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# AD8452 Battery Testing and Formation Evaluation Board

## FEATURES

**Fully functional Li-Ion cell formation and testing similar to real-world manufacturing equipment**
**Ability to charge and discharge batteries under constant current and constant voltage control**
**Energy recycling from discharging battery into a dc bus**
**Full featured system evaluation board based on the AD8452**
**PC software for control and monitoring of system parameters**
**Compatible with the System Demonstration Platform, SDP-S (EVAL-SDP-CS1Z)**

## EVALUATION KIT CONTENTS

**Analog interface board**
**Power module board (10 V to 20 V dc operating range)**
**SDP-S board for data transfer to PC**
**Standard USB A to Mini-B USB cable**
**Printed user guide**
**Evaluation kit software CD**

## HARDWARE REQUIREMENTS

**Bench power supply, 12 V to 24 V dc (current depending on desired battery charge rate)**
**Test battery or electronic load**
**Windows PC with a USB port**

## WARNING

When testing this system with lithium-ion (Li-Ion) batteries, take care not to overcharge or overdischarge the batteries, or to sink/source more than the maximum current recommended by the manufacturer of the battery. Exceeding these ratings can not only damage the battery, but can also cause it to explode or catch on fire.

## GENERAL DESCRIPTION

The AD8452 system demo evaluation kit is a recommended starting point for users building battery formation and test equipment based on the Analog Devices, Inc., AD8452 precision analog front end and pulse-width modulation (PWM) controller. The evaluation kit includes an analog interface board and a power module board.

In addition to the AD8452, the analog interface board also includes an AD5689R 16-bit, precision digital-to-analog converter (DAC) to set the current and voltage set points, and an AD7173-8 24-bit, Σ-Δ analog-to-digital converter (ADC) to monitor the battery voltage and current.

The analog interface board includes built-in voltage regulators so that it can be powered either from the bus power inputs or directly from a 15 V dc supply through a screw terminal connector.

The analog interface board connects to the Analog Devices System Demonstration Platform (SDP-S) through a 120-pin connector. The SDP-S board connects to the user interface software through the USB port, allowing the user to set the current and voltage set point as well as the mode of operation (charge or discharge). In addition, the user can monitor the battery voltage and current by reading the data output from the AD7173-8.

The analog interface board connects to the power module board through three multipin headers. This modular approach allows the user to design and test their own power module boards, designed for the current output range in their end applications, with the analog interface board of this reference design.

The standard power module board supports charge and discharge currents of up to 10 A. It includes the power metal-oxide semiconductor field effect transistors (MOSFETs), the inductor, and the input and output capacitors required to implement a buck or boost regulator, depending on the operating mode.

Full specifications of the AD8452 are available in the product data sheet, which must be consulted in conjunction with this user guide when working with the evaluation kit.

# TABLE OF CONTENTS



## REVISION HISTORY

**10/2017—Revision 0: Initial Version**

# EVALUATION BOARD PHOTOGRAPH

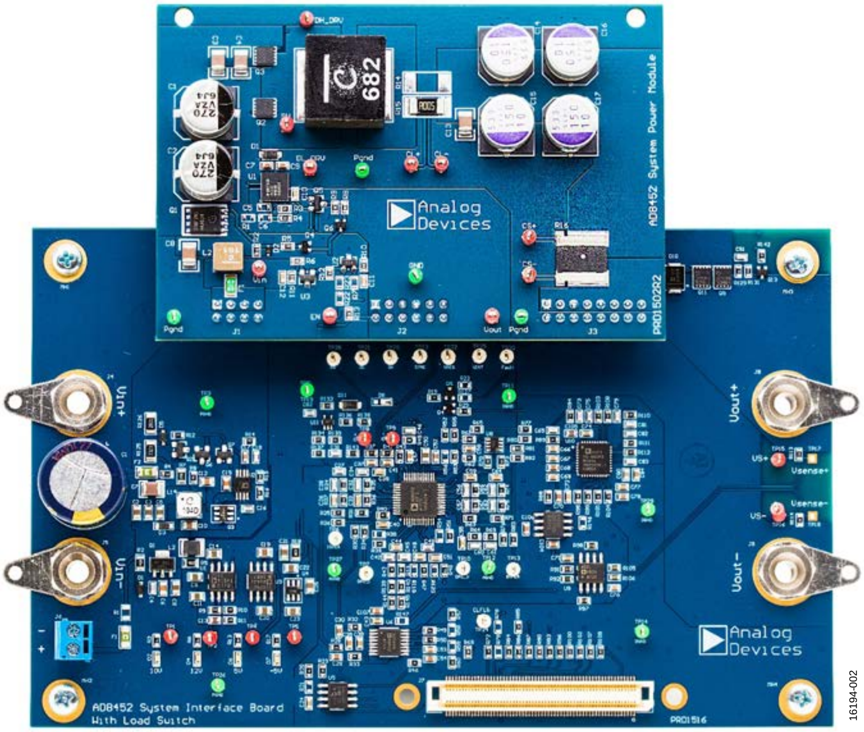


*Figure 1. Power Module Board (Top), Analog Interface Board (Bottom)*

## SIMPLIFIED EVALUATION BOARD BLOCK DIAGRAM

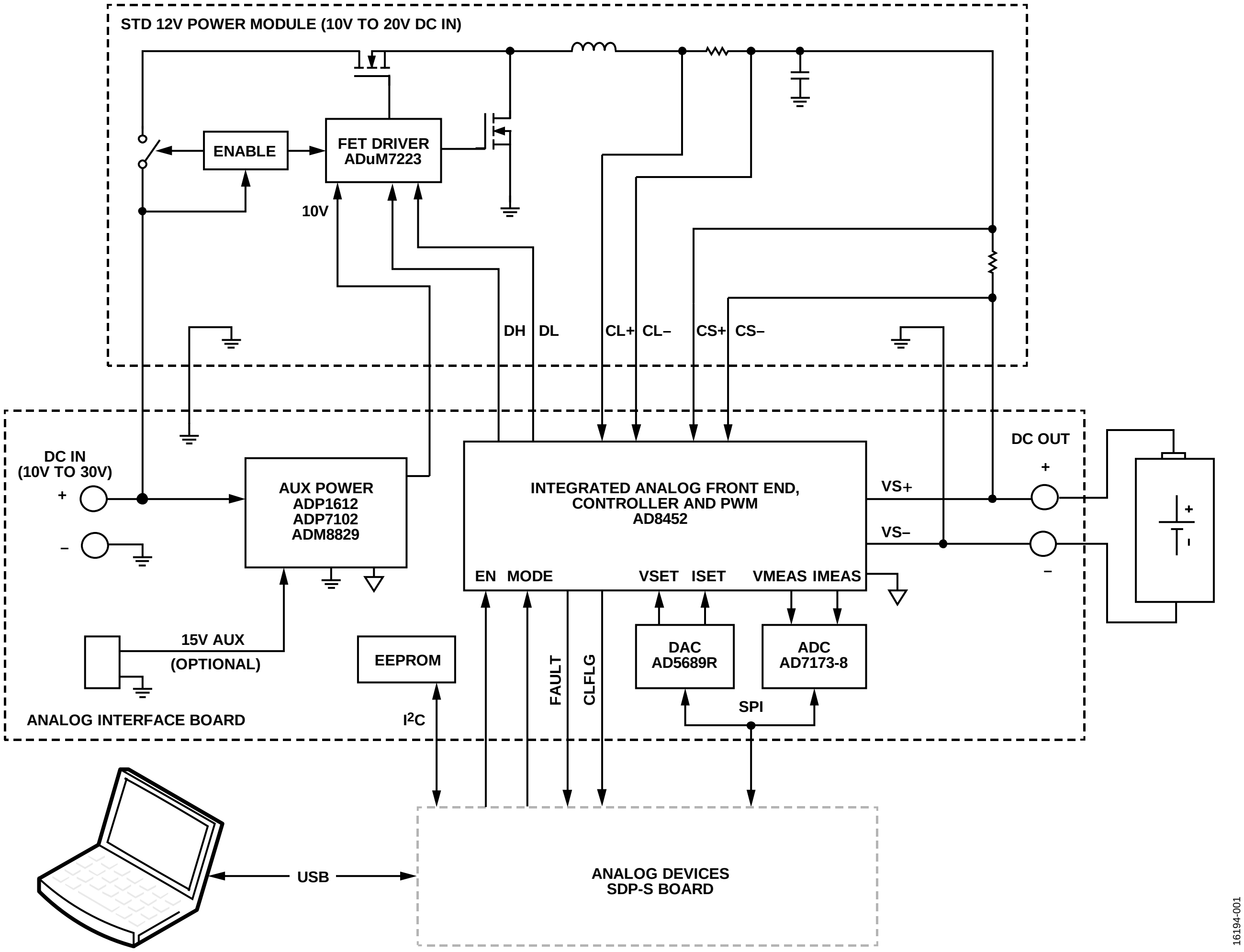


*Figure 2. System Diagram*

# EVALUATION BOARD HARDWARE

## SETTING UP THE EVALUATION SYSTEM

Figure 25 to Figure 27 show the analog interface board schematics, and Figure 17 shows the power module board schematic.

The analog interface board includes the AD8452 (U7), the AD7173-8 24-bit Σ-Δ ADC (U10), and the AD5689R 16-bit DAC (U6).

Connector J1, Connector J2, and Connector J3 mate with the power module board to provide the PWM control signals for the MOSFET drivers, as well as the battery voltage, the current signals, and the supply voltage for the analog interface board. The modular approach of the system allows users to use the analog interface board with their custom design power module. Table 1, Table 2, and Table 3 list the header pin names and functionalities.

The power module board includes an ADuM7223 MOSFET driver (U1), a high-side and low-side power MOSFET, switching inductor, and input output capacitors.

Connect the boards as shown in Figure 1.

## POWERING THE SYSTEM

The evaluation system requires power from an external dc power source. The main power input is connected through the banana terminals labeled J4 and J5 on the analog interface board. The input voltage to the system can be between a 10 V minimum and a 30 V maximum, depending on the operating voltage of the power module board. The standard power module board, included in this system, allows operation up to 20 V. The input current depends on the desired load current (that is, battery charge current). To run the board at the rated 10 A charge current into a 5 V load, the input 12 V power supply must be capable of delivering at least 5 A.

The analog interface board can be powered from the main power input or from a separate dc supply using the J6 screw terminal connector. In the default configuration, the analog interface is powered from the main power input terminals. To power the analog interface board from an independent 15 V source, remove Resistor R4 and populate a 0 Ω jumper at R1.

To turn on the board, apply 12 V input power of the correct polarity between terminals J4 and J5. The light emitting diodes (LEDs) on the lower left of the analog interface board illuminate, indicating the analog interface voltage regulators are operating.

The battery or electronic load can be connected to the banana terminals labeled J8 and J9.

## AD8452 COMPENSATION NETWORKS

The evaluation system ships configured for connection to a Chroma 63600 series electronic load. If the electronic load of the user has a different response, or if the user wants to use the system with a rechargeable battery, adjust the compensation values in each of the four AD8452 control loops to ensure system stability. The online AD8450/AD8451 compensator design tool at http://analogplayground.com/AD8450 can be used to assist with compensation by adding the current limit shunt resistance to the inductor equivalent series resistance (ESR) and entering the sum in the **$R_L$ Inductor ESR (Ω)** entry box. See the AN-1319 for detailed analysis of the compensation.

## SERIAL INTERFACE

The evaluation system uses the serial peripheral interface (SPI) on the SDP-S board to read the current and voltage ADCs, and to set the current and voltage set points with the AD5689R DAC.

**Table 1. J1 Board to Board Connector Pinout**

| Pin No. | Name | Description |
|---|---|---|
| 1, 3, 5, 7 | Vin+ | Supply rail from analog interface board |
| 2, 4, 6, 8 | PGND | Power ground |

**Table 2. J2 Board to Board Connector Pinout**

| Pin No. | Name | Description |
|---|---|---|
| 1 | GND | Digital ground |
| 2 | 5 V | Logic supply |
| 3 | DL | Low side FET logic signal |
| 4 | 10 V | Supply for FET drive |
| 5 | DH | High side FET logic signal |
| 6 | AUX_EN | Control signal to/from analog interface board |
| 7 | GND | Digital ground |
| 8 | GND | Digital ground |
| 9 | CL+ | Inductor current sense (+) |
| 10 | CS− | Output current sense (−) |
| 11 | CL− | Inductor current sense (−) |
| 12 | CS+ | Output current sense (+) |

**Table 3. J3 Board to Board Connector Pinout**

| Pin No. | Name | Description |
|---|---|---|
| 1, 3, 5, 7, 9, 11, 13, 15 | Vout+ | Output to analog interface board |
| 2, 4, 6, 8, 10, 12, 14, 16 | PGND | Power ground |

## POWER MODULE BOARD DESCRIPTION

Figure 17 shows the power module board schematic. The input bus supply connects to the power module board through the J1 connector. MOSFET Q1 is used to connect or disconnect the input power bus to the switching power section if the input is within the operating voltage range.

The power module includes input capacitors, a low-side and high-side MOSFET, an inductor, and output capacitors. Depending on the mode of operation, the AD8452 drives the power module in either step-down (buck) or step-up (boost) mode. The AD8452 drives the power module in synchronous mode for improved efficiency. A current sense resistor (R14) is connected in series with the inductor to provide inductor current feedback to the AD8452 to prevent reverse current.

The ADuM7223 translates the 5 V level PWM signals from the AD8452 into low impedance, 10 V drive signals for the MOSFETs. A simple linear regulator circuit on the analog interface board generates the 10 V rail for the MOSFET driver from the main input rail.

The power module board includes a 3 mΩ sense resistor (R16) for measuring the output current. The output of the power module board connects to the analog interface board through Connector J3.

## ANALOG INTERFACE BOARD DESCRIPTION

The analog interface board includes the AD8452 as well as an AD5689R DAC to configure the set points and an AD7173-8 ADC to monitor the current and voltage.

The analog interface board includes an ADP1612 single-ended primary inductor converter (SEPIC) to provide a wide input voltage range followed by a pair of ADP7102 linear regulators to generate 12 V and 5 V, and an ADM8829 switched capacitor inverter that generates −5 V for the AD8452 so that it can measure and output voltages close to 0 V.

The current sense programmable gain instrumentation amplifier (PGIA) of the AD8452 has a fixed gain of 66. With a gain of 66, a 10 A output current results in an output voltage of 1.98 V at TP6 (Pin ISMEA).

The voltage sense programmable gain difference amplifier (PGDA) has a fixed gain of 0.4. With a gain of 0.4, a 4 V battery voltage results in a 1.6 V output at TP13 (Pin BVMEA).

The AD7173-8 ADC measures the voltage and current signals and reports the values to the user interface software through the SDP-S interface. The default full-scale input range of the AD7173-8 is configured at 2.5 V. The AD5689R DAC Output A configures the constant current set point, and Output B sets the constant voltage set point. The default DAC output range is also from 0 V to 2.5 V. Given the current and voltage gain settings of the AD8452, the current and voltage set points can be calculated as follows:

$$PGIA\_GAIN = 66$$

$$PGDA\_GAIN = 0.4$$

$$Constant\_Current\_Setpoint = V_{DAC\_A}/(PGIA\_GAIN \times 0.003)$$

$$Constant\_Current\_Setpoint = V_{DAC\_B}/(PGDA\_GAIN)$$

The ADCMP370 comparator at U11 controls the transition from nonsynchronous to synchronous switching. When the output current is less than 1 A, the comparator clamps the SS pin to less than 4.5 V and forces the AD8452 to operate in nonsynchronous switching mode. When the output current exceeds 1 A, the SS pin is allowed to rise above 4.5 V, and the AD8452 transitions to synchronous switching mode. Operating in nonsynchronous switching mode at low output currents effectively eliminates reverse current though the inductor. At higher currents, synchronous switching provides improved converter efficiency.

The Q8, Q9, Q10, and Q11 output transistors form a bidirectional load switch on the output of the dc-to-dc converter. The load switch is disabled by default with a shorting jumper across JP1. Removing the shorting jumper across JP1 enables the load switch and demonstrates how the load switch can control current direction during low current operation.

The state of the load switch FETs is determined by the operating mode and the output current. When the ADCMP370 at U17 detects that the output current is less than 500 mA, the mode signal enables one pair of load switch FETs and disables the second pair of load switch FETs. Current is forced through the diode in parallel with the disabled FET pair, controlling the direction of current flow. Additionally, the increased output impedance of the diode allows enhanced current control when operating below 500 mA. When the output current exceeds 500 mA, both pairs of load switch FETs are enabled, providing a low resistance current path and maximum power efficiency.

# EVALUATION BOARD SOFTWARE

## INSTALLING THE SOFTWARE

The evaluation board software can be downloaded from the AD8452 product page on the Analog Devices website.

Install the software prior to connecting the SDP-S board to the USB port of the PC. This procedure ensures that the SDP-S board is recognized when it connects to the PC.

1. Start the Windows® operating system and download the software from the AD8452 product page on the Analog Devices website.
2. Unzip the downloaded file. Run the **setup.exe** file.
3. After installation is complete, plug the SDP-S board into the PC using a USB cable, and power up the evaluation board as described in the Powering the System section.
4. Launch the software.
5. When the software detects the evaluation board, proceed through any dialog boxes that appear to finalize the installation.

The default location for the software is **C:\Program Files (x86)\Analog Devices\AD8452_SystemDemoBoard**.

This location contains the executable software and support files.

## INSTALLATION STEPS

Proceed through the installation, allowing the software and drivers to be placed in the appropriate locations. Connect the SDP-S board to the PC only after the software and drivers are fully installed.

There are two parts to the software installation. The first part installs the software related to the evaluation board, as shown in Figure 3 to Figure 6.

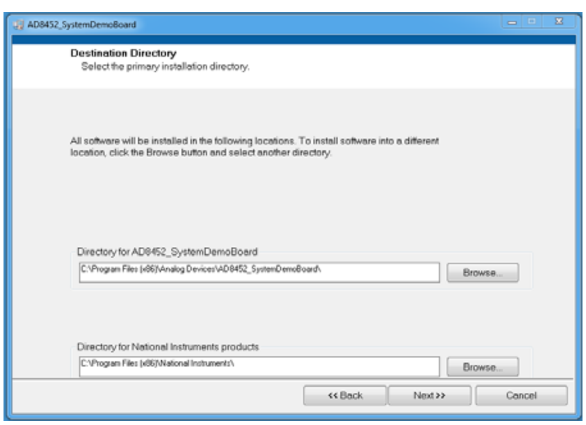


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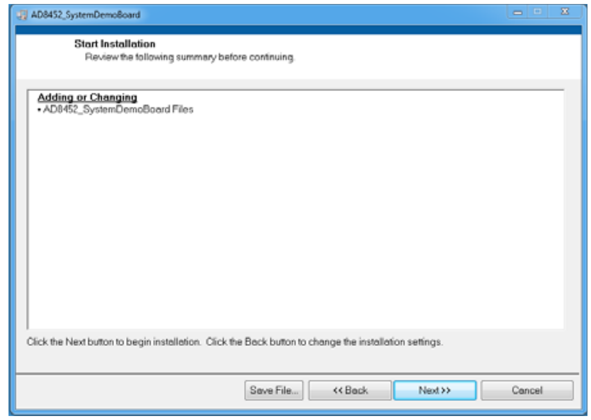
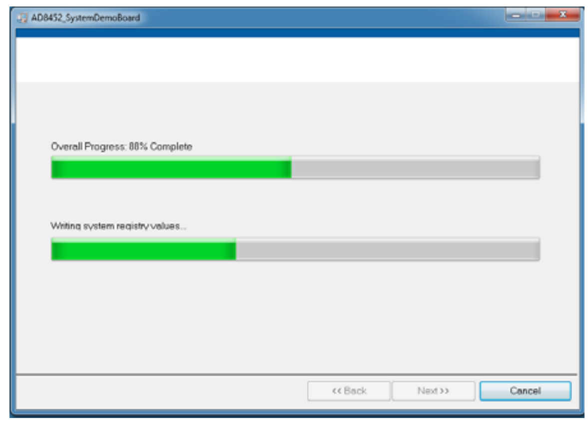
*Figure 3. Choose Folder Location (Default Folder Shown)*



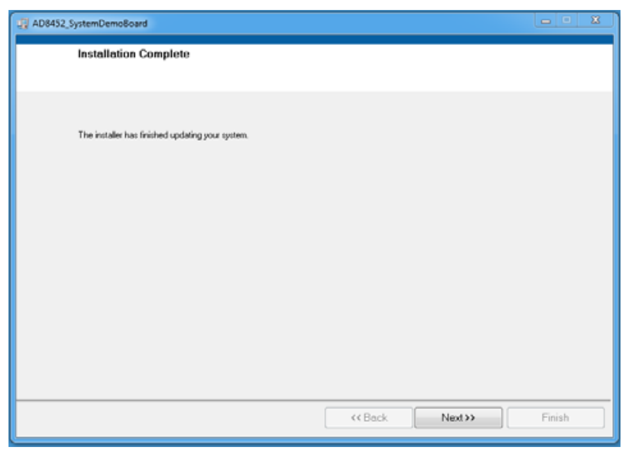

16194-004

*Figure 4. Click **Next >>** to Install Software*




16194-005

*Figure 5. Progress Bar Showing Installation Progress*




16194-006

*Figure 6. Installation Complete, Click **Next >>** to Finish*

The second part of the software installation is the drivers related to the SDP-S board (see Figure 7 to Figure 10). These drivers must be installed for the evaluation board to function correctly.


*Figure 7. Installation for SDP Drivers Starting*


*Figure 8. Click **Next >** to Install the SDP Drivers*

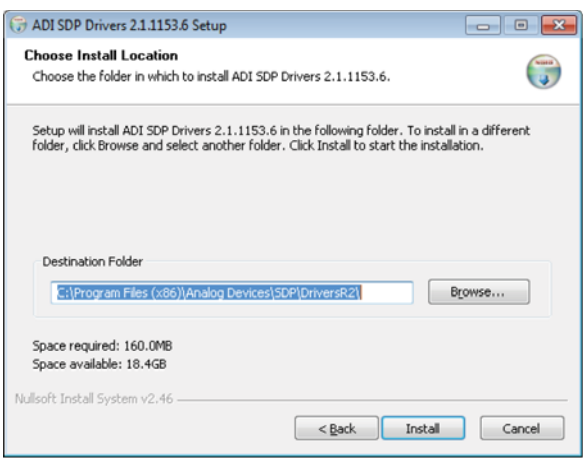



*Figure 9. Choose Install Location (Default Folder Shown)*

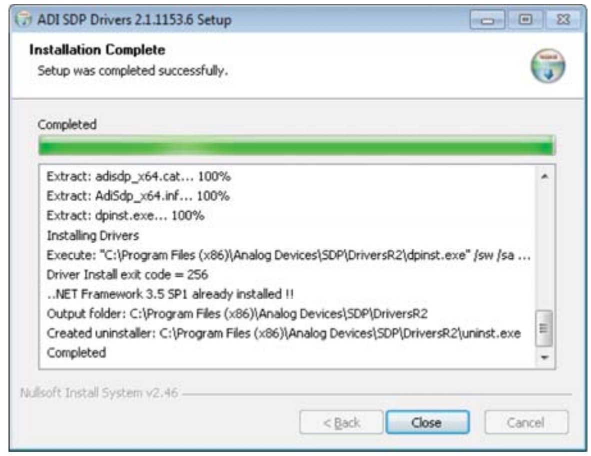



*Figure 10. Click **Close** to Complete Installation*

When the SDP-S board is first plugged into the PC via the USB cable provided, allow the new **Found Hardware Wizard** to run. Check that the drivers and the board are connected correctly by looking at the **Device Manager** of the PC. The **Analog Devices System Development Platform SDP-S** appears under **ADI Development Tools** (see Figure 11).


*Figure 11. Device Manager*

## BOARD OPERATION/CONNECTION SEQUENCE

The following is the board operation/connection sequence:

1. Connect the SDP-S controller board to the analog interface board with the J7 connector (screw into place as required).
2. Power the board with the appropriate supply as described in the Powering the System section.
3. Connect an electronic load or battery.
4. Connect the SDP-S board to the PC with the USB cable.
5. To launch the software, click **Start**, **All Programs**, **Analog Devices**, **AD8452_SystemDemoBoard**, **AD845_SystemDemoBoard**.
6. Configure the set points and use the software to monitor the battery state.

## RUNNING THE SOFTWARE WITH THE HARDWARE CONNECTED

To run the program, take the following steps:

1. Click **Start**, **All Programs**, **Analog Devices**, **AD8452_SystemDemoBoard**, **AD8452_SystemDemoBoard**.
2. If the SDP-S board is not connected to the USB port when the software is launched, a connectivity error displays (see Figure 12). Connect the SDP-S board to the USB port of the PC, wait a few seconds until the board appears in the lower section of the window, and click **Select** (see Figure 12).

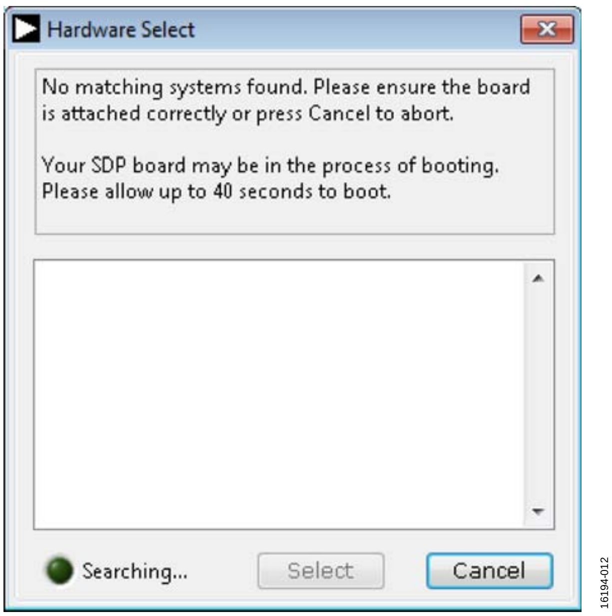



*Figure 12. SDP-S Board Not Connected to the USB Port*

3. When the AD8452 analog interface board is detected, the message in Figure 13 displays. Click **Select** to continue.

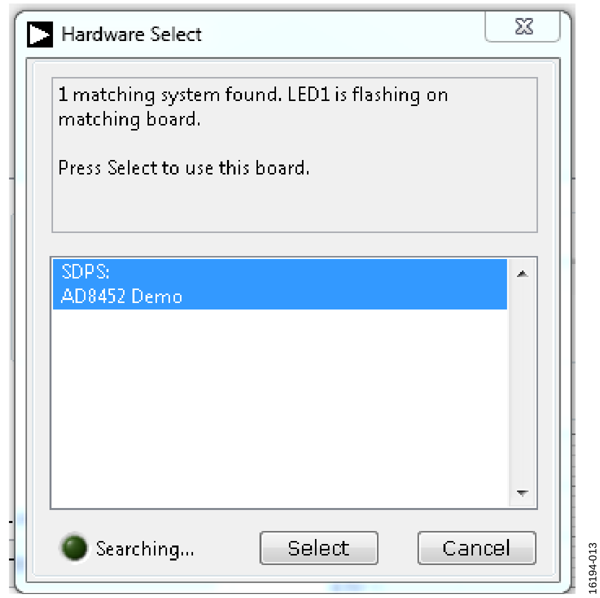



*Figure 13. Software Detects Evaluation Board*

4. The software then connects to the board, and the software window opens.

# SOFTWARE OPERATION

When the software launches, the window shown in Figure 14 opens and the software starts communicating with the analog interface board. The software starts with the power module disabled, which allows the user to configure the set points before any current flows into the load.

## DESCRIPTION OF THE MAIN WINDOW

The main window shows the system status at a glance. The system diagram quickly shows whether the system is set to either charge mode or discharge mode, and the digital indicators next to the battery icon and the current icon show the readings for battery voltage and current.

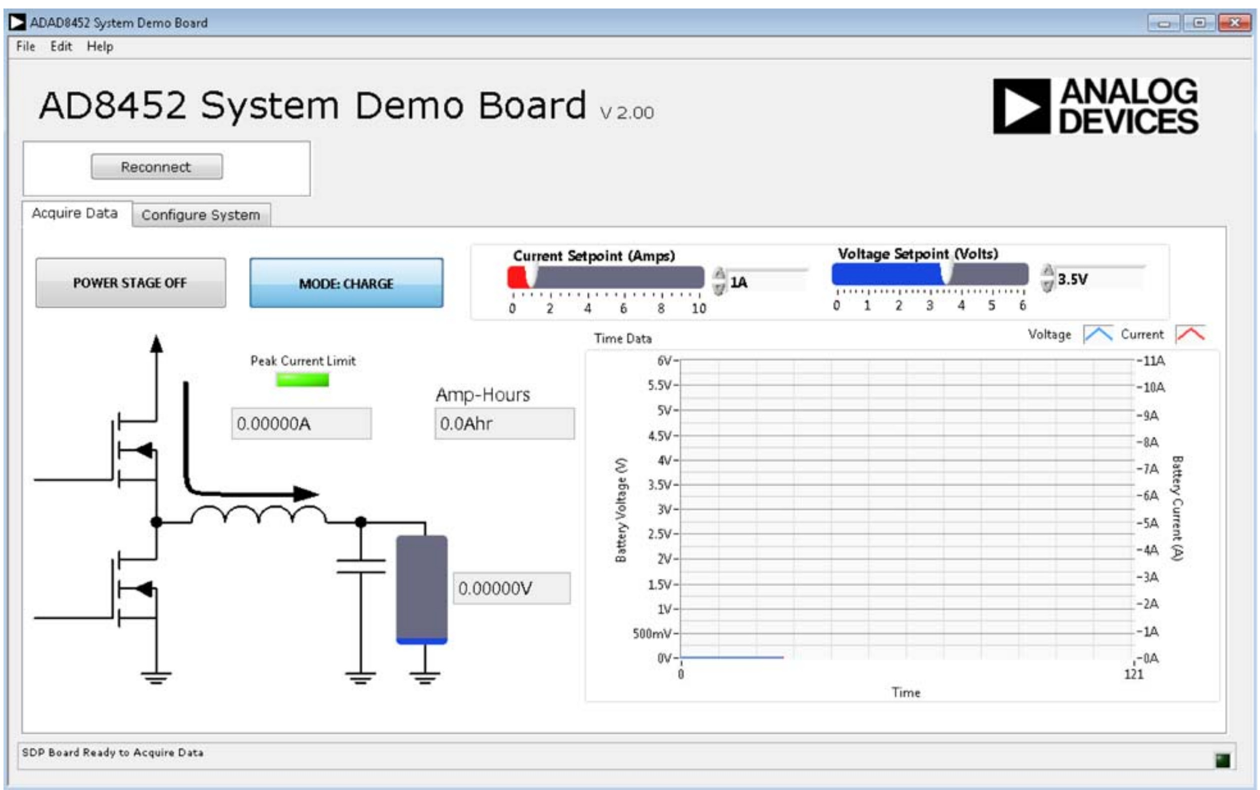
The **POWER STAGE OFF** button indicates that the system is disabled. Clicking this button enables the power module (and the text changes to **POWER STAGE ON**). Similarly, the **MODE: CHARGE** button indicates that the system is currently in charge mode. Clicking this button changes the power module configuration (and the text changes to **MODE: DISCHARGE**).

The **Amp-Hours** indicator is a simple integrator. It takes the battery current measurement every 100 ms, calculates the equivalent amp-hour value, and accumulates the result with the previous result. This calculation allows the system to measure battery capacity from the time the battery is enabled until it is fully charged or discharged, or until the mode setting is changed.

To change the constant current or constant voltage set point values, type the new value into the corresponding field, in units of amps or volts, respectively, and press the Enter key.

The time data chart shows a strip chart of current and voltage while the battery charges or discharges.

Figure 15 shows the main window in constant current, discharge mode.




16194-014

*Figure 14. **AD8452 System Demo Board** Software Main Window*

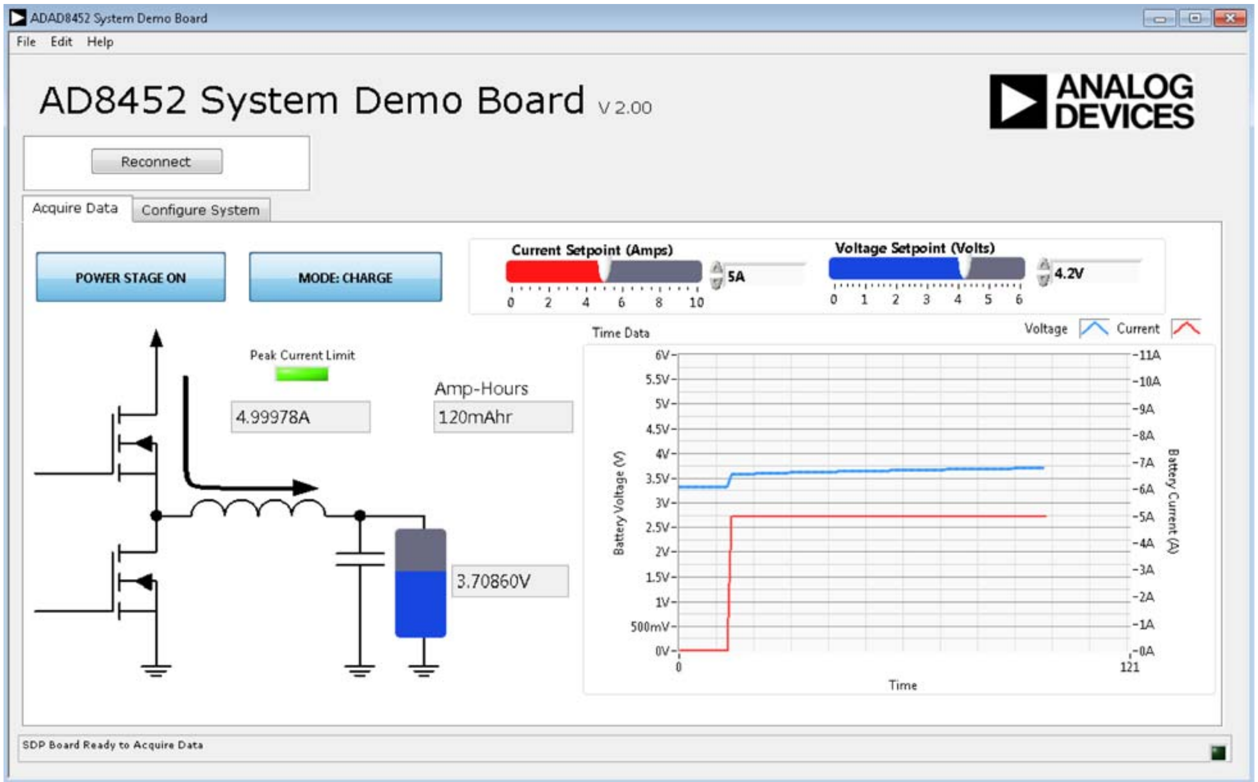



*Figure 15. Software Main Window During Normal Operation*

## CONFIGURATION TAB

Click **Configure System** to open the configuration tab. This tab contains several options described in the following sections.

### *Sample Timing Controls*

**Sample Interval** sets the rate at which the system updates the battery voltage and current measurements. The sample interval is the rate at which the screen updates, and is completely independent of the analog control loop.

**Graphing Sampling Rate Multiple** sets the update rate for the main window as a ratio of the sample interval. For example, setting the **Sample Interval** to 1 sec and the **Graphing Sample Rate Multiple** to 1 results in chart updates every second. Setting the **Graphing Sampling Rate Multiple** to 5 results in graph updates only every 5 sec.

### *Calibration Controls*

The gain correction and offset controls allow the user to perform system level calibration. The measurements displayed in the main window are the nominal output from the ADC scaled with the following equation:

$$Output\ Measurement = (Nominally\ Scaled\ Measurement - Offset\ Correction) \times Gain\ Correction$$

where *Nominally Scaled Measurement* uses the typical values for the sense resistor, the ADC reference, the AD8452 gain, and so on.

**Current Gain Correction** is the gain correction constant for the current measurement. The default is 1.

**Current Offset (A)** is the offset correction constant for the current channel, in units of amps. The default is 0.

**Voltage Gain Correction** is the gain correction constant for the voltage measurement. The default is 1.

**Voltage Offset (V)** is the offset correction constant for the voltage channel, in units of volts. The default is 0.

### *Hardware Configuration Controls*

As indicated in the main window, the hardware configuration controls must reflect the actual configuration of the power module and analog interface boards. If there is a mismatch between the settings in these controls and the actual hardware configuration, excessive current can be sourced into (or sunk from) the battery.

**ADC Range (V)** is the nominal ADC input range, with a default of 2.5 V.

**DAC Range (V)** is the nominal DAC output range, with a default of 2.5 V.

**Sense Resistor (Ohms)** is the nominal value of the sense resistor on the power module board. The default is 0.003 Ω (3 mΩ).

**Current Sense Gain** is the gain setting for the AD8452 programmable gain current sense instrumentation amplifier. The default value is 66.

**Voltage Sense Gain** is the gain setting for the AD8452 programmable gain differential voltage sense amplifier. The default is 0.4.

**Full Scale Current** is the setting to change the scaling of the current setpoint range. This value matches the full-scale current of the power module.

Clicking **Reset Ahr Meter** resets the amp-hour counter in the main window to 0.

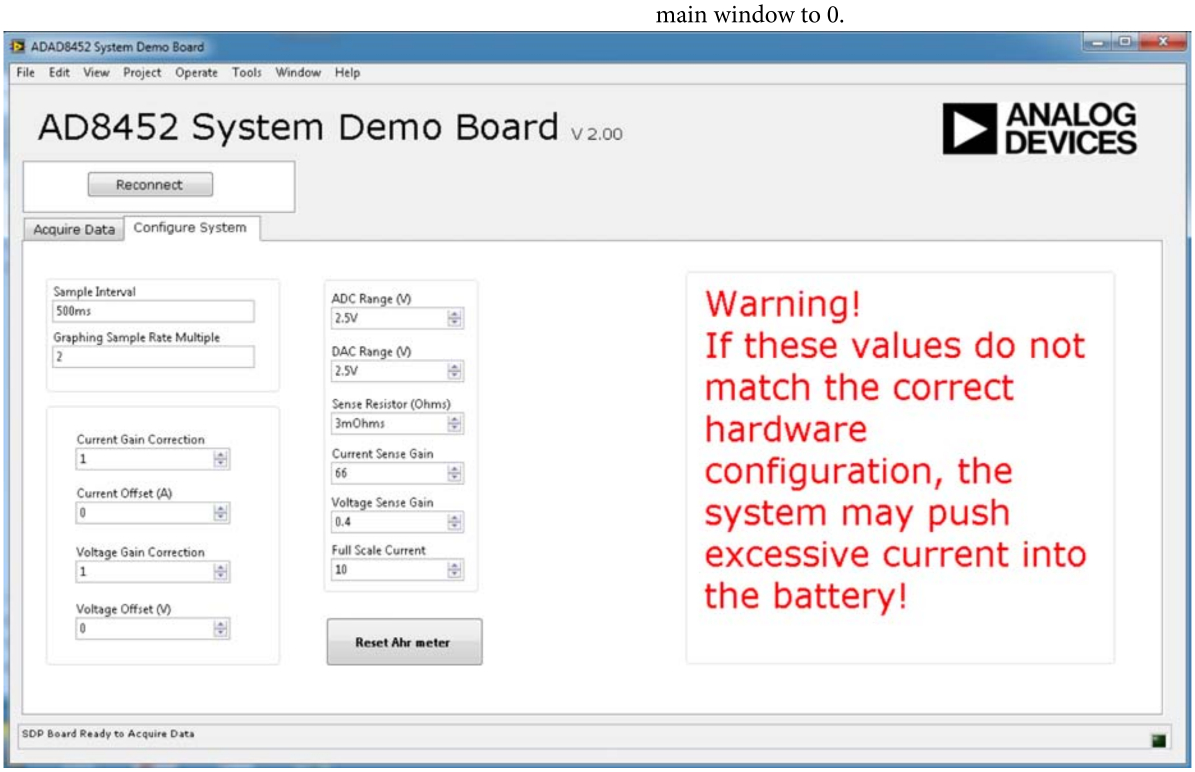



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*Figure 16. Configuration Tab*

# EVALUATION BOARD SCHEMATICS—POWER MODULE BOARD

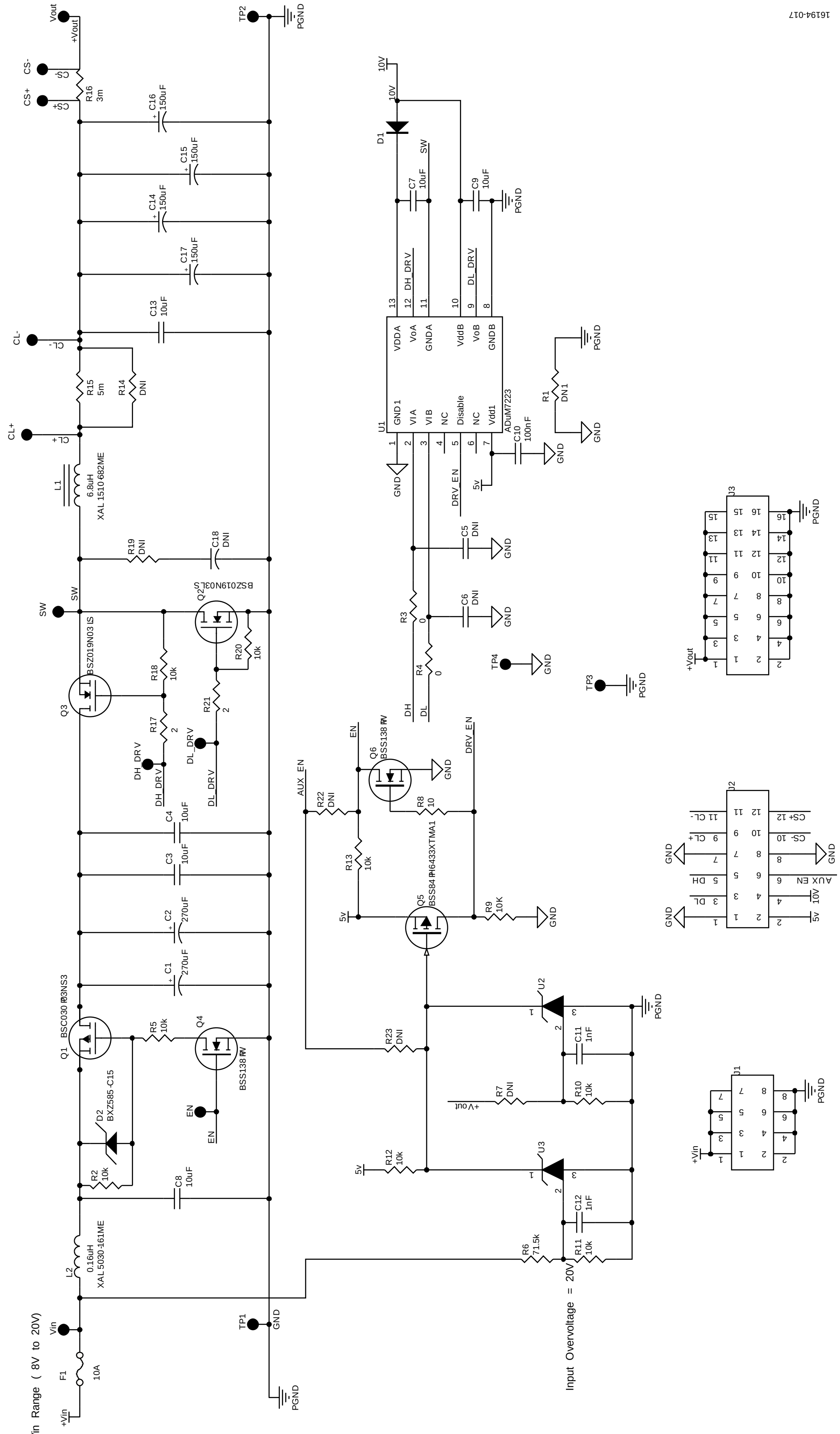

*Figure 17. Power Module Schematic*

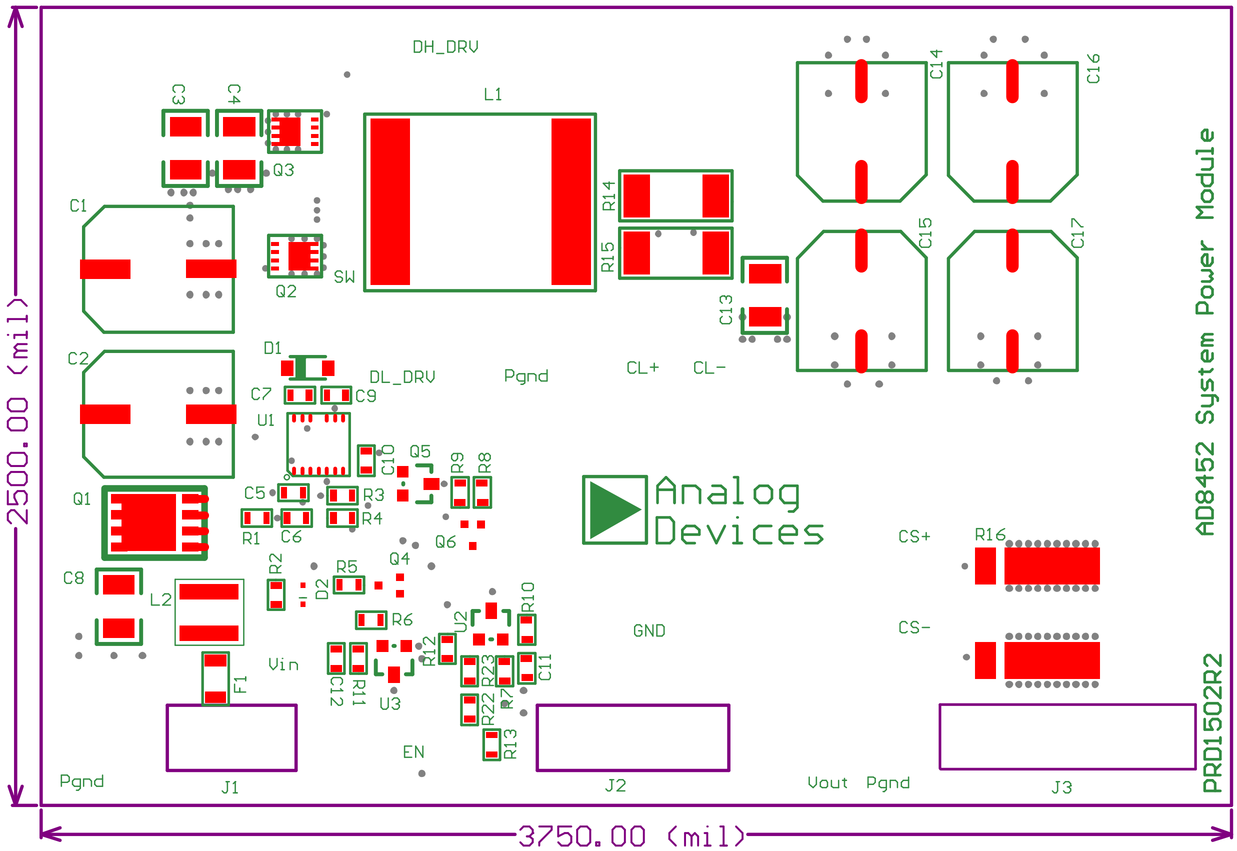


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*Figure 18. Power Module Board Top Silkscreen*

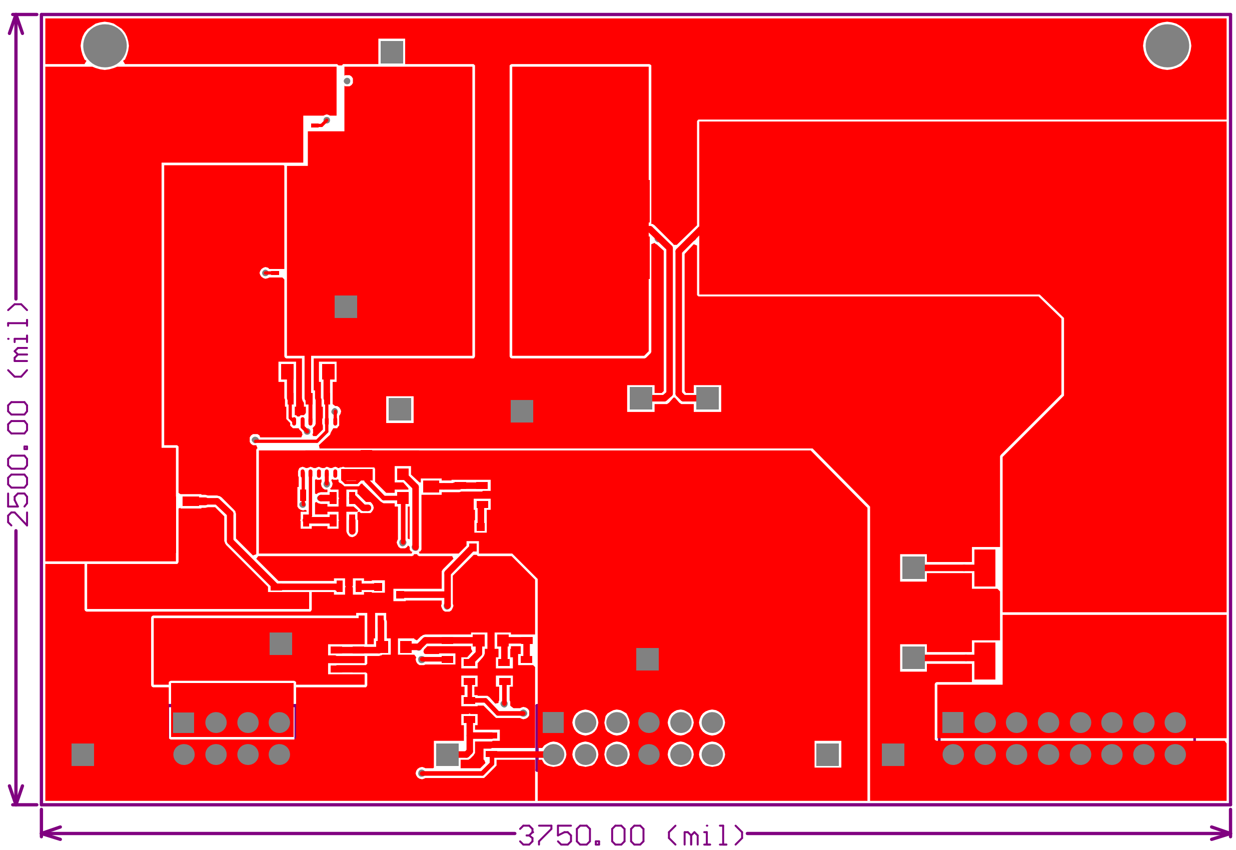


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*Figure 19. Power Module Board Top Layer*

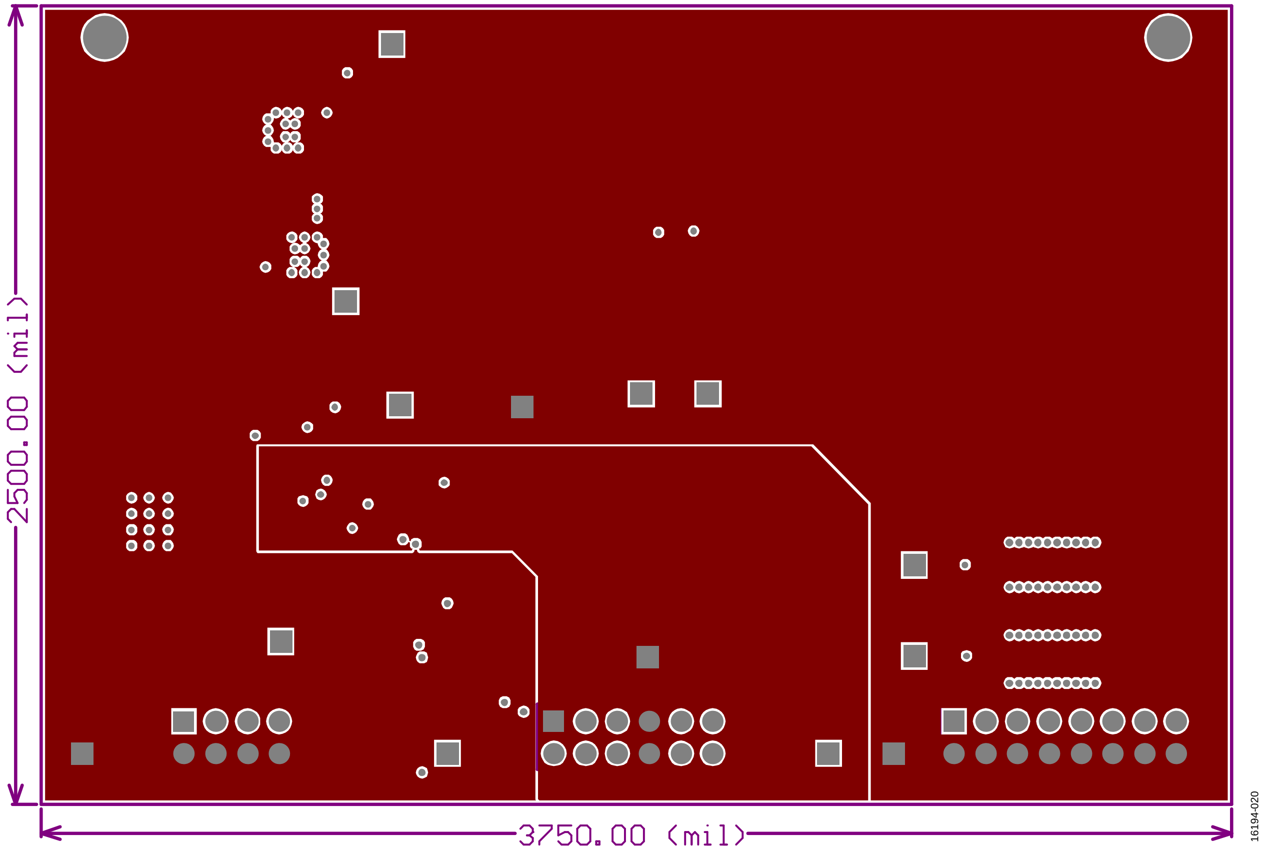


*Figure 20. Power Module Board Layer 2*

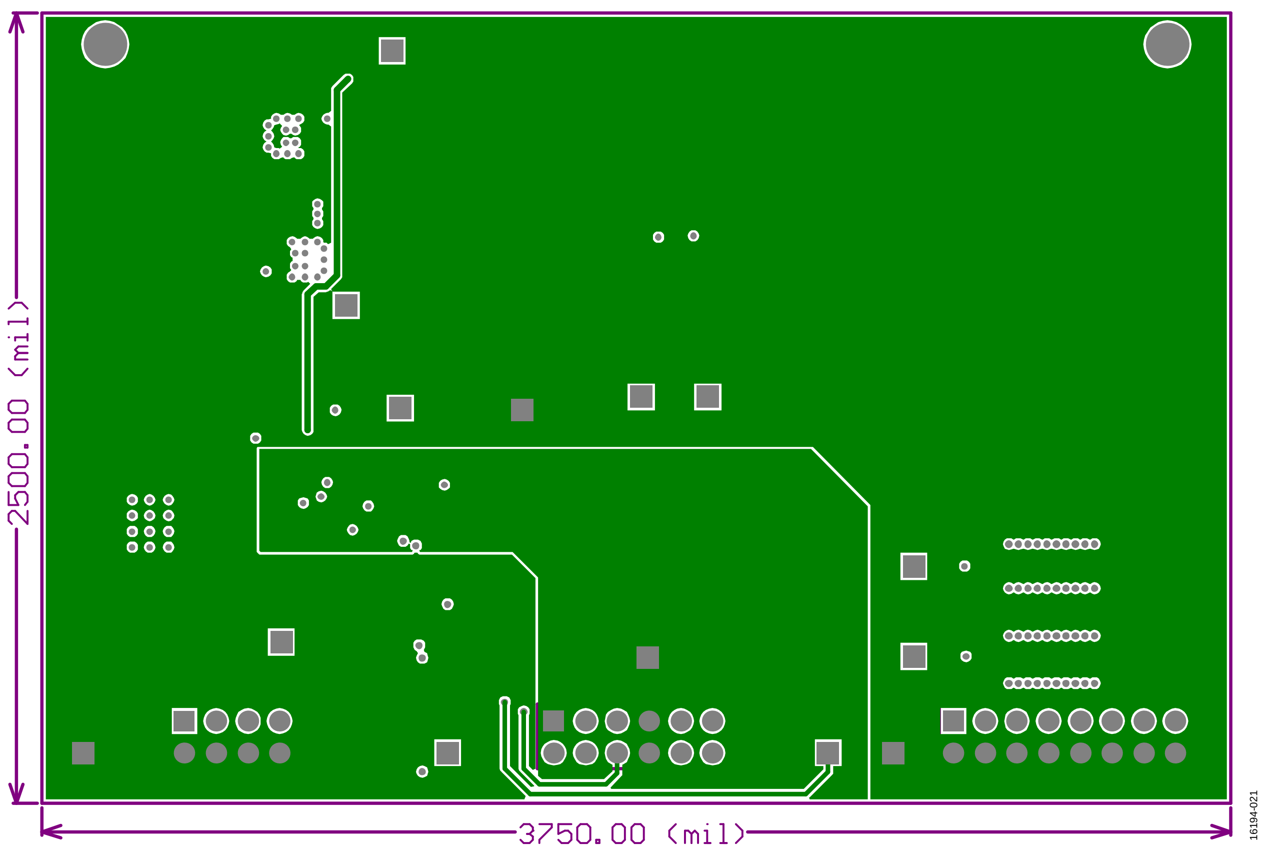


*Figure 21. Power Module Board Layer 3*

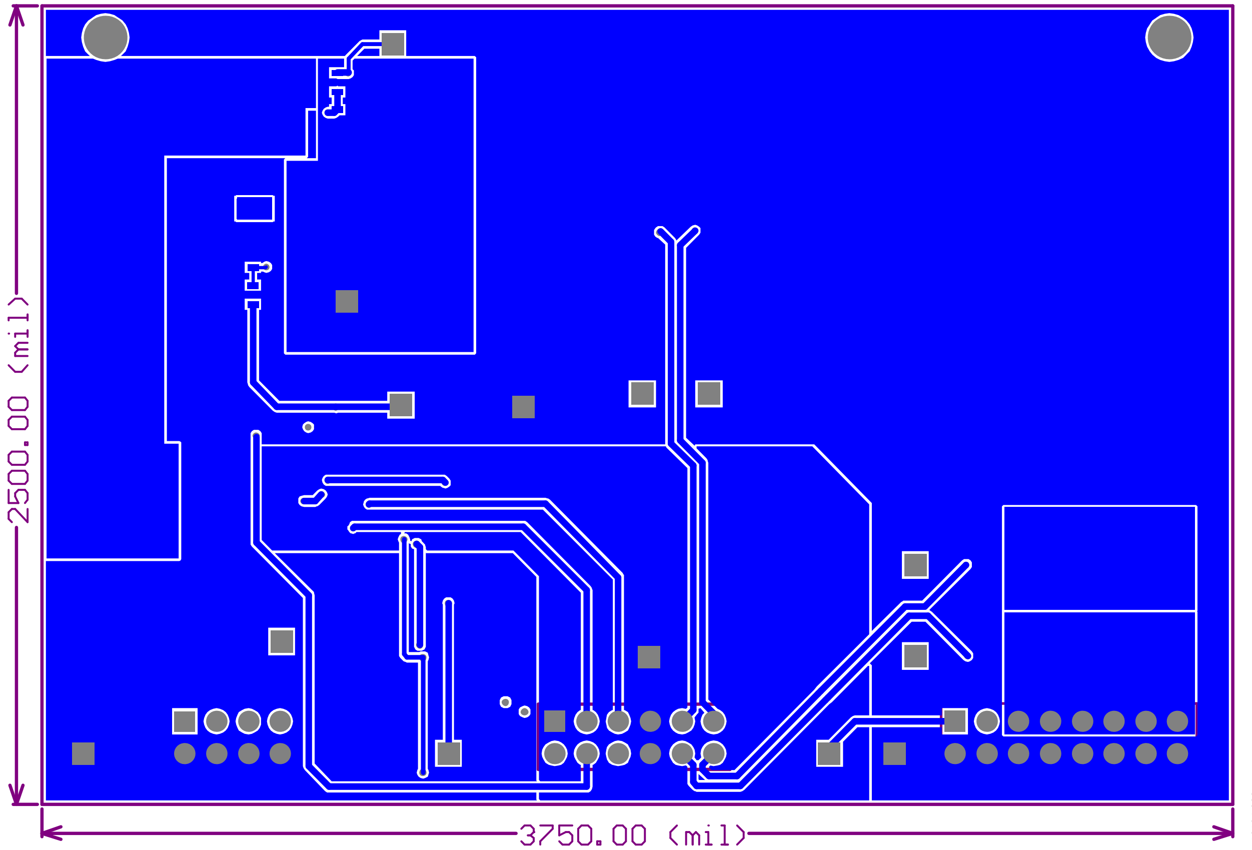


Figure 22. Power Module Board Bottom Layer

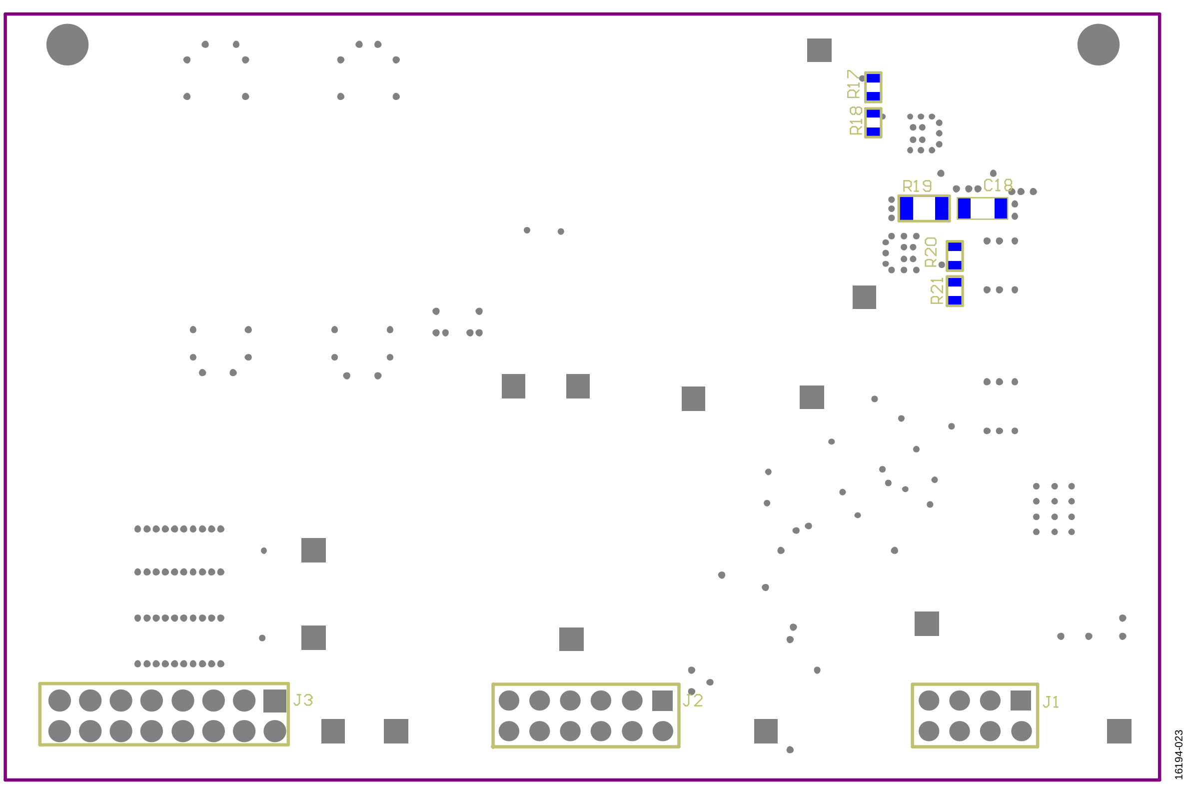


Figure 23. Power Module Board Bottom Silkscreen

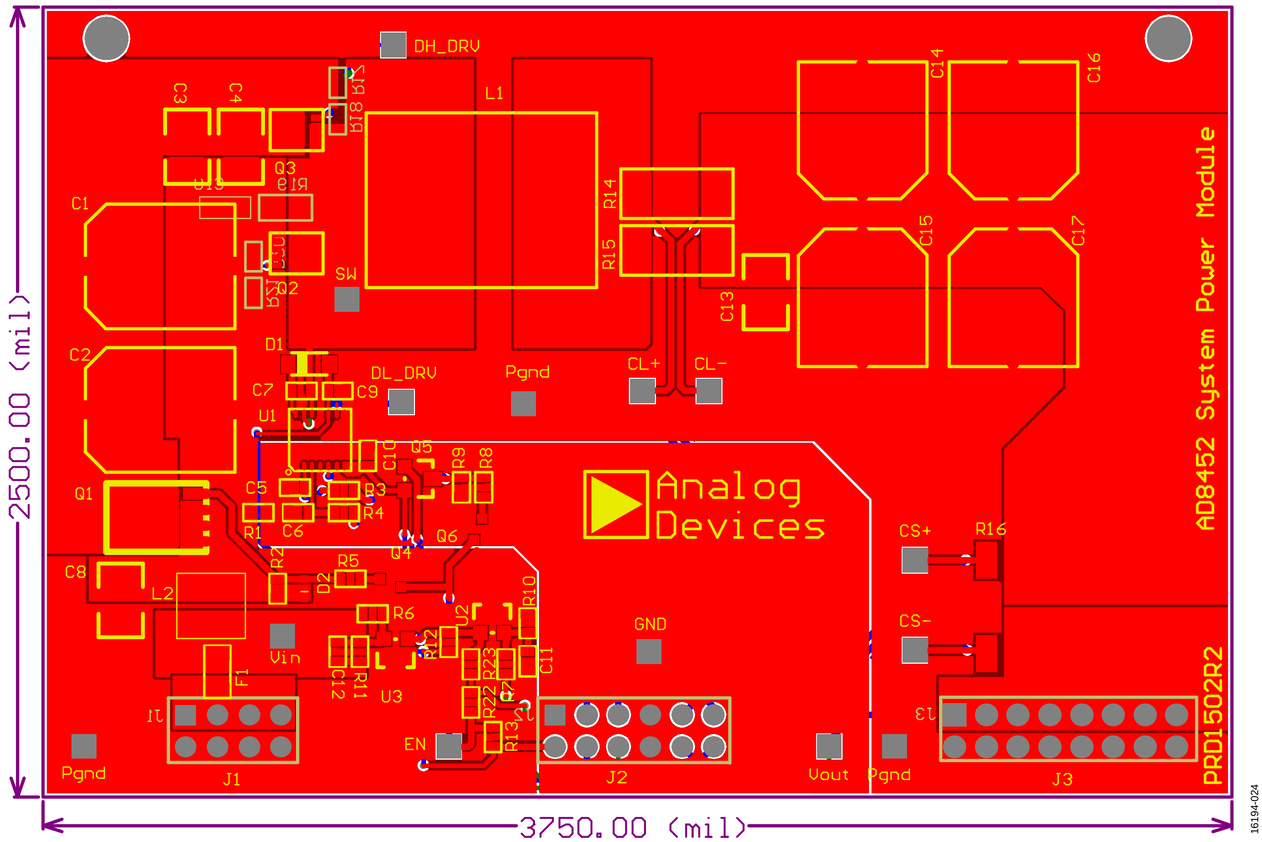


*Figure 24. Power Module Board*

# EVALUATION BOARD SCHEMATICS—ANALOG INTERFACE BOARD

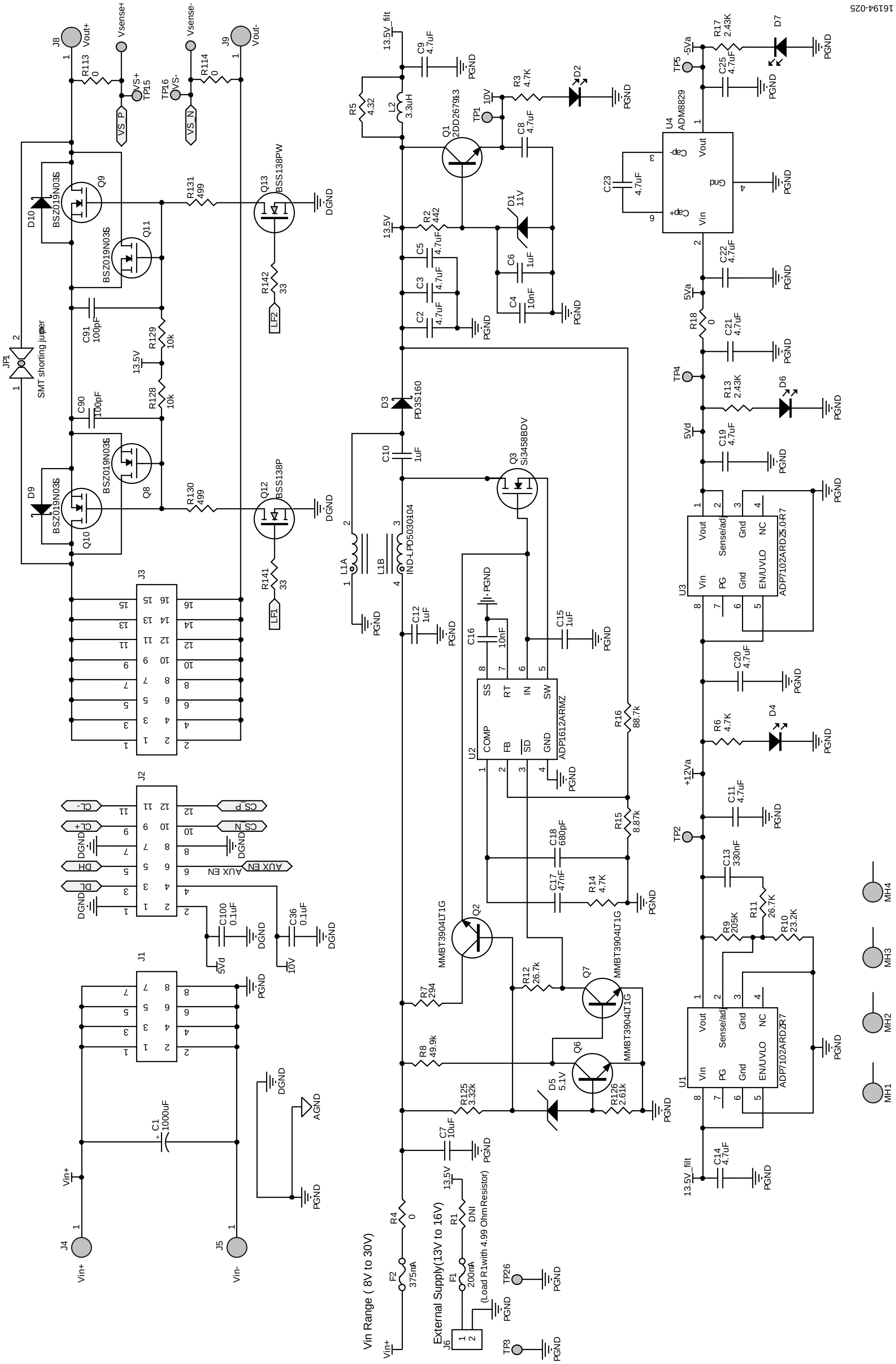


*Figure 25. Power Module Connectors and Auxiliary Power Supplies*

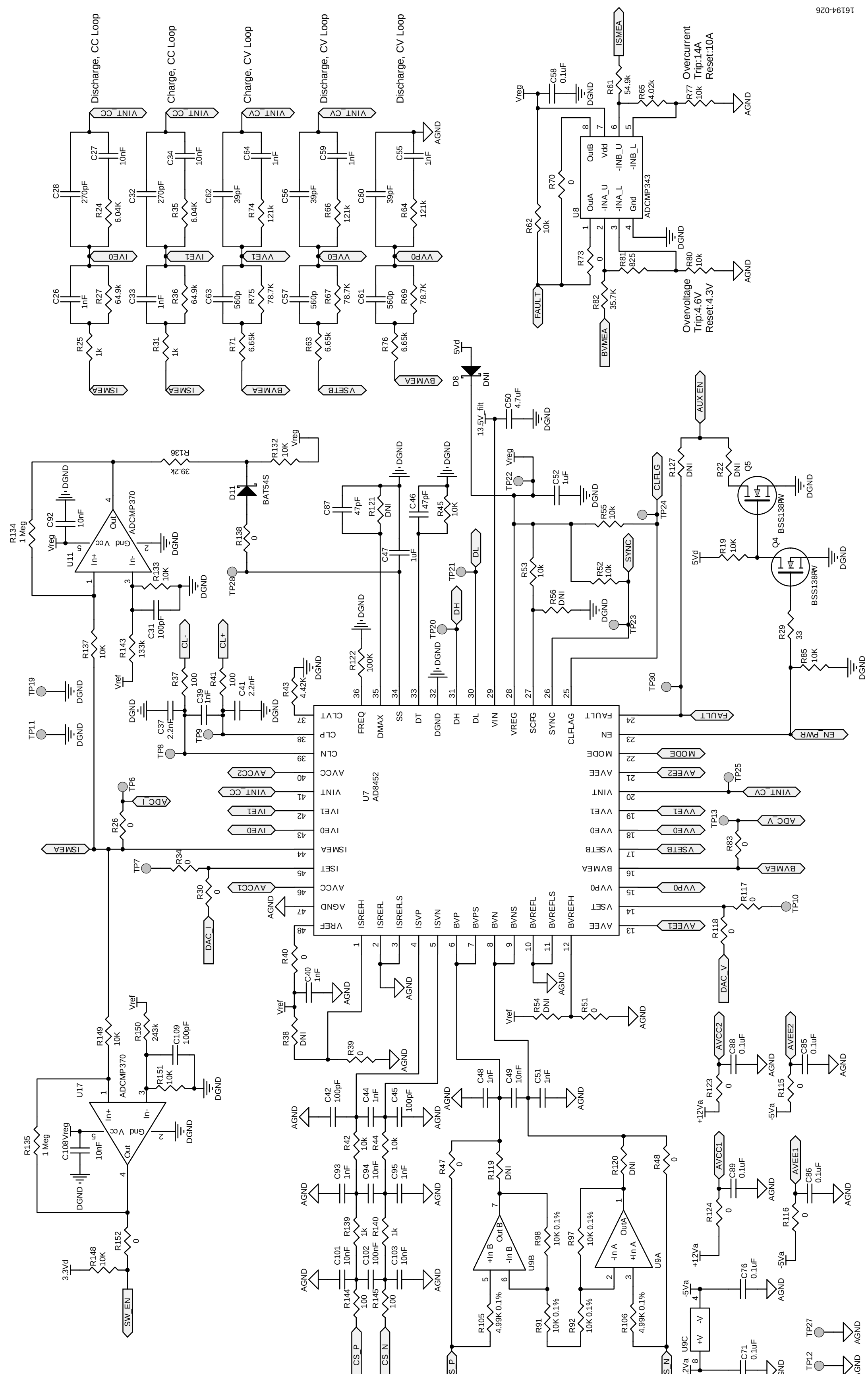


*Figure 26. AD8452 and Compensation Networks*

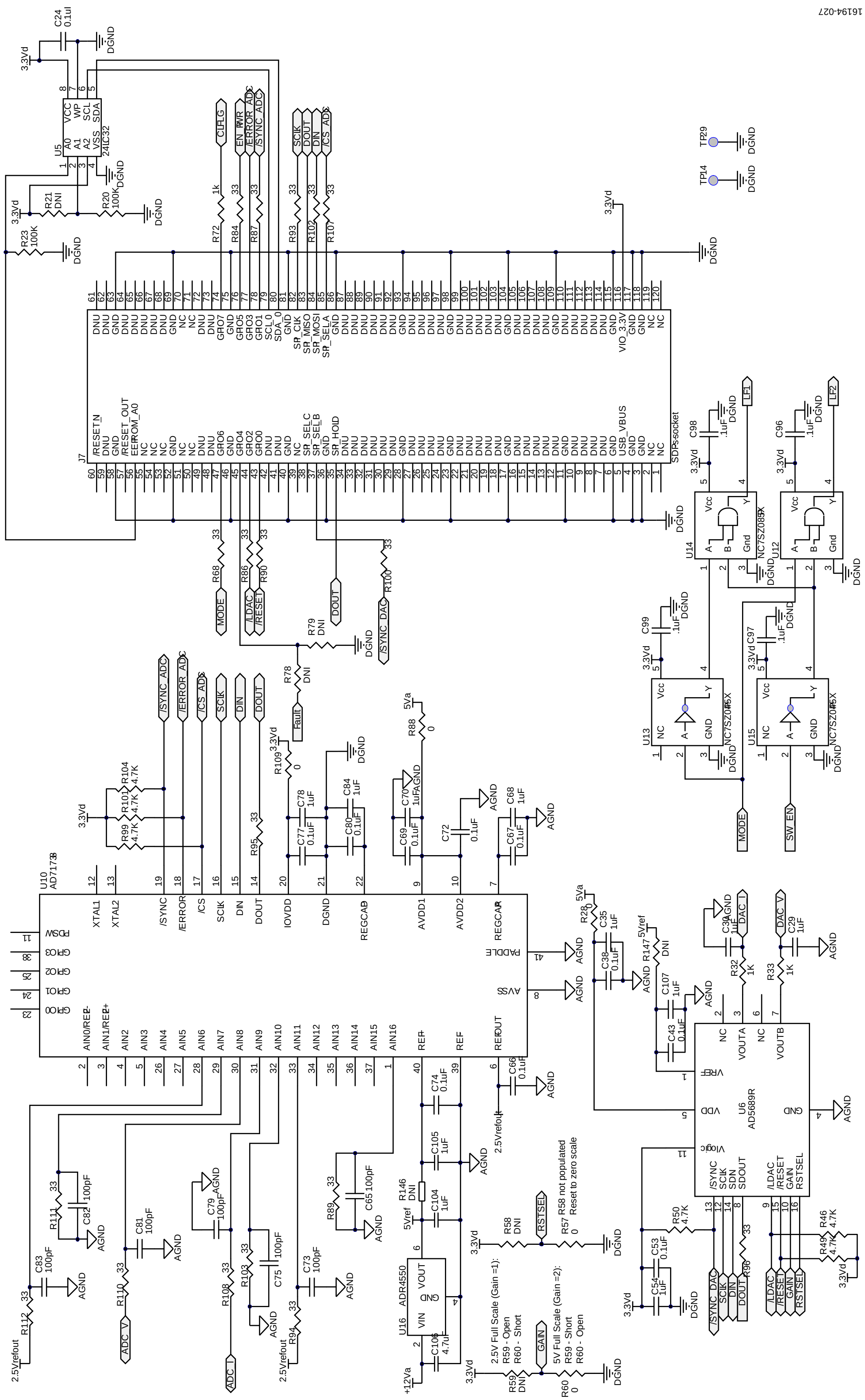

Figure 27. ADC, DAC, and SDP Connector

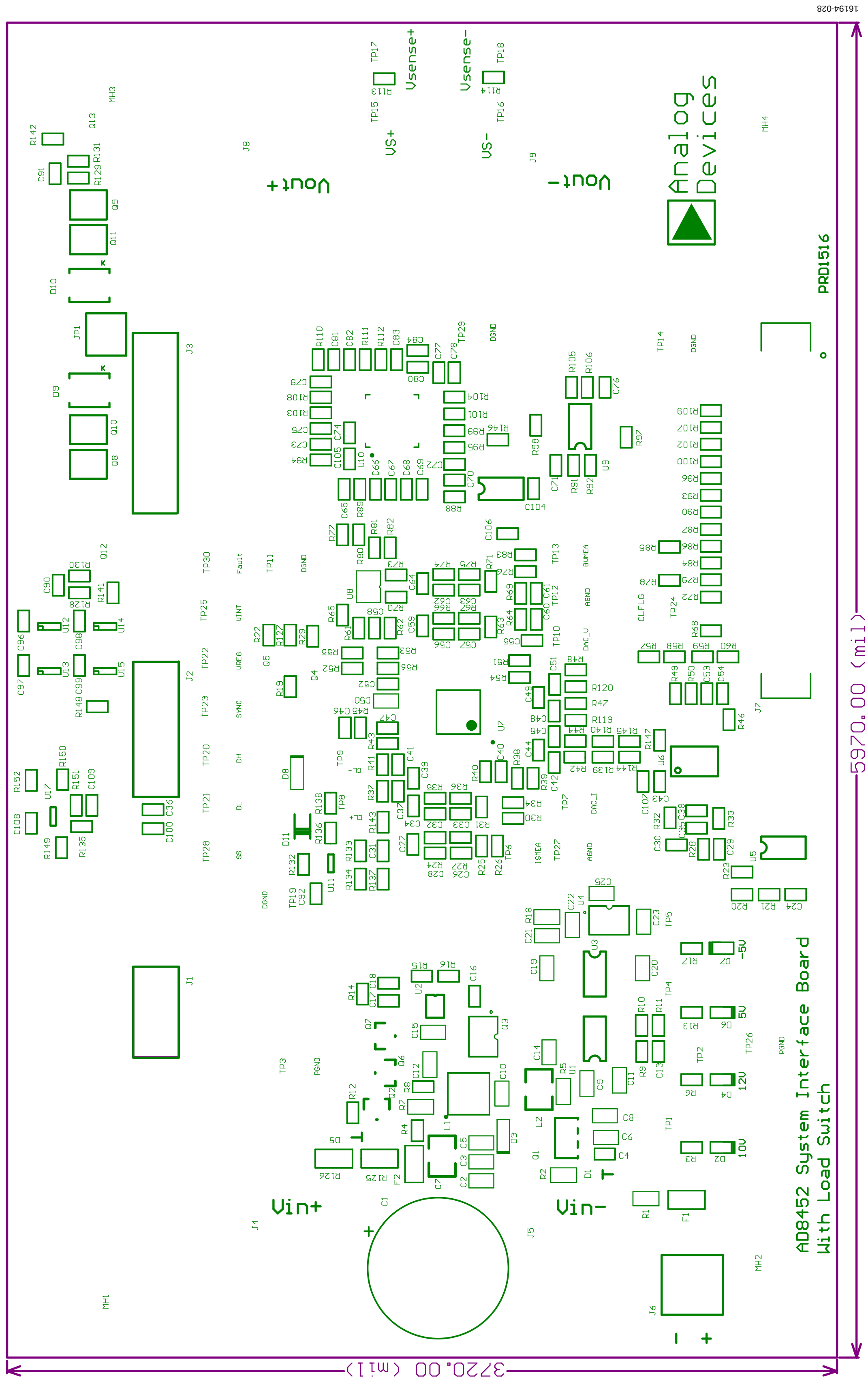


*Figure 28. Analog Interface Board Top Silkscreen*

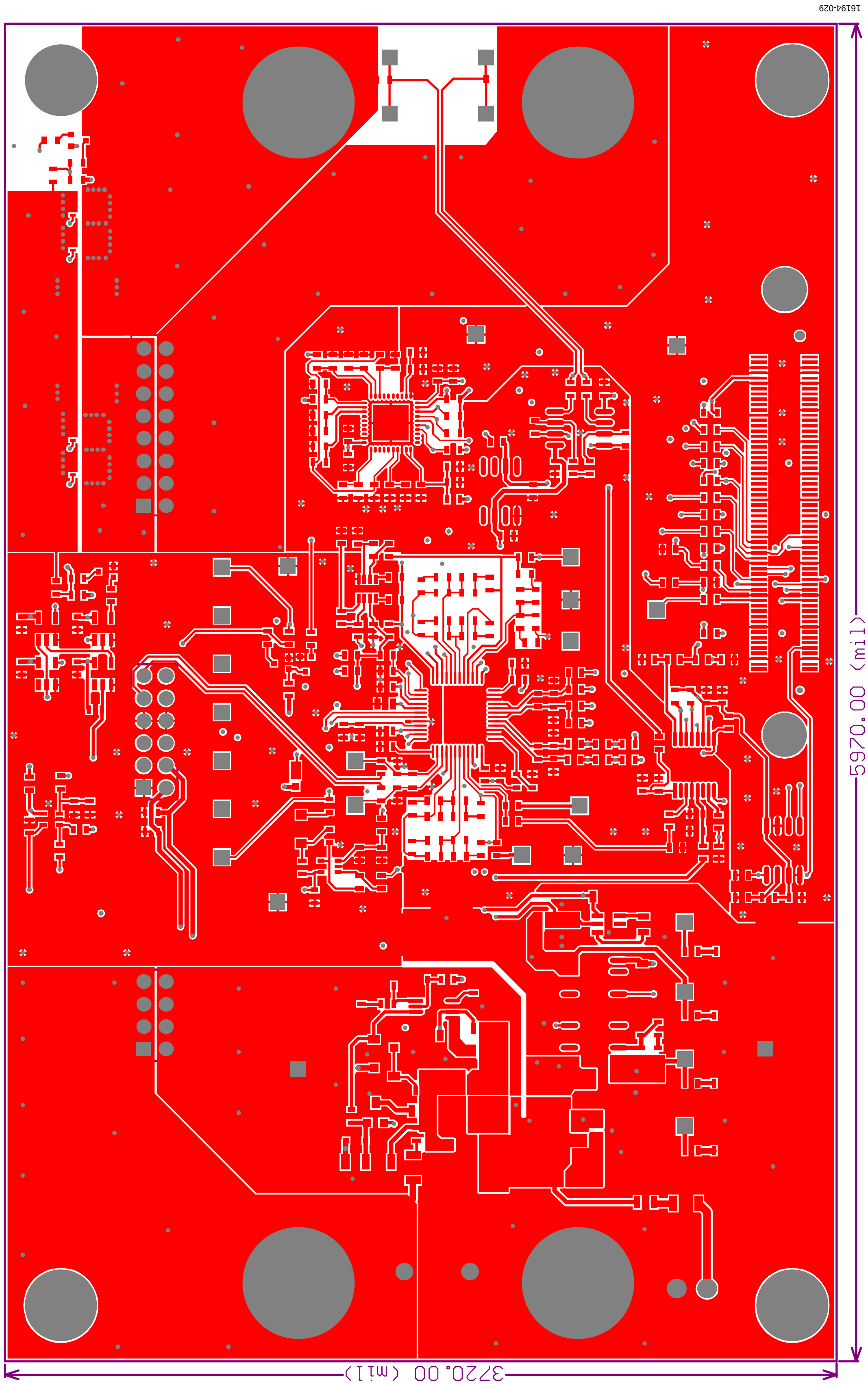


*Figure 29. Analog Interface Board Top Layer*

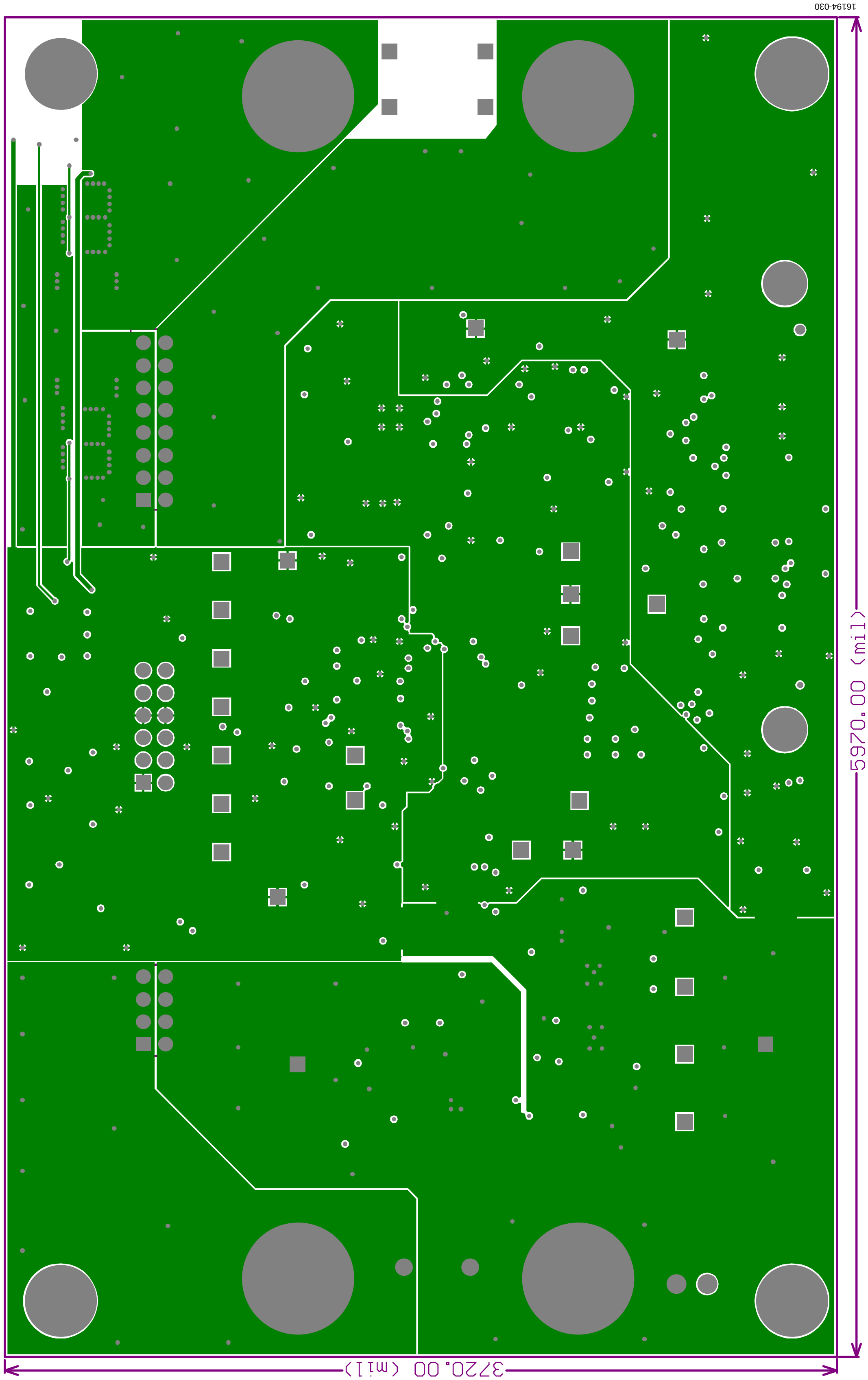


Figure 30. Analog Interface Board Layer 2

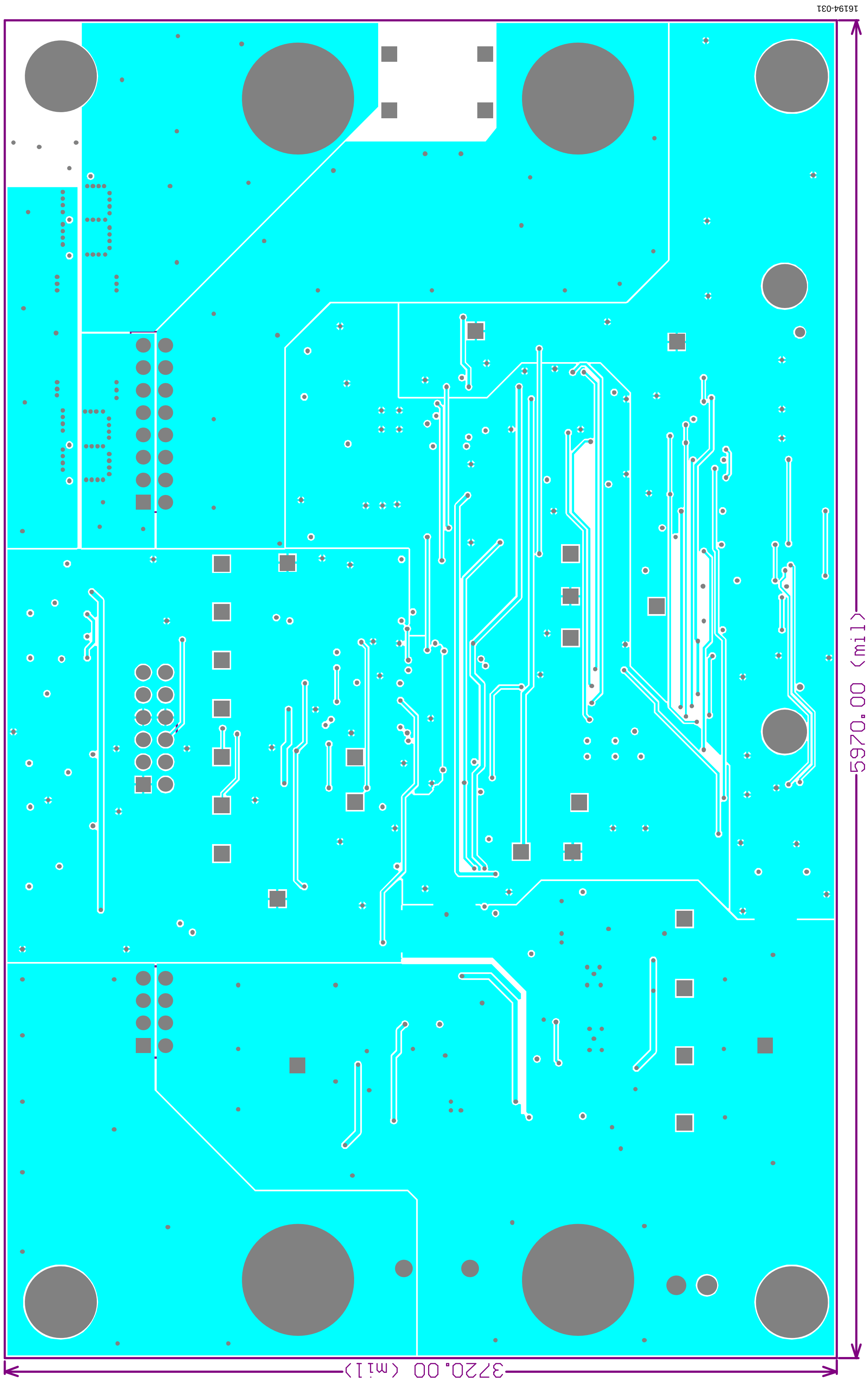


*Figure 31. Analog Interface Board Layer 3*

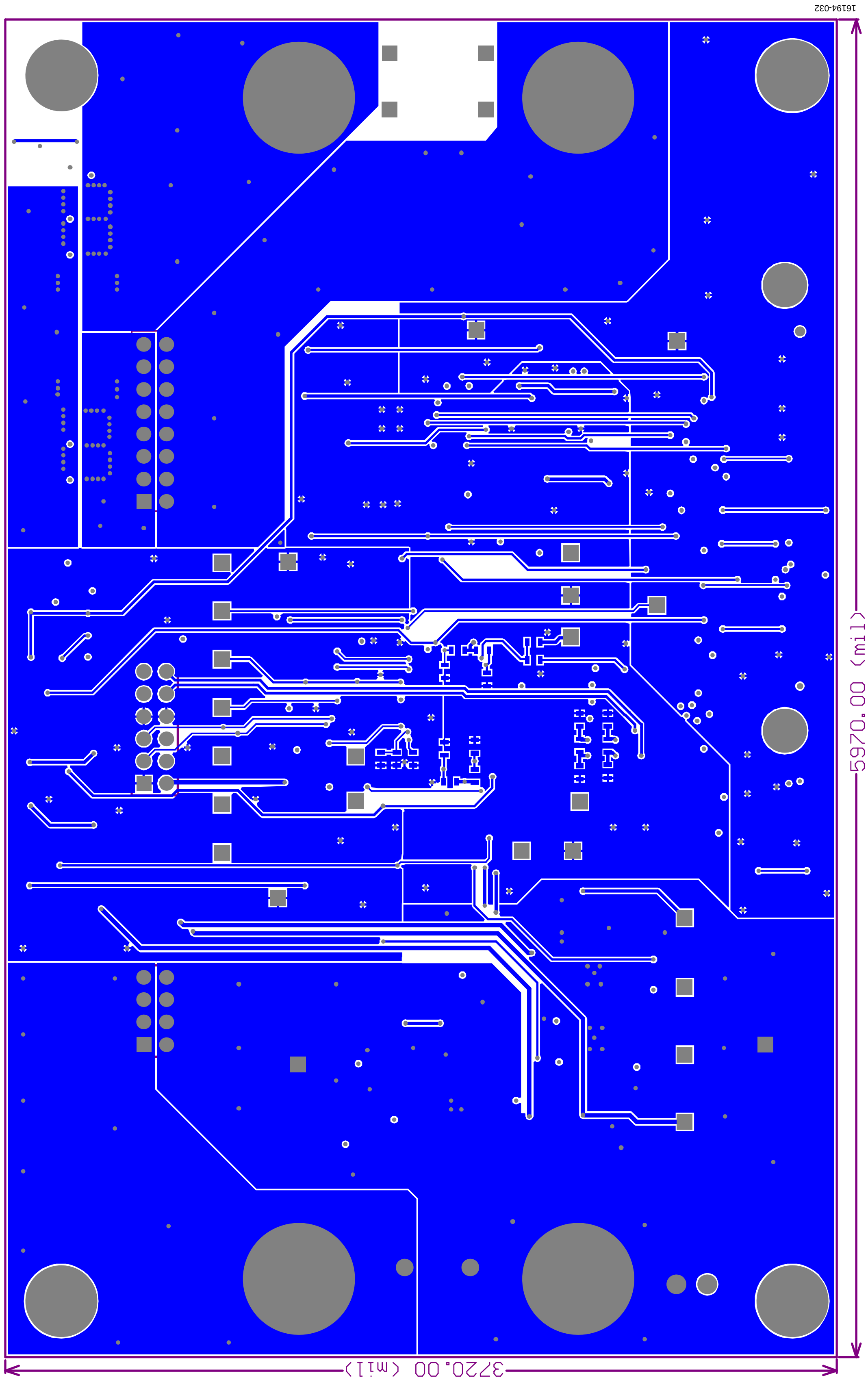


*Figure 32. Analog Interface Board Bottom Layer*

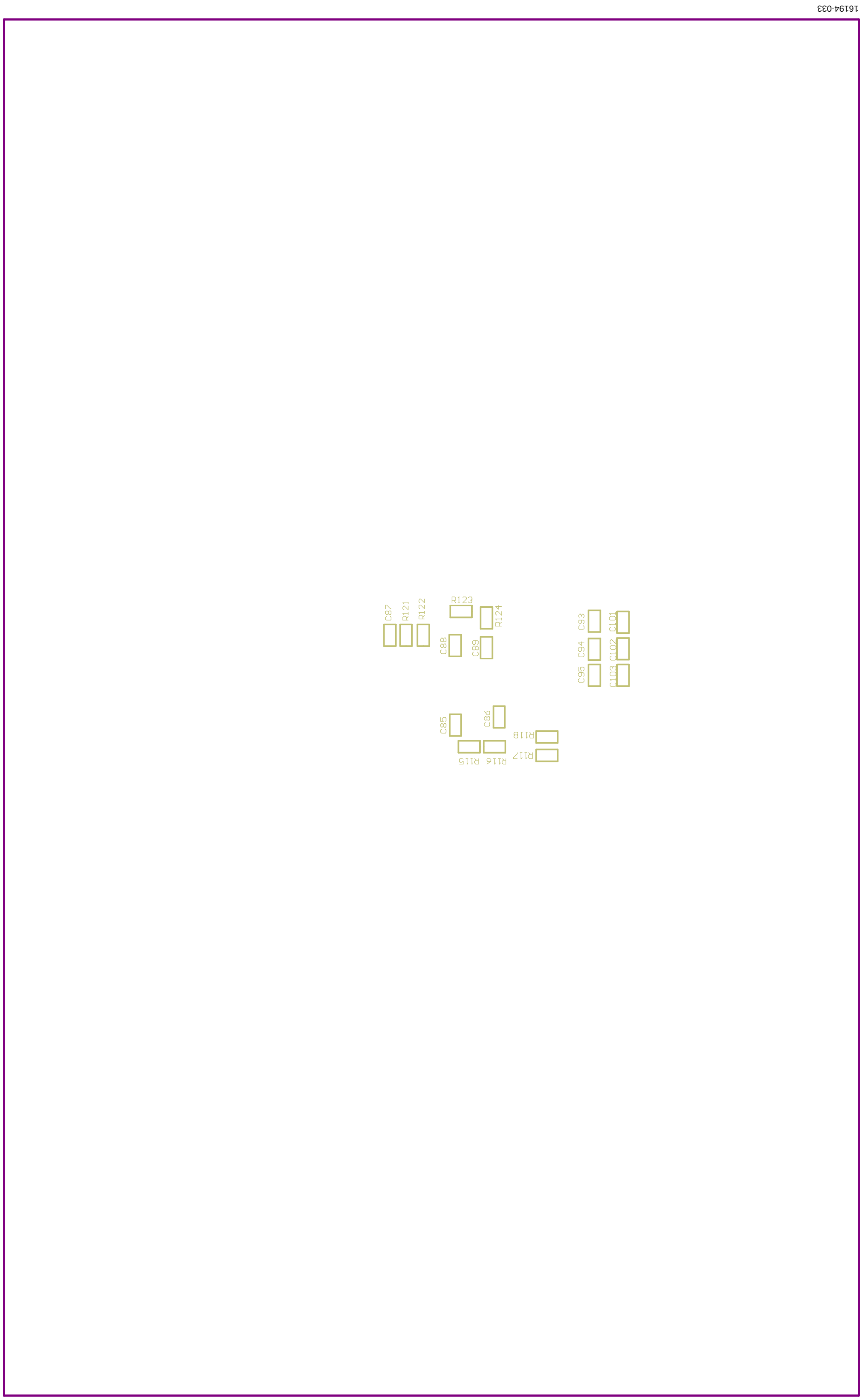


*Figure 33. Analog Interface Board Bottom Silkscreen*

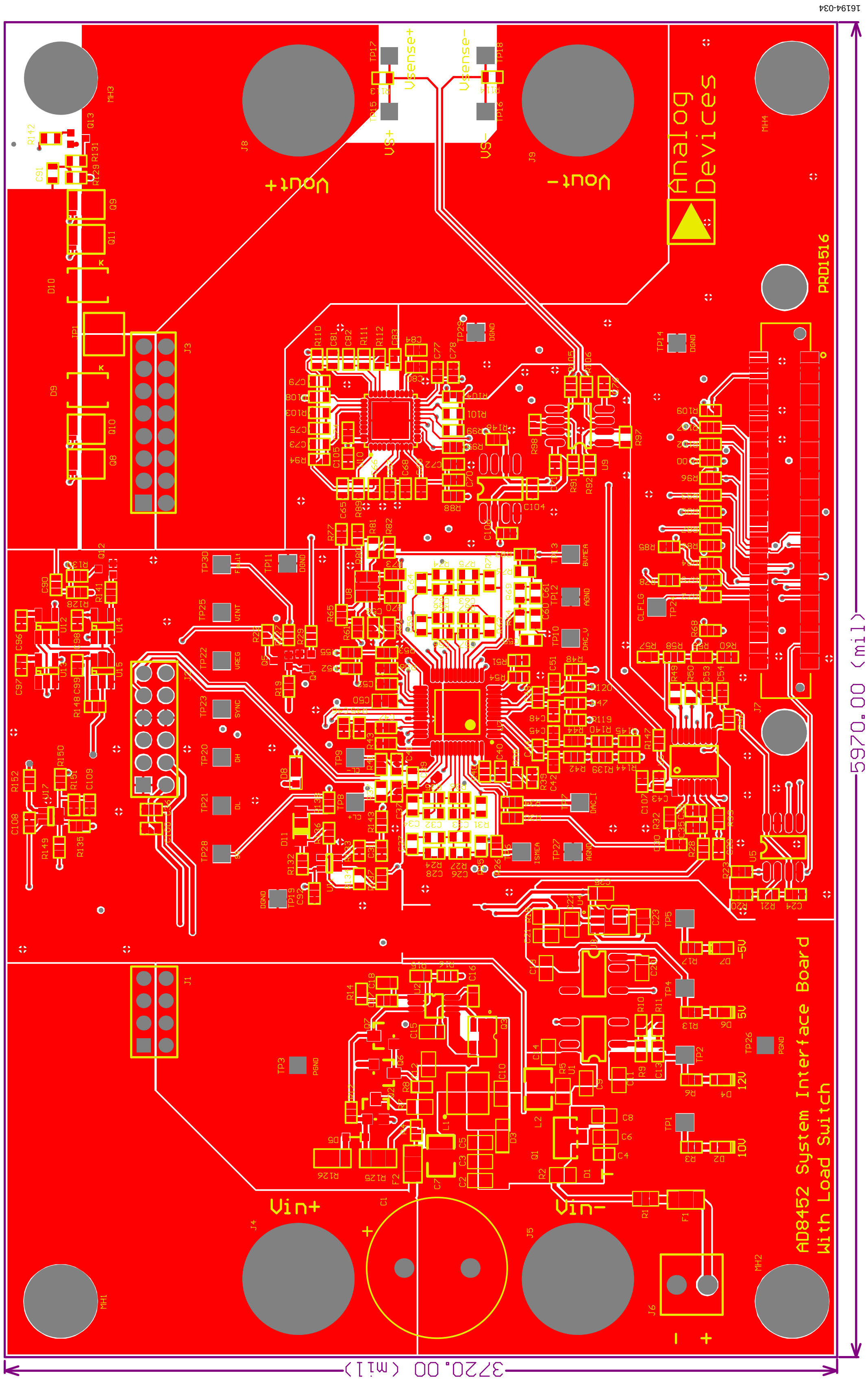


*Figure 34. Analog Interface Board*

# TROUBLESHOOTING

## SOFTWARE

To troubleshoot the software, take the following steps:

1. Always install the software prior to connecting the hardware to the PC.
2. Always allow the install to fully complete (the software is a two part install: the ADC software and the SDP drivers). Completing the install may require a PC restart.
3. When you first plug in the SDP-S board via the USB cable provided, allow the new **Found Hardware Wizard** to run. This step may take a little time; however, the wizard must run to completion prior to starting the software.
4. When the board does not appear to be functioning, ensure that the ADC evaluation board is connected to the SDP-S board and that the board is being recognized in the **Device Manager**, as shown in Figure 11.

## HARDWARE

To troubleshoot the hardware, take the following steps:

1. If the software does not read any data back, check that the power is applied within the power ranges described in the Powering the System section.
2. Using a voltmeter, verify the following voltages on the analog interface board:
    - 10.5 V ±3% at TP1
    - 12 V at TP2
    - 5 V at TP4
    - −5 V at TP5
3. Launch the software and read the data. If nothing happens, exit the software.
4. Power down the board and relaunch the software.
5. If no data is read back, confirm that the power module board is plugged into the analog interface board, and that the analog interface board is connected to the SDP-S board and that the board is being recognized in the **Device Manager**, as shown in Figure 11.

# ORDERING INFORMATION

## BILL OF MATERIALS

Table 4. Power Module Board

| Reference Designator | Description | Manufacturer | Part No. |
|---|---|---|---|
| C1, C2 | 270 μF, 35 V, aluminum-polymer capacitors, radial | Panasonic | EEH-ZA1V271P |
| C3, C4, C8, C13 | 10 μF, 50 V, ceramic capacitors, X5R, 1210 | Murata | GRM32ER61H106KA12 |
| C7, C9 | 10 μF, 25 V, ceramic capacitors, X5R, 0603 | Murata | GRM188R61E106MA73 |
| C10 | 0.10 μF, 50 V, ceramic capacitor, X7R, 0603 | Murata | GRM188R71H104KA93D |
| C11, C12 | Capacitor, ceramic, 1000 pF, 50 V, X7R, 0603 | Murata | GRM188R71H102KA01D |
| C14, C15, C16, C17 | 150 μF, 10 V, aluminum-polymer capacitors, radial | Panasonic | 10SVPS150M |
| CL+, CL−, CS+, CS−, DH_DRV, DL_DRV, EN, SW, Vin, Vout | Test points, PC, multipurpose, red | Keystone Electronics | 5000 |
| D1 | Diode, Schottky, 30 V, 1 A, SOD123L | ON Semiconductor | MBR130LSFT1G |
| D2 | Diode, Zener, 15 V, 300 MW, SOD523 | NXP | BZX585-C15 |
| F1 | Fuse board mount, 10 A, 32 V ac, 63 V dc | Schurter Inc. | 3413.0328.22 |
| J1 | 8-position header, 0.100" (2.54 mm), gold | Sullins Connector | PBC04DAAN |
| J2 | 12-position header, 0.100" (2.54 mm), gold | Sullins Connector | PBC06DAAN |
| J3 | 16-position header, 0.100" (2.54 mm), gold | Sullins Connector | PBC08DAAN |
| L1 | 6.8 μH high current shielded power inductor | Coilcraft | XAL1510-682ME |
| L2 | 0.16 μH high current shielded power inductor | Coilcraft | XAL5030-161ME |
| Q1 | MOSFET, P-channel, 30 V, 100 A | Infineon | BSC030P03NS3 |
| Q2, Q3 | MOSFETs, N-channel, 30 V, 22 A | Infineon | BSZ019N03LS |
| Q4, Q6 | MOSFETs, N-channel, 60 V, 320 mA, SOT323 | NXP | BSS138PW |
| Q5 | MOSFET, P-channel, 60 V 170 mA, SOT-23 | Infineon | BSS84PH6433XTMA1 |
| R2, R5, R9, R10, R11, R12, R13, R18, R20 | Resistors, SMD, 10 kΩ, 1%, 1/10 W, 0603 | Yageo | RC0603FR-0710KL |
| R3, R4 | Resistors, SMD, 0.0 Ω jumper, 1/10 W, 0603 | Yageo | RC0603JR-070RL |
| R6 | Resistor, SMD, 71.5 kΩ, 1%, 1/10 W, 0603 | Yageo | RC0603FR-0771K5L |
| R8 | Resistors SMD, 10 Ω, 1%, 1/10 W, 0603 | Yageo | RC0603FR-0710RL |
| R15 | Resistors SMD, 0.005 Ω, 1%, 2 W, 2512 | Stackpole Electronics | CSNL2512FT5L00 |
| R16 | Precision current shunt, 0.003 Ω, 0.1%, 15 ppm, 3 W | Vishay Precision Group | Y14880R00300B9R |
| R17, R21 | Resistors, SMD, 2 Ω, 1%, 1/10 W, 0603 | Yageo | RC0603FR-072RL |
| TP1, TP2, TP3, TP4 | Test points, PC, miniature T/H, green | Keystone Electronics | 5116 |
| U1 | Isolated precision half-bridge driver, 4 A output | Analog Devices | ADuM7223ACCZ |
| U2, U3 | IC VREF shunts, ADJ SOT23 | Diodes Incorporated | ZTL431AFTA |

Table 5. Analog Interface Board

| Reference Designator | Description | Manufacturer | Part Number |
|---|---|---|---|
| C1 | 1000 μF, 35 V, aluminum capacitor, radial | Panasonic | EEU-FC1V102S |
| C2, C3, C5, C8, C9, C11, C14, C19, C20, C21, C22, C23, C25, C50 | Capacitor, ceramic, 4.7 μF, 25 V, X5R, 0805 | Taiyo Yuden | TMK212BJ475KG-T |
| C4, C16, C27, C34, C49, C92, C94, C101, C103, C108 | Capacitor, ceramic, 10000 pF, 50 V, NP0, 0603 | Murata | GRM1885C1H103JA01D |
| C6, C10, C12, C15 | Capacitor, ceramic, 1 μF, 50 V, X7R, 0805 | Murata | GRM21BR71H105KA12L |
| C7 | Capacitor, ceramic, 10 μF, 50 V, X7R, 1210 | Murata | GRM32ER71H106KA12L |
| C13 | Capacitor, ceramic, 0.33 μF, 16 V, X7R, 0603 | TDK Corporation | C1608X7R1C334K080AC |
| C17 | Capacitor, ceramic, 0.047 μF, 50 V, X7R, 0603 | Murata | GRM188R71H473KA61D |
| C18 | Capacitor, ceramic, 680 pF, 50 V, C0G, 0603 | TDK Corporation | C1608C0G1H681K080AA |
| C24, C36, C38, C43, C53, C58, C66, C67, C69, C71, C72, C74, C76, C77, C80, C85, C86, C88, C89, C96, C97, C98, C99, C100, C102 | Capacitor, ceramic, 0.1 μF, 25 V, X7R, 0603 | Murata | GRM188R71E104KA01D |

| Reference Designator | Description | Manufacturer | Part Number |
|---|---|---|---|
| C26, C33, C39, C40, C44, C48, C51, C55, C59, C64, C93, C95 | Capacitor, ceramic, 1000 pF, 50 V, X7R, 0603 | Murata | GRM188R71H102KA01D |
| C28, C32 | Capacitor, ceramic, 270 pF, 50 V, NP0, 0603 | Murata | GRM1885C1H271JA01D |
| C29, C30, C35, C47, C52, C54, C68, C70, C78, C84, C104, C105, C106, C107 | Capacitor, ceramic, 1 µF, 25 V, X7R, 0603 | Murata | GRM188R71E105KA12D |
| C31, C42, C45, C65, C73, C75, C79, C81, C82, C83, C90, C91, C109 | Capacitor, ceramic, 100 pF, 50 V, C0G, 0603 | TDK Corporation | C1608C0G1H101J080AA |
| C37, C41 | Capacitor, ceramic, 2200 pF, 50 V, X7R, 0603 | Murata | GRM188R71H222KA01D |
| C46, C87 | Capacitor, ceramic, 47 pF, 50 V, NP0, 0603 | AVX Corporation | 06035A470JAT2A |
| C56, C60, C62 | Capacitor, ceramic, 39 pF, 50 V, C0G, 0603 | TDK Corporation | CGA3E2C0G1H390J080AA |
| C57, C61, C63 | Capacitor, ceramic, 560 pF, 50 V, NP0, 0603 | Murata | GRM1885C1H561JA01D |
| D1 | Diode, Zener, 11 V, 200 MW, SOD323F | Fairchild Semiconductor | MM3Z11VB |
| D2, D4, D6, D7 | Green, 573 nm, LEDs, indication - 0603 | OSRAM Opto | LG Q396-PS-35 |
| D3 | Diode, Schottky, 60 V, 1 A, POWERDI323 | Diodes Incorporated | PD3S160-7 |
| D5 | Diode, Zener, 5.1 V, 200 MW, SOD323 | Diodes Incorporated | DDZ9689S-7 |
| D9, D10 | Diode, Schottky, 40 V, 3 A, SMB | Diodes Incorporated | B340LB-13-F |
| D11 | Diode, Schottky, 30 V, 200 mA, SOD123 | ON Semiconductor | BAT54T1G |
| F1 | Fuse board mount, 200 mA, 125 V ac/dc | Littelfuse Inc. | 0466.200NR |
| F2 | Fuse board mount, 375 mA, 125 V ac/dc | Littelfuse Inc. | 0466.375NR |
| J1 | 8-position header connector, 0.100" (2.54 mm) | Sullins Connector | PPPC042LFBN-RC |
| J2 | 12-position header connector, 0.100" (2.54 mm) | Sullins Connector | PPPC062LFBN-RC |
| J3 | 16-position header connector, 0.100" (2.54 mm) | Sullins Connector | PPPC082LFBN-RC |
| J4, J5, J8, J9 | Banana jack connectors, standard banana | Johnson-Cinch Connectivity | 108-0740-001 |
| J6 | Terminal block, 2-position side ENT, 3.5 mm | TE Connectivity AMP | 1776275-2 |
| J7 | 120-position connector receptacle, center strip contacts, surface mount, gold | Hirose Electric Co Ltd | FX8-120S-SV(21) |
| L1 | Coupled inductor, LPD5030, 100 µH | Coilcraft | LPD5030-104MRB |
| L2 | Fixed inductor, 3.3 µH, 1.2 A, 120 MΩ | Murata | LQH32PN3R3NN0L |
| MH1, MH2, MH3, MH4 | Hex standoff threaded M3 × 0.5 brass 0.630" | Harwin Inc. | R30-1011602 |
| MH1, MH2, MH3, MH4 | Machine screw, Pan Phillips M3 | B&F Fastener Supply | MPMS 003 0008 PH |
| Q1 | Transistor, NPN, 30 V, 2 A, SOT89-3 | Diodes Incorporated | 2DD2679-13 |
| Q2, Q6, Q7 | Transistors, NPN, 40 V, 0.2 A, SOT23 | ON Semiconductor | MMBT3904LT1G |
| Q3 | MOSFET, N-channel, 60 V, 4.1 A, 6-TSOP | Vishay Siliconix | SI3458BDV-T1-E3 |
| Q4, Q5, Q12, Q13 | MOSFET, N-channel, 60 V, 320 mA, SOT323 | NXP Semiconductors | BSS138PW,115 |
| Q8, Q9, Q10, Q11 | MOSFET, N-channel, 30 V 22 A, TSDSON-8 | Infineon Technologies | BSZ019N03LS |
| R1 | | | DNI (Do Not Install) |
| R2 | Resistor, SMD, 442 Ω, 1%, 1/10 W, 0805 | Vishay Dale | CRCW0805442RFKEA |
| R3, R6, R14, R46, R49, R50, R99, R101, R104 | Resistors, SMD, 4.7 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW06034K70FKEA |
| R4, R26, R28, R30, R34, R39, R40, R47, R48, R51, R57, R60, R70, R73, R83, R88, R109, R113, R114, R115, R116, R117, R118, R123, R124, R138, R152 | Resistors, SMD, 0.0 Ω, jumper, 1/10 W, 0603 | Vishay Dale | CRCW06030000Z0EA |
| R5 | Resistor, SMD, 4.32 Ω, 1%, 1/8 W, 0805 | Vishay Dale | CRCW08054R32FKEA |
| R7 | Resistor, SMD, 294 Ω, 1%, 1/10 W, 0805 | Vishay Dale | CRCW0805294RFKEA |
| R8 | Resistor, SMD, 49.9 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW060349K9FKEA |
| R9 | Resistor, SMD, 205 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW0603205KFKEA |
| R10 | Resistor, SMD, 23.2 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW060323K2FKEA |
| R11, R12 | Resistors, SMD, 26.7 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW060326K7FKEA |
| R13, R17 | Resistors, SMD, 2.43 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW06032K43FKEA |
| R15 | Resistor, SMD, 8.87 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW06038K87FKEA |

| Reference Designator | Description | Manufacturer | Part Number |
|---|---|---|---|
| R16 | Resistor, SMD, 88.7 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW060388K7FKEA |
| R18 | Resistor, SMD, 0.0 Ω, jumper, 1/8 W, 0805 | Vishay Dale | CRCW08050000Z0EA |
| R19, R42, R44, R45, R52, R53, R55, R62, R77, R80, R85, R128, R129, R132, R133, R137, R148, R149, R151 | Resistors, SMD, 10 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW060310K0FKEA |
| R20, R23, R122 | Resistors, SMD, 100 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW0603100KFKEA |
| R24, R35 | Resistors, SMD, 6.04 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW06036K04FKEA |
| R25, R31, R32, R33, R72, R139, R140 | Resistors, SMD, 1 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW06031K00FKEA |
| R27, R36 | Resistors, SMD, 64.9 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW060364K9FKEA |
| R29, R68, R84, R86, R87, R89, R90, R93, R94, R95, R96, R100, R102, R103, R107, R108, R110, R111, R112, R141, R142 | Resistors, SMD, 33 Ω, 1%, 1/10 W, 0603 | Vishay Dale | CRCW060333R0FKEA |
| R37, R41, R144, R145 | Resistors, SMD, 100 Ω, 1%, 1/10 W, 0603 | Vishay Dale | CRCW0603100RFKEA |
| R43 | Resistor, SMD, 4.42 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW06034K42FKEA |
| R61 | Resistor, SMD, 54.9 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW060354K9FKEA |
| R63, R71, R76 | Resistors, SMD, 6.65 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW06036K65FKEE |
| R64, R66, R74 | Resistors, SMD, 121 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW0603121KFKEA |
| R65 | Resistor, SMD, 4.02 kΩ, 1%, 1/4 W, 0603 | Vishay Dale | CRCW06034K02FKEA |
| R67, R69, R75 | Resistors, SMD, 78.7 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW060378K7FKEA |
| R81 | Resistor, SMD, 825 Ω, 1%, 1/10 W, 0603 | Vishay Dale | CRCW0603825RFKEA |
| R82 | Resistor, SMD, 35.7 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW060335K7FKEA |
| R91, R92, R97, R98 | Resistors, SMD, 10 kΩ, 0.1%, 1/16 W, 0603 | TE Connectivity | RN73C1J10KBTG |
| R105, R106 | Resistors, SMD, 4.99 kΩ, 0.1%, 1/16 W, 0603 | TE Connectivity | RN73C1J4K99BTDF |
| R125 | Resistor, SMD, 3.32 kΩ, 1%, 1/8 W, 1206 | Vishay Dale | CRCW12063K32FKEA |
| R126 | Resistor, SMD, 2.61 kΩ, 1%, 1/8 W, 1206 | Vishay Dale | CRCW12062K61FKEA |
| R130, R131 | Resistors, SMD, 499 Ω, 1%, 1/10 W, 0603 | Vishay Dale | CRCW0603499RFKEA |
| R134, R135 | Resistors, SMD, 1 MΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW06031M00FKEA |
| R136 | Resistor, SMD, 39.2 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW060339K2FKEA |
| R143 | Resistor, SMD, 133 kΩ, 1% 1/10 W, 0603 | Vishay Dale | CRCW0603133KFKEA |
| R150 | Resistor, SMD, 243 kΩ, 1%, 1/10 W, 0603 | Vishay Dale | CRCW0603243KFKEA |
| TP1, TP2, TP4, TP5, TP8, TP9, TP15, TP16 | Test points PC mini, .040" D, red | Keystone Electronics | 5000 |
| TP3, TP11, TP12, TP14, TP19, TP26, TP27, TP29 | Test points PC mini, .040" D, green | Keystone Electronics | 5116 |
| TP6, TP7, TP10, TP13. TP20, TP21, TP22, TP23, TP24, TP25, TP28, TP30 | Test points PC mini, .040" D, white | Keystone Electronics | 5002 |
| U1 | IC, regulator, LDO ADJ, 0.3 A, 8-lead SOIC | Analog Devices | ADP7102ARDZ-R7 |
| U2 | IC, regulator, BST SEPIC ADJ, 1.4 A, 8-lead MSOP | Analog Devices | ADP1612ARMZ-R7 |
| U3 | IC, regulator, LDO, 5 V, 0.3 A, 8-lead SOIC | Analog Devices | ADP7102ARDZ-5.0-R7 |
| U4 | IC, regulator, switched capacitor inverter, 25 mA, 6-lead SOT23 | Analog Devices | ADM8829ARTZ-REEL7 |
| U5 | IC EEPROM, 32 kb, 400 kHz, 8-lead SOIC | Microchip Technology | 24LC32A-I/SN |
| U6 | IC DAC, 16 bit, SRL, 16-lead TSSOP | Analog Devices | AD5689RBRUZ |
| U7 | Battery charge controller, PWM, IC, 48-lead LQFP | Analog Devices | AD8452ASTZ |
| U8 | IC comparator, dual OD, 8-lead SOT23 | Analog Devices | ADCMP343YRJZ-REEL7 |
| U9 | IC, op amp, JFET, 5 MHz, 8-lead SOIC | Analog Devices | ADTL082ARZ |
| U10 | IC ADC 8-channel mux, low power, 40-lead LFCSP | Analog Devices | AD7173-8BCPZ |
| U11, U17 | IC comparator. open-drain, 5-lead SC70 | Analog Devices | ADCMP370AKS |
| U12, U14 | IC gate AND, 1-channel, 2-input, SOT-23 | Fairchild/ON Semi | NC7SZ08M5X |
| U13, U15 | IC inverter, SGL TinyLogic SOT-23 | Fairchild/ON Semi | NC7SZ04M5X |
| U16 | IC VREF series, 5 V, 8-lead SOIC | Analog Devices | ADR4550BRZ |

## PRODUCTS ON THIS EVALUATION SYSTEM

Table 6.

| Product | Ordering Model | Description |
|---|---|---|
| AD8452 | AD8452ASTZ | Precision analog front end and controller and PWM for battery test/formation systems |
| AD7173-8 | AD7173-8BCPZ | Low power, 8-/16-channel, 31.25 kSPS, 24-bit, highly integrated Σ-Δ ADC |
| AD5689R | AD5689RACPZ | Dual, 16-bit *nano*DAC+ with 2 ppm/°C reference |
| ADR4550 | ADR4550BRZ | Ultra low noise, high accuracy 5.0 V voltage reference |
| ADTL082 | ADTL082ARZ | Low cost JFET input dual operational amplifier |
| ADP1612 | ADP1612ARMZ | 650 kHz/1.3 MHz step-up PWM dc-to-dc switching converter |
| ADP7102 | ADP7102ARDZ | 20 V, 300 mA, low noise, CMOS LDO |
| ADM8829 | ADM8829ART | Switched capacitor voltage inverter with shutdown |
| ADuM7223 | ADM7223ACCZ | Isolated precision half-bridge driver, 4 A output |
| ADCMP343 | ADCMP343YRJZ | Dual 0.275% comparator and reference with programmable hysteresis |
| ADCMP370 | ADCMP370AKSZ | General-purpose comparator with an open-drain output |

## RELATED LINKS

| Resource | Description |
|---|---|
| Battery Formation and Testing | Battery Formation and Testing Application Page |
| Technical Article | Power Efficient Battery Formation/Testing System with Energy Recycling |
| AN-1319 Application Note | Compensator Design for a Battery Charge/Discharge Unit Using the AD8450 or the AD8451 |
| AD8450/AD8451 Compensator Design Tool | Simulation Design Tools for the AD8450/AD8451 |