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Evaluating the ADP5360 Advanced Battery Management PMIC with Ultralow I_Q Buck and Buck Boost

FEATURES

VBUS input voltage: 4.0 V to 6.5 V
Fully featured evaluation board for the ADP5360
Evaluation software and installation CD included
Simple device measurements and demonstrable with
- **A voltage power supply**
- **A battery or battery simulator**
- **A voltage meter**
- **Load resistors or an electrical load**

EQUIPMENT NEEDED

USB to I²C dongle USB-SDP-CABLEZ (not included in the evaluation kit and must be ordered separately)
Li-ion battery or battery simulator
PC running Windows® 10 operating system

DOCUMENTS NEEDED

ADP5360 data sheet

SOFTWARE NEEDED

ADP5360 GUI Tool Software

GENERAL DESCRIPTION

This user guide describes the hardware and software used in the ADP5360CB-EVALZ evaluation board and includes detailed schematics and printed circuit board (PCB) layouts.

The ADP5360 includes a high performance linear regulator for single Li-ion/Li-ion battery charging, ultralow quiescent current fuel gauge and battery protection circuit, an ultralow quiescent buck and a buck boost switching regulator, and a supervisory circuit.

The ADP5360CB-EVALZ evaluation board supports an external USB dongle connection and the graphic user interface (GUI) software allows the user to evaluate the comprehensive functionalities provided by the I²C interface.

The ADP5360 operates over the −40°C to +85°C junction temperature range and is available in a 32-ball, 2.56 mm × 2.56 mm WLCSP.

More information on the ADP5360 is provided in the ADP5360 data sheet, available from www.analog.com, which must be consulted in conjunction with this evaluation board user guide.

EVALUATION BOARD PHOTOGRAPH

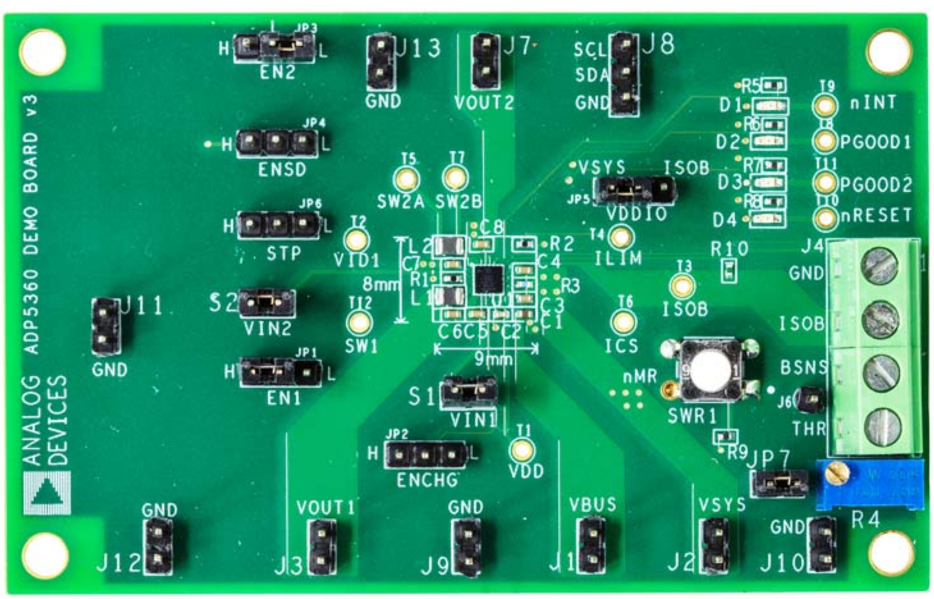

Figure 1.

TABLE OF CONTENTS

REVISION HISTORY

10/2019—Revision 0: Initial Version

INSTALLING THE SOFTWARE

The ADP5360 GUI Tool Software evaluates all functions and features of the program registers.

Before starting the software installation, ensure that the ADP5360CB-EVALZ evaluation board is not connected to the USB PC port.

INSTALLING LabVIEW

If the PC already has LabVIEW™ installed, this step is not required.

The application software is a compiled LabVIEW program, which requires LabVIEW 8.5 or later and a run-time engine installed on the PC. Download the LabVIEW runtime engine from the National Instruments™ website.

INSTALLING THE ADP5360 GUI SOFTWARE

After installation, it may be necessary to reboot the PC if the software is not working to complete the operation.

1. Launch the **Setup.exe** file, which is downloaded from the ADP5360CB-EVALZ product page. After the file has been launched, the dialog box shown in Figure 2 appears.

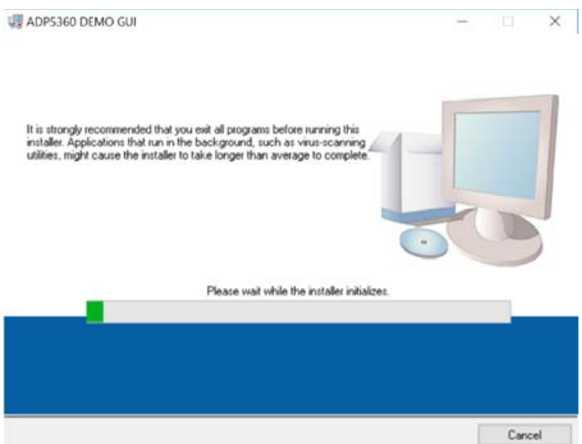

Figure 2. ADP5360 Evaluation Software Setup

2. Click the **Next** button to install the software to the default destination folder or click the **Browse…** button to choose a different file (see Figure 3).

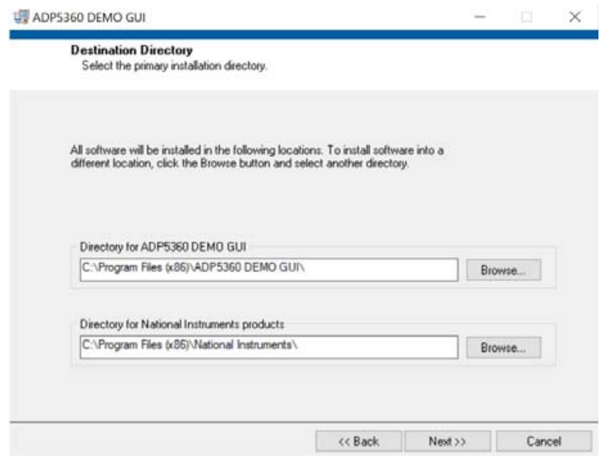

Figure 3. Choose Destination Location

3. Click the **Next** >> button to install the program (see Figure 4).

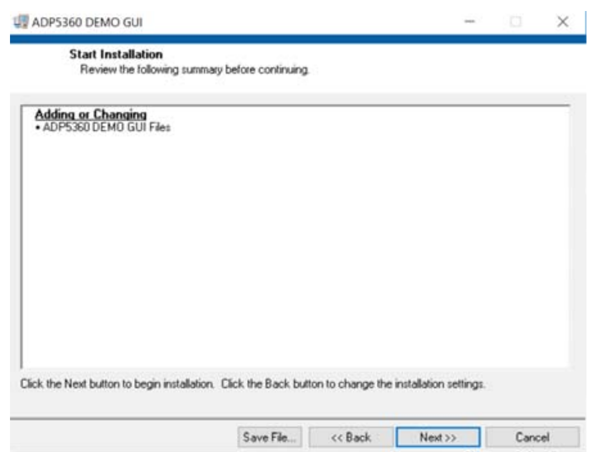

Figure 4. Select Program Folder

4. Click the **Finish** button to complete the installation, and the window in Figure 5 then appears.

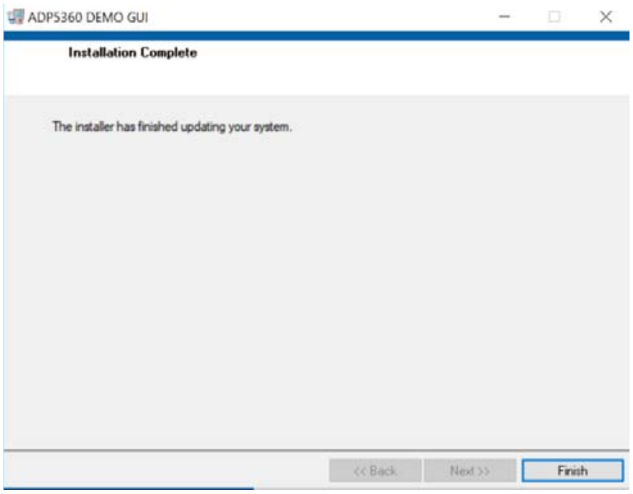

Figure 5. Installation Complete

INSTALLING THE SDP DRIVERS

To install the Analog Devices, Inc., system demonstration platform (SDP) drivers, complete the following steps:

1. After installing the ADP5360 GUI Tool Software, the SDP drivers begins installing.
2. A welcome window, shown in Figure 6, appears. Click **Next** > to install the drivers.

Figure 6. SDP Drivers Setup Wizard

3. Click the **Install** button after verifying the destination folder. Ensure the system environment has enough space (see Figure 7).

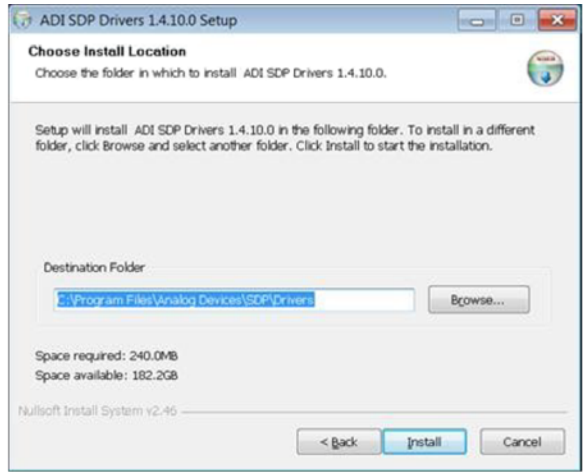

Figure 7. Verify the Destination Folder

4. After clicking the **Install** button, the next window, shown in Figure 8, appears. Click the **Finish** button to complete the driver installation.

Figure 8. Driver Installation Complete

5. To verify that the USB driver is installed properly, click the **Start** menu. Select **Control Panel** > **System** and open the **Device Manager** window shown in Figure 9 to check if **USB-SDP-CABLEZ** appears in the list.

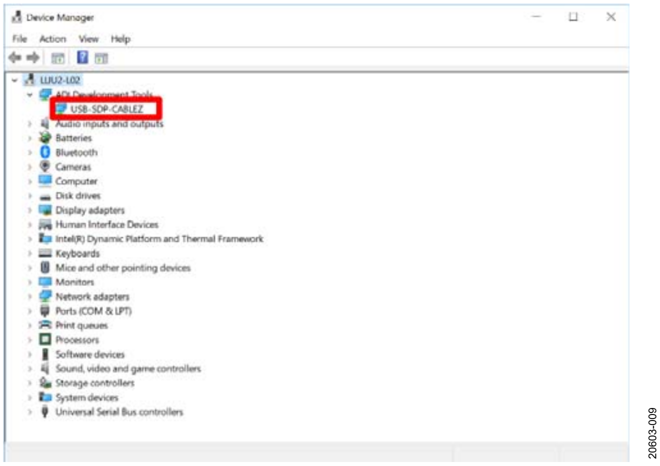

Figure 9. Verify Driver Installation

When the USB dongle is connected to a PC port that is different from the one used to install the driver, the PC device driver may require the user to install the driver again for that specific port. If the driver does need to be reinstalled, repeat Step 1 through Step 4.

USING THE ADP5360 GUI SOFTWARE

OPERATING THE BOARD WITH THE GUI

Before running the software, take the following steps:

1. Ensure that the USB to I²C dongle, USB-SDP-CABLEZ, is plugged into the PC USB port.
2. Connect a 5 V power supply between the VBUS and GND screw terminals (see Figure 17 for a connection diagram). Or connect a Li-ion battery or battery simulator between ISOB and GND (see Figure 17).
3. Click **Start** > **All Programs** > **ADP5360 GUI 1v0** > **ADP5360 GUI**.

The software is now ready to use, and the window shown in Figure 10 appears. The GUI software automatically reads the content of the registers and updates the status of the registers in real time.

BASIC CHARGING PARAMETER SETTINGS

To start the ADP5360 charger, adhere to the following steps:

1. Connect a 5 V power supply between the VBUS and GND screw terminals. Connect a discharged Li-ion battery or simulation battery between ISOB and GND (see Figure 17).
2. The resistance in the thermistor (THR) input corresponds to a battery temperature between 10°C and 45°C. If the THR resistance does correspond with the battery temperature, the **THR Status**, located in the **Charger_Status1** section (see Figure 10), reads **Thermistor OK**. If not, adjust the R4 variation resistor using a screwdriver to achieve the **Thermistor OK** message in **THR Status**.
3. Click **EN_CHG** in the **Charge Function Setting** section shown in Figure 10 to set the EN_CHG bit high (**EN_CHG** lights up in the GUI) to start the charger.

Charging begins with the default operational parameter settings when the EN_CHG bit is set high. The options under **Charge Parameter Control** on the left side of the **Charge Control** tab can also be selected before the ADP5360 charges.

Besides **Charge Parameter Control**, the **Charge Control** tab includes other options such as the **Charge Function Setting**, **Timer Setting**, **Battery Protection Setting**, and **Battery Thermistor Control**. This tab also indicates the charger status, battery status, and THR status.

20603-010

*Figure 10. ADP5360 GUI Software, **Charge Control** Tab*

BATTERY FUEL GAUGE SETTINGS

Program the battery state of charge (SoC) curve with the proper voltage from battery characterization or the default setting in the **Battery SoC %** section. This section is located in the **Fuel Gauge Control** tab (see Figure 11). Enter all battery characterization data, then click the **Program SoC Curve** button to write all data to the ADP5360. The GUI then updates the **Battery SoC Curve** graph. Other battery parameters in the GUI include the **BAT_CAP**, **BATCAP_TEMP**, and **BATCAP_AGE**. Sleep mode related setting options, such as **SLP_CURR** and **SCP_TIME**, are selected in the bottom left of the **Fuel Gauge Control** tab as well.

The **Battery SoC %**, **Battery Voltage (V)**, and **BAT_SOCACM %** values are read in the tab in Figure 11.

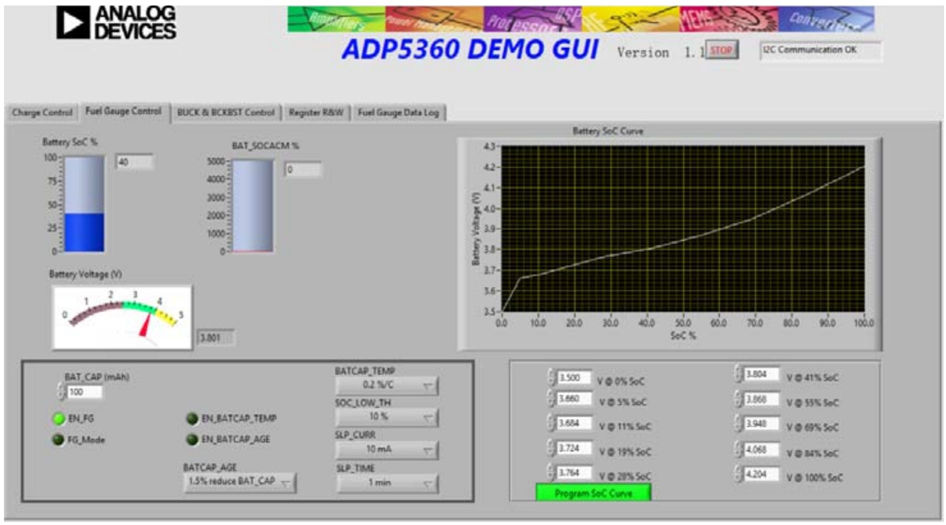

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*Figure 11. ADP5360 GUI Software, **Fuel Gauge Control** Tab*

BUCK AND BUCK BOOST SETTINGS

In the **BUCK & BCKBST Control** tab shown in Figure 12, users can program the buck regulator mode selection (**BUCK_MODE**), soft start time (**BUCK_SS**), and output voltage (**VOUT_BUCK**) in the **Buck Setting** section located on the top left.

Program the buck boost soft start time (**BUCKBST_SS**) and output voltage (**VOUT_BUCKBST**) in the **Buck Boost Setting** section located in the top middle of the GUI (see Figure 12).

Program the power supervisory parameter (**RESET_TIME**) in the **Supervisory Setting** section located on the bottom left of the GUI (see Figure 12).

To clear a fault, if a fault occurs and any of the fault bits are high as indicated in the **Fault Status** section (see Figure 12), verify that the open fault is cleared on the evaluation board and then click the **Fault Clear** button in the **Fault Status** section.

Select the interrupt event in the **Interrupt Setting** section located in the top right of the GUI (see Figure 12). If an interrupt occurs, information about the occurred interrupt appears in red in the **Interrupt Message** indication and blinks for 5 sec.

In addition, the power-good indications and mask control settings are located in the **Power Good Setting and Indicate** box.

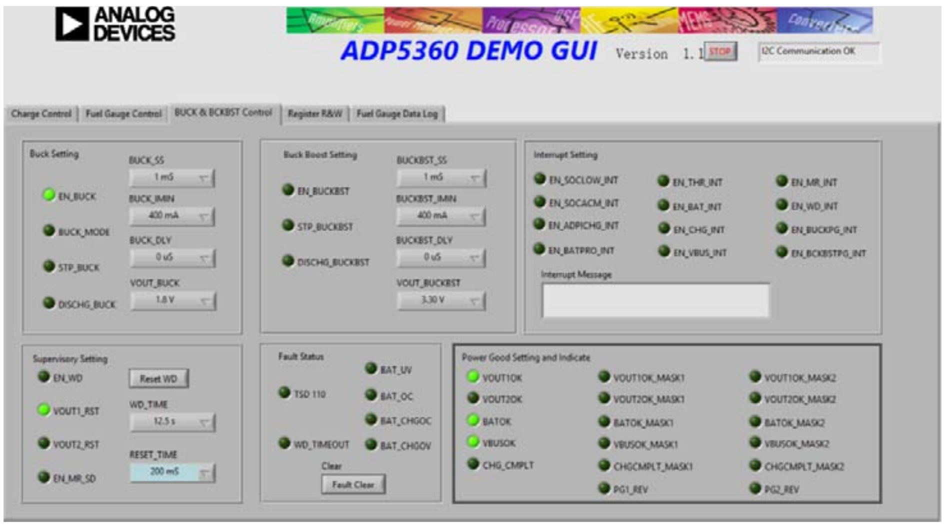

*Figure 12. ADP5360 GUI Software, **Buck & BCKBST Control** Tab*

DIRECT REGISTER WRITE AND READ

Users can read and write the contents of each register using the **Register R&W** tab shown in Figure 13. Clicking the **Read All Registers** button updates the content of each register to the GUI. Use the buttons and text fields in the **Read/Write a Single Register** section to initiate a single register read or write. Enter the register address in the **Register Address** box. Then, either click the **Read** button to read the binary data or click the **Write** button to write the binary data. Some registers, such as Register 0x00 and Register 0x01, are read only registers and cannot be overwritten.

FUEL GAUGE DATA LOG

In the **Fuel Gauge Data Log** tab, the data for the battery voltage and SOC updates in the **Battery SoC/Voltage** graph every 1 sec (see Figure 14).

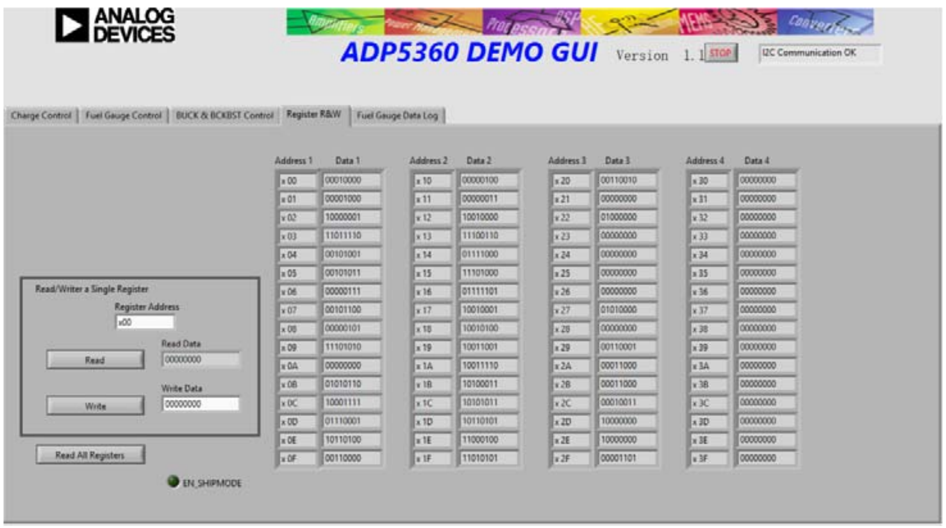

*Figure 13. ADP5360 GUI Software, **Register R&W** Tab*

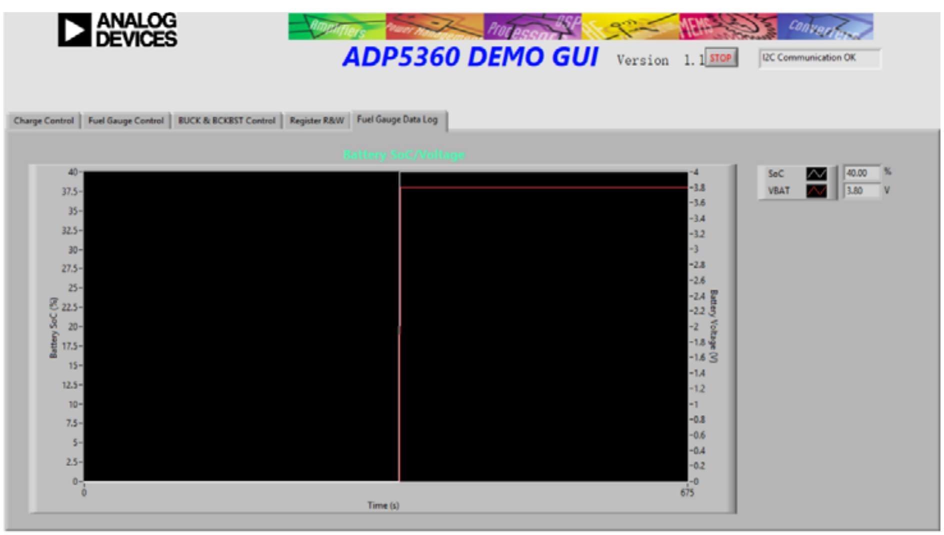

*Figure 14. ADP5360 GUI Software, **Fuel Gauge Data Log** Tab*

GUI TROUBLESHOOTING

If the GUI is not responding and the GUI error report window shown in Figure 15 appears. This issue may be because the USB-SDP-CABLEZ is not connected to the computer.

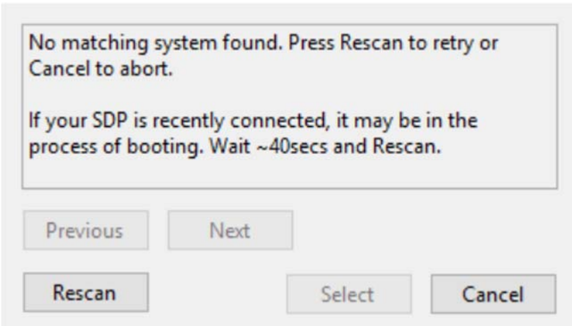

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Figure 15. GUI Error Report Window

If the GUI shows the **I2C Not Responding** warning blinking in red in the top right corner of the window next to the **STOP** button (see Figure 16), this may mean the I^2C bus is not detecting the ADP5360. Check that the cable is securely connected to the ADP5360CB-EVALZ evaluation board and ensure that power is being supplied to the ADP5360 device.

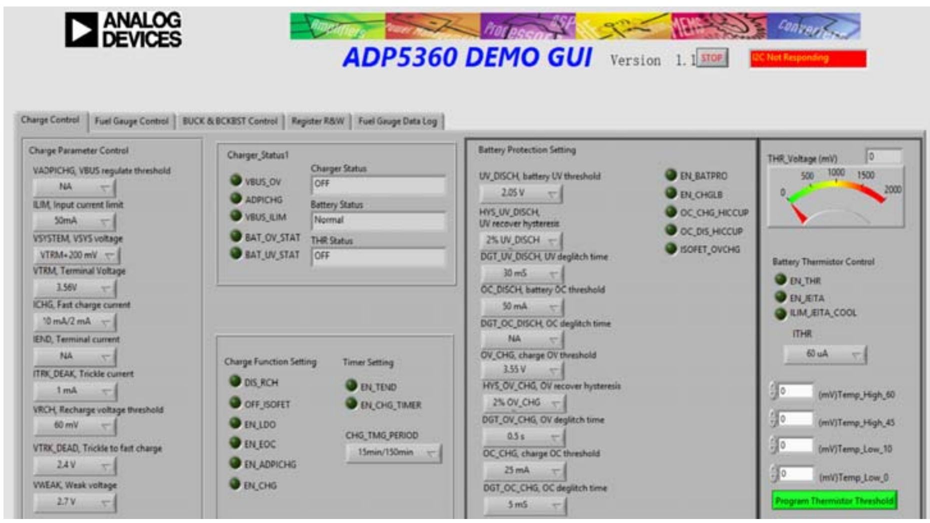

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*Figure 16. ADP5360 GUI Software, **I2C Not Responding Message***

USING THE EVALUATION BOARD

POWERING UP THE EVALUATION BOARD

The ADP5360CB-EVALZ evaluation board is supplied fully assembled and tested. Before supplying power to the evaluation board, follow the procedures detailed in the Input Jumpers section and Quick Start section. See Figure 17 for component locations.

Input Jumpers

Because VIN1 and VIN2 must be connected to VSYS, the input jumpers, S1 and S2, are shunted by default.

Set the ENSD jumper high to enable ADP5360 shutdown mode. After a Li-ion battery or battery simulator is connected to the ADP5360CB-EVALZ board, set the ENSD jumper low to disable shutdown mode.

Either set the ENCHG jumper to the high side or set the EN_CHG bit (see Figure 10) high in the GUI to enable the charger.

Set the EN1 jumper to the high side and click **EN_BUCK** in the **Buck Setting** section (see Figure 12) to set the EN_BUCK bit high to enable the buck regulator.

Either set the EN2 jumper to the high side or set the EN_BUCKBST bit in the **Buck Boost Setting** section (see Figure 12) high to enable the buck boost regulator.

Set the VDDIO jumper to VSYS or ISOB to select the logic voltage source.

Quick Start

Adhere to the following steps to construct a typical test setup:

1. Connect the USB-SDP-CABLEZ cable from the PC USB port to the ADP5360CB-EVALZ evaluation board.
2. Set the dc power supply to 5 V and connect the power supply to the on-board VBUS and GND to a dc power supply. Skip this step if the charge function does not need to be evaluated.
3. Use a charged battery or a battery simulator to connect to the ISOB and GND nodes.
4. Start the GUI software.

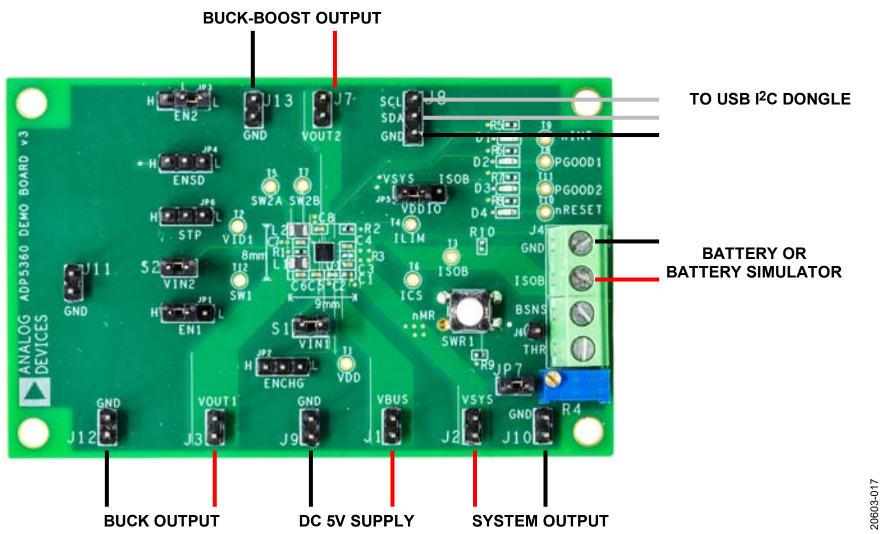

Figure 17. ADP5360CB-EVALZ WLCSP Board Connection Diagram

EVALUATION BOARD MEASUREMENTS

CHARGE FUNCTION EVALUATION

Input Current Limit

The input current-limit function of the ADP5360 can be evaluated in fast CC charging mode. An additional system load must be connected to the VSYS node to measure the input current limit of the VBUS node (see Figure 17) across the full programming range of 50 mA to 500 mA. Adhere to the following steps to evaluate the input current-limit function:

1. Set the supply voltage of the VBUS node on the ADP5360CB-EVALZ board to 5.0 V and then, either populate a charged battery (V_{BAT} > V_{WEAK}) or connect a battery simulator to the ISOB node (see Figure 17).
2. Use the **ILIM, Input current limit** option and **ICHG, Fast charge current** option in the **Charge Parameter Control** section to program the charge current higher than the input current-limit value (see Figure 10).
3. Measure the VBUS node input current by reading the input supply current in the dc power supply and check whether the **VBUS_ILIM** indicator is lit in the **Charger_Status1** section of the **Charge Control** tab (see Figure 10).

Connect an additional load to the VSYS node to evaluate values at the higher end (more than 300 mA) of the programming range.

Fast Charge Current

To measure the fast charge current value, adhere to the following steps:

1. Set the supply voltage of the on-board VBUS node to 5.0 V, populate a discharged battery (V_{BAT} > V_{WEAK}) and then either connect a battery simulator to the ISOB node, with the voltage set to 3.8 V.
2. Use the **ILIM, Input current limit** option in the **Charge Parameter Control** section under the **Charge Control** tab to program the input current limit to the maximum value, 500 mA.
3. Check that the **THR Status** box shows the **Thermistor OK** message in the **Charger_Status1** section of the **Charge Control** tab. Otherwise, the variable resistor, R1, must be tuned until the **THR Status** box shows **Thermistor OK**.
4. The default value for the fast charge current is 100 mA. Set the charge current with the range 10 mA to 320 mA in the **ICHG, Fast charge current** box in the **Charge Control** tab.
5. Click the **EN_CHG** indicator under the **Charge Function Setting** section in the **Charge Control** tab to set the EN_CHG bit high. Then measure the input charge current of the battery by reading the battery simulator.

The fast charge current may be reduced due to one of the following conditions:

- The V_{ISOB} (the voltage at the ISOB node) level is close to the **VTRM, Termination Voltage** value in the **Charge Parameter Control** box (see Figure 10). The default value is 4.16 V. The device is operating in constant voltage mode upon power-up.
- The input voltage is lower than expected, 4.5 V or lower, and close to the battery voltage.
- The Japan Electronic Information Technology Association (JEITA) function is enabled, which occurs when the EN_JEITA bit is set high in the **Charge Control** tab, and the temperature is cool. See the ADP5360 data sheet for more information.

Termination Charge Voltage

It recommended to use a battery simulator to measure the termination charge voltage. Take the following steps to use the battery simulator to measure the termination charge voltage:

1. Set the supply voltage of the on-board VBUS node to 5.0 V.
2. Set the termination voltage to 4.2 V in the **VTRM, Terminal Voltage** box in the **Charge Parameter Control** section (see Figure 10).
3. Increase the battery voltage in the battery simulator, until the **Charger Status** box under the **Charger_Status1** section in the GUI shows **Fast Charge (CV Mode)** and the charge current, measured in the battery simulator, drops lower than the charge current setting (see Figure 10).
4. Measure the termination voltage between the BSNS and GND nodes by using the voltage meter.

FUEL GAUGE FUNCTION EVALUATION

In the **Fuel Gauge Control** tab in Figure 11, the SoC value and battery voltage are all shown when users enable the EN_FG bit. The battery SoC value indicates the remaining battery capacity and is found in the **Battery SoC %** gauge located in the **Fuel Gauge Control** tab. Enabling sleep mode for the fuel gauge places the ADP5360 in very low power consumption mode.

Before enabling the fuel gauge function, the battery SoC vs. battery voltage characterization data must be entered in the **SoC** and **VBAT** boxes located in the right side of the **Fuel Gauge Data Log** tab (see Figure 14). Click the **Program SoC Curve** button in the bottom right of the **Fuel Gauge Control** tab to program the data (see Figure 11). The battery capacity can be filled in the **BAT_CAP** box located at the bottom left of the **Fuel Gauge Control** tab.

Set the FG_MODE bit high (located under the **BAT_CAP** box in Figure 11) by clicking the **FG_Mode** indicator to light it up in the GUI. Setting this bit high allows the fuel gauge to run in sleep mode, which achieves a low quiescent current. Set the EN_BATCAP_TEMP and EN_BATCAP_AGE bits high (see Figure 11) high by clicking the corresponding indicators to light them up in the GUI. Setting these bits high enable the battery capacity temperature and aging compensation feature.

BATTERY PROTECTION FUNCTION EVALUATION

All battery protection voltage and current threshold settings, hysteresis setting, and deglitch time is set up in the **Battery Protection Setting** section, under the **Charge Control** tab, shown in Figure 18.

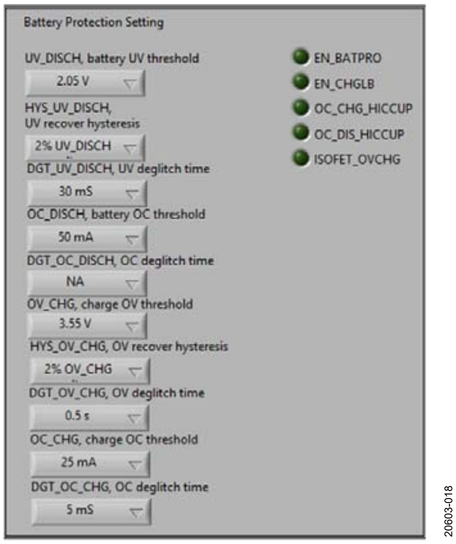

*Figure 18. GUI **Charge Parameter Control** Settings*

Ensure the EN_BATPRO bit, corresponding indicator located in the **Charge Control** tab (see Figure 11), is set to high and that the battery protection feature is enabled and lit up.

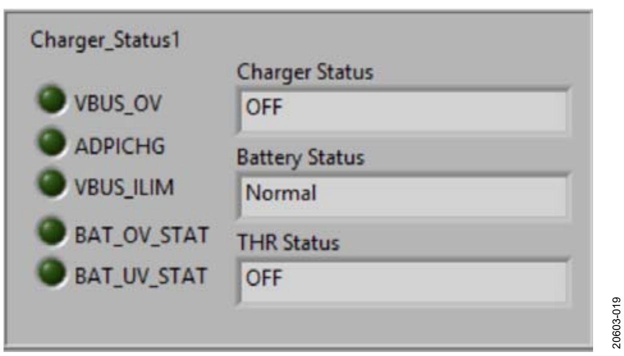

*Figure 19. GUI **Charger_Status1** Settings*

For UV protection, set the ISOB voltage lower than the default 2.5 V **UV_DISCH, battery UV threshold** value (see Figure 18). Next, check that the **BAT_UV_STATUS** (see Figure 19) status bit is set to high, the VSYS node voltage is shut down, and that the battery is isolated from the VSYS side.

For overvoltage (OV) protection, set the battery simulator voltage higher than the default 4.3 V **OV_CHG, charge OV threshold** (see Figure 18) value. Then check that the **BAT_OV_STATUS** (see Figure 19) status bit set to high and that the VSYS node is isolated from the ISOB node.

To enable the overdischarge current protection, set the VSYS load current (see Figure 17) at the system output to the default **OC_DISCH, battery OC threshold** value (see Figure 18). Next, check that the battery ISOB node is isolated from the VSYS side, and that the BAT_OC fault bit (see Figure 20) is set high (**BAT_OC** lit up).

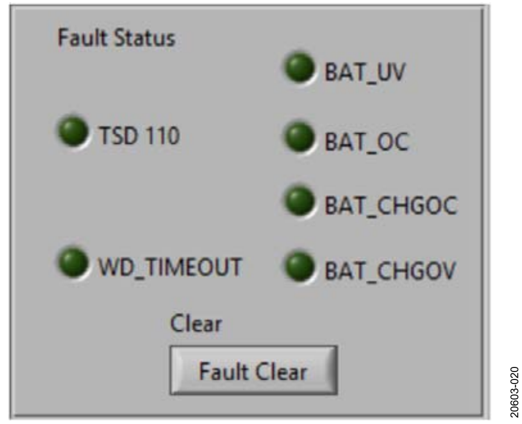

*Figure 20. GUI **Fault Status** Settings*

To enable overcharge current protection, set the charge current higher than the default **OC_CHG, charge OC threshold** value (see Figure 18). Next, check that the charger has shut down and that the BAT_CHGOC fault bit (see Figure 20) is set high.

BUCK REGULATOR EVALUATION

Check that the EN1 jumper is set high on the evaluation board. Next, set the EN_BUCK bit high by clicking **EN_BUCK** in the GUI (see Figure 21).

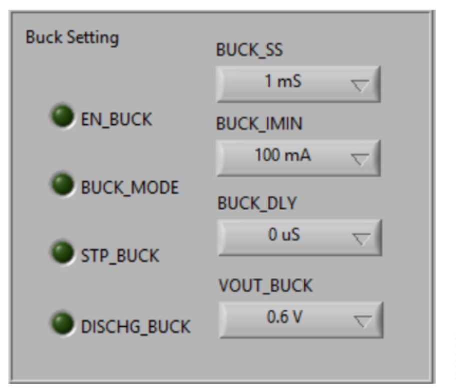

*Figure 21. GUI **Buck Setting** in **BUCK & BCKBST Control** Tab*

In the **Buck Setting** section shown in Figure 21, keep the BUCK_MODE bit low (default) to select buck operation as hysteresis mode for low quiescent current. If the BUCK_MODE bit is set high, the buck regulator operates in force PWM (pulse-width modulation) mode for low noise using a lower noise power requirement.

The default buck regulator output voltage is 1.2 V. Program the VOUT_BUCK bits (see Figure 21) to set the other output voltages in the **VOUT_BUCK** dropdown list.

Measure Load Regulation

After the VOUT1 board terminal voltage reaches 1.2 V, increase the load current at VOUT1 before checking the voltage between VOUT1 and GND with the voltage meter.

Measure Regulator Efficiency

The regulator efficiency is measured by dividing input power by output power.

Change Buck Soft Start Time

Set the soft start time in the BUCK_SS bits in the **Buck Setting** box (see Figure 21).The default soft start time is 1 ms and users must select a different soft start time. The soft start time options are 1 ms (not recommended), 8 ms, 64 ms, and 512 ms.

BUCK BOOST REGULATOR EVALUATION

Set the EN_BUCKBST bit (see Figure 22) high to enable the buck boost regulator.

The default buck boost regulator output voltage is 5 V. Program the VOUT_BUCKBST bits (see Figure 22) to set the output voltage.

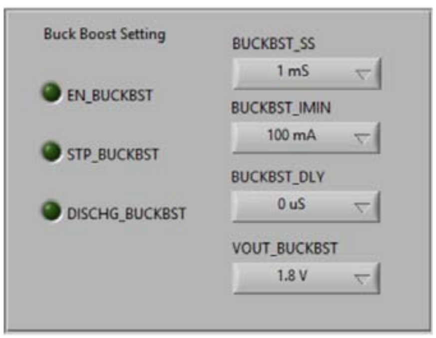

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Figure 22. GUI **Buck Boost Setting** in **BUCK & BCKBST Control** Tab

Measure Load Regulation

After the VOUT2 board terminal voltage reaches 5 V, increase the load current at VOUT2, then check the voltage between the on-board VOUT2 and GND.

Measure Regulator Efficiency

The efficiency is measured by dividing the input power by the output power.

Change Buck Boost Soft Start Time

Set the soft start time for the BUCKBST_SS bits in the **Buck Boost Setting** box (see Figure 22). The default soft start time is 1 ms and users must select a different soft start time. The soft start time options are 1 ms (not recommended), 8 ms, 64 ms, and 512 ms.

POWER SUPERVISORY EVALUATION

In the **Supervisory Setting** box (see Figure 23), set the EN_WD bit high to enable the watchdog function. Program the watchdog timeout through the WD_TIME bits (see Figure 23). Click the **RESET WD** button, located above the **WD_TIME** box, to toggle the ADP5360 watchdog.

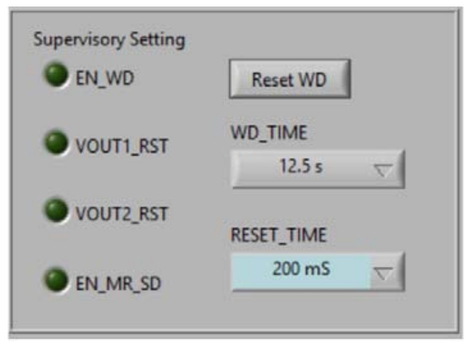

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Figure 23. GUI **Supervisory Setting** in **BUCK & BCKBST Control** Tab

Select V_{OUT1} or V_{OUT2} as the ADP5360 monitor voltage rail and use an oscilloscope to observe the $\overline{\text{RESET}}$ pin voltage (see Figure 1).

EVALUATION BOARD SCHEMATICS AND ARTWORK

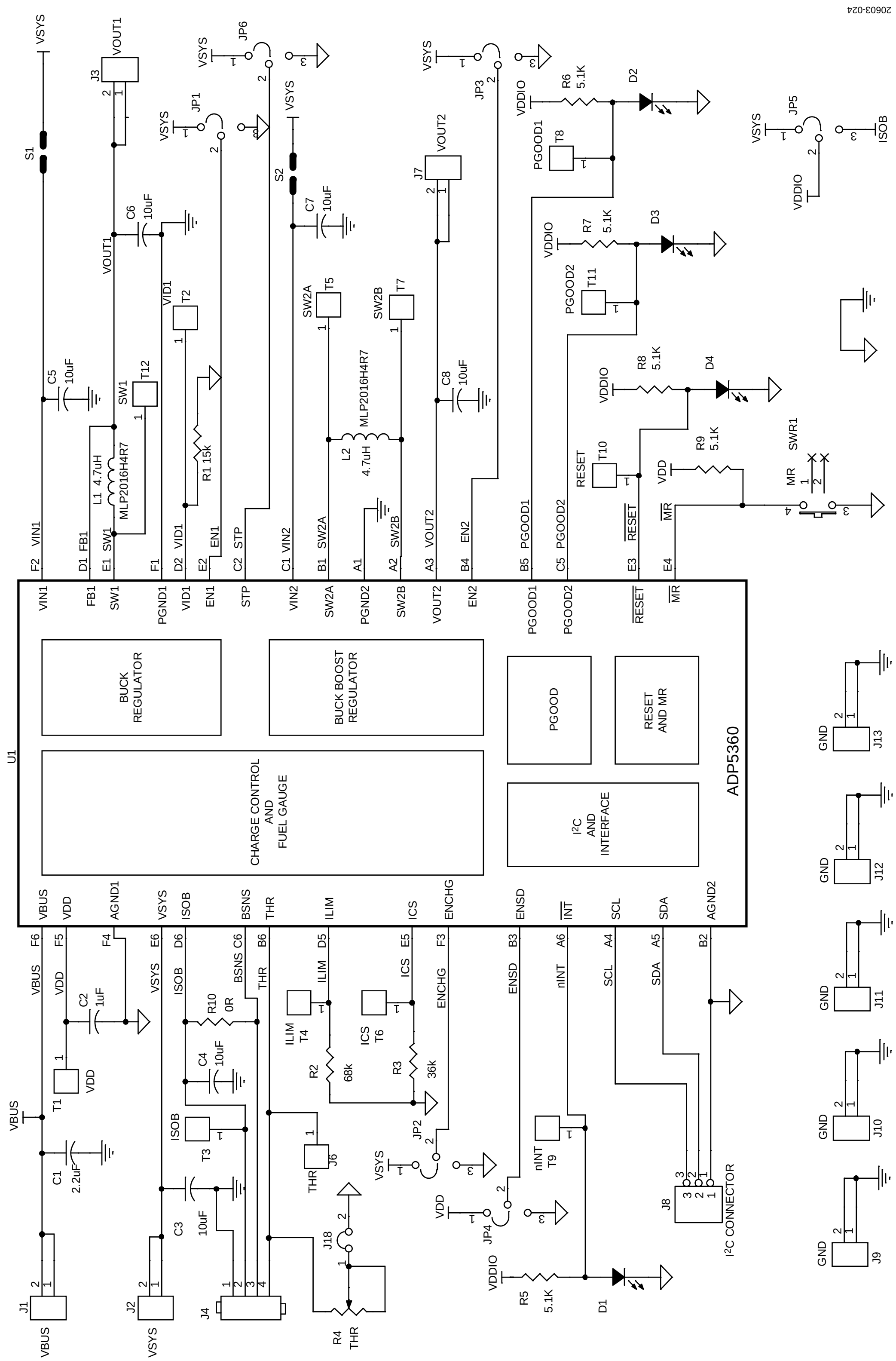

Figure 24. Evaluation Board Schematic of the ADP5360CB-EVALZ Evaluation Board

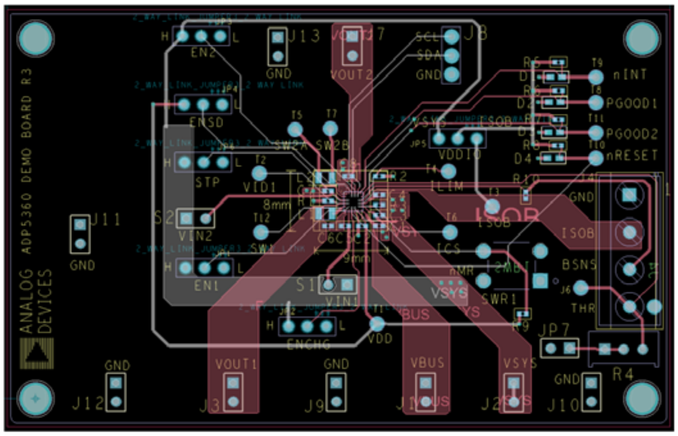

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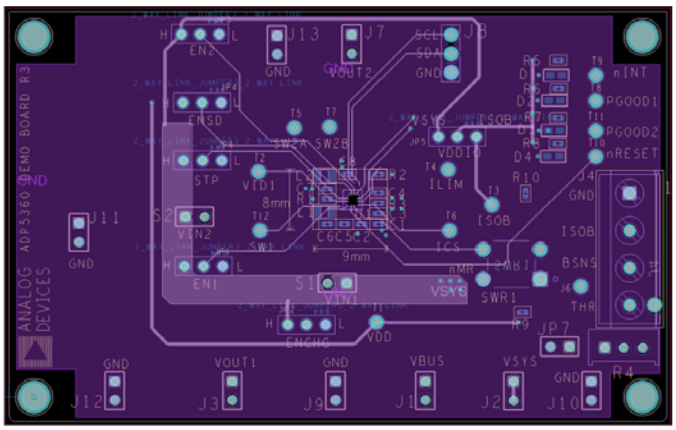
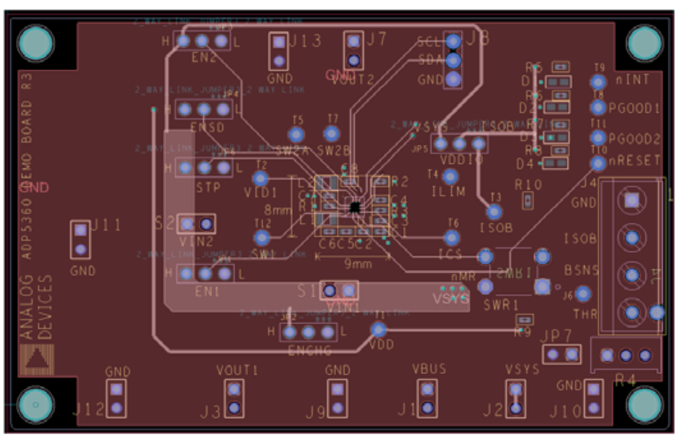
Figure 25. Top Layer, Recommended Layout for the ADP5360CB-EVALZ Evaluation Board



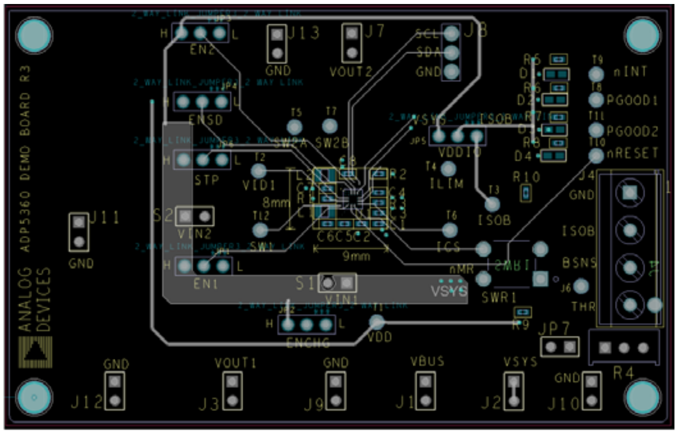
20603-026

Figure 26. Second Layer, Recommended Layout for the ADP5360CB-EVALZ Evaluation Board



20603-027

Figure 27. Third Layer, Recommended Layout for the ADP5360CB-EVALZ Evaluation Board



20603-028

Figure 28. Bottom Layer, Recommended Layout for the ADP5360CB-EVALZ Evaluation Board

ORDERING INFORMATION

BILL OF MATERIALS

Table 1.

Quantity	Reference Designator	Description	Manufacturer	Part Number
1	U1	Battery management and power management IC (PMIC)	Analog Devices	ADP5360
1	C1	Ceramic capacitor, 2.2 µF, 25 V, 20%, X5R, 0402	Murata	GRM155R61E225ME15D
1	C2	Ceramic capacitor, 1 µF, 6.3 V, 20%, X5R, 0402	Murata	GRM155R60J105KE19D
6	C3 to C8	Ceramic capacitor, 10 µF, 6.3 V, 20%, X5R, 0402	Murata	GRM155R60J106ME44D
4	D1 to D4	LED indicator	LITE-ON	LTST-C191KGKT
2	L1, L2	Inductor, 4.7 µH	Wurth Elektronik	74479776247A
1	R4	Slide resistor, 200 kΩ	Bourns	3296W-1-204LF
1	R1	Film resistor, surface-mount device (SMD), 0402, 15 kΩ	Yageo	RC0402FR-0715KL
1	R2	Film resistor, SMD, 0402, 68 kΩ	Yageo	RC0402FR-0768KL
1	R3	Film resistor, SMD, 0402, 36 kΩ	Yageo	RC0402FR-0736KL
5	R5 to R9	Film resistor, SMD, 0402, 5.1 kΩ	Yageo	RC0402FR-075K1L
1	R10	Film resistor, SMD, 0402, 0 Ω	Yageo	RC0402FR-070RL
1	SW1	Switcher	Multicomp	MC32829

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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