Evaluating the ADP5061 Tiny I²C 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 I²C interface
Evaluation software included

PACKAGE CONTENTS
ADP5061CB-EVALZ evaluation board
USB Micro 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 (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 I²C bus connector. The I²C bus interfaces with the ADP5061 directly, and the digital input/output signals are controlled through an on-board input/output expander circuit on 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.

The ADP5061CB-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.

After proper installation of the USB-SDP-CABLEZ drivers, insert the ADP5061CB-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. I2C 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-to-USB 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 completed, the software is ready to use.

VIN must be above 2.5 V in order for the I2C 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 I2C communication, the status indicators show an error message (see Number 9 in Figure 2). When I2C 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 I²C write to Register 0x09.

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
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 I²C sub address in the **Sub Address for READ or 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 I²C write, and then press **ENTER**. Note that some registers, such as Register 0x00 and Register 0x01, are read only registers and cannot be overwritten.
TYPICAL OPERATION

The typical test setup for the ADP5061 charger consists of a dc power supply unit (PSU) for VIN_F, a source meter unit (SMU) or a battery simulator for the ISO_B_x pins, and a variable power resistor or electronic load for the ISO_S_x pins.

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.

The SMU at the ISO_B node must 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 include the following:

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

Figure 5. ADP5061 WLCSP Demo Board Typical Operation Setup.
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 I2C input/output (I/O) expander (see U2 and U3A in Figure 8). The LDO generates a 3.4 V VDDIO voltage for the I2C 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).

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 I2C 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 VIN 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 I2C 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 $BAT_{_SNS} > V_{weak}$.
4. Set the $VINx$ 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 kΩ 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.

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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 kΩ 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 kΩ to 0 Ω.

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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.
SCHEMATIC DIAGRAM

Figure 8. ADP5061 WLCSP Demo Board Schematic

Test connections. Not assembled.

C7, C9, C10 not assembled. Pads are on the bottom side.

C7, C9, C10 not assembled. Pads are on the bottom side.
## ORDERING INFORMATION

### BILL OF MATERIALS

Table 1.

<table>
<thead>
<tr>
<th>Qty</th>
<th>Reference Designator</th>
<th>Description</th>
<th>Manufacturer/Vendor</th>
<th>Vendor Number</th>
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<td>U2</td>
<td>ADP5061 tiny i²C programmable linear battery charger with power path and USB mode compatibility</td>
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<td>8-bit i²C-bus I/O port with reset</td>
<td>NXP</td>
<td>PCA9557PW, 112</td>
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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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