

## Evaluating the **ADF4401A** Translation Loop, PLL, VCO Module

### FEATURES

Evaluation board including the ADF4401A SiP with integrated VCO, loop filter (5 MHz), phase frequency detector, USB interface, and voltage regulators

PC software for control of SiP functions

Externally powered by 6 V

### EVALUATION KIT CONTENTS

EV-ADF4401ASD2Z evaluation board

### EQUIPMENT NEEDED

Windows® PC with USB port for evaluation software  
**EVAL-SDP-CS1Z (SDP-S) controller board (not provided in the EV-ADF4401ASD2Z kit)**

6 V power supply

Signal source analyzer or spectrum analyzer

Low noise REF\_PF source (50 MHz to 1 GHz)

Low noise LO source (3 GHz to 9 GHz)

REFP source (10 MHz to 500 MHz)

50 Ω terminators

### DOCUMENTS NEEDED

ADF4401A data sheet

### REQUIRED SOFTWARE

**ACE software (latest version)**

**ADF4401A ACE plugin (latest version)**

### GENERAL DESCRIPTION

The EV-ADF4401ASD2Z evaluates the performance of the ADF4401A system in package (SiP) for offset phase-locked loops (PLLs). Figure 1 shows the evaluation board photograph. The EV-ADF4401ASD2Z contains the ADF4401A integrated SiP, phase frequency detector (PFD), active loop filter, power supply connectors, and Subminiature Version A (SMA) connectors.

The EV-ADF4401ASD2Z requires an EVAL-SDP-CS1Z (SDP-S) system demonstration platform (SDP), which allows software programming of the EV-ADF4401ASD2Z.

For full details on the ADF4401A, see the ADF4401A data sheet, which must be consulted in conjunction with this user guide when using the EV-ADF4401ASD2Z.

### EVALUATION BOARD PHOTOGRAPH

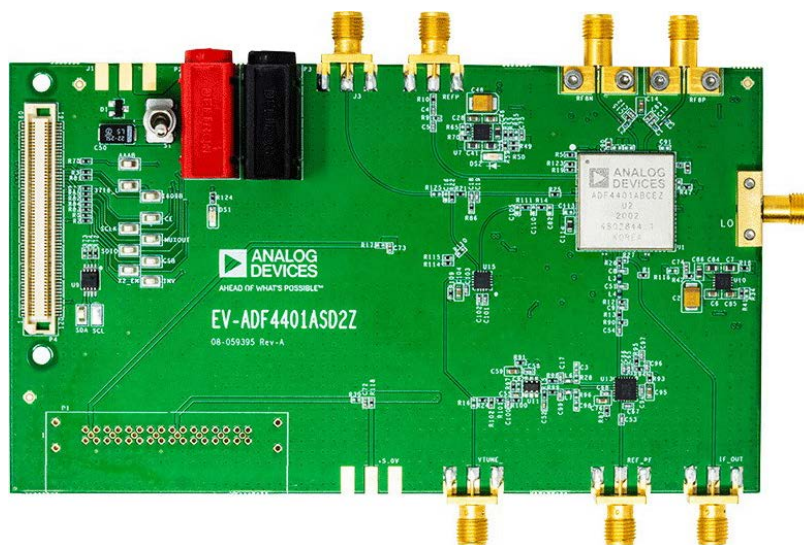


Figure 1.

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**REVISION HISTORY**

12/2020—Revision 0: Initial Version

## GETTING STARTED

### SOFTWARE INSTALLATION PROCEDURES

To install the Analysis | Control | Evaluation (ACE) software and the [ADF4401A](#) plugin, perform the following steps:

1. Download and install the latest version of the ACE software from the ACE software page.
2. Install the latest version of the ADF4401A ACE plugin from the **Available Packages** section in the **Plug-in Manager** in ACE. If the plugin is not available, proceed to Step 3. Otherwise, proceed to Step 4.
3. Download the latest ADF4401A plugin file from the EV-ADF4401ASD2Z product page to a local drive. Double click the ADF4401A plugin file to install the plugin.

4. Check that the ADF4401A plugin appears when the EV-ADF4401ASD2Z is connected to the PC via the [SDP-S](#).

### EVALUATION BOARD SETUP PROCEDURES

To run the ACE software, perform the following steps:

1. From the **Start** menu of the PC, select **All Programs > Analog Devices > ACE > ACE.exe**.
2. In the **Start** tab in ACE, select the EV-ADF4401ASD2Z icon in the **Attached Hardware** section.
3. When connecting the EV-ADF4401ASD2Z to the PC, allow 5 sec to 10 sec for ACE to detect the attached board.

## EVALUATION BOARD HARDWARE

The EV-ADF4401ASD2Z requires the [SDP-S](#) platform that uses the [EVAL-SDP-CS1Z](#). The [SDP-B](#) is not recommended.

The EV-ADF4401ASD2Z schematics are shown in Figure 8, Figure 9, Figure 10, Figure 11, and Figure 12. The silkscreens are shown in Figure 13 and Figure 14.

### POWER SUPPLIES

The EV-ADF4401ASD2Z is powered by a 6 V power supply (VSUPPLY) connected to the red banana plug, P2. Connect GND to the black banana plug, P3. A current limit of approximately 1 A is recommended.

The power supply circuitry has seven [ADM7150](#), high performance, low noise, and low dropout (LDO) regulators.

Use Switch S1 to switch the 6 V power supply to the EV-ADF4401ASD2Z on and off.

### RF OUTPUT

The EV-ADF4401ASD2Z has one pair of SMA, 3.5 mm output connectors: RF8P and RF8N. Because these ports are sensitive to impedance mismatch, connect the RF outputs to equal load impedances.

If only one port of the differential pair is used, terminate the complementary port with an equal load terminator (in general, a 50  $\Omega$  terminator).

### CALIBRATION REFERENCE SOURCE

The EV-ADF4401ASD2Z requires a dedicated reference to the calibration circuit of the voltage controlled oscillator (VCO). This calibration reference can range from 10 MHz to 500 MHz with a recommended approximate power level of 0 dBm.

Connect a reference source to the REFP SMA connector. If the reference source is not connected, the internal PFD and autocalibration of the ADF4401A VCO malfunctions.

### PHASE FREQUENCY DETECTOR

The [HMC3716](#) is used as the external PFD to complete the offset loop. The high frequency operation range and ultralow phase noise floor of the HMC3716 make it possible to design wide bandwidth loop filters.

### REFERENCE TO PHASE FREQUENCY DETECTOR

A reference frequency to the REF\_PF SMA connector equal to the IF frequency is required to lock the offset loop. A high performance reference is required to meet the achievable performance of the ADF4401A. The R&S® SMA100B with the phase noise improvement options was used to test the EV-ADF4401ASD2Z. Alternatively, a high performance direct digital synthesizer (DDS) can be used.

### LOOP FILTERS

The EV-ADF4401ASD2Z contains two loop filters: a passive three component filter, and a filter used to close the loop in offset mode.

The passive three component filter closes the internal loop and locks the correct frequency by using the internal PFD on the ADF4401A. In this configuration, the S4B input of the [ADG1609BCPZ](#) is selected to connect the internal charge pump output to the VTUNE pin.

This internal loop allows users to understand the configuration in detail and to compare the performance of the internal loop with the external offset loop. This loop filter is not needed in the normal operation and can be omitted in a design. However, a switch is required to break the connection between the VTUNE input and the external PFD output, which is essential for VCO calibration.

Another filter is used to close the loop in offset mode. A differential loop filter with an [LT6200](#) op amp is used to integrate the HMC3716 output pulses into a proper tune voltage to drive the ADF4401A VCO. The LT6200 op amp is selected for its high gain bandwidth product and low noise. These features are critical to designing a wide bandwidth loop.

Once the VCO calibration completes, the U15 switch (see Figure 9) is thrown to any one of the other positions, and the offset mode is activated. In this offset loop mode, a significant performance improvement is observed.

### LOCAL OSCILLATOR

An ultrahigh performance local oscillator (LO) is required to mix with either the sum or difference of the IF and VCO frequencies. The phase noise performance of this LO appears inside the loop bandwidth of the offset loop and must be of sufficient quality to meet the performance requirements.

To use a doubled external LO frequency at the mixer, GPIO2 (Pin 44 of P4) is selected logic high.

**DEFAULT CONFIGURATION**

Together with the power supplies, calibration reference, PFD reference, and LO signal, and appropriate programming instructions from the PC, frequencies from 62.5 MHz to 8 GHz can be generated from the RF outputs of the ADF4401A.

Figure 2 shows the setup diagram.

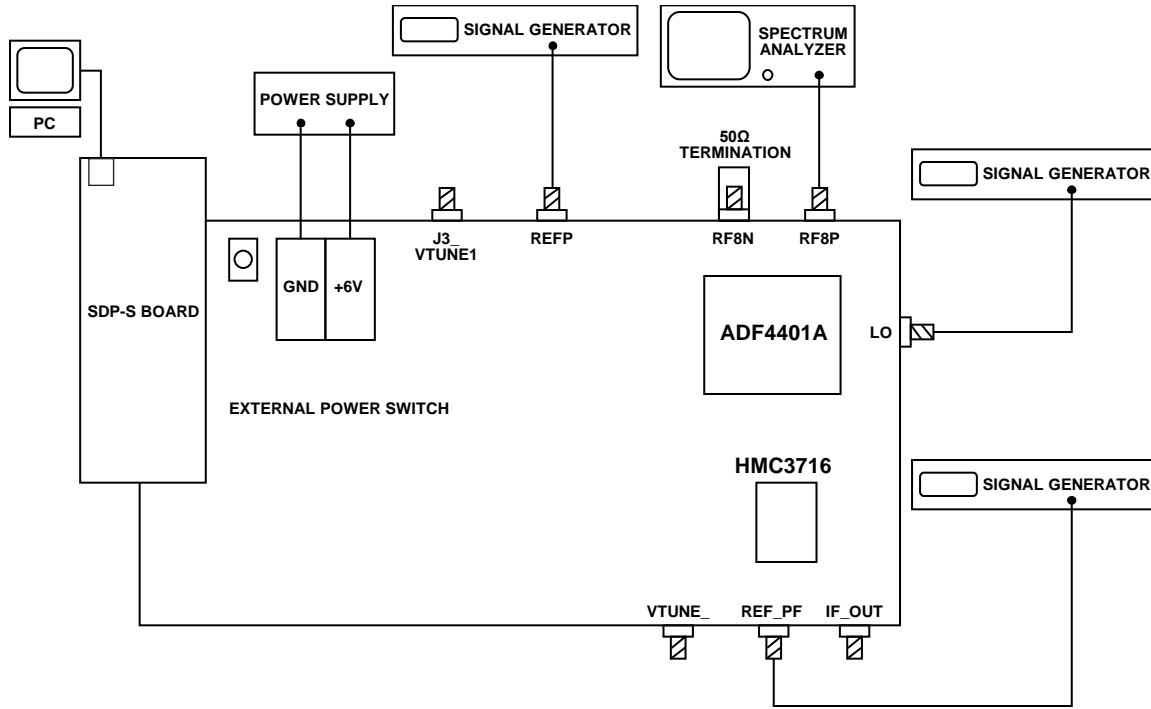


Figure 2. Setup Diagram

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## EVALUATION BOARD SOFTWARE

The ACE software is the main platform used to control the EV-ADF4401ASD2Z. The ADF4401A ACE plugin includes user interfaces that relate to the ADF4401A and allow the evaluation of the device. Take the following steps to open the main control window for the ADF4401A in ACE:

1. Launch the ACE software. When the SDP-S is connected to the EV-ADF4401ASD2Z, the EV-ADF4401ASD2Z icon

appears in the **Attached Hardware** section of the **Start** tab, as shown in Figure 3.

2. Double click the EV-ADF4401ASD2Z icon to open the EV-ADF4401ASD2Z tab, as shown in Figure 4.
3. Double click the ADF4401A icon in the EV-ADF4401ASD2Z tab to open the main control window in the ADF4401A tab, as shown in Figure 5 and Figure 6.

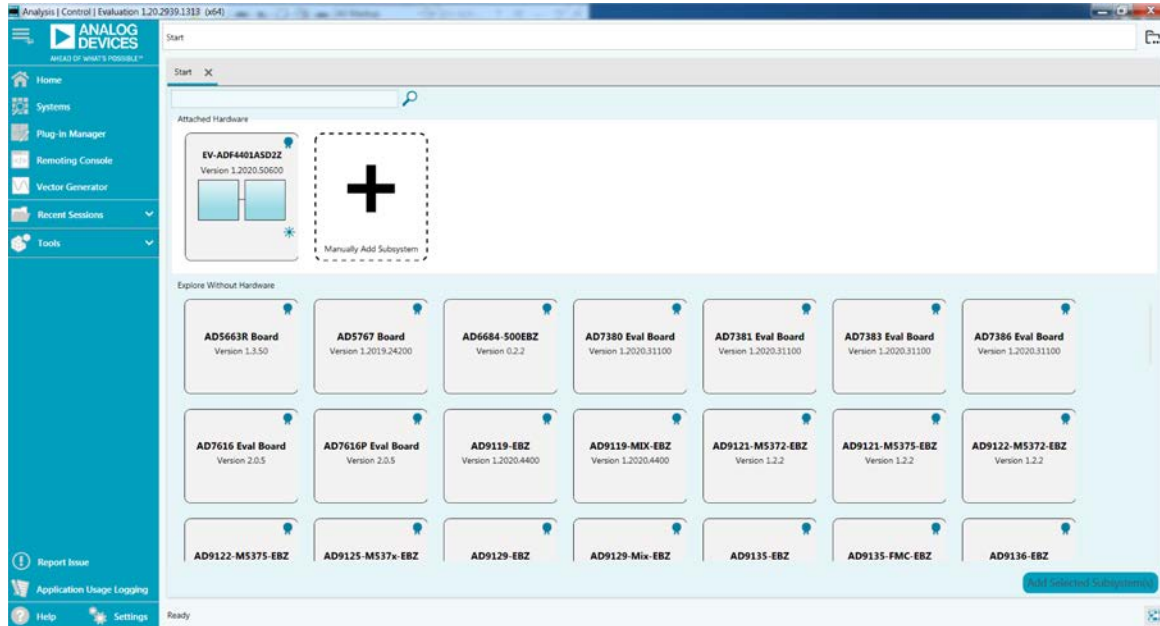


Figure 3. ACE Start Tab, Attached Hardware

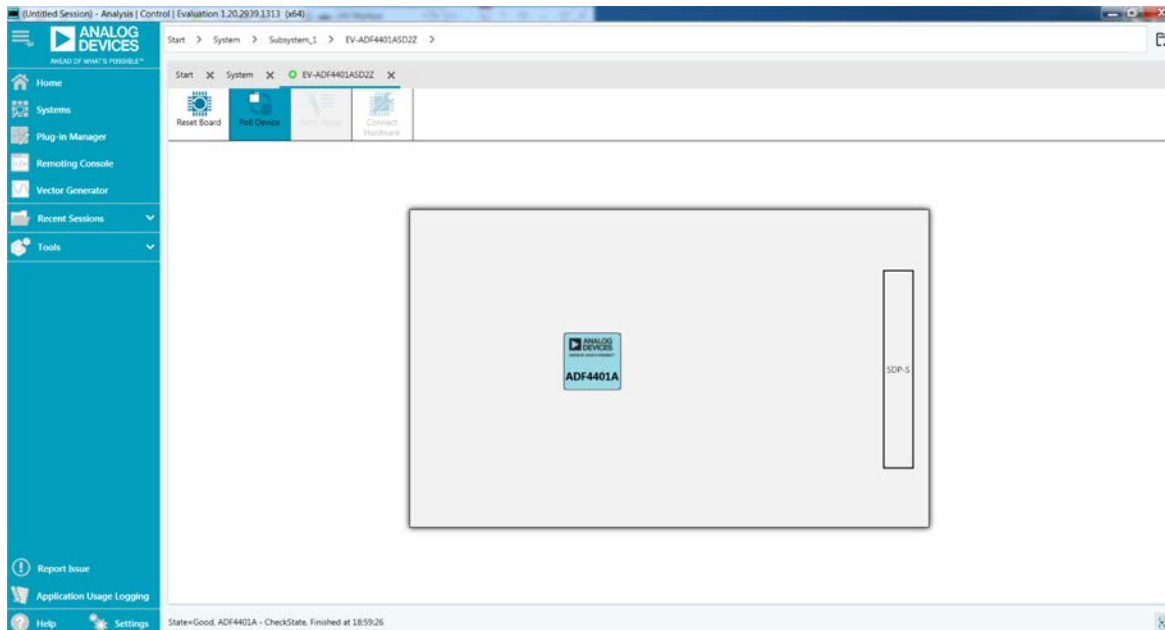


Figure 4. ACE EV-ADF4401ASD2Z Tab, Device Selection

**MAIN CONTROLS**

The main controls in **ACE** are available in the high level register map shown in Figure 5 and Figure 6. To modify the registers, perform the following steps:

1. Set the **Calibration Ref** frequency (typically between 25 MHz and 100 MHz), **External LO** frequency and **External Reference** frequency (the reference of the **HMC3716**).
2. Set the output divider value in the ÷ dropdown menu. Note that the **RFOUT** and **VCO** frequencies are updated simultaneously. Alternatively, setting the **RFOUT** frequency updates the **VCO** and **External LO** frequencies automatically.
3. Select the **Hi Injection** check box or **Lo Injection** check box to enable high-side injection or low-side injection as required.
4. To use doubled LO frequency, clear the **X2 Off** check box.
5. Click **Initialize/Change Frequency** to load all registers and initialize the device. This button is disabled when clicked once. To re-enable this button, set a new value in any frequency box.
6. When the initialization completes, change the mode from **Calibration Mode** to **Translation Loop Mode** by clicking **Change Loop Mode**. Click this button to return to **Calibration Mode**. The current mode is indicated below the **Change Loop Mode** button, and the switch position is updated accordingly, as shown in Figure 6.
7. Use the dropdown menus to enable or disable the **RFOUT** frequency (**RF On**), adjust the output power (**+5dBm**), or select the output divider value (÷). Click **Apply Changes** to update the registers.
8. To set new frequencies, follow Step 1 to Step 7.

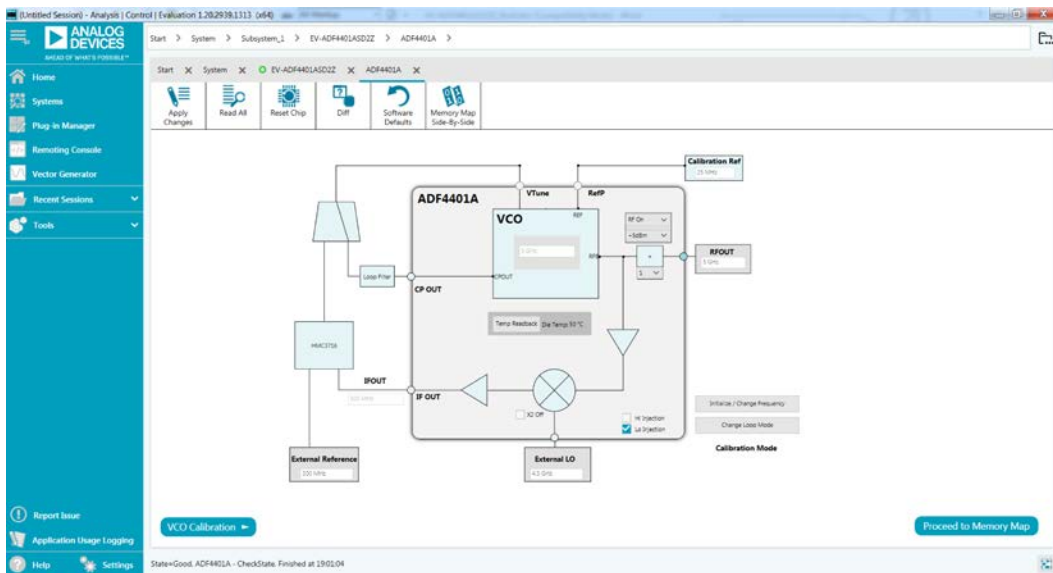


Figure 5. ADF4401A Tab, Main Control Window (Calibration Mode)

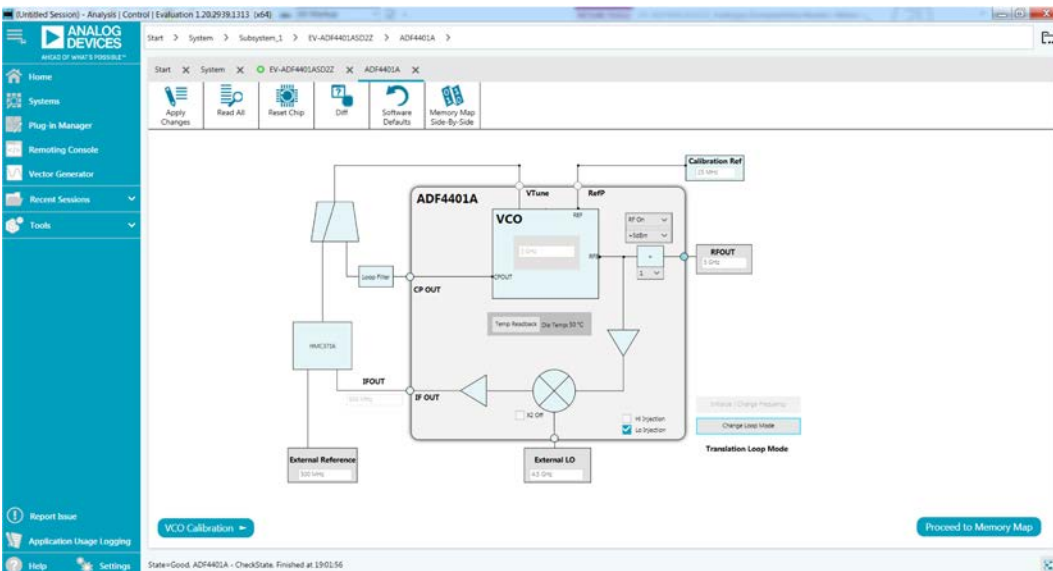


Figure 6. ADF4401A Tab, Main Control Window (Translation Loop Mode)

## EVALUATION AND TEST

To evaluate and test the performance of the [ADF4401A](#), prepare the hardware and software setup as explained in the Evaluation Board Hardware section and the Evaluation Board Software section and perform the following steps:

1. Connect the [SDP-S](#) to the EV-ADF4401ASD2Z and PC.
2. Power up the EV-ADF4401ASD2Z with 6 V.
3. Run the [ACE](#) software. Set the **Calibration Ref** to 25 MHz, the **External Reference** to 500 MHz, and the **External LO** to 4.5 GHz (see Figure 5).

4. Click **Initialize/Change Frequency** to generate a tone at 5 GHz (**Calibration Mode**).
5. Click **Change Loop Mode** to toggle the operation mode to **Translation Loop Mode**.
6. Adjust the output power if necessary.

Figure 7 shows a phase noise plot at 5 GHz output.

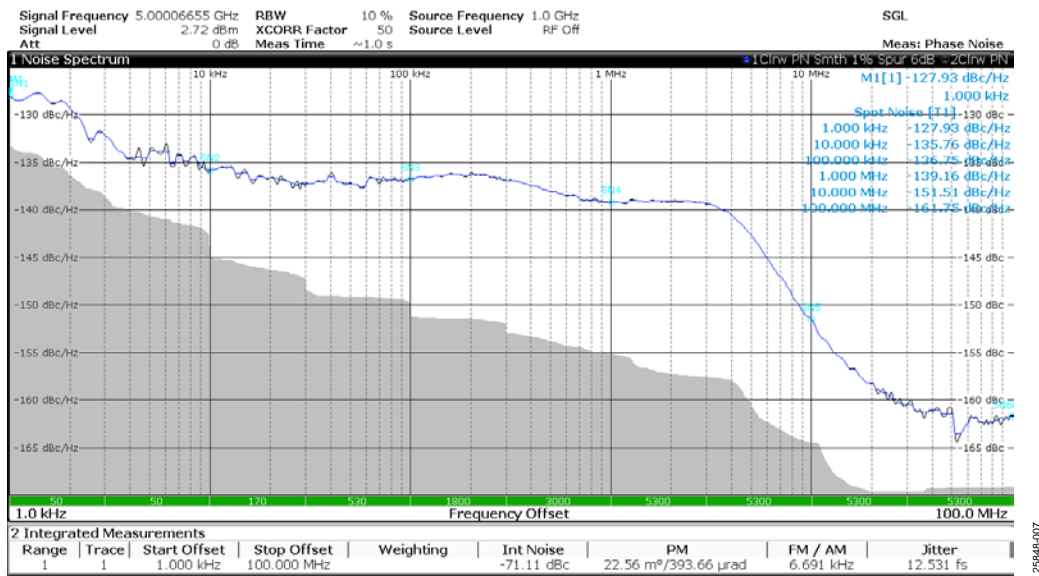


Figure 7. Single Sideband Phase Noise at 5 GHz



EVALUATION BOARD SCHEMATICS AND ARTWORK

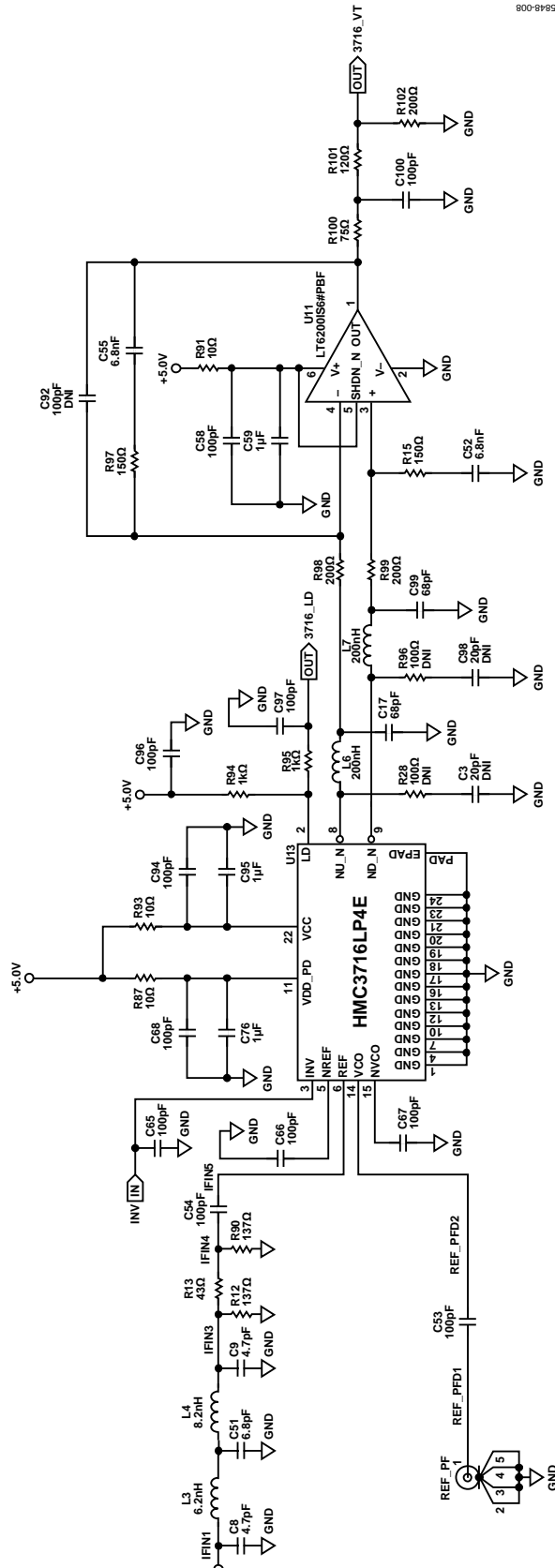


Figure 8. EV-ADF4401ASD2Z Schematic, HMC3716 and Loop Filter

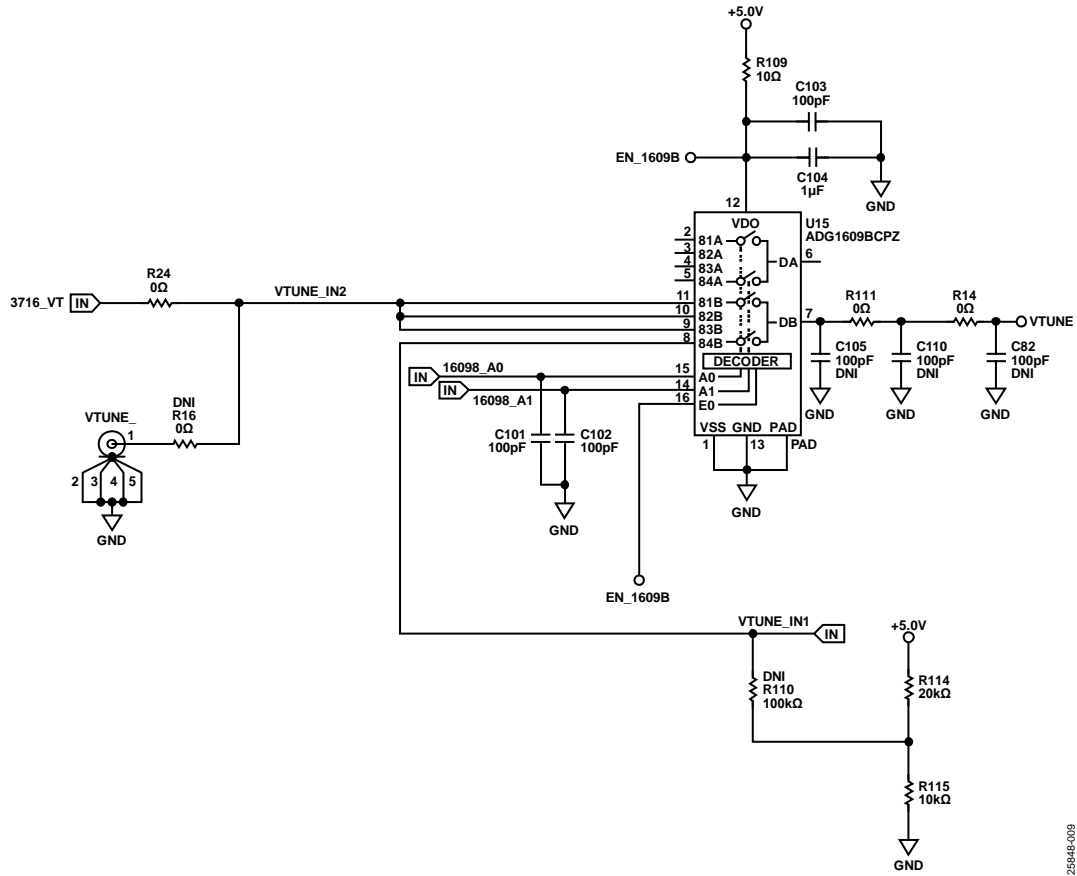


Figure 9. EV-ADF4401ASD2Z Schematic, Loop Selecting Switch

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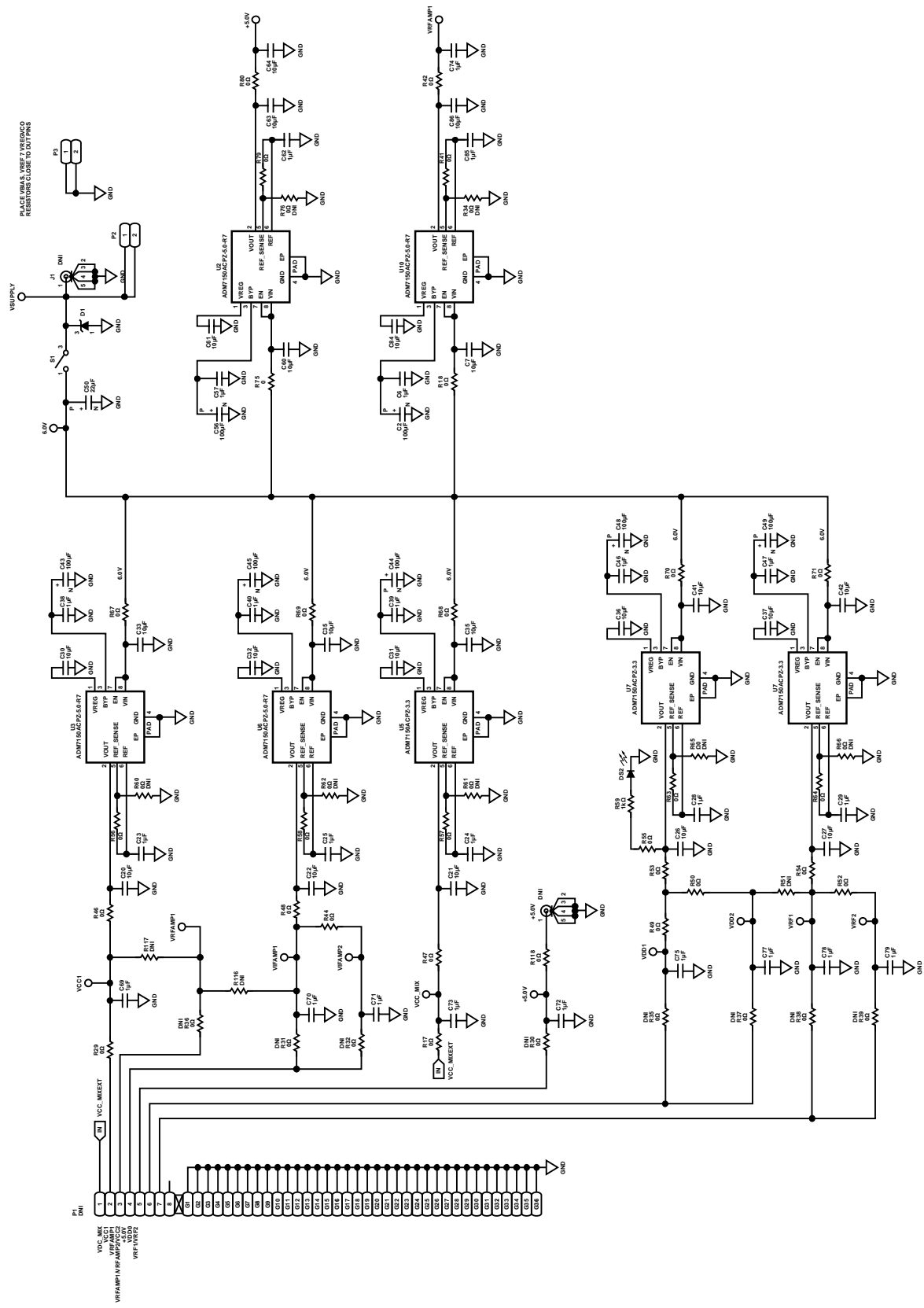


Figure 10. EV-ADF4401ASD2Z Schematic, Regulators

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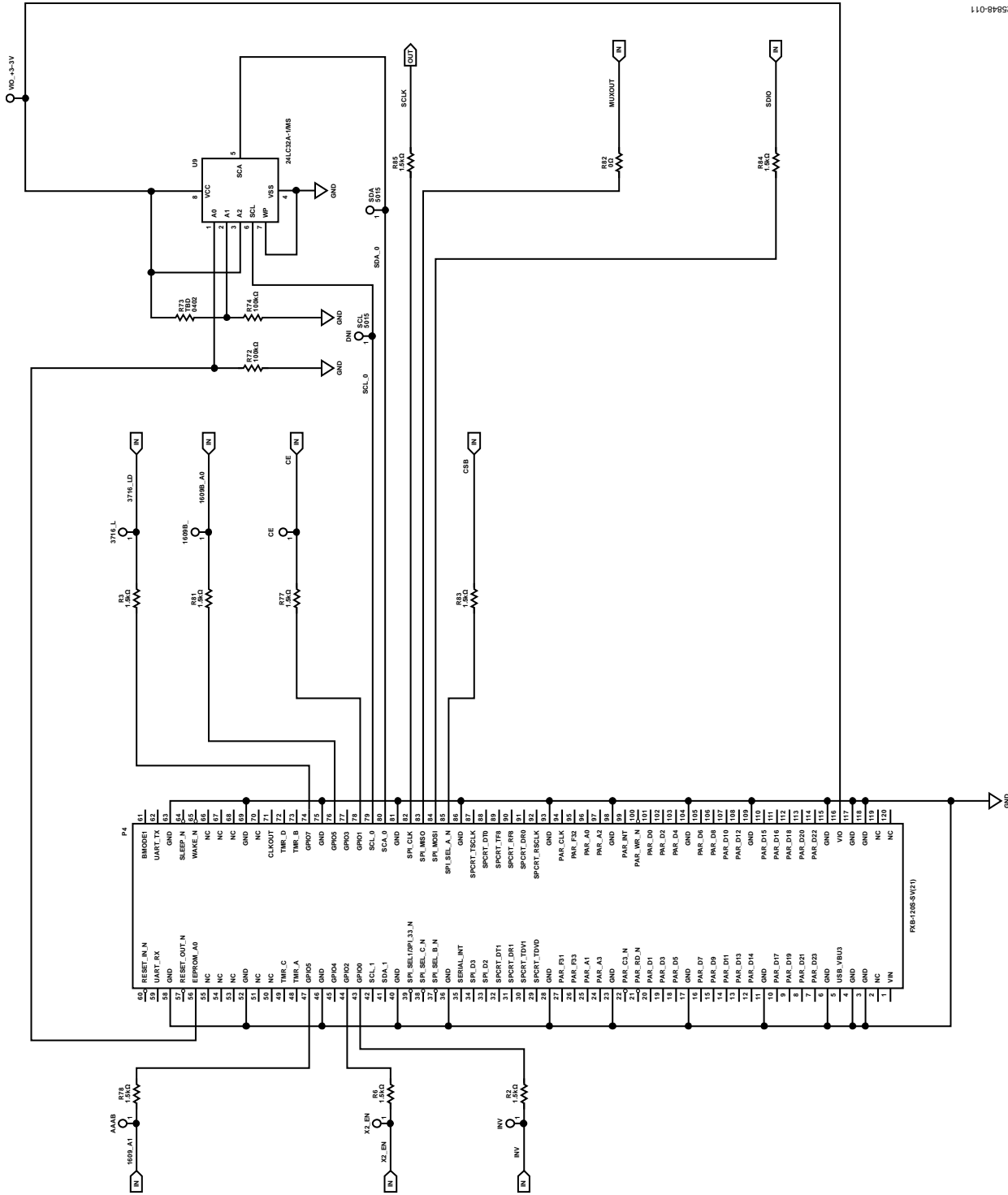


Figure 11. EV-ADF4401ASD2Z Schematic, Board Connector

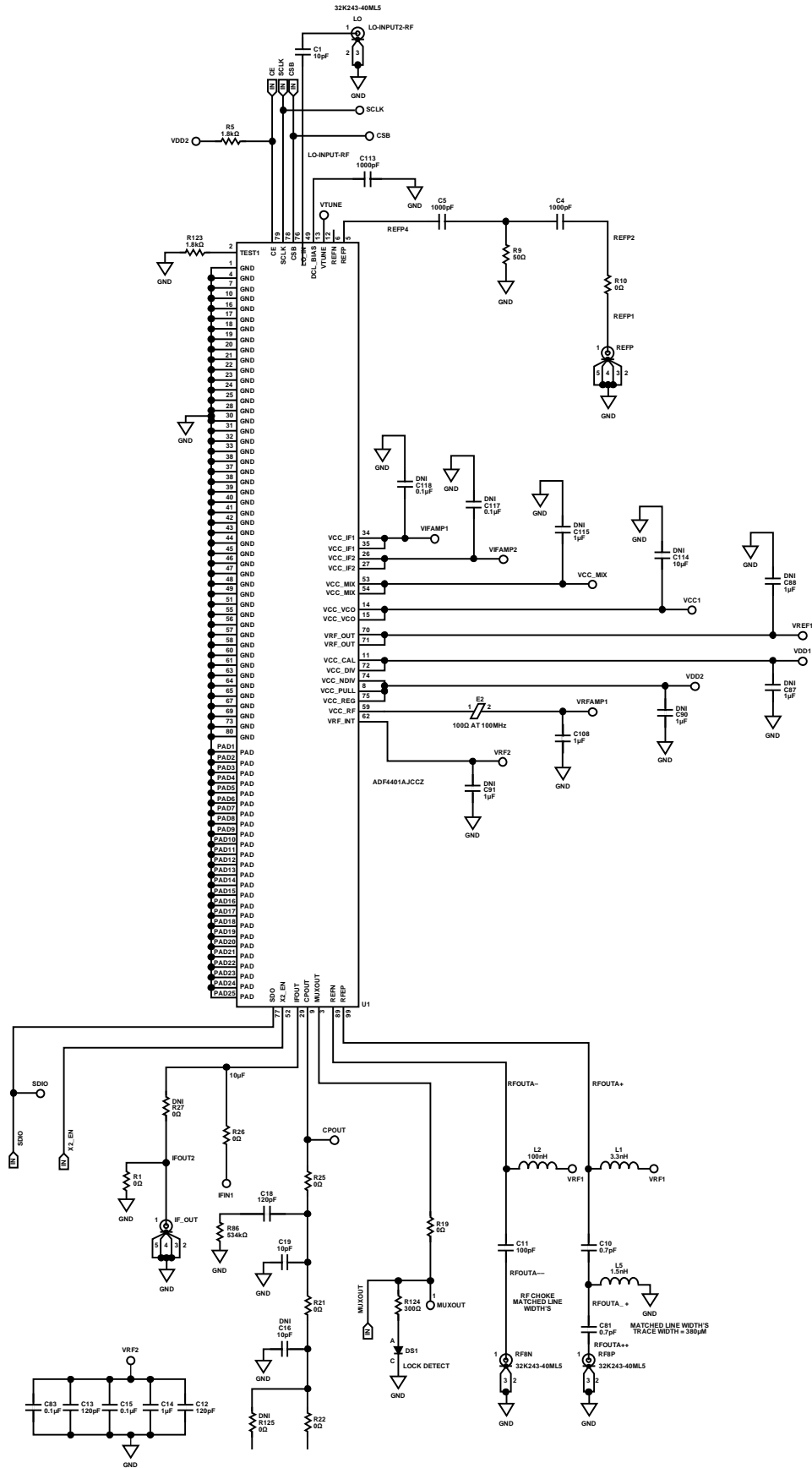


Figure 12. EV-ADF4401ASD2Z Schematic, ADF4401A Connections

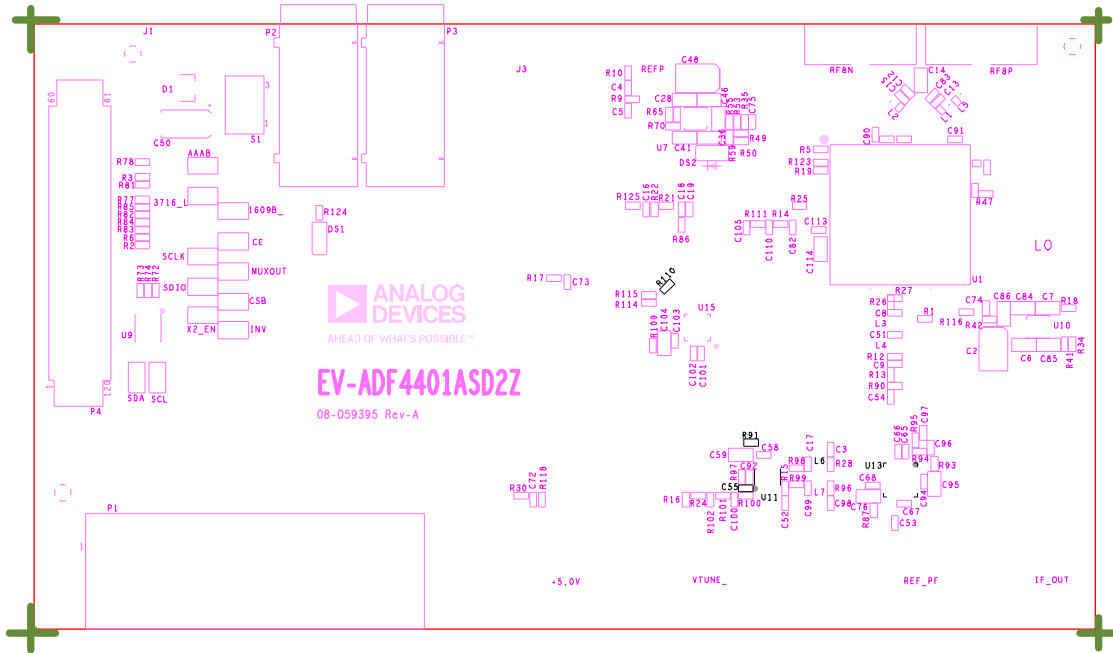


Figure 13. EV-ADF4401ASD2Z Silkscreen, Top Side

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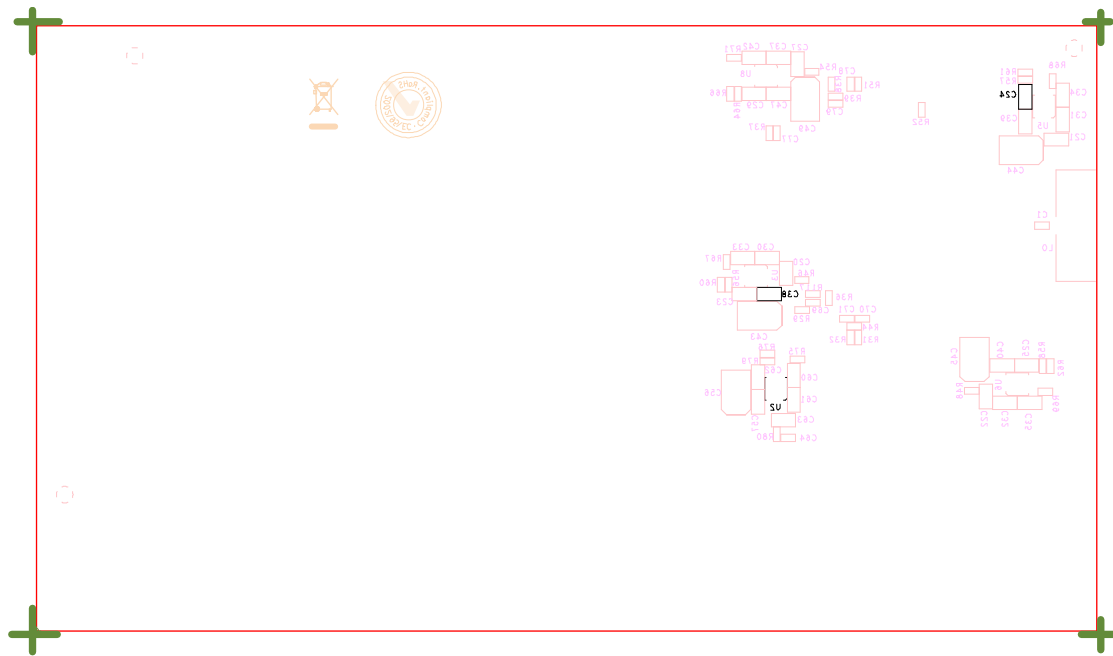


Figure 14. EV-ADF4401ASD2Z Silkscreen, Bottom Side

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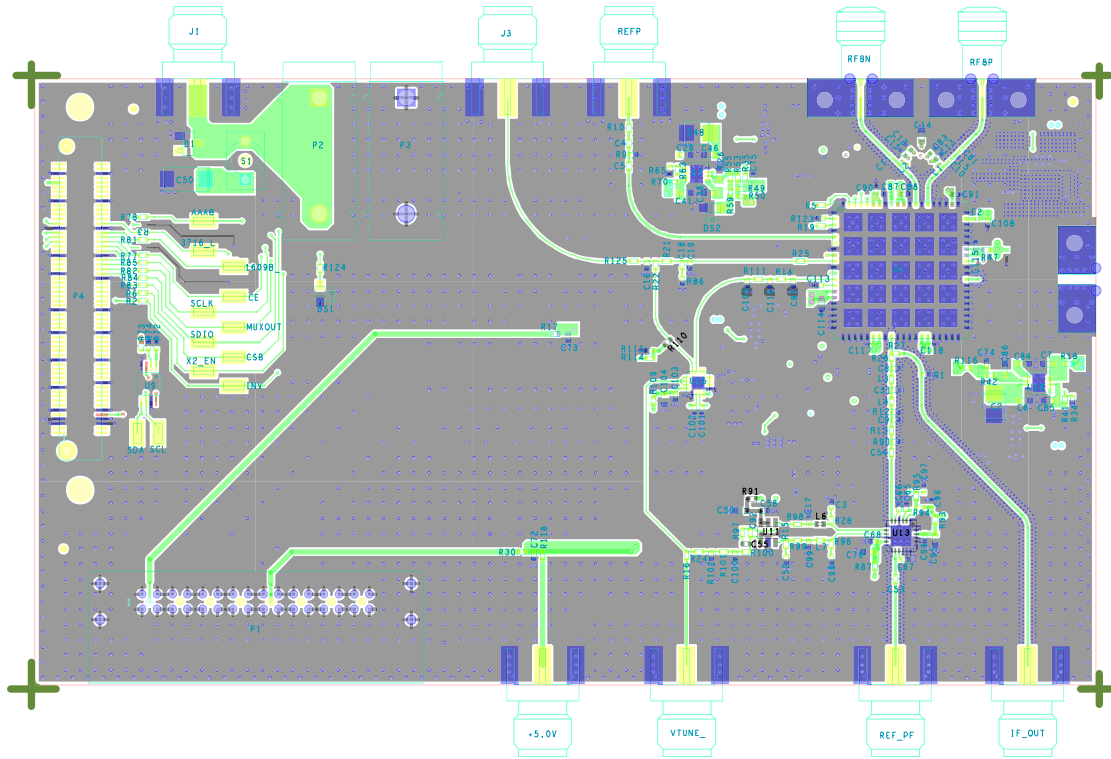


Figure 15. EV-ADF4401ASD2Z Layer 1, Primary

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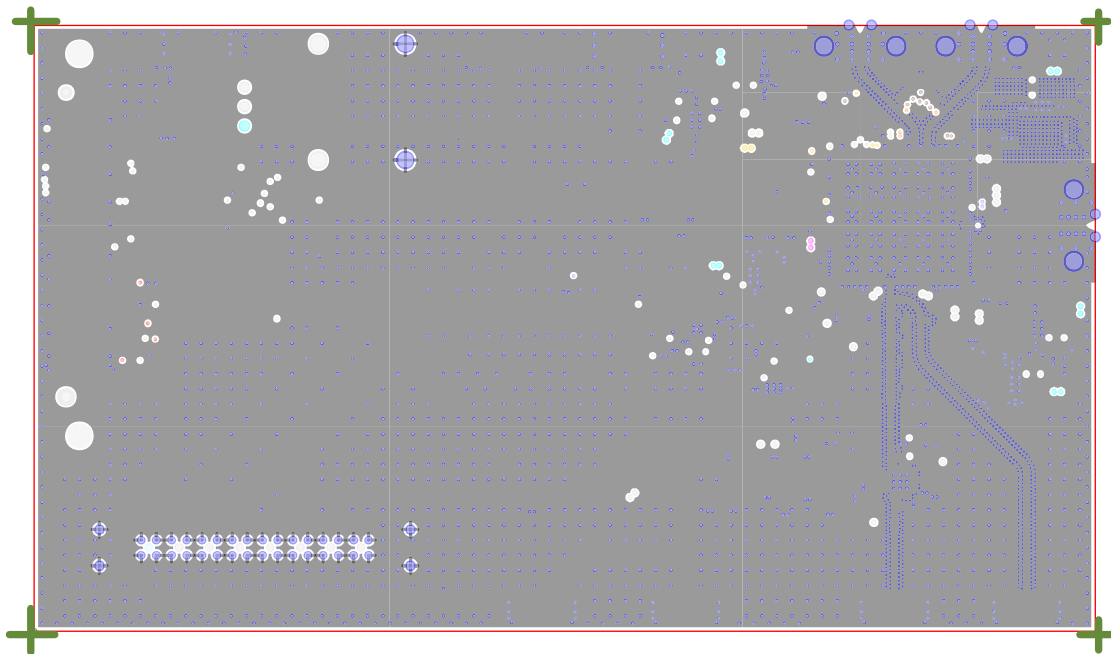
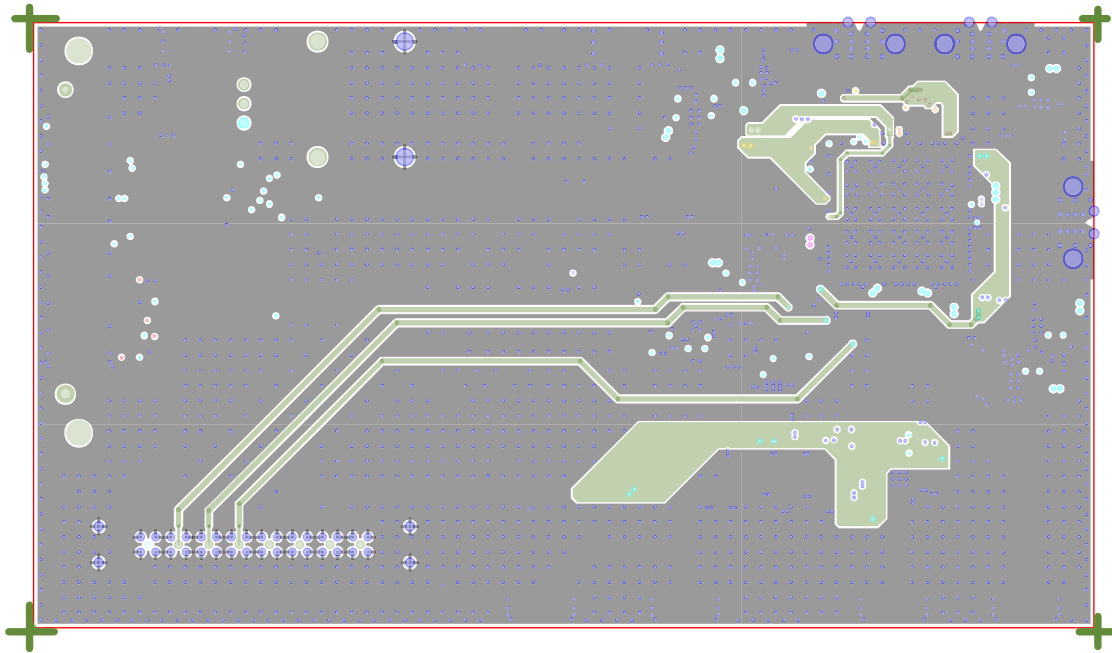


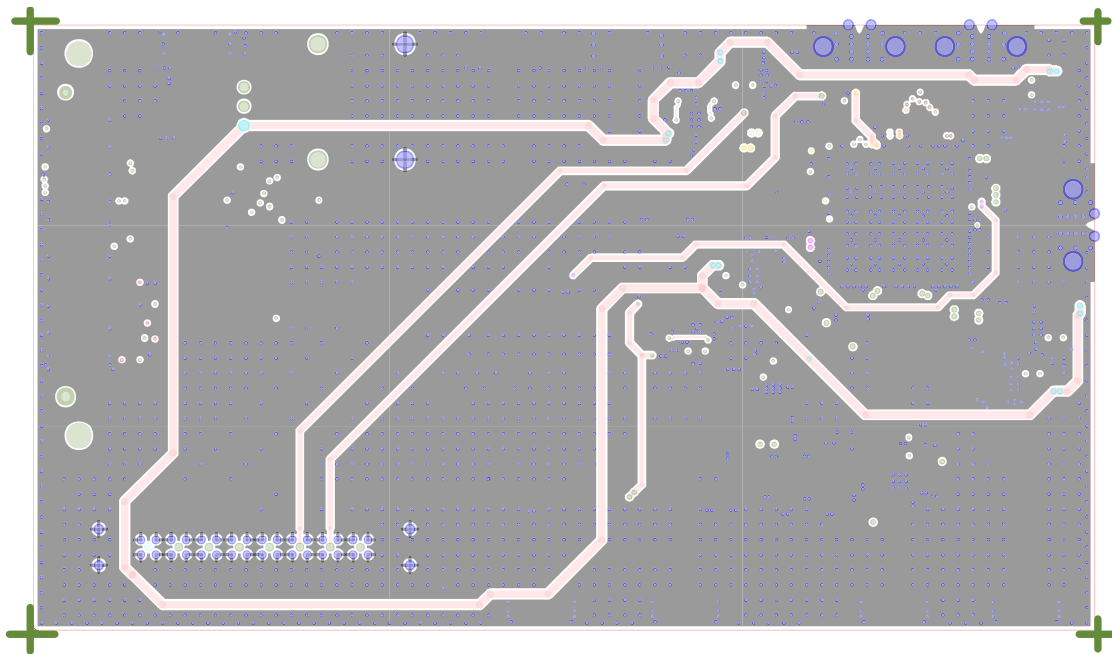
Figure 16. EV-ADF4401ASD2Z Layer 2, Ground

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Figure 17. EV-ADF4401ASD2Z Layer 3, Power



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Figure 18. EV-ADF4401ASD2Z Layer 4, Secondary



# ORDERING INFORMATION

## BILL OF MATERIALS

Table 1.

Reference Designator	Description	Value	Manufacturer	Part Number
1609B_, 3716_L, AAAB, CE, CSB, INV, MUXOUT, SCLK, SDA, SDIO, X2_EN	Printed circuit board (PCB) test point connectors	Not applicable	Keystone Electronics	5015
C1, C19	Ceramic capacitors, multilayer, NP0, 0402	10 pF	Yageo	CC0402JRNP09BN100
C10, C81	Ceramic capacitors, C0G (NP0), general purpose	0.7 pF	Murata	GJM0335C1ER70BB01D
C100	Ceramic capacitors, for automotive use, C0G	100 pF	Murata	GCM1555C1H101JA16D
C53, C54, C58, C65, C66, C67, C68, C94, C96, C97, C101, C102, C103	Ceramic capacitors, 50 V, C0G (NP0), 0402	100 pF	Murata	GCM1555C1H101FA16D
C6, C14, C23, C24, C25, C28, C29, C38, C39, C40, C46, C47, C57, C59, C62, C76, C85, C95, C104	Ceramic capacitors, X7R	1 μF	AVX	0603YC105KAT2A
C90, C108	Ceramic capacitors, X7S, for automotive use	1 μF	Murata	GCM155C71A105KE38D
C11	Ceramic capacitor, C0G (NP0), general purpose	100 pF	Murata	GRM0335C1H101JA01D
C7, C20, C21, C22, C26, C27, C30 to C37, C41, C42, C60, C61, C63, C84, C86, C114	Ceramic capacitors, X5R	10 μF	TDK	C1608X5R1C106M080AB
C12, C13, C18	Ceramic capacitors, X7R, 0402	120 pF	AVX	04023C121JAT2A
C15, C83	Ceramic capacitors, X7R	0.1 μF	Kemet	C0402C104K4RACTU
C17, C99	Ceramic capacitors, C0G, automotive grade	68 pF	Murata	GCM1555C1H680JA16D
C2, C43, C44, C45, C48, C49, C56	Tantalum capacitors, chip	100 μF	AVX	TAJB107K006RNJ
C4, C5	Ceramic capacitors, C0G (NP0), general purpose	1000 pF	Murata	GRM1555C1H102JA01
C50	Tantalum, solid electrolytic capacitor	22 μF	AVX	TCJC226M025R0100
C51	Ceramic capacitors, C0G (NP0), high frequency, high-Q	6.8 pF	Murata	GJM1555C1H6R8CB01D
C52, C55	Multilayer ceramic capacitors (MLCCs), X7R, general purpose	6.8 nF	Samsung	CL05B682KB5NNNC
C64, C69, C70 to C75, C77, C78, C79	Ceramic capacitors, X5R, 0402	1 μF	AVX	04026D105KAT2A
C8, C9	Ceramic capacitors, C0G (NP0), high frequency, high-Q	4.7 pF	Murata	GJM1555C1H4R7WB01D
D1	Diode, 6.8 V, Zener	Not applicable	Philips	BZX84-C6V8
DS1, DS2	Light emitting diode (LED) 570 nM, surface-mount device (SMD), green	Not applicable	Broadcom Limited	HSMG-C170
E2	Chip ferrite bead, general use	1000 Ω at 100 MHz	Murata	BLM03HG102SN1D
IF_OUT, J3, REFP, REF_PF, VTUNE_	PCB, coaxial, SMA, end launch connectors	Not applicable	Cinch Connectivity	142-0701-801
L1	RF thin film chip inductors	3.3 nH	Murata	LQP03TN3N3B02D
L2	RF thin film chip inductors	100 nH	Murata	LQP03TNR10J02D
L3,L4	RF thin film chip inductors	8.2 nH	Murata	LQW15AN8N2J00D
L5	RF thin film chip inductors	1.5 nH	Murata	LQP03TN1N5B02D

Reference Designator	Description	Value	Manufacturer	Part Number
L6, L7	High frequency, multilayer, inductors, 0.07 A, 6.2 $\Omega$ , dc resistance	200 nH	TDK	MLK1005SR20JTD25
LO, RF8N, RF8P	PCB, SMA, right angle jack connectors	Not applicable	Rosenberger	32K243-40ML5
P2	PCB, single socket connector, red	Not applicable	Deltron	571-0500
P3	PCB, single socket connector, black	Not applicable	Deltron	571-0100
P4	PCB, vertical type receptacle, surface-mount device (SMD) connector	Not applicable	HRS	FX8-120S-SV(21)
R1, R10, R14, R18, R19, R21, R22, R24, R25, R26, R41, R42, R44, R46, R47, R48, R49, R50, R52 to R58, R63, R64, R67, R68, R69, R70, R71, R75, R79, R80, R82, R111, R118	Thick film, chip resistors	0 $\Omega$	Multicomp (SPC)	MC00625W040210R
R100	Precision thick film, chip resistor	75 $\Omega$	Panasonic	ERJ-2RKF75R0X
R101	SMD film resistor	120 $\Omega$	Panasonic	ERJ-2GEJ121X
R98, R99, R102	Precision thick film, chip resistors	200 $\Omega$	Panasonic	ERJ-2RKF2000X
R87, R91, R93, R109	Precision thick film, chip resistors	10 $\Omega$	Panasonic	ERJ-2RKF10R0X
R114	Precision thick film, chip resistor	20 k $\Omega$	Panasonic	ERJ-2RKF2002X
R115	Precision thick film, chip resistor	10 k $\Omega$	Panasonic	ERJ-2RKF1002X
R12, R90	Precision thick film, chip resistors	137 $\Omega$	Panasonic	ERJ-2RKF1370X
R5, R123	SMD film resistors	1.8 k $\Omega$	Multicomp (SPC)	CR10B182JT
R124	SMD film resistor	300 $\Omega$	Panasonic	ERJ-2GEJ301X
R13	Precision thick film, chip resistor	43 $\Omega$	Panasonic	ERJ-2RKF43R0X
R15, R97	SMD film resistors	150 $\Omega$	Panasonic	ERJ-2GEJ151X
R2, R3, R6, R77, R78, R81, R83, R84, R85	Precision thick film, chip resistors	1.5 k $\Omega$	Panasonic	ERJ-2RKF1501X
R59, R94, R95	Precision thick film, chip resistors	1 k $\Omega$	Panasonic	ERJ-2RKF1001X
R72, R74	Thick film, chip resistors	100 k $\Omega$	Panasonic	ERJ-2GEJ104X
R86	Precision thick film, chip resistor	5.4 k $\Omega$	Panasonic	ERJ-2RKF5401X
R9	High frequency, chip resistor	50 $\Omega$	Vishay	FC0402E50R0FST1
S1	Single-pole, single-throw, momentary switch	Not applicable	TE Connectivity/ Alcoswitch	TT11AGPC104
U1	Translation loop, PLL, VCO module	Not applicable	Analog Devices, Inc.	<a href="#">ADF4401AJCCZ</a>
U2, U3, U6, U10	800 mA, ultralow noise, high power supply rejection ratio (PSRR), RF linear regulator, 5.0 V output	Not applicable	Analog Devices	<a href="#">ADM7150ACPZ-5.0-R7</a>
U11	OP amp, single, low noise, rail-to-rail amp	Not applicable	Analog Devices	<a href="#">LT6200IS6#PBF</a>
U13	HBT digital phase frequency detector	Not applicable	Analog Devices	<a href="#">HMC3716LP4E</a>
U15	4-channel multiplexer	Not applicable	Analog Devices	<a href="#">ADG1609BCPZ-REEL7</a>
U5, U7, U8	800 mA, ultralow noise, high PSRR, RF linear regulator, 3.3 V output	Not applicable	Analog Devices	<a href="#">ADM7150ACPZ-3.3-R7</a>
U9	32 kB, serial electronically erasable programmable read-only memory (EEPROM)	Not applicable	Microchip Technology	24LC32A-I/MS

## 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 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.

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