

## Evaluating the **ADP5061** Tiny I<sup>2</sup>C Programmable Linear Battery Charger with Power Path and USB Mode Compatibility

### FEATURES

Input voltage 4.0 V to 6.7 V

High current terminals for **ADP5061** power connection (VINx), system voltage (ISO\_Sx), and battery voltage (ISO\_Bx) pins

**ADP5061** operation configurable via I<sup>2</sup>C interface

Evaluation software included

### PACKAGE CONTENTS

**ADP5061CB-EVALZ** evaluation board

USB A-to-USB Micro B cable

USB A adapter board

Evaluation CD: **ADP5061** evaluation software installer

### HARDWARE REQUIREMENTS

USB-to-serial-I/O interface **USB-SDP-CABLEZ** (The **USB-SDP-CABLEZ** is not supplied in the evaluation kit and should be ordered separately from Analog Devices, Inc.)

### SOFTWARE REQUIREMENTS

Analog Devices **ADP5061** SDP evaluation software

### GENERAL DESCRIPTION

The **ADP5061** charger evaluation system is composed of an evaluation board, an USB A-to-USB Micro B cable, and an USB A adapter board. All evaluation board functions and circuits are controlled via one I<sup>2</sup>C bus connector. The I<sup>2</sup>C bus interfaces with the **ADP5061** directly, and the digital input/output signals are controlled through an on-board input/output expander circuit on the I<sup>2</sup>C 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.

The **ADP5061-EVALZ** evaluation kit contains a CD with the **ADP5061** graphical user interface (GUI) Version 3.0 installer. Use the GUI in conjunction with the **USB-SDP-CABLEZ** USB to serial I/O interface.

Full performance details are provided in the **ADP5061** data sheet, and the **ADP5061** data sheet should be consulted in conjunction with this user guide.

### ADP5061 EVALUATION BOARD

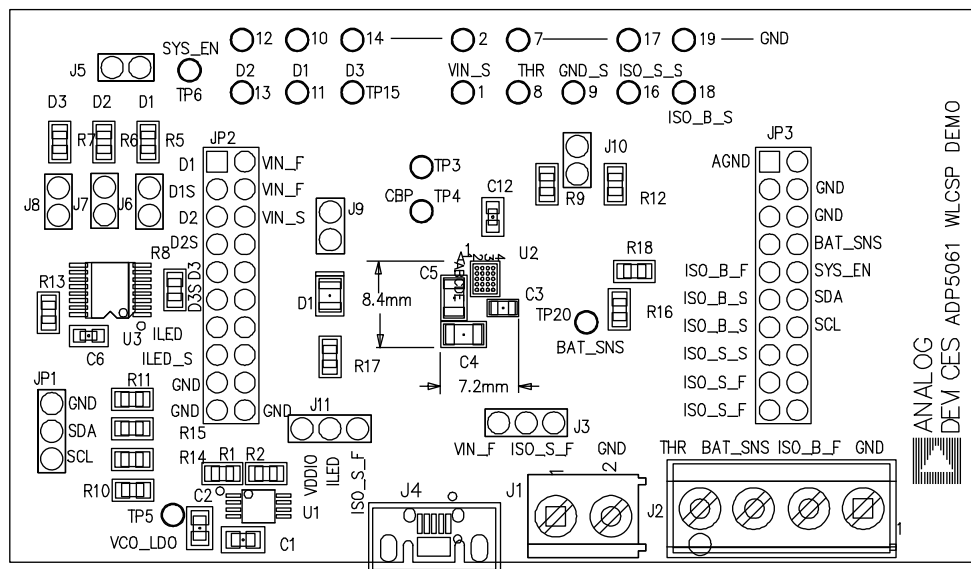


Figure 1.

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## REVISION HISTORY

11/12—Revision 0: Initial Version

## EVALUATION BOARD SOFTWARE

### INSTALLING ADP5061 EVALUATION SOFTWARE

Before installing the ADP5061 evaluation software, the drivers for the USB-SDP-CABLEZ must be installed. The software and the instructions can be obtained from [www.analog.com/USB-SDP-CABLEZ](http://www.analog.com/USB-SDP-CABLEZ).

After proper installation of the USB-SDP-CABLEZ drivers, insert the ADP5061-EVALZ setup CD and run the Setup.exe.

### USING THE SOFTWARE GUI

The following are the GUI operation controls and status tools (see Figure 2):

1. Operation parameter controls
2. Functional enables
3. Interrupt register indicator (Register 0x0A)
4. Charger status
5. Battery status
6. Fault indicators
7. Watchdog control
8. Digital I/O controls
9. I<sup>2</sup>C Communication Status Indicators

### OPERATING THE BOARD WITH THE GUI

Complete the following steps to use the board:

1. Before running the software, ensure that the Analog Devices USB-SDP-CABLEZ is plugged into the USB port of the PC.
2. Connect a 5 V power supply to VIN\_F using the USB Micro A/Micro B connector or alternatively connect the power supply between the VIN\_F test point and GND (see Figure 5).
3. Click **START > All Programs > ADP506x GUI 3Vx SDP > ADP506x GUI SDP**. Once this step is done, the software is ready to use.

VIN must be above 2.5 V in order for the I<sup>2</sup>C communication of the ADP5061 to start working. The VIN voltage level is monitored, and the indicators are shown in the charger status indicators (see Number 4 in Figure 2). The GUI automatically reads the content of the registers after every 0.3 seconds from the last action and updates the status of the registers on screen.

If there is a problem in the I<sup>2</sup>C communication, the status indicators will show an error message (see Number 9 in Figure 2). When I<sup>2</sup>C communication is operational, status indicators show I2C\_STATUS\_OK (see Figure 2).

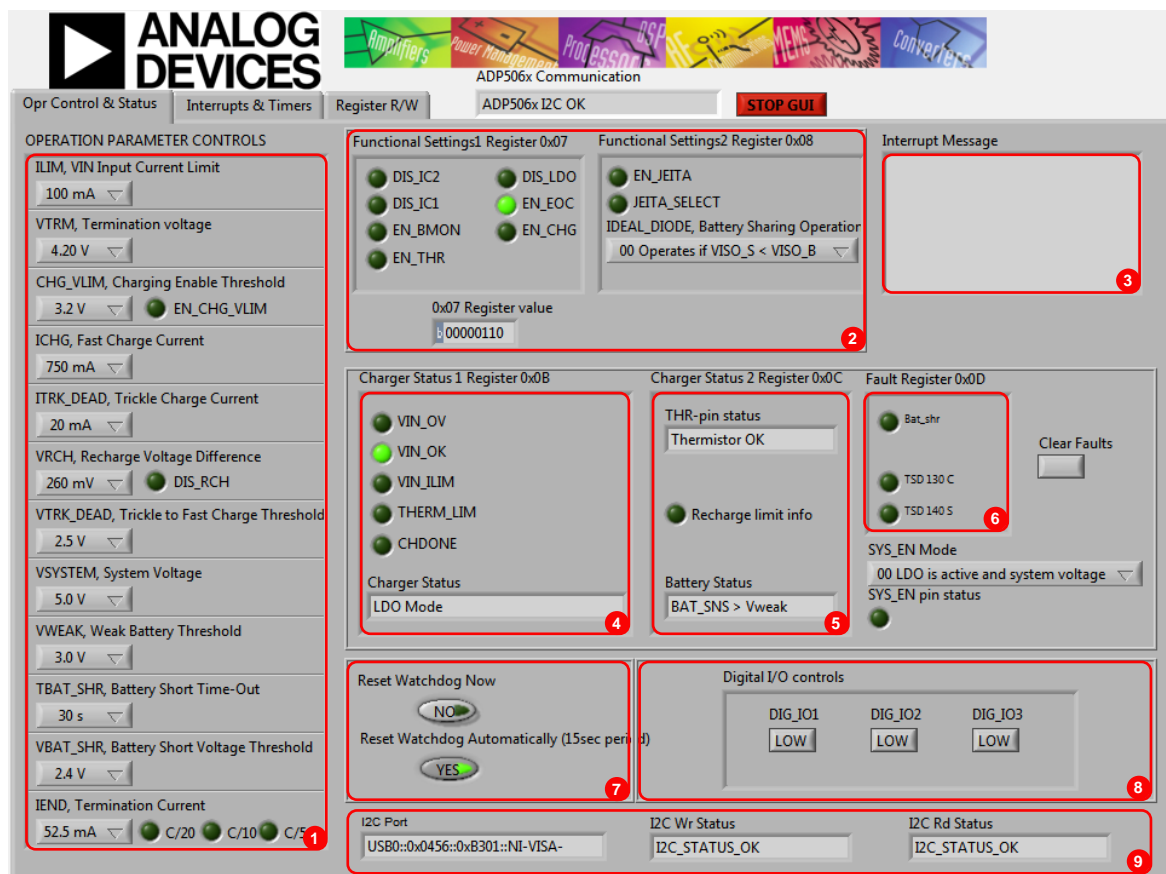


Figure 2. ADP5061 GUI Operation Control and Status Tab

## BASIC CHARGING PARAMETER SETTINGS

After the input power supply is connected and is between 4.0 V and 6.7 V, the **ADP5061** is operational and capable of charging the battery. Charging starts with default operational parameter settings. It is possible to change settings using the controls on the left side of the **Opr Control & Status** tab.

## SETTING INTERRUPTS

The **ADP5061** 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 I<sup>2</sup>C write to Register 0x09.

The **Interrupts & Timers** tab (see Figure 3) in the GUI controls the register settings. Register 0x0A is automatically read after every 0.3 second timeout from 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, an interrupt message is shown in the **Opr Control & Status** tab (see Number 3 in Figure 2).

## SETTING TIMERS

The default settings of the timers are shown in Figure 3. Changing the timer settings can be done by clicking items in the **Timer Settings (Write to Register 0x06)** box.

Register 0x09 controls the interrupt enables, and Register 0x06 controls the timer settings.

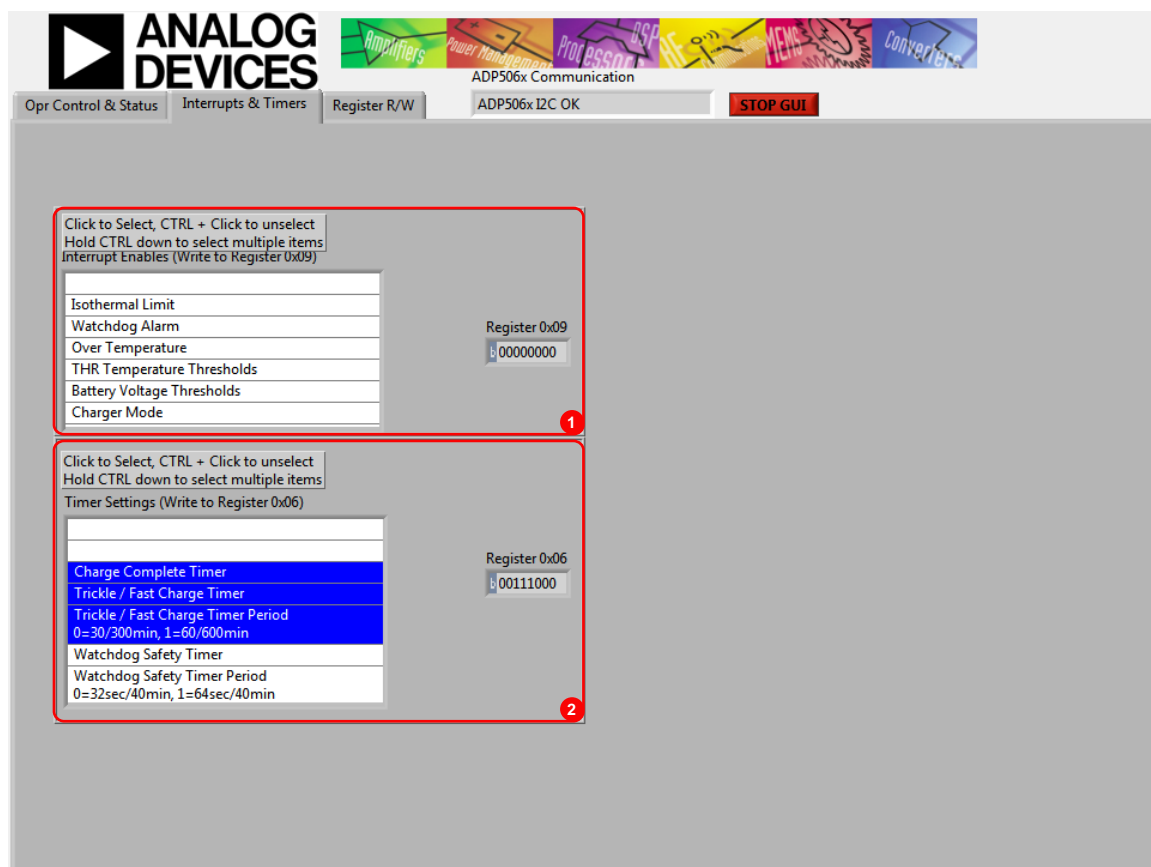


Figure 3. **ADP5061** Evaluation Software GUI, **Interrupts & Timers** Tab

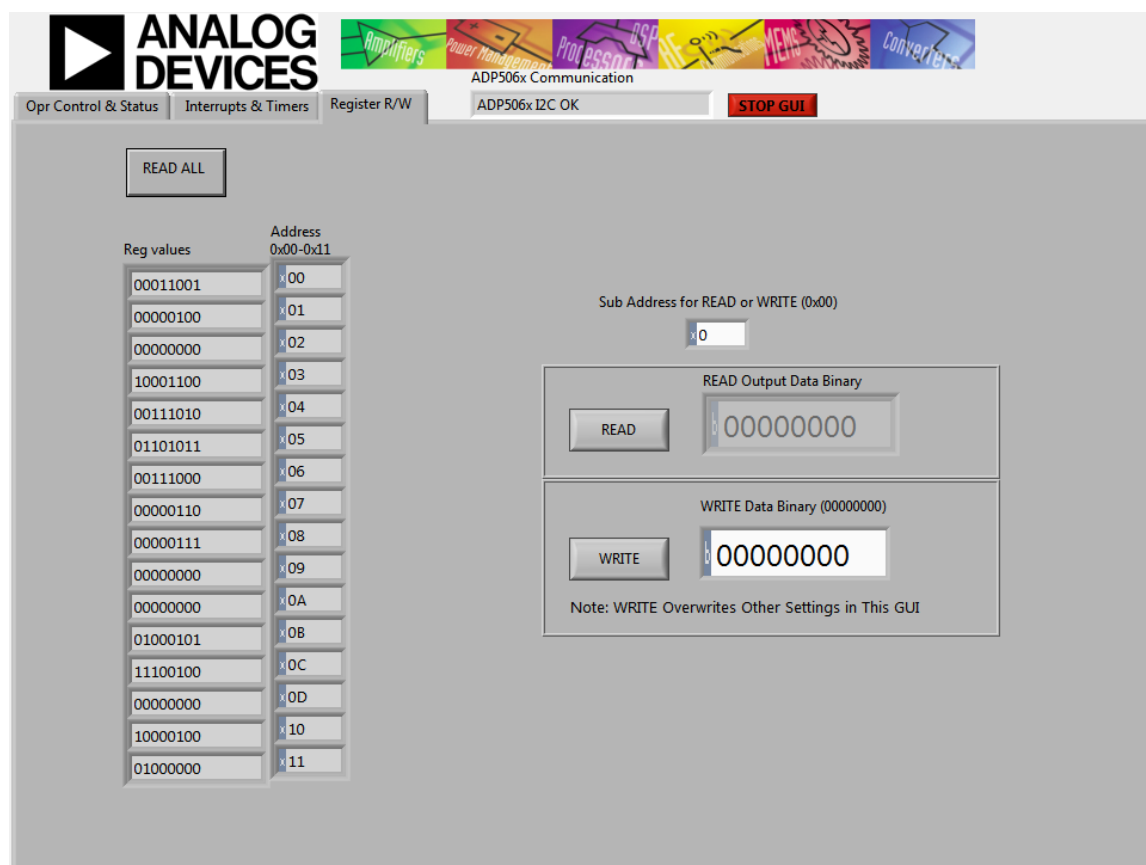


Figure 4. ADP5061 Evaluation Software GUI, Register R/W Tab

## 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. Click **READ ALL** to update the contents of each register in the GUI. A single register read or write can be done using the controls on the right side of the **Register R/W** tab of the GUI. Type the I<sup>2</sup>C sub address in the

**Sub Address for READ and WRITE (0x00)** box, and then press **ENTER**. Click **READ** to read the binary data, or click **WRITE** to write the binary data. Type the binary data for an I<sup>2</sup>C write, and then press **ENTER**. Note that some registers, such as Register 0x00 and Register 0x01, are read only registers and cannot be overwritten.

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When the charger operates at high current rates, the voltage drop over the USB cable and USB connectors can be significant. For easy evaluation of real cable and connector losses, the [ADP5061](#) evaluation kit contains an USB cable and an USB A adapter board that includes a screw terminal for the VIN\_F voltage supply.

- Keithley 2306 battery simulator
- Keithley 2602A SMU
- Agilent 6784A/6762A SMU

## INPUT CURRENT

### Measuring Total Input Current ( $I_{VIN}$ )

When measuring VINx input quiescent currents, take into account that the evaluation board includes an LDO (U1) and I<sup>2</sup>C input/output (I/O) expander (see U2 and U3A in Figure 8). The LDO generates a 3.4 V VDDIO voltage for the I<sup>2</sup>C bus and SYS\_EN open-drain output, and the I/O expander controls digital inputs DIG\_IO1, DIG\_IO2, and DIG\_IO3.

In the ADP5061 evaluation board typical setup, the U1 and the U3 are powered through a pin header, J3. Typically, the combined current consumption of the U1 and the U3 are in the range of 1 mA to 2 mA. To separate the evaluation board quiescent current from the ADP5061 VINx quiescent current, leave J3 open and connect a second dc power supply (3.5 V to 5.0 V) to the TP5 test point (see Figure 6).

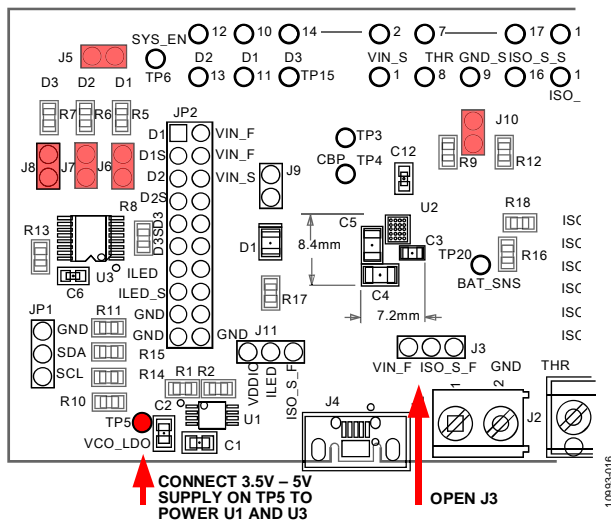


Figure 6. Board Setup for VINx Quiescent Current Measurement

### VINx Current Limit

The VINx current limit of the ADP5061 can be evaluated in charging mode. Note that the maximum programming for the charge current into the battery (ISO\_Bx) is 1300 mA. For measuring the input current limit across the full programming range from 100 mA to 2100 mA, additional system load has to be connected to the ISO\_Sx pins.

To measure the VINx current limit, do the following:

1. Set the  $V_{VIN}$  supply voltage to 5.0 V.
2. Set the  $V_{ISO\_B}$  voltage to 3.6 V on SMU B.
3. Enable charging by setting Register 0x07, Bit D0 (EN\_CHG), to high.
4. Confirm that the ADP5061 is in charging mode by the following:
  - The **Battery Status** indicator on the GUI must show **BAT\_SNS > Vweak** (see Figure 2).
  - The ADP5061 must start charging 80 mA to 90 mA current into the battery.
5. Measure the current on VINx supply.
6. Use the GUI to change the input current limit programming and repeat the measurement.

A 1300 mA charge current into the battery may not be large enough to drive the input current up to the limit when the current limit programming values of 1200 mA or higher are used. Connect an additional load on the ISO\_Sx node to evaluate the higher end of the input current limit programming range.

### TRICKLE CHARGE CURRENT

Trickle charge can only be activated during a battery charging startup sequence, if the voltage level at the ISO\_Bx pins is lower than the  $V_{TRK\_DEAD}$  threshold (typically 2.5 V). When  $V_{VIN}$  is 5.0 V, initiate a charge startup sequence by setting an I<sup>2</sup>C write of Register 0x07, Bit D0 (EN\_CHG), high. To measure the trickle charge current level, do the following:

1. Set the  $V_{ISO\_B}$  voltage (SMU or battery simulator) to 2 V.
2. Set the  $V_{IN}$  supply voltage to 5.0 V.
3. Check that the GUI **Charger Status** indicator shows **Trickle Charge**.
4. Check that the GUI **Battery Status** indicator shows **BAT\_SNS < Vtrk**.
5. Check the battery short detection by doing the following:
  - Wait for a 30 second timeout to expire
  - Check that the GUI shows that the I<sup>2</sup>C fault register (Register 0x0D, Bit D3) BAT\_SHR flag is set.
  - Use the GUI to change the battery short timeout setting from 1 second to 180 second.
6. Measure the trickle charge current level to the battery. The default value for  $I_{TRK\_DEAD}$  is 20 mA. It is possible to change the trickle charge current setting from 5 mA to 80 mA using the GUI.
7. Adjust the  $V_{ISO\_B}$  voltage up until the **Battery Status** indicator shows **Vtrk < BAT\_SNS < Vweak**.
8. The **Charger Status** indicator on the GUI should show **Fast Charge (CC-Mode)**. The charge current is now programmed  $I_{CHG} + I_{TRK\_DEAD}$ , if it is not limited by the input current limit.



## FAST CHARGE CURRENT

To measure the fast charge current, do the following:

1. Set the  $V_{IN}$  supply voltage to 5.0 V.
2. Set  $V_{ISO\_B}$  to 3.9 V.
3. Verify that the GUI **Battery Status** indicator shows **BAT\_SNS > Vweak**.
4. Set the  $V_{INx}$  input current limit to the maximum value 2100 mA.
5. Measure the charge current into the battery. The default value for the fast charge current is 750 mA. It is possible to change the fast charge current setting from 50 mA to 1300 mA using the GUI.
6. The fast charge current may be reduced because of the following conditions:
  - The  $V_{BAT\_SNS}$  level is close to the termination voltage  $V_{TRM}$  (default 4.20 V).
  - The die temperature  $T_j$  exceeds the isothermal charging temperature  $T_{LIM}$  (typically 115 °C).

## TERMINATION VOLTAGE AND END OF CHARGE (EOC) CURRENT

### Measuring Termination Voltage Using SMU or Battery Simulator

The [ADP5061](#) fast charge constant voltage (CV) regulation is optimized for batteries with series resistance in the 100 mΩ to 250 mΩ range. When using a SMU or a battery simulator connected to the  $ISO\_Bx$ , set the series resistance ( $R_s$  in Figure 5) within this range.

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

To measure the termination voltage, do the following:

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 EOC by setting the  $EN\_EOC$  bit (D2) to low in the functional settings register, Register 0x07.
4. Disable charge complete timer register, Register 0x06, using the GUI (see Figure 3).
5. Sweep  $V_{ISO\_B}$  up until **Charger Status** indicator in the GUI shows **Fast Charge (CV-Mode)**.
6. Sweep  $V_{ISO\_B}$  up until charge current has dropped to 50 mA. In fast charge CV mode, 1 mV step up of  $V_{ISO\_B}$  can reduce the charge current by several mA.
7. Measure termination voltage between the  $BAT\_SNS$  (TP20) and  $GND\_S$  (TP9) nodes.

## Measuring EOC Current

To measure the EOC current, do the following:

8. Use the GUI to set the termination current to 52.5 mA.
9. Step  $V_{ISO\_B}$  down 100 mV.
10. Enable the EOC by setting the  $EN\_EOC$  bit (D2) to high in the functional settings register, Register 0x07.
11. Step  $V_{ISO\_B}$  up and monitor the charge current for each step until the **Charger Status** indicator in the GUI shows **Charge Complete**. The last charge current value before **Charge Complete** is the charge complete current threshold. Charging stops and there is no current flowing into the  $ISO\_Bx$  node.

## Measuring Recharge Voltage

To measure the recharge voltage, do the following:

12. Step  $V_{ISO\_B}$  down and monitor the voltage until the **Charger Status** indicator on the GUI shows **Fast Charge (CC-Mode)** and charge current flows to the  $ISO\_Bx$  node. Last value before the charger status change is the recharge voltage level. With default settings, the recharge voltage threshold is 3.94 V ( $V_{ISO\_B}$ ).
13. Use the GUI to change the termination current and recharge voltage programming. Repeat Step 9 to Step 12 to evaluate different settings.



## THR INPUT AND JEITA SETTINGS

The THR input of the [ADP5061](#) evaluation board is equipped with two 10 k $\Omega$  resistors (R9 and R12) and jumper J10. When using an actual Li-Ion NTC thermistor terminal, configure the board according to Figure 7.

1. Remove the R9 resistor.
2. Connect the Li-Ion battery NTC thermistor to the screw terminal, J2, at Pin 4.

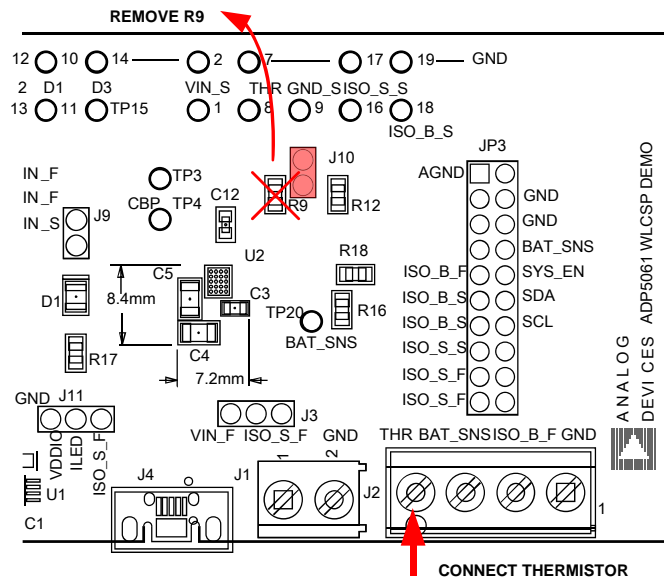


Figure 7. THR Input Evaluation Setup.

## Evaluating THR Input Using Typical Board Setup

To evaluate the THR input using the typical board setup, do the following:

1. Set the  $V_{IN}$  supply voltage to 5.0 V.
2. Set  $V_{ISO\_B}$  to 3.9 V.
3. Set the charge current setting to 750 mA using the GUI.
4. Set  $V_{IN}$  input current limit to 1500 mA.
5. Enable charging (EN\_CHG = high).
6. Measure current to ISO\_Bx, value should be 750 mA.
7. Remove jumper J10 from the board.
8. The **THR-pin status** indicator on the GUI must show **BatCool**.
9. Enable JEITA by setting EN\_JEITA bit high in functional settings register, Register 0x08.
10. Measure current to ISO\_Bx. Charging current must now be half of the fast charge current setting.
11. Reinstall Jumper J10 to the board.
12. The charge current must return to the full charge current setting value.
13. The **THR-pin status** indicator must show **Thermistor OK**.

## Evaluating THR Input Using a Trimmer Resistor

It is possible to evaluate the resistance thresholds according to the JEITA Li-Ion battery temperature levels with a 50 k $\Omega$  trimmer resistor. Use the setup shown in Figure 7; however, connect the trimmer resistor to the THR input of the J2 screw terminal instead of the battery thermistor.

1. Set the  $V_{IN}$  supply voltage to 5.0 V.
2. Set  $V_{ISO\_B}$  to 3.9 V.
3. Set the charge current setting to 750 mA using the GUI.
4. Set the  $V_{IN}$  input current limit to 1500 mA.
5. Enable charging (EN\_CHG = high).
6. Enable JEITA by setting EN\_JEITA bit high in functional settings register, Register 0x08.
7. Change the trimmer resistor setting to evaluate the JEITA thresholds. The THR input resistance thresholds are specified in the [ADP5061](#) data sheet.
8. The **THR-pin status** indicator in the GUI must show **BatCold**, **BatCool**, **Thermistor OK**, **BatWarm**, or **BatHot** when adjusting the trimmer resistance from 50 k $\Omega$  to 0  $\Omega$ .

## SCHEMATIC DIAGRAM

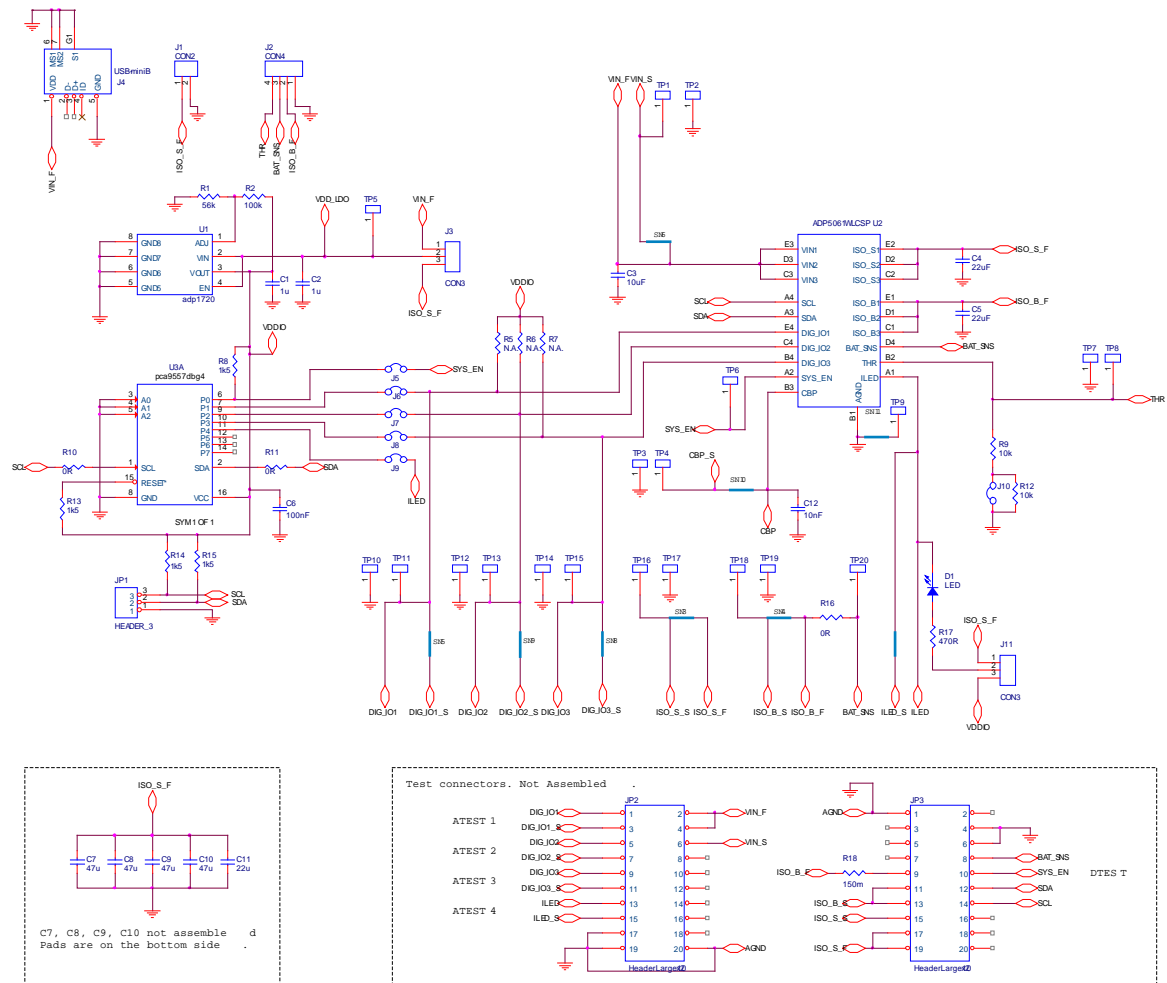


Figure 8. ADP5061 WLCSP Demo Board Schematic

## ORDERING INFORMATION

## BILL OF MATERIALS

Table 1.

Qty	Reference Designator	Description	Manufacturer/Vendor	Vendor Number
2	C1, C2	Capacitors, MLCC, 1 $\mu$ F, 10 V, 0805, X7R	Murata	GRM21BR71A105KA01
1	C3	Capacitor, MLCC, 10 $\mu$ F, 25 V, 0805, X5R	Murata	GRM21BR61E106MA73
3	C4, C5, C11	Capacitors, MLCC, 22 $\mu$ F, 6.3 V, 1206, X5R	Murata	GRM31CR60J226ME19
1	C6	Capacitor, MLCC, 100 nF, 16 V, 0402, X7R	Murata	GRM155R71C104KA88
1	C12	Capacitor, MLCC, 10 nF, 16 V, 0402, X7R	Murata	GRM15XR71C103KA86
4	C7, C8, C9, C10	Capacitors, size 1206	Not assembled	Not assembled
1	D1	Red LED 2.2 mm $\times$ 1.4 mm	Toshiba or equivalent	TLRF1060(T18)
1	JP1	Connector header, 3 pins $\times$ 1 pin	Sullins Electronics	PEC36SAAN
2	JP2, JP3	Connector headers, 10 pins $\times$ 1 pin	Not assembled	Not assembled
1	J1	MKDS 1, 5/2-terminal block, PCB, 5 mm, 2-way	Phoenix Contact or equivalent	MKDS 1, 5/2
1	J2	Terminal block PCB connector, 4 position	Tyco Electronics	282836-4
2	J3, J11	Connector headers, 3 pins $\times$ 1 pin	Sullins Electronics	PEC36SAAN
1	J4	USB Micro AB connector receptacle	Molex	47590-0001
6	J5, J6, J7, J8, J9, J10	Connector headers, 2 pins $\times$ 1 pin	Sullins Electronics	PEC36SAAN
1	R1	Resistor, 56 k $\Omega$ , 1%, 0805, SMD	Vishay or equivalent	CRCW080556K0FKEA
1	R2	Resistor, 100 k $\Omega$ , 1%, 0805, SMD	Panasonic	ERJ-6ENF1003V
3	R5, R6, R7	Resistors, 0805, SMD, no assembly	Not applicable	Not applicable
4	R8, R13, R14, R15	Resistors, 1.5 k $\Omega$ , 1%, 0805, SMD	Vishay or equivalent	CRCW08051K50FKEA
2	R9, R12	Resistors, 10 k $\Omega$ , 1%, 0805, SMD	Vishay or equivalent	CRCW080510K0FKEA
3	R10, R11, R16	Resistors, 0 $\Omega$ , 1%, 0805, SMD	Vishay or equivalent	CRCW08050000Z0EA
1	R17	Resistor, 470 $\Omega$ , 1%, 0805, SMD	Vishay or equivalent	CRCW0805470RFKEA
1	R18	Resistor, 0.150 $\Omega$ , 1%, 0805, SMD	Rohm	MCR10EZHFRL150
20	TP1 to TP20	Test point, test header, 1.0 mm hole	Vero Technologies	20-2137
1	U1	<a href="#">ADP1720</a> 50 mA high voltage, micropower linear regulator, 8-lead MSOP	Analog Devices, Inc.	<a href="#">ADP1720</a> ARMZ-R7
1	U2	<a href="#">ADP5061</a> tiny I <sup>2</sup> C programmable linear battery charger with power path and USB mode compatibility	Analog Devices, Inc.	<a href="#">ADP5061</a>
1	U3A	8-bit I <sup>2</sup> C-bus I/O port with reset	NXP	PCA9557PW,112

## 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.

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