

## Evaluating the **AD74412R** Quad-Channel, Software Configurable Input/Output

### FEATURES

Fully featured evaluation board for the **AD74412R**

On-board 2.5 V **ADR4525** reference

SPI

PC-based software for control

### EVALUATION KIT CONTENTS

EV-AD74412RSDZ evaluation board

### EQUIPMENT NEEDED

**EVAL-SDP-CS1Z**

Benchtop power supply and connector cables

### DOCUMENTS NEEDED

**AD74412R** data sheet

### SOFTWARE NEEDED

**AD74412R** evaluation software for control

### GENERAL DESCRIPTION

The EV-AD74412RSDZ (see Figure 1) is a fully featured evaluation board that can be used to evaluate the features of the **AD74412R**. The **AD74412R** is a quad-channel, software configurable, input/output device. The device has functionality for analog output, analog input, digital input, and resistance temperature detector (RTD) measurements integrated into a single-chip solution with a serial peripheral interface (SPI)-compatible interface.

The EV-AD74412RSDZ can be controlled via a system demonstration platform (SDP). The **EVAL-SDP-CS1Z** (SDP-S) board allows the EV-AD74412RSDZ to be controlled via the USB port of a PC using the **AD74412R** evaluation software.

The EVAL- AD74412RSDZ requires an AVDD operating supply of 14 V to 26.4 V. When the EV-AD74412RSDZ is connected to the PC, the PC provides power to the **SDP-S** board.

For full details on the **AD74412R**, see the **AD74412R** data sheet, which must be consulted in conjunction with this user guide when using the EV-AD74412RSDZ.

### EVALUATION BOARD PHOTOGRAPH

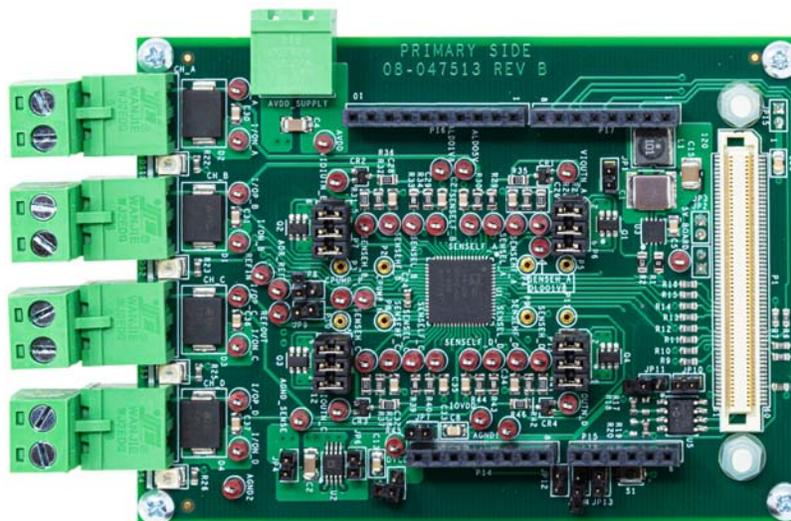


Figure 1.

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**REVISION HISTORY**

9/2019—Revision 0: Initial Version

## EVALUATION BOARD HARDWARE

### POWER SUPPLIES

The EV-AD74412RSDZ comes with a single power supply connector that provides power directly to the AVDD pin of the AD74412R. Set this supply as described in the AD74412R data sheet.

The AVDD supply on the EV-AD74412RSDZ powers an on-board regulator (ADP2360), which generates a 5 V supply to the EV-AD74412RSDZ (see Figure 2). The 5 V supply can be used for the following purposes:

- Power a 2.5 V external reference (ADR4525). The ADR4525 can be used as an alternative to the AD74412R on-chip reference.
- Power a 3.3 V regulator (ADP1720). The 3.3 V from the regulator powers the DVCC and IOVDD supplies of the AD74412R.

Figure 2 shows a simplified drawing of the power connections on the EV-AD74412RSDZ.

### REFERENCE OPTIONS

By default, the EV-AD74412RSDZ is configured to use the AD74412R on-chip reference by shorting the REFOUT pin to the REFIN pin. There is also an external reference option available on the EV-AD74412RSDZ. The ADR4525 can be used instead of the internal reference. The appropriate jumpers must be connected if using the external reference. See Table 1 for the specific link options and functions.

### OUTPUT CHANNELS

The four channels of the AD74412R are configured as described in the AD74412R data sheet. Figure 13 shows the schematic details for all four channels.

There are four channel screw terminal connectors on the EV-AD74412RSDZ. These terminals (CH\_A, CH\_B, CH\_C, and CH\_D) are used to connect the desired loads to the four channels of the AD74412R.

### SPI COMMUNICATION

The SDP-S board handles the communication to the EV-AD74412RSDZ via the PC. By default, the SDP-S board controls the SPI communication, controls the RESET pin (driven high) and LDAC pin (driven low), and monitors the ALERT pin, ADC\_RDY pin, and the GPO\_x pins of the AD74412R.

A reset button (S1) is also available on the EV-AD74412RSDZ.

The EV-AD74412RSDZ supports the use of an Arduino® board (such as the EVAL-ADICUP3029) when connected to the headers provided. See Table 1 for the necessary links to the Arduino header.

### TEST POINTS

Multiple test points are available on the EV-AD74412RSDZ. Debug access is available for all pins on the AD74412R and on the four channel screw terminals. The test points are located adjacent to the relevant pins on the AD74412R.

### LINK CONFIGURATION OPTIONS

The JPx and Px jumpers must be set properly for operation of the EV-AD74412RSDZ before using the EV-AD74412RSDZ. The functions and default states of these options are listed in Table 1.

Before applying power and signals to the EV-AD74412RSDZ, ensure that all links are set to the default positions, as defined in Table 1.

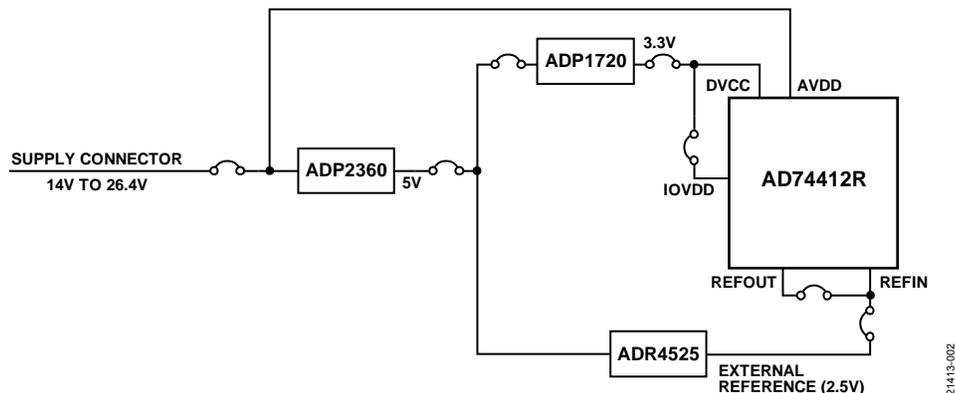


Figure 2. EV-AD74412RSDZ Simplified Power Diagram

Table 1. EV-AD74412RSDZSDZ Link Option Functions

Link	Function	Default Position
JP1	When inserted, the AVDD supply is used to power the <a href="#">ADP2360</a> .	Inserted
JP2	When inserted, 5 V is supplied by the Arduino connector. When not inserted, JP3 can be used to provide the 5 V supply instead.	Not inserted
JP3	When inserted, 5 V is supplied by the <a href="#">ADP2360</a> . When not inserted, JP2 can be used to provide the 5 V supply instead.	Inserted
JP4	When inserted, 5 V is used to power the <a href="#">ADP1720</a> . When not inserted, no power is provided to the <a href="#">ADP1720</a> .	Inserted
JP5	When inserted, the DVCC voltage is supplied by the Arduino connector. When not inserted, JP6 can be used to provide the DVCC supply instead.	Not inserted
JP6	When inserted, the DVCC voltage is supplied by the <a href="#">ADP1720</a> . When not inserted, the DVCC supply can be supplied by the Arduino connector instead.	Inserted
JP7	When inserted the IOVDD voltage is connected to the DVCC voltage. When not inserted, no power is applied to the IOVDD pin.	Inserted
JP8	When inserted, the REFIN pin is tied to the output of the <a href="#">ADR4525</a> .	Not inserted
JP9	When inserted, the REFIN pin is tied to the REFOUT pin (the internal reference of the <a href="#">AD74412R</a> ).	Inserted
JP10	When inserted, 3.3 V is provided by the <a href="#">SDP-S</a> board. When not inserted, JP11 can be used to provide the 3.3 V supply instead.	Inserted
JP11	When inserted, 3.3 V is provided by the Arduino connector. When not inserted, JP10 can be used to provide the 3.3 V supply instead.	Not inserted
JP12	When inserted, the <a href="#">AD74412R</a> reset can be triggered by the Arduino reset function.	Not inserted
JP13	When inserted, the <a href="#">AD74412R</a> reset can be provided by the reset button on the EV-AD74412RSDZ.	Inserted
JP14	When inserted, the <a href="#">AD74412R</a> reset can be triggered by an Arduino general-purpose input/output (GPIO).	Not inserted
JP15	When inserted, the 5 V supply can be used to supply the <a href="#">SDP-S</a> board.	Not inserted
P6	Can be used to connect or to bypass the optional P-channel field effect transistor (PFET) for low resistive loads on Channel A of the <a href="#">AD74412R</a> . Can be used to connect the <a href="#">AD74412R</a> to the external screw terminal via the external PFET by connecting Pin 1 to Pin 2, Pin 3 to Pin 4, and Pin 5 to Pin 6. Can be used to bypass the external PFET by connecting Pin 1 and Pin 3.	PFET connected
P7	Can be used to connect or bypass the optional PFET for low resistive loads on Channel B of the <a href="#">AD74412R</a> . Can be used to connect the <a href="#">AD74412R</a> to the external screw terminal via the external PFET by connecting Pin 1 to Pin 2, Pin 3 to Pin 4, and Pin 5 to Pin 6. Can be used to bypass the external PFET by connecting Pin 1 and Pin 3.	PFET connected
P8	Can be used to connect or to bypass the optional PFET for low resistive loads on Channel C of the <a href="#">AD74412R</a> . Can be used to connect the <a href="#">AD74412R</a> to the external screw terminal via the external PFET by connecting Pin 1 to Pin 2, Pin 3 to Pin 4, and Pin 5 to Pin 6. Can be used to bypass the external PFET by connecting Pin 1 and Pin 3.	PFET connected
P9	Can be used to connect or to bypass the optional PFET for low resistive loads on Channel D of the <a href="#">AD74412R</a> . Can be used to connect the <a href="#">AD74412R</a> to the external screw terminal via the external PFET by connecting Pin 1 to Pin 2, Pin 3 to Pin 4, and Pin 5 to Pin 6. Can be used to bypass the external PFET by connecting Pin 1 and Pin 3.	PFET connected

## SOFTWARE QUICK START PROCEDURES

### ACCESSING THE AD74412R EVALUATION SOFTWARE GRAPHICAL USER INTERFACE (GUI)

The AD74412R evaluation software is used to communicate with the EV-AD74412RSDZ. To download the software executable, go to [www.analog.com/AD74412R](http://www.analog.com/AD74412R).

### CONFIGURING THE BOARD

To set up the EV-AD74412RSDZ, take the following steps:

1. Connect a USB cable to the PC and then to the SDP-S board.
2. Connect the SDP-S board to the EV-AD74412RSDZ. The PC recognizes the EV-AD74412RSDZ.
3. Power up the EV-AD74412RSDZ with the relevant power supplies.
4. If not opened already, open the AD74412R evaluation software GUI. The GUI displays a green indicator to confirm that the AD74412R is connected (see Figure 3).
5. Click **Start** to begin configuration.

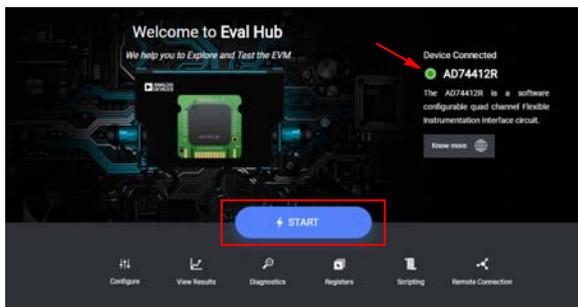


Figure 3. AD74412R Evaluation Software Start Page

### USING THE SOFTWARE FOR EVALUATION

#### Configure Tab

The **Configure** tab is used to configure the four channels of the AD74412R. Each channel can be configured as described in the AD74412R data sheet. The dropdown menus are used to configure the required use case (see Figure 4).

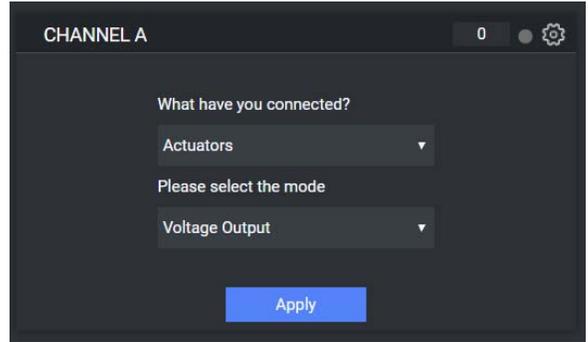


Figure 4. Channel Use Case View

When the use case is selected, the associated advanced settings display (see Figure 5). The gear icon in the top right corner of the page allows the user to toggle between the main settings and the advanced settings.

Click **Apply** to update the device with the selected settings.

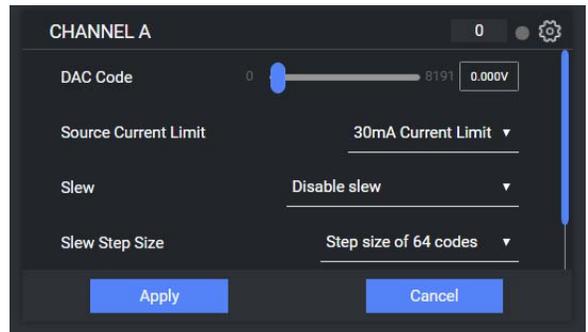


Figure 5. Channel Use Case Advanced Settings

#### View Results Tab

When the channel configuration is applied, click the **View Results** tab to see the channel monitor. Results from each channel are shown in a separate graph (see Figure 6).

#### Diagnostics Tab

In the **Diagnostics** tab, click the test points to enable measurements of the required diagnostics. Up to four diagnostics can be enabled at once (see Figure 7).



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Figure 6. View Results Tab



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Figure 7. Diagnostics Tab

**Register Map**

The register map can also be used to interface directly to the [AD74412R](#).

Immediate mode allows register writes to execute as soon as the bit fields are changed.

In deferred mode, no register edits are applied to the [AD74412R](#) until the **Write Register** button is clicked. The **Read Register** button must also be clicked in deferred mode to manually read from the device (see Figure 9).

Any changes made on the register map are automatically reflected in the **Configure** tab. Click **Apply** in the **Configure** tab to display results in the **View Results** tab.

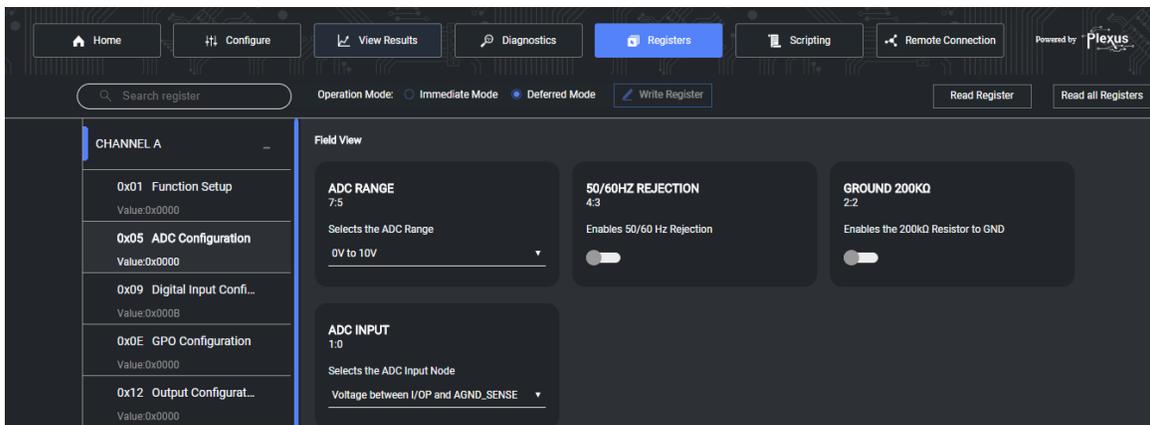
**Scripting Tab**

The scripting tool allows simple scripts to be programmed, executed, and saved. When a script is written in the left panel, click the Run icon (see Figure 8) to execute the writes to the [AD74412R](#). The panel on the right side of the page displays the results from any readbacks executed in the script. Commands supported by this page are currently limited to write and read operations (see Figure 10). The scripting feature has autocomplete enabled by default and validates the written syntax. The user can save and load configurations.



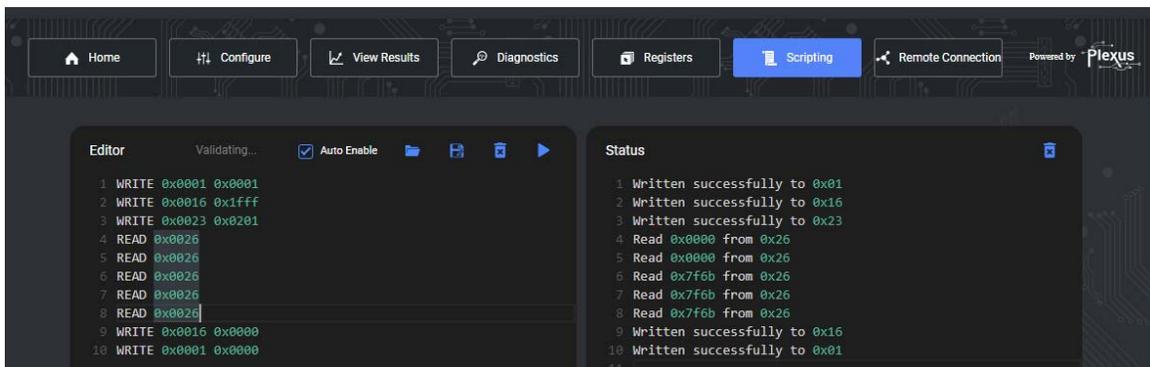
21413-008

Figure 8. Run Icon



21413-009

Figure 9. Register Map Display



21413-010

Figure 10. Scripting Page Display

## EXAMPLE SEQUENCE

This section demonstrates how to configure the AD74412R for a selected function. The AD74412R data sheet must be consulted when programming the device.

### Force Voltage Measure Current Example

This example is used to configure the AD74412R in voltage output mode, sourcing 11 V across the Channel A screw terminals. This example also measures the corresponding current through the  $R_{SENSE}$  resistor using the on-chip, analog-to-digital converter (ADC). The ADC measurement is completed using a conversion rate of 20 SPS with 50 Hz and 60 Hz rejection enabled. See Table 2 for the full list of commands.

A suitable load must be placed across the screw terminals. Refer to the AD74412R data sheet for more information.

To complete the register write steps shown in Table 2 using the AD74412R GUI, take the following steps:

1. In the **Configure** tab, use the dropdown menus to select **Actuators** and **Voltage Output** (see Figure 4).
2. In the **Advanced Settings** panel, set the **DAC Code** slider to 8191 (11 V).
3. Click **Apply**. This executes all writes required to configure the device and to enable ADC conversions in the default mode. This configuration allows the AD74412R to measure voltage across the  $R_{SENSE}$  resistor in the 0 V to 2.5 V range at a 20 SPS conversion rate.
4. Click the **View Results** tab to view the ADC results.

See Figure 10 for the corresponding script.

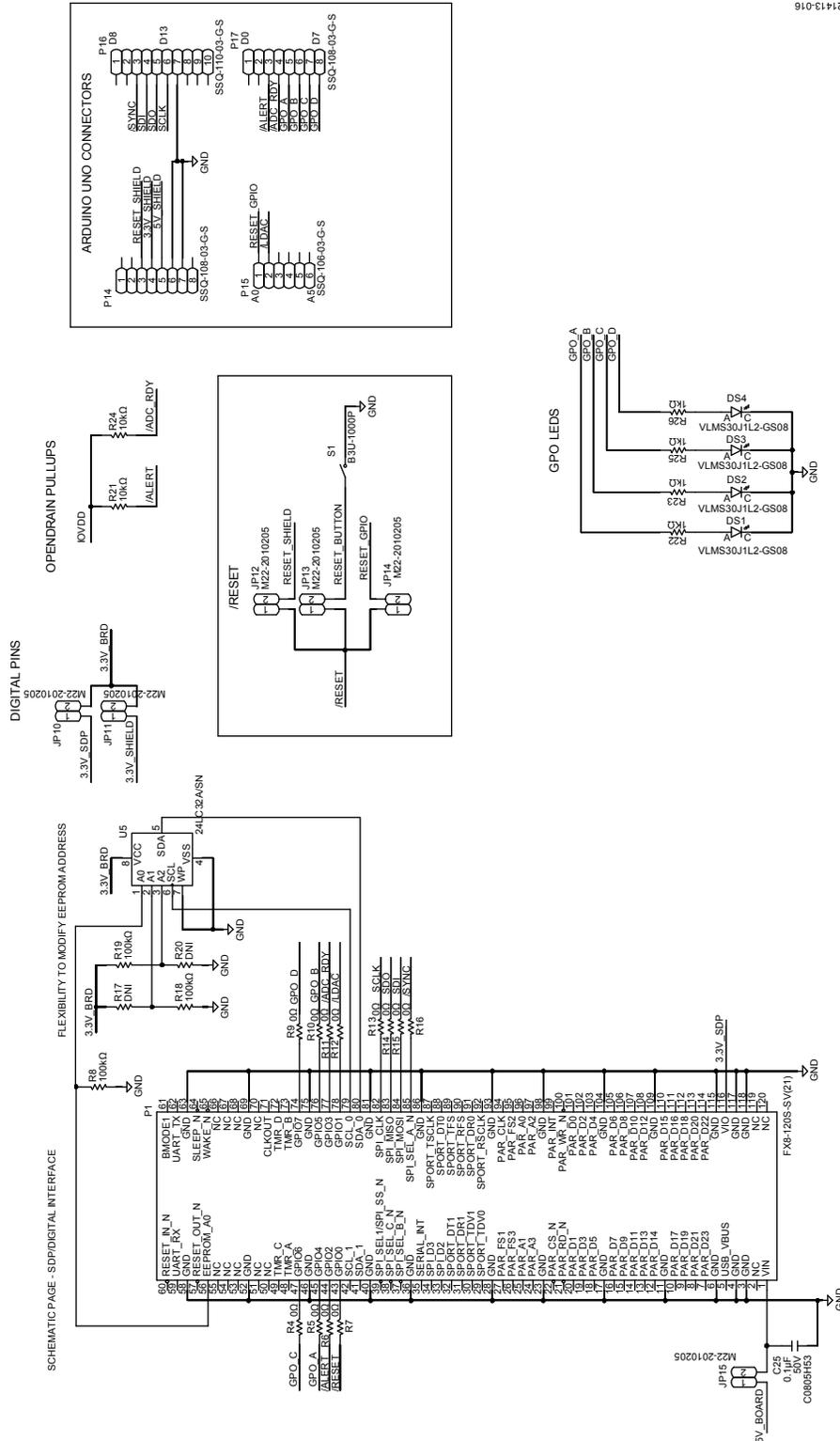
**Table 2. Force Voltage Measure Current Instruction Set**

Instruction	Instruction Description	W/R <sup>1</sup>	Register Name and Address	Data	Notes
1	Configure Channel A in voltage output mode	W	CH_FUNC_SETUPA, Address 0x01	0x0001	
2	Write full-scale code to DAC_A to generate 11 V	W	DAC_CODEA, Address 0x16	0x1FFFF	$\overline{LDAC}$ pin voltage = 0 V to allow outputs to be updated instantly.
3	Measure 11 V across Channel A screw terminals	N/A <sup>2</sup>	N/A <sup>2</sup>	N/A <sup>2</sup>	Use handheld meter to verify voltage.
4	Enable ADC to convert and measure current through $R_{SENSE}$ resistor	W	ADC_CONV_CTRL, Address 0x23	0x0201	When the write in Instruction 1 is executed, the ADC automatically configures to measure voltage across the $R_{SENSE}$ resistor in a 0 V to 2.5 V range.
5	Read ADC results	R	ADC_RESULTA, Address 0x26		
6	Calculate current through $R_{SENSE}$ resistor using the equation available in the AD74412R data sheet	N/A <sup>2</sup>	N/A <sup>2</sup>	N/A <sup>2</sup>	$I_{R_{SENSE}} = \frac{\left( V_{MIN} + \left( \left( \frac{AD\_CODE}{65535} \right) \times Voltage\ Range \right) \right)}{R_{SENSE}}$ <p>where:  <math>I_{R_{SENSE}}</math> is the current through the <math>R_{SENSE}</math> resistor.  <math>V_{MIN}</math> is -2.5 V, the minimum voltage is in the -2.5 V to 2.5 V range.  The voltage range is 5 V.</p>
7	Stop ADC conversions	W	ADC_CONV_CTRL, Address 0x23	0x0000	
8	Program DAC_A to zero scale	W	DAC_CODEA, Address 0x16	0x0000	Cleanup of DAC code and channel configuration is recommended before reprogramming the device.
9	Reset Channel A to high-Z mode	W	CH_FUNC_SETUPA, Address 0x01	0x0000	

<sup>1</sup> W is write and R is read.

<sup>2</sup> N/A is not applicable.





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Figure 12. Digital Pins Including SDP-5 Board and Arduino Board Connections

CHANNEL EXTERNAL COMPONENTS

ALL COMPONENTS TO BE CONFIRMED!

CONFIGURING PX, PY, PZ, PA  
TO USE PMOS:  
CONNECT 1 TO 2, 3 TO 4, 5 TO 6  
TO BYPASS PMOS:  
CONNECT 1 TO 3

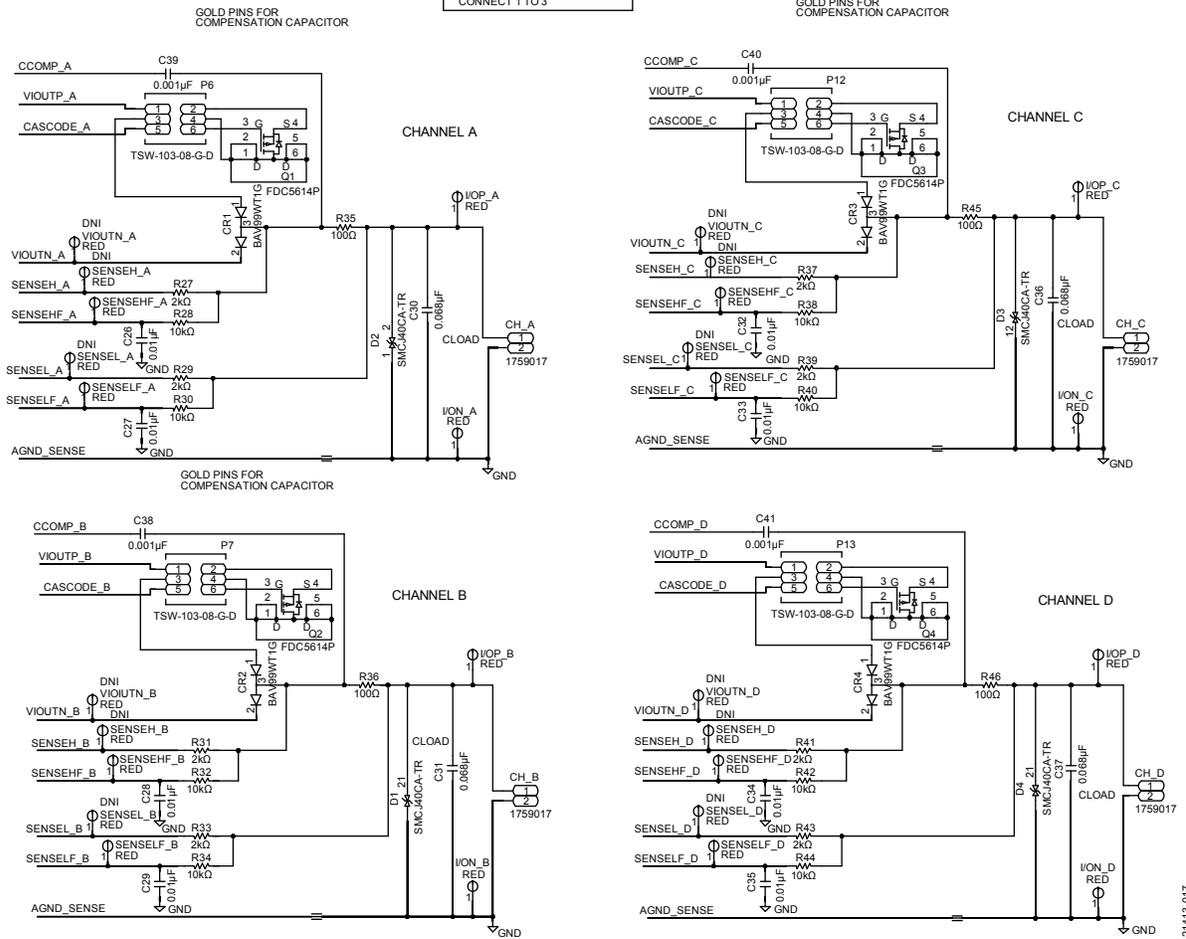
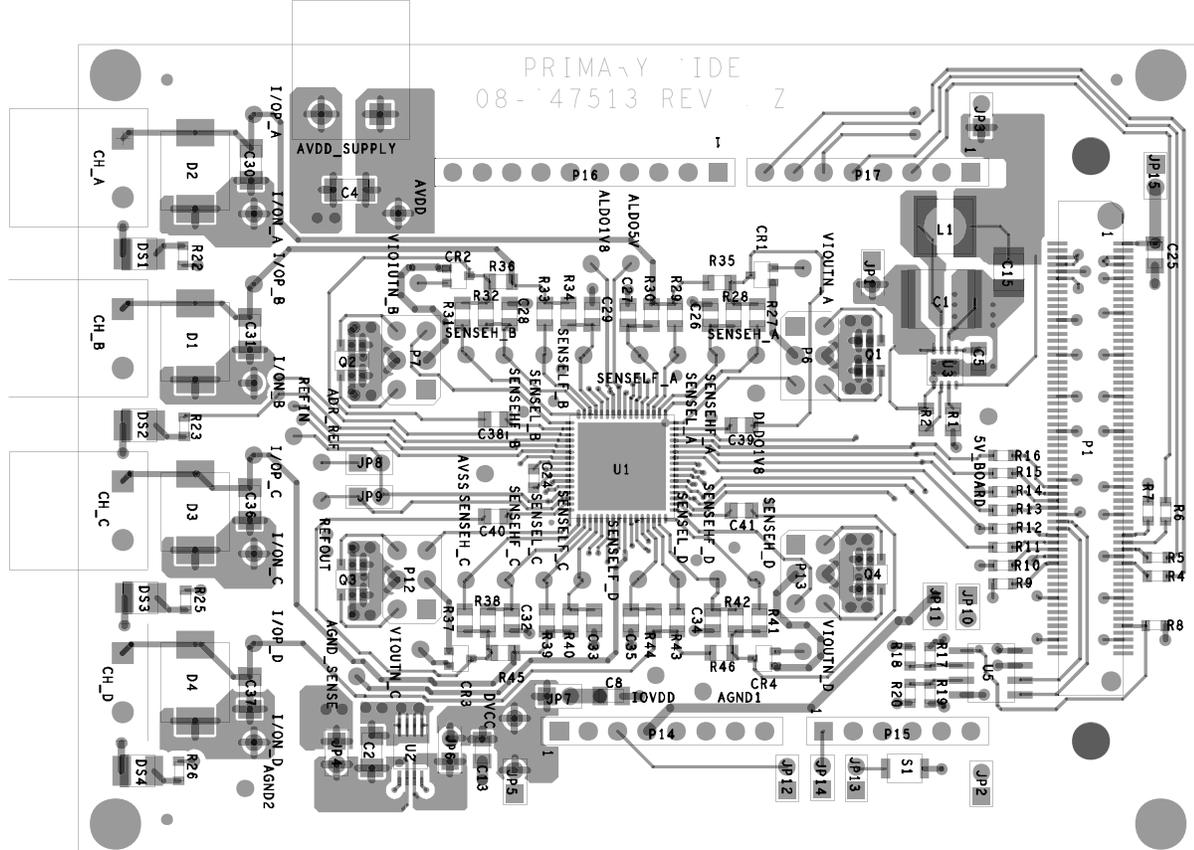


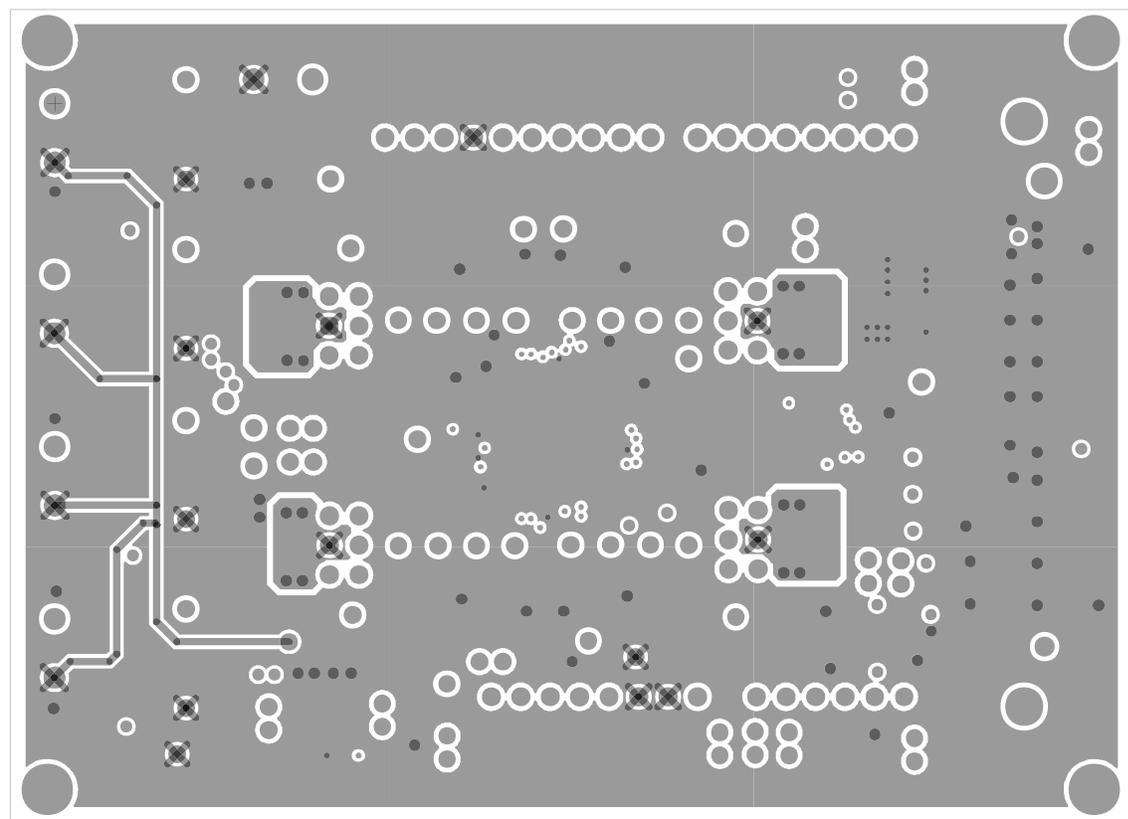
Figure 13. Channel Input/Output Circuitry Including Screw Terminals

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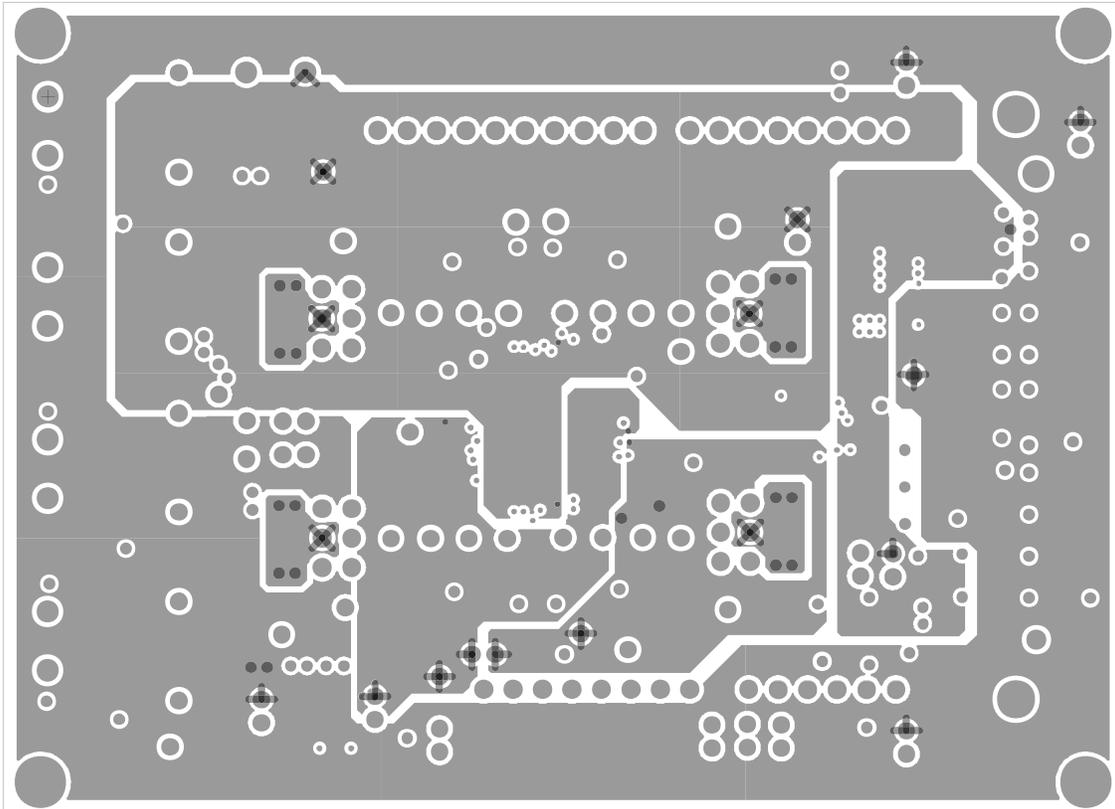
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Figure 14. Layer 1, Top Layer



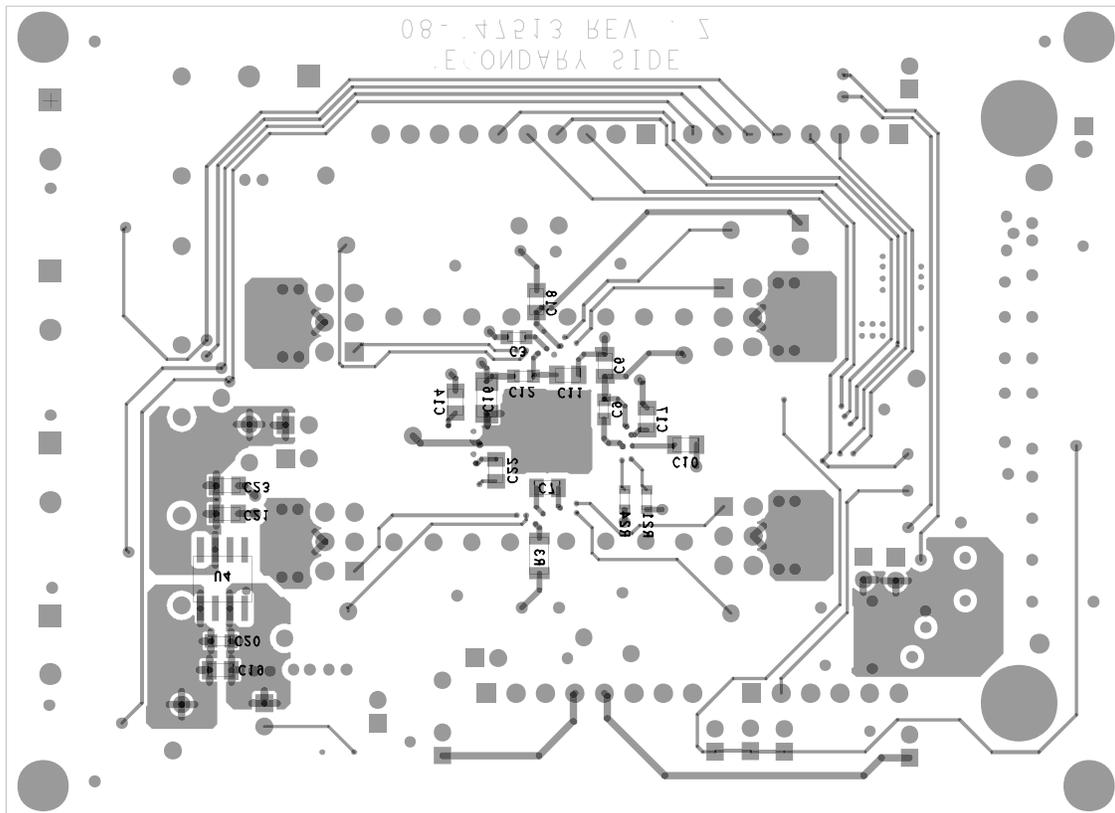
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Figure 15. Layer 2, Ground Layer



21413-014

Figure 16. Layer 3, Power Layer



21413-015

Figure 17. Layer 4, Bottom Layer

## ORDERING INFORMATION

## BILL OF MATERIALS

Table 3.

Qty	Reference Designator	Description	Manufacturer	Part Number
30	5V_BOARD, ADR_REF, AGND1, AGND2, AGND_SENSE, ALDO1V8, ALDO5V, AVDD, AVSS, DLDO1V8, DVCC, I/ON_A, I/ON_B, I/ON_C, I/ON_D, I/OP_A, I/OP_B, I/OP_C, I/OP_D, IOVDD, REFIN, REFOUT, SENSEHF_A, SENSEHF_B, SENSEHF_C, SENSEHF_D, SENSELF_A, SENSELF_B, SENSELF_C, SENSELF_D	Red test points	Vero Technologies	20-313137
5	AVDD_SUPPLY, CH_A, CH_B, CH_C, CH_D	Printed circuit board (PCB) connectors, 2-position header	Phoenix Contact	1759017
1	C1	10 $\mu$ F capacitor	TDK	C5750X7S2A106M230KB
7	C7, C10, C14, C17, C18, C22, C25	0.1 $\mu$ F capacitors	AVX Corporation	08055C104K4T4A
2	C6, C11	2.2 $\mu$ F capacitors	YAGEO	CC0805KKX7R6BB225
4	C3, C9, C12, C20	0.1 $\mu$ F capacitors	Dielectric Labs	P62BN820MA2636
2	C8, C13	10 $\mu$ F capacitors	Murata	GRM21BR61C106KE15L
1	C15	10 $\mu$ F capacitor	Murata	GRM32ER71H106KA12L
3	C2, C4, C16	10 $\mu$ F capacitors	Samsung	CL31B106KBHNNNE
3	C19, C21, C23	1 $\mu$ F capacitors	Murata	GCM21BR71E105KA56L
1	C24	0.33 $\mu$ F capacitor	AVX	0603YD334KAT2A
9	C5, C26, C27, C28, C29, C32, C33, C34, C35	0.01 $\mu$ F capacitors	Murata	GRM2195C1H103JA01D
4	C30, C31, C36, C37	0.068 $\mu$ F capacitors	TDK	C3216C0G1H683J
4	C38, C39, C40, C41	0.001 $\mu$ F capacitors	Panasonic	ECH-U1H102JX5
4	CR1, CR2, CR3, CR4	Screw terminal isolation diodes	ON Semiconductor	BAV99WT1G
4	D1, D2, D3, D4	Transient voltage suppressors (TVSs)	ST Microelectronics	SMCJ40CA-TR
4	DS1, DS2, DS3, DS4	Red light emitting diodes (LEDs)	VISHAY	VLMS30J1L2-GS08
15	JP1, JP2, JP3, JP4, JP5, JP6, JP7, JP8, JP9, JP10, JP11, JP12, JP13, JP14, JP15	2-pin jumpers	HARWIN	M22-2010205
1	L1	100 $\mu$ H inductor	Wurth Elektronik Group	744043101
1	P1	120-pin connector	HRS	FX8-120S-SV(21)
4	P6, P7, P12, P13	6-pin jumpers	SAMTEC	TSW-103-08-G-D
2	P14, P17	8-pin connectors	SAMTEC	SSQ-108-03-G-S
1	P15	6-pin connector	SAMTEC	SSQ-106-03-G-S
1	P16	10-pin connector	SAMTEC	SSQ-110-03-G-S
4	Q1, Q2, Q3, Q4	Power metal-oxide semiconductor field effect transistors (MOSFETs)	Fairchild Semiconductor	FDC5614P
1	R1	0 $\Omega$ resistor	Panasonic	ERJ-6GEY0R00V
12	R4, R5, R6, R7, R9, R10, R11, R12, R13, R14, R15, R16	0 $\Omega$ resistors	Multicomp (SPC)	MC0603WG00000T5E-TC
3	R8, R18, R19	100 k $\Omega$ resistors	Multicomp (SPC)	MC 0.063W 0603 1% 100K
1	R2	22 m $\Omega$ resistor	Stackpole Electronics, INC.	RMCF 1/10 22M 5% R
2	R21, R24	10 k $\Omega$ resistors	Panasonic	ERJ-3EKF1002V
4	R22, R23, R25, R26	1 k $\Omega$ resistors	Panasonic	ERJ-3EKF1001V
4	R27, R31, R37, R41	2 k $\Omega$ resistors	TE Connectivity	RN73C2A2K0BTG
8	R28, R30, R32, R34, R38, R40, R42, R44	10 k $\Omega$ resistors	Panasonic	ERJ-6ENF1002V
4	R29, R33, R39, R43	2 k $\Omega$ resistors	Panasonic	ERJ-6ENF2001V
1	R3	0 $\Omega$ resistor	Panasonic	ERJ-8GEY0R00V
4	R35, R36, R45, R46	100 $\Omega$ resistors	YAGEO	RT0805BRB07100RL
1	S1	Switch	OMRON	B3U-1000P

Qty	Reference Designator	Description	Manufacturer	Part Number
1	U1	Software configurable input/output	Analog Devices	AD74412RBCPZ
1	U2	3.3 V Regulator	Analog Devices	ADP1720ARMZ-3.3-R7
1	U3	Buck regulator	Analog Devices	ADP2360ACPZ-5.0-R7
1	U4	External reference	Analog Devices	ADR4525BRZ
1	U5	I <sup>2</sup> C serial electrically erasable programmable read-only memory (EEPROM)	Microchip Technology	24LC32A/SN
5	Not applicable	Terminal plug	Phoenix Contact	1757019

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 NON-INFRINGEMENT 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.

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