

Evaluation Board for the **AD7091R** Analog-to-Digital Converter

FEATURES

- Full-featured evaluation board for the **AD7091R**
- On-board power supplies
- Standalone capability
- PC control in conjunction with system demonstration platform (**EVAL-SDP-CB1Z**)
- PC software for control and data analysis

EVAL-AD7091RSDZ CONTENTS

- Evaluation board hardware
- Evaluation software CD for the **AD7091R**
- Mains power supply adapter

ADDITIONAL EQUIPMENT NEEDED

- System demonstration platform (**EVAL-SDP-CB1Z**) when using evaluation software
- Signal source

EVALUATION BOARD DESCRIPTION

The **EVAL-AD7091RSDZ** is a full-featured evaluation board designed to allow the user to easily evaluate all features of the **AD7091R** analog-to-digital converter. The evaluation board can be controlled via the SDP connector (J4). The SDP board allows the evaluation board to be controlled through the USB port of a PC using the **EVAL-AD7091RSDZ** software.

On-board components include: the **AD8031** high speed precision rail-to-rail op amp, the **AD8032** high speed precision rail-to-rail dual op amp, and the **ADP3303** high accuracy 200 mA low dropout linear regulator.

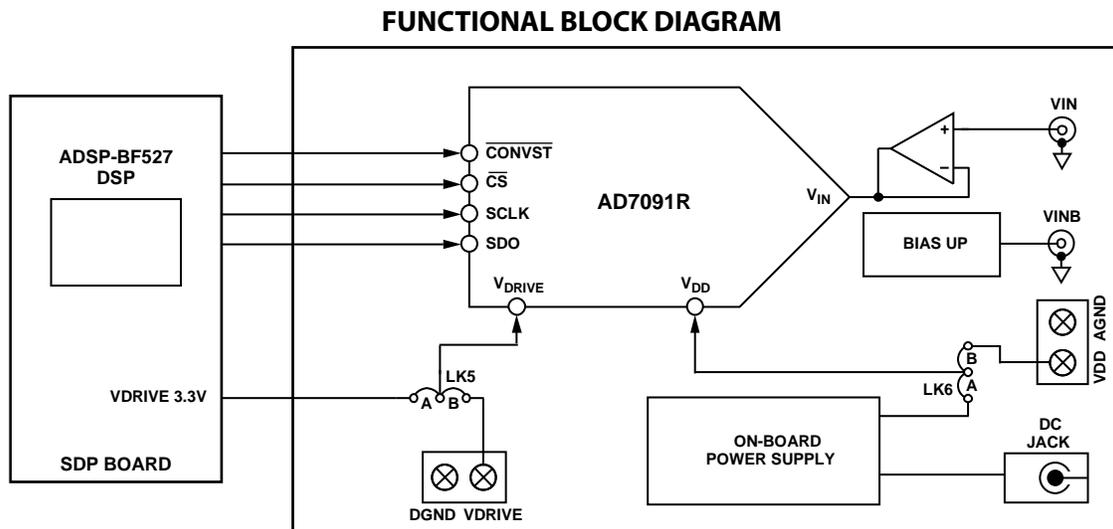


Figure 1. EVAL-AD7091RSDZ Block Diagram

10702-001

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REVISION HISTORY

8/12—Revision 0: Initial Version

EVAL-AD7091RSDZ QUICK START GUIDE

Follow these steps to quickly evaluate the [AD7091R](#):

1. Install the [EVAL-AD7091RSDZ](#) software from the enclosed CD. Ensure that the [EVAL-SDP-CB1Z](#) board is disconnected from the USB port of the PC while installing the software. The PC may need to be restarted after the installation.
2. Ensure that the default link options are configured as outlined in Table 2.
3. Connect the [EVAL-SDP-CB1Z](#) board to the [EVAL-AD7091RSDZ](#) board as shown in Figure 2.
4. Screw the two boards together with the enclosed nylon screw/nut set to ensure that the boards connect firmly together.
5. Connect the power supply adapter included in the kit to Connector J1 on the [EVAL-AD7091RSDZ](#) board.
6. Connect the [EVAL-SDP-CB1Z](#) board to the PC via the USB cable. For Windows® XP, you may need to search for the [EVAL-SDP-CB1Z](#) drivers. Choose to automatically search for the drivers for the [EVAL-SDP-CB1Z](#) board if prompted by the operating system.
7. Launch the [AD7091R](#) software from the **Analog Devices** subfolder in the **Programs** menu.
8. Connect a bipolar input signal via the VINB connector, J6.
9. Remove LK4.

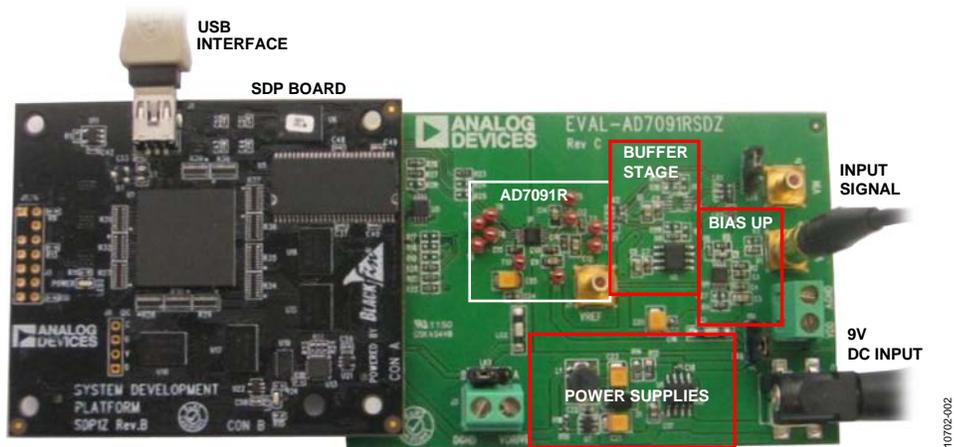


Figure 2. Hardware Configuration—Setting Up the [EVAL-AD7091RSDZ](#)

EVALUATION BOARD HARDWARE

DEVICE DESCRIPTION

This user guide describes the evaluation board for the [AD7091R](#) analog-to-digital converter.

The [AD7091R](#) is a 12-bit, ultralow power, successive approximation ADC. The [AD7091R](#) operates from a single 2.7 V to 5.25 V power supply and is capable of achieving a throughput rate of 1 MSPS. The [AD7091R](#) also features an on-chip conversion clock, an accurate reference, and a high speed serial interface.

The conversion process and data acquisition are controlled using a CONVST signal and an internal oscillator. The [AD7091R](#) has a serial interface allowing data to be read after the conversion, while achieving 1 MSPS throughput rate. The [AD7091R](#) uses advanced design and process techniques to achieve ultralow power dissipation at high throughput rates. An on-chip, accurate 2.5 V reference is available.

Complete specifications for the [AD7091R](#) are provided in the [AD7091R](#) data sheet, available from Analog Devices, which should be consulted in conjunction with this user guide when using the evaluation board.

Full details on the [EVAL-SDP-CB1Z](#) are available at <http://www.analog.com/EVAL-SDP-CB1Z>.

HARDWARE LINK OPTIONS

The functions of the link options are described in Table 2. The default setup is configured to operate the board with the mains power supply adapter and to interface to the [EVAL-SDP-CB1Z](#) board.

POWER SUPPLIES

Care should be taken before applying power and signals to the evaluation board to ensure that all link positions are set according to the required operating mode. See Table 2 for the complete list of link options.

This evaluation board is supplied with a wall-mountable switching power supply that provides a 9 V dc output. Connect the supply to a 100 V to 240 V ac wall outlet at 50 Hz to 60 Hz.

The output from the supply is provided through a 2.0 mm inner diameter jack that connects to the evaluation board at J1. The 9 V supply is connected to the on-board 5 V linear regulator that supplies the correct bias to each of the various sections on the board and the [EVAL-SDP-CB1Z](#) board.

When using this evaluation board with the [EVAL-SDP-CB1Z](#) board, it is necessary to power the board through the J1 connector.

If the evaluation board is used without the 9 V adapter, an external power supply in the range of 2.7 V to 5.25 V must be connected to the VDD input to supply the [AD7091R](#) V_{DD} pin. In addition, an external supply in the range of 1.65 V to 5.25 V must be connected to the VDRIVE input to supply the [AD7091R](#) V_{DRIVE} pin.

Each supply is decoupled on this board using 10 μ F tantalum and 100 nF multilayer ceramic capacitors.

There are two main ground planes, AGND and DGND. These are connected at one location close to the [AD7091R](#).

Caution

When the [EVAL-AD7091RSDZ](#) evaluation board is connected to the [EVAL-SDP-CB1Z](#), care must be taken to ensure that, if an external voltage is supplied to the VDRIVE input connector, J3, the voltage does not exceed 3.3 V. Otherwise, permanent damage may occur to the [EVAL-SDP-CB1Z](#) board.

Table 1. External Power Supplies Required

Power Supply	Voltage Range	Purpose
DC Jack	9V \pm 5%	Supplies power to on-board power management devices
VDD	2.7 V to 5.25 V	Analog supply rail
VDRIVE	1.65 V to 5.25 V	Digital supply rail without EVAL-SDP-CB1Z connected
	3.3 V \pm 5%	Digital supply rail with EVAL-SDP-CB1Z connected

Table 2. Link Options

Category	Link	Default Position	Function
Buffer Settings	LK1	A	This link is used to select the analog signal path. In Position A, the analog signal is buffered via U2, a unity gain buffer. In Position B, the analog signal is buffered via U3, a unity gain buffer. In Position C, the analog signal bypasses U2 and U3.
	LK2	A	This link is used to select the source of the analog input signal to the AD7091R . In Position A, the analog signal is sourced via the U2 op amp. In Position B, the analog signal is sourced via the U3 op amp. In Position C, the analog signal bypasses U2 and U3.
	LK3	Fitted	This resistor link option is used to select a biased signal as the analog input signal. Fitted—bias up circuit connected to the signal path. Not fitted—bias up circuit disconnected from the signal path.
Termination	LK4	Inserted	Adds a 51 Ω termination resistor to AGND at VIN. Inserted—51 Ω termination on the VIN input. Not inserted—no 51 Ω termination on the VIN input.
Power Supplies	LK5	A	This link is used to select the source of the VDRIVE supply for the AD7091R . In Position A, the VDRIVE supply is sourced externally via the J3 connector. In Position B, the VDRIVE supply is sourced from the EVAL-SDP-CB1Z via the J4 connector.
	LK6	A	This link is used to select the source of the VDD supply for the AD7091R and on-board buffers. In Position A, the VDD supply is sourced internally from the on-board power supplies. In Position B, the VDD supply is sourced externally via the J2 connector.

SOCKETS/CONNECTORS

The connectors and sockets on the [EVAL-AD7091RSDZ](#) are as outlined in Table 3.

Table 3. On-Board Connectors

Connector	Function
J1	9 V, 2.0 mm dc jack connector
J2	External VDD and AGND power connector
J3	External VDRIVE and DGND power connector
J4	120-way connector for EVAL-SDP-CB1Z interface
J5	VIN analog input signal
J6	VINB analog input signal to bias up circuit
J7	External reference voltage connector

The default interface to this evaluation board is via the 120-way connector, which connects the [EVAL-AD7091RSDZ](#) to the [EVAL-SDP-CB1Z](#) board.

TEST POINTS

There are numerous test points on the [EVAL-AD7091RSDZ](#) board. These test points enable the user to have easy access to the signals from the evaluation board for probing, evaluation, and debugging.

It is also possible to access the [AD7091R](#) via the test points to operate the [EVAL-AD7091RSDZ](#) in standalone mode without the need for the [EVAL-SDP-CB1Z](#) board.

EVAL-AD7091RSDZ BASIC HARDWARE SETUP

The EVAL-AD7091RSDZ board connects to the EVAL-SDP-CB1Z system demonstration platform board. The EVAL-SDP-CB1Z board is the controller board, which is the communication link between the PC and the main evaluation board. Figure 2 shows a photograph of the connections between the EVAL-AD7091RSDZ daughter board and the EVAL-SDP-CB1Z board.

The analog input range to the AD7091R is 0 V to V_{REF} and should not be exceeded. When using the on-chip reference, V_{REF} is 2.5 V. An input signal in the range of 2.5 V p-p should be connected to the EVAL-AD7091RSDZ board via VIN or VINB.

A bipolar input signal should be connected to VINB, the J6 connector. This signal is biased to 1.25 V via the bias up circuitry on the EVAL-AD7091RSDZ. The signal source should be a low impedance source. An on-board unity gain amplifier buffers the signal to the AD7091R. This is the default configuration on the EVAL-AD7091RSDZ.

A unipolar input signal should be connected to VIN, the J5 connector. An on-board unity gain amplifier buffers the signal to the AD7091R.

Before connecting power, connect the EVAL-AD7091RSDZ board to Connector A on the EVAL-SDP-CB1Z board. A nylon screw/nut set is included in the EVAL-AD7091RSDZ kit and can

be used to ensure that the EVAL-AD7091RSDZ and EVAL-SDP-CB1Z boards are connected firmly together.

Ensure that the link options are in the default positions as outlined in Table 2.

After the EVAL-AD7091RSDZ board and the EVAL-SDP-CB1Z board are connected securely, connect the power to the EVAL-AD7091RSDZ board. The EVAL-AD7091RSDZ board requires an external power supply adapter, which is included in the evaluation board kit. Connect this power supply to Connector J1 on the EVAL-AD7091RSDZ board. For further details on the required power supply connections and options, see the Power Supplies section.

Before connecting the EVAL-SDP-CB1Z board to your PC, ensure that the EVAL-AD7091RSDZ software has been installed from the enclosed CD. The full software installation procedure is detailed in the Evaluation Board Software section.

Finally, connect the EVAL-SDP-CB1Z board to the PC via the USB cable enclosed in the EVAL-SDP-CB1Z kit. If using a Windows XP platform, you may need to search for the EVAL-SDP-CB1Z drivers. Choose to automatically search for the drivers for the EVAL-SDP-CB1Z board if prompted by the operating system.

EVALUATION BOARD SOFTWARE SOFTWARE INSTALLATION

The [EVAL-AD7091RSDZ](#) kit includes software on a CD. Double-click the **setup.exe** file from the CD to run the install. The default location for the software is

C:\Program Files\Analog Devices\AD7091R\

Install the evaluation software before connecting the evaluation board and the [EVAL-SDP-CB1Z](#) board to the USB port of the PC to ensure that the evaluation system is correctly recognized when connected to the PC.

There are two parts to the installation:

- [EVAL-AD7091RSDZ](#) board software installation
- [EVAL-SDP-CB1Z](#) system demonstration platform board drivers installation

Follow Step 1 to Step 4 (see Figure 3 to Figure 6) to install the [EVAL-AD7091RSDZ](#) software. Follow Step 5 to Step 8 (see Figure 7 to Figure 10) to install the [EVAL-SDP-CB1Z](#) drivers. Proceed through all of the installation steps, allowing the software and drivers to be placed in the appropriate locations. Connect the [EVAL-SDP-CB1Z](#) board to the PC only after the software and drivers have been installed.



Figure 3. [EVAL-AD7091RSDZ](#) Installation—User Account Control

1. Click **Yes** to begin the installation process.

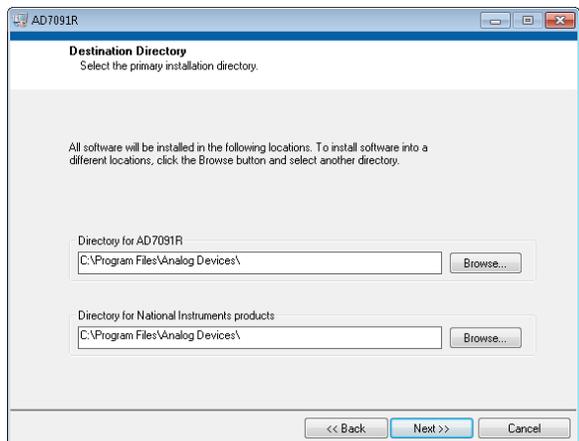


Figure 4. [EVAL-AD7091RSDZ](#) Installation—Destination Directory

2. Select the installation directory. Click **Next**.

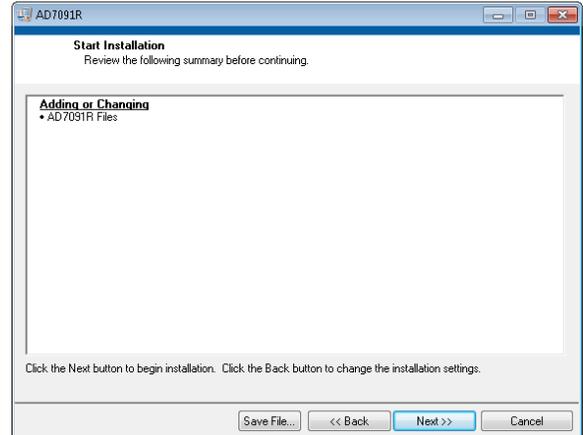


Figure 5. [EVAL-AD7091RSDZ](#) Installation—Start Installation

3. Click **Next** to install the software.

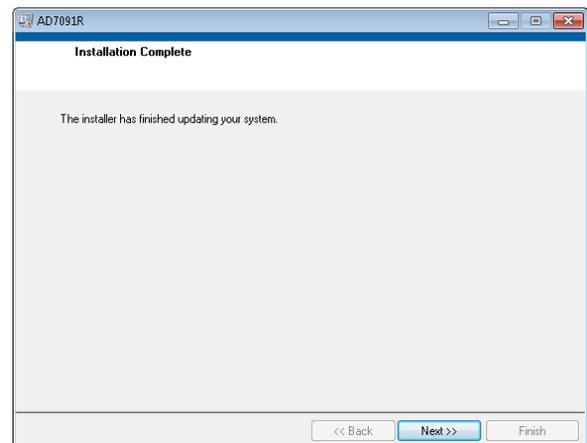


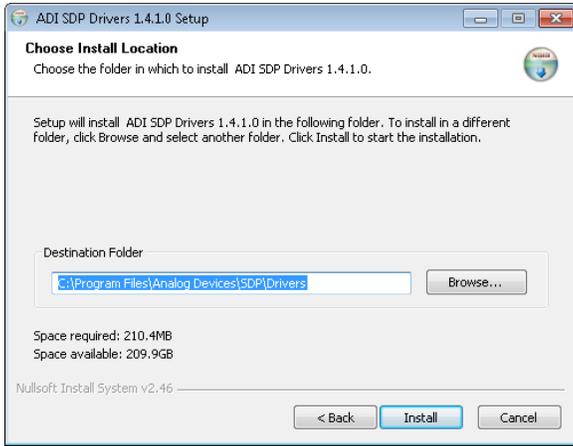
Figure 6. [EVAL-AD7091RSDZ](#) Installation—Installation Complete

4. The installation of the evaluation software completes. Click **Next** to proceed with the installation of the drivers.



Figure 7. [EVAL-SDP-CB1Z](#) Drivers Installation—Setup Wizard

5. The setup wizard opens. Click **Next** to begin the driver installation process.



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Figure 8. EVAL-SDP-CB1Z Drivers Installation—Choose Install Location

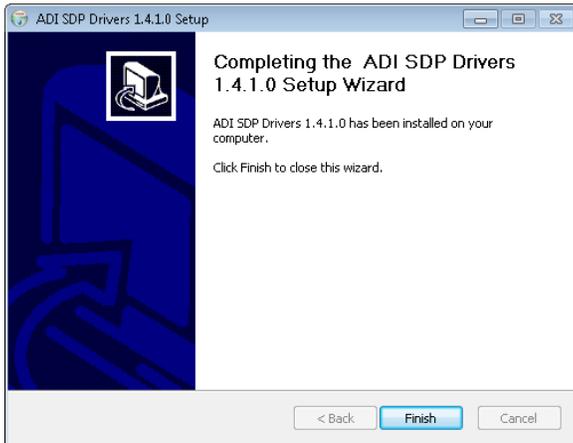
6. Select a destination folder for the SDP drivers, and click **Install**.



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Figure 9. EVAL-SDP-CB1Z Drivers Installation—Windows Security

7. Click **Install** to proceed with the installation.



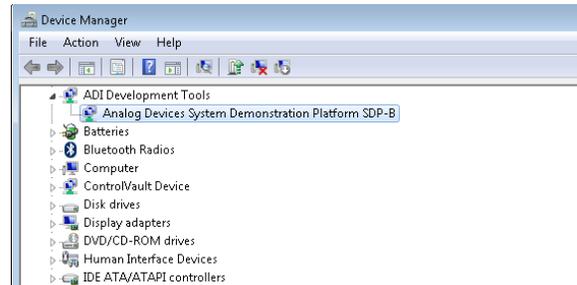
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Figure 10. EVAL-SDP-CB1Z Drivers Installation—Complete

8. Click **Finish**.

After installation from the CD is complete, connect the EVAL-AD7091RSDZ board to the EVAL-SDP-CB1Z board as described in the Evaluation Board Hardware section.

When you first plug in the EVAL-SDP-CB1Z board via the USB cable provided, allow the **Found Hardware Wizard** to run. After the drivers are installed, you can check that the board is connected correctly by looking at the **Device Manager** of the PC. The **Device Manager** can be found by right-clicking **My Computer > Manage > Device Manager** from the list of **System Tools**, as shown in Figure 11. The EVAL-SDP-CB1Z SDP-B board should appear under **ADI Development Tools**. This completes the installation.



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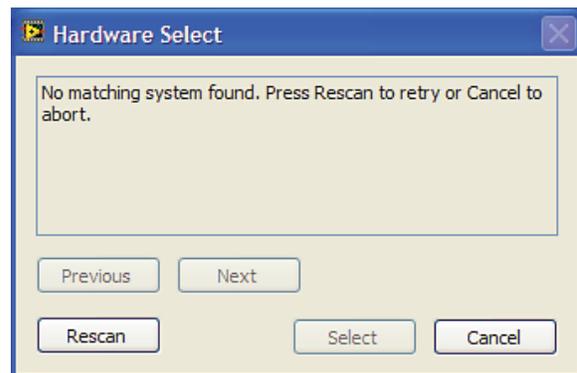
Figure 11. Device Manager

LAUNCHING THE SOFTWARE

After the EVAL-AD7091RSDZ and EVAL-SDP-CB1Z boards are correctly connected to your PC, the EVAL-AD7091RSDZ software can be launched.

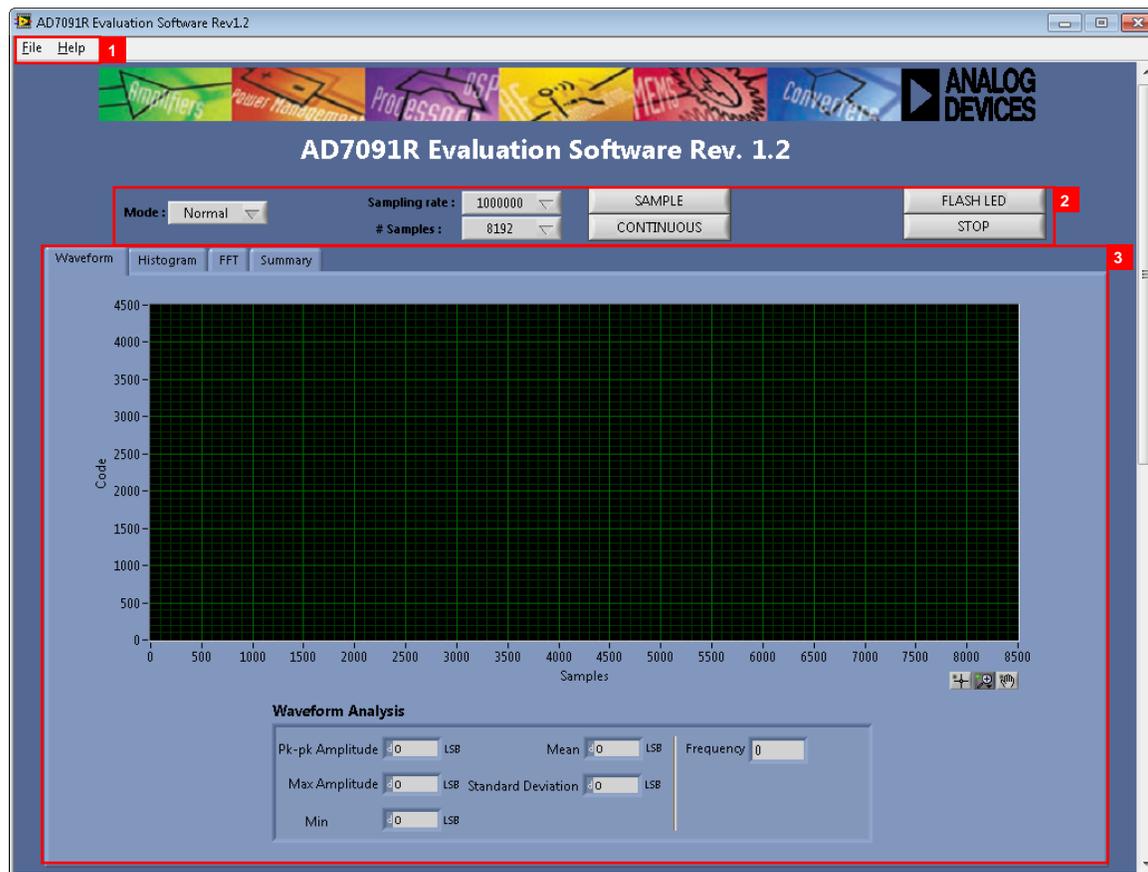
To launch the software, perform the following steps:

1. From the **Start** menu, select **Programs > Analog Devices > AD7091R**. The main window of the software then opens (see Figure 13).
2. If the EVAL-AD7091RSDZ board is not connected to the USB port via the EVAL-SDP-CB1Z when the software is launched, a connectivity error displays (see Figure 12). Connect the evaluation board to the USB port of the PC, wait a few seconds, click **Rescan**, and follow the instructions.



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Figure 12. Connectivity Error Alert



1. MENU BAR.
2. CONTROL BUTTONS.
3. DATA CAPTURE DISPLAY.

Figure 13. Evaluation Software Main Window

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DESCRIPTION OF MAIN SOFTWARE WINDOW

The following tools allow user control of the different chart displays. When the software is launched, the main software window opens (see Figure 13).

The user software panel as shown in Figure 13 has the following features:

- Menu bar
- Control buttons
- Data capture display

Menu Bar

The menu bar consists of the **File** and **Help** menus.

File Menu

Open (Sample Data). Loads previously captured data in TSV (tab separated values) format for analysis.

Save (Sample Data). Saves captured data in TSV (tab separated values) format for future analysis.

Print Front Panel Picture. Prints the software window displayed.

Save As Picture. Saves the front panel as a JPEG file.

Exit. Exits the program.

Help Menu

Open analog.com. Opens www.analog.com.

Control Buttons

The **EVAL-AD7091RSDZ** software includes the following control buttons, drop-down boxes, and indicators.

Mode. Selects the operating mode of the AD7091R. In **Normal** mode, the ADC is ready to acquire samples. In **Sleep** mode, the device enters power-down mode when the **SAMPLE** button is clicked.

Sampling rate. Selects the sampling rate of the data acquisition.

Samples. Selects the number of samples to be completed in a single acquisition.

SAMPLE. Initiates the sampling and readback of the defined number of measurements.

CONTINUOUS. Performs a continuous capture from the ADC. Click a second time to stop sampling.

FLASH LED. Causes the orange LED1A on the SDP board to flash, which can be a useful debugging tool.

STOP. Stops the program.

Data Capture Display

There are four tabs that display the conversion data in different formats: **Waveform**, **Histogram**, **FFT**, and **Summary**.

The tools shown in Figure 14 allow user control of the different chart displays.



1. USED FOR CONTROLLING THE CURSOR IF PRESENT.
2. USED FOR ZOOMING IN AND OUT.
3. USED FOR PLANNING.

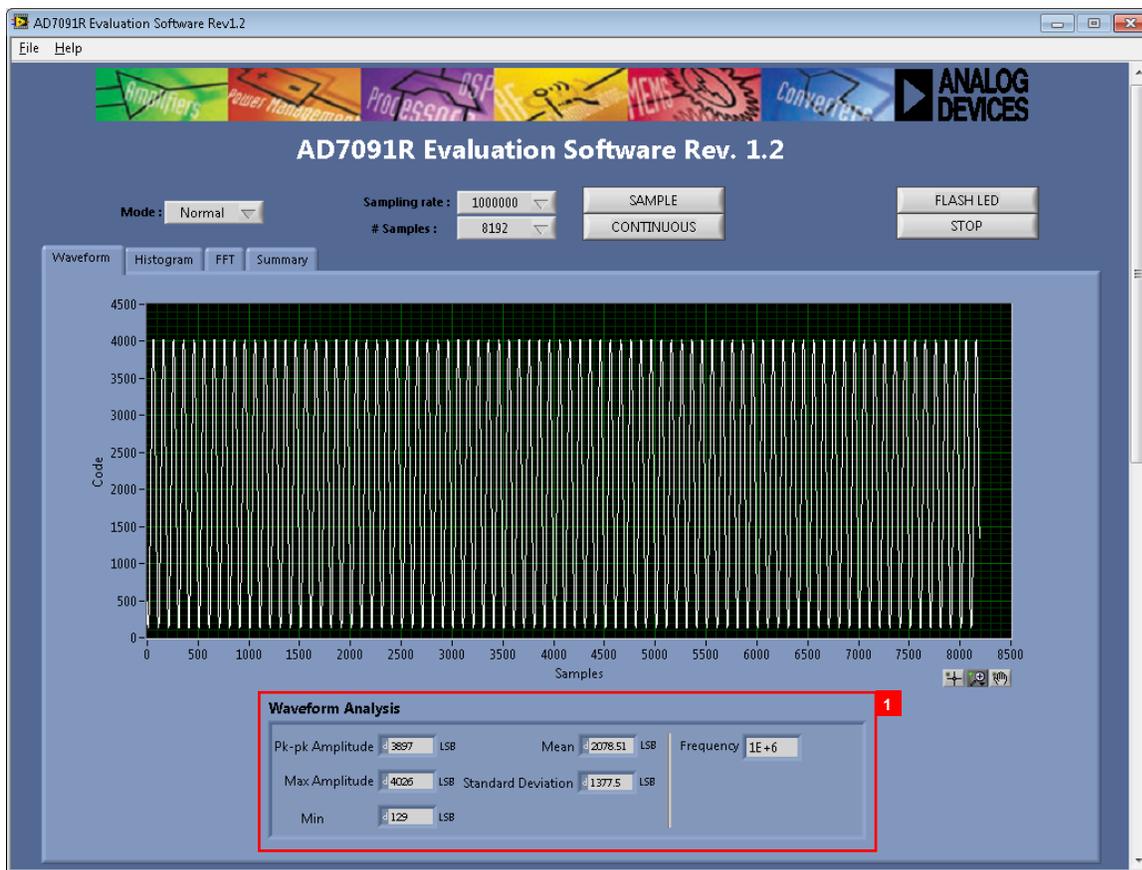
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Figure 14. Chart Tools

WAVEFORM CAPTURE

Figure 15 illustrates the waveform capture tab.

The waveform analysis reports the amplitudes recorded from the captured signal in addition to the frequency of the signal tone.



1. WAVEFORM ANALYSIS.

Figure 15. Waveform Capture Tab

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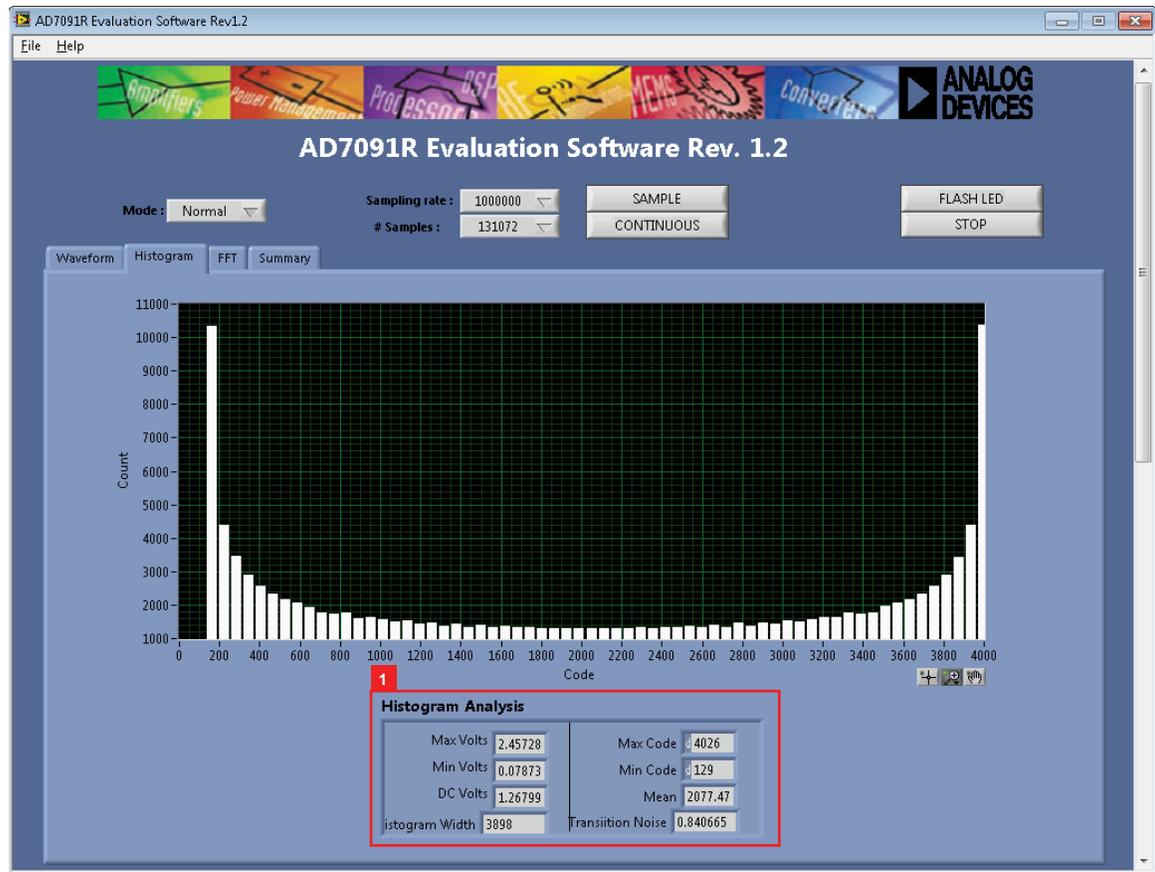


Figure 16. Histogram Capture Tab

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AC TESTING—HISTOGRAM

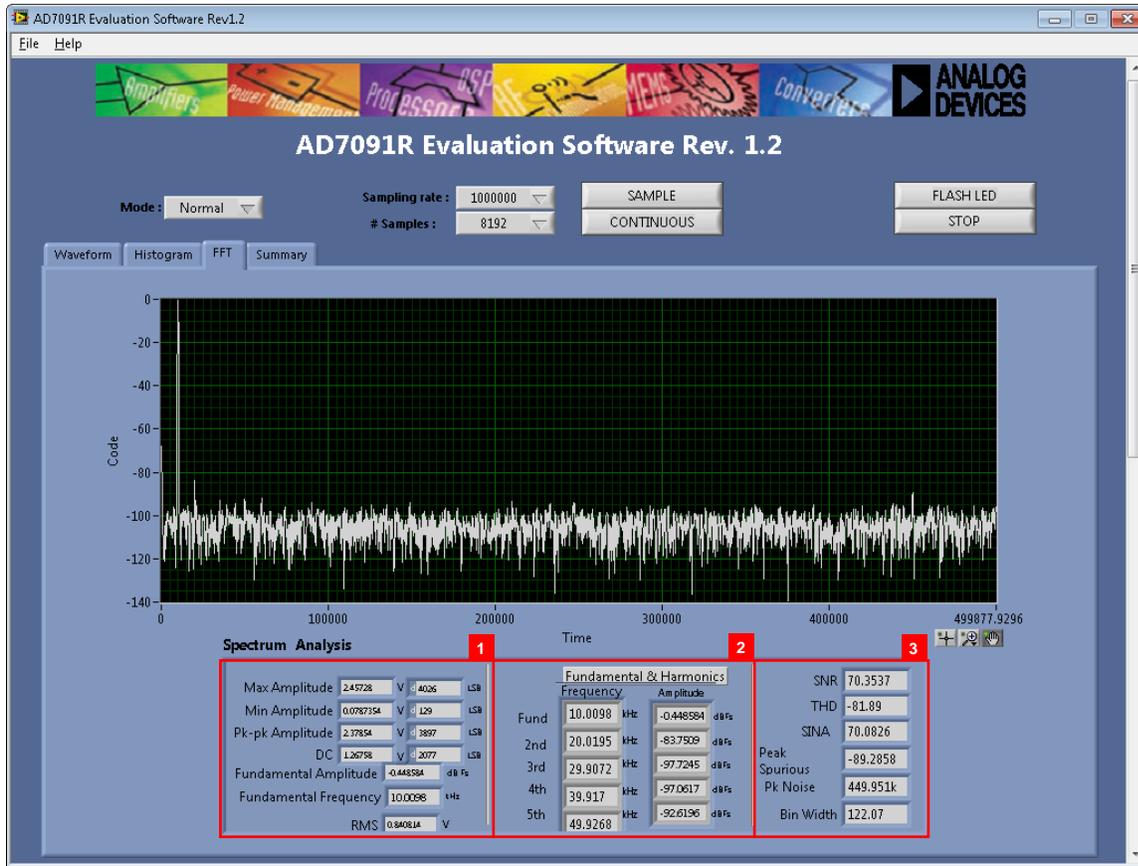
Figure 16 shows the histogram capture tab. This tests the ADC for the code distribution for the ac input and computes the mean and standard deviation, or transition noise of the converter, and displays the results.

Raw data is captured and passed to the PC for statistical computations. To perform a histogram test, select the **Histogram** tab in the evaluation software main window and click the **SAMPLE** button.

Note that an ac histogram requires a quality signal source applied to the input VIN/VINB connectors.

DC TESTING—HISTOGRAM

The histogram is more commonly used for dc testing. Similar to ac testing, this tests the ADC for the code distribution for the dc input and computes the mean and standard deviation, or transition noise of the converter, and displays the results. Raw data is captured and passed to the PC for statistical computations. To perform a histogram test, select the **Histogram** tab in the evaluation software main window and click the **SAMPLE** button.



1. INPUT SIGNAL INFORMATION.
 2. FUNDAMENTAL FREQUENCY AND AMPLITUDE.
 3. PERFORMANCE DATA.

10708-017

Figure 17. FFT Capture Tab

AC TESTING—FFT CAPTURE

Figure 17 shows the FFT capture tab. This tests the traditional ac characteristics of the converter and displays a fast Fourier transform (FFT) of the results. As in the histogram test, raw data is captured and passed to the PC where the FFT is performed, displaying SNR, SINAD, THD, and SFDR. To perform an ac test, apply a sinusoidal signal to the evaluation board at the SMB input, J5 or J6. Low distortion, better than 115 dB, is required to allow true evaluation of the part. One possibility is to filter the input signal from the ac source. There is no suggested band-pass filter but consideration should be taken in the

choice. Furthermore, if using a low frequency band-pass filter when the full-scale input range is more than a few volts peak to peak, it is recommended to use the on-board amplifiers to amplify the signal, thus preventing the filter from distorting the input signal.

Figure 17 displays the results of the captured data.

- Section 1 shows the input signal information.
- Section 2 displays the fundamental frequency and amplitude in addition to the 2nd to 5th harmonics.
- Section 3 displays the performance data: SNR, dynamic range, THD, SINAD, and noise performance.

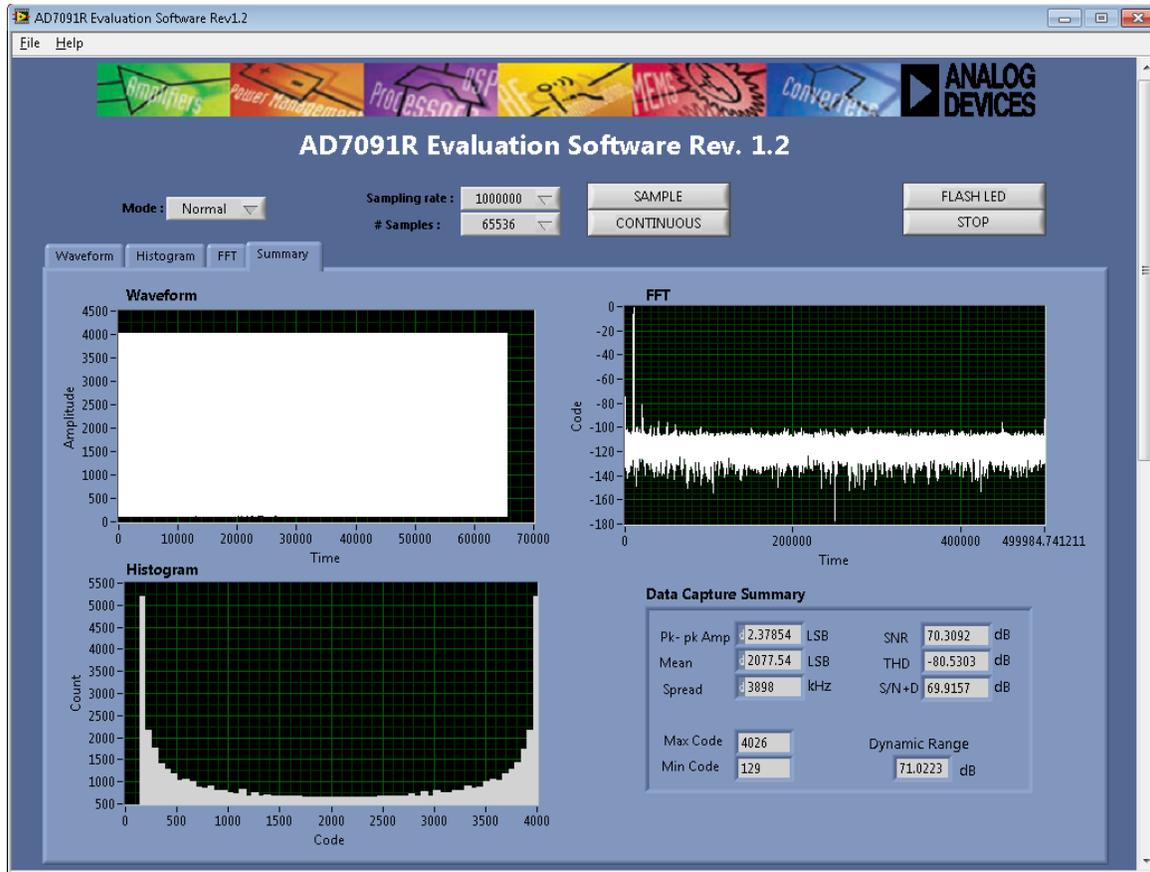


Figure 18. Summary Tab

SUMMARY TAB

Figure 18 shows the summary tab. The summary tab captures all the display information and provides them in one panel with a synopsis of the information, including key performance parameters such as SNR and THD.

SAVE FILE

The software can save the current captured data for future analysis.

Go to the **File** menu, and click **Save (Sample Data)**. The save dialog box opens. Save to an appropriate folder location.

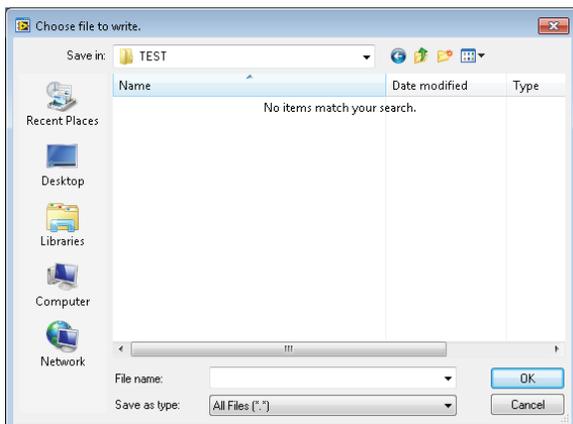


Figure 19. Save File dialog Box

OPEN FILE

The software can load captured data for analysis.

Go to the **File** menu, and click **Open (Sample Data)**. The open file dialog box opens. Load an appropriate file.

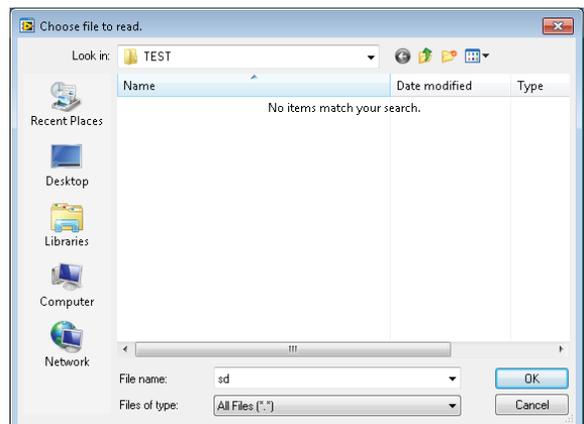


Figure 20. Open File Dialog Box

EVALUATION BOARD SCHEMATICS AND ARTWORK

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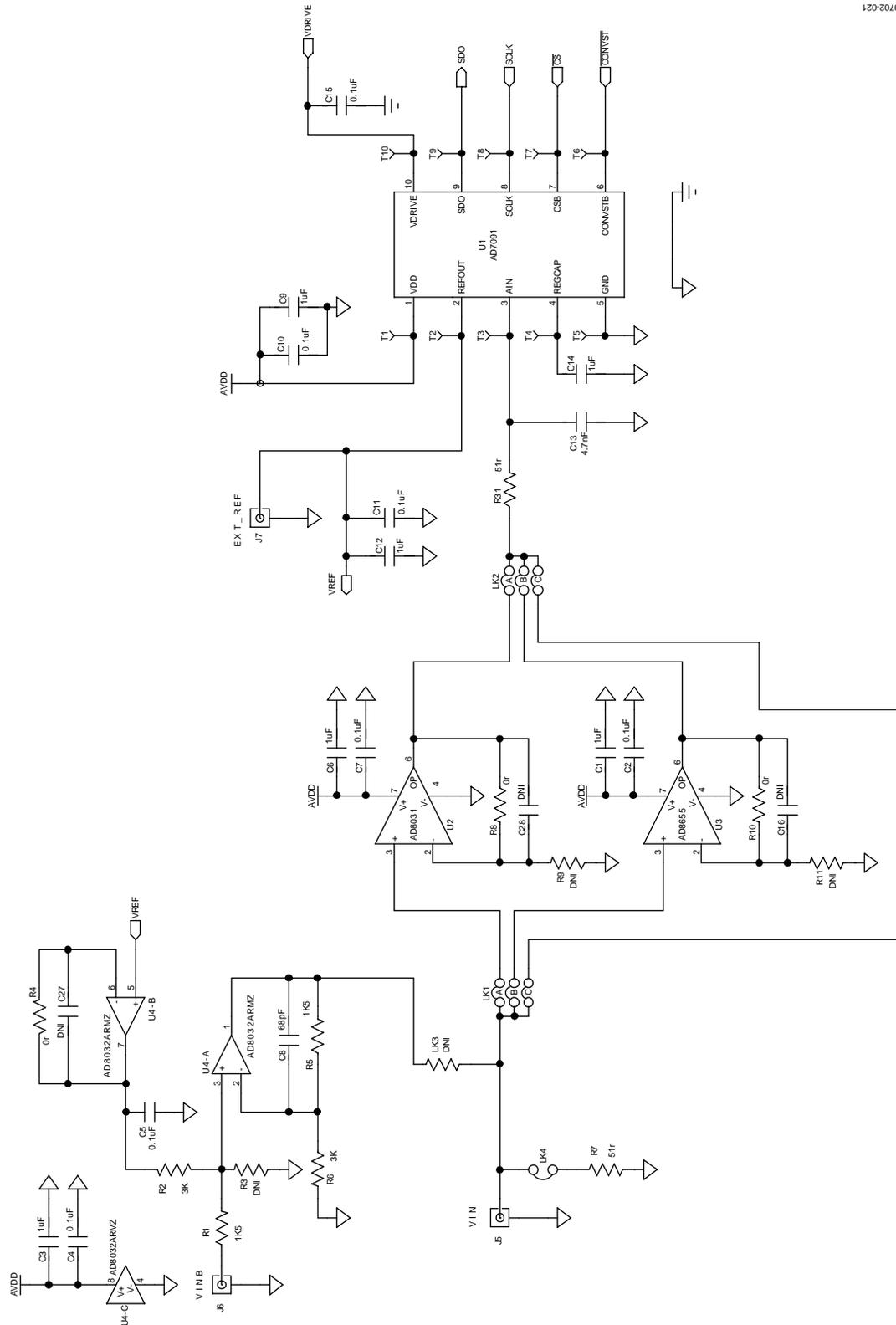


Figure 21. Schematic Page 1

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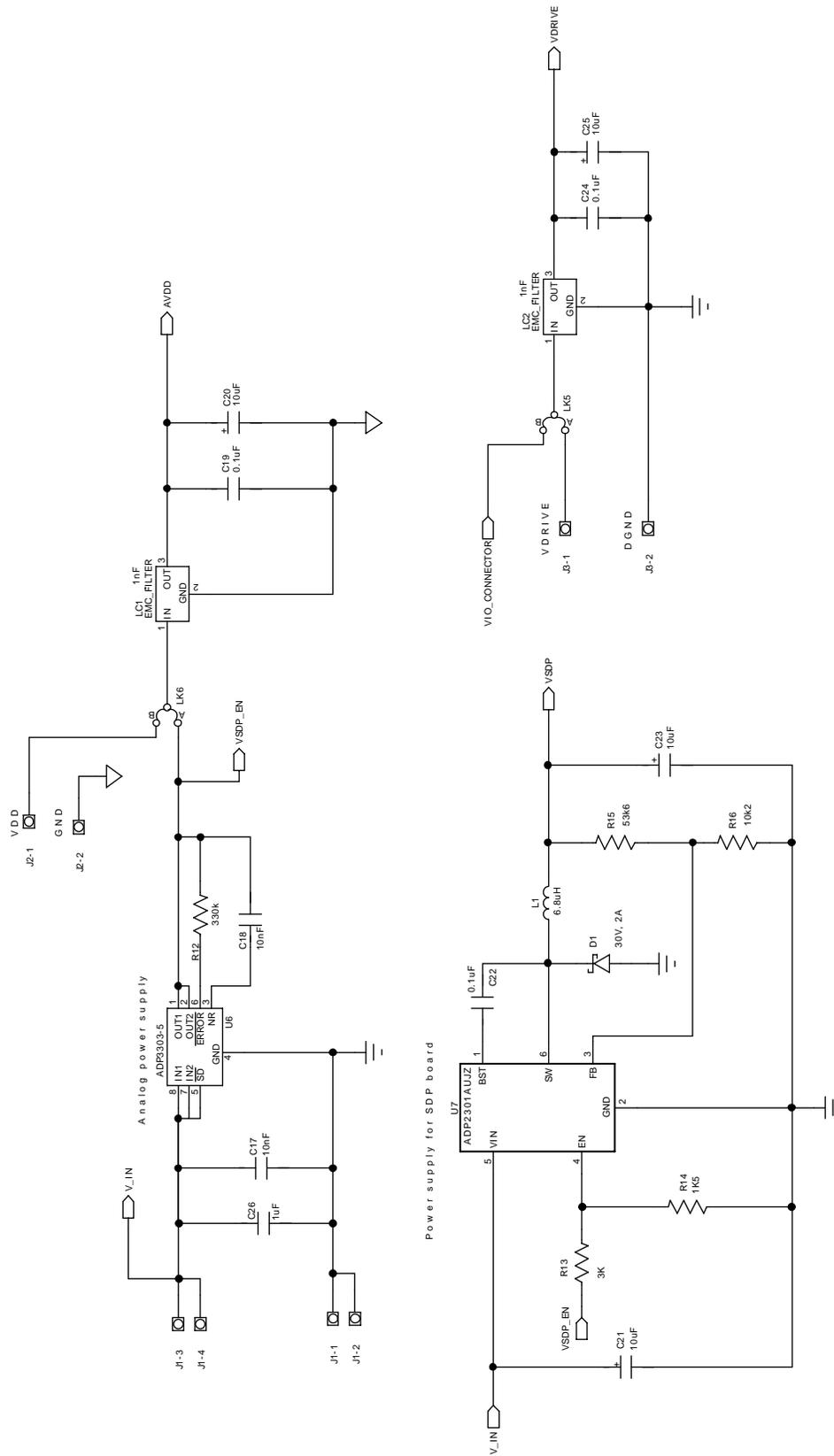


Figure 22. Schematic Page 2

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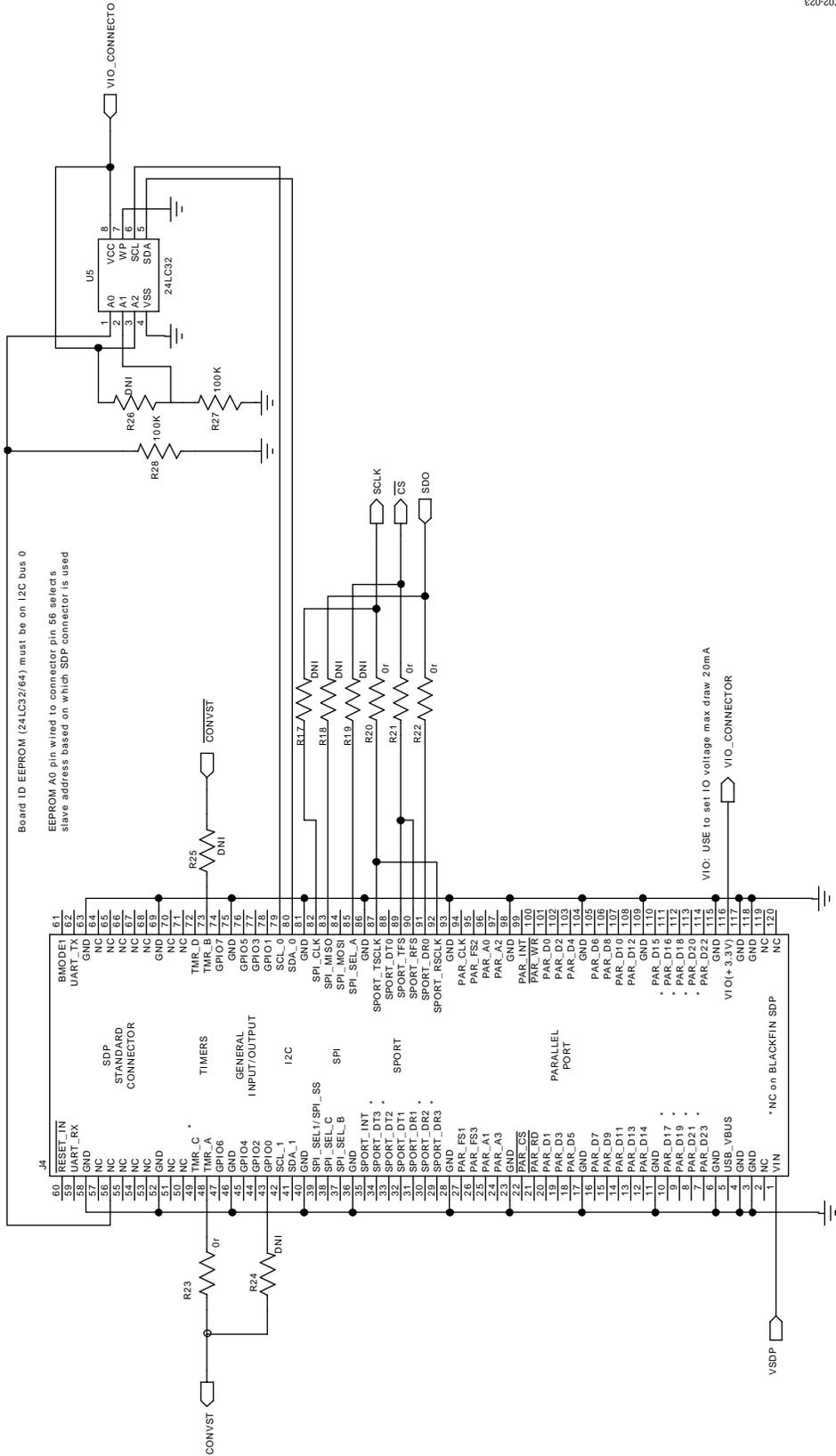
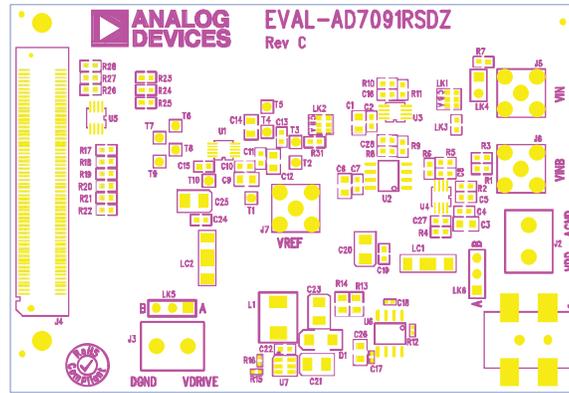
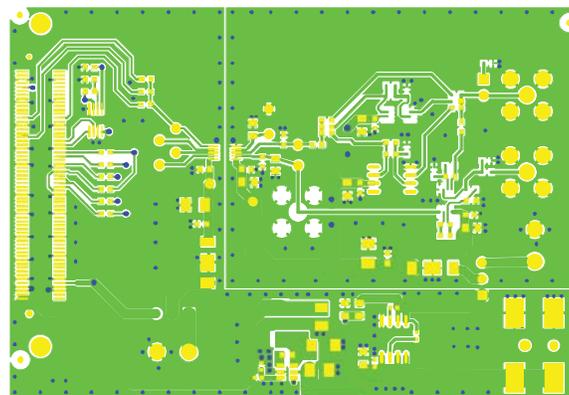


Figure 23. Schematic Page 3



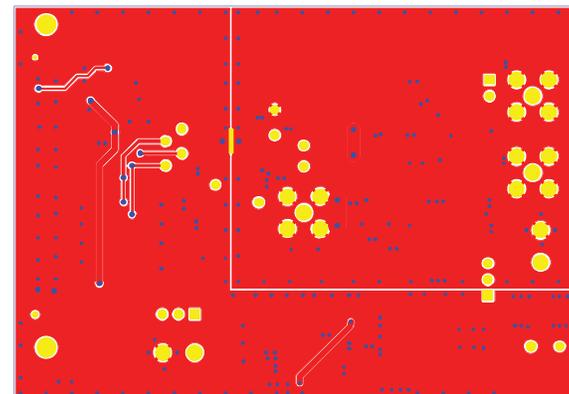
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Figure 24. EVAL-AD7091RSDZ Top-Side Silkscreen



10702-025

Figure 25. EVAL-AD7091RSDZ Top Layer



10702-026

Figure 26. EVAL-AD7091RSDZ Bottom Layer

ORDERING INFORMATION

See Table 4 for a list of the evaluation boards compatible with the hardware described in this user guide.

Table 4. Compatible Boards

Model¹	Description
EVAL-AD7091RSDZ	AD7091R evaluation board
EVAL-SDP-CB1Z	Evaluation controller board
ADZS-BRKOUT-EX3	Signal breakout board

¹ Z = RoHS-compliant part.

NOTES

NOTES

**ESD Caution**

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

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.