

## Evaluation Board for the AD5235 Digital Potentiometer

### FEATURES

Full featured evaluation board for the AD5235

Several test circuits

Various ac/dc input signals

PC control via a separately purchased system demonstration platform (SDP)

PC control software

26 extra bytes in EEMEM for user-defined information

Resistor tolerance error stored in EEMEM

### PACKAGE CONTENTS

EVAL-AD5235SDZ evaluation board

CD that includes

Self-installing software that allows users to control the board and exercise all functions of the device

Electronic version of the AD5235 data sheet

Electronic version of the UG-258 document

### GENERAL DESCRIPTION

This user guide describes the evaluation board for evaluating the [AD5235](#)—a dual-channel, 1024-position, nonvolatile memory digital potentiometer. With versatile programmability, the AD5235 allows multiple modes of operation, including read/write access in the RDAC and EEMEM registers, increment/decrement of resistance, resistance changes in  $\pm 6$  dB scales, wiper setting read-back, and extra EEMEM for storing user-defined information, such as memory data for other components or a lookup table.

The AD5235 supports dual-supply  $\pm 2.25$  V to  $\pm 2.75$  V operation and single-supply 2.7 V to 5.5 V operation, making the device suited for battery-powered applications and many other applications. In addition, the AD5235 uses a versatile SPI-compatible serial interface, allowing speeds of up to 50 MHz.

The EVAL-AD5235SDZ can operate in single-supply and dual-supply mode and incorporates an internal power supply from the USB.

Complete specifications for the AD5235 part can be found in the [AD5235](#) data sheet, which is available from Analog Devices, Inc., and should be consulted in conjunction with this user guide when using the evaluation board.

## DIGITAL PICTURE OF EVALUATION BOARD WITH SYSTEM DEMONSTRATION PLATFORM



Figure 1.

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REVISION HISTORY

3/11—Revision 0: Initial Version

## EVALUATION BOARD HARDWARE

### POWER SUPPLIES

The EVAL-AD5235SDZ supports the use of single and dual power supplies.

In single-supply mode, the evaluation board can be powered either from the SDP port or externally by the J1-1, J1-2, and J1-3 connectors, as described in Table 1.

If dual-supply mode is required, the J1-1, J1-2, and J1-3 connectors must provide the external power supply, as described in Table 1.

All supplies are decoupled to ground using 10  $\mu$ F tantalum and 0.1  $\mu$ F ceramic capacitors.

**Table 1. Maximum and Minimum Voltages of the Connectors**

| Connector No. | Label   | Voltage                                                                                                                                             |
|---------------|---------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| J1-1          | EXT VDD | Analog positive power supply, $V_{DD}$ .<br>For single-supply operation, it is 2.7 V to 5.5 V.<br>For dual-supply operation, it is 2.5 V to 2.75 V. |
| J1-2          | GND     | Analog GND.                                                                                                                                         |
| J1-3          | EXT VSS | Analog negative power supply, $V_{SS}$ .<br>For single-supply operation, it is 0 V.<br>For dual-supply operation, it is –2.5 V to –2.75 V.          |

**Table 3. Link Functions**

| Link No. | Power Supply | Options                                                                                                                                                            |
|----------|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A25      | $V_{DD}$     | This link selects one of the following as the positive power supply:<br>5 V (from SDP).<br>3.3 V (from SDP).<br>EXT VDD (external supply from the J1-1 connector). |
| A24      | $V_{SS}$     | This link selects one of the following as the negative power supply:<br>GND (analog ground).<br>VDD VSS (external supply from the J1-3 connector).                 |

### LINK OPTIONS

Several link and switch options are incorporated into the evaluation board and should be set up before using the board. Table 2 describes the positions of the links to control the evaluation board by a PC, via the SDP board, using the EVAL-AD5235SDZ in single-supply mode. The functions of these link and switch options are described in detail in Table 3 through Table 6.

**Table 2. Link Options Setup for SDP Control (Default)**

| Link No. | Option |
|----------|--------|
| A25      | 3.3 V  |
| A24      | GND    |

## TEST CIRCUITS

The EVAL-AD5235SDZ incorporates several test circuits to evaluate the AD5235 performance.

### DAC

RDAC1 can be operated as a digital-to-analog converter (DAC), as shown in Figure 2.

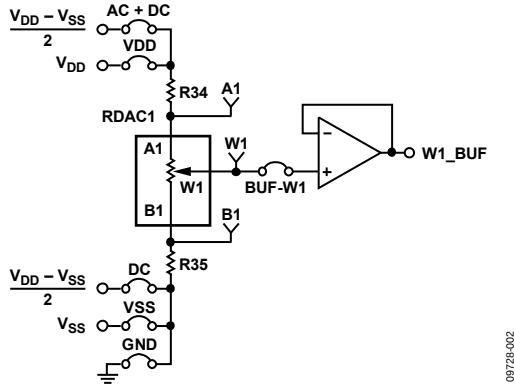


Figure 2. DAC

Table 4 shows the options available for the voltage references.

Table 4. DAC Voltage References

| Terminal | Link   | Options          | Description                                                                                                                |
|----------|--------|------------------|----------------------------------------------------------------------------------------------------------------------------|
| A1       | A20    | AC + DC<br>VDD   | Connects Terminal A1 to $(V_{DD} - V_{SS})/2$<br>Connects Terminal A1 to $V_{DD}$                                          |
| W1       | BUF-W1 |                  | Connects Terminal W1 to an output buffer                                                                                   |
| B1       | A21    | DC<br>VSS<br>GND | Connects Terminal B1 to $(V_{DD} - V_{SS})/2$<br>Connects Terminal B1 to $V_{SS}$<br>Connects Terminal B1 to analog ground |

The output voltage is defined in Equation 1.

$$V_{OUT} = (V_{A1} - V_{B1}) \times \frac{RDAC1}{1024} \quad (1)$$

where:

$RDAC1$  is the code loaded in the RDAC1 register.

$V_{A1}$  is the voltage applied to the A1 terminal (A20 link).

$V_{B1}$  is the voltage applied to the B1 terminal (A21 link).

Using the R34 and R35 external resistors, you can reduce the voltage of the voltage references. In this case, use the A1 and B1 test points to measure the voltage applied to the A1 and B1 terminals and recalculate  $V_{A1}$  and  $V_{B1}$  in Equation 1.

### AC Signal Attenuation

RDAC1 can be used to attenuate an ac signal, which must be provided externally using the AC\_INPUT connector, as shown in Figure 3.

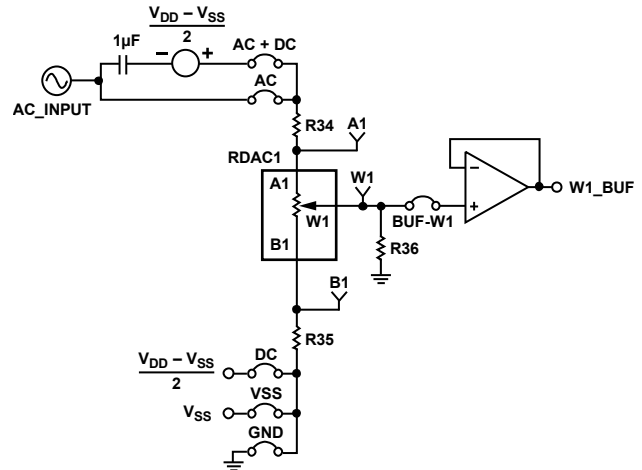


Figure 3. AC Signal Attenuator

Depending on the voltage supply rails and the dc offset voltage of the ac signal, various configurations can be used, as described in Table 5.

Table 5. AC Signal Attenuation Link Options

| Voltage Supply | Maximum AC Signal Amplitude | Link | Options    | Conditions                                                                                                                                                    |
|----------------|-----------------------------|------|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Single         | $V_{DD}$                    | A20  | AC + DC    | No dc offset voltage. AC signal is outside the voltage supply rails due to the dc offset voltage. DC offset voltage $\neq V_{DD}/2^1$ . All other conditions. |
|                |                             |      | AC         |                                                                                                                                                               |
|                |                             | A21  | DC<br>GND  | Use in conjunction with AC + DC link. All other conditions.                                                                                                   |
| Dual           | $V_{DD}/V_{SS}$             | A20  | AC + DC    | AC signal is outside the voltage supply rails due to the dc offset voltage. DC offset voltage $\neq 0V^1$ . All other conditions.                             |
|                |                             |      | AC         |                                                                                                                                                               |
|                |                             | A21  | GND<br>VSS | Use in conjunction with AC + DC link. All other conditions.                                                                                                   |

<sup>1</sup> Recommended to ensure optimal total harmonic distortion (THD) performance.

The signal attenuation is defined in Equation 2.

$$Attenuation \text{ (dB)} = 20 \times \log \left( \frac{R_{WB1} + R_W}{R_{END-TO-END}} \right) \quad (2)$$

where:

$R_{WB1}$  is the resistor between the W1 and B1 terminals.

$R_W$  is the wiper resistance.

$R_{END-TO-END}$  is the end-to-end resistance value.

In addition, R36 can be used to achieve a pseudologarithmic attenuation. To do so, adjust the R36 resistor until a desirable transfer function is found.

### Signal Amplifier

RDAC2 can be operated as an inverting or noninverting signal amplifier supporting linear or pseudologarithmic gains. Table 6 shows the available configurations.

**Table 6. Amplifier Selection Link Options**

| Amplifier    | Gain              | Link | Label        |
|--------------|-------------------|------|--------------|
| Noninverting | Linear            | A27  | LINEAR       |
|              |                   | A29  | NONINVERTING |
|              |                   | A30  | NONINVERTING |
|              | Pseudologarithmic | A27  | PSEUDOLOG    |
|              |                   | A29  | NONINVERTING |
|              |                   | A30  | NONINVERTING |
| Inverting    | Linear            | A27  | LINEAR       |
|              |                   | A29  | INVERTING    |
|              |                   | A30  | INVERTING    |
|              | Pseudologarithmic | A27  | PSEUDOLOG    |
|              |                   | A29  | INVERTING    |
|              |                   | A30  | INVERTING    |

The noninverting amplifier with linear gain is shown in Figure 4, and the gain is defined in Equation 3.

$$G = 1 + \frac{R_{WB2}}{R38} \quad (3)$$

where  $R_{WB2}$  is the resistor between the W2 and B2 terminals.

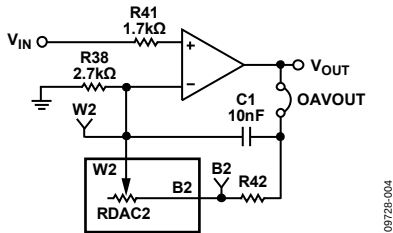


Figure 4. Linear Noninverting Amplifier

The noninverting amplifier with pseudologarithmic gain is shown in Figure 5, and the gain is defined in Equation 4.

$$G = 1 + \frac{R_{WB2}}{R_{AW2}} \quad (4)$$

where:

$R_{WB2}$  is the resistor between the W2 and B2 terminals.

$R_{AW2}$  is the resistor between the A2 and W2 terminals.

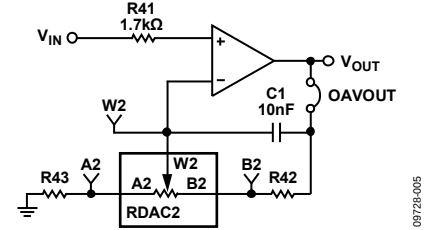


Figure 5. Pseudologarithmic Noninverting Amplifier

R43 and R42 can be used to set the maximum and minimum gain limits.

The inverting amplifier with linear gain is shown in Figure 6, and the gain is defined in Equation 5.

$$G = -\frac{R_{WB2}}{R38} \quad (5)$$

where  $R_{WB2}$  is the resistor between the W2 and B2 terminals.

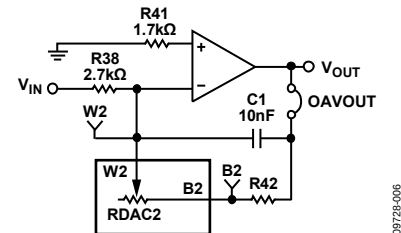


Figure 6. Linear Inverting Amplifier

The inverting amplifier with pseudologarithmic gain is shown in Figure 7, and the gain is defined in Equation 6.

$$G = -\frac{R_{WB2}}{R_{AW2}} \quad (6)$$

where:

$R_{WB2}$  is the resistor between the W2 and B2 terminals.

$R_{AW2}$  is the resistor between the A2 and W2 terminals.

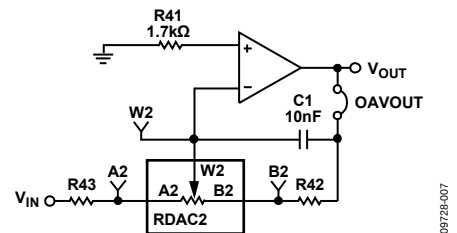


Figure 7. Pseudologarithmic Inverting Amplifier

R43 and R42 can be used to set the maximum and minimum gain limits.

## EVALUATION BOARD SOFTWARE

### INSTALLING THE SOFTWARE

The EVAL-AD5235SDZ evaluation kit includes evaluation board software provided on a CD. The software is compatible with Windows® XP, Windows Vista, and Windows 7 (both 32 and 64 bits).

Install the software before connecting the [SDP board](#) to the USB port of the PC to ensure that the SDP board is recognized when it is connected to the PC.

1. Start the Windows operating system and insert the CD.
2. The installation software must open automatically. If it does not, run the **setup.exe** file from the CD.
3. After installation is completed, power up the evaluation board as described in the Power Supplies section.
4. Plug the EVAL-AD5235SDZ into the SDP board and the SDP board into the PC using the USB cable provided
5. When the software detects the evaluation board, follow the instructions that appear to finalize the installation.

To uninstall the program, click **Start > Control Panel > Add or Remove Programs > AD5235 Eval Board**.

### RUNNING THE SOFTWARE

To run the evaluation board software, do the following:

1. Click **Start > All Programs > Analog Devices > AD5235 > AD5235 Eval Board**.
2. If the SDP board is not connected to the USB port when the software is launched, a connectivity error is displayed (see Figure 8). Connect the evaluation board to the USB port of the PC, wait a few seconds, click **Rescan**, and follow the instructions.

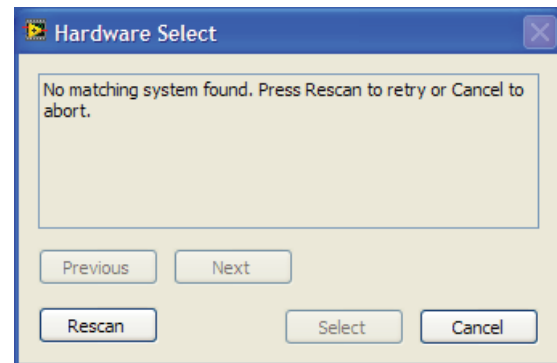


Figure 8. Pop-Up Window Error

The main window of the EVAL-AD5235SDZ evaluation software then opens, as shown in Figure 9.

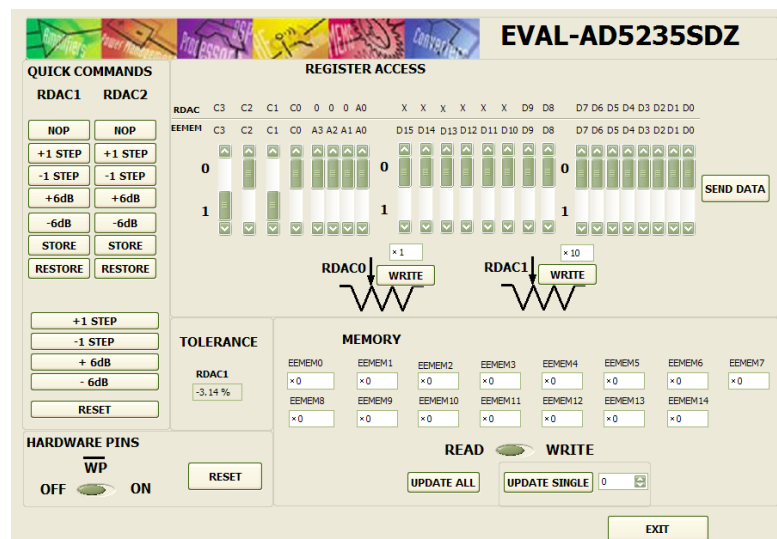


Figure 9. EVAL-AD5235SDZ Evaluation Board Software Main Window

## SOFTWARE OPERATION

The main window of the EVAL-AD5235SDZ software is divided into the following sections: **QUICK COMMANDS**, **REGISTER ACCESS**, **HARDWARE PINS**, **TOLERANCE**, and **MEMORY**. The features of the main window are as follows:

- The **QUICK COMMANDS** section allows you to send the [AD5235](#) quick commands directly to the AD5235.
- The **REGISTER ACCESS** section can be used to update the RDAC registers by typing a value into a window and clicking **WRITE**. Alternatively, you can send a customized SPI data-word by manually switching the scroll bars from 0 to 1 or from 1 to 0, as desired, and then clicking **SEND DATA**. When **WRITE** is clicked or a quick command is executed, a write-read operation is performed, and the values displayed in this section are updated with the actual RDAC register values. This function can be used to verify whether the write operation was completed successfully. The scroll bars are updated upon each write transfer.
- The **HARDWARE PINS** section enables or disables the AD5235 **WP** pin and the **RESET** pin.
- The **TOLERANCE** section displays the stored tolerance of the RDAC1 internal resistor.
- The **MEMORY** section displays the data stored in the memory block. The data can be updated by switching the scroll bar from **READ** to **WRITE**, updating a particular window value, clicking **UPDATE ALL** or **UPDATE SINGLE**, and selecting the memory location to write.
- Clicking **EXIT** closes the program but does not reset the part.

## EVALUATION BOARD SCHEMATICS AND ARTWORK

## MULTICHANNEL

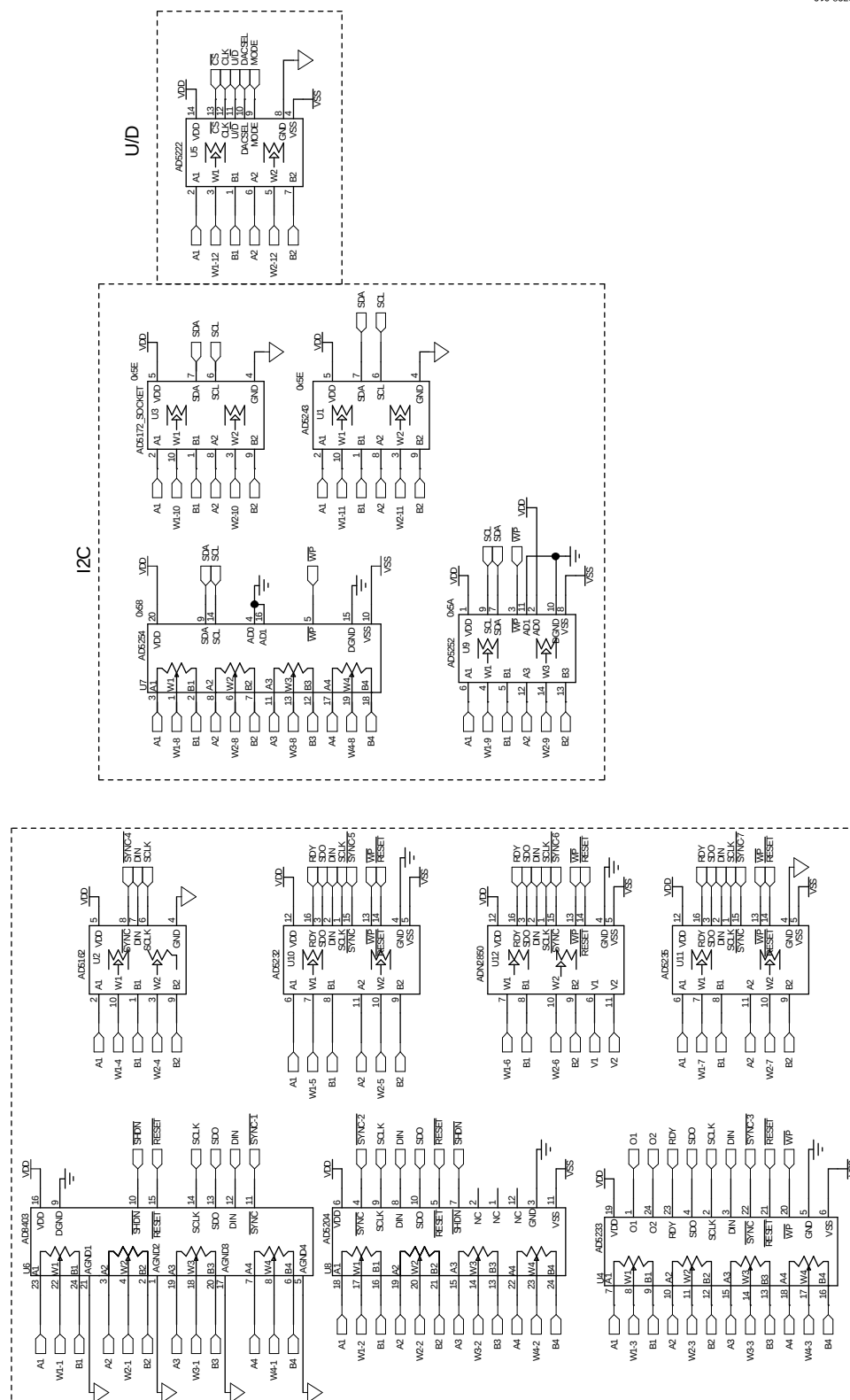


Figure 10. Schematic of Multiboard Digital Potentiometers

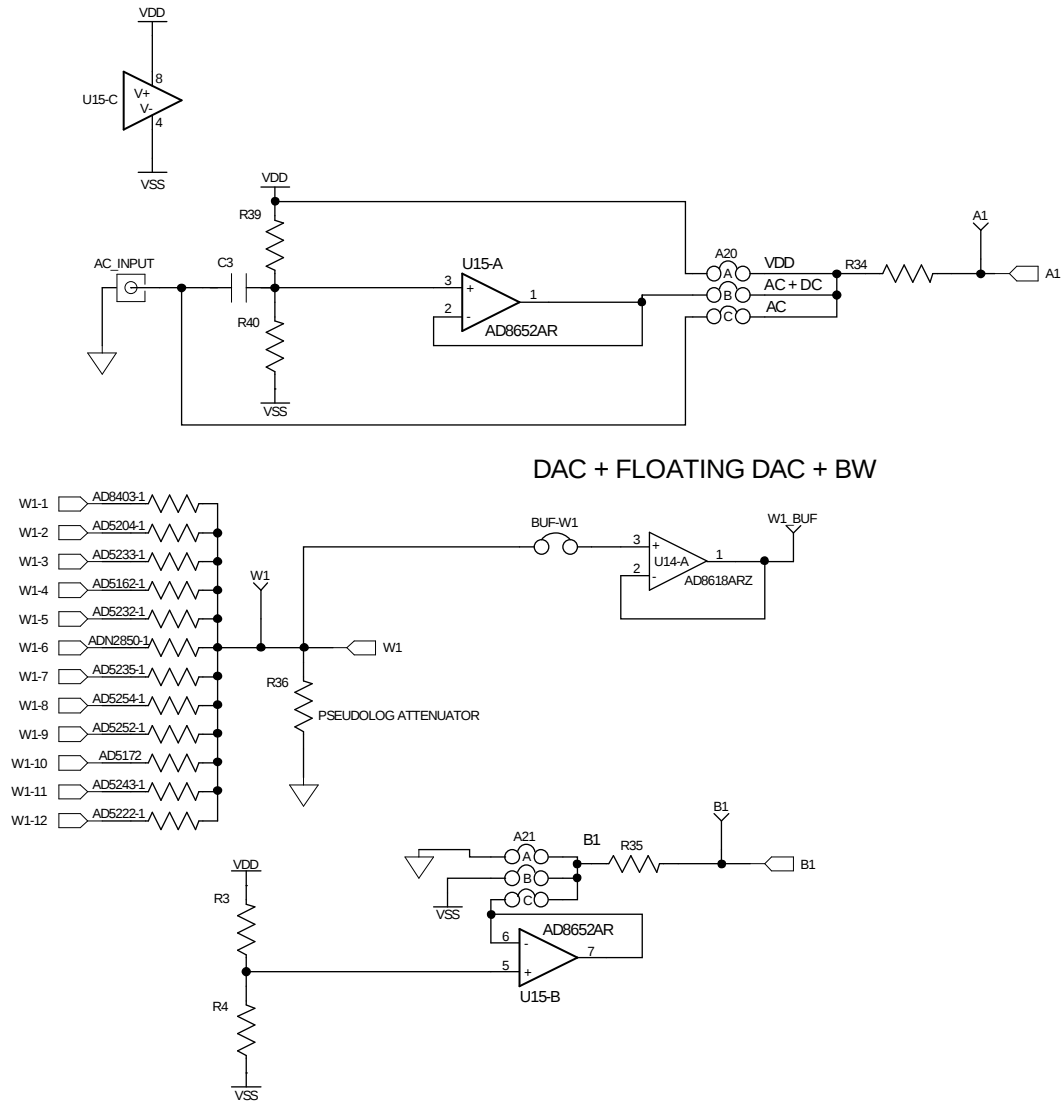


Figure 11. Schematic of Multiboard RDAC0 Circuits

## INVERTING AND NON-INVERTING WITH LINEAR AND PSEUDO-LOG GAIN

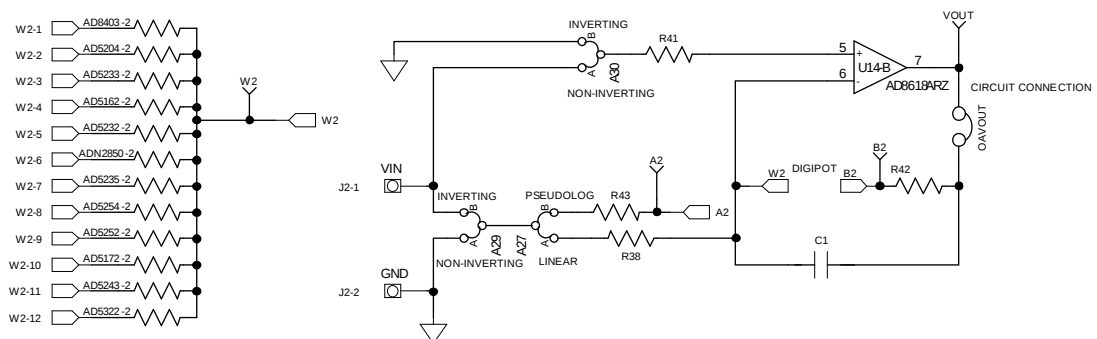
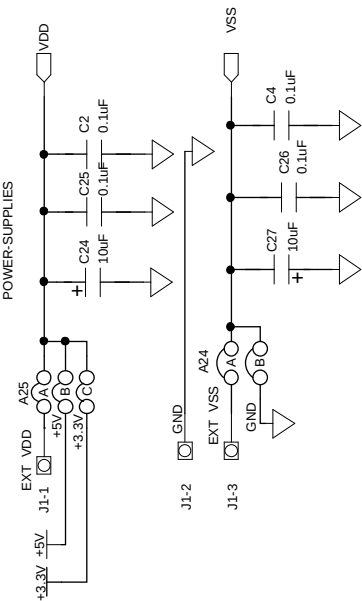


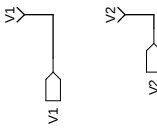
Figure 12. Schematic of Multiboard RDAC1 Circuits

09728-017

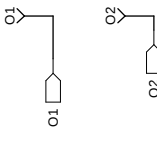
POWER-SUPPLY



CURRENT MONITOR



DIGITAL PINS



CHANNELS 3 AND 4

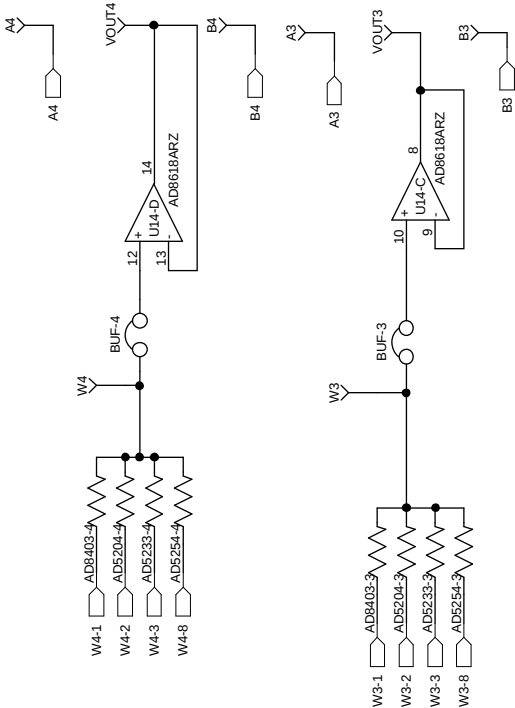
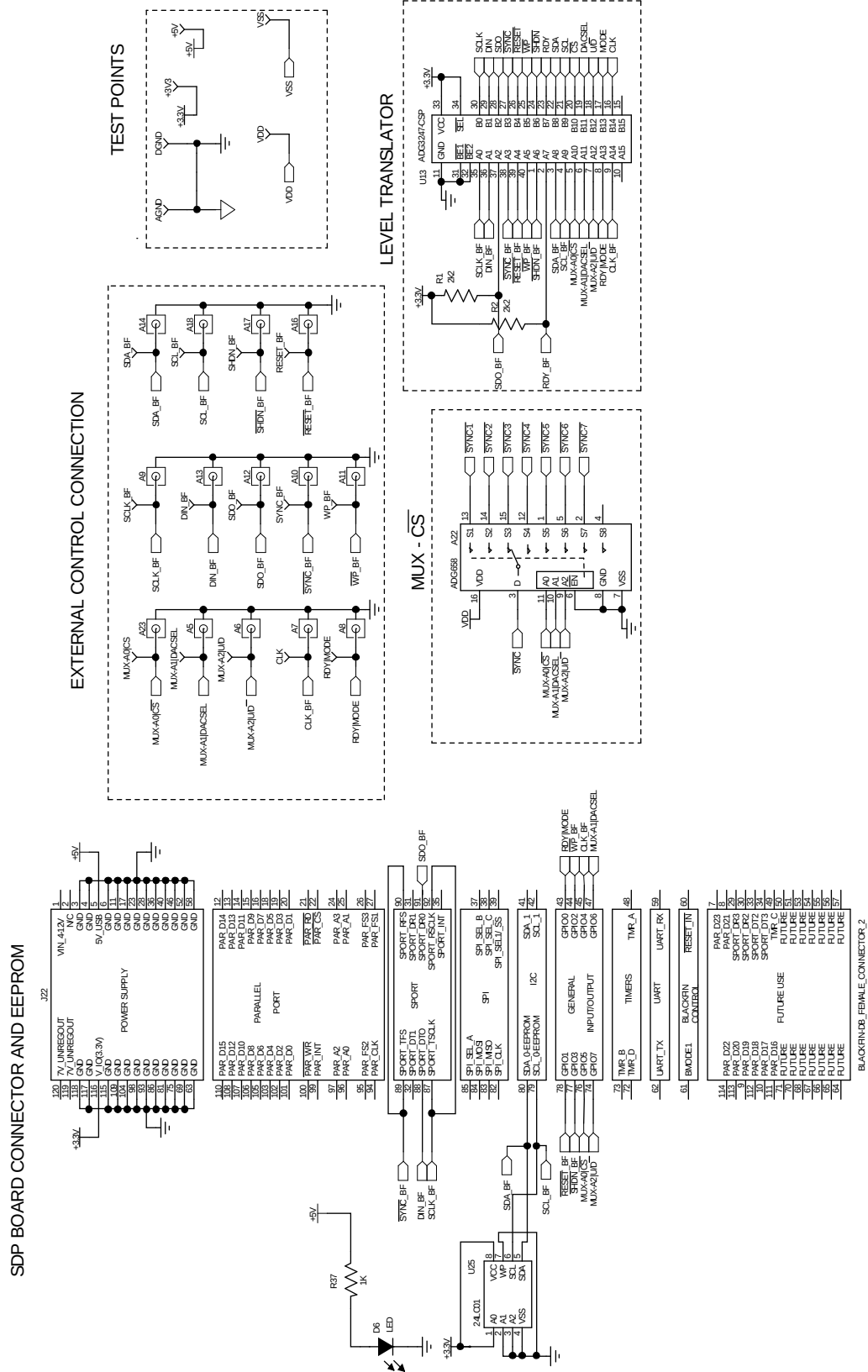


Figure 13. Schematic of AD5235 Power Supplies and Other Channels

09728-018



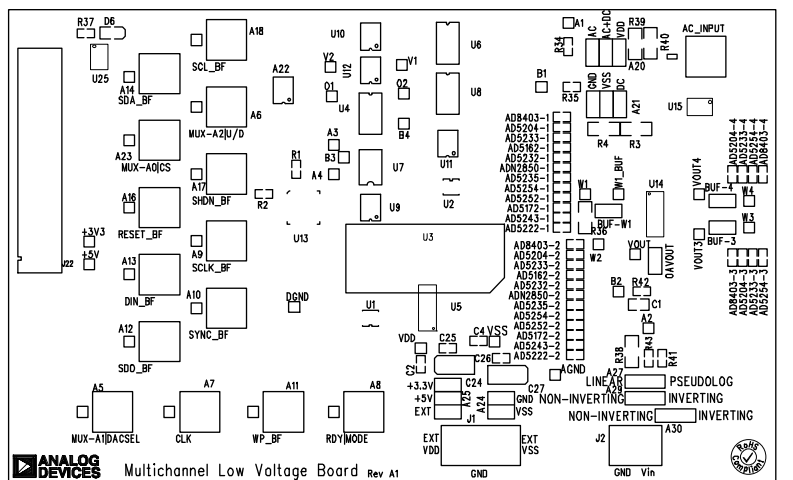


Figure 15. Component Side View

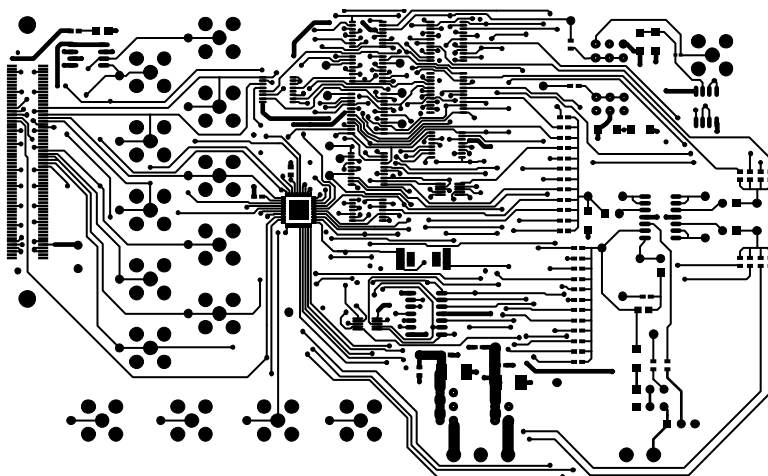


Figure 16. Component Placement Drawing

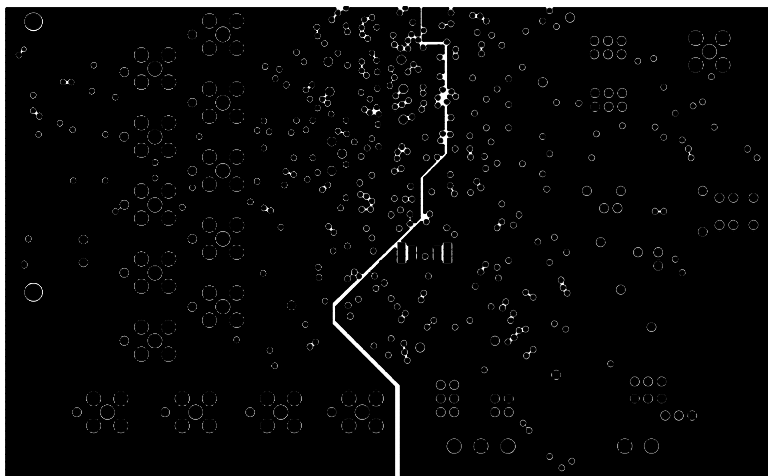


Figure 17. Layer 2 Side PCB Drawing

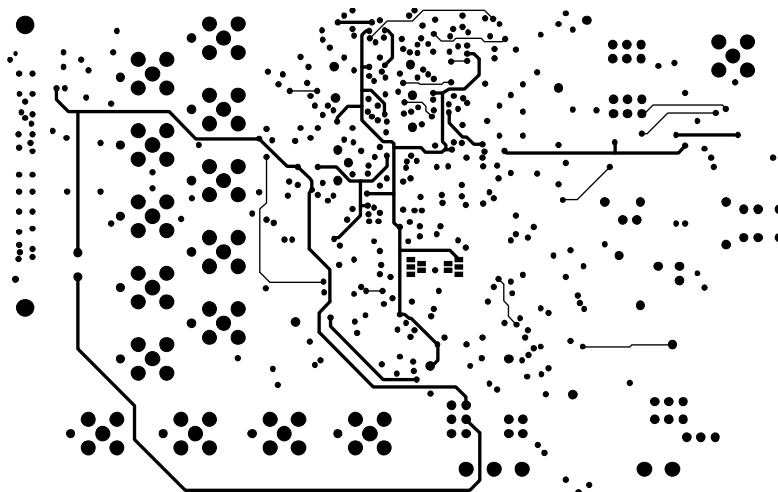


Figure 18. Layer 3 Side PCB Drawing

09725-015

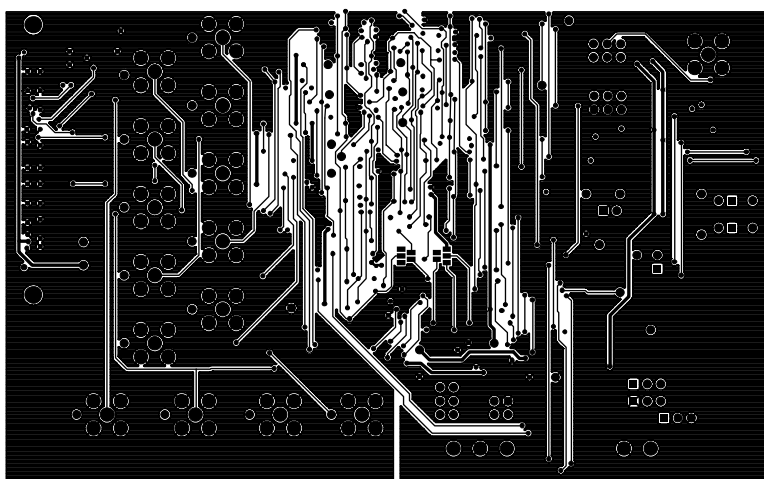


Figure 19. Solder Side PCB Drawing

09725-013

## ORDERING INFORMATION

## BILL OF MATERIALS

Table 7.

| Qty | Reference Designator                                                                                                                                                                                                                                                                                                                                 | Description                                          | Supplier <sup>1</sup> /Part Number |
|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|------------------------------------|
| 1   | C1                                                                                                                                                                                                                                                                                                                                                   | 10 nF capacitor, 0805                                | FEC 1692285                        |
| 4   | C2, C4, C25, C26                                                                                                                                                                                                                                                                                                                                     | 0.1 $\mu$ F capacitor, 0603                          | FEC 138-2224                       |
| 1   | C3                                                                                                                                                                                                                                                                                                                                                   | 1 $\mu$ F capacitor, 0402                            | FEC 1288253                        |
| 2   | C24, C27                                                                                                                                                                                                                                                                                                                                             | 10 $\mu$ F capacitor, 1206                           | FEC 1611967                        |
| 1   | D6                                                                                                                                                                                                                                                                                                                                                   | LED, green                                           | FEC 579-0852                       |
| 1   | J1                                                                                                                                                                                                                                                                                                                                                   | 3-pin connector                                      | FEC 151790                         |
| 1   | J2                                                                                                                                                                                                                                                                                                                                                   | 2-pin connector                                      | FEC 151789                         |
| 1   | J22                                                                                                                                                                                                                                                                                                                                                  | Receptacle, 0.6 mm, 120 way                          | Digi-Key H1219-ND                  |
| 4   | A20, A21, A24, A25                                                                                                                                                                                                                                                                                                                                   | Header, 2-row, 36 + 36 way, and jumper socket, black | FEC 148-535 and FEC 150-410        |
| 3   | A27, A29, A30                                                                                                                                                                                                                                                                                                                                        | Header, 1-row, 3-way, and jumper socket, black       | FEC 102-2248 and FEC 150-410       |
| 4   | BUF-W1, OAVOUT, BUF-3, BUF-4                                                                                                                                                                                                                                                                                                                         | Header, 1-row, 2-way, and jumper socket, black       | FEC 102-2247 and FEC 150-410       |
| 1   | R41                                                                                                                                                                                                                                                                                                                                                  | 1.78 k $\Omega$ resistor, 0603, 1%                   | FEC 1170811                        |
| 2   | R1, R2                                                                                                                                                                                                                                                                                                                                               | 2.2 k $\Omega$ resistor, 0603, 1%                    | FEC 933-0810                       |
| 5   | R3, R4, R38, R39, R40                                                                                                                                                                                                                                                                                                                                | 2.7 k $\Omega$ resistor, 1206, 1%                    | FEC 9337288                        |
| 36  | AD5162-1, AD5162-2, AD5172-1, AD5172-2, AD5204-1, AD5204-2, AD5204-3, AD5204-4, AD5222-1, AD5222-2, AD5232-1, AD5232-2, AD5233-1, AD5233-2, AD5233-3, AD5233-4, AD5235-1, AD5235-2, AD5243-1, AD5243-2, AD5252-1, AD5252-2, AD5235-1, AD5235-2, AD5235-3, AD5235-4, AD8403-1, AD8403-2, AD8403-3, AD8403-4, ADN2850-1, ADN2850-2, R34, R35, R42, R43 | 0 $\Omega$ resistor, 0603                            | FEC 9331662                        |
| 1   | R37                                                                                                                                                                                                                                                                                                                                                  | 1 k $\Omega$ resistor, 0603, 1%                      | FEC 933-0380                       |
| 6   | 3.3 V, 5 V, DGND, AGND, VDD, VSS                                                                                                                                                                                                                                                                                                                     | Test point, PCB, black, PK100                        | FEC 873-1128                       |
| 35  | A1, A2, A3, A4, RDY MODE, RESET_BF, SCL_BF, SCLK_BF, SDA_BF, SDO_BF, SHDN_BF, SYNC_BF, MUX-A0 CS, MUX-A1 DACSEL, MUX-A2 U/D, O1, O2, DIN_BF, CLK, B1, B2, B3, B4, V1, V2, VOUT, VOUT2, VOUT3, VOUT4, W1, W1_BUF, W2, W3, W4, WP_BUF                                                                                                                  | Test point, PCB, red, PK100                          | FEC 873-1144                       |
| 1   | U1                                                                                                                                                                                                                                                                                                                                                   | AD5243                                               | Analog Devices AD5243              |
| 1   | U2                                                                                                                                                                                                                                                                                                                                                   | AD5162                                               | Analog Devices AD5162              |
| 1   | U3                                                                                                                                                                                                                                                                                                                                                   | AD5172                                               | Analog Devices AD5172              |
| 1   | U4                                                                                                                                                                                                                                                                                                                                                   | AD5233                                               | Analog Devices AD5233              |
| 1   | U5                                                                                                                                                                                                                                                                                                                                                   | AD5222                                               | Analog Devices AD5222              |
| 1   | U6                                                                                                                                                                                                                                                                                                                                                   | AD8403                                               | Analog Devices AD8403              |
| 1   | U7                                                                                                                                                                                                                                                                                                                                                   | AD5235                                               | Analog Devices AD5235              |
| 1   | U8                                                                                                                                                                                                                                                                                                                                                   | AD5204                                               | Analog Devices AD5204              |
| 1   | U9                                                                                                                                                                                                                                                                                                                                                   | AD5252                                               | Analog Devices AD5252              |
| 1   | U10                                                                                                                                                                                                                                                                                                                                                  | AD5232                                               | Analog Devices AD5232              |
| 1   | U11                                                                                                                                                                                                                                                                                                                                                  | AD5235                                               | Analog Devices AD5235              |
| 1   | U12                                                                                                                                                                                                                                                                                                                                                  | ADN2850                                              | Analog Devices ADN2850             |
| 1   | U13                                                                                                                                                                                                                                                                                                                                                  | ADG3247                                              | Analog Devices ADG3247             |
| 1   | U14                                                                                                                                                                                                                                                                                                                                                  | AD8618                                               | Analog Devices AD8618              |
| 1   | U15                                                                                                                                                                                                                                                                                                                                                  | AD8652                                               | Analog Devices AD8652              |
| 1   | A22                                                                                                                                                                                                                                                                                                                                                  | ADG658                                               | Analog Devices ADG658              |
| 1   | U25                                                                                                                                                                                                                                                                                                                                                  | 24LC64                                               | FEC 975-8070                       |

<sup>1</sup> FEC refers to Farnell Electronic Component Distributors; Digi-Key refers to Digi-Key Corporation.

## NOTES

## NOTES

I<sup>2</sup>C refers to a communications protocol originally developed by Philips Semiconductors (now NXP Semiconductors).

**ESD Caution**

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

**Legal Terms and Conditions**

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