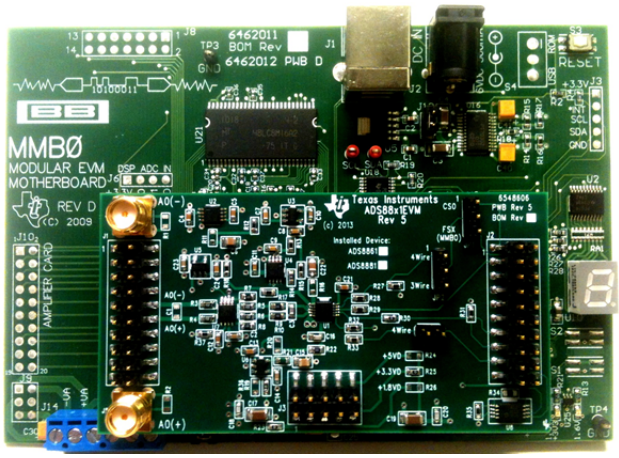
ADS8881EVM-PDK



ADS8881EVM-PDK

This user's guide describes the operation and use of the ADS8881 evaluation module (EVM). ADS8881 is an 18-bit true-differential unipolar successive approximation register (SAR) analog-to-digital converter (ADC) with a maximum throughput of 1 MSPS. It is a very low power ADC with excellent noise and distortion performance for ac or dc signals. The performance demonstration kit (PDK) eases EVM evaluation with additional hardware and software for computer connectivity through universal serial bus (USB). The ADS8881EVM-PDK includes the ADS8881EVM as a daughter card, MMB0 motherboard, A-to-B USB cable, and 6-V wall-adapter power supply. This user's guide covers circuit description, schematic diagram, and bill of materials for the ADS8881EVM daughter card.

The following related documents are available through the Texas Instruments website at http://www.ti.com.

Related Documentation

Device	Literature Number
ADS8881	SBAS547
REF5045	SBOS410
OPA333	SBOS351
OPA330	SBOS432
THS4281	SLOS432
THS4521	SBOS458
TPS78833	SLVS382

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Contents

1 ADS8881EVM-PDK Overview 3
2 EVM Analog Interface 4
3 EVM Digital Interface 6
4 EVM Power Supply Inputs 7
5 EVM Digital Configuration 8
6 PDK Kit Setup 9
7 PDK Kit Operation 11
8 Bill of Materials, Schematics, and Layout 14

List of Figures

1 Differential Input Example 4
2 Single Ended Signal Example 5
3 THS4281 Reference Driver with Complementary OPA333 for Drift and Offset Correction 5
4 Serial 3-Wire Configuration 8
5 Serial 4-Wire Configuration 8
6 Plug-In Installer 9
7 MMB0 Motherboard Jumper Configuration 10
8 ADS8881EVM Jumper Configuration 10
9 Loading EVM Plug-in 11
10 ADS8881EVM Plug-in: Device Configuration Tab 12
11 ADCPro Test Plug-ins 13
12 ADS8881EVM PCB: Top Layer 16
13 ADS8881EVM PCB: Ground Layer 16
14 ADS8881EVM PCB: Power Layer 17
15 ADS8881EVM PCB: Bottom Layer 17

List of Tables

1 J1: Analog Interface Pinout (Samtec 10 x 2) 4
2 SMA Analog Inputs 4
3 J2: Serial Interface Header 6
4 J3: Power-Supply Interface Header 7
5 ADS8881EVM Bill of Materials 14

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1 ADS8881EVM-PDK Overview

The ADS8881EVM is an evaluation module built to the TI Modular EVM system specifications. The EVM by itself has no microprocessor and cannot run software. Thus, it is available as part of the ADS8881EVM-PDK kit that combines the ADS8881EVM as a daughter board with the DSP-based MMB0 motherboard using ADCPro™ software as graphical user interface (GUI).

ADCPro software collects, records, and analyzes data from ADC evaluation boards. It runs different plug-in programs to easily expand testing and data collection capabilities. In combination with the ADS8881EVM plug-in program, it offers a comprehensive evaluation environment for the ADS8881. For more details on ADCPro, see the *ADCPro Analog-to-Digital Converter Evaluation Software User's Guide* (literature number SBAU128), available for download from the TI website.

ADS8881EVM Daughter Board Features:

- Includes support circuitry as a design example to match ADC performance
- 3.3-V slave serial peripheral interface (SPI)
- Serial interface header for easy connection to TI DSP-based communication systems
- Compatible with the TI Modular EVM system
- Designed for 5-V analog supply
- Onboard 4.5-V voltage reference
- Bipolar (–4.3-V to 4.3-V) or unipolar (0-V to 8.6-V) input range
- Allows single ended or differential input signals

ADS8881EVM-PDK Kit Additional Features:

- USB port for computer interfacing
- Regulated 5-V and 3.3-V supplies for powering EVM daughter board
- Easy-to-use evaluation software for Windows® operating system
- Data collection to text files
- Built-in analysis tools including scope, FFT, and histogram displays
- Easily expandable with new analysis plug-in tools from Texas Instruments

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2 EVM Analog Interface

The ADS8881EVM is designed for easy interfacing to multiple analog sources. SMA connectors allow the EVM to have input signals connected through coaxial cables. In addition, the Samtec connector provides a convenient 10-pin, dual-row, header/socket combination at J1. Consult Samtec at http://www.samtec.com or call 1-800-SAMTEC-9 for a variety of mating connector options. All analog inputs are buffered by THS4521 high-speed fully differential amplifier in order to properly drive the ADS8881 ADC inputs.

Use appropriate caution when handling these pins. Table 1 summarizes the pinout for analog interface J1.

Table 1. J1: Analog Interface Pinout (Samtec 10 x 2)

Pin Number	Signal	Description
J1.10	A0(-)	CH0 negative differential input. This pin can be grounded for single ended signals.
J1.12	A0(+)	CH0 positive differential input or input for single ended signals

Table 2 lists the SMA analog inputs.

Table 2. SMA Analog Inputs

Pin Number	Signal	Description
J4	A0(-)	CH0 negative differential input. This pin can be grounded for single ended signals.
J5	A0(+)	CH0 positive differential input or input for single ended signals

2.1 Differential Input Signal Configuration

The ADS8881 can only convert differential signals with common mode between 0 V and V_{REF}, but the THS4521 can condition a bipolar signal changing its common mode. This EVM sets the THS4521 output common mode to 2.25 V, that corresponds to V_{REF} / 2. Thus, a bipolar differential signal with a common mode of 0 V can be applied at the EVM inputs A0(-) and A0(+). Then, the THS4521 shifts the common mode to 2.25 V. Although input common mode can be corrected, since the THS4521 is powered by a 5-V supply, the input signals must limit the differential range from –4.3 V to 4.3 V to avoid saturating the amplifier output. Figure 1 illustrates an input signal with 0-V common mode and 8.6-V differential, which common mode is changed from 0 V to 2.25 V.

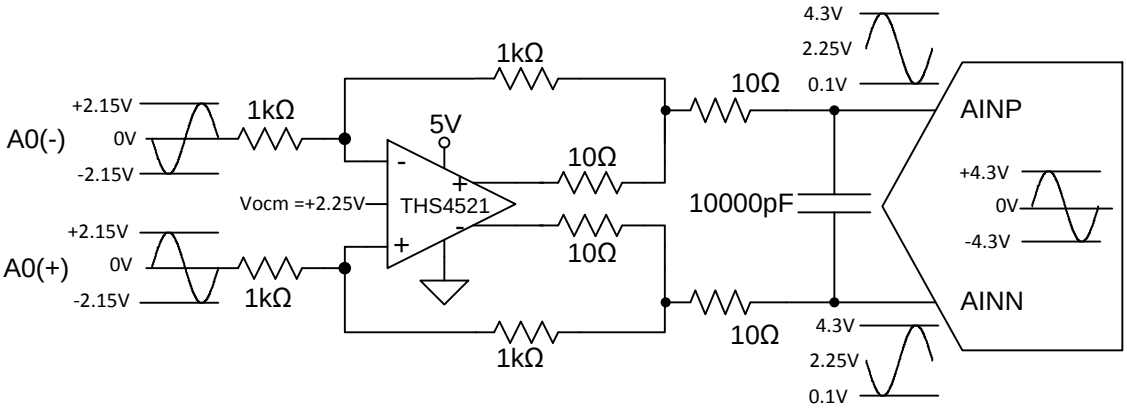


Figure 1. Differential Input Example

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2.2 Single Ended Signal Configuration

The ADS8881 can only convert single ended signals between 0 V and V_{REF}. The THS4521 can condition a single ended to a differential signal allowing a larger input voltage range for the EVM input A0(+). The single ended signal range can be 0 V to 8.6 V or –4.3 V to 4.3 V to avoid saturating amplifier output. The EVM A0(-) input should be grounded for single-ended signals as illustrated in Figure 2.

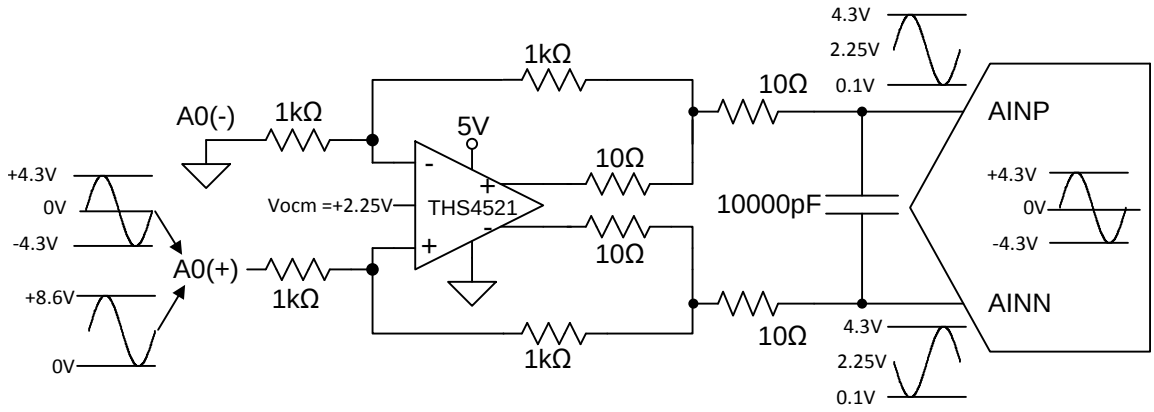


Figure 2. Single Ended Signal Example

2.3 Voltage Reference

Since the EVM is powered by a 5-V analog supply, the reference should be a value below 5 V. This EVM uses a 4.5 V created by the on-board REF5045. Then, it is filtered by an RC filter of 160-Hz cutoff frequency to minimize its noise contribution. Finally, the EVM is buffered by the THS4281, which can drive the 10-µF required at the ADC reference (with 2 MHz of an effective bandwidth and 22-µVrms of total noise). OPA333 and the additional feedback is optional, but it complements the THS4281 minimizing its offset and drift.

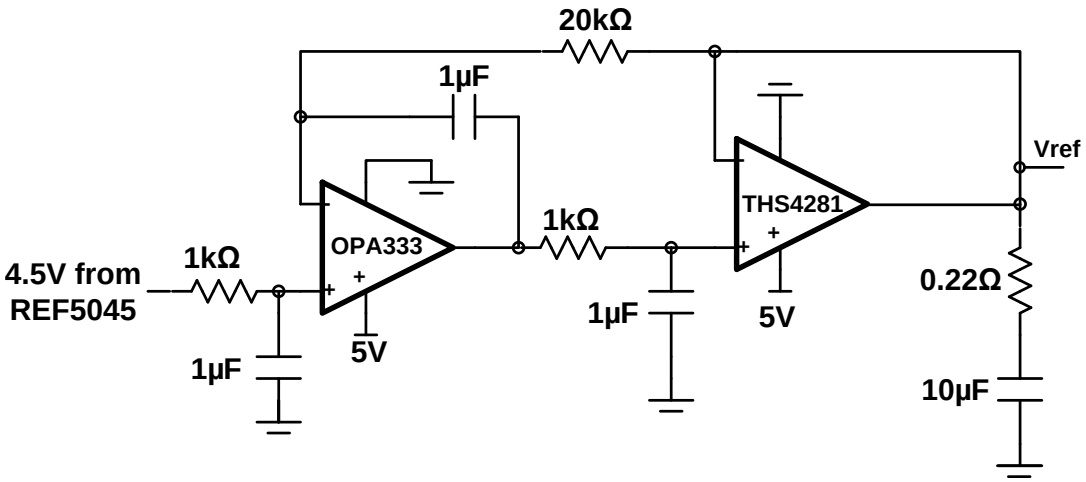


Figure 3. THS4281 Reference Driver with Complementary OPA333 for Drift and Offset Correction

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3 EVM Digital Interface

Samtec part numbers SSW-110-22-F-D-VS-K and TSM-110-01-L-DV-P provide a convenient 10-pin, dual-row, header and socket combinations at P1. The header and/or socket provides access to the digital control pins of the ADC. Consult Samtec at http://www.samtec.com or call 1-800-SAMTEC-9 for a variety of mating connector options.

Table 3 summarizes the pinouts for digital interface J2.

Table 3. J2: Serial Interface Header

Pin Number	Signal	Description
J2.1	$\overline{CS}$ or CONVST	Chip select input that could be used as convert start
J2.3	SCLK	Serial clock input
J2.7	$\overline{CS}$ or CONVST	Chip select input that could be used as convert start meant for the MMB0 motherboard
J2:13	SDO or MISO	SDO or MISO output
J2.15	INT	20-kΩ pull for detecting falling edges at end of conversion
J2.17	CONVST	Direct connection to convert start pin if JP3 is installed
J2.4, J2.10, and J2.18	GND	Digital ground connections
J2.16, J2.20	I^2C™ bus	I^2C bus; used only used to program the U4 EEPROM on the EVM board
J2.2, J2.5-6, J2.8-9, J2.11-12, J2.14, and J2:19	Unused	Unused

3.1 Serial Interface (SPI)

The ADS8881 ADC uses SPI serial communication in mode 1 (CPOL = 0, CPHA = 1) with high speed clocks higher than 30 MHz or mode 0 (CPOL = 0, CPHA = 0) for slower clocks. Because the serial clock (SCLK) frequency can be as fast as 80 MHz, the ADS8881EVM offers 47-Ω resistors between the SPI signals and J2 to aid with signal integrity. Typically, in high-speed SPI communication, fast signal edges can cause overshoot; these 47-Ω resistors slow down the signal edges in order to minimize signal overshoot.

3.2 I^2C™ Bus for Onboard EEPROM

The ADS8881EVM has an I^2C bus that records the board name and assembly date to communicate with the onboard EEPROM. It is not used in any form by the ADS8881 converter.

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4 EVM Power Supply Inputs

J3 is the power-supply input connector. Table 4 lists the configuration details for J3.

Table 4. J3: Power-Supply Interface Header

Pin Number	Pin Name	Function	Required
J3.3	+5VA	5-V analog supply	Yes
J3.5	GND	Digital ground input	Yes
J3.6	GND	Analog ground input	Yes
J3.7	1.8 VD	1.8-V digital supply	Optional
J3.9	3.3 VD	3.3-V digital supply	Yes
J3.10	5 VD	5-V digital supply	No
P3.1-2, P3.4, and P3.7-8	Unused	Unused	No

4.1 Analog Power Options

The ADS8881EVM board is designed to work with a 5-V analog power supply connected to J3.3. The ADS8881 is limited to 3.6 V as analog supply, so the board regulates down the 5-V analog supply with an on-board 3.3-V LDO (TPS78833).

4.2 Digital Power Options

The ADS8881EVM connects the digital power supply of the ADS8881 to 3.3 VD (J3.10) with a 0-Ω resistor. This matches the logic level of the MMB0 motherboard.

4.3 Analog and Digital Grounds

The EVM only has one ground plane for analog and digital supplies, so pins J3.5 and J3.6 are tied together to this ground plane. Therefore, both supply grounds should be connected to pins J3.5–6 so they share the same ground.

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5 EVM Digital Configuration

The EVM offers two jumpers (JP2 and JP3) to configure the EVM in either 3-wire SPI mode or 4-wire SPI mode. By default, the EVM jumper settings are 3-wire. JP1 only establishes the pin that carries the chip-select signal from the J2 header.

5.1 SPI 3-Wire Mode (JP2:2–3 and JP3:OPEN)

The chip-select signal is used to bring the ADS8881 digital output out of Tri-State and initialize conversions. The rising edge of the chip-select signal starts a conversion, then after conversion time the falling edge of chip-select brings the digital output out of Tri-State.

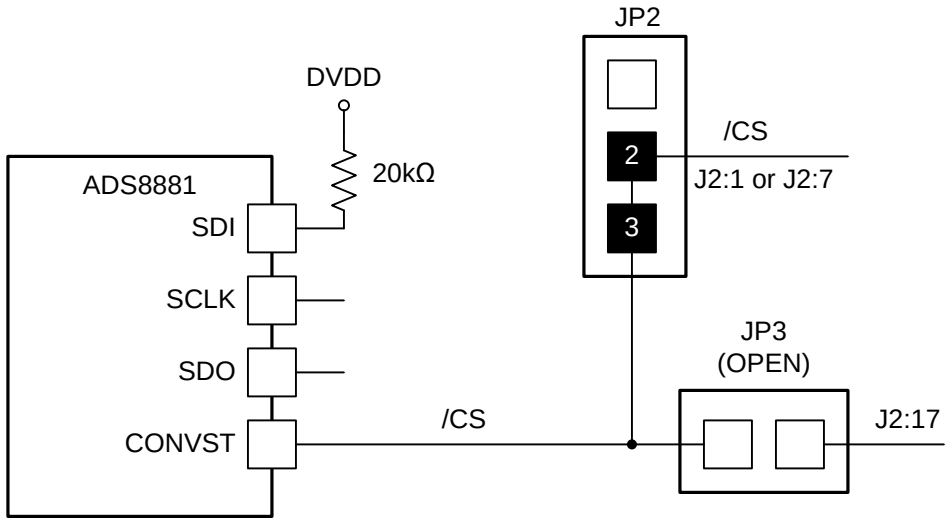


Figure 4. Serial 3-Wire Configuration

5.2 SPI 4-Wire Mode (JP2:1–2 and JP3:CLOSED)

The chip-select signal is used to bring the ADS8881 digital output out of Tri-State. However, conversion is initialized from J3:17 as an independent signal. The rising edge of J3:17 (CONVST) starts a conversion, then after conversion time the falling edge of chip-select brings the digital output out of Tri-State.

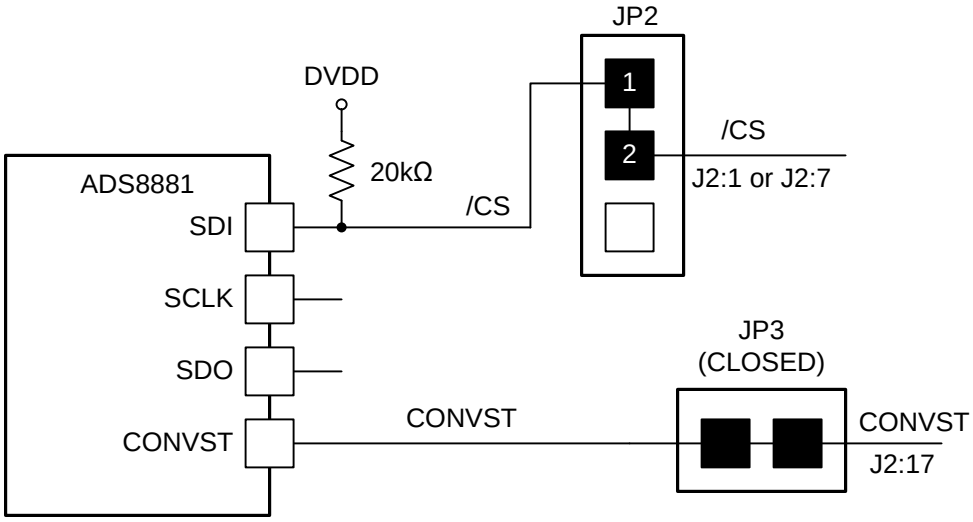


Figure 5. Serial 4-Wire Configuration

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6 PDK Kit Setup

CAUTION

Do not connect the ADS8881EVM-PDK to a PC before completing Section 6. Failure to observe this caution may cause Microsoft Windows to disregard the ADS8881EVM-PDK as a connected device.

This section presents the steps required to set up the ADS8881EVM-PDK kit before operating it.Section 7 explains how to operate the kit to acquire and analyze data.

The steps to setup the kit are the following and must be completed before attempting to capture data:

Step 1. Download and install the ADCPro software (if not already installed) on a PC.

Step 2. Download and install the ADS8881EVM-PDK EVM plug-in software.

Step 3. Configure the ADS8881EVM-PDK hardware.

Step 4. Power up the ADS8881EVM-PDK.

Each task is described in the subsequent sections of this document.

6.1 Installing the ADCPro™ Software

ADCPro is the primary program used to evaluate the ADS8881. It is available from the TI website at www.ti.com/tool/adcpro. Refer to the *ADCPro User's Guide* (literature number: SBAU128) for detailed installing instructions.

6.2 Installing ADS8881EVM-PDK Plug-In Software

NOTE: ADCPro should be installed before attempting to install the ADS8881EVM-PDK plug-in software.

The installation file link for the PDK plug-in can be found in the ADS8881EVM-PDK product folder at www.ti.com/tool/ads8881evm-pdk. In the software section look for a link with a file named **ads888x-adcproplugin-<version #>.exe** (<*version #*> refers to the installation file version number, and increments with software version releases). Download and double-click the file to run it; then follow the instructions as shown.

Figure 6 shows the initial and completed installer screenshots, respectively.

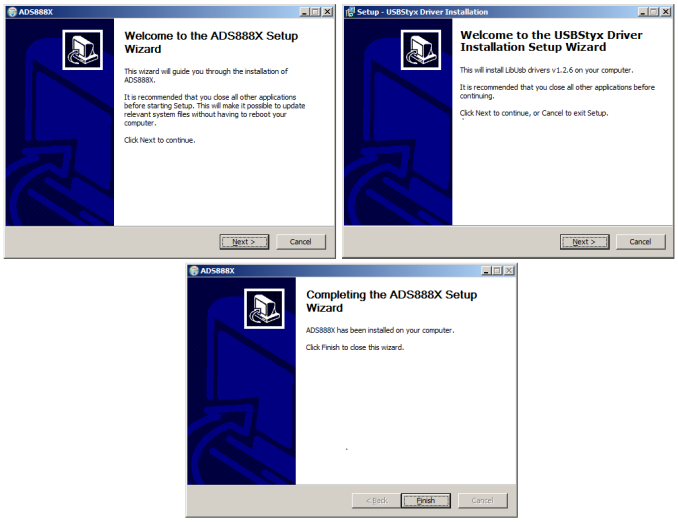


Figure 6. Plug-In Installer

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6.3 Configuring the ADS8881EVM-PDK Hardware

The ADS8881EVM-PDK contains both the ADS8881EVM and the MMB0 motherboard; however, the devices may be shipped unconnected or configured incorrectly. Follow these steps to verify that ADS8881EVM-PDK kit is properly configured and connected.

Step 1. Unpack the ADS8880EVM-PDK kit.

Step 2. Set the J12 to closed, J13A to open, and J13B to closed on the MMB0 as shown in Figure 7.

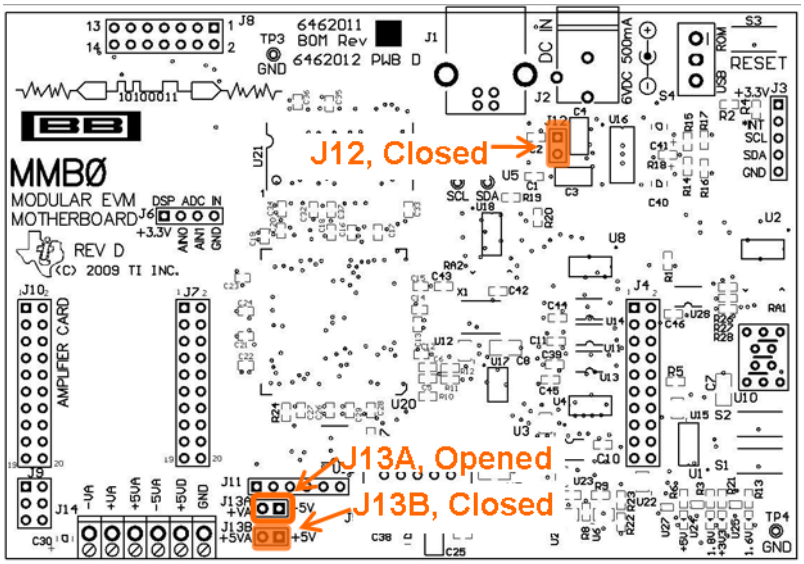


Figure 7. MMB0 Motherboard Jumper Configuration

- J12 must be closed. This setting allows the wall supply to power up the MMB0 and the ADS8880EVM through J2 (6-VDC input), and regulate down to 5 V, 3.3 V.
- J13B must be closed. This connects the 5-V analog power supply with the 5-V digital power supply.
- J13A must be opened. This setting allows the 5-V analog power supply to be regulated on board.

Step 3. Set JP1:2–3, JP2:2–3, and JP3:open on the ADS8881EVM as shown in Figure 8.

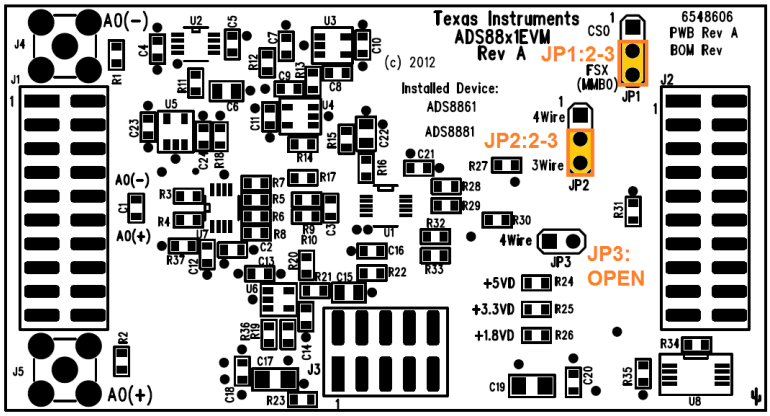


Figure 8. ADS8881EVM Jumper Configuration

Step 4. Plug the ADS8881EVM into the MMB0.

CAUTION

Do not misalign the pins when plugging the ADS8881EVM into the MMB0. Check the pin alignment carefully before applying power to the PDK.

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6.4 Powering up the ADS8881EVM-PDK.

Once the ADS8881EVM-PDK kit is configured, power can be applied to the MMB0. This power comes from a wall supply that delivers 6 VDC to the MMB0 through J2 on the MMB0 motherboard. This wall power supply is included with the PDK.

After the power supply is connected, four green light emitting diodes (LEDs) in the bottom right-hand corner of the MMB0 motherboard should light up. If these LEDs do not light up, disconnect the power and verify that J12 is closed on the MMB0 motherboard.

7 PDK Kit Operation

The evaluation software is based on ADCPro. This program operates using a variety of plug-ins. To use ADCPro, load an EVM plug-in and a test plug-in (select them from the EVM and Test menus, respectively). To unload a plug-in, select the Unload option from the corresponding menu.

The following sections describe how to use ADCPro and the ADS8881EVM plug-in to acquire data.

7.1 About MMB0

The MMB0 provides the USB interface between the PC and the ADS8881EVM. The MMB0 is a modular EVM system motherboard. It is designed around the TMS320VC5509, a DSP with an onboard USB interface from Texas Instruments. The MMB0 also has 16 MB of SDRAM installed.

The MMB0 is not sold as a DSP development board, and it is not available separately. TI cannot offer support for the MMB0 except as part of an EVM kit. For schematics or other information about the MMB0, contact Texas Instruments.

7.2 Loading the ADS8881EVM-PDK Plug-in

Step 1. Make sure the PDK kit is configured and powered up as explained in Section 6. Then, press the **Reset** button on the MMB0 (in the top right-hand corner) once to clear the board memory.

Step 2. Connect the MMB0 to a PC using the USB cable provided with the kit.

Step 3. Start ADCPro from the Windows *Start* menu.

Step 4. Load the ADS888XEVM plug-in from the ADCPro drop-down *EVM* menu; see Figure 9. Note that only one EVM plug-in can be loaded at a time. If a different plug-in is selected, the previous plug-in is unloaded.

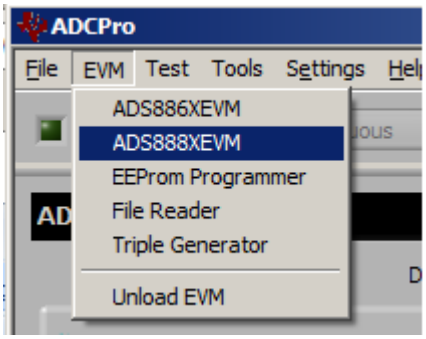


Figure 9. Loading EVM Plug-in

Step 5. When the plug-in is loaded, the plug-in searches for the board. A series of messages in the status area indicates this action, eventually showing *Connected to EVM*.

The plug-in is now loaded and ready to work with the ADS8881EVM.

7.3 Using the ADS8881EVM Plug-in

The ADS8881EVM allows the user to evaluate the ADS8881 ADC. Figure 10 shows the device configuration tab of the ADS8881EVM plug-in that is used to change acquisition parameters such as sample rate and voltage reference.

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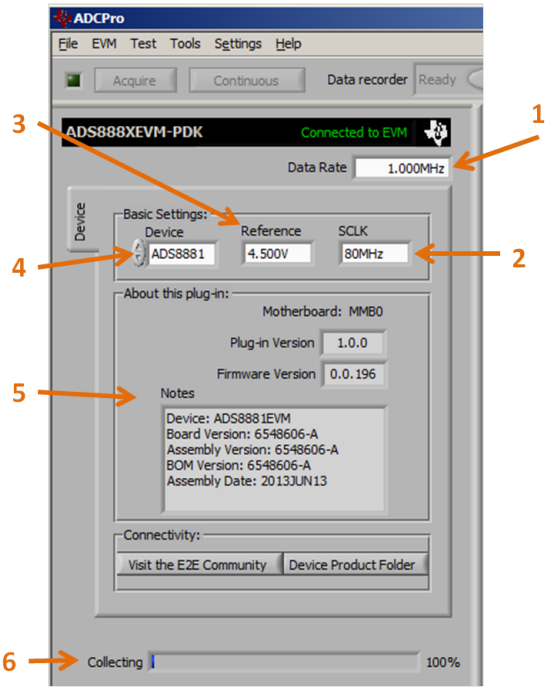


Figure 10. ADS8881EVM Plug-in: Device Configuration Tab

The device configuration tab contains the following controls.

Data Rate— By default, it is 1 MSPS. This control shows the data rate or sampling frequency used by the ADC to acquire data. With SCLK frequency of 80 MHz, it can be set to be values between 19.536-KSPS to 1-MSPS. With SCLK frequency of 10-MHz, it can be set to a value between 4 KSPS to 344.827-KSPS.

SCLK— By default, it is 80 MHz. Sets the clock frequency used by the SPI interface to capture data. It should be a value between 70 MHz to 80 MHz for 1 MSPS. For slow sampling rates, use 10 MHz. Do not use SLCK frequencies between 30 MHz and 50 MHz.

Reference— By default, it is 4.5 V, which matches the on-board reference of the EVM. The value of this control should always match the reference used by the ADC to read accurate voltages.

Device Information— By default is ADS8881, and it cannot be modified.

About— This control shows the plug-in version, MMB0 firmware version, ADS8881EVM assembly date, and ADS8881EVM board revision information.

Collection Bar— This feature shows the percentage of data collected during an acquisition session.

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7.4 Loading Test Plug-in

Once the ADS8881EVM plug-in is configured, one of the four test plug-ins must be loaded to acquire data. Using the drop-down Test menu, as shown in Figure 11. Note that only one Test plug-in can be loaded at a time. If a different plug-in is selected, the previous plug-in is unloaded.

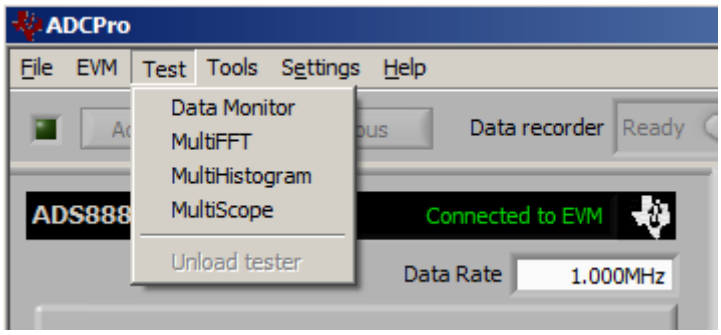


Figure 11. ADCPro Test Plug-ins

There are four different test options available for the ADS8881EVM:

- **Data monitor:** This test acquires data and exports it in table format as hexadecimal data.
- **MultiFFT:** This test allows the user to acquire data and create an FFT graph of power vs. frequency to display data.
- **MultiHistogram:** This option acquires data and creates a histogram of code values.
- **MultiScope:** This feature acquires data and displays it in a graph of voltage vs. time.

For further details regarding how to set up and use the various test plug-ins, refer to the *ADCPro User's Guide* (literature number: SBAU128).

7.5 Acquiring Data

Once the ADS8881EVM is configured for the desired test scenario, press the **Acquire** button to start the data collection process; the software collects the number of data points specified in the *Test* plug-in **Block Size** control. While acquiring data, the ADS8881EVM plug-in disables all front panel controls, and the collection process bar displays the completion progress.

7.6 Troubleshooting

If the ADS8881EVM plug-in cannot find the ADS8881EVM-PDK, press the **RESET** button on the MMB0 and try again.

If ADCPro stops responding while the ADS8881EVM-PDK is connected, shut down and restart the ADCPro software. Also, try unplugging the USB cable from the PDK.

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8 Bill of Materials, Schematics, and Layout

Schematics for the ADS8881EVM are appended to this user's guide. The bill of materials is provided in Table 5. Section 8.2 shows the PCB layouts for the ADS8881EVM.

8.1 Bill of Materials

NOTE: All components should be compliant with the European Union Restriction on Use of Hazardous Substances (RoHS) Directive. Some part numbers may be either leaded or RoHS. Verify that purchased components are RoHS-compliant. (For more information about TI's position on RoHS compliance, see the http://www.ti.com.)

Table 5. ADS8881EVM Bill of Materials

Item No.	Qty	Value	Ref Des	Description	Manufacturer	Part Number
1	1	—		Printed Circuit Board, 3.2 in x 1.7 In. x 0.062 in.	Texas Instruments	6548606
2	1	—	C1	Not Installed	—	—
3	5	0.1 µF	C2, C10, C11, C14, C23	Capacitor, X7R Ceramic ±10%, 25WV, 0603	Murata	GRM188R71E104KA01D
4	1	10000 pF	C3	Capacitor, NP0 Ceramic ±5%, 50WV, 0603	TDK	C1608C0G1H103J
5	9	1 µF	C4, C5, C7, C8, C9, C12, C13, C21, C24	Capacitor, X7R Ceramic ±10%, 25WV, 0603	Murata	GRM188R71E105KA12D
6	3	10 µF	C6, C15, C22	Capacitor, X7R Ceramic ±10%, 10WV, 0805	Murata	GRM21BR71A106KE51L
7	3	1000 pF	C16, C18, C20	Capacitor, C0G Ceramic ±5%, 50WV, 0603	Murata	GRM1885C1H102JA01D
8	2	10 µF	C17, C19	Capacitor, X7R Ceramic ±10%, 16WV, 1206	TDK	C3216X7R1C106K
9	2	—	J1, J2 (Top)	Header 20 Pin SMT Plug, .100" Gold (2x10)	Samtec	TSM-110-01-L-DV-P
10	2	—	J1, J2 (Bottom)	Header 20 Pin SMT Socket, .100" Gold (2x10)	Samtec	SSW-110-22-F-D-VS-K
11	1	—	J3 (Top)	Header 10 Pin SMT Plug, .100" Gold (2x5)	Samtec	TSM-105-01-L-DV-P
12	1	—	J3 (Bottom)	Header 10 Pin SMT Socket, .100" Gold (2x5)	Samtec	SSW-105-22-F-D-VS-K
13	2	—	J4, J5	CONN SMA JACK STRAIGHT PCB	Amphenol	132134
14	2	—	JP1, JP2	Header Strip, 3 pin .100" Gold (1x3)	Samtec	TSW-103-07-L-S
15	1	—	JP3	Header Strip, 2 pin .100" Gold (1x2)	Samtec	TSW-102-07-L-S
16	7	—	R1, R2, R20, R24, R26, R34, R36	Not Installed	—	—
17	4	1k	R3, R4, R5, R6	Resistor, Thin Film Chip, 0.1%, 1/10W, 0603	Panasonic	ERA-3AEB102V
18	5	10	R7, R8, R9, R10, R22	Resistor, Thick Film Chip, 1%, 1/10W, 0603	Vishay/Dale	CRCW060310R0FKEA
19	3	0.22	R11, R16, R21	Resistor, Thin Film Chip, 1%, 1/5W, 0603	Susumu	RL0816S-R22-F
20	3	1k	R12, R13, R37	Resistor, Thick Film Chip, 1%, 1/10W, 0603	Panasonic	ERJ-3EKF1001V
21	5	0	R14, R19, R23, R25, R30	Resistor, Thick Film Chip, 1/10W, 0603	Panasonic	ERJ-3GEY0R00V
22	5	20k	R15, R17, R18, R27, R31	Resistor, Thick Film Chip, 1%, 1/10W, 0603	Panasonic	ERJ-3EKF2002V
23	5	47	R28, R29, R32, R33, R35	Resistor, Thick Film Chip, 1%, 1/10W, 0603	Panasonic	ERJ-3EKF47R0V
24	1	—	U1	IC ADC 18-bit 1MSPS Fully Diff 10-MSOP	Texas Instruments	ADS8881IDGS
25	1	—	U2	IC VREF SERIES PREC 4.5V 8-MSOP	Texas Instruments	REF5045IDGK

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Table 5. ADS8881EVM Bill of Materials (continued)

Item No.	Qty	Value	Ref Des	Description	Manufacturer	Part Number
26	1	—	U3	IC OPAMP CHOP R-R 350KHZ SOT23-5	Texas Instruments	OPA333AIDBV
27	1	—	U4	IC OPAMP VFB R-R 95MHZ SOT23-5	Texas Instruments	THS4281DBV
28	1	—	U5	IC OPAMP GP R-R CMOS SOT23-5	Texas Instruments	OPA330AIDBV
29	1	—	U6	IC REG LDO 3.3V .15A SOT-23-5	Texas Instruments	TPS78833DBV
30	1	—	U7	IC OPAMP DIFF R-R 145MHZ 8MSOP	Texas Instruments	THS4521IDGK
31	1	—	U8	IC EEPROM 256KBIT 400KHZ 8TSSOP	Microchip	24LC256-I/ST
32	2	—	—	0.100 Shunt - Black Shunts	3M	969102-0000-DA

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8.2 Board Layouts

Figure 12 through Figure 15 show the PCB layouts for the ADS8881EVM.

NOTE: Board layouts are not to scale. These figures are intended to show how the board is laid out; they are not intended to be used for manufacturing ADS8881EVM PCBs.

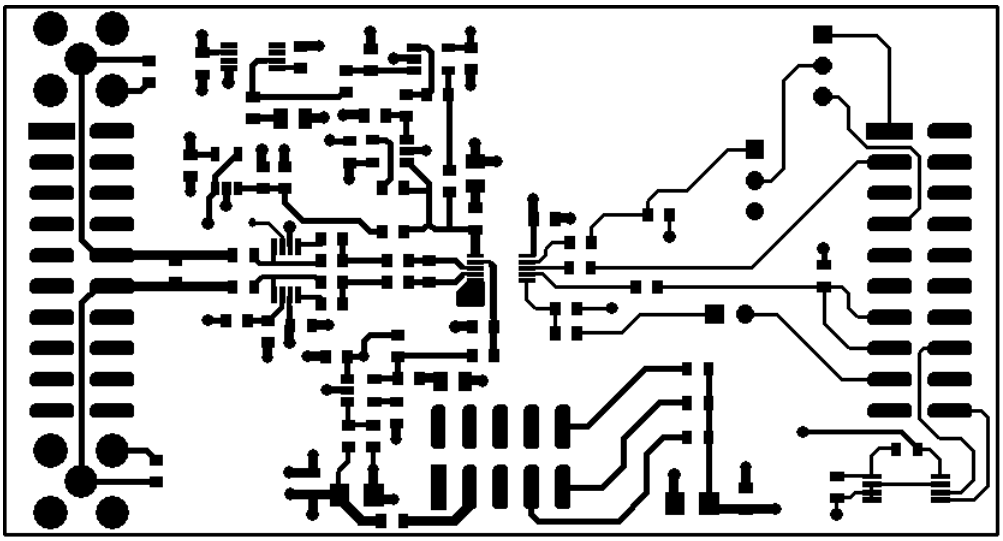


Figure 12. ADS8881EVM PCB: Top Layer

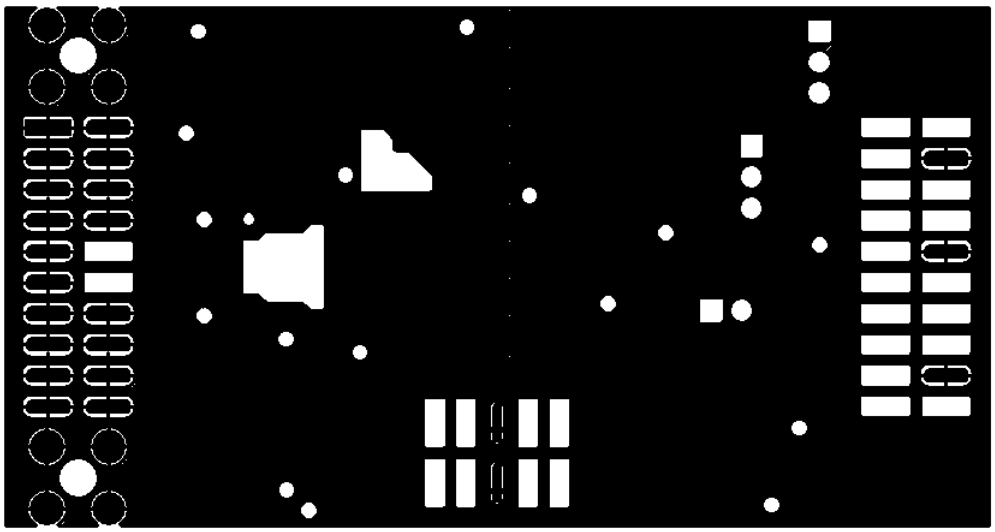


Figure 13. ADS8881EVM PCB: Ground Layer

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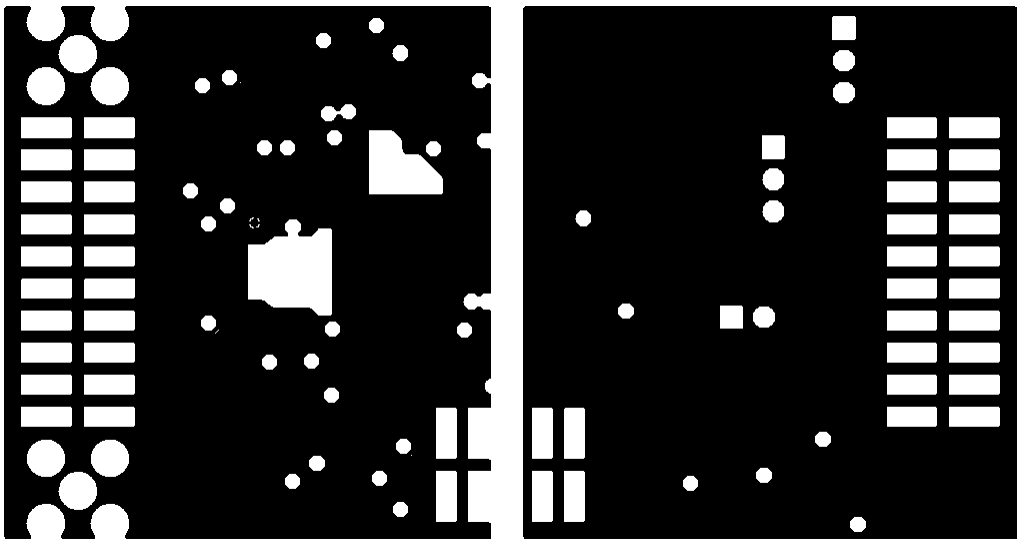


Figure 14. ADS8881EVM PCB: Power Layer

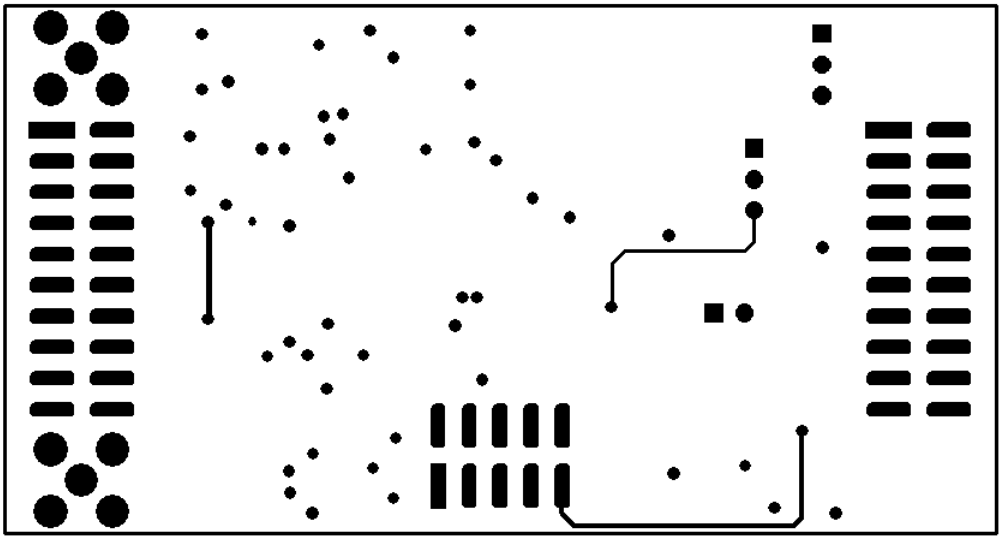
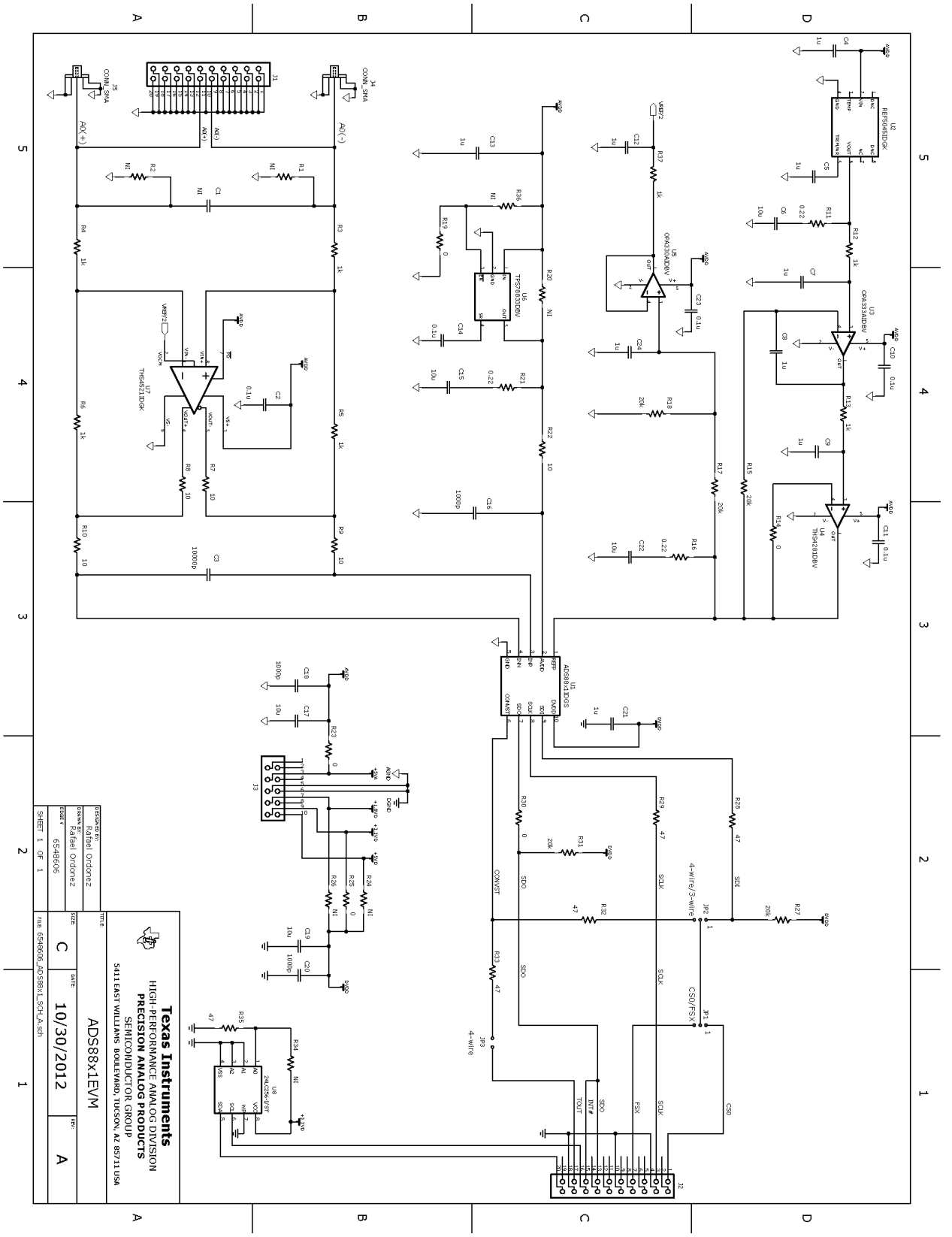


Figure 15. ADS8881EVM PCB: Bottom Layer

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8.3 Schematic



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It is important to operate this EVM within the input voltage range of –5 V to 5 V and the output voltage range of 0 V to 5 V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 27°C. The EVM is designed to operate properly with certain components above 60°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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