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ADP5065 Evaluation Board Manual

FEATURES

Input voltage of 4.0 V to 5.5 V
High current terminals for ADP5065 power connection (VINx), system voltage (ISO_Sx), and battery voltage (ISO_Bx) pins
ADP5065 operation is configurable via I²C interface
Evaluation software included

GENERAL DESCRIPTION

The ADP5065 charger evaluation system is composed of an evaluation board and an USB-to-IIC converter dongle. All evaluation board functions and circuits are controlled via one I²C bus connector. The I²C bus interfaces to the ADP5065 directly, and the digital input/output signals are controlled through an on-board input/output expander circuit for the I²C bus. The evaluation board also features a 3.4 V regulator for VDDIO generation. The board contains jumpers and numerous test points for easy evaluation.

Full performance details are provided in the ADP5065 data sheet, which is available at www.analog.com. The ADP5065 data sheet should be consulted in conjunction with this user guide.
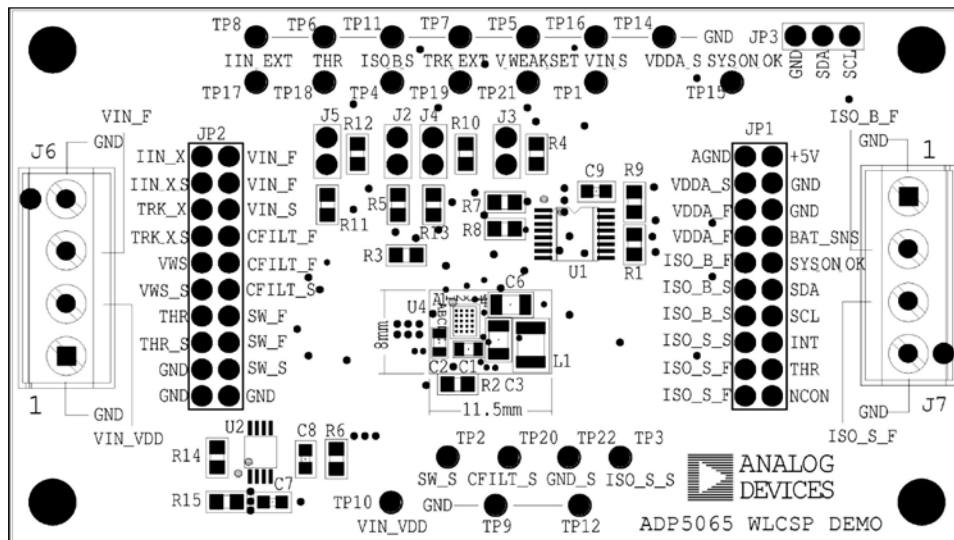
ADP5065 EVALUATION BOARD

Figure 1.

PLEASE SEE THE LAST PAGE FOR AN IMPORTANT
WARNING AND LEGAL TERMS AND CONDITIONS.

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REVISION HISTORY

8/12—Revision 0: Initial Version

SOFTWARE INSTALLATIONS

INSTALLING THE EVALUATION SOFTWARE

1. Insert the ADP5065-EVALZ setup CD into the CD-ROM and run the file **Setup.exe**.
2. When the dialog box shown in Figure 2 appears, click **Next>>** to install the files to the default destination folder or click **Browse…** to choose a different location.
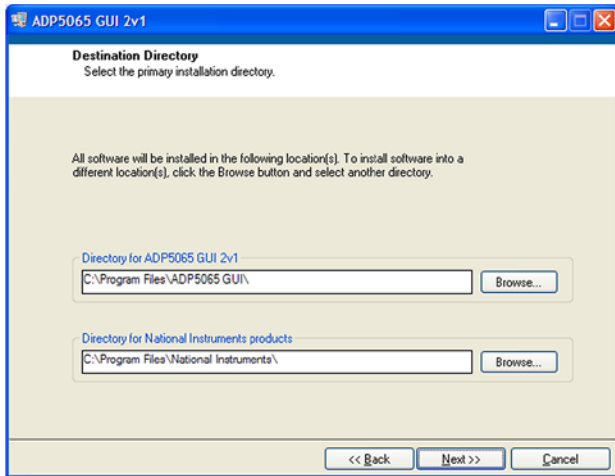

Figure 2. ADP5065 Evaluation Software Setup

3. Select **I accept the License Agreement(s)**, and then click **Next>>** to continue.
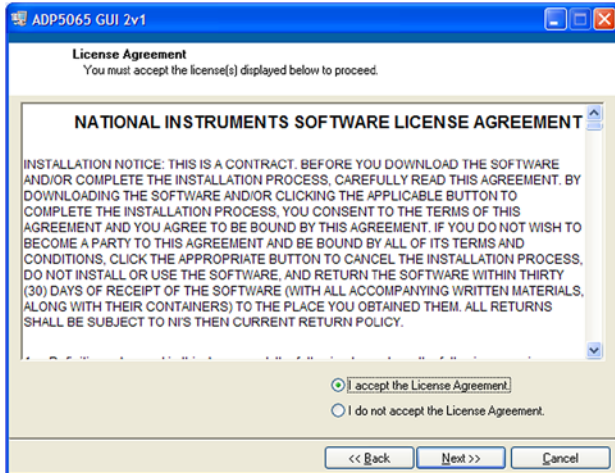

Figure 3. National Instruments Software License Agreement
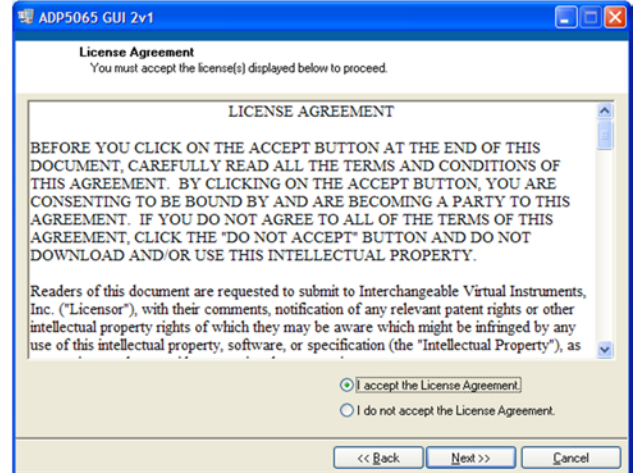

Figure 4. IVI License Agreement

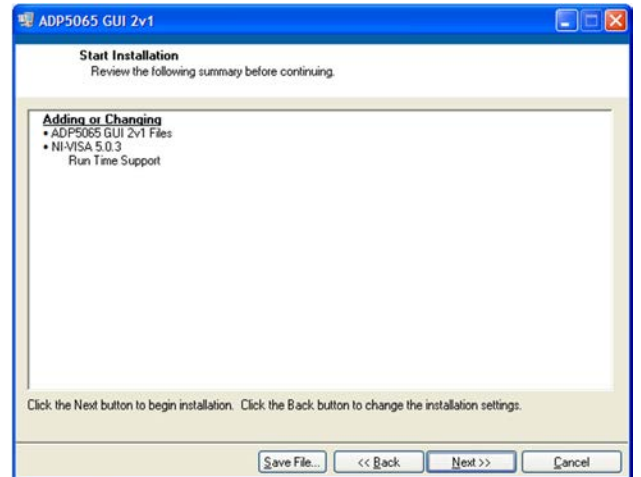4. A summary of the installation appears. Click **Next>>** to continue.

Figure 5. Installation Summary

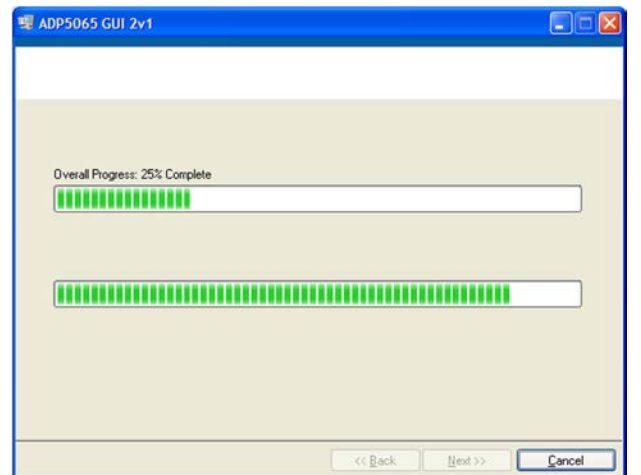5. Wait while the software is installed.

Figure 6. Installation Progress

6. Click **Finish** to complete the installation.
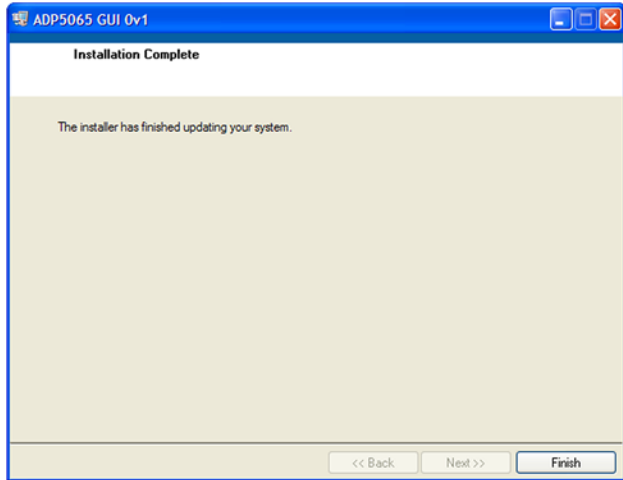
Figure 7. Installation Complete

7. After the installation is completed, a dialog box opens prompting you to restart your computer if LabVIEW® Run-Time Engine 8.6 was not previously installed on the PC. Click **Restart** to complete the operation.

INSTALLING THE USB DRIVER

1. Plug the Analog Devices, Inc., USB-to-IIC converter dongle into the USB port of the computer. After the system recognizes the dongle, the dialog box **Found New Hardware Wizard** appears.

Figure 8. New Hardware Wizard

2. If there is more than one compatible driver found, select **windows\inf\usb-iic converter**, and then click **Next >** to install the driver.

Figure 9. Compatible Drivers

3. Click **Continue Anyway**, and then click **Finish** to complete the driver installation.

Figure 10. New Hardware Installation
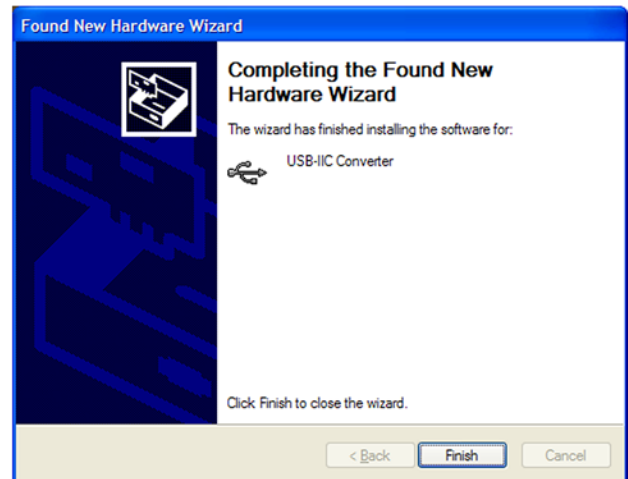
Figure 11. New Hardware Installation Completion

USING THE SOFTWARE GUI

OPERATING THE BOARD WITH THE GUI

Before running the software,

1. Ensure that the Analog Devices USB-to-IIC converter is plugged into the USB port of the computer.
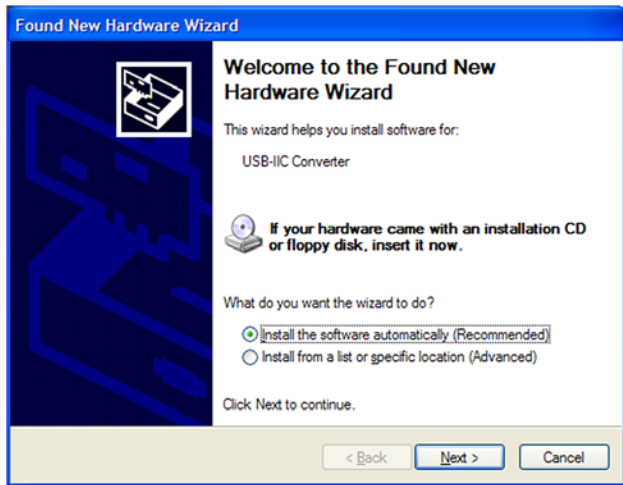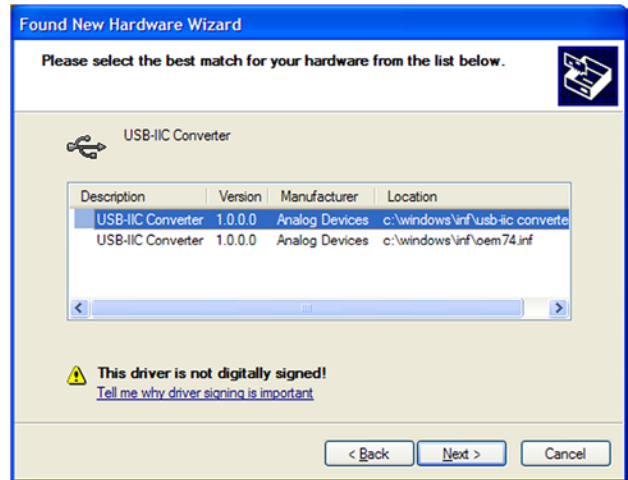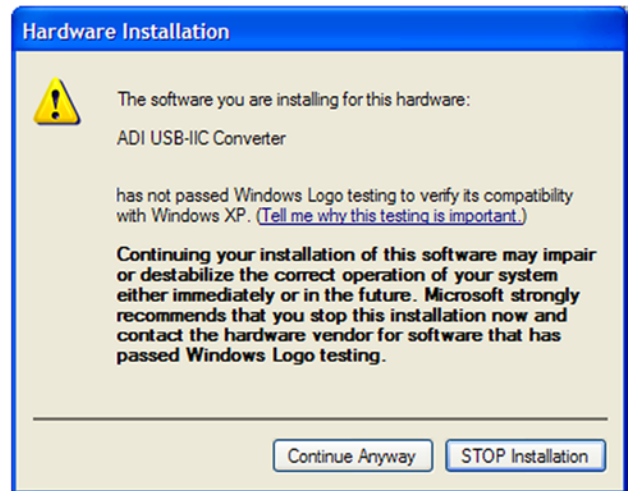2. Connect a 5 V power supply between the VIN_F and GND screw terminals (see Figure 15).
3. Click **START** > **All Programs** > **ADP5065 GUI** > **ADP5065 GUI 2vX**.

The software is then ready to use. The input voltage (V_{VIN}) should be greater than 2.5 V for ADP5065 I²C communication to start

working. The input voltage level is monitored, and indicators relay status information in the charger status area of the box (see Section 4 in Figure 12). The GUI automatically reads the content of registers every 0.3 sec after the last action and updates the status of registers on-screen.

If there is a problem with I²C communication, the status indicators on the bottom of the screen show an error message. When I²C communication is fully operational, the status indicators show I2C_STATUS_OK.
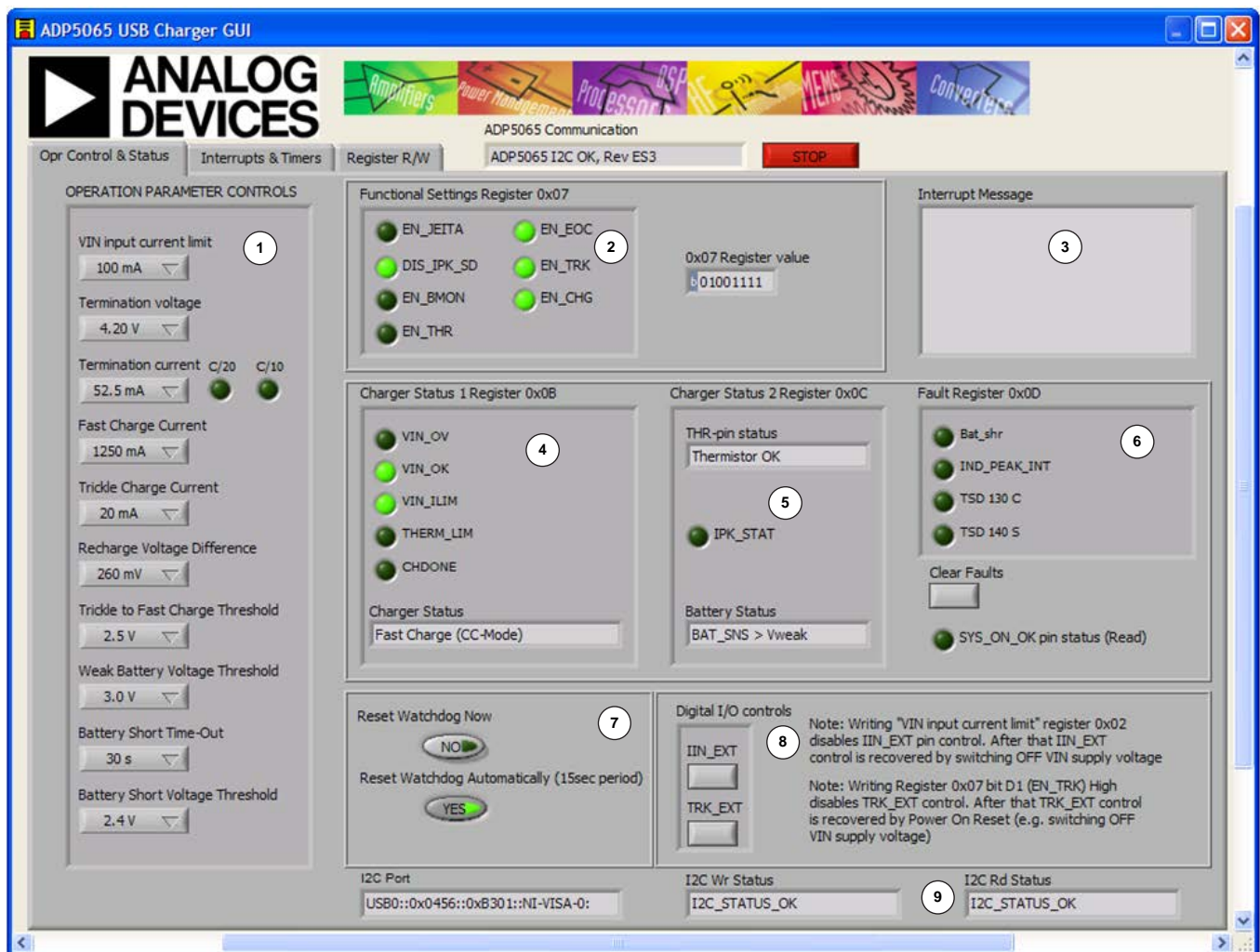
NOTES
1. OPERATION PARAMETER CONTROLS.
2. FUNCTIONAL ENABLES.
3. INTERRUPT REGISTER INDICATOR (REG 0x0A).
4. CHARGER STATUS.
5. BATTERY STATUS.
6. FAULT INDICATORS.
7. WATCHDOG CONTROL.
8. DIGITAL I/O CONTROLS.
9. I²C COMMUNICATION STATUS INDICATORS.

*Figure 12. ADP5065 Evaluation Software GUI, **Opr Control & Status** Tab*

BASIC CHARGING PARAMETER SETTINGS

After the input power supply is connected and is between 4.0 V and 5.4 V, the ADP5065 starts the charging startup. If resistance in the THR input corresponds to the battery temperature being between 0°C and 60°C when the battery detection indicates that the battery is connected at the ISO_B and BAT_SNS inputs, the ADP5065 goes into charging mode.

Charging starts with the default operational parameter settings. It is possible to change settings using controls on the left side of the **Opr Control & Status** tab.

SETTING INTERRUPTS

The ADP5065 includes several interrupt flags to inform the system microcontroller of a status change in the corresponding charger function. All interrupts are disabled by default, and each interrupt can be separately enabled by issuing an I²C write to Register 0x09.

The **Interrupts & Timers** tab (see Figure 13) in the GUI controls the register settings. Interrupt Register 0x0A is automatically read every 0.3 sec after the last user action involving the GUI. When a certain interrupt is enabled and there is a status change in the corresponding function during charging, the interrupt message is shown in the **Opr Control & Status** tab (see Section 3 of Figure 12).

SETTING TIMERS

The default settings of the timers are shown in Figure 13. Changing the timer settings can be done by clicking items in the **Timer Settings (Write to Register 0x06)** box.
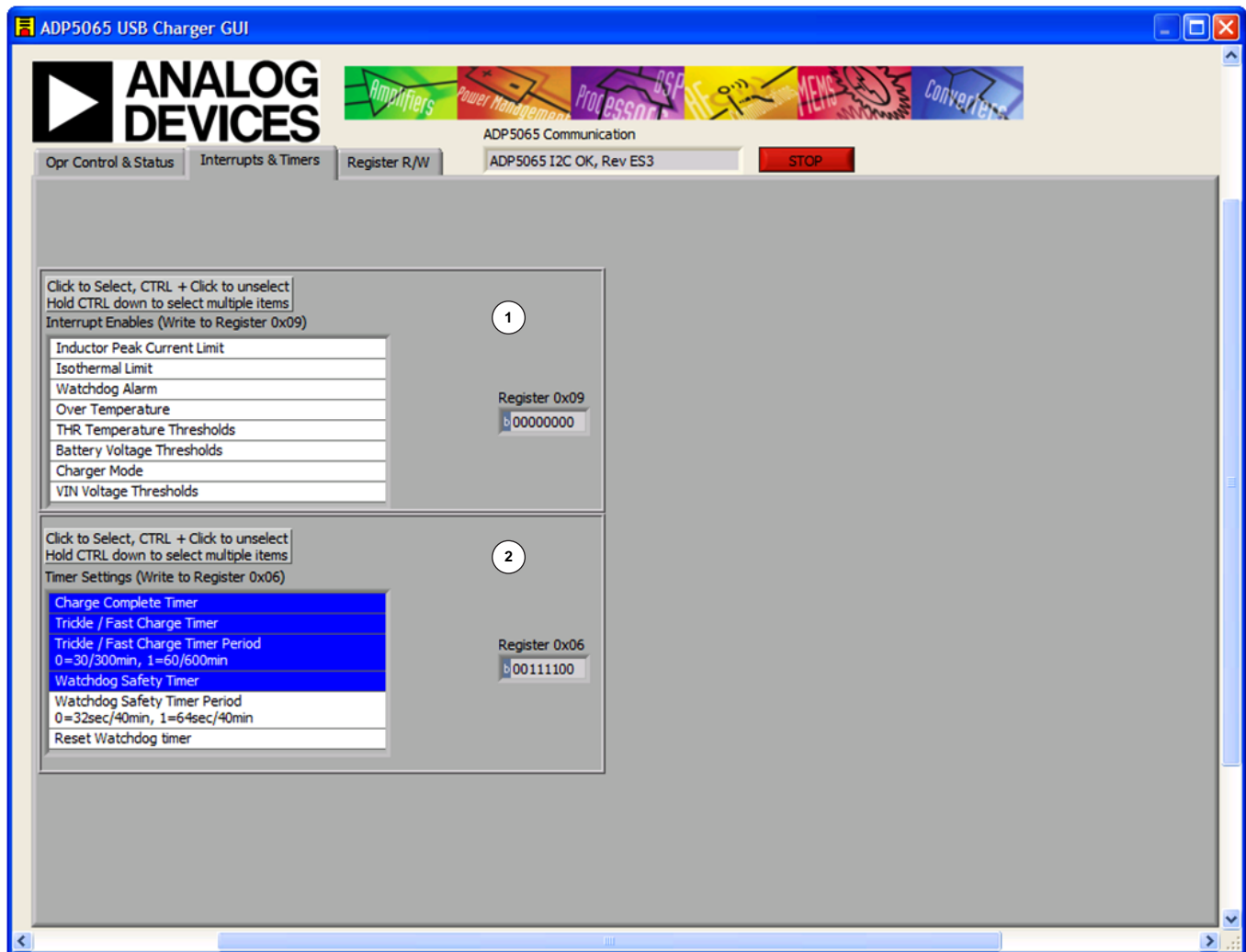
NOTES
1. REGISTER 0x09 CONTROLS: INTERRUPT ENABLES.
2. REGISTER 0x06 CONTROLS: TIMER SETTINGS.

*Figure 13. ADP5065 Evaluation Software GUI, **Interrupts & Timers** Tab*

DIRECT REGISTER READ AND WRITE

It is possible to read and write the content of each register using the **Register R/W** tab as indicated in the GUI. Clicking **READ ALL** updates the content of each register to the GUI. A single register read or write can be initiated by using the controls on the right side of the **Register R/W** tab of the GUI. Type the I²C

subaddress in the **Sub Address for READ or WRITE (0x00)** box, and then press the ENTER key. Click **READ** to read the binary data, or click **WRITE** to write the binary data. Type the binary data for an I²C write, and then press the ENTER key. Note that some registers, such as Register 0x00 and Register 0x01, are read only registers and cannot be overwritten.
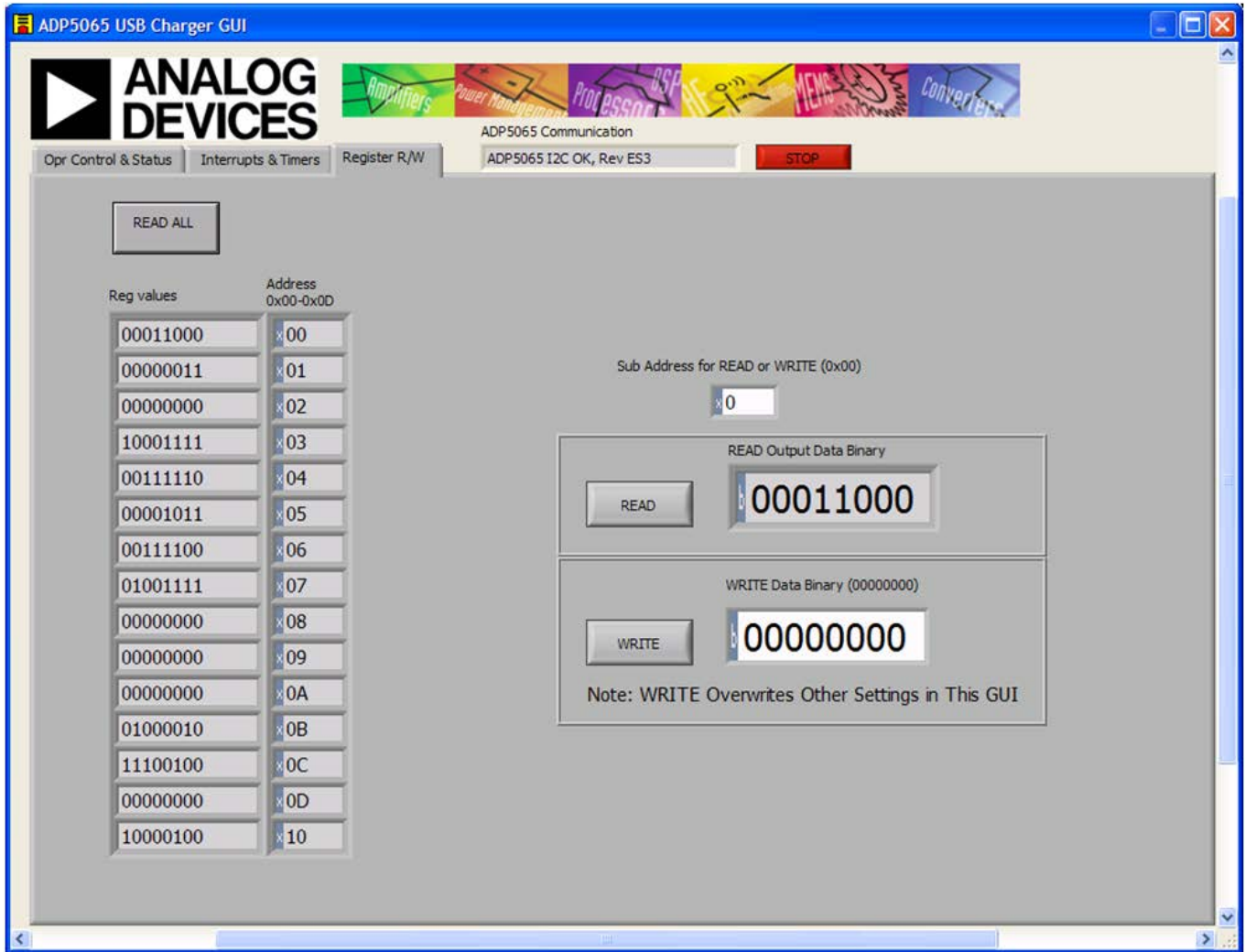
Figure 14. *ADP5065* Evaluation Software GUI, **Register R/W** Tab

GUI TROUBLESHOOTING

If the GUI is not responding to an I²C read or write command, the reason might be related to the USB-to-IIC converter communication failing due to one of the reasons discussed in this section.

Issue

The LDO ADP1720 (U1 in the schematic shown in Figure 18) is needed to generate the VDDIO voltage for the SCL/SDA pull-up resistors. If U1 does not have the proper supply voltage, the USB-to-IIC converter communication may fail.

Solution

Connect a voltage supply of greater than 3.4 V to TP5 to power up the VDDIO, or use Jumper J3 to connect the VIN_F or

ISO_S_F voltage to U1 after ensuring that there is greater than 3.4 V voltage at either of these nodes.

Issue

The ADP5065 GUI is running, and the Analog Devices USB-to-IIC converter dongle is connected. You have disconnected the LDO U1 power and then reconnected it again. For example, if U1 is powered from VIN_F and the V_{VIN} supply is switched off and then back on, the USB-to-IIC converter communication may fail.

Solution

To regain communication, stop the GUI by clicking **STOP**. Disconnect the USB-to-IIC converter dongle from your PC and then reconnect it. Start the ADP5065 GUI by clicking the **Run** button (represented by a right arrow icon).

EVALUATION BOARD OVERVIEW

TYPICAL OPERATION

A typical test setup for the ADP5065 charger consists of a dc power supply unit (PSU) for V_{VIN}, a source meter unit (SMU) or a battery simulator for the ISO_Bx pin, and a variable power resistor or an electronic load for the ISO_Sx pin (see Figure 15).

The SMU at the ISO_Bx node should have a 100 mΩ to 250 mΩ

resistor (R_S) in series with its positive lead. The resistor emulates the equivalent series resistance of a real battery. Some SMU models that have been successfully used for the ISO_Bx node are

- Keithley 2306—battery simulator
- Keithley 2602A—SMU
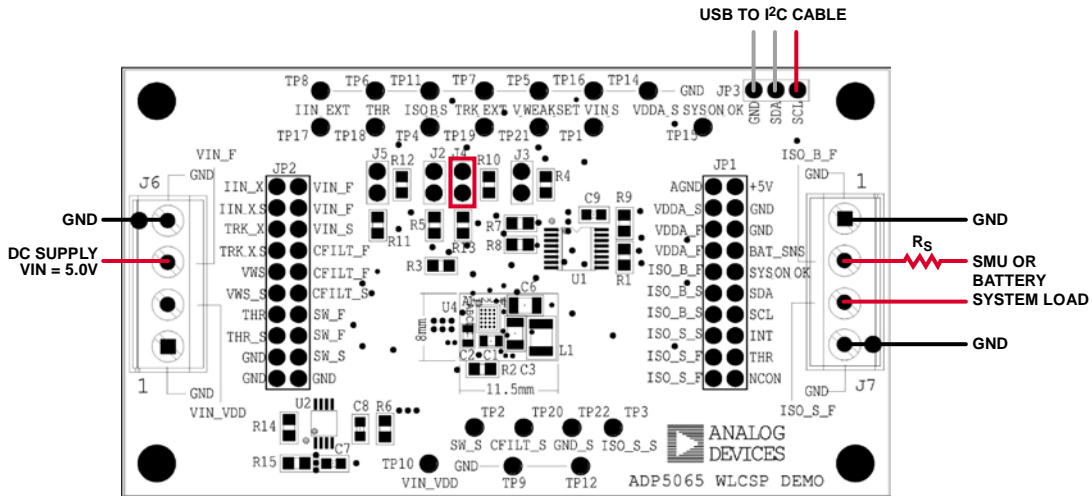- Agilent N6784A/N6762A—SMU

Figure 15. ADP5065 WLCSP Demo Board Typical Operation Setup

INPUT CURRENT

Measuring Total Input Current (I_VIN)

When measuring the total input current (I_VIN), take into account that the evaluation board includes an LDO (U1) and an I²C input/output expander (U2A). The LDO generates a 3.4 V VDDIO voltage for the I²C bus and the SYS_ON_OK open-drain output, and the input/output expander controls the IIN_EXT and TRK_EXT digital inputs.

In the default setup of the ADP5065 evaluation board, U1 and U2A are powered from the V_VIN voltage through a 0 Ω resistor (R6). Typically, the additional current consumption due to U1 and U2A is in the range of 1 mA to 2 mA. For accurate measurements of the total input current (I_VIN), remove R6 and connect a second dc power supply (in the range of 3.4 V to 5.0 V) to Screw Terminal J6 (see Figure 16).
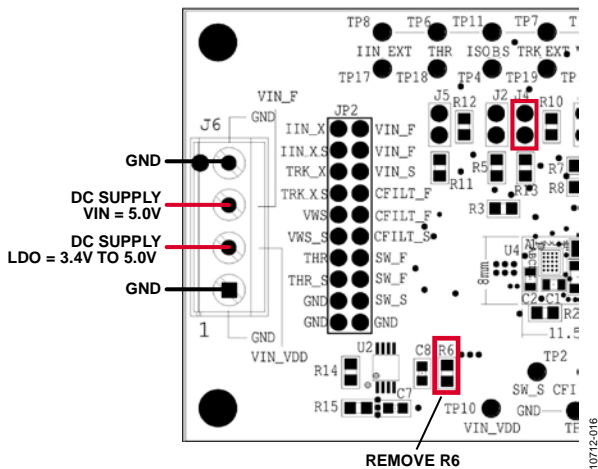
Figure 16. Board Setup for Total Input Current (I_VIN) Measurement

VINx Pin Input Current Limit

The VINx pin input current limit of the ADP5065 can be evaluated in charging mode. The maximum value that can be programmed for the charge current into the battery (ISO_Bx) is 1250 mA. For measuring the VINx pin input current limit across the full programming range of 100 mA to 1500 mA, additional system load must be connected to the ISO_Sx pin.

1. Set the V_VIN supply voltage to 5.0 V.
2. Set the V_ISO_Bx voltage to 3.2 V using an SMU or a battery simulator.
   a. The **Battery Status** box in the **Opr Control & Status** tab of the GUI (see Section 5 in Figure 12) should show **BAT_SNS > Vweak**.
   b. The ADP5065 should start charging about 110 mA of current into the battery.
3. Measure the VINx pin input current.
4. Use the GUI to change the programmed value of the input current limit and repeat the measurement.

A 1250 mA charge current into the battery might not be large enough to drive the input current up to the limit when the current limit is programmed to a value of 1000 mA or higher. Connect additional load to the ISO_Sx node to evaluate values at the higher end of the programming range.

TRICKLE CHARGE CURRENT

Trickle charge is activated only during the battery charging startup sequence if the voltage level at the ISO_Bx pin is lower than the V_{TRK_DEAD} threshold (typically 2.5 V). The startup sequence is initiated automatically by connecting V_{VIN}. When V_{VIN} is already at 5.0 V, you can initiate the startup sequence by issuing an I²C write to the EN_CHG bit (Bit D0, Register 0x07) to bring the EN_CHG bit low, disabling the dc-to-dc converter, and then issuing another write to bring the EN_CHG bit back to high. To measure the trickle charge current level,

1. Set the V_{ISO_B} voltage (SMU or battery simulator) to 2 V.
2. Set the V_{VIN} supply voltage to 5.0 V.
3. Check that the GUI **Charger Status** box (see Section 4 in Figure 12) shows **Trickle Charge**.
4. Check that the GUI **Battery Status** box (see Section 5 in Figure 12) shows **BAT_SNS < Vtrk**.
5. Check whether a battery short was detected by waiting for the 30 sec timeout to expire and then checking that the **Bat_shr** indicator is illuminated in the GUI **Fault Register 0x0D** box (see Section 6 in Figure 12). You can change the setting in the **Battery Short Time-Out** drop-down box (see Section 1 in Figure 12) to a value between 1 sec and 180 sec.
6. Measure the trickle charge current into the battery. The default value for I_{TRK_DEAD} is 20 mA. You can change the setting in the GUI **Trickle Charge Current** box from 5 mA to 20 mA.
7. Sweep up the V_{ISO_B} voltage until the GUI **Battery Status** box (see Section 5 in Figure 12) shows **Vtrk < BAT_SNS < Vweak**.
8. The GUI **Charger Status** box (see Section 4 in Figure 12) should show **Fast Charge (CC-Mode)**. In this mode, the charge current is programmed to $I_{CHG} + I_{TRK\_DEAD}$ or lower if it is limited by the input current limit.

FAST CHARGE CURRENT

To measure the fast charge current level,

1. Set the V_{VIN} supply voltage to 5.0 V.
2. Set the V_{ISO_B} voltage to 3.6 V.
3. Check that the GUI **Battery Status** box (see Section 5 in Figure 12) shows **BAT_SNS > Vweak**.
4. Set the VINx pin input current limit to its maximum value, 1500 mA.
5. Measure the charge current into the battery. The default value for the fast charge current is 1250 mA. You can change the setting in the GUI **Fast Charge Current** box to a value between 550 mA to 1250 mA.
6. Note that the fast charge current might be reduced due to one of the following conditions:
   a. The V_{BAT_SNS} level is close to the termination voltage, V_{TRM} (default 4.20 V).
   b. The die temperature, T_J, exceeds the isothermal charging temperature, T_{LIM} (typically 115°C).
   c. The available current from the dc-to-dc converter output of the ADP5065 is limited by the maximum duty cycle (for example, when the I_{CHG} setting is 1250 mA and $V_{ISO\_B} > 3.7$ V).

TERMINATION VOLTAGE AND END-OF-CHARGE CURRENT

Measuring Termination Voltage Using an SMU or Battery Simulator

The ADP5065 fast charge constant voltage (CV) regulation has been optimized for batteries that have series resistance in the range of 100 mΩ to 250 mΩ. When using an SMU or a battery simulator connected to ISO_Bx, the series resistance (R_S in Figure 15) should be within this range.

Some battery simulators, such as Keithley 2306, have programmable source resistance integrated in the instrument itself. For SMU units, an external resistor should be used to obtain accurate measurement results of the termination voltage.

To measure the termination current,

1. Set the V_{VIN} supply voltage to 5.0 V.
2. Set the termination voltage to 4.2 V using the GUI.
3. Disable the end of charge by setting the EN_EOC bit to low in the Functional Settings1 register (Address 0x07).
4. Disable the charge complete timer bit (EN_TEND) in Register 0x06 using the GUI (see Figure 13).
5. Sweep V_{ISO_B} up until the GUI **Charger Status** box (see Section 4 in Figure 12) in the GUI shows **Fast Charge (CV Mode)**.
6. Sweep V_{ISO_B} up until the charge current drops to 50 mA. Note that in the fast charge CV mode, a 1 mV step-up of V_{ISO_B} can reduce the charge current by several milliamperes.
7. Measure the termination voltage between the BAT_SNS (Pin 8 of JP1) and GND_S (TP22) nodes.

Measuring the End-of-Charge Current

To measure the end-of-change current,

1. Set the **Termination Current** (see Section 1 of Figure 12) to 52.5 mA.
2. Step V_{ISO_B} down to 100 mV.
3. Enable the end of charge by setting the EN_EOC bit to high in the Functional Settings1 register (Address 0x07).
4. Step V_{ISO_B} up and monitor the charge current for each step until the GUI **Charger Status** box (see Section 4 in Figure 12) shows **Charge Complete**. The last charge current value before **Charge Complete** is displayed is the charge complete current threshold. Charging is stopped, and there is no current flowing into the ISO_Bx node.

Measuring Recharge Voltage

To measure the recharge voltage,

1. Step V_{ISO_B} down and monitor the voltage until the GUI **Charger Status** box (see Section 4 in Figure 12) shows **Fast Charge (CC-Mode)** and charge current flows to the ISO_Bx node. The last value before the **Charger Status** changes is the recharge voltage level. With the default settings, the recharge voltage threshold is 3.94 V (V_{ISO_B}).
2. It is possible to use the GUI to change the termination current and the recharge voltage. Repeat the steps in the

Measuring the End-of-Charge Current section and the Measuring Recharge Voltage section to evaluate various settings.

THR INPUT AND JEITA SETTINGS

The THR input of the ADP5065 evaluation board is equipped with two 10 kΩ resistors (R10 and R13) and Jumper J4. When using the actual Li-Ion battery NTC thermistor terminal, the board should be configured as shown in Figure 17.

1. Remove Resistor R10.
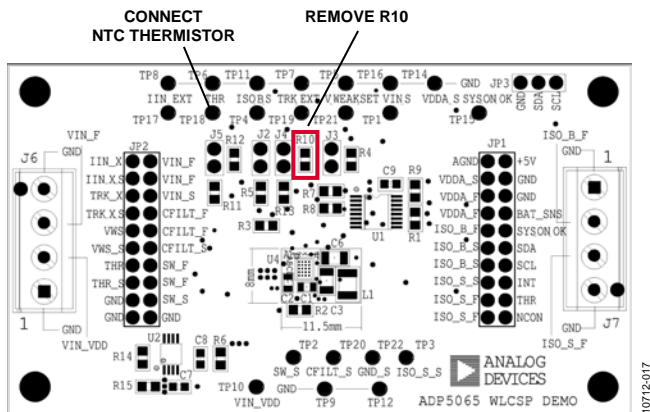2. Connect the Li-Ion battery NTC thermistor terminal to THR, Test Point TP18.

Figure 17. THR Input Evaluation Setup

Evaluating THR Input Using the Typical Board Setup

To evaluate the THR input using the typical board setup,

1. Set the V_{VIN} supply voltage to 5.0 V.
2. Set the V_{ISO_B} voltage to 3.6 V
3. Set the GUI **Fast Charge Current** to 550 mA (see Section 1 in Figure 12).
4. Set the **VIN Input Current Limit** to 1500 mA.
5. Measure the current to ISO_Bx; the value should be 550 mA.

6. Remove Jumper J4 from board.
7. The GUI **THR-pin status** box (see Section 5 in Figure 12) should show **BatCool**.
8. Enable JEITA by setting the EN_JEITA bit (Bit 7 of Register 0x07) high.
9. Measure the current to ISO_Bx. The charging current should now be half of the fast charge current setting.
10. Reinstall Jumper J4 on the board.
11. The charge current should return to the full charge current setting value.
12. The GUI **THR-pin status** box (see Section 5 in Figure 12) should show **Thermistor OK**.

Evaluating THR Input Using a Trimmer Resistor

Evaluating the resistance thresholds according to JEITA Li-Ion battery temperature levels is possible with a trimmer resistor of, for example, 50 kΩ. To evaluate the THR input using a trimmer resistor,

1. Use the setup shown in Figure 17, but connect the trimmer resistor between the THR input and GND instead of connecting it to the battery thermistor.
2. Set the V_{VIN} supply voltage to 5.0 V.
3. Set the V_{ISO_B} voltage to 3.6 V
4. Set the GUI **Fast Charge Current** to 550 mA (see Section 1 in Figure 12).
5. Set the **VIN Input Current Limit** to 1500 mA.
6. Enable JEITA by setting the EN_JEITA bit (Bit 7 of Register 0x07) high.
7. Change the trimmer resistor setting to evaluate the JEITA thresholds. The THR input resistance thresholds are specified in the ADP5065 data sheet.
8. The GUI **THR-pin status** box (see Section 5 in Figure 12) should show **BatCold**, **BatCool**, **Thermistor OK**, **BatWarm**, or **BatHot** when adjusting the trimmer resistance to a value between 0 Ω and 50 kΩ.

EVALUATION BOARD SCHEMATIC AND LAYOUT

Figure 18. ADP5065 WLCSP Demo Board Schematic
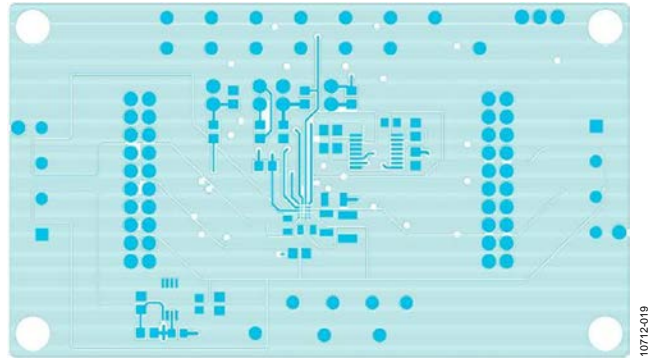
PCB LAYOUT

Figure 19. ADP5065 Evaluation Board Top Layer
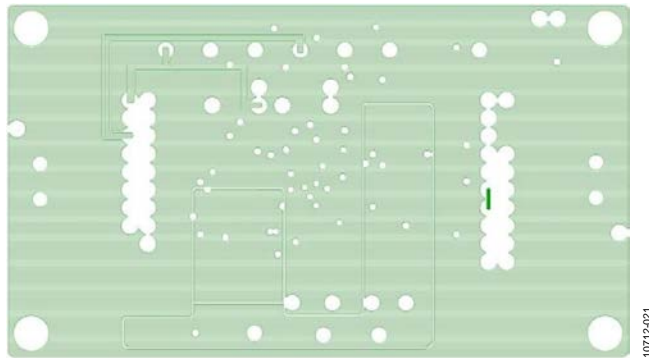

Figure 20. ADP5065 Evaluation Board Layer 2
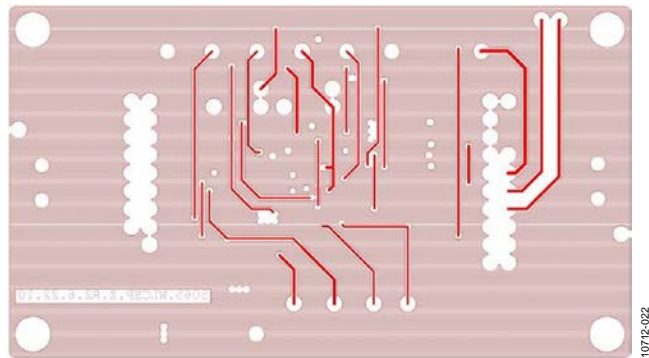

Figure 21. ADP5065 Evaluation Board Layer 3

Figure 22. ADP5065 Evaluation Board Bottom Layer (View from the Top)

BILL OF MATERIALS

Table 1.

Qty	Reference Designator	Description	Manufacturer/Vendor	Vendor Part No.
1	C1	Capacitor, MLCC, 4.7 µF, 10 V, 0805, X5R, 10%	Murata	GRM219R61A475KE19D
1	C2	Capacitor, MLCC, 2.2 µF, 25 V, 0805, X5R, 10%	Murata	GRM21BR71E225K
2	C3, C6	Capacitor, MLCC, 22 µF,10 V, 1206, X5R	Murata	GRM31CR61A226ME19L
2	C7, C8	Capacitor, MLCC, 1 µF, 10 V, 0805, X7R	Murata	GRM21BR71A105KA01
1	C9	Capacitor, MLCC,100 nF, 25 V, 0603, X7R	Murata	GRM188R71E104K
4	J2, J3, J4, J5	Connector header, 2 pins × 1	Sullins Electronics	PEC36SAAN
2	J6, J7	Terminal block PCB connector, four positions	Tyco Electronics	282836-4
2	JP1, JP2	Connector receptacle, 10 pins × 2	Samtec	SSW-110-03-G-D
1	JP3	Connector header, 3 pins × 1	Sullins Electronics	PEC36SAAN
1	L1	Inductor, 1 µH, 3.2 mm × 2.5 mm × 1.5 mm	Murata	LQH32PN1R0NN0
4	R1, R7, R8, R9	Resistor, 1.5 kΩ, 1%, 0805, SMD	Vishay or Equivalent	CRCW08051K50FKEA
5	R2, R3, R4, R5, R6	Resistor, 0 Ω, 1%, 0805, SMD	Vishay or Equivalent	CRCW08050000Z0EA
4	R10, R11, R12, R13	Resistor, 10 kΩ, 1%, 0805, SMD	Vishay or Equivalent	CRCW080510K0FKEA
1	R14	Resistor, 56 kΩ, 1%, 0805, SMD	Vishay or Equivalent	CRCW080556K0FKEA
1	R15	Resistor, 100 kΩ, 1%, 0805, SMD	Panasonic	ERJ-6ENF1003V
21	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP14, TP15, TP16, TP17, TP18, TP19, TP20, TP21, TP22	Test point test header 1.0 mm hole	Vero Technologies	20-2137
1	U1	8-bit I²C-bus I/O port with reset	NXP	PCA9557PW,112
1	U2	ADP1720 50 mA HV regulator, 8-lead MSOP	Analog Devices	ADP1720ARMZ-R7
1	U4	ADP5065 20-ball WLCSP	Analog Devices	ADP5065ACBZ-1-R7

RELATED LINKS

Resource	Description
ADP5065	Product Page: Fast Charge Battery Management with Power Path and USB Compatibility
ADP1720	Product Page: 50 mA, High Voltage, Micropower Linear Regulator

NOTES

ESD Caution

ESD (electrostatic discharge) sensitive device. Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

Legal Terms and Conditions

By using the evaluation board discussed herein (together with any tools, components documentation or support materials, the "Evaluation Board"), you are agreeing to be bound by the terms and conditions set forth below ("Agreement") unless you have purchased the Evaluation Board, in which case the Analog Devices Standard Terms and Conditions of Sale shall govern. Do not use the Evaluation Board until you have read and agreed to the Agreement. Your use of the Evaluation Board shall signify your acceptance of the Agreement. This Agreement is made by and between you ("Customer") and Analog Devices, Inc. ("ADI"), with its principal place of business at One Technology Way, Norwood, MA 02062, USA. Subject to the terms and conditions of the Agreement, ADI hereby grants to Customer a free, limited, personal, temporary, non-exclusive, non-sublicensable, non-transferable license to use the Evaluation Board FOR EVALUATION PURPOSES ONLY. Customer understands and agrees that the Evaluation Board is provided for the sole and exclusive purpose referenced above, and agrees not to use the Evaluation Board for any other purpose. Furthermore, the license granted is expressly made subject to the following additional limitations: Customer shall not (i) rent, lease, display, sell, transfer, assign, sublicense, or distribute the Evaluation Board; and (ii) permit any Third Party to access the Evaluation Board. As used herein, the term "Third Party" includes any entity other than ADI, Customer, their employees, affiliates and in-house consultants. The Evaluation Board is NOT sold to Customer; all rights not expressly granted herein, including ownership of the Evaluation Board, are reserved by ADI. CONFIDENTIALITY. This Agreement and the Evaluation Board shall all be considered the confidential and proprietary information of ADI. Customer may not disclose or transfer any portion of the Evaluation Board to any other party for any reason. Upon discontinuation of use of the Evaluation Board or termination of this Agreement, Customer agrees to promptly return the Evaluation Board to ADI. ADDITIONAL RESTRICTIONS. Customer may not disassemble, decompile or reverse engineer chips on the Evaluation Board. Customer shall inform ADI of any occurred damages or any modifications or alterations it makes to the Evaluation Board, including but not limited to soldering or any other activity that affects the material content of the Evaluation Board. Modifications to the Evaluation Board must comply with applicable law, including but not limited to the RoHS Directive. TERMINATION. ADI may terminate this Agreement at any time upon giving written notice to Customer. Customer agrees to return to ADI the Evaluation Board at that time. LIMITATION OF LIABILITY. THE EVALUATION BOARD PROVIDED HEREUNDER IS PROVIDED "AS IS" AND ADI MAKES NO WARRANTIES OR REPRESENTATIONS OF ANY KIND WITH RESPECT TO IT. ADI SPECIFICALLY DISCLAIMS ANY REPRESENTATIONS, ENDORSEMENTS, GUARANTEES, OR WARRANTIES, EXPRESS OR IMPLIED, RELATED TO THE EVALUATION BOARD INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANTABILITY, TITLE, FITNESS FOR A PARTICULAR PURPOSE OR NONINFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS. IN NO EVENT WILL ADI AND ITS LICENSORS BE LIABLE FOR ANY INCIDENTAL, SPECIAL, INDIRECT, OR CONSEQUENTIAL DAMAGES RESULTING FROM CUSTOMER'S POSSESSION OR USE OF THE EVALUATION BOARD, INCLUDING BUT NOT LIMITED TO LOST PROFITS, DELAY COSTS, LABOR COSTS OR LOSS OF GOODWILL. ADI'S TOTAL LIABILITY FROM ANY AND ALL CAUSES SHALL BE LIMITED TO THE AMOUNT OF ONE HUNDRED US DOLLARS ($100.00). EXPORT. Customer agrees that it will not directly or indirectly export the Evaluation Board to another country, and that it will comply with all applicable United States federal laws and regulations relating to exports. GOVERNING LAW. This Agreement shall be governed by and construed in accordance with the substantive laws of the Commonwealth of Massachusetts (excluding conflict of law rules). Any legal action regarding this Agreement will be heard in the state or federal courts having jurisdiction in Suffolk County, Massachusetts, and Customer hereby submits to the personal jurisdiction and venue of such courts. The United Nations Convention on Contracts for the International Sale of Goods shall not apply to this Agreement and is expressly disclaimed.

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