TI Designs

Tiny I²C-Controlled Single-Cell Charger Reference Design for Wearable Applications

TEXAS INSTRUMENTS

Description

The TIDA-03042 TI Design is a single-cell charger reference design for wearable applications which have a very limited design space. TIDA-03042 works with a host controller through I²C control, supports 5-V, 9-V, or 12-V input adaptors and can charge up to 1.5 A. The actual charger design only requires a space of 1.7 cm², allowing for high charging efficiency while minimizing the total count of components and board size.

Resources

TIDA-03042	Design Folder
BQ25898	Product Folder

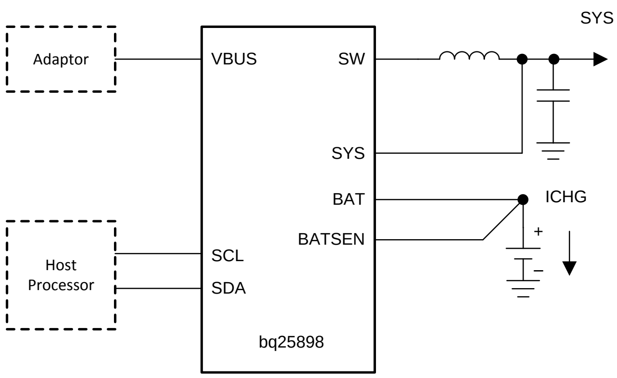
TI E2E™ Community — ASK Our E2E Experts

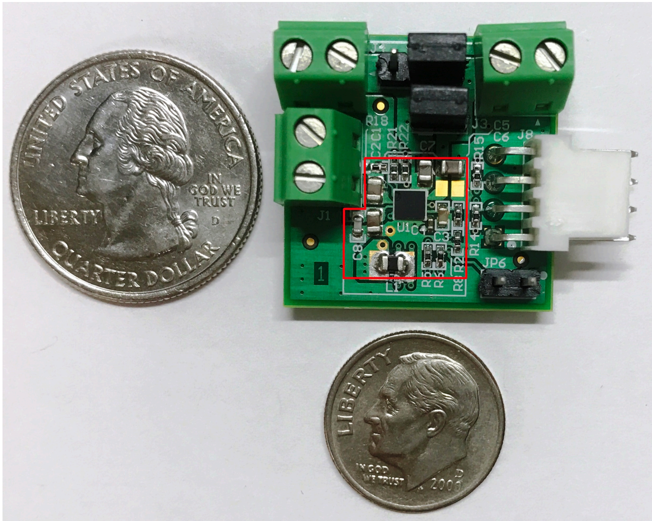
Features

- Up to 1.5-A Single-Cell Charger
- Charge Efficiency of 92% at 0.5 A and 1.5 A
- Low-Power PFM Mode for Light Load Operations
- High-Input Voltage Operation Range From 3.9 V to 14 V

Applications

- Smart Watch
- Activity Tracker
- Headset





An IMPORTANT NOTICE at the end of this TI reference design addresses authorized use, intellectual property matters and other important disclaimers and information.

1 System Overview

1.1 System Description

This system is designed as a reference for smart watch and all other wearable applications that require up to 1.5-A charge current for a single-cell Li-Ion battery. This TIDA-03042 design requires a host controller to set the target pre-charge current, fast charge current, charge termination current, charge voltage limit, and the applicable charging profile parameters for the specific single-cell Li-Ion battery in use through I^2C control. The TIDA-03042 design can be used as a standard charger module for various single-cell Li-Ion battery designs.

1.2 Key System Specifications

Table 1. Key System Specifications

PARAMETER	DESCRIPTION	MIN	TYP	MAX	UNIT
VBUS	Input voltage from AC adaptor	3.9	—	14	V
VBAT	Voltage applied to BAT pin	0	—	4.5	V
ICHG	Fast charge current	0	—	2	A
IINDPM	Input current limit	0	—	1.5	A

1.3 Block Diagram

Figure 1 shows the block diagram of the TIDA-03042.

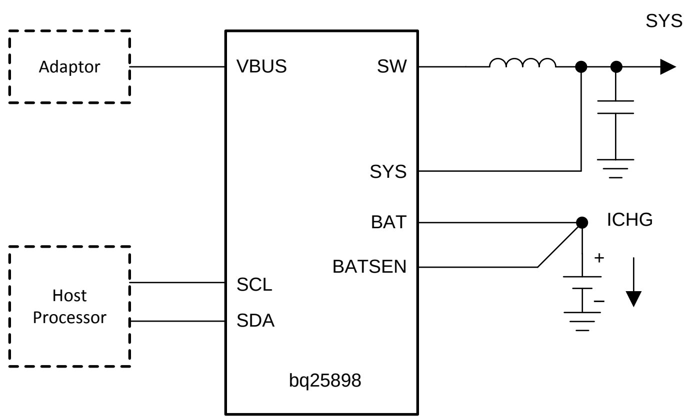


Figure 1. TIDA-03042 Block Diagram

1.4 Highlighted Products

1.4.1 BQ25898

The BQ25898 is a highly-integrated switch-mode battery charge management and system power path management device for a single-cell Li-Ion and Li-polymer battery for power banks, tablets, and other portable device applications. Its low-impedance power path optimizes switch-mode operation efficiency, reduces battery charging time, and extends battery life during discharging phase. The I^2C serial interface with charging and system settings makes the device a truly flexible solution. The device has the following key features:

- High-efficiency, 1.5-MHz switch mode buck charge
  - Pulse-frequency modulation (PFM) at light load to boost low-power efficiency
- Single input to support USB input and adjustable high-voltage adapters
  - Supports 3.9-V to 14-V input voltage range
  - Input current limit (100 mA to 3.25 A with 50-mA resolution) to support USB2.0, USB3.0 standard, and high-voltage adapters
- Narrow VDC (NVDC) power-path management
  - Instant-on works with no battery or deeply-discharged battery
  - Ideal diode operation in battery supplement mode
- BATFET control to support ship mode, wakeup, and full-system reset
- Remote battery sensing
- High regulation accuracy
  - ±0.5% charge voltage regulation
  - ±5% charge current regulation
  - ±7.5% input current regulation

2 System Design Theory

2.1 Charger With Remote Battery Sensing

The bq25898 charger integrated circuit (IC) is used in this TI Design with remote battery sensing to improve the charge voltage accuracy and reduce the charge time.

2.2 Default Power-On Reset Setting

All registers reset to the default values when the device has been powered up on reset. Table 2 lists the device default charging parameters.

Table 2. bq25898 Charging Parameter Default Setting

DEFAULT MODE	bq25898
Charging voltage	4.208 V
Charging current	2.048 A
Pre-charge current	128 mA
Termination current	256 mA
Temperature profile	JEITA
Safety timer	12 hours

2.3 Host Control

The host can access all the registers after power-on reset (POR) and control the charging operations and optimize the charging parameters by writing to the corresponding registers through I^2C.

The input current limit set by the ILIM pin is 1.5 A. The actual input current limit is the lower limit set by the ILIM pin (when the EN_ILIM bit REG00[6] is high) or IINLIM register bits (REG00[5:0]).

3 Getting Started Hardware and Software

3.1 Hardware

3.1.1 Power Supplies

For testing purposes, this reference design requires a power supply capable of supplying at least 2 A.

3.1.2 Battery Simulator

For testing purposes, a battery simulator capable of sinking and sourcing current with constant voltage mode is required to test the charging function of the reference design.

3.1.3 EV2300/EV2400 I^2C Adapter for PC Connection

The EV2300/EV2400 is a USB-based interface board for the PC that can be used to evaluate battery charger circuits designed with ICs from Texas Instruments. The EV2300/EV2400 board has connections on it for a USB cable and also accepts inputs from the communication port of a battery charger circuit. The EV2300/EV2400 interface board allows the user to evaluate the battery charger circuit by running the appropriate PC software for the corresponding charger IC.

NOTE: The driver on this page is for the 32-bit version of the Windows® operating system. See the post for the 64-bit driver on the E2E™ online community for the 64-bit Microsoft Windows® 7 driver information.

3.2 bqStudio Software

Battery Management Studio (bqStudio) offers a full suite of robust tools to assist with the process of evaluating, designing with, configuring, testing, or otherwise using TI battery-management products. This software includes the following features:

- Full access to registers and data memory including support for real-time watching, graphing, and logging an easy interface to send commands, direct low-level communication, and I/O
- Automated and guided support for configuration, calibration, performing a learning cycle, and generating useful files for taking the device to production

NOTE: Older products such as bq2419x and bq2429x are not supported in bqStudio. Download the specific evaluation software from the appropriate product page.

To download the bqStudio software, see the file "Battery Management Studio (bqStudio) Software Suite" at http://www.ti.com/tool/bqstudio.

4 Testing and Results

4.1 Test Equipment

The following subsections describe the test equipment and their purpose when testing this TI Design.

4.1.1 Laptop PC

A laptop PC with a Windows 7 operating system is used to run the bqStuido software with an EV2300/EV2400 adapter.

4.1.2 EV2300/EV2400 Adapter

The EV2300/EV2400 adapter is used between the PC and the reference design board for I^2C communication to control the test.

4.1.3 Agilent Multimeters

Multimeters are used to measure the currents and voltages during the related tests.

4.1.4 Kepco Bipolar Operational Power Supply

A Kepco power supply is used to simulate a battery that can be charged and discharged.

4.1.5 Hewlett Packard System DC Power Supply

A power supply is used to supply the VBUS power to charge during the charger test.

4.1.6 TIDA-03042 Board

The TIDA-03042 board is a printed-circuit board (PCB) with all the devices in this design.

4.2 Test Bench Setup

Figure 2 shows the test bench setup.

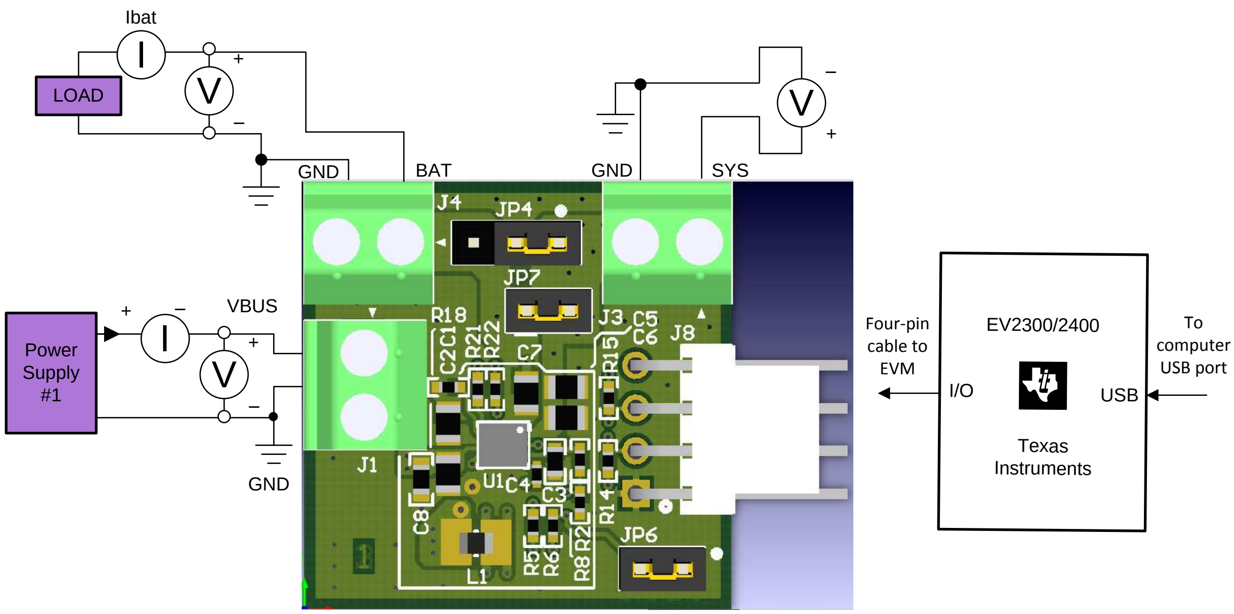


Figure 2. Test Setup

4.3 Test Results

4.3.1 Major Outputs Test

Table 3. Major Outputs Test Results

PARAMETER	TEST CONDITION	TYP	UNIT
SYS voltage	VBUS = 5 V, ICHG = 0 mA (charge disabled), MIN SYS SETTING = 3.5 V	3.74	V
Precharge current	VBUS = 5 V, VBAT = 2.8 V, IPRECHG SETTING = 128 mA	149	mA
Fast charge current	VBUS = 5 V, VBAT = 3.8 V, ICHG SETTING = 2 A	1.937	A
Charge voltage limit	VBUS = 5 V, VBAT SETTING = 4.208 V	4.208	V
OTG output voltage	VBAT = 4 V, IOTG = 0 A, VOTG SETTING = 4.998 V	5.028	V

4.3.2 Charging Efficiency at VBUS = 5 V

Figure 3 shows the efficiency values for common charge-current thresholds using the TIDA-03042 with a bq25898 device. In this example, users can see that the efficiency peaks around ICHG = 0.7 A @ about 92.5% efficiency.

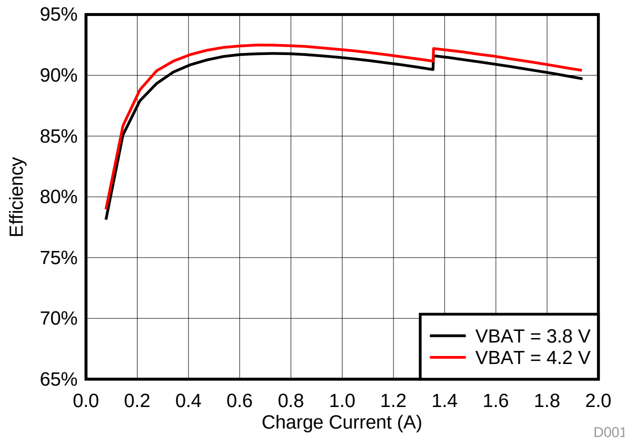


Figure 3. Charging Efficiency at VBUS = 5 V

4.3.3 Thermal Performance at VBUS = 5 V and ICHG = 0.5 A

Figure 4, Figure 5, and Figure 6 show the thermal performances of the TIDA-03042 design. The IC temperature only rises to approximately 37°C when ICHG = 0.5 A on such a tiny board.

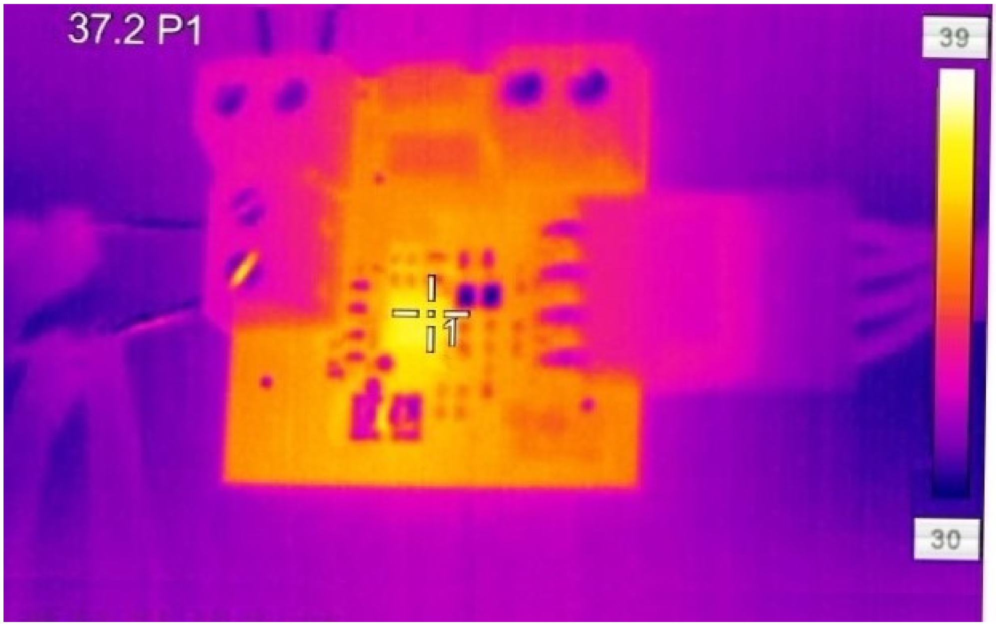


Figure 4. Thermal Performance at VBUS = 5 V and ICHG = 0.5 A

4.3.4 Thermal Performance at VBUS = 5 V and ICHG = 1.0 A

Figure 5 shows the IC temperature rises to approximately 42°C when ICHG = 1 A.

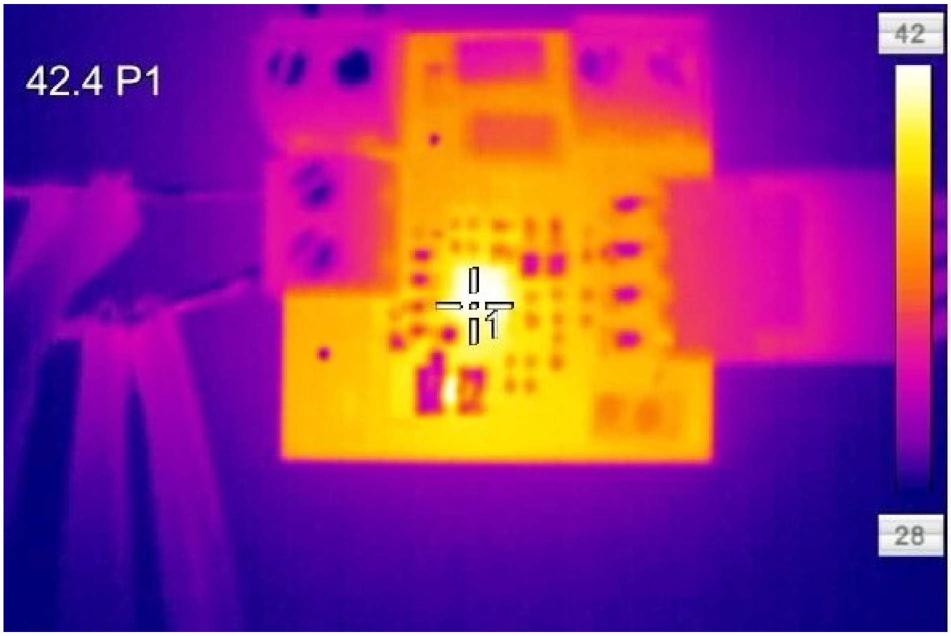


Figure 5. Thermal Performance at VBUS = 5 V and ICHG = 1 A

4.3.5 Thermal Performance at VBUS = 5 V and ICHG = 1.5 A

Figure 6 shows the IC temperature rises to approximately 50°C when ICHG = 1.5 A.

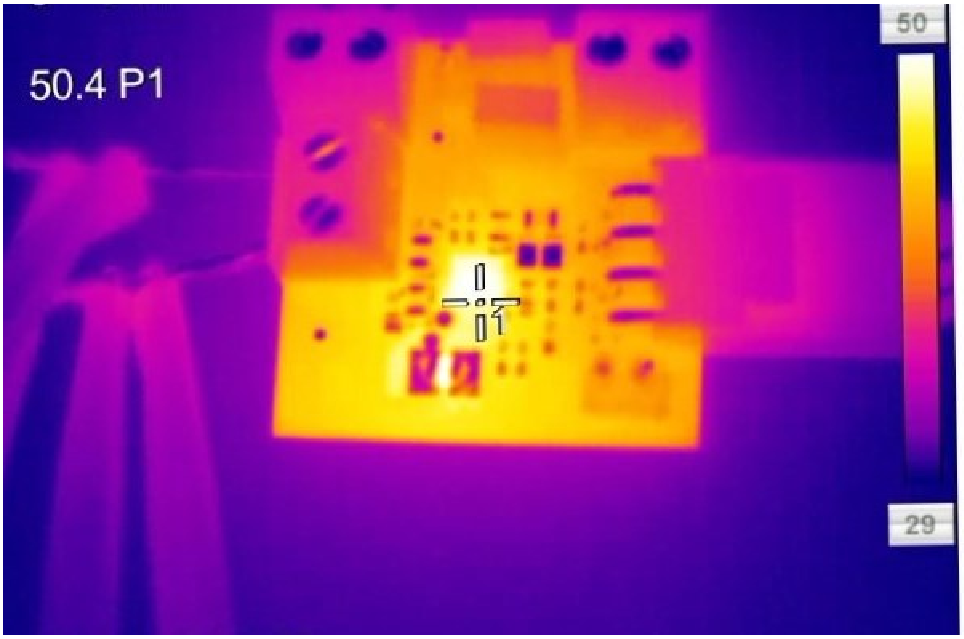


Figure 6. Thermal Performance at VBUS = 5 V and ICHG = 1.5 A

5 Design Files

5.1 Schematics

To download the schematics, see the design files at TIDA-03042.

5.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-03042.

5.3 Altium Project

To download the Altium project files, see the design files at TIDA-03042.

5.4 Gerber Files

To download the Gerber files, see the design files at TIDA-03042.

5.5 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-03042.

5.6 Trademarks

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6 About the Author

NING TANG is an applications engineer at Texas Instruments supporting switching converter solutions in battery charging applications. She is responsible for providing technical support and developing EVMs and design notes for single-cell chargers. Ning brings to this role her more than 10 years of extensive experiences in the switching power supply design field.