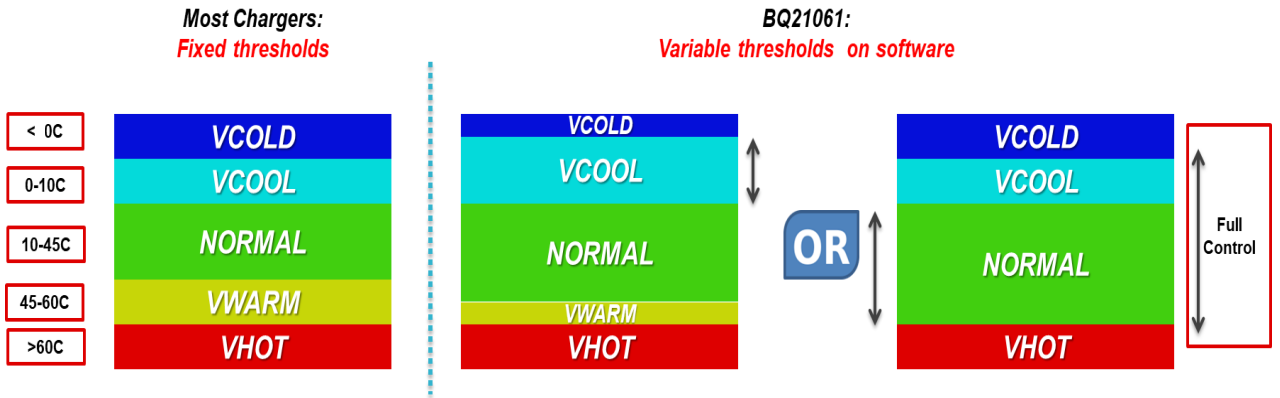
TI: minimal I_Q, no external component

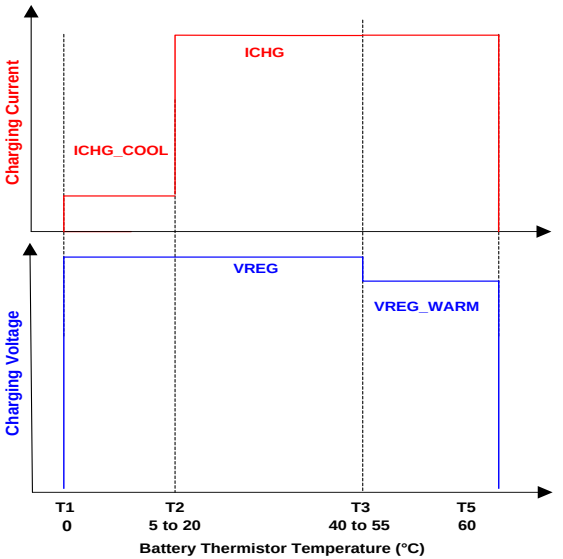


- When not measuring the NTC, the TS bias current is off
- No external circuit needed

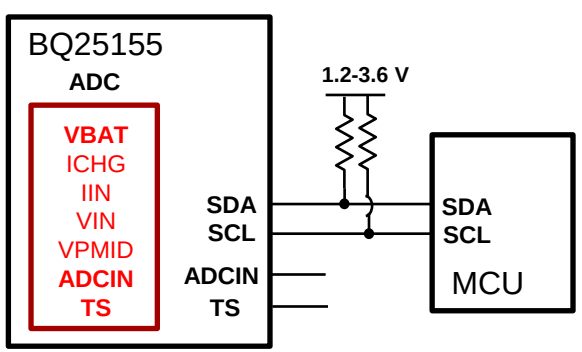
Increase battery safety and reliability: Flexible JEITA, temp monitoring

1. Flexible JEITA: configurable cutoffs and actions





2. BAT, board temp monitoring using ADC



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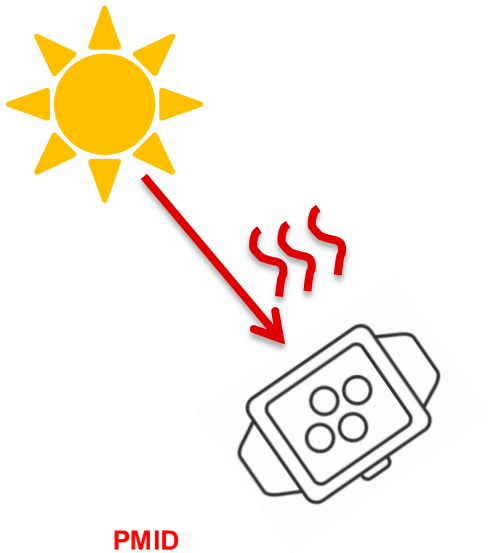
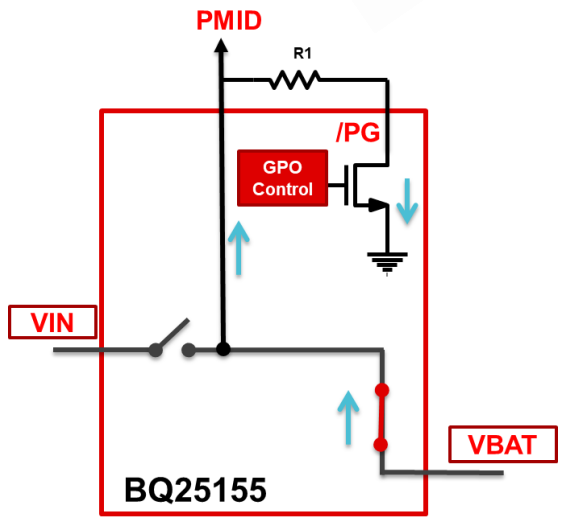
Increase battery safety and reliability: Warm/hot battery discharge

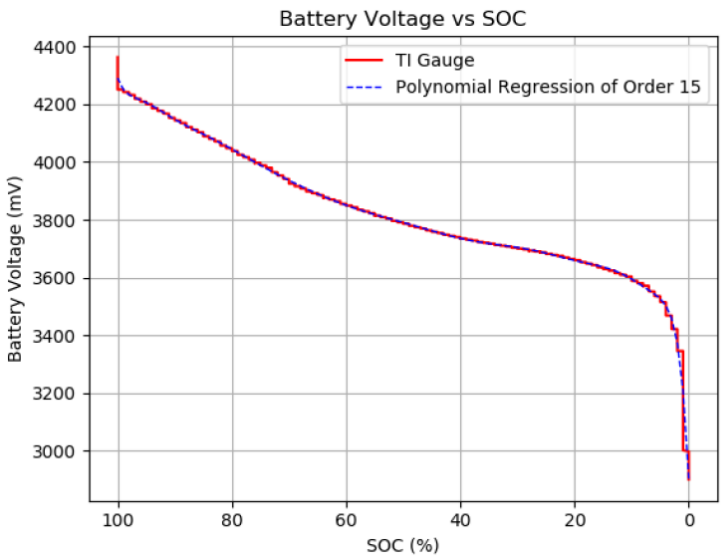
- Most chargers have options to lower the battery regulation voltage during charging at warm temperatures(JEITA)
- Systems also need a way to reduce the Vbat when battery is charged and the warm/hot condition happens
- BQ25155 has options to discharge the battery in any of the external conditions



- **Implementation:**
  - Using the built-in ADC comparators to identify when battery voltage is full and temperature is warm/hot
  - If the condition happens, the host will receive an interrupt
  - Convert PMID mode to VBAT. This disables the adapter
  - Convert the /PG as GPO and pull low
  - This will begin the discharge process

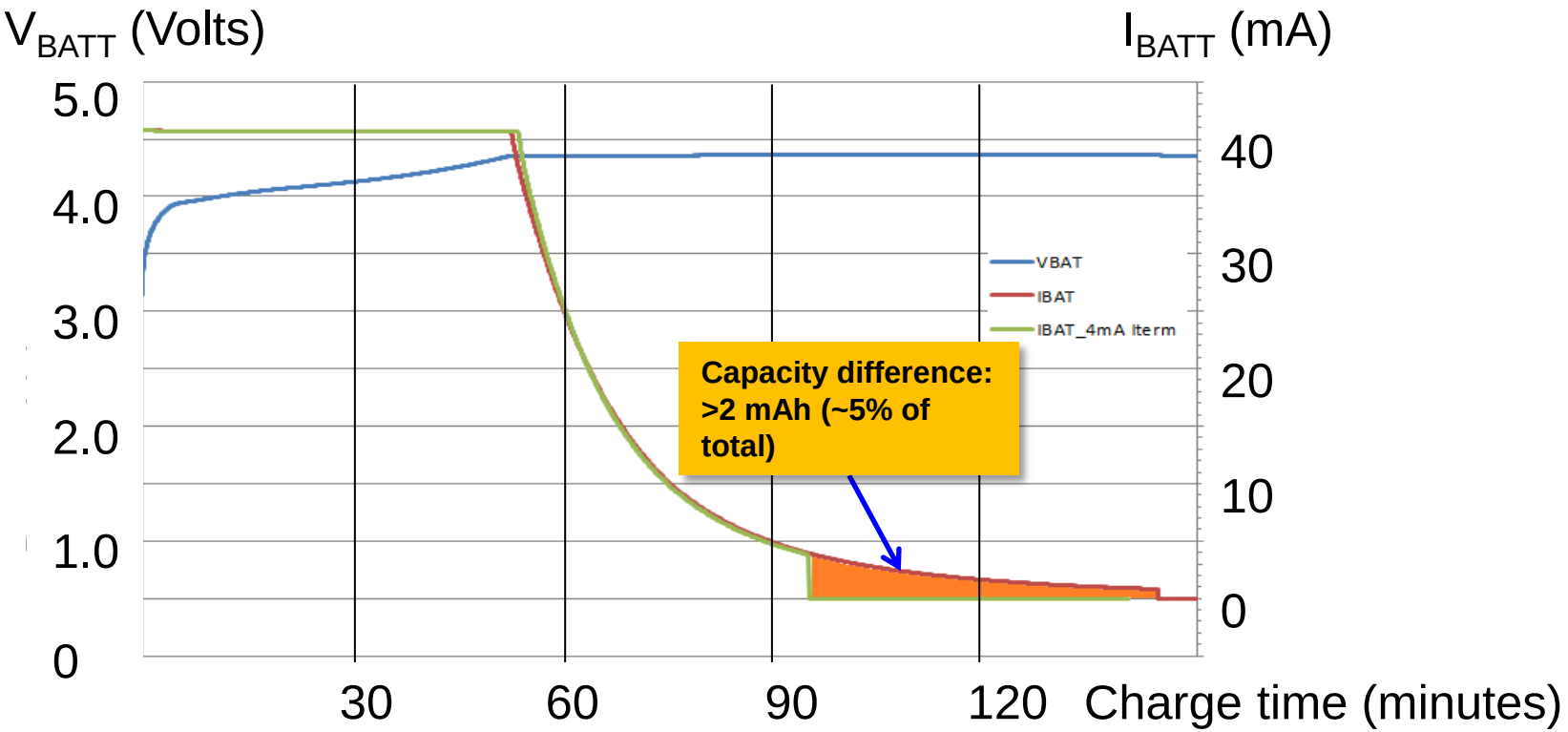


Tell the status of charge (SoC) using a gauge or ADC



- For high accuracy, gauge ICs are needed – will take temperature, current information into consideration
- For lower accuracy, BQ25155 has a 16 bit ADC that can measure the V_{BAT}, which can be used to look up the SoC value

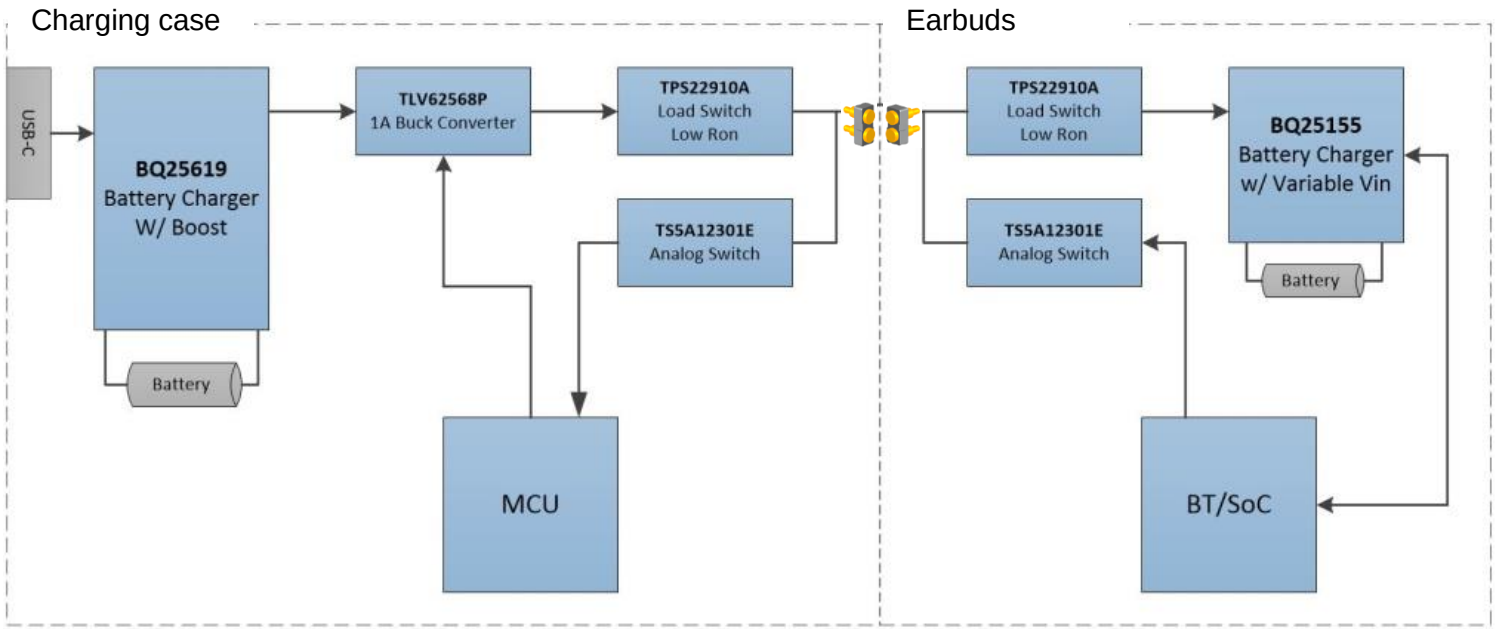
Utilize battery better: Accurate charge termination



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

SPECIFIC CHALLENGES FOR TWS

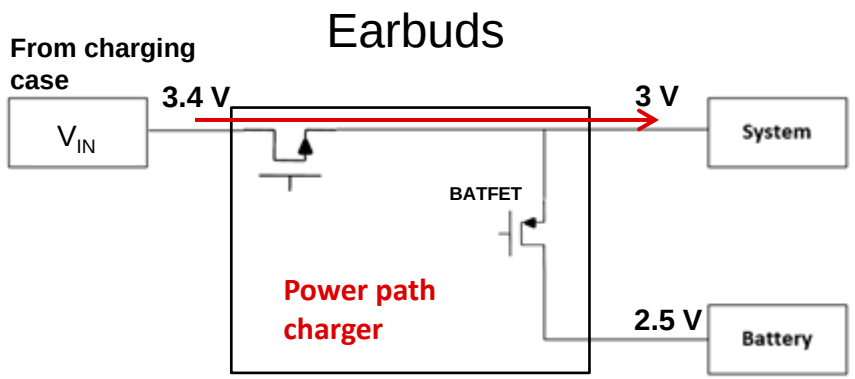
How to get more charging cycles and less heat in TWS – 2 pin charging + communication



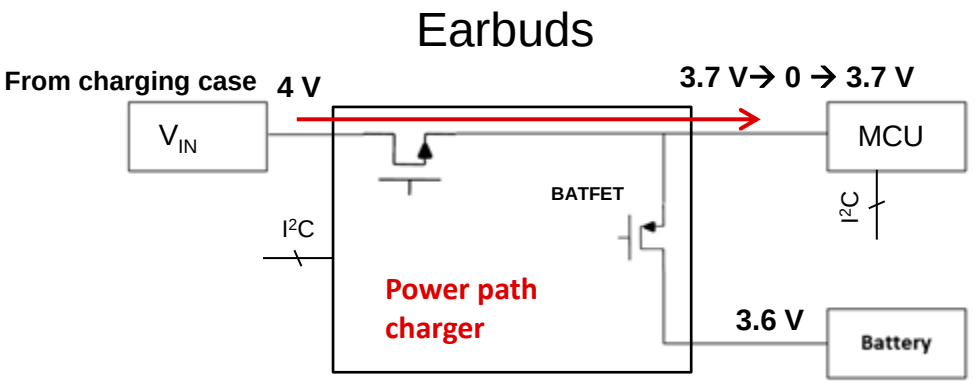
- Why do we need it?
  - TWS case has limited number of charges for earbuds
  - TWS earbuds gets hot when charging
- How do we solve it?
  - Single line communication between the earbud and charging case for optimal V_{IN} for earbuds
  - Increased efficiency w/dynamic case output voltage adjustment allowing for more charge cycles and cooler devices

Example in the picture: TI application report SLUAA04

Connectivity requirement – Instant power on when inserting the earbuds



Watchdog for power cycling in MCU stuck situation



- When earbuds are being charged in the case and MCU is stuck
- Need watchdog to power cycle
- The BQ21061 and BQ25125 integrate a 14-sec watchdog timer that performs a HW reset/power cycle if no I^2C transaction is detected within 14 seconds of a valid Vin being connected

Chargers portfolio for TWS

Earbuds

BQ25125

- I²C control
- V_{IN} = 3.4-5.5 V, max 20 V
- Linear: I_{CHG} = 5-300 mA
- Buck: 1.8 V (1.1-3.3 V)/300 mA
- LDO/load switch: 100 mA
- Ship mode 2 nA
- 2.5 mm x 2.5 mm WCSP

BQ21061/25155

- I²C control
- V_{IN} = 3.4-5.5 V, max 20 V
- Programmable JEITA
- Regulated PMID
- 1.25 mA – 500 mA accurate I_{CHG}
- 0.5 mA low termination current
- LDO/load switch: 150 mA
- Pushbutton control
- Ship mode 10 nA
- 16 bit ADC (BQ25155)
- 1.6 mm x 2 mm WCSP

BQ2510x

- V_{IN} = 4.45-6.45 V, max 30 V
- V_{REG} = 4.2/4.35 V
- I_{CHG} = 250 mA, I_{TERM} ~1 mA
- I_Q <~75 nA
- 1.6 mm x 0.9 mm WCSP6

BQ25170 (preview TI.com)

- Next gen of existing hero BQ24040
- V_{IN} abs max 30 V
- V_{REG} pin programmable 4.05-4.4V
- I_{CHG} = 10-800mA
- 2 mm x 2 mm SON10

Case

BQ25619

- 1.5 A high efficiency SW charger
- Power path
- V_{IN} = 4-13.5 V, max 22 V
- I²C programmable V_{REG} (3.5 V - 4.52 V)
- >94% efficiency
- OTG boost V_{OTG} with 4.6 V / 4.75 V / 5 V / 5.15 V
- 20 mA low termination current
- 9.5 µA quiescent battery current
- 7 µA ship mode
- 4 mm x 4 mm QFN

BQ2407x(T)

- Power path
- V_{IN} = 4.35-6.4/10.2 V, max 30 V
- V_{REG} = 4.1/4.2/4.35/4.4 V
- I_{CHG} up to 1.5 A
- Voltage based TS (flexible TS threshold setting)
- 3 mm x 3 mm QFN16

Features & performance

< 500 mA

> 500 mA

Charging current

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SPECIFIC CHALLENGES FOR WEARABLES

Wearable: Wake up/power off flexibility with pushbutton

- Completely customized
  - Long press and short press button actions
  - Ship mode entry/exit
  - System power cycling
  - Configurable timers

Chargers portfolio for wearables

Features & performance

BQ25125

- I²C control
- V_{IN} = 3.4-5.5 V, max 20 V
- Linear: I_{CHG} = 5-300 mA
- Buck: 1.8 V (1.1-3.3 V)/300 mA
- LDO/load switch: 100 mA
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BQ2510x

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- I_{CHG} = 250 mA, I_{TERM} ~1 mA
- I_Q <~75 nA
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BQ21061/25155

- I²C control
- V_{IN} = 3.4-5.5 V, max 20 V
- Programmable JEITA
- Regulated PMID
- 1.25 mA – 500 mA accurate I_{CHG}
- 0.5 mA low termination current
- LDO/load switch: 150 mA
- Pushbutton control
- Ship mode 10 nA
- 16 bit ADC (BQ25155)
- 1.6 mm x 2 mm WCSP

BQ25618

- 1.5 A high efficiency SW charger
- Power path
- V_{IN} = 4-13.5 V, max 22 V
- I²C programmable V_{REG} (3.5 V - 4.52 V)
- >94% efficiency
- OTG boost V_{OTG} with 4.6 V / 4.75 V / 5 V / 5.15 V
- 20 mA low termination current
- 9.5 µA quiescent battery current
- 7 µA ship mode
- 2 mm x 2.4 mm CSP

BQ25170 (preview TI.com)

- Next gen of existing hero BQ24040
- V_{IN} abs max 30 V
- V_{REG} pin programmable 4.05-4.4V
- I_{CHG} = 10-800mA
- 2 mm x 2 mm SON10

BQ2407x(T)

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- V_{IN} = 4.35-6.4/10.2 V, max 30 V
- V_{REG} = 4.1/4.2/4.35/4.4 V
- I_{CHG} = 1.5 A
- Voltage based TS (flexible TS threshold setting)
- 3 mm x 3 mm QFN16

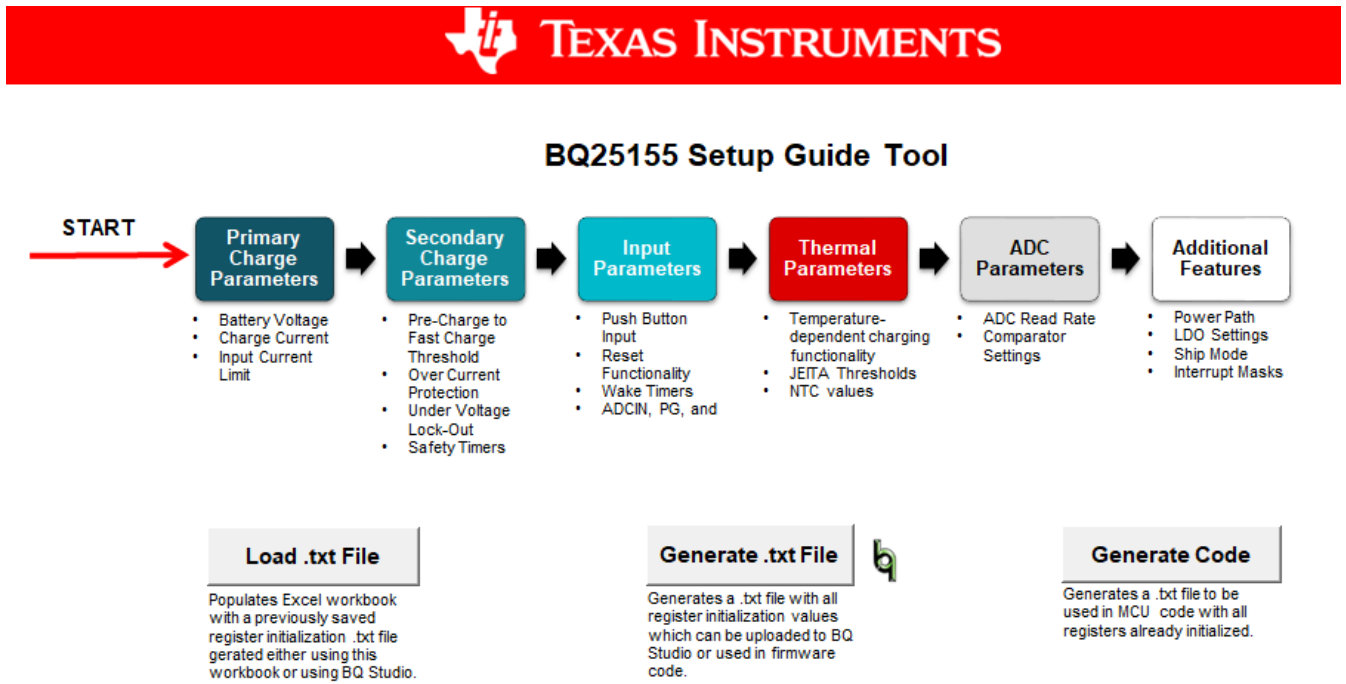
< 500 mA

> 500 mA

Charging current

DESIGN RESOURCES

Setup guide


TEXAS INSTRUMENTS
BQ25155 Setup Guide Tool
START
Primary Charge Parameters
Battery Voltage
Charge Current
Input Current Limit
Secondary Charge Parameters
Pre-Charge to Fast Charge Threshold
Over Current Protection
Under Voltage Lock-Out
Safety Timers
Input Parameters
Push Button Input
Reset Functionality
Wake Timers
ADCIN, PG, and
Thermal Parameters
Temperature-dependent charging functionality
JEITA Thresholds
NTC values
ADC Parameters
ADC Read Rate
Comparator Settings
Additional Features
Power Path
LDO Settings
Ship Mode
Interrupt Masks
Load .txt File
Populates Excel workbook with a previously saved register initialization .txt file gerated either using this workbook or using BQ Studio.
Generate .txt File
Generates a .txt file with all register initialization values which can be uploaded to BQ Studio or used in firmware code.
Generate Code
Generates a .txt file to be used in MCU code with all registers already initialized.

BQ25150 reference design PMP21884 – Tiny, ultra-low I_Q DC/DC power supply with battery charging reference design for wearables

Features

- Ultra-small (48 mm^2) total footprint power supply solution
- 400 nA I_Q linear battery charge management solution with fast charge, LDO, load switch and ADC
- Seven rails for various peripherals: 1.8 V @ 1 A, 0.3 A, 0.1 A; 1.2 V @ 0.2 A; 12 V @ 0.06 A or 5 V @ 0.150 A
- Selectable, integrated boost rail for PMOLED display or heart rate monitor LED driver
- Ultra-small, ultra-low I_Q regulation: 0.48 mm^2 1 µA I_Q LDO plus 0.70 mm^2 2.3 µA I_Q buck converter and 2.5 mm^2 370 nA I_Q dual buck + boost converter

Applications

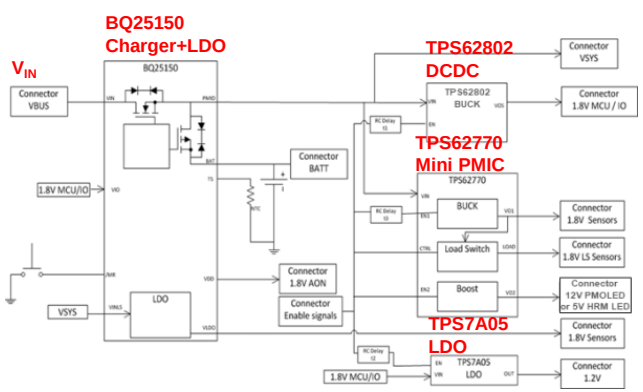
- Smartwatch and fitness trackers
- Consumer and medical wearables

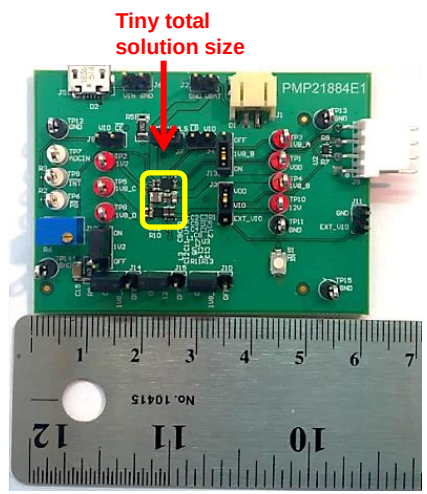
Tools & resources

- PMP21884 folder
- **Design guide**
- **Design files:** schematics, BOM, Gerbers, software, etc..
- **Device datasheets:**
  - BQ25150
  - TPS62770
  - TPS62801
  - TPS7A05

Benefits

- Battery charger dynamic power path management optimizes charger for weak adapters
- Full power supply with smallest possible footprint and ultra low I_Q ideal for small wearables for extended battery run time
- Boost hardware selectable between 12 V for PMOLED display bias or 5 V for LED driver supply pin for bio-sense AFE IC
- Integrated, ultra-low I_Q buck plus boost saves space and battery





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Summary

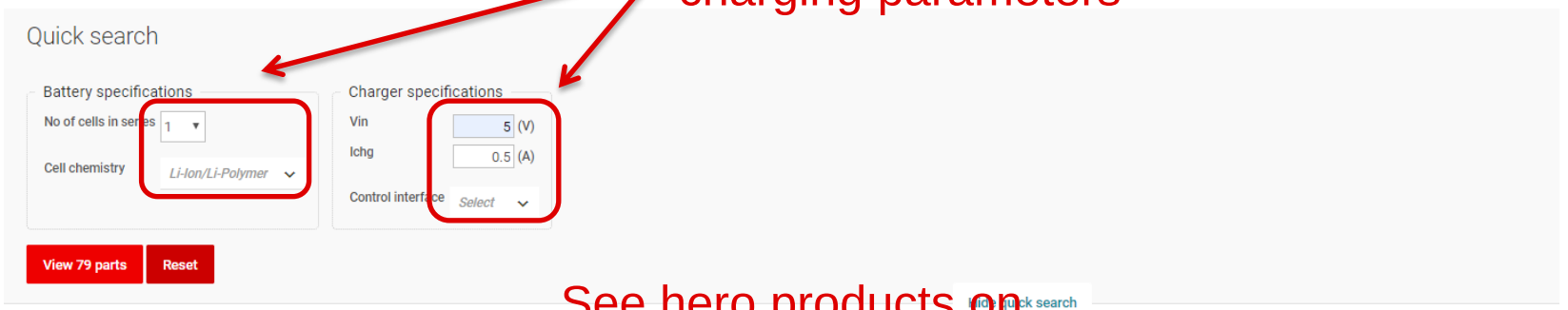
- Wireless headset and wearables market are growing fast
- Common design considerations (i.e., power integration, standby time, safety/reliability, SoC, I_{term}, benefits of power path)
- Specific design considerations for TWS (i.e., charge efficiency, connectivity, power recycle) and wearables (i.e., pushbutton flexibility)
- TI has design resources to help you design products!

Battery charger quick search tool

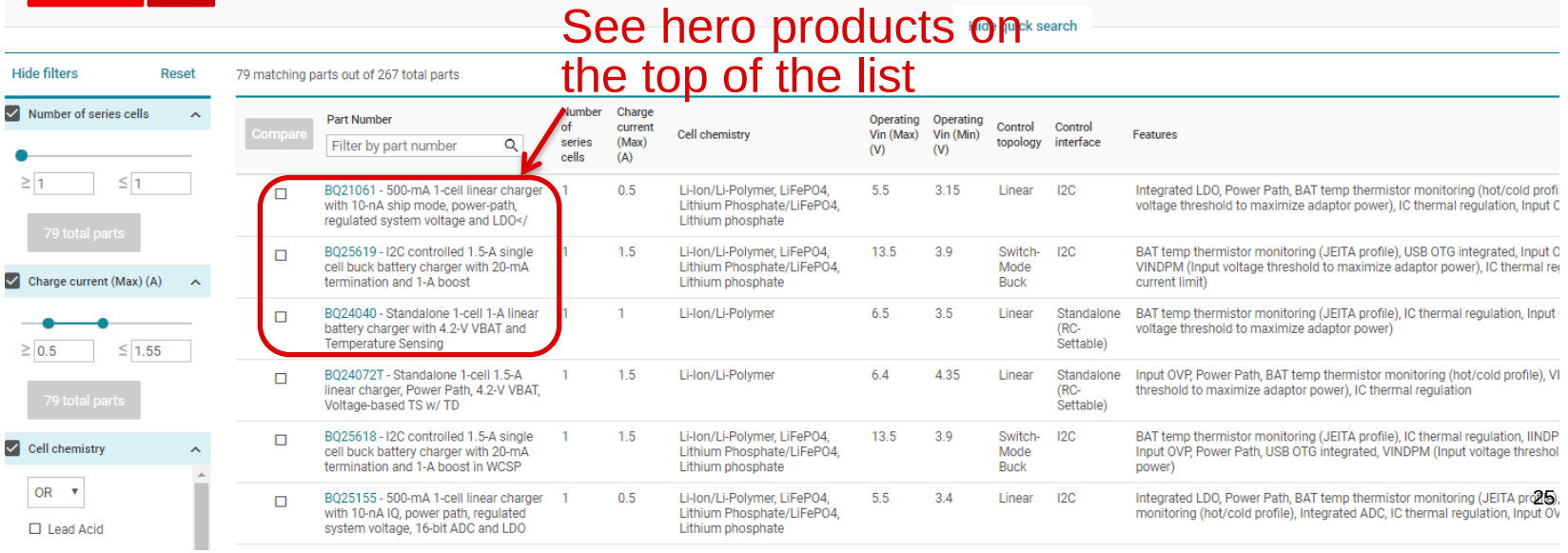
- quickly helps you find the products you need

([link])

Put in a few charging parameters



See hero products on the top of the list



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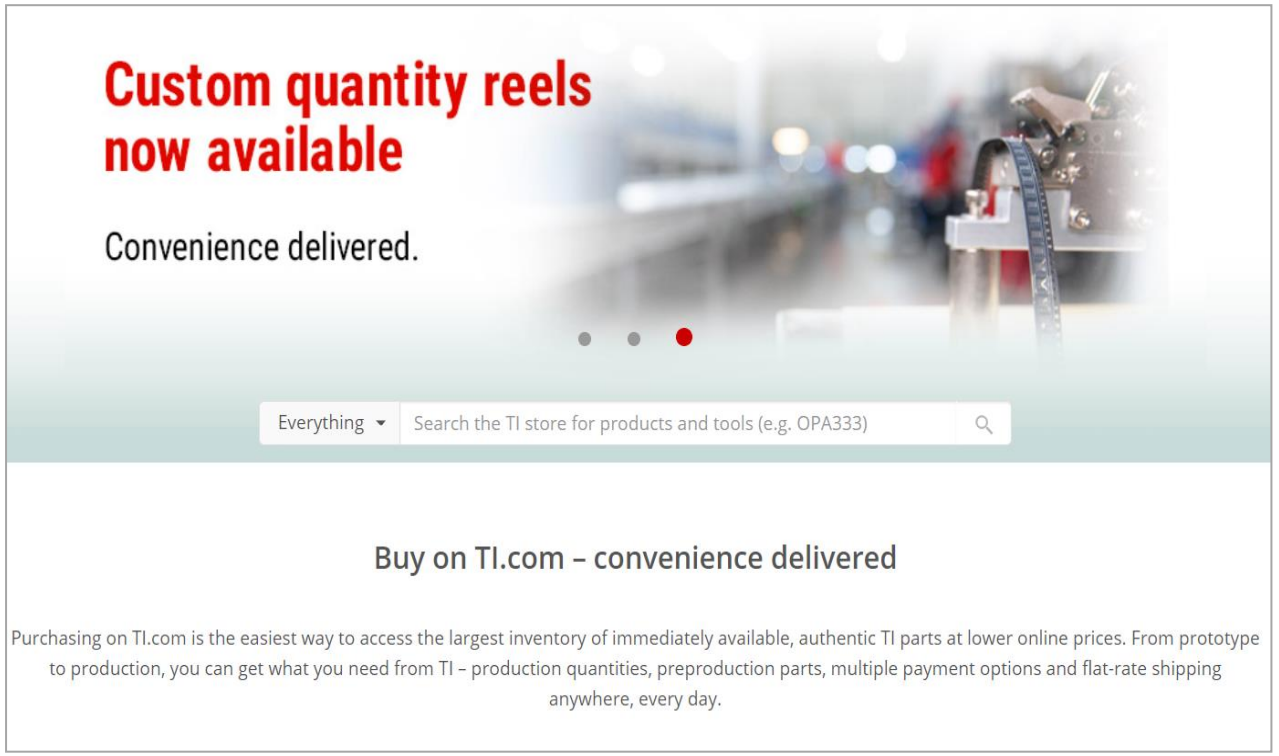

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