# TI Design: TIDA-00712

Battery Management Reference Design for Smartwatch & Wearable Applications

TEXAS INSTRUMENTS

## TI Designs

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## Design Resources

| | |
|---|---|
| TIDA-00712 | Design Folder |
| bq51003 | Product Folder |
| bq25120 | Product Folder |
| bq27421 | Product Folder |
| bq2970 | Product Folder |
| TPS61046 | Product Folder |

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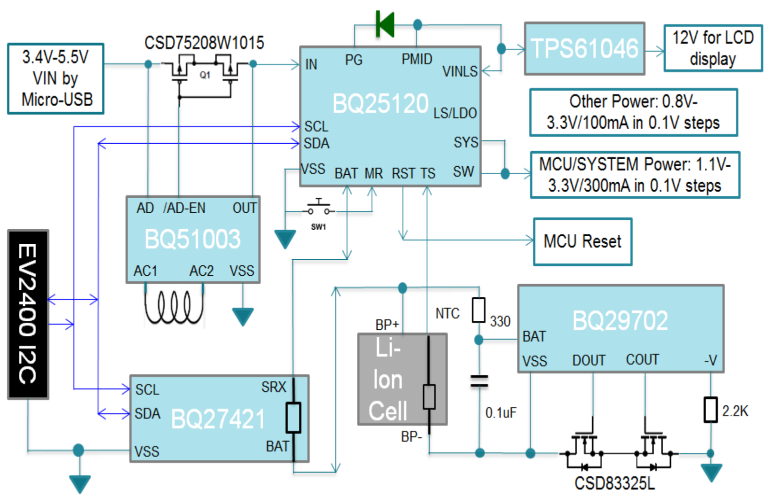
## Design Features

- **BQ25120 charger with PMIC functions:**
  - ✓ Buck and LDO output programmable for system
  - ✓ Manual reset timer output for system reset
- **BQ51003 Wireless Receiver (Option):**
  - ✓ 93% efficiency optimized only one IC required
  - ✓ WPC V1.1 compatible in size of 1.9mm x 3.0mm
- **BQ27421 Impedance Tracking Gauge (Option):**
  - ✓ On-board single-cell battery fuel gauge
  - ✓ Easiest to configure – virtually plug-n-play gauge
- **BQ2970 Battery Full Protection IC (Option):**
  - ✓ Most cost-effective voltage and current protection

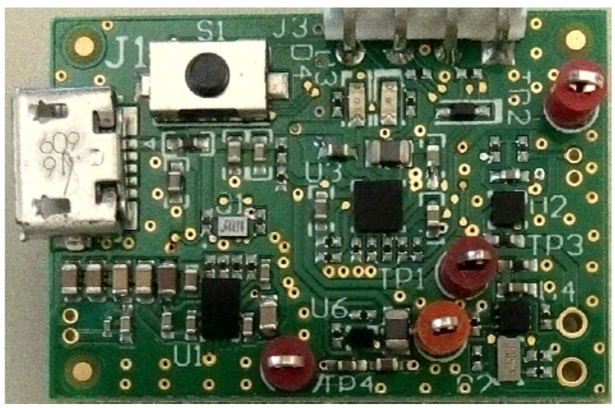
## Featured Applications

- Smartwatch
- Sensors and Field Transmitters
- Portable Instruments
- IoT (Internet of Things)
- Wearables

## Block Diagram




## Board Image



## 1. System Description

The TI design TIDA-00712 is a reference design for Smartwatch BMS (Battery Management Solution); It's suitable for low power wearable devices like smartwatch applications. The design includes following devices:

- bq25120, it's an ultra-low current 1 cell Li-ion linear charger;
- bq51003, it's a highly integrated Qi-compliant wireless power receiver;
- bq2970, it's a cost-effective voltage and current protection Integrated Circuit;
- bq27421, it's a system-side(tm) with integrated sense resistor battery fuel gauge;
- TPS61046, it's a booster with output up to 28V for LCD kinds of display devices.

The design is implemented in a small size (20mm x 29mm) PCB; its input power can be from a Micro-USB connector or Qi-compliant wireless power transmitter; the selection of 2 input power sources is automatically, wireless power will be turned off whenever 5V power supply from Micro-USB connector is detected.

The design gives capability of options for customers' specified application choice; following functions can be bypassed by a 0-Ohm resistor: wireless power; gas gauging and protection.

The design can support charging currents from 5 mA to 300 mA; its configurable termination current can be down to 0.5mA. The included schematic is designed for 260mA charge current and 8 mA termination current by external resistor, but can be overwrote by I2C configuration.

## 1.1 bq25120

The bq25120 is a highly integrated family of single cell Li-Ion and Li-Pol chargers. The charger can be used to charge a battery, power a system or both. The charger has three phases of charging: pre-charge to recover a fully discharged battery, fast-charge constant current to supply the charge safely and voltage regulation to safely reach full capacity. The charger is very flexible, allowing programming of the fast-charge current and Pre-charge/Termination Current. The charger input power can be from a Micro-USB connector or Qi-compliant wireless power transmitter; the selection of 2 input power sources is automatically, wireless power will be turned off whenever 5V power supply from Micro-USB connector is detected.

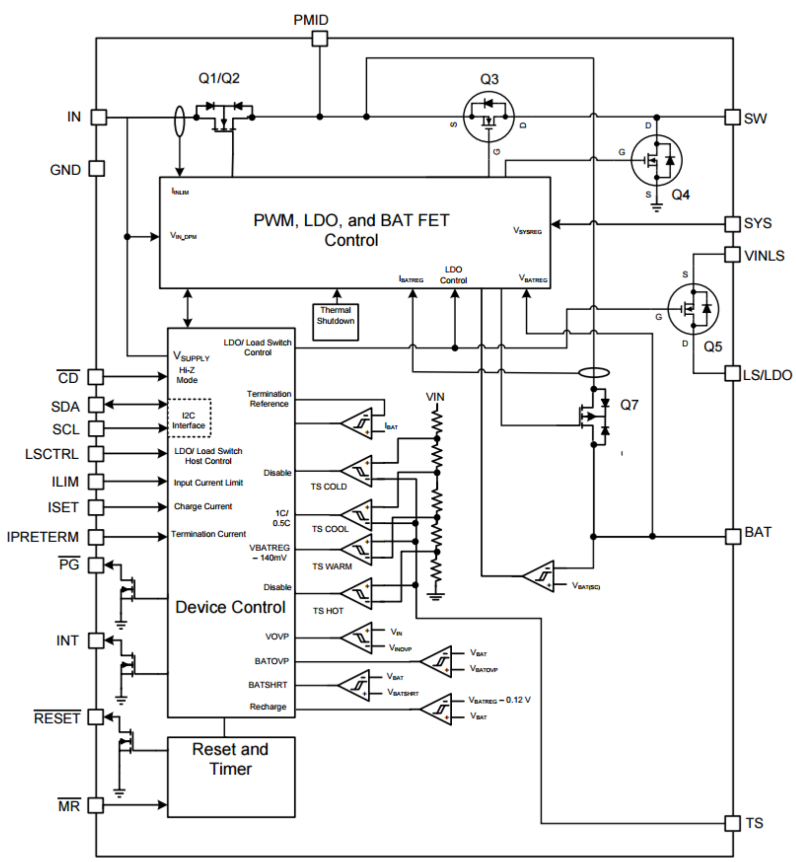
The design can support charging currents from 5 mA to 300 mA; its configurable termination current can be down to 0.5mA. The included schematic is designed for 260mA charge current and 8 mA termination current by external resistor, but can be overwrote by I2C configuration.

This charger has a buck convertor for system power need; its output voltage is programmable by its I2C from 0.8V to 3.3VDC with up to 300mA current output in 0.1V step.

This charger also has an either load switch or LDO function, both support up to 100mA current output, its output voltage is also programmable by its I2C from 0.8V-3.3VDC in 0.1V steps.

The charge has a pin to generate a delay reset pulse output by a input pin which can be connected to a button for manual reset input or power up input.

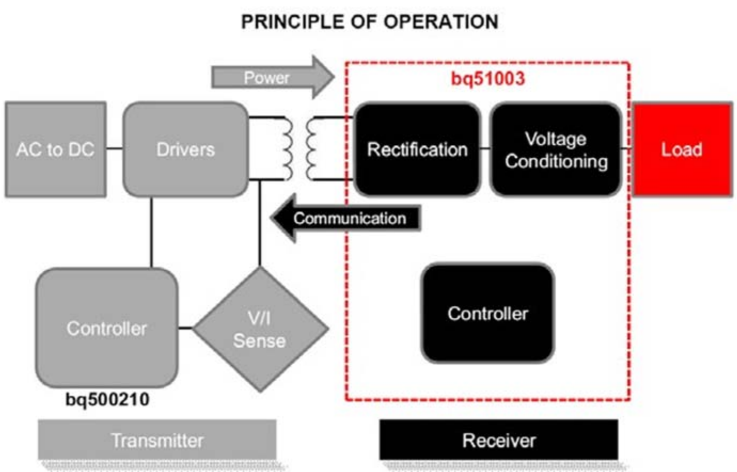
In summary, the charge IC bq25120 not only work for battery charge but also can be working as a supervisor circuit, along with its buck convertor and LDO function, it's also work as a simple PMIC IC.



## 1.2 bq51003

A wireless system consists of a charging pad (transmitter or primary) and the secondary-side equipment (receiver or secondary). There is a coil in the charging pad and in the secondary equipment which are magnetically coupled to each other when the secondary is placed on the primary. Power is then transferred from the transmitter to the receiver via coupled inductors (e.g. an air-core transformer). Controlling the amount of power transferred is achieved by sending feedback (error signal) communication to the primary (that is, to increase or decrease power).

The receiver communicates with the transmitter by changing the load seen by the transmitter. This load variation results in a change in the transmitter coil current, which is measured and interpreted by a processor in the charging pad. The output of the wireless receiver is 5Vdc which is supplied to the input of the charger circuit.

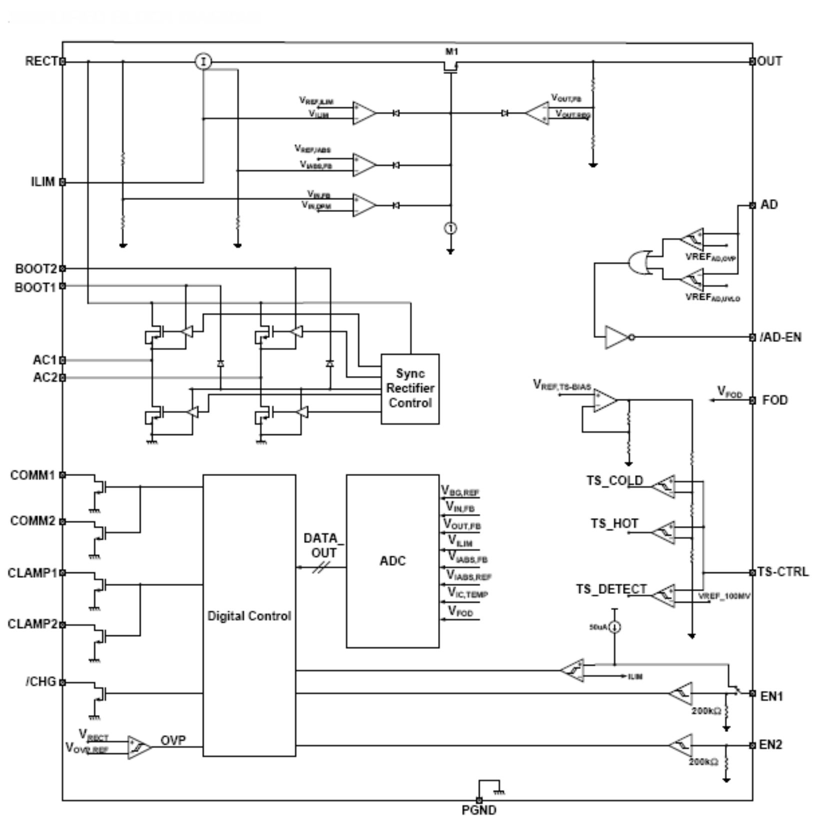



The bq51003 is an advanced, integrated, receiver IC for wireless power transfer in portable applications.

The device provides the AC/DC power conversion while integrating the digital control required complying with the Qi v1.1 communication protocol. Together with the bq500210 transmitter controller, the bq51003 enables a complete contact-less power transfer system for a wireless power supply solution. By using near-field inductive power transfer, the receiver coil embedded in the portable device receives the power transmitted by the transmitter coil via mutually coupled inductors. The AC signal from the receiver coil is then rectified and regulated to be used as a power supply for down-system electronics. Global feedback is established from the secondary to the transmitter in order to stabilize the power transfer process via back-scatter modulation. This feedback is established by using the Qi v1.1 communication protocol supporting up to 2.5-W applications.

The device integrates a low-impedance full synchronous rectifier, low-dropout regulator, digital control, and accurate voltage and current loops.

Wireless Receiver Simplified Block Diagram



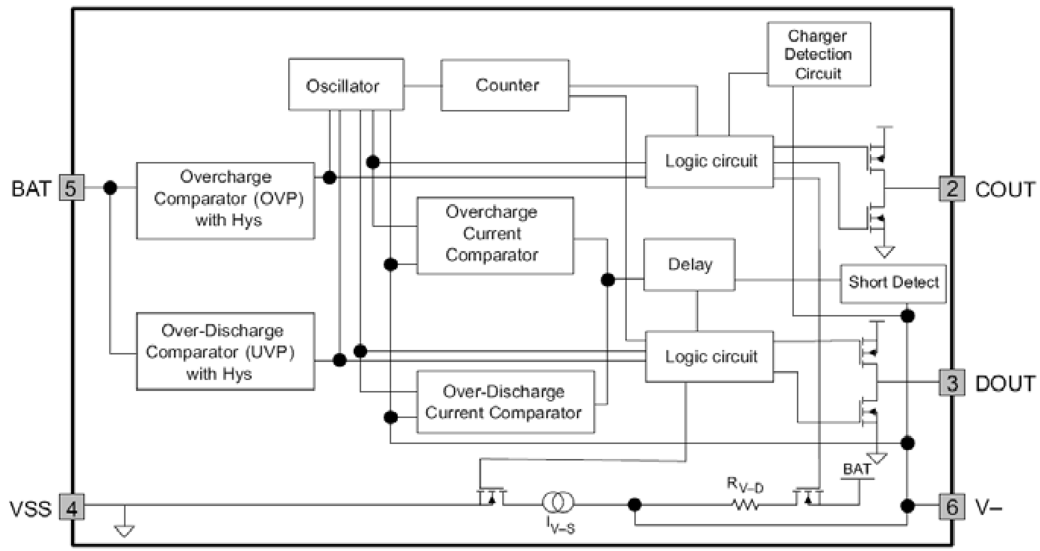

## 1.3 bq2970

This bq2970 device is a primary protector for a single-cell Li-Ion/Li-Polymer battery pack. The device uses a minimum number of external components to protect for overcurrent conditions due to high discharge/charge currents in the application. In addition, it monitors and helps to protect against battery pack overcharging or depletion of energy in the pack. See the chart below for the functional levels of protection.

In the condition when a fault is triggered, there are timer delays before the appropriate action is taken to turn off either the CHG or DSG FETs. There is also a timer delay for the recovery period once the threshold for recovery condition is satisfied. There is also a feature called zero voltage charging that enables depleted cells to be charged to an acceptable level before the battery pack can be used for normal operation. Zero voltage charging is allowed if the charger voltage is above 1.7 V.

| PART NUMBER | OVP (V) | OVP DELAY (s) | OVP REC DELAY (ms) | UVP (V) | UVP DELAY (ms) | UVP REC DELAY (ms) | OCC (V) | OCC DELAY (ms) | OCC REC DELAY (ms) | OCD (V) | OCD DELAY (ms) | OCD REC DELAY (ms) | SCD (V) | SCD DELAY (µs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| bq29702 | 4.350 | 1 | 12 | 2.800 | 96 | 8 | 0.155 | 8 | 8 | 0.160 | 16 | 8 | 0.3 | 250 |

Protector Simplified Block Diagram:




## 1.4 bq27421

The fuel gauge IC bq27421 is an easy-to-configure microcontroller peripheral that provides system-side fuel gauging for single-cell Li-Ion batteries. The device requires minimal user configuration and system microcontroller firmware development. The fuel gauge uses the patented (7mΩ, Typical) Impedance Track algorithm for fuel gauging, and provides information such as remaining battery capacity (mAh), state-of-charge (SoC in %), and battery voltage (mV).

Information is accessed through a series of commands, called Standard Commands. Further capabilities are provided by the additional Extended Commands set. Both sets of commands, indicated by the general format Command (), are used to read and write information contained within the control and status registers, as well as its data locations.

Commands are sent from system to gauge using the I2C serial communications engine, and can be executed during application development, system manufacture, or end-equipment operation.

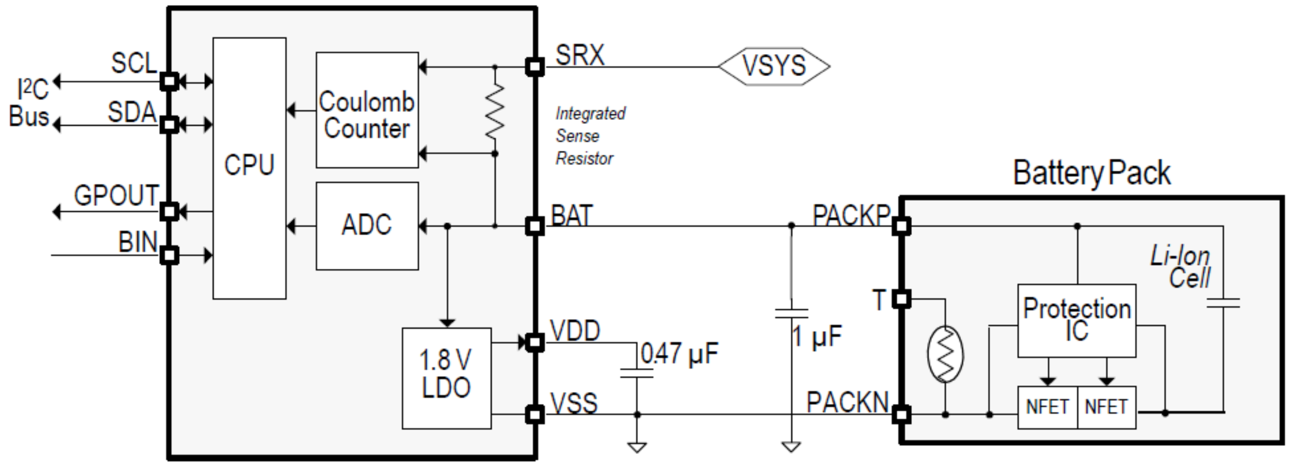
The key to the high-accuracy gas gauging prediction is Texas Instruments proprietary Impedance Track™ algorithm. This algorithm uses cell measurements, characteristics, and properties to create state-of-charge predictions that can achieve high-accuracy across a wide variety of operating conditions and over the lifetime of the battery.

The fuel gauge measures the charging and discharging of the battery by monitoring the voltage across a small value sense resistor. When a cell is attached to the fuel gauge, cell impedance is computed, based on cell current, cell open-circuit voltage (OCV), and cell voltage under loading conditions.

The fuel gauge uses an integrated temperature sensor for estimating cell temperature. Alternatively, the host processor can provide temperature data for the fuel gauge.

More details are found in the bq27421-G1 Technical Reference Manual (SLUUAC5).

Functional Block Diagram:




Battery detail specifications are necessary for better performance of gauging, or, characterize battery by Texas Instruments Gauge Development Kit (GDK) which is a complete evaluation system for any single-cell fuel.

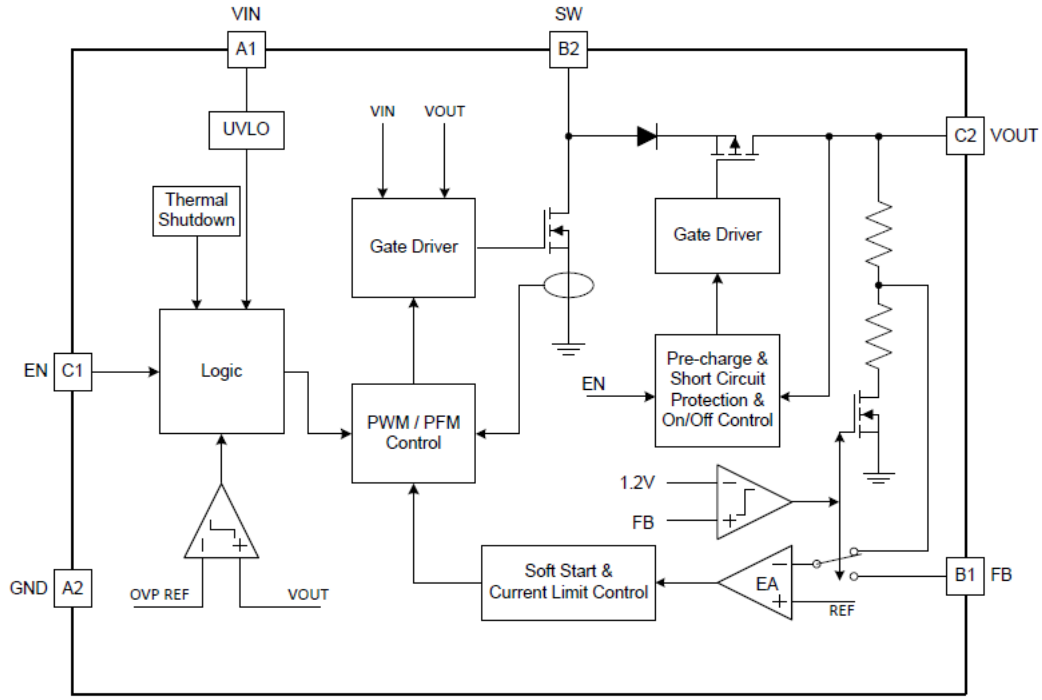
## 1.5 TPS61046

The TPS61046 is a highly integrated boost converter designed for applications requiring high voltage and tiny solution size such as PMOLED panel power supply and sensor module. The TPS61046 integrates a 30-V power switch, input/output isolation switch, and power diode. It can output up to 28 V from input of a Li+ battery or two cell alkaline batteries in series.

One common issue with conventional boost regulators is the conduction path from input to output even when the power switch is turned off. It creates three problems, which are inrush current during start-up, output leakage current during shutdown and excessive over load current. In the TPS61046, the isolation switch is turned off under shutdown mode and over load conditions, thereby opening the current path. Thus the TPS61046 can truly disconnect the load from the input voltage and minimize the leakage current during shutdown mode.

The TPS61046 operates with a switching frequency at 1.0 MHz. This allows the use of small external components. The TPS61046 has an internal default 12-V output voltage setting by connecting the FB pin to the VIN pin. Thus it only needs three external components to get 12-V output voltage. Together with WCSP package, the TPS61046 gives a very small overall solution size. The TPS61046 has typical 900-mA switch current limit. It has 10-ms built-in soft start time to minimize the inrush current. The TPS61064 also implements output short circuit protection, output over-voltage protection and thermal shutdown.

TPS61046 Functional Block Diagram is showing below:




## 1.6 Battery Cell

Any rechargeable Lithium-Ion battery cell can be used, but the maximum charge current is 300mA limited by the charger device bq25120, so, it's better to limit your battery cell capacity to 300mAH which is usual used in smartwatch and wearable device. The battery detail specifications come from the battery manufacture. You should become familiar with this battery and it's limitations before using it in a design.

For better performance, battery cell shall be characterized individually; this can be done by Texas Instruments Gauge Development Kit (GDK) which is a complete evaluation system for any single-cell fuel.

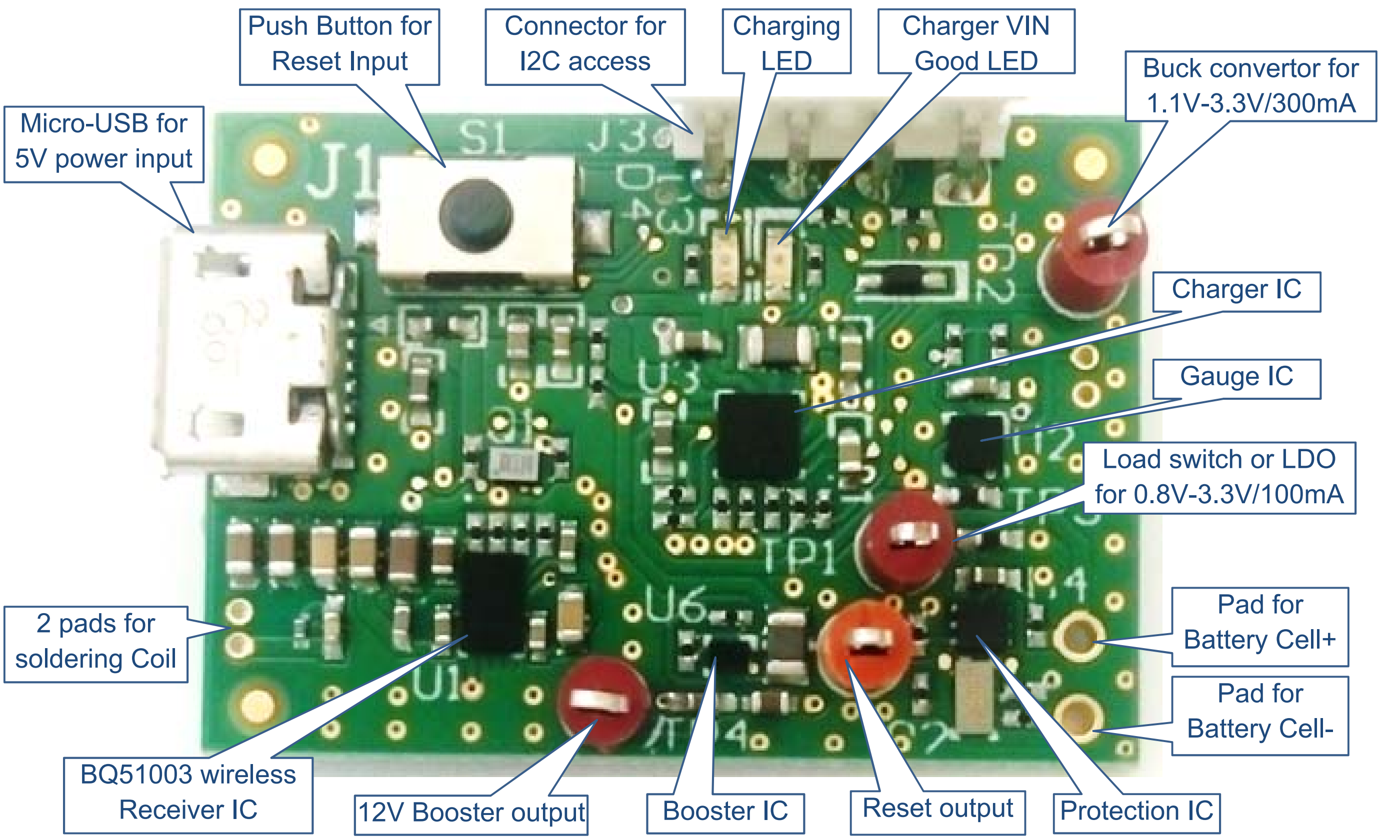
The GDK is a single, printed circuit board (PCB) equipped with a programmable load, programmable charger, an optional onboard fuel gauge, and an integrated EV2400 for PC interaction via Battery Management Studio (bqSTUDIO).

A USB PC cable, 6-V 2.5-A DC jack (or equivalent power supply connection), and the latest version of bqSTUDIO is needed when using the GDK. The GDK is by default configured for an external single-cell fuel gauge EVM to be connected, but with minor adjustments to the GDK, the optional onboard fuel gauge can be used instead of an external EVM. Once the GDK is connected to a PC via USB cable, bqSTUDIO enables the user to do the following:

- Read the connected fuel gauge data registers
- Configure the connected fuel gauge
- Discharge the connected battery
- Charge the connected battery
- Log cycle data for evaluation
- Automate Learning Cycle(s)
- Evaluate the overall functionality of the connected fuel gauge solution under different charge and discharge conditions

## 2. System Setup

Picture below shows all major functions and parts for your evaluation setup. Although the design can works alone without I2C connection, but it's required for fully control the gauge and charger circuits.



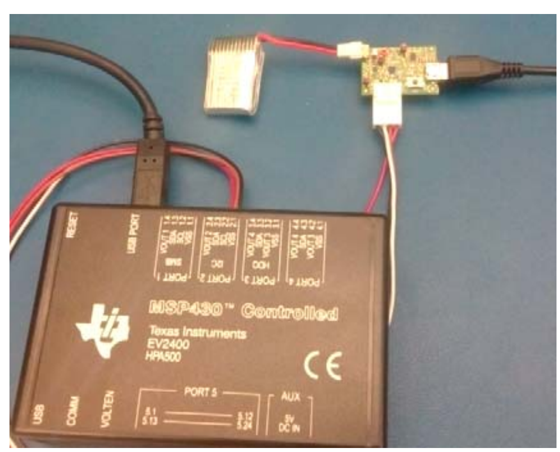

## 2.1 Basic Setup

The basic setup is for basic evaluation purpose, other than the design board, followings are required:

- Micro-USB connector connected to any PC/laptop USB port with normal 5V/500mA output;
- TI EV2300 / EV2400 I2C controller to be connected to PC USB port and runs TI BQ studio GUI;
- A battery about 300mAH connected to the design board.

For last version of the software and more details, please check the link below:

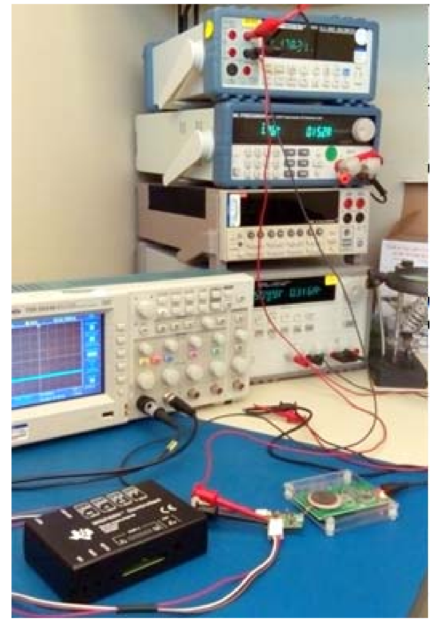
http://www.ti.com/tool/bqstudio



## 2.2 Test Setup

The test setup described here is for function test. Test equipment is listed below:

- Fluke Multi-meter
- 2400 Keithley Source Meter
- E3649A Agilent Programmable Power Supply
- Texas Instruments TIDA-00334 wireless power supply transmitter
- TI EV2300/ EV2400 I2C controller
- PC with 2 USB ports and TI bqStudio GUI installed (TI



## 2.3 Charging Test

- Connect micro-USB cable to PC USB port to power on the board with specified Li_Ion battery, the Charger VIN Good LED shall be turned on.
- After power on, the red charging LED may be fully on if the battery is in charging status, may be off if battery full charged, or lightly on for other faults.
- The schematic is designed for 260mA charge current and 8 mA termination current by external resistors, but can be overwritten by I2C configuration.

## 2.4 Discharging Test

By applying a load (<300mA) to load switch output TP1 to discharge the battery cell.

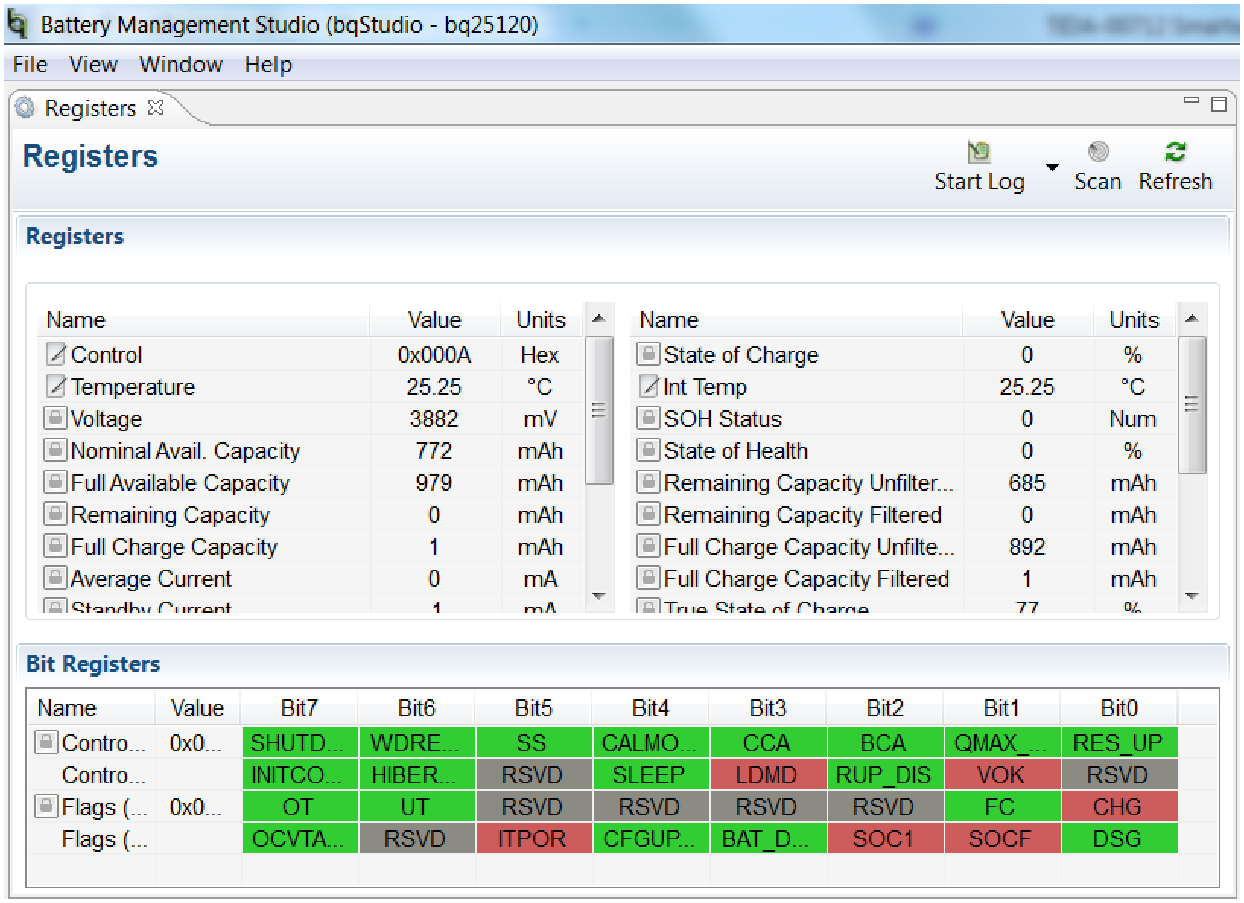
## 2.5 Wireless Receiver Test

- Remove the micro-USB cable from TIDA-00712 board and plug into the TIDA-00334 wireless power supply transmitter as showing by picture above.
- Place the receiver coil soldered on TIDA-00712 board in the center of the transmitter coil (to be perfect coupling for better efficiency, a transparent tape can be used to fix the setup.
- The wireless receiver schematic is designed for up to 300mA charging current.

## 2.6 Gauging Function Test

Gauging function test has to be implemented by adding followings:

- TI EV2300 or EV2400 I2C controller connected with a PC USB port.
- Run TI bqStudio GUI to detect the gauge IC automatically.
- By running charging and discharging, the GUI will show the battery voltage, current and other status, like state-of-charge (SoC in %), etc. as showing by picture below. More details are available in GDK user guide.




## 2.7 Protection Test

Tests below use multi-meter to measure voltage at TP1 which is load switch output for voltage type protection tests; use multi-meter measure battery cell current for current type protection tests.

### 2.7.1 Overcharge Detection (OVP):

- Use a 4.2V full charged battery cell, by I2C configuration, adjust charger termination voltage, when multi-meter voltage reading drop below 0.4V, the OVP occurs, it shall be about 4.35V.
- Test data: 4.38V

### 2.7.2 Over-Discharge Detection (UVP):

- Remove input power supply, use a 3.5V full discharged battery cell; keep discharging the battery, when multi-meter reading drop below 0.4V, the UVP occurs; it shall be about 2.8V.
- Test data: 2.88V

### 2.7.3 Charge Overcurrent Detection (OCC):

- Use a 3.7V full discharged battery cell, by I2C configuration, adjust charger current, when GUI “Charger Status” display between “Charging Done” and “Charging in Progress”,  the OCC occurs; the OCC shall occur about 275mA.
- Test data: 272mA

### 2.7.4 Discharge Overcurrent Detection (OCD):

- Remove input power supply, use a 4.2V battery cell; discharging the battery by 2400 Keithley Source Meter, add discharge current from 275mA, when multi-meter current reading drop below 1mA, the OCD occurs; the OCD shall be about 290mA.
- Test data: 285mA

### 2.7.5 Load Short-Circuit Detection (SCP):

- Short the load switch output TP1 to ground; the multi-meter current reading shall be less than 1mA which shows SCP occurs.
- Test data: Pass.

## 2.8 Booster Test

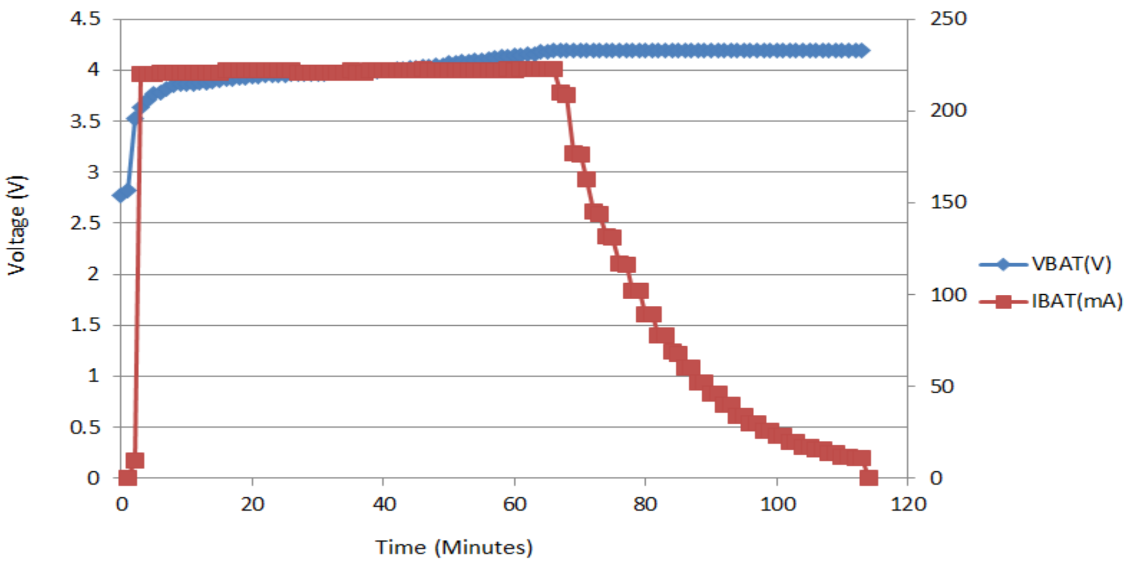
- **No load voltage output:** Use multi-meter measures the booster output at TP4 test loop which shall be 12V (+/-5%);
- Test data: 12.07V.
- **Loaded voltage output:** Apply 25mA load to the booster output at TP4, the output shall be still in the range of 12V (+/-5%);
- Test data: 11.56V

## 3. Charger Test Data in Plots

The test data showing by plots is followings:

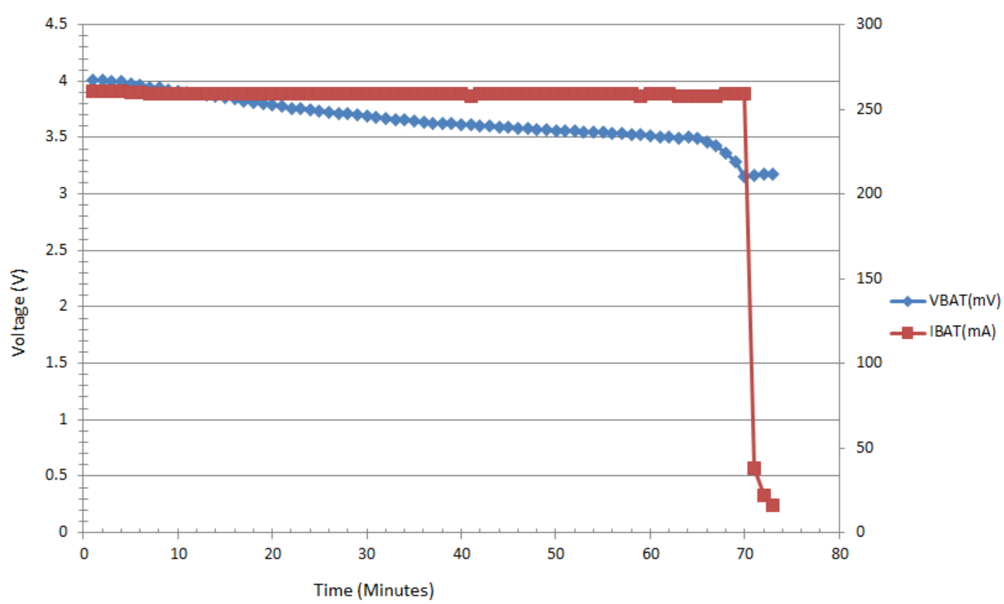
### 3.1 bq25120 220mA Charging Plot

Plot below shows battery charged by micro-USB 5V power input through bq25120, the charging terminated when charging current reaching 10mA. There is about 2 minutes pre-charge when battery voltage lower than 3.5V.



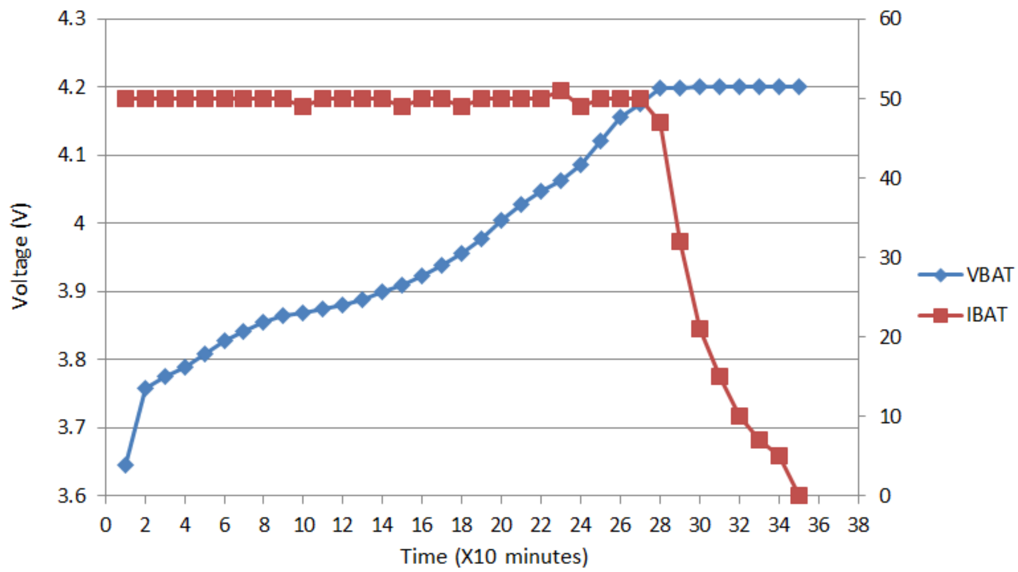

### 3.2 bq25120 260mA Discharging Plot

Plot below shows battery discharged by 260mA constant current, the discharging terminated when battery voltage below than 3.15V.



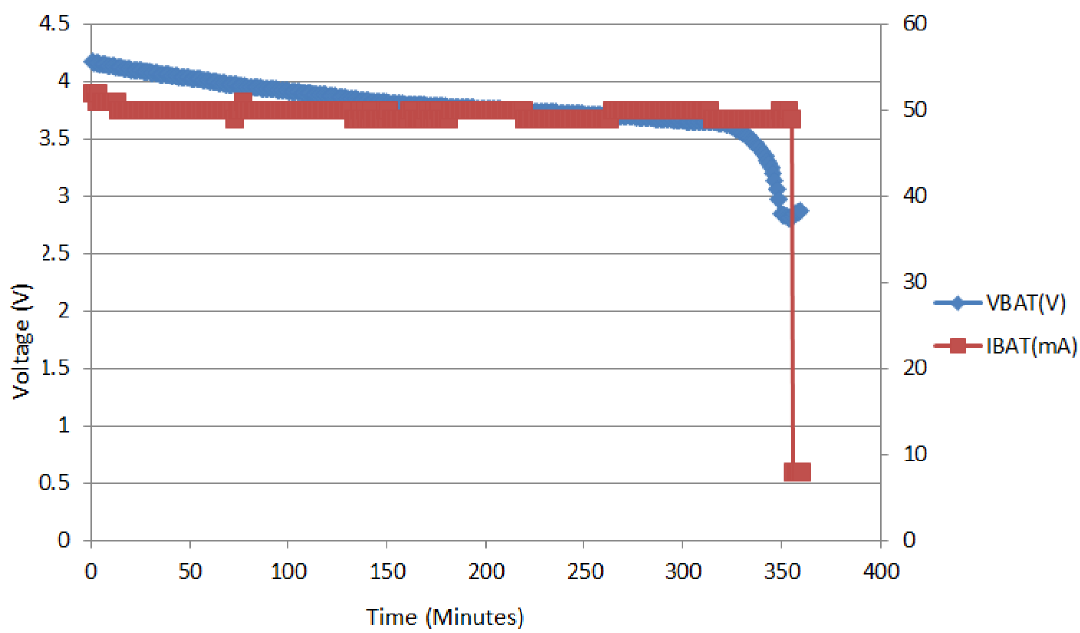
## 3.3 bq25120 50mA Charging Plot

Plot below shows battery charged by 50mA constant current, the charging terminated when charging current below than 0.5mA.



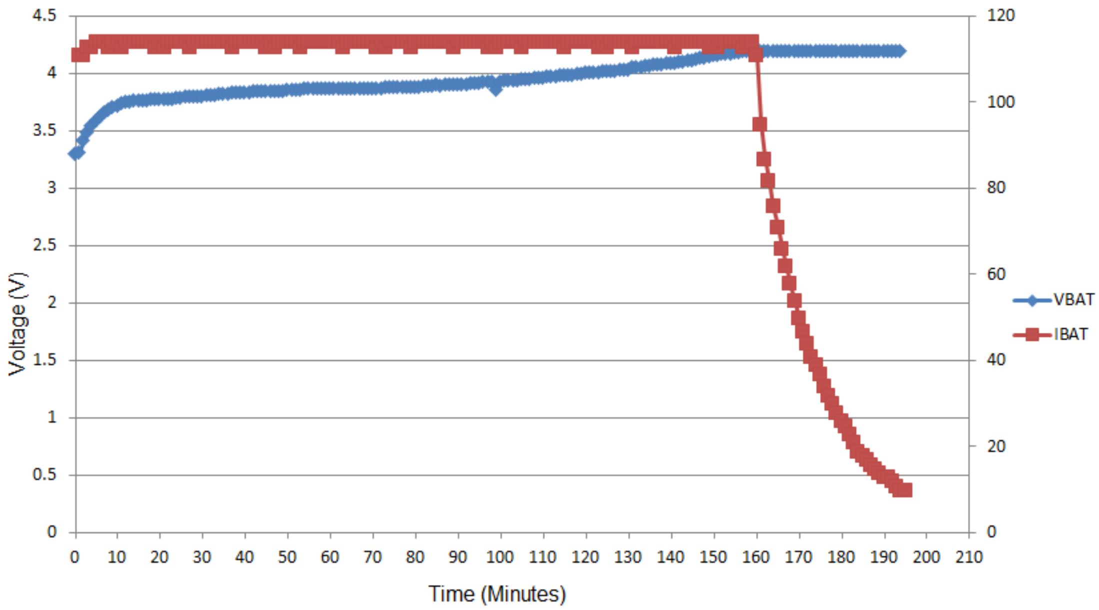

## 3.4 bq25120 50mA Discharging Plot

Plot below shows battery discharged by 50mA constant current, the discharging terminated when battery voltage below than 2.85V.



## 3.5 bq25120 110mA Charging Plot by Wireless Power

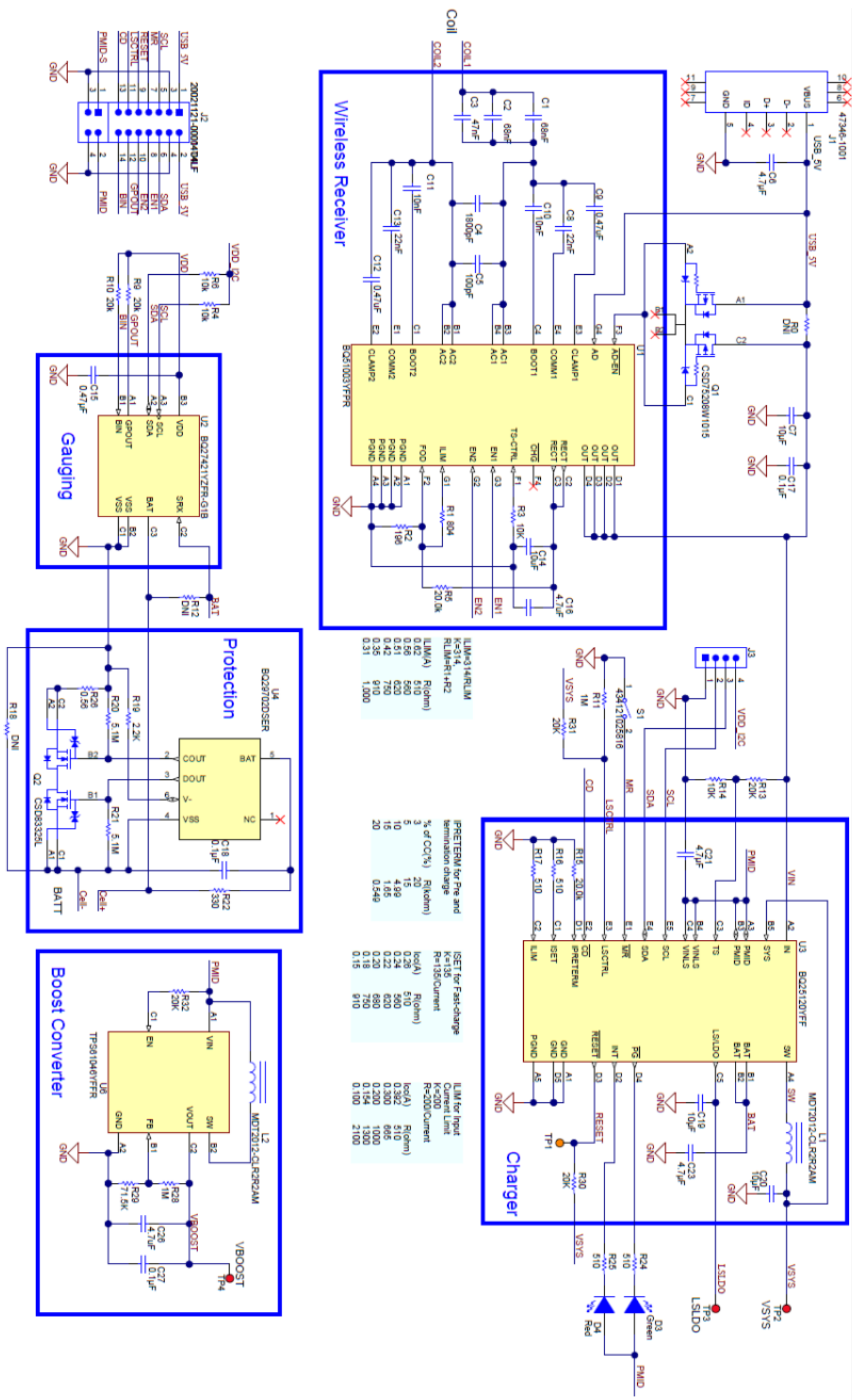
Plot shows 110mA constant current charge cycle powered by wireless power receiver.




# 4 Design Files

## 4.1 Schematic

To download the Schematic for the board, see the design files at http://www.ti.com/tool/TIDA-00712


Wireless Receiver
Gauging
Protection
Boost Converter
Charger
Coil

## 4.2 Bill of Materials

| QTY | Designator | Description | Part Number |
|---|---|---|---|
| 2 | C1, C2 | CAP, CERM, 0.068uF, 25V, +/-10%, X7R, 0603 | GRM188R71E683KA01D |
| 1 | C3 | CAP, CERM, 0.047uF, 25V, +/-5%, X7R, 0603 | 06033C473JAT2A |
| 1 | C14 | CAP, CERM, 10uF, 16V, +/-20%, X5R, 0603 | EMK107BBJ106MA-T |
| 1 | C5 | CAP, CERM, 100pF, 25V, +/-10%, X7R, 0201 | GRM033R71E101KA01D |
| 1 | C15 | CAP, CERM, 0.47 µF, 6.3 V, +/- 10%, X5R, 0402 | GRM155R60J474KE19D |
| 2 | C6, C21, C23 | CAP, CERM, 4.7 µF, 10V, +/- 20%, X5R, 0402 | GRM155R61C475ME11D |
| 1 | C17, C18, C27 | CAP, CERM, 0.1 µF, 16 V, +/- 10%, X7R, 0402 | GRM155R71C104KA88D |
| 2 | C10, C11 | CAP, CERM, 0.01uF, 25V, +/-10%, X7R, 0402 | GRM155R71E103KA01D |
| 2 | C8, C13 | CAP, CERM, 0.022uF, 25V, +/-10%, X7R, 0402 | GRM155R71E223KA61D |
| 1 | C4 | CAP, CERM, 1800 pF, 50 V, +/- 10%, X7R, 0402 | GRM155R71H182KA01D |
| 2 | C16, C26 | CAP, CERM, 4.7uF, 16V, +/-10%, X5R, 0603 | GRM188R61C475KAAJ |
| 2 | C9, C12 | CAP, CERM, 0.47uF, 25V, +/-10%, X7R, 0603 | GRM188R71E474KA12D |
| 1 | D4 | LED, Red, SMD | LTST-C190CKT |
| 1 | D3 | LED, Green, SMD | LTST-C191KGKT |
| 3 | C7, C19, C20 | CAP, CERM, 10 µF, 10 V, +/- 20%, X5R, 0402 | CL05A106MP5NUNC |
| 3 | FID1, FID2, FID3 | Fiducial mark.  There is nothing to buy or mount. | Fiducial |
| 1 | J1 | Receptacle, Micro-USB-B, Right Angle, SMD | 1050170001 |
| 1 | J3 | Header (friction lock), 100mil, 4x1, R/A, TH | 640457-4 |
| 1 | Q1 | MOSFET, P-CH, -20 V, -1.6 A, | CSD75208W1015 |
| 1 | Q2 | MOSFET, N-CH,  V,  A, | CSD83325L |
| 2 | L1, L2 | Inductor, Multilayer, 2.2 µH, 1.35 A, 0.23 ohm, SMD | MDT2012-CLR2R2AM |
| 1 | R1 | RES, 804, 1%, 0.05 W, 0201 | CRCW0201845RFKED |
| 1 | R2 | RES, 196, 1%, 0.05 W, 0201 | CRCW0201196RFKED |
| 1 | R3, R4, R6 | RES, 10k, 5%, 0.05 W, 0201 | ERJ-1GEJ103C |
| 7 | R5, R9, R10, R15, R30, R31, R32 | RES, 20.0 k, 1%, 0.05 W, 0201 | CRCW020120K0FKED |
| 1 | R11, R28 | RES, 1M, 5%, 0.05 W, 0201 | ERJ-1GEF1004C |
| 1 | R13 | RES, 14.0K, 1%, 0.05 W, 0201 | ERJ-1GEF1402C |
| 1 | R14 | RES, 14.3K, 1%, 0.05 W, 0201 | ERJ-1GEF1432C |
| 1 | R29 | RES, 71.5K, 1%, 0.05 W, 0201 | ERJ-1GEF7152C |
| 1 | R19 | RES, 2.2K, 1%, 0.05 W, 0201 | ERJ-1GEJ222C |
| 2 | R20, R21 | RES, 5.1M, 5%, 0.05 W, 0201 | ERJ-1GEJ515C |
| 1 | R22 | RES, 330 Ohm, 5%, 0.05 W, 0201 | ERJ-1GEJ331C |
| 4 | R17, R16, R24, R25 | RES, 510 Ohm, 5%, 0.05 W, 0201 | ERJ-1GEJ511C |
| 1 | R26 | RES, 0.56, 5%, 0.05 W, 0201 | UCR006YVPFLR560 |
| 1 | S1 | SWITCH TACTILE SPST-NO 0.05A 32V | 732-7045-1-ND |
| 1 | TP1 | Test Point, Miniature, Orange, TH | 5003K-ND |
| 3 | TP2, TP3, TP4 | Test Point, Compact, Red, TH | 5005K-ND |
| 0 | TP5, TP6 | Test Point, Compact, Black, TH | 5006K-ND |
| 1 | U1 | Highly Integrated Wireless Receiver Qi (WPC v1.1) Compliant Power Supply, YFP0028APAL | BQ51003YFPR |
| 1 | U2 | System-Side Impedance Track Fuel Gauge With Integrated Sense Resistor, YZF0009AKAL | BQ27421YZFR-G1B |
| 1 | U3 | YFF0025AWAW | BQ25120YFP |
| 1 | U4 | Cost-Effective Voltage and Current Protection Integrated Circuit for Single-Cell Li-Ion/Li-Polymer Batteries, DSE0006A | BQ2970DSER |
| 1 | U6 | 28-V Output Voltage Boost Converter in WCSP Package, YFF0006AAAA | TPS61046YFFR |

## 4.3 PCB Layout Recommendations

**Layout Guidelines**

As for all switching power supplies, the PCB layout is an important step in the design, especially at high peak currents and high switching frequencies. If the layout is not carefully done, the boost charger and buck converter could show stability problems as well as EMI problems. Therefore, use wide and short traces for the main current path and for the power ground paths. The input and output capacitors as well as the inductors should be placed as close as possible to the IC. For the boost charger the first priority is the output capacitors, including the 0.1uF bypass capacitor (CBYP). Next the input capacitor should be placed as close as possible between VIN and VSS. Last in priority is the boost charger's
inductor, which should be placed close to LBOOST and VIN. For the buck converter, the output capacitor COUT should be placed as close as possible between VOUT and VSS. The buck converter inductor (L2) should be placed as close as possible between the switching node LBUCK and VOUT. It is best to use vias and bottom traces for connecting the inductors to their respective pins instead of the capacitors.

To minimize noise pickup by the high impedance voltage setting nodes the external resistors should be placed so that the traces connecting the midpoints of each divider to their respective pins are as short as possible. When laying out the non-power ground return paths (for example, from resistors and CREF), it is recommended to use short traces as well, separated from the power ground traces and connected to VSS. This avoids ground shift problems, which can occur due to superimposition of power ground current and control ground current. The PowerPAD should not be used as a power ground return path.

The remaining pins are either NC pins that should be connected to the PowerPAD as shown below or digital signals with minimal layout restrictions.

During board assembly, contaminants such as solder flux and even some board cleaning agents can leave residue that may form parasitic resistors across the physical resistors/capacitors and/or from one end of a resistor/capacitor to ground, especially in humid, fast airflow environments. This can result in the voltage regulation and threshold levels changing significantly from those expected per the installed components. Therefore, it is highly recommended that no ground planes be poured near the voltage setting resistors or the sample and hold capacitor. In addition, the boards must be carefully cleaned, possibly rotated at least once during cleaning, and then rinsed with de-ionized water until the ionic contamination of that water is well above 50mOhm. If this is not feasible, then it is recommended that the sum of the voltage setting resistors be reduced to at least 5X below the measured ionic contamination.

**Thermal Considerations**

Implementation of integrated circuits in low-profile and fine-pitch surface-mount packages typically requires special attention to power dissipation. Many system-dependent issues such as thermal coupling, airflow, added heat sinks and convection surfaces, and the presence of other heat-generating components affect the power dissipation limits of a given component.

Three basic approaches for enhancing thermal performance are listed below.

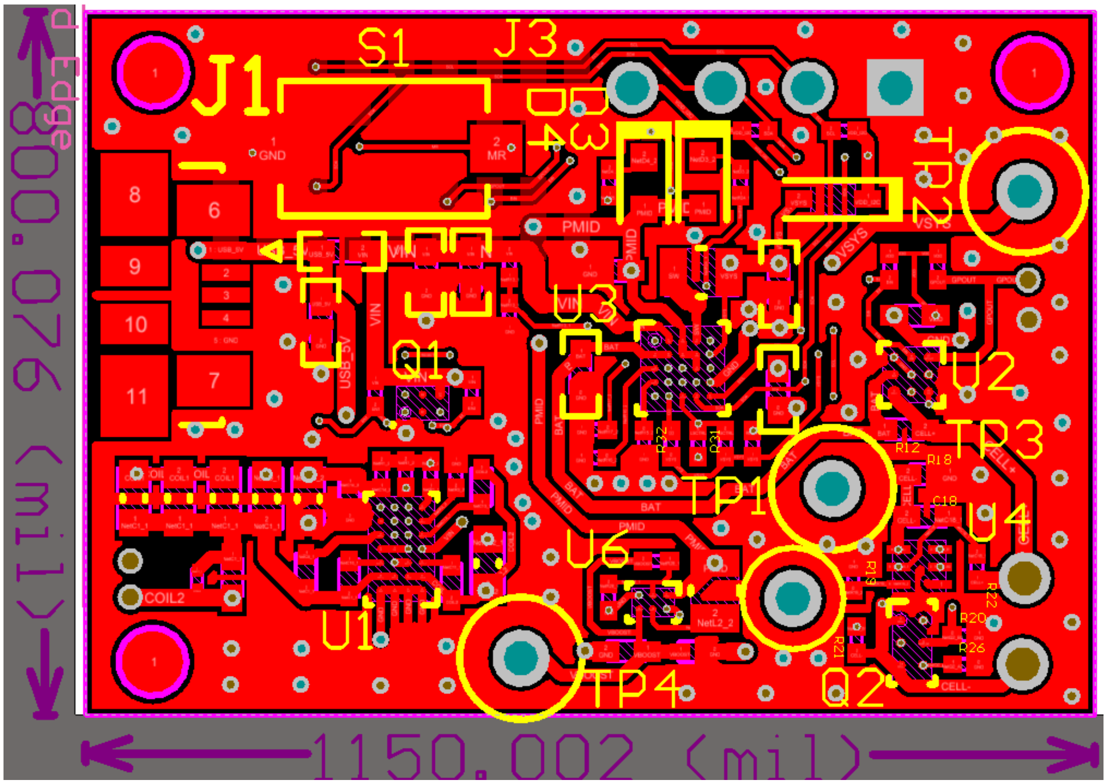
- Improving the power-dissipation capability of the PCB design
- Improving the thermal coupling of the component to the PCB
- Introducing airflow in the system

For more details on how to use the thermal parameters in the dissipation ratings table please check the Thermal Characteristics Application Note (SZZA017) and the IC Package Thermal Metrics Application Note (SPRA953).

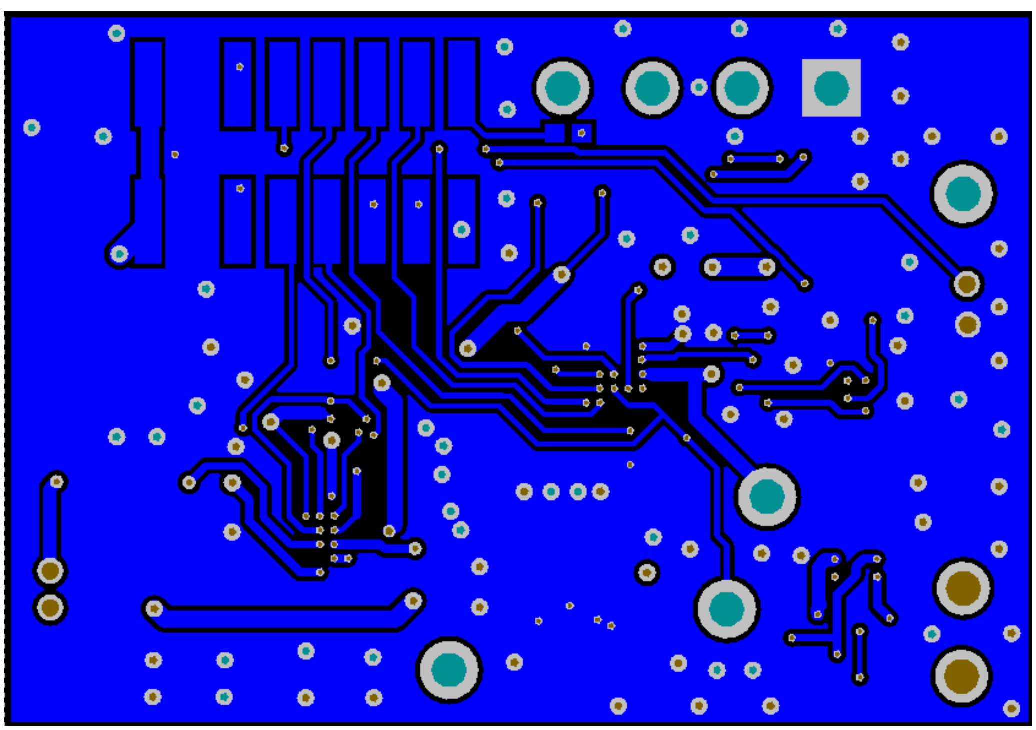
## 4.4 Layout Prints

To download the Layout Prints for each board, see the design files at http://www.ti.com/tooi/TIDA-00712

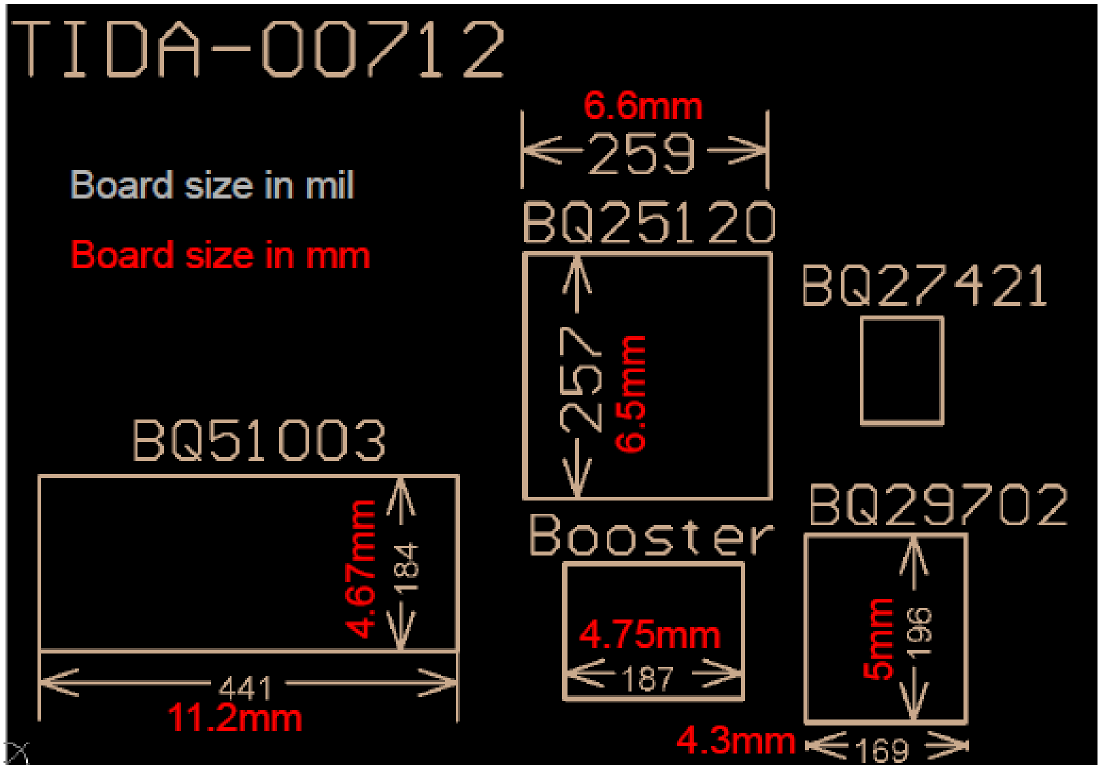
**PCB top layer printout:**




**PCB bottom layer printout:**



**PCB bottom over layer printout shows each circuit size below:**




PCB components body printout shows below: