

ADS1x2U04 Evaluation Module

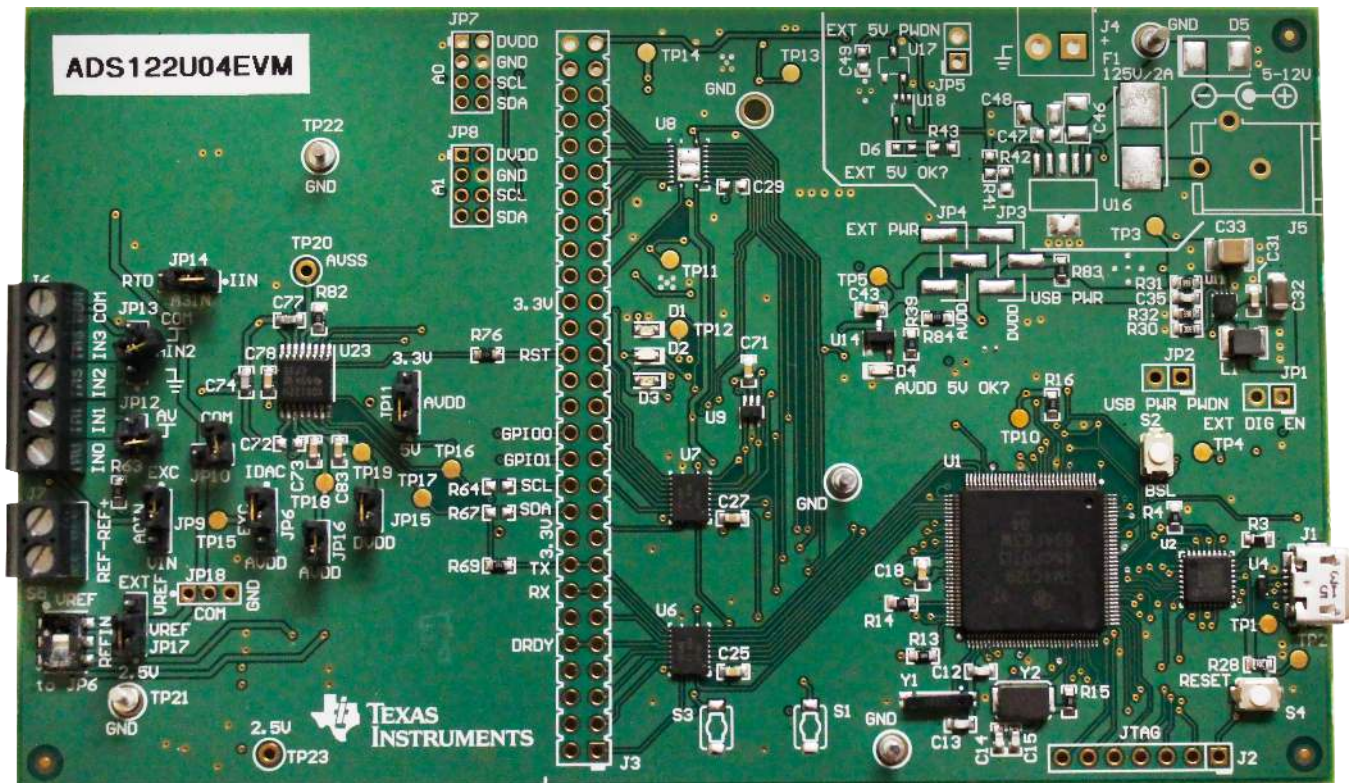


Figure 1. ADS1x2U04 Evaluation Module (ADS122U04EVM Shown)

The ADS1x2U04EVM is an evaluation module kit that provides hardware and software support for evaluation of the devices in the ADS122U04 family. The ADS122U04 is a 24-bit delta-sigma analog-to-digital converter (ADC). The kit utilizes the TM4C1294NCPDT processor to communicate with the ADC via UART and provide communication with a PC over USB interface. The kit also includes a software application that runs on a PC allowing for register manipulation and data collection from the ADC. The ADS1x2U04EVM kit includes the ADS1x2U04 device along with a USB micro cable, and downloadable supporting software (SW).

This document includes a detailed description of the hardware (HW), software, bill of materials (BOM), and schematic for the ADS1x2U04EVM.

Throughout this document the term *EVM* is synonymous with *ADS1x2U04EVM*, *demonstration kit*, and *evaluation module*. The term *ADS1x2U04EVM* is a generic name that applies to any EVM in the ADS122U04 device family. Specifically, the ADS122U04EVM uses the ADS122U04 as the main device on the EVM. The term *GUI* is synonymous with *Delta-Sigma ADC Evaluation Software*, core application, and EVM software. The use of *Tiva™* is synonymous with the TM4C1294NCPDT microcontroller.

Table 1. Related Documentation

Device	Literature Number
ADS122U04	SBAS752

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1 EVM Overview

1.1 Description

This user guide describes the operation and use of the ADS1x2U04 evaluation module. One example is the ADS122U04EVM. The ADS122U04 is a 24-bit, 2-kSPS, 4-channel delta-sigma analog-to-digital converter (ADC) for precision sensor measurement applications. The ADS1x2U04EVM platform is intended for evaluating the ADS122U04 device family for performance and functionality.

1.2 Requirements

1.2.1 Software Requirements

PC with Microsoft® Windows® 7 or higher operating system.

1.2.2 Hardware Requirements

PC with available USB 2.0 or greater connection.

1.2.2.1 Power Supply

USB powered.

1.3 Software Reference

Refer to the *Delta-Sigma ADC Evaluation Software User Manual* ([SBAU260](#)) for the core software documentation or navigate to the *File -> About* option from within the GUI, then click on the *Software user guide* icon.

1.4 Supported Functionality

1.4.1 Supported Hardware Functionality

- Unipolar (3.3 V or 5 V) AVDD and AVSS (GND) supply operation
- 3.3-V DVDD
- Digital header for external processor or controller configuration
- Configurable for direct sensor input
- Onboard 2.5-V reference or user-supplied external ADC voltage reference

1.4.2 Supported Software Functionality

- Start/sync control
- Device software reset
- Device sleep
- Register read and write
- Conversion result readback
- Missed conversion detection through data conversion result counter information
- Data integrity check by CRC of data or by inverted conversion result

2 Quick Start

This section provides a guide to quickly begin using the EVM.

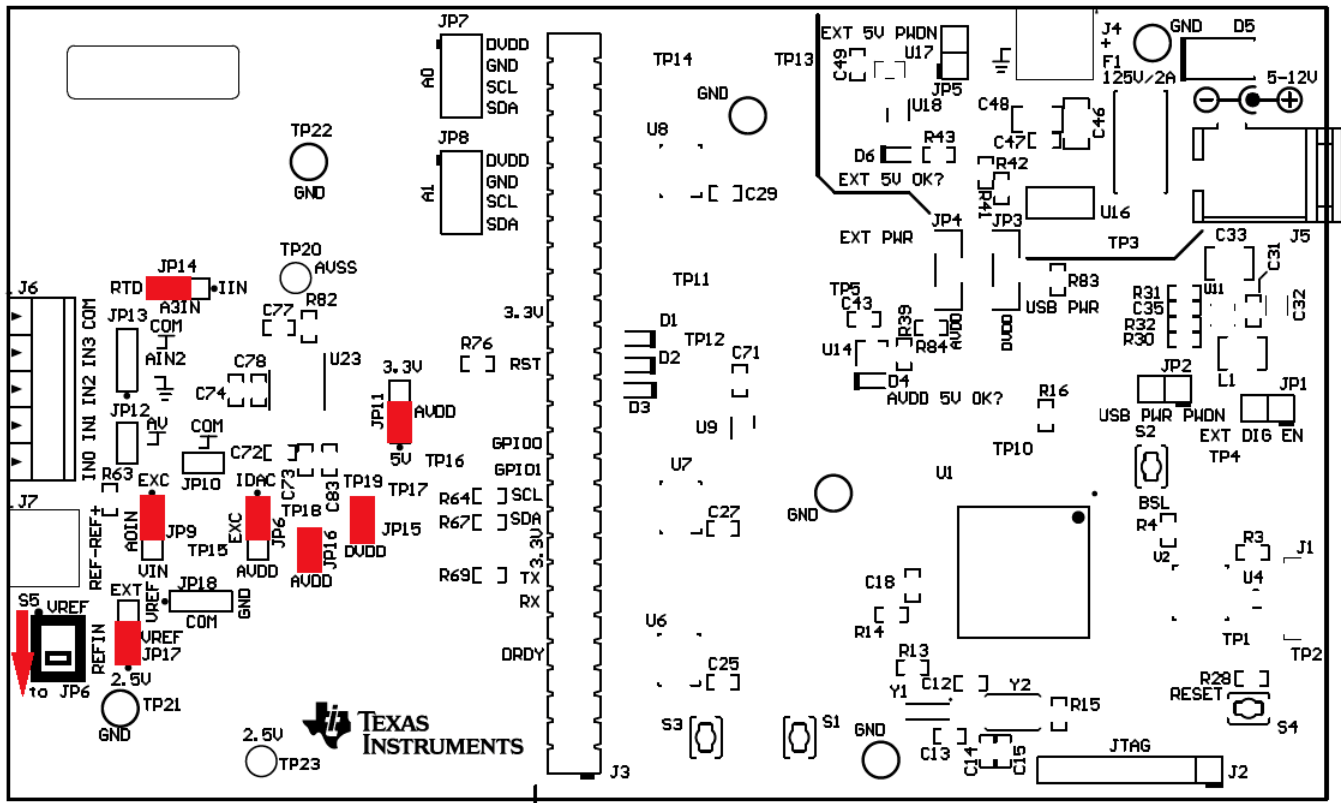
2.1 Default Jumper and Switch Configuration

The EVM should come configured with the settings listed in [Table 2](#) and illustrated in [Figure 2](#).

Table 2. Default Settings

Jumper	Position	Function
JP1	Not Installed	Use onboard processor
JP2	Not Installed	USB-derived supplies ON
JP3	Not Installed	DVDD from USB supply (1-2 connection via R83)
JP4	Not Installed	AVDD from USB supply (1-2 connection via R84)
JP5	Not Installed	N/A
JP6 ⁽¹⁾	1-2	Excitation source connected to IDAC using REFP
JP7	Not Installed	N/A
JP8	Not Installed	N/A
JP9 ⁽¹⁾	1-2	J6 pin 5 connected to excitation source
JP10	Not Installed	AIN0 not connected to input voltage divider
JP11 ⁽¹⁾	1-2	AVDD supply sourced from 5 V
JP12	Not Installed	Weak pullup to AVDD not connected to AIN1
JP13 ⁽¹⁾	Not Installed	Weak pulldown to GND not connected to AIN2
JP14 ⁽¹⁾	2-3	RTD bias pedestal connected
JP15	Installed	DVDD supply connected
JP16	Installed	AVDD supply connected
JP17 ⁽¹⁾	1-2	VREF is supplied by the 2.5-V onboard reference (U24)
JP18 ⁽¹⁾	Not Installed	COM connected to GND (2-3 connection via R90)
Switch	Position	Function
S5	Down	External reference connected to JP6

⁽¹⁾ Pin 1 is identified with a dot on the PCB silkscreen.


Figure 2. ADS1x2U04 EVM

2.2 Power Connection

The EVM is powered through the USB interface with the PC. Connect the EVM to a USB connector on the PC to power the board.

2.3 Startup

Use the following steps at startup:

1. Install the core application software on the PC.
2. Install the device software on the PC. (For example, *ADS122U04 Device Package* for the ADS122U04EVM.)
3. Ensure all jumpers and switches are configured in the default configuration per [Table 2](#) and [Figure 2](#).
4. Connect the EVM to the PC using a USB cable.
5. If prompted, install any required drivers.
6. Start the GUI software on your PC.

NOTE: The device has powered correctly if D1 and D4 are both lit green.

3 Hardware Reference

3.1 Jumper and Switch Configuration Reference

[Table 3](#) provides all jumper and switch configuration settings for the EVM.

Table 3. Jumper and Switch Options

Jumper	Position	Description
JP1	Operation of EVM with external digital signals	
	Installed (ON)	Hold Tiva processor (U1) in reset and disable level shifters to allow external digital signals
	Uninstalled (OFF)	Normal operation with onboard Tiva processor (default)
JP2	Power down USB power supplies	
	Installed (ON)	USB-derived power supplies disabled and powered down
	Uninstalled (OFF)	USB-derived power supplies enabled and ON (default)
JP3	Digital supply source	
	1-2 shorted	Provided from USB power (default using R83 as the short)
	2-3 shorted	External supply source
	Open	No digital system power provided
JP4	Analog supply source	
	1-2 shorted	Provided from USB power (default using R84 as the short)
	2-3 shorted	External supply source
	Open	No analog system power provided
JP5	External 5-V power down	
	Installed (ON)	External supply regulator (U16) disabled and powered down
	Uninstalled (OFF)	External supply regulator (U16) enabled and ON (default)
JP6 ⁽¹⁾	AIN0 input connection (U23)	
	1-2 shorted	Current excitation possible when S5 is in the down position to JP6 (default)
	2-3 shorted	Voltage excitation through AVDD
	Open	Not connected to an excitation source
JP7	Not installed	
	1-2 shorted	N/A
	3-4 shorted	N/A
	5-6 shorted	N/A
	7-8 shorted	N/A
	Open	(default)
JP8	Not installed	
	1-2 shorted	N/A
	3-4 shorted	N/A
	5-6 shorted	N/A
	7-8 shorted	N/A
	Open	(default)
JP9 ⁽¹⁾	AIN0 input from J6 pin 5	
	1-2 shorted	Excitation source from JP6 connected to J6, pin 5 (default)
	2-3 shorted	J6, pin 5 voltage divider input
	Open	J6 disconnected from AIN0 (isolates J6 from input when RT1 is installed)
JP10	Input voltage divider connection to analog COM	
	Installed (ON)	Voltage divider connects to analog COM (COM connects to AGND via R90)
	Uninstalled (OFF)	Voltage divider is not used and disconnected from analog COM (default)
JP11 ⁽¹⁾	ADC AVDD supply (U23)	
	1-2 shorted	AVDD supply powered from 5 V (default)
	2-3 shorted	AVDD supply powered from DVDD supply at 3.3 V
	Open	No supply powering AVDD
JP12	AIN1 input from J6 pin 4	
	Installed (ON)	AIN1 weak pullup useful for thermocouple sensor input biasing
	Uninstalled (OFF)	No pullup to AIN1 (default)

Table 3. Jumper and Switch Options (continued)

Jumper	Position	Description
JP13 ⁽¹⁾	AIN2 input from J6 pin 3	
	1-2 shorted	AIN2 weak pulldown useful for thermocouple sensor input biasing
	2-3 shorted	AIN2 connection to J6 pin 1 (and connected to analog COM)
	Open	AIN2 connected to J6 pin 3 only (default)
JP14 ⁽¹⁾	AIN3 input from J6 pin 2	
	1-2 shorted	AIN3 connected to current shunt resistor R80
	2-3 shorted	AIN3 connected to RTD pedestal biasing resistor R79 (default)
	Open	AIN3 connected to J6 pin 2 only
JP15	ADC DVDD supply (U23)	
	Installed (ON)	DVDD supply powered from digital 3.3-V source (default)
	Uninstalled (OFF)	No supply powering DVDD (connection is useful for direct current measurement)
JP16	ADC AVDD supply (U26)	
	Installed (ON)	AVDD supply pin powered from selection of JP11 (3.3 V or 5 V) (default)
	Uninstalled (OFF)	No supply powering AVDD (connection is useful for direct current measurement)
JP17 ⁽¹⁾	ADC external reference input to VREF at S5	
	1-2 shorted	2.5-V onboard reference from U24 (default)
	2-3 shorted	External reference input from J7 pin 1
	Open	No VREF reference input to S5
JP18 ⁽¹⁾	Analog COM connection at J6 pin 1 (not installed)	
	1-2 shorted	COM connected to VREF
	2-3 shorted	COM connected to AGND (default via R90)
	Open	COM connected to J6 pin 1 only
Switch	Position	Description
S2 ⁽²⁾	BSL mode for <i>Device Firmware Update</i> (DFU)	
	Closed (on RESET)	Total Tiva FLASH erasure (on release Tiva enumerates as a DFU device)
	Open	Normal operation
S4 ⁽²⁾	Reset onboard controller (U1 $\overline{\text{RST}}$)	
	Closed	Tiva held in RESET
	Open	Normal operation
S5 ⁽³⁾	External reference input	
	Up (VREF connection via JP17)	JP17, 1-2 connects to 2.5-V onboard reference (U24) or JP17, 2-3 connects to the J7 input
	Down (to JP6)	JP6, 1-2 connects the IDAC current source or JP6, 2-3 connects the AVDD voltage source

⁽¹⁾ Pin 1 is identified with a dot on the PCB silkscreen.

⁽²⁾ Switch is momentary and normally open. Switch is closed when depressed.

⁽³⁾ Switch is DPDT. Pin 1 is identified with a dot on the PCB silkscreen.

3.2 Header, Connector and Test Point Reference

This section provides connection information for all of the connectors and test points utilized on the EVM.

3.2.1 Analog Input Terminal Blocks

Analog input to the EVM can be connected at the terminal blocks located on the left side of the board (see [Figure 3](#)) to provide an external analog signal input to the EVM for evaluation purposes. The functions for these terminal blocks are listed in [Table 4](#) and [Table 5](#). Information and connection diagrams for direct sensor input are detailed in [Section 5.1](#). At no time should a voltage be applied that exceeds the absolute maximum ratings for the input of the ADS1x2U04. The only exception is when measuring an external voltage as discussed in [Section 5.1.4](#).



Figure 3. Input Terminal Blocks

Table 4. Analog Input Terminal Block, J6

Function	Signal Name	Pin
Analog common	COM	1
Analog input to ADC (excitation return current)	IN3 (AIN3)	2
Analog input to ADC	IN2 (AIN2)	3
Analog input to ADC	IN1 (AIN1)	4
Analog input to ADC (voltage excitation or current source output for 2-, 3-, and 4-wire RTD)	IN0 (AIN0)	5

Table 5. Analog Input Terminal Block, J7

Function	Signal Name	Pin
Analog external voltage reference + input to ADC (REFP via S5)	REF+	1
Analog external voltage reference – input voltage to ADC (REFN via S5) ⁽¹⁾	REF–	2

⁽¹⁾ REF- from J7 pin 2 connects to analog ground (AGND) through resistor R85. R85 can be removed for a non-ground referenced differential input.

3.2.2 Digital Interface Header

Table 6 lists the functions and pin numbers for all signals used on the digital interface.

Table 6. Digital Interface, J3

Function	ADC Side		Processor Side	
	Signal Name	Pin Number ⁽¹⁾	Pin Number ⁽²⁾	Signal Name
External voltage input	GND	56	55	EXT_5V
Bank2 level-shifter voltage	DVDD	36	35	DIG_VOLT2
GPIO for ADC	ADC_RESET	32	31	GPIO_1
	ADC_GPIO0	26	25	GPIO_4
	ADC_GPIO1	24	23	GPIO_5
Bank1 level-shifter voltage	DVDD	18	17	DIG_VOLT1
Signaling and Communication	ADC_TX	16	15	UART_RX
	ADC_RX	14	13	UART_TX
	ADC_DRDY	10	9	SPI0_OTHERB

⁽¹⁾ Even-numbered pins not included are not connected.

⁽²⁾ Odd-numbered pins not included are connected to the Tiva microcontroller but the functionality is not used for this EVM. See Figure 32 for connection details.

3.2.3 Test Points

The test points listed in Table 7 may be used to probe onboard voltage supplies and signals.

Table 7. Useful Test Points

Function	Signal Name	Test Point	Restrictions
USB-sourced supply	USB_VBUS	TP1	Probe only
USB-sourced supply	USB_VBUSP	TP2	Probe only
5.5-V output (U11)	USB_IREG	TP3	Probe only
1.8-V output (U13)	1.8V	TP4	Probe only
5.0-V output (U12)	AVDD_5	TP5	Probe only
AGND = DGND = GND	GND	TP6 - TP9	AGND = DGND = GND
3.3-V output (U15)	DVDD_3.3V	TP10	Probe only
Voltage divider input to AIN0		TP15	Probe only
UART RX to ADC (U23)	ADC_RX	TP16	Probe only
UART TX from ADC (U23)	ADC_TX	TP17	Probe only
AVDD at ADC (U23)		TP18	Probe only
DVDD at ADC (U23)		TP19	Probe only
AVSS at ADC (U23)		TP20	Remove R82 connection to AGND if a different AVSS source voltage is applied
AGND = DGND = GND	GND	TP21 - TP22	AGND = DGND = GND
2.5-V output (U24)		TP23	

4 Software Details

4.1 Installing the Software

4.1.1 Delta-Sigma ADC Evaluation Software

Download the *Delta-Sigma ADC Evaluation Software* installer from the [EVM tool page](#) and save to a known folder. Run the installer and follow the on-screen prompts. Note that future software versions may show slightly different screens.

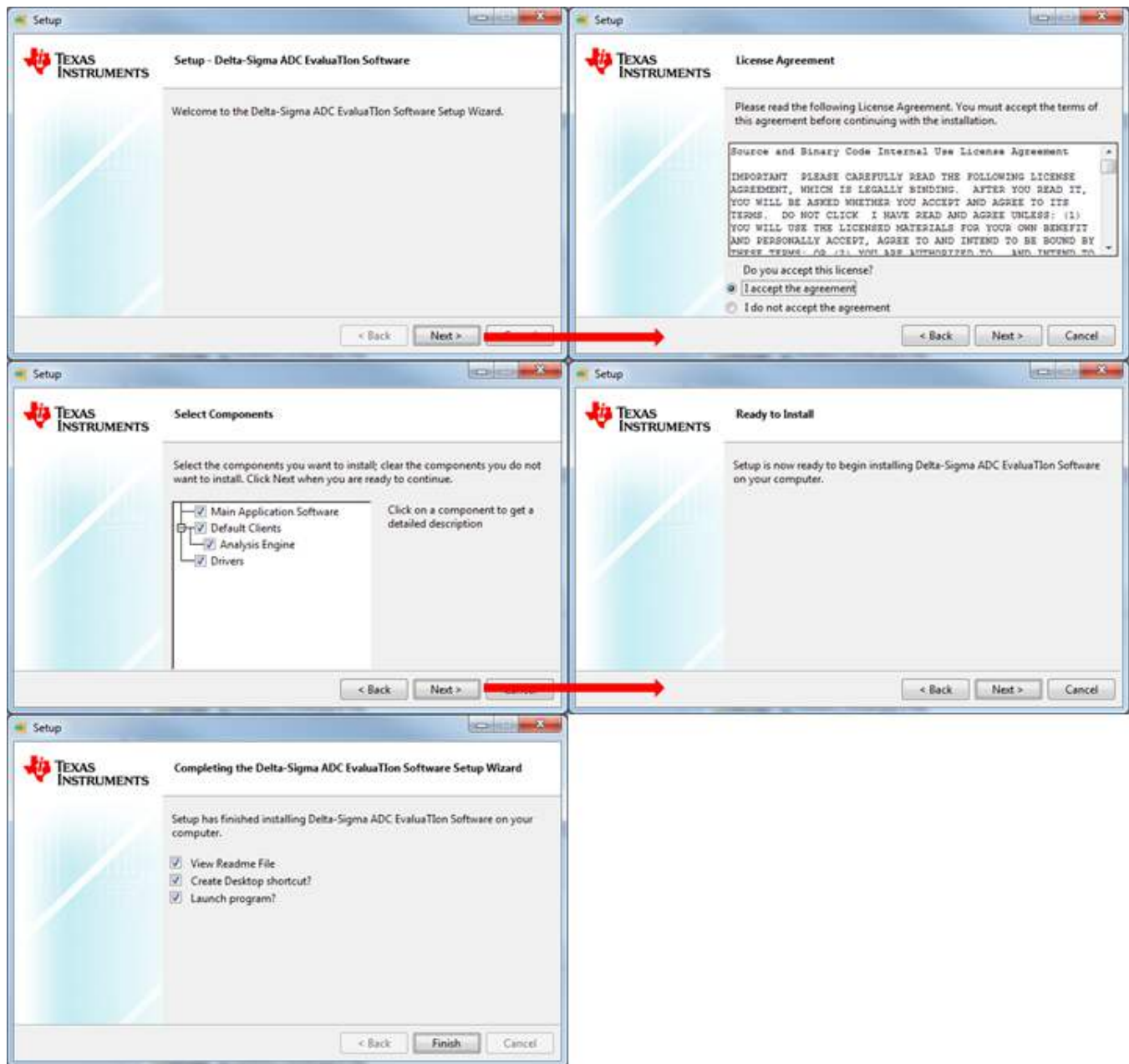


Figure 4. Delta-Sigma Evaluation Engine Installation Instructions

4.1.2 ADS1x2U04 Device Package

Download the appropriate *ADS1x2U04 Device Package* installer. For example, download the *ADS122U04 Device Package* from the [EVM tool page](#) and save to a known folder. Run the appropriate *ADS1x2U04 Device Package* installer and follow the on-screen prompts. Note that future software versions may show slightly different screens. The ADS122U04 device package installation is shown in [Figure 5](#).

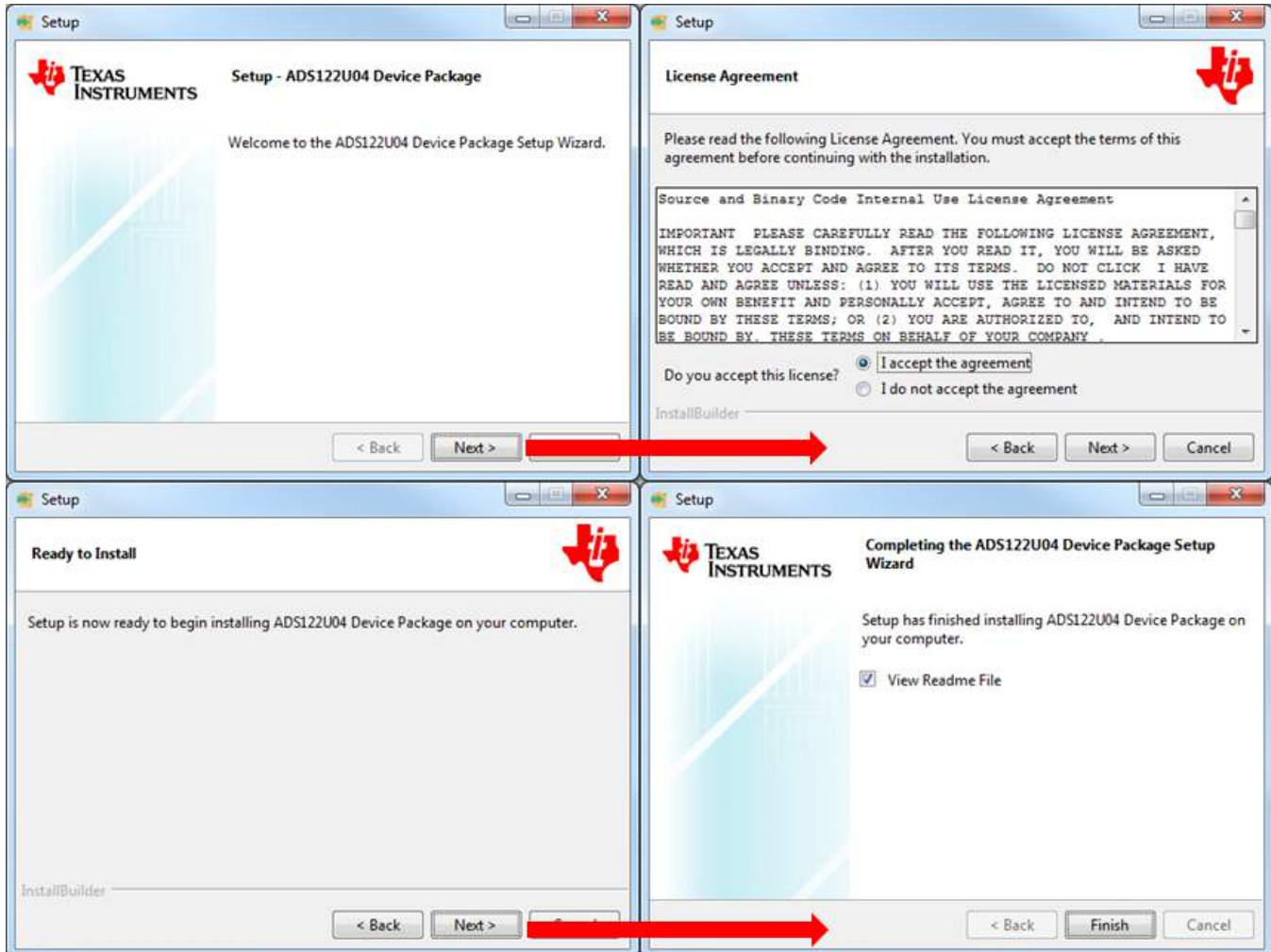


Figure 5. ADS1x2U04 Device Package Installation Instructions (ADS122U04 Shown)

4.2 Connecting to the EVM Hardware

After the *Delta-Sigma ADC Evaluation Software* and the *ADS1x2U04 Device Package* are installed, ensure that all jumpers and switches are in their default positions per [Table 2](#), and then connect the hardware with the provided USB micro cable. Start the *Delta-Sigma ADC Evaluation Software*. The GUI automatically detects the connected hardware and displays the device register map under the *Device* tab as shown in [Figure 6](#).

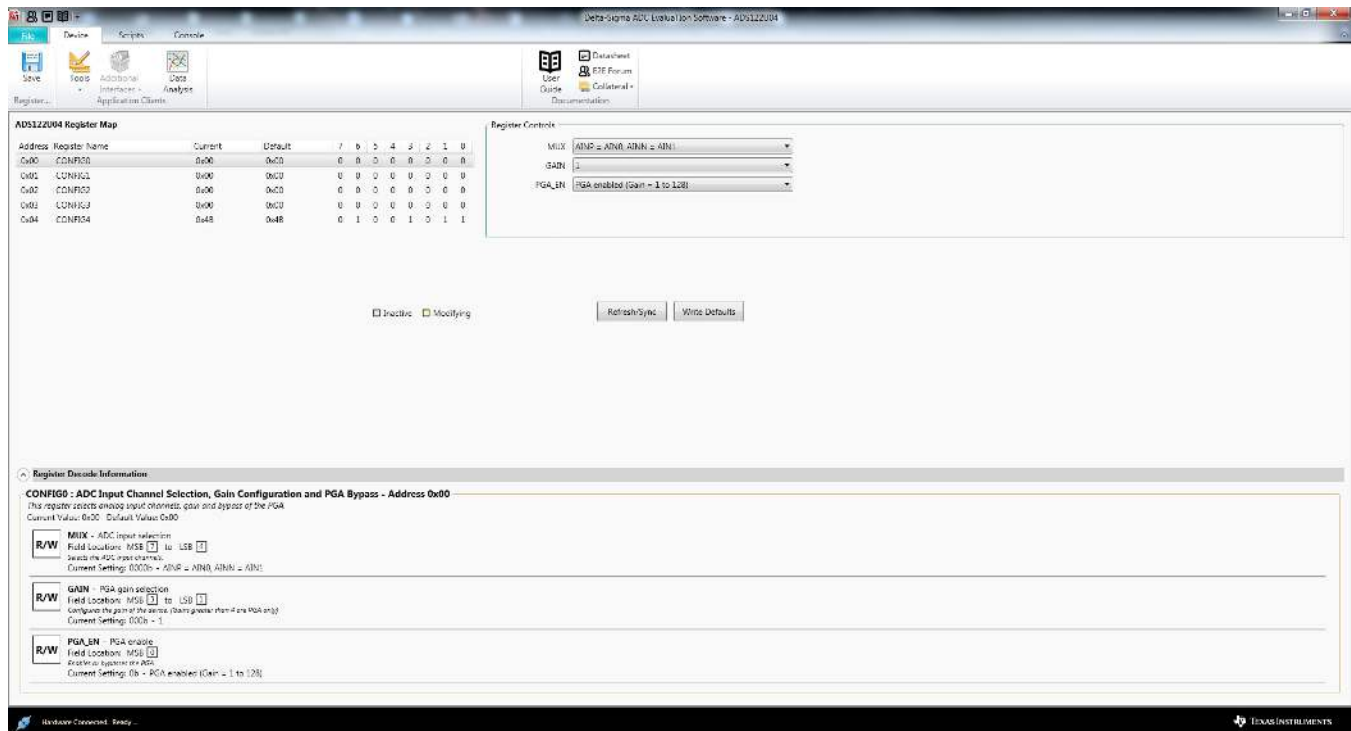


Figure 6. ADS1x2U04 Device Tab (ADS122U04 Shown)

4.3 Using the Software With the ADS1x2U04EVM

This section covers the functionality of the *ADS1x2U04 Device Package* only. For more information about the GUI operation and functionality, refer to the *Delta-Sigma ADC Evaluation Software User Manual (SBAU260)* for the core software documentation. A link to the documentation is also available by navigating to *File -> Options* from within the GUI.

Upon startup, the GUI scans for the connected hardware. Once the ADS1x2U04EVM is plugged into the USB, the *Device* tab refreshes to display the ADS1x2U04 *Register Map* as shown in [Figure 6](#). The *Device* tab also grants user control over register settings with a detailed description for the current values in each register. Click the *Refresh/Sync* button to read back the value in all registers and update the register map. Selecting a single register will provide a detailed description for the current values in the *Register Decode Information* panel below the register map (see the lower portion of [Figure 7](#)).

As an example for register configuration, [Figure 7](#) and [Figure 8](#) show specific details for the input *MUX* in the CONFIG0 register. In the figures are two columns showing the *Current* and *Default* values represented in hex for the ADS1x2U04 registers. There is also a column of the binary representation of the current register settings. The default settings shown are not necessarily the device power-up default values, but rather the default settings used by the GUI for proper communication and timing. Some of the settings cannot be changed by the user within the GUI.

In the *Register Control* section are drop-down menu options for each available setting for the register. Using the CONFIG0 register as an example, the upper 4 bits correspond to the input *MUX* selection. The drop-down menu items are shown for the *MUX* selection in [Figure 8](#) with the upper 4 bits highlighted. A similar action occurs for each of the registers resulting in the binary column having the affected bits highlighted by each selected menu drop down. In this way, the bit segments of the register can be identified for the menu items affecting the changes.

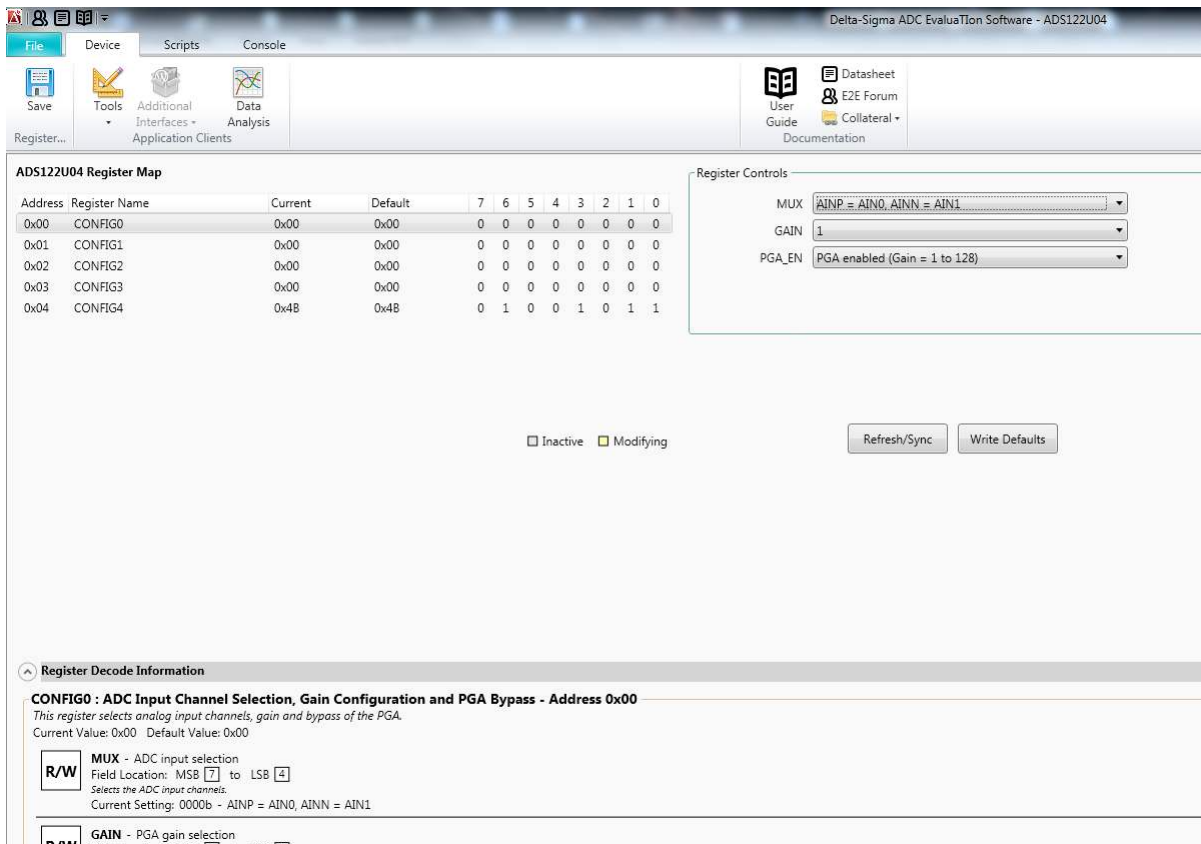


Figure 7. ADS1x2U04 Input MUX Config 0 Register (ADS122U04 Shown)

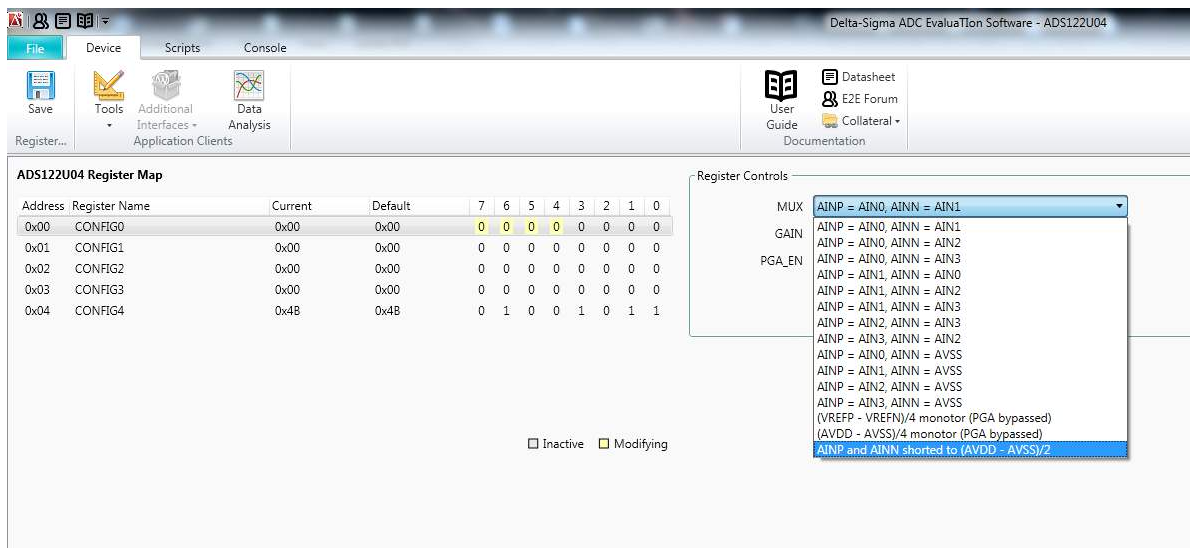


Figure 8. ADS1x2U04 Input MUX Selection

As stated earlier, some of the bits or register contents cannot be changed. One such example is the CONFIG4 register. This is due to keeping the operation of data collection within specific timing and control. For some other registers, data collection timing prohibits some specific register settings relative to the selected data rate (CONFIG1) and the selected data integrity options (CONFIG2) when running in continuous mode. The maximum Baud rate for the EVM is 115,200 Baud which limits the amount of data that can be transmitted between conversion periods. The data integrity options in CONFIG2 take precedence over data rate, so when using *Data Analysis* the data rate may be lowered to fit the Baud rate timing window. If the data rate changes with the EVM firmware, you will not see that this has happened unless you *Refresh/Sync* the register settings in the *Device* tab window.

4.3.1 Data Collection

Data is collected through the GUI using the *Data Analysis* client which is accessed by clicking the corresponding *Data Analysis* icon in the upper left area in either the *Device* or *Scripts* tab. Details about data collection and saving collected data to a file are given in the *Delta-Sigma ADC Evaluation Software User Manual (SBAU260)*. In the lower right portion of the *Data Analysis* window is a voltage reference setting (*VRef*) that defaults to the value of the internal reference of the ADS1x2U04. The correct *VRef* value is important when displaying the *Time Domain* plot. There is also an input selection for the number of samples to collect. The default value is 2048 samples. When ready to collect data and display the results in the window, press the *Collect Data* button. The desired number of samples will be collected and displayed. The EVM will flash the D2 LED approximately once a second during the data collection as an indicator that conversion data are being collected.

Three views of the data are possible. The first view, [Figure 9](#), is the *Data Inspector*. This view shows the result codes collected as either decimal or hex values. The result data can be saved to a file for later review or as import into another application.

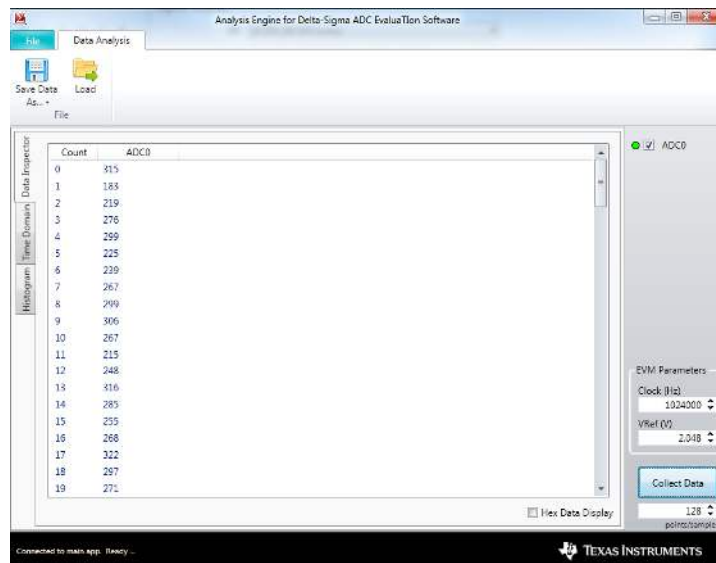


Figure 9. Data Inspector

The second view is shown in [Figure 10](#) and is the *Time Domain* plot of the data. The data will display in the window based on the selection from the drop-down menu. The options are *Volts (Input Referred)*, *Volts*, and *Codes*. At the bottom of the display are statistic calculations of the collected data.

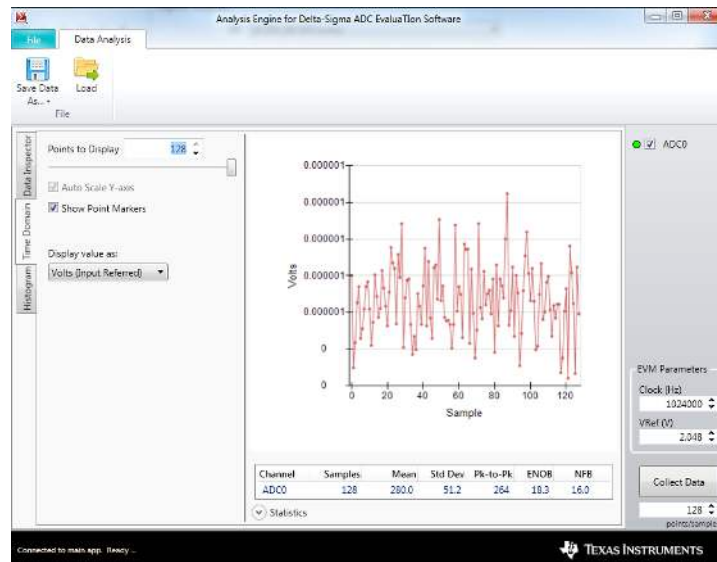


Figure 10. Time Domain

Along with the statistics information is the third view; the *Histogram* plot (Figure 11). The *Histogram* shows the distribution of the collected data based on the desired number of bins (# Bins) and the number of codes per bin (# Codes/Bin).

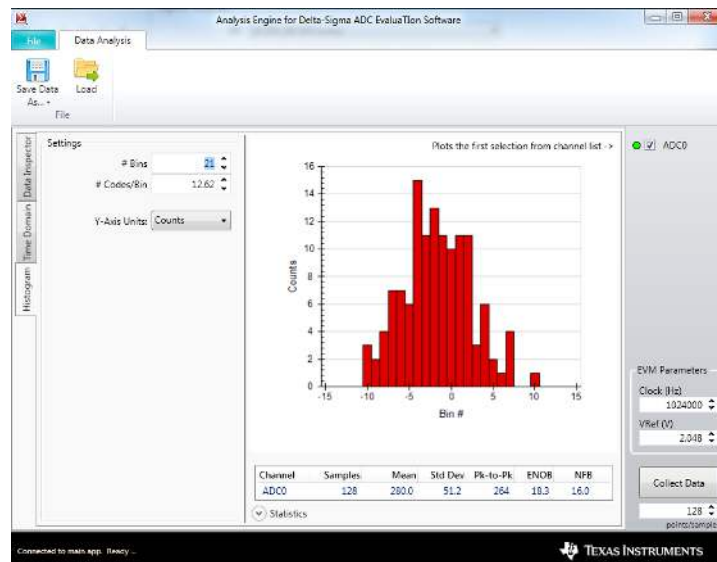


Figure 11. Histogram

The previous discussion pertains specifically to the ADC result data. In addition to the ADC data there is additional information that can be displayed depending on the settings in the *CONFIG2* register. When the conversion counter is enabled, the *Data Analysis* labels this information as *DSTATUS*. When the option for sending inverted conversion results is selected, the inverted count is labeled *USTATUS*. When either CRC or inverted conversion result is selected, the data integrity value is labeled as *CRC*. An example of the additional data are shown in Figure 12 and Figure 13. The result from the additional data must be manually determined from the *Data Inspector* view. The data for CRC or inverted conversion results will be meaningless for the *Time Domain* and *Histogram* views. TI recommends unchecking the boxes for *DSTATUS0*, *USTATUS0*, and *CRC0* boxes when viewing the *Time Domain* or *Histogram* plots.

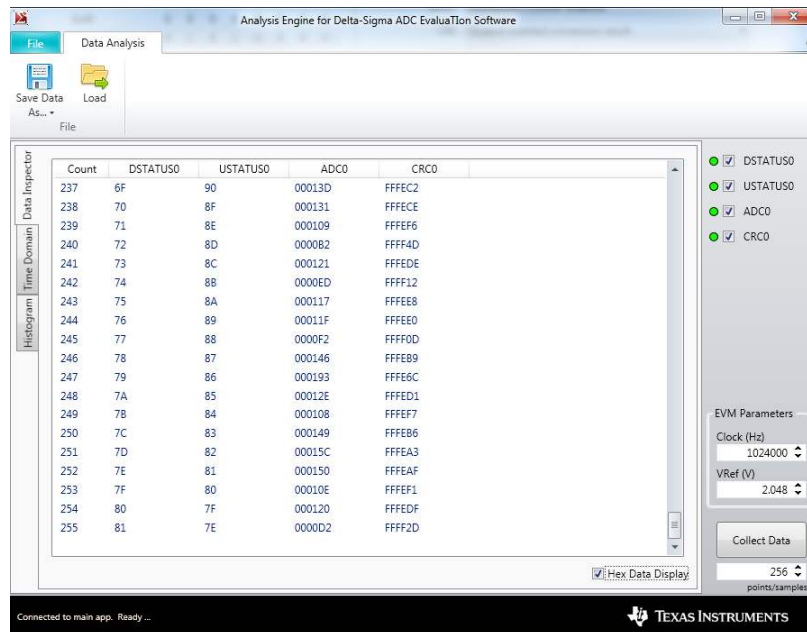


Figure 12. Data Displayed as HEX Values

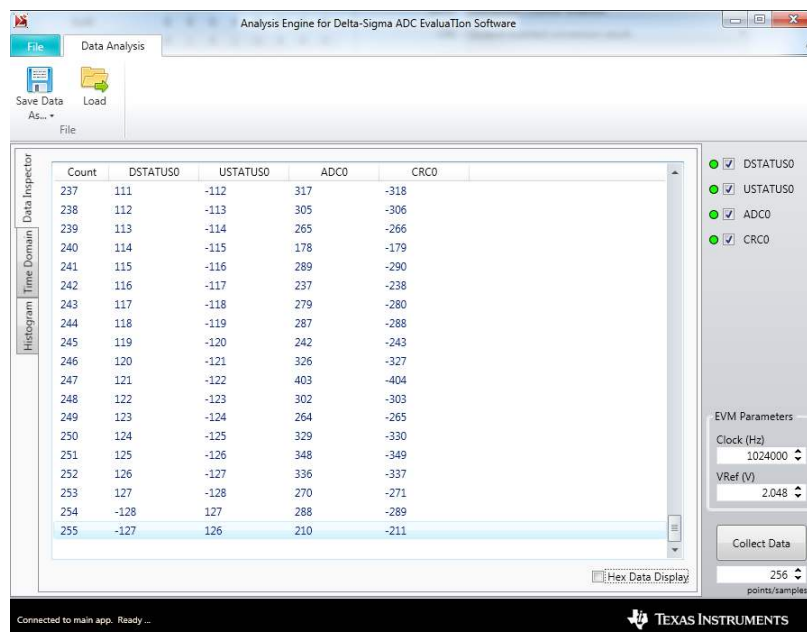


Figure 13. Data Displayed as Decimal Values

All data sent to the *Data Analysis* are considered to be signed data. This means that when viewing the data as decimal numbers, the *Count* will jump from 127 to -128 due to numerical signing. When viewing the *Inverted* data, the bit value returned is the complement of the original data and can be easily observed in the *Hex Data Display* mode of the *Data Inspector* tab as displayed in [Figure 12](#). However, due to signing of the decimal value, the inverted result will appear as one less than the inverted decimal number of the original value. For example, if the original non-inverted decimal value is 125, the inverse of this number will be -125. Subtract one count from the inverted value. The result is -126, which is the inverted value displayed in the *Data Analysis*. This behavior can actually be useful when analyzing large numbers as the original data and the inverted data will only be one count apart other than the sign itself. An example showing the inverted decimal values is shown in [Figure 13](#).

4.3.2 ADS1x2U04 Commands

The ADS1x2U04EVM commands are given in [Table 8](#). These commands are available for use within the *Scripts* tab. For more information about using scripts, refer to the *Delta-Sigma ADC Evaluation Software User Manual (SBAU260)*. Script usage as it applies to the ADS1x2U04EVM is further explained in [Section 4.3.3](#).

Table 8. ADS1x2U04 EVM Software Commands

Command	Description	Format
SLEEP	Enter a low power state	SLEEP
RESET	Software reset - forces device into a POR state	RESET
START	Start or restart (synchronize) conversions	START
RREG	Read <number> registers beginning at <address>	RREG <address> <number>
WREG	Write register <address> with <data>	WREG <address> <data>
RDATA	Read conversion result	RDATA
EVM GPIO Commands		
SETGPIO0	Sets GPIO0 I/O state for the ADC with <number>	SETGPIO0 <number>
		ADC GPIO0 is an input = 0
		ADC GPIO0 is an output = 1
SETGPIO1	Sets GPIO1 I/O state for the ADC with <number>	SETGPIO1 <number>
		ADC GPIO1 is an input = 0
		ADC GPIO1 is an output = 1
GPIO0OUT	Sets GPIO0 output state with <number>	GPIO0OUT <number>
		GPIO0 is logic low = 0
		GPIO0 is logic high = 1
GPIO1OUT	Sets GPIO1 output state with <number>	GPIO1OUT <number>
		GPIO1 is logic low = 0
		GPIO1 is logic high = 1
GPIO0IN	Reads the current logic state of GPIO0	GPIO0IN
GPIO1IN	Reads the current logic state of GPIO1	GPIO1IN
Standard EVM Commands		
COLLECT	Collect data by collecting a <number> of samples	COLLECT <number>
COLLECTSTOP	End any data collection in progress	COLLECTSTOP
COMMANDLIST	Return the complete list of all available commands	COMMANDLIST
ID	Send EVM identification	ID
REGMAP	Return the current contents of the ADC register map	REGMAP

4.3.3 Using Scripts

There are a number of *Predefined* scripts found under the *Scripts* tab. Scripts are available for each of the sensor input configurations listed in [Section 5.1](#). These *Predefined* scripts are meant to be a type of pseudo code describing the setup of registers and sequence of events for the various configurations.

[Figure 14](#) demonstrates one of the *Predefined* scripts within the script window. Once loaded, the script will highlight the top entry. The script can *Run* through the entire script all at once, or can run *Step by step*. The same script can be run again by first clicking *Reset* to highlight the first step in the script. The *Predefined* scripts contain a description of the purpose of the script, and each element of the script describes the action contained in each step. A more detailed view of the script is shown in [Figure 15](#). Each script element acts as pseudo code for showing the register configuration and program flow that can be used in an end-application.

The scripts can be edited and saved as *User-defined* scripts. Other scripting commands are given in [Table 9](#) in addition to the commands for the EVM in [Table 8](#).

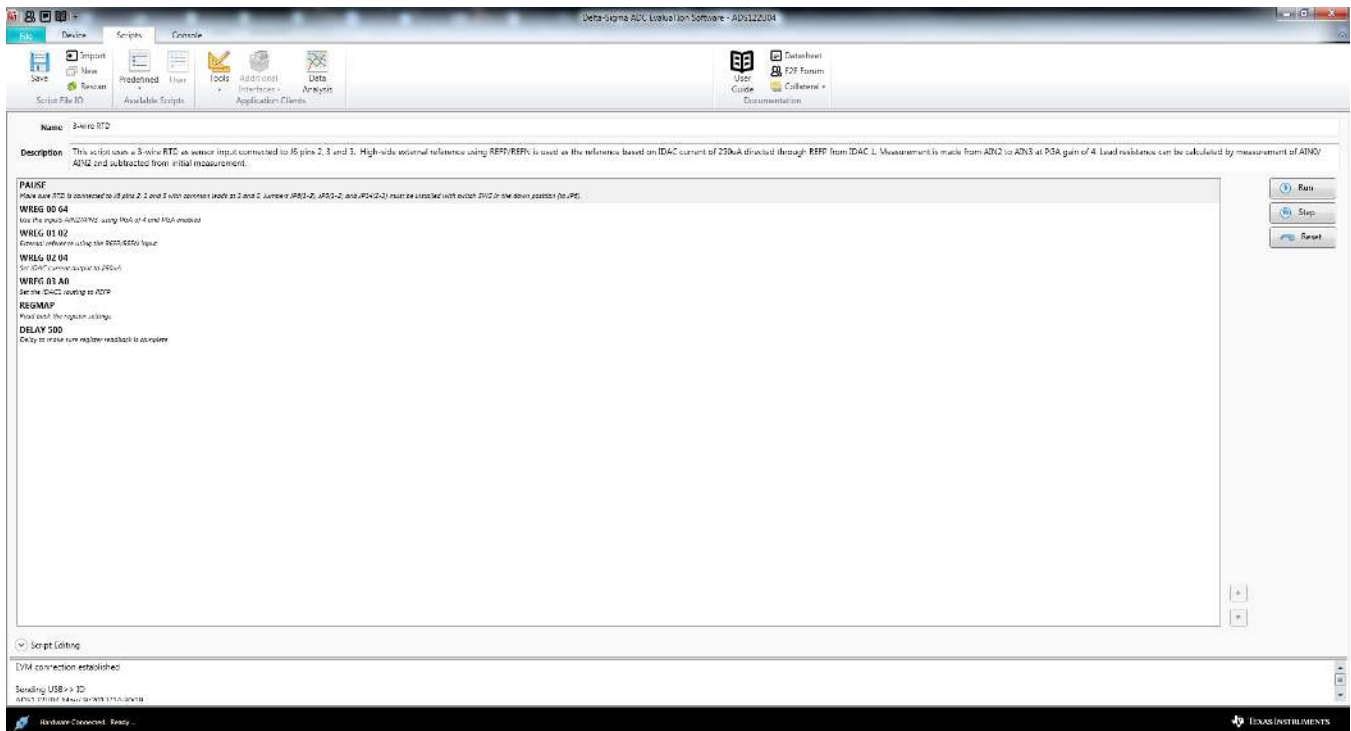
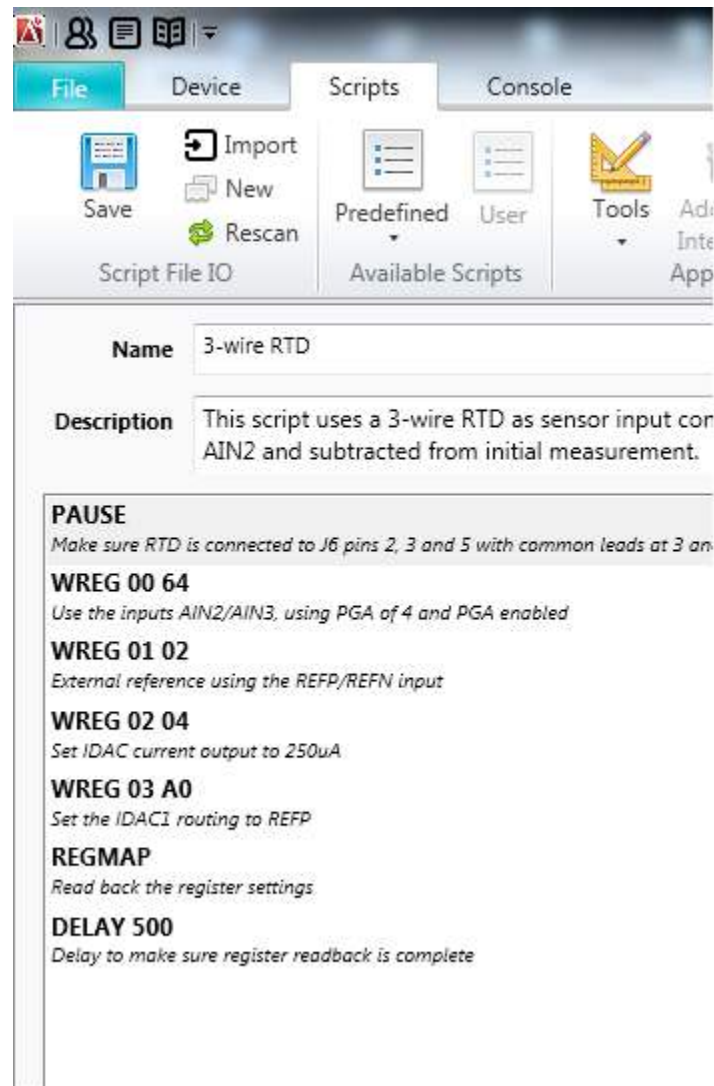


Figure 14. 3-Wire RTD Predefined Script


Figure 15. 3-Wire RTD Script Detail
Table 9. Special Scripting Commands

Command	Description	Format
DELAY	Delay <number> of milliseconds	DELAY <number>
PAUSE	Pause execution of running script	PAUSE
COLLECT	Collect <number> samples of data	COLLECT <number>
ANALYSIS	Open <i>Data Analysis</i> client to display data	ANALYSIS

5 EVM Hardware Details

5.1 Analog Inputs

The analog inputs to the EVM can be connected at the terminal blocks located on the left side of the board (J6 and J7). At no time should an input voltage be applied that will exceed the absolute maximum input ratings of the ADS1x2U04 for the AVDD supply voltage being used. The only exception is when measuring an external voltage as discussed in [Section 5.1.4](#). Various combinations for direct sensor input are provided for common sensor types used with the ADS1x2U04. However, sensor connections are not limited to the devices mentioned and many additional sensor types and combinations can also be connected to the ADS1x2U04.

In the following discussion, the various sensor connections are meant to show how those sensors can be connected and used with the ADS1x2U04. J6 allows for an RTD, thermocouple, or bridge sensor as well as voltage or current measurement. J7 is an external reference input only.

Five different sensor, or measurement types can be connected to J6. [Table 10](#) demonstrates the various connections for each sensor type, the excitation source and ADC measurement channels used. Thermocouple and RTDs are the primary sensor types. The simplified input diagrams contain some extra components that are not populated on the EVM. These devices relate to input protection such as diodes and fuses. The components are not installed on the EVM as the devices can add measurement error. However, the input protection devices are shown in the diagrams as an example of how input protection may be applied to prevent damage when excessive voltage is applied to the input.

Table 10. J6 Sensor Connector Options

Sensor	J6 Connection					EXC ⁽¹⁾ Source	Reference	Jumper and Switch Settings	ADC Inputs	
	TB-1	TB-2	TB-3	TB-4	TB-5				AINP	AINN
2-wire RTD		B			A	I	IDAC × R77	JP6, 1-2; JP9, 1-2; JP14, 2-3; S5 to JP6 (down)	AIN0	AIN3
3-wire RTD		B	B		A	I	IDAC × R77	JP6, 1-2; JP9, 1-2; JP14, 2-3; S5 to JP6 (down)	AIN2	AIN3
4-wire RTD		B	B	A	A	I	IDAC × R77	JP6, 1-2; JP9, 1-2; JP14, 2-3; S5 to JP6 (down)	AIN1	AIN2
Thermocouple ⁽²⁾			–	+			2.048-V internal	JP12 installed; JP13 1-2	AIN1	AIN2
Bridge	EXC -		–	+	EXC +	V	AVDD-AVSS reference MUX	JP6, 2-3; JP9, 1-2	AIN1	AIN2
Voltage	COM				+		2.5-V onboard	JP9, 2-3; JP10 installed, JP17, 1-2; S5 to VREF (up)	AIN0	AIN2
Current	COM	+					2.5-V onboard	JP14, 1-2; JP17, 1-2; S5 to VREF (up)	AIN3	AIN2

⁽¹⁾ EXC Source refers to the sensor excitation source.

⁽²⁾ Thermocouple cold-junction can be measured by installing temperature sensor RT1 and using the 2-wire RTD configuration. See [Table 12](#) for sensor part information. Bias for proper common-mode can be provided by installing JP12 and JP13, 1-2.

5.1.1 RTD Measurement Configurations

For RTD measurements the EVM circuit is designed for PT100 sensors. The sensor circuit uses a high-side ratiometric reference with a current source for excitation using REFP and a current of 250 μ A. The excitation current creates a voltage across R77 that is used for the external REF inputs when S5 is in the down position pointing to JP6. The same reference current also excites the RTD for any RTD sensor type. To maintain a proper common-mode voltage when using PGA gain, return current from the RTD passes through R79. Resistor values for R77 and R79 can be changed as required, such as when using a PT1000 RTD. A connection diagram for a 3-wire RTD is shown in [Figure 16](#). The same J6 terminal block is also used for 2-wire and 4-wire RTDs, but the input configuration is different for each RTD type. See [Figure 17](#) for 2-wire connections and [Figure 18](#) for 4-wire connections.

Using the high-side reference as a single current source allows for a ratiometric measurement for all RTD sensor types. This is not the case for a low-side reference and a 3-wire RTD using two current sources. The second current source cancels lead resistance from the measurement, but also adds the noise of the current source to the low-side reference. For the 3-wire case, the RTD and low-side reference are not truly ratiometric. This differs from the high-side reference which still allows the cancellation of the lead resistance for 3-wire RTDs by measuring the voltage drop of just the lead resistance (AIN0 and AIN2) and then subtracting the measured voltage drop from the RTD measured voltage.

The measurement result will be the ratio of the RTD resistance to the reference resistance. The voltage drop across the RTD (V_{RTD}) is equal to the value of one code (LSB) times the number of codes in the ADC result. The full-scale range is based on the reference voltage which is equal to R77 times the excitation current (I_{EXC}).

$$\text{Code}_{\text{LSB}} = \text{Full-Scale Range} / \text{Total Number of Codes} = \pm V_{\text{REF}} / \text{PGA} / (2^{24} - 1) = 2 \times V_{\text{REF}} / \text{PGA} / (2^{24} - 1) \quad (1)$$

$$V_{\text{RTD}} = \text{Code}_{\text{LSB}} \times \text{Result}_{\text{CODES}} = (2 \times R77 \times I_{\text{EXC}} / \text{PGA}) / (2^{24} - 1) \times \text{Result}_{\text{CODES}} \text{ V} \quad (2)$$

V_{RTD} is also equal to the resistance of the RTD times the excitation current.

$$V_{\text{RTD}} = R_{\text{RTD}} \times I_{\text{EXC}} \quad (3)$$

Equating Equation 2 to Equation 3 and solving for the RTD resistance (R_{RTD}), the I_{EXC} term drops out of the equation and the RTD resistance R_{RTD} is found to be directly proportional to R77.

$$R_{\text{RTD}} = (2 \times R77 \times \text{Result}_{\text{CODES}} / \text{PGA}) / (2^{24} - 1) \quad (4)$$

The value of $\text{Result}_{\text{CODES}}$ also includes the lead resistance. The codes returned from the lead resistance measurement, $\text{Result}_{\text{LEADCODES}}$ can be subtracted from $\text{Result}_{\text{CODES}}$ prior to the resistance calculation given in Equation 4.

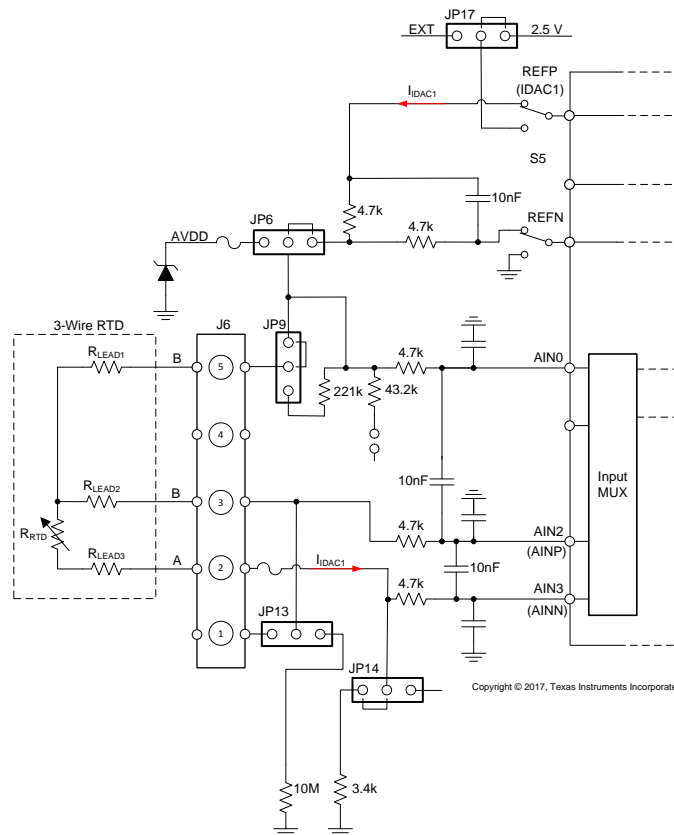


Figure 16. Simplified 3-Wire RTD Input Diagram

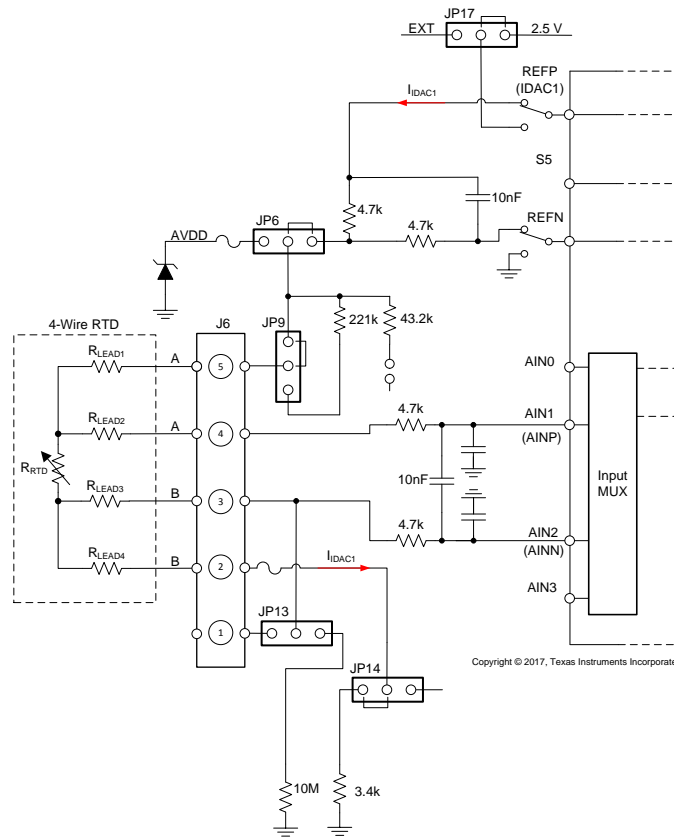
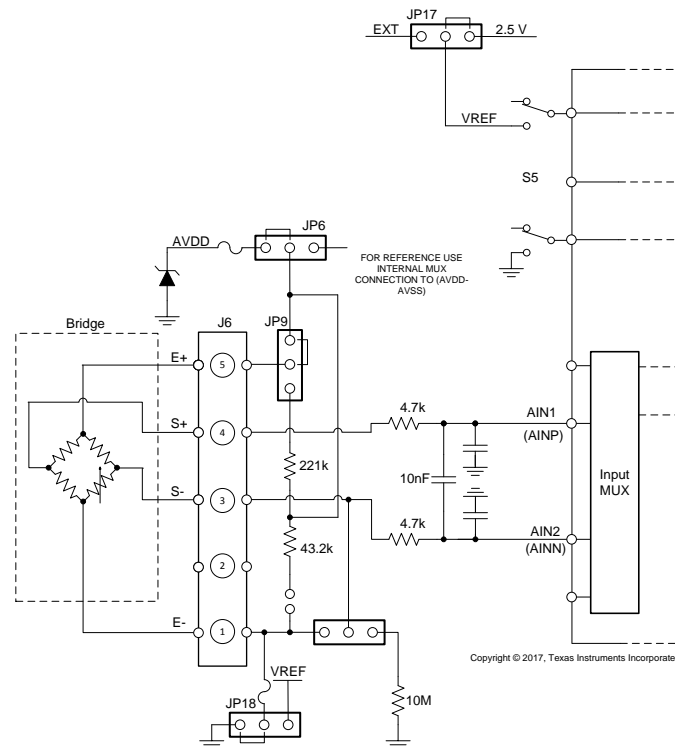


Figure 18. Simplified 4-Wire RTD Input Diagram

5.1.2 Thermocouple Measurement Configuration

When connecting a thermocouple to J6, the junction of the thermocouple and the terminal block create a second thermocouple. The temperature effect of the undesired thermocouple needs to be removed from the total temperature calculation. Typically, this calculation is described as cold-junction compensation. The cold-junction temperature can be measured by attaching an SMD RTD chip at RT1 (see [Table 12](#) for device information) and calculating the cold-junction temperature from the RT1 resistance. [Figure 19](#) is a connection diagram showing excitation of RT1 and the thermocouple input measurement channels.


Figure 20. Simplified Bridge Input Diagram

When jumper JP6 is connected to the AVDD supply by connecting pins 2 and 3, AVDD becomes the source for excitation at J6 pin 5. The excitation return current to AGND is accomplished by connection to J6 pin 1. To keep the measurement ratiometric, the AVDD supply should be used as the reference for the ADC. This can be accomplished in the VREF reference MUX selection of the CONFIG1 register and selecting *Analog Supply (AVDD - AVSS) used as the reference* option.

As the measurement circuit is ratiometric, the output of the bridge will be proportional to the excitation. One type of bridge circuit is a strain gauge load-cell which is used in weight scales. A load-cell will have a sensitivity of a specific output voltage at full-rated capacity for each volt of excitation and is expressed as mV / V for full-scale output. The most common sensitivities range from 1 to 3 mV / V at the rated capacity of the load-cell. The desired result might be in resistance, weight, or pressure. However, the ADC output code result is related to a fraction of the reference voltage and because of this, bridge measurements are often confusing. A conversion to the desired result is required as the ADC does not measure any of the desired quantities directly.

As an example, the load-cell case will be used with a sensitivity of 2 mV / V and a full-scale capacity of 10 kg. The excitation and reference voltage is 5 V. The full-scale output voltage will be equal to the excitation voltage multiplied by the sensitivity.

$$V_{\text{OUTPUT}} = V_{\text{EXC}} \times V_{\text{SENSITIVITY}} = 5 \text{ V} \times 2 \text{ mV} / \text{V} = 10 \text{ mV} \quad (7)$$

The full-scale range of the ADC is two times the reference voltage divided by the applied gain. As the output is very small, the maximum PGA gain can be applied.

$$V_{\text{FS}} = \pm(V_{\text{REF}} / \text{PGA}) = 2 \times V_{\text{EXC}} / \text{PGA} = 2 \times 5 \text{ V} / 128 = 10 / 128 = 78.125 \text{ mV} = \pm 39.0625 \text{ mV} \quad (8)$$

For this example, only about one-eighth of the total available full-scale range will be utilized. The impact of noise on the measurement must be carefully considered. Conversion noise will be a factor of the PGA and data rate settings. The conversion noise will directly impact the flicker-free scale resolution. A flicker-free or noise-free resolution occurs at the point where noise no longer affects the repeatability of the measurement. Repeatability can be calculated in a couple of different ways. One approach is to use the capacity of the load-cell times the noise (peak to peak) divided by the full-scale output at the rated capacity for the excitation being used. This approach gives a quick indication of the best case noise-free resolution of the measurement.

$$\text{Repeatability} = (\text{Capacity} \times V_{\text{NOISEP-10-p}}) / V_{\text{OUTPUT}} \quad (9)$$

Continuing the example using a PGA gain of 128, and data rate of 90 SPS, there may be typical noise of 850 nV, peak to peak. The repeatability can be calculated for the 10-kg capacity load-cell used.

$$\text{Repeatability} = (10 \text{ kg} \times 850 \text{ nV}) / 10 \text{ mV} = 850 \text{ mg} \quad (10)$$

Repeatability is also the representation of the value of a single noise-free code (count). As proof, a similar analysis approach using noise-free counts will result in the same repeatability. The ADC result has a voltage relationship that directly relates to the reference voltage and applied gain. A single count (code) is a function of the full-scale range of the ADC divided by the total available codes. As an example, the 24-bit ADS122U04 will be used for the following calculations.

$$V_{\text{CODE}} = V_{\text{FS}} / (2^{24} - 1) = 78.125 \text{ mV} / 16777215 = 4.66 \text{ nV} \quad (11)$$

The number of codes representing conversion noise is the noise voltage divided by the voltage value of one code.

$$\text{Code}_{\text{NOISE}} = V_{\text{NOISEP-10-p}} / V_{\text{CODE}} = 850 \text{ nV} / 4.66 \text{ nV} = 182.5 \text{ codes} \quad (12)$$

The number of noise codes can be easily converted to number of bits which equates to 7.512 bits of noise. The total number of noise-free bits equals the total number of ADC bits (24-bit resolution for the ADS122U04) less the noise bits. For the example, the noise-free bits total 16.487 bits. The number of noise-free counts for the capacity of the load-cell is equal to the total available counts for noise-free resolution times the ratio of the maximum output of the load-cell to the full-scale range.

$$\text{Counts}_{\text{NOISE-FREE}} = 2^{16.487} \times V_{\text{OUTPUT}} / V_{\text{FS}} = 91912 \times 10 \text{ mV} / 78.125 \text{ mV} = 11765 \text{ codes} \quad (13)$$

Using the noise-free counts the repeatability will be equal to the capacity divided by the number of counts.

$$\text{Repeatability} = \text{Capacity} / \text{Counts}_{\text{NOISE-FREE}} = 10 \text{ kg} / 11765 = 850 \text{ mg} \quad (14)$$

As shown, the result of [Equation 10](#) equates to [Equation 14](#) and is proportional to the noise. The repeatability calculation is a best-case scenario based solely on the typical converter noise with shorted input. Any system noise, such as EMI / RFI, will degrade the repeatability further.

5.1.4 Voltage and Current Measurement Configurations

Voltage measurements greater than AVDD and current measurements up to 24 mA can be made using J6. The possible input combinations are shown in [Figure 21](#). [Table 11](#) details the allowable input range for various configurations and analog supply voltages. The EVM uses a voltage divider (R61 and R62) so that up to 30 V can be applied when analog COM is connected to AGND (default EVM condition), installing JP10 and using 5-V AVDD as the reference voltage. The AVDD reference can be selected from the reference MUX option in the CONFIG1 register by selecting *Analog supply (AVDD - AVSS) used as the reference option*.

The bipolar voltage and current measurements require modification to the EVM. When analog COM is connected to VREF (JP18), the input range changes to ± 15 V to ensure the input remains within AVDD to AVSS. The measured voltage from the ADC must be converted to the proper input voltage value based on the scaling of the values of the resistor divider.

$$V_{\text{IN}} = V_{\text{R62}} \times (R61 + R62) / R62 = V_{\text{R62}} \times (221 + 43.2) / 43.2 = V_{\text{R62}} \times (264.2 / 43.2) V \quad (15)$$

When voltage measurements are taken, JP9 must be connected to the voltage divider input by installing the jumper between pins 2 and 3. Also, JP10 must be installed to complete the current path to COM. JP13 must also have the jumper installed between pins 2 and 3 for connecting the analog COM to AIN2 as the AIN0 and AIN2 input combination is used for the measurement.

To make bipolar measurements, the resistor R90 must be removed to disconnect COM from AGND. In addition, COM must now connect to VREF by adding a short between pins 1 and 2 of JP18. Make sure VREF is connected to the 2.5-V reference by installing the jumper at JP17 to 1 and 2. VREF can also be used as the reference source by setting S5 to the up position (VREF) and selecting the CONFIG1 register setting for the reference MUX to *External reference using the REFP and REFN inputs*.

Current measurement is a calculated measurement using the low-side shunt resistor R80 (100 Ω). The voltage drop across this resistor is measured by the ADC and current is calculated from the voltage result divided by the value of R80. Jumper JP14 must have the jumper installed between pins 1 and 2 to complete the current path to analog COM. JP13 must also have the jumper installed between pins 2 and 3 for connecting the analog COM to AIN2 as the AIN3/AIN2 input combination is used for the measurement.

$$I_{\text{IN}} = V_{\text{IN}} / R80 = V_{\text{IN}} / 100 \text{ A} \quad (16)$$

Table 11. Voltage and Current Measurement Options

Sensor	J6 Connection			AVDD (V)	COM (JP18)	ADC Inputs	
	TB-1	TB-2	TB-5			AINP	AINN
0–30 V (REF = 5 V)	+		-	5	AGND	AIN0	AIN2
0–20 V (REF = AVDD)	+		-	5 or 3.3	AGND	AIN0	AIN2
±15 V (REF = 2.5 V)	±		Common	5	VREF	AIN0	AIN2
0–24 mA (REF = 2.5 V)		+	-	5 or 3.3	AGND	AIN3	AIN2
±24 mA (REF = 2.5 V)		±	Common	5	VREF	AIN3	AIN2
±7 mA (REF = 2.5 V)		±	Common	5 or 3.3	VREF	AIN3	AIN2

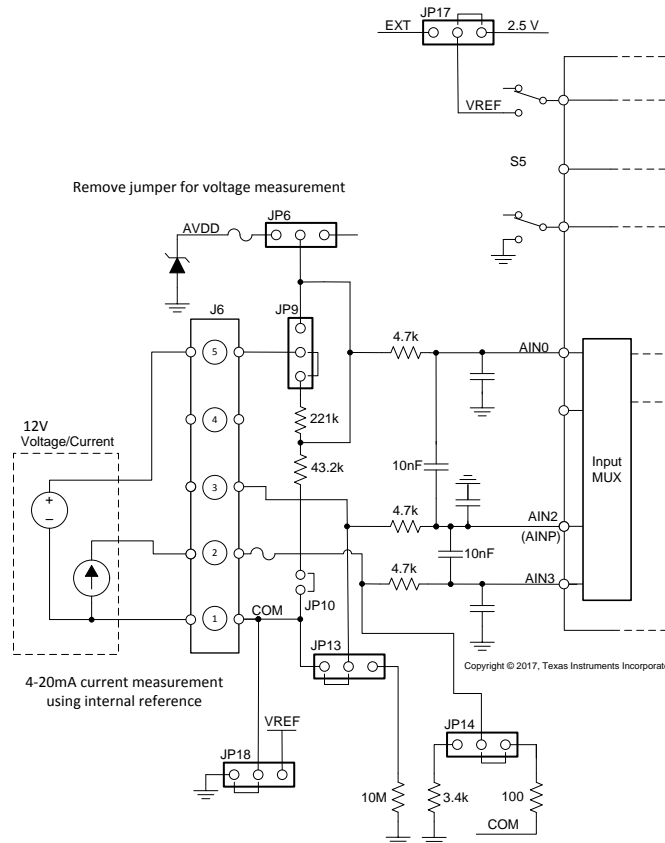


Figure 21. Simplified Voltage and Current Input Diagram

5.2 Digital Inputs

Access the digital signals of the device using J3. The J3 header allows for the connection to a logic analyzer or when the EVM is used in a stand-alone configuration for connections to an external microprocessor or microcontroller.

If controlling the ADS1x2U04 with an external processor, power down the onboard TM4C1294NCPDT by placing a jumper on JP1. This can be accomplished by soldering a wire between the JP1 terminals or by installing a 2-pin, 0.1-in spaced header that has the pins shorted with a shorting block (see Table 3).

5.3 ADC Reference

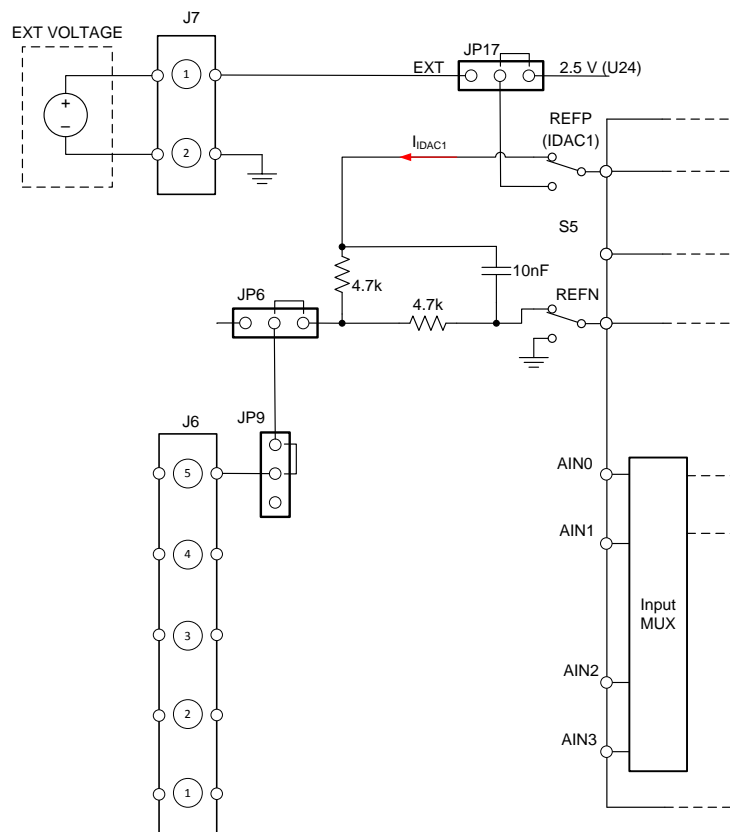
The reference of the ADC can be provided by using the internal reference of the ADS1x2U04, or by using the reference MUX selection in the CONFIG1 register to an external source. Reference MUX selections to external sources can be AVDD minus AVSS, or by the voltage source connected to the REFP and REFN inputs. Various external references to REFP and REFN are possible such as connecting an external reference source to J7, by using the onboard 2.5-V reference (U24), or by using the IDAC established reference through R77 on the EVM. External reference inputs are differential input pairs.

The IDAC reference using R77 is selected by switching S5 to the down position to JP6. This input pair is dedicated for use with the high-side reference for ratiometric RTD measurements, and is excited by using the ADC IDAC current sourced from REFP. The IDAC current source must make a complete circuit path to AVSS (analog ground) for current to flow through resistor R77, when used to establish the reference voltage.

Using the AVDD minus AVSS MUX selection is primarily used for making ratiometric bridge measurements or measuring large input voltages when using the voltage divider input circuit.

An external voltage can be routed to the REFP and REFN inputs through S5. When connecting an external voltage, S5 must be in the up position to VREF. The voltage applied to VREF can come from the externally-supplied voltage at J7 or can be supplied from the 2.5-V onboard reference (U24) on the EVM. JP17 with the jumper installed at pins 1 and 2 select the onboard reference, while JP17 pins 2 and 3 select the reference connected to J7. The simplified reference input diagram is shown in Figure 22.

The REFP and REFN inputs are a differential input pair. Except for the IDAC created reference through R77, all other externally supplied reference voltages are analog ground referenced due to the R85 shorting resistor. R85 can be removed when applying voltages to J7, but there must be an analog ground reference for REFN when using the onboard reference.



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Figure 22. Simplified External REF Input

5.4 **Reset**

Hardware reset the ADC by pressing S4. This is a whole system reset which resets the microcontroller and will re-enumerate the Tiva, when released. If only a reset of the ADC is required, then use the *Reset* command.

6 Power Supply Connections – EVM and ADC

6.1 Powering the EVM

The EVM is only powered by the USB connection at J1.

6.2 Powering the ADS1x2U04

The ADS1x2U04 analog supply is provided at the AVDD and AVSS connections. The digital section of the ADS1x2U04 requires a DVDD supply for the ADC core digital and digital interface.

6.2.1 Analog Supply Configuration

The EVM is designed to be operated by using a unipolar supply. This means that AVSS is tied to analog ground and bipolar supply operation is unavailable on the EVM without modification and an externally supplied source. For AVDD, two possible voltage sources are available at jumper JP11. Achieving 3.3 V is possible when JP11 pins 2 and 3 are shorted and 5 V is possible by shorting JP11 pins 1 and 2 (default). Jumper JP16 can be used for direct current measurement of the AVDD current into the ADC by removing the jumper and connecting a DC current meter between the pins.

It is possible to change the analog supply configuration to a different voltage than what is supplied on the EVM. Using a different unipolar AVDD supply voltage, such as 2.5 V, JP16 can be used to supply the voltage by removing the jumper and attaching the externally supplied voltage to pin 2 of JP16. Make sure that the proper return path for the external supply is connected to one of the GND test points on the EVM. Using a bipolar supply is accomplished by connecting the positive voltage supply to JP16 pin 2, as stated previously. The negative voltage supply can be connected to TP20 after removing the R82 shorting resistor to GND. The bipolar supply common can be connected to one of the GND test points.

6.2.2 Digital Supply

The digital supply has only one voltage source option of 3.3 V for DVDD. Jumper JP15 can be used for direct current measurement of the DVDD current into the ADC by removing the jumper and connecting a DC current meter between the pins.

7 ADS1x2U04 Bill of Materials, PCB Layouts, and Schematics

7.1 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 <http://www.ti.com>.)

Table 12. ADS1x2U04 EVM Bill of Materials

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
!PCB1	1		Printed Circuit Board		PA034	Any		
C1, C21	2	2.2uF	CAP, CERM, 2.2 μ F, 35 V, \pm 10%, X5R, 0603	0603	GRM188R6YA225KA12D	Murata		
C2, C3, C4, C5, C6, C9, C11, C17, C18, C19, C20, C23, C24, C25, C26, C27, C28, C31 C36, C43, C70, C71	22	0.1uF	CAP, CERM, 0.1 μ F, 25 V, \pm 5%, X7R, 0603	0603	06033C104JAT2A	AVX		
C12, C13	2	6.8pF	CAP, CERM, 6.8 pF, 50 V, \pm 4%, C0G/NP0, 0603	0603	06035A6R8CAT2A	AVX		
C14, C15	2	12pF	CAP, CERM, 12 pF, 50 V, \pm 5%, C0G/NP0, 0603	0603	C0603C120J5GACTU	Kemet		
C22, C39, C40, C42, C45, C85, C86	7	1uF	CAP, CERM, 1 μ F, 25 V, \pm 10%, X7R, 0603	0603	GRM188R71E105KA12D	Murata		
C33	1	22uF	CAP, CERM, 22 μ F, 16 V, \pm 10%, X7R, 1210	1210	GRM32ER71C226KE18L	Murata		
C32, C34	2	10uF	CAP, CERM, 10 μ F, 25 V, \pm 10%, X7R, 1206_190	1206_190	C1206C106K3RACTU	Kemet		
C35	1	100pF	CAP, CERM, 100 pF, 25 V, \pm 10%, X7R, 0603	0603	06033C101KAT2A	AVX		
C37	1	47uF	CAP, CERM, 47 μ F, 16 V, \pm 15%, X5R, 1206	1206	C3216X5R1C476M160AB	TDK		
C38, C74, C75, C76, C77	5	0.01uF	CAP, CERM, 0.01 μ F, 50 V, \pm 5%, C0G/NP0, 0603	0603	C1608NP01H103J080AA	TDK		
C41, C44	2	1000pF	CAP, CERM, 1000 pF, 100 V, \pm 5%, X7R, 0603	0603	06031C102JAT2A	AVX		
C73, C78, C83	3	0.1uF	CAP, CERM, 0.1 μ F, 16 V, \pm 5%, X7R, 0603	0603	C1608NP01H103J080AA	TDK		
C79, C80, C81, C82	4	1000pF	CAP, CERM, 1000 pF, 50 V, \pm 5%, C0G/NP0, 0603	0603	06031C102JAT2A	AVX		
C84	1	10uF	CAP, CERM, 10 μ F, 25 V, \pm 20%, X5R, 0603	0603	GRM188R61E106MA73D	Murata		
D1, D2, D4	3	Green	LED, Green, SMD	LED_0603	LTST-C191TGKT	Lite-On		
D3	1	Red	LED, Red, SMD	LED_0603	LTST-C191KRKT	Lite-On		
D9	1	5.6V	Diode, Zener, 5.6 V, 5 W, SMB	SMB	SMBJ5339B-TP	Micro Commercial Components		
H1, H2, H3, H4	4		Bumpon, Cylindrical, 0.312 X 0.200, Black	Black Bumpon	SJ61A1	3M		
J1	1		Connector, Receptacle, Micro-USB Type B, R/A, Bottom Mount SMT	7.5x2.45x5mm	0473460001	Molex		
J6	1		Terminal Block, 3.5mm Pitch, 5x1, TH	17.5x8.2x6.5mm	ED555/5DS	On-Shore Technology		
J7	1		Terminal Block, 3.5mm Pitch, 2x1, TH	7.0x8.2x6.5mm	ED555/2DS	On-Shore Technology		
JP10, JP12, JP15, JP16	4		Header, 2mm, 2x1, Tin, TH	Header, 2mm, 2x1	TMM-102-01-T-S	Samtec		
JP6, JP9, JP11, JP13, JP14, JP17	6		Header, 2mm, 3x1, Tin, TH	Header, 2mm, 3x1	TMM-103-01-T-S	Samtec		
L1	1	1uH	Inductor, Wirewound, Ferrite, 1 μ H, 2.05 A, 0.045 ohm, SMD	1210	LQH32PN1R0NN0	Murata		

Table 12. ADS1x2U04 EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
R1, R4, R7, R12	4	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale		
R2, R25, R26, R27, R39	5	1.00k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	CRCW06031K00FKEA	Vishay-Dale		
R3	1	8.06k	RES, 8.06 k, 1%, 0.1 W, 0603	0603	CRCW06038K06FKEA	Vishay-Dale		
R8, R11	2	100	RES, 100, 1%, 0.1 W, 0603	0603	CRCW0603100RFKEA	Vishay-Dale		
R13	1	1.00Meg	RES, 1.00 M, 1%, 0.1 W, 0603	0603	CRCW06031M00FKEA	Vishay-Dale		
R14	1	4.87k	RES, 4.87 k, 1%, 0.1 W, 0603	0603	CRCW06034K87FKEA	Vishay-Dale		
R15	1	2.00k	RES, 2.00 k, 1%, 0.1 W, 0603	0603	CRCW06032K00FKEA	Vishay-Dale		
R16, R23, R24, R33, R36, R69, R71, R81, R82, R83, R84, R85, R90	13	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale		
R17	1	51	RES, 51, 5%, 0.1 W, 0603	0603	CRCW060351R0JNEA	Vishay-Dale		
R20, R21, R29	3	100k	RES, 100 k, 1%, 0.1 W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale		
R28	1	0.1	RES, 0.1, 1%, 0.1 W, 0603	0603	ERJ-L03KF10CV	Panasonic		
R30	1	20.0k	RES, 20.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0720KL	Yageo America		
R31	1	768k	RES, 768 k, 1%, 0.1 W, 0603	0603	RC0603FR-07768KL	Yageo America		
R32	1	215k	RES, 215 k, 1%, 0.1 W, 0603	0603	RC0603FR-07215KL	Yageo America		
R61	1	221k	RES, 221 k, 0.1%, 0.1 W, 0603	0603	RG1608P-2213-B-T5	Susumu Co Ltd		
R62	1	43.2k	RES, 43.2 k, 0.1%, 0.1 W, 0603	0603	RG1608P-4322-B-T5	Susumu Co Ltd		
R63, R74	2	10.0Meg	RES, 10.0 M, 1%, 0.1 W, 0603	0603	CRCW060310M0FKEA	Vishay-Dale		
R68, R70 R72, R75, R87, R88	6	4.70k	RES, 4.70 k, 1%, 0.5 W, AEC-Q200 Grade 0, 0805	0805	ERJ-P06F4701V	Panasonic		
R73, R76	2	47	RES, 47, 5%, 0.1 W, 0603	0603	CRCW060347R0JNEA	Vishay-Dale		
R77, R78	2	4.70k	RES, 4.70 k, 0.1%, 0.4 W, AEC-Q200 Grade 0, 1206	1206	RTAN1206BKE4K70	Stackpole Electronics Inc		
R79	1	3.40k	RES, 3.40 k, 1%, 0.5 W, AEC-Q200 Grade 0, 0805	0805	CRCW08053K40FKEAHP	Vishay-Dale		
R80	1	100	RES, 100, 0.1%, 1 W, AEC-Q200 Grade 0, 1206	1206	HRG3216P-1000-B-T1	Susumu Co Ltd		
R86	1	1.10	RES, 1.10, 1%, 0.1 W, 0603	0603	CRCW06031R10FKEA	Vishay-Dale		
R89	1	150	RES, 150, 1%, 0.1 W, 0603	0603	CRCW0603150RFKEA	Vishay-Dale		
R91, R92, R93, R94	4	0	RES, 0, 5%, 0.25 W, 1206	1206	RC1206JR-070RL	Yageo America		
S2, S4	2		Switch, Tactile, SPST-NO, 0.05A, 12V, SMT	Switch, 4.4x2x2.9 mm	TL1015AF160QG	E-Switch		
S5	1		SLIDE SWITCH DPDT .1A, SMT	SWITCH, 5.4x2.5x3.9mm	CAS-220TA	Copal Electronics		
SH-JP6, SH-JP9, SH-JP10, SH-J11, SH-JP12, SH-JP13, SH-JP14, SH-JP15, SH-JP16, SH-JP17	10	1x2	Shunt, 2mm, Gold plated, Black	2mm Shunt, Closed Top	Samtec	2SN-BK-G		
TP6, TP8, TP9, TP21, TP22	5	Double	Terminal, Turret, TH, Double	Keystone1573-2	1573-2	Keystone		
U1	1		Tiva C Series Microcontroller, PDT0128A	PDT0128A	TM4C1294NCPDTI3R	Texas Instruments	TM4C1294NCPDTI3	Texas Instruments
U2	1		Highly Integrated Full Featured Hi-Speed USB 2.0 ULPI Transceiver, QFN-32	5x5 QFN-32	USB3320C-EZK	Microchip		
U3	1		High-Speed USB 2.0 (480 Mbps) 1:2 Multiplexer / Demultiplexer Switch with Single Enable, 6 ohm RON, 2.5 to 3.3V, -40 to 85 deg C, 10-Pin UQFN (RSE), Green (RoHS & no Sb/Br)	RSE0010A	TS3USB221ERSER	Texas Instruments	Equivalent	Texas Instruments

Table 12. ADS1x2U04 EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
U4	1		USB ESD Solution with Power Clamp, 4 Channels, -40 to +85 deg C, 6-pin SON (DRY), Green (RoHS & no Sb/Br)	DRY0006A	TPD4S012DRYR	Texas Instruments	Equivalent	Texas Instruments
U6, U7	2		8-BIT BIDIRECTIONAL VOLTAGE-LEVEL TRANSLATOR FOR OPEN-DRAIN AND PUSH-PULL APPLICATIONS, RGY0020A	RGY0020A	TXS0108ERGYR	Texas Instruments		Texas Instruments
U9	1		Dual Inverter Buffer/Driver With Open-Drain Outputs, DCK0006A	DCK0006A	SN74LVC2G06DCKR	Texas Instruments		Texas Instruments
U10	1		Single Inverter Buffer/Driver With Open-Drain Output, DCK0005A	DCK0005A	SN74LVC1G06DCKR	Texas Instruments	SN74LVC1G06DCKT	Texas Instruments
U11	1		TINY 1.5-A BOOST CONVERTER WITH ADJUSTABLE INPUT CURRENT LIMIT, DSG0008A	DSG0008A	TPS61252DSGR	Texas Instruments	TPS61252DSGT	Texas Instruments
U12	1		36-V, 1-A, 4.17- μ VRMS, RF LDO Voltage Regulator, RGW0020A	RGW0020A	TPS7A4700RGWR	Texas Instruments	TPS7A4700RGWT	Texas Instruments
U13	1		Single Output High PSRR LDO, 150 mA, Fixed 1.8 V Output, 2.5 to 6.5 V Input, with Low IQ, 5-pin SC70 (DCK), -40 to 85 deg C, Green (RoHS & no Sb/Br)	DCK0005A	TPS71718DCKR	Texas Instruments	Equivalent	Texas Instruments
U14	1		3-Pin Voltage Supervisors with Active-Low, Open-Drain Reset, DBZ0003A	DBZ0003A	TLV803MDBZR	Texas Instruments	TLV803MDBZT	Texas Instruments
U15	1		1-A Low-Dropout Regulator With Reverse Current Protection, DRV0006A	DRV0006A	TPS73733DRVR	Texas Instruments	TPS73733DRVT	Texas Instruments
U23	1		Low-Power, Low-Noise, Highly-Integrated, 4-Channel, 24-Bit (16-bit), Delta-Sigma Analog-to-Digital Converter (ADC) with Programmable Gain Amplifier (PGA) and Voltage Reference, PW0016A	PW0016A	ADS122U04IPWR	Texas Instruments	ADS122U04IPW	Texas Instruments
U24	1		Low Noise, Very Low Drift, Precision Voltage Reference, -40 to 125 deg C, 8-pin MSOP(DGK), Green (RoHS & no Sb/Br)	DGK0008A	REF5025AIDGKR	Texas Instruments	Equivalent	Texas Instruments
Y1	1		CRYSTAL, 32.768KHZ, 7PF, SMD	1.5x1.4x6.7mm	SSPT7F-7PF20-R	Seiko Instruments		
Y2	1		Crystal, 25 MHz, 18 pF, SMD	ABM3	ABM3-25.000MHZ-D2Y-T	Abracon Corporation		
G7	0	10 μ F	CAP, CERM, 10 μ F, 25 V, \pm 20%, X5R, 0603	0603	GRM188R61E106MA73D	Murata		
C8, C10, C16, C29, C30, C47, C56, C57, C61, C67	0	0.1 μ F	CAP, CERM, 0.1 μ F, 25 V, \pm 5%, X7R, 0603	0603	06033C104JAT2A	AVX		
C46, C48, C50, C52, C53, C55, C63, C64, C66	0	10 μ F	CAP, CERM, 10 μ F, 35 V, \pm 10%, X7R, 1206	1206	GMK316AB7106KL	Taiyo Yuden		
C49, C54, C58, C65, C69	0	0.01 μ F	CAP, CERM, 0.01 μ F, 25 V, \pm 10%, X7R, 0603	0603	GRM188R71E103KA01D	Murata		
C51	0	1 μ F	CAP, CERM, 1 μ F, 25 V, \pm 10%, X7R, 0603	0603	GRM188R71E105KA12D	Murata		
C59	0	1100pF	CAP, CERM, 1100 pF, 50 V, \pm 5%, C0G/NP0, 0603	0603	GRM1885C1H112JA01D	Murata		
C60	0	0.22 μ F	CAP, CERM, 0.22 μ F, 25 V, \pm 10%, X5R, 0603	0603	06033D224KAT2A	AVX		
C62	0	10pF	CAP, CERM, 10 pF, 50 V, \pm 5%, C0G/NP0, 0603	0603	06035A100JAT2A	AVX		
C68	0	4700pF	CAP, CERM, 4700 pF, 100 V, \pm 10%, X7R, 0603	0603	06031C472KAT2A	AVX		
C72	0	0.01 μ F	CAP, CERM, 0.01 μ F, 25 V, \pm 5%, C0G/NP0, 0603	0603	C0603H103J3GACTU	Kemet		
D5	0	12V	Diode, TVS, Uni, 12 V, 600 W, SMB	SMB	SMBJ12A-13-F	Diodes Inc.		
D6	0	Green	LED, Green, SMD	LED_0603	LTST-C191TGKT	Lite-On		
D7	0	20V	Diode, Schottky, 20 V, 1 A, SOD-123F	SOD-123F	PMEG2010AEH,115	NXP Semiconductor		
D8	0	20V	Diode, Schottky, 20 V, 1.1 A, DO-219AB	DO-219AB	SL02-GS08	Vishay-Semiconductor		
D10, D11	0	5.6V	Diode, Zener, 5.6 V, 5 W, SMB	SMB	SMBJ5339B-TP	Micro Commercial Components		

Table 12. ADS1x2U04 EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
F1	0		Fuse, 2 A, 125 V, SMD	SMD, 2-Leads, Body 9.73x5.03mm	0154002.DRT	Littelfuse		
J2	0		Header, 100mil, 7x1, Gold, TH	7x1 Header	TSW-107-07-G-S	Samtec		
J3	0		Header, 2.54 mm, 28x2, Gold, TH	Header, 2.54 mm, 28x2, TH	TSW-128-07-S-D	Samtec		
J4	0		Terminal Block, 6A, 3.5mm Pitch, 2-Pos, TH	7.0x8.2x6.5mm	ED555/2DS	On-Shore Technology		
J5	0		Connector, DC Jack 2.1X5.5 mm, TH	POWER JACK, 14.4x11x9mm	PJ-102A	CUI Inc.		
JP1, JP2, JP5	0		Header, 100mil, 2x1, Gold, TH	2x1 Header	TSW-102-07-G-S	Samtec		
JP3, JP4	0		Header, 100mil, 3x1, Gold, SMT	Samtec_TSM-103-01-X-SV	TSM-103-01-L-SV	Samtec		
JP7, JP8	0		Header, 100mil, 3x1, Gold, SMT	Header, 2mm, 4x2, TH	TMM-104-01-T-D	Samtec		
JP18	0		Header, 2mm, 4x2, Tin, TH	Header, 2mm, 3x1	TMM-103-01-T-S	Samtec		
L2	0	3.3uH	Inductor, Shielded Drum Core, Ferrite, 3.3 μH, 1.5 A, 0.033 ohm, SMD	CDPH4D19F	CDPH4D19FNP-3R3MC	Sumida		
L3	0	10uH	Inductor, Shielded Drum Core, Ferrite, 10 μH, 1.2 A, 0.124 ohm, SMD	CDRH5D18	CDRH5D18NP-100NC	Sumida		
R5, R9, R18, R19, R40, R54	0	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale		
R6, R10	0	100	RES, 100, 1%, 0.1 W, 0603	0603	CRCW0603100RFKEA	Vishay-Dale		
R22, R52	0	100k	RES, 100 k, 1%, 0.1 W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale		
R34, R35, R37, R38, R55, R56, R57, R58, R59, R60, R64, R67	0	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale		
R41	0	9.31k	RES, 9.31 k, 1%, 0.1 W, 0603	0603	CRCW06039K31FKEA	Vishay-Dale		
R42	0	3.01k	RES, 3.01 k, 1%, 0.1 W, 0603	0603	CRCW06033K01FKEA	Vishay-Dale		
R43, R65, R66	0	1k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	CRCW06031K00FKEA	Vishay-Dale		
R44	0	51.1k	RES, 51.1 k, 1%, 0.1 W, 0603	0603	CRCW060351K1FKEA	Vishay-Dale		
R45	0	158k	RES, 158 k, 1%, 0.1 W, 0603	0603	CRCW0603158KFKEA	Vishay-Dale		
R46	0	15.0k	RES, 15.0 k, 1%, 0.1 W, 0603	0603	CRCW060315K0FKEA	Vishay-Dale		
R47	0	453k	RES, 453 k, 1%, 0.1 W, 0603	0603	CRCW0603453KFKEA	Vishay-Dale		
R48	0	49.9k	RES, 49.9 k, 1%, 0.1 W, 0603	0603	CRCW060349K9FKEA	Vishay-Dale		
R49	0	10.0	RES, 10.0, 1%, 0.1 W, 0603	0603	CRCW060310R0FKEA	Vishay-Dale		
R50	0	121k	RES, 121 k, 1%, 0.1 W, 0603	0603	CRCW0603121KFKEA	Vishay-Dale		
R51	0	1.30Meg	RES, 1.30 M, 1%, 0.1 W, 0603	0603	CRCW06031M30FKEA	Vishay-Dale		
R53	0	93.1k	RES, 93.1 k, 1%, 0.1 W, 0603	0603	CRCW060393K1FKEA	Vishay-Dale		
RT1	0	100 ohm	Temperature Sensor, 100 ohm, 1%, 1206	1206	PTS120601B100RP100	Vishay/Beyschlag		
S1, S3	0		Switch, Tactile, SPST-NO, 0.05A, 12V, SMT	Switch, 4.4x2x2.9 mm	TL1015AF160QG	E-Switch		
SH-JP1, SH-JP2, SH-JP3, SH-JP4, SH-JP5	0	1x2	Shunt, 100mil, Gold plated, Black	Shunt	969102-0000-DA	3M	SNT-100-BK-G	Samtec
SH-JP7, SH-JP8, SH-JP18	0	1x2	Shunt, 2mm, Gold plated, Black	2mm Shunt, Closed Top	2SN-BK-G	Samtec		
TP7	0	Double	Terminal, Turret, TH, Double	Keystone1573-2	1573-2	Keystone		
TP20	0		Test Point, Miniature, Black, TH	Black Miniature Testpoint	5001	Keystone		
TP23	0	Blue	Test Point, Miniature, Blue, TH	Blue Miniature Testpoint	5117	Keystone		
U5	0		256K I2C™ CMOS Serial EEPROM, TSSOP-8	TSSOP-8	24AA256-I/ST	Microchip		

Table 12. ADS1x2U04 EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer	Alternate Part Number	Alternate Manufacturer
U8	0		8-BIT BIDIRECTIONAL VOLTAGE-LEVEL TRANSLATOR FOR OPEN-DRAIN AND PUSH-PULL APPLICATIONS, RGY0020A	RGY0020A	TXS0108ERGYR	Texas Instruments		Texas Instruments
U16	0		1.5-A LOW-NOISE FAST-TRANSIENT-RESPONSE LOW-DROPOUT REGULATOR, DCQ0006A	DCQ0006A	TL1963ADCQR	Texas Instruments	TL1963ADCQT	Texas Instruments
U17	0		3-PIN VOLTAGE SUPERVISORS, DBV0003A	DBV0003A	TPS3809I50QDBVRQ1	Texas Instruments		Texas Instruments
U18	0		Single Inverter Buffer/Driver With Open-Drain Output, DCK0005A	DCK0005A	SN74LVC1G06DCKR	Texas Instruments	SN74LVC1G06DCKT	Texas Instruments
U19	0		Step-Up DC-DC Converter with Forced PWM Mode, 2.3 to 6 V, -40 to 105 deg C, 8-pin SOP (PW8), Green (RoHS & no Sb/Br)	PW0008A	TPS61085TPWR	Texas Instruments	Equivalent	Texas Instruments
U20	0		Single Output High PSRR LDO, 150 mA, Adjustable 1.2 to 33 V Output, 3 to 36 V Input, with Ultra-Low Noise, 8-pin MSOP (DGN), -40 to 125 deg C, Green (RoHS & no Sb/Br)	DGN0008D	TPS7A4901DGNR	Texas Instruments	Equivalent	Texas Instruments
U21	0		DC-DC INVERTER, DRC0010J	DRC0010J	TPS63700DRCR	Texas Instruments	TPS63700DRCT	Texas Instruments
U22	0		Single Output High PSRR LDO, 200 mA, Adjustable -1.18 to -33 V Output, -3 to -36 V Input, with Ultra-Low Noise, 8-pin MSOP (DGN), -40 to 125 deg C, Green (RoHS & no Sb/Br)	DGN0008D	TPS7A3001DGNR	Texas Instruments	Equivalent	Texas Instruments
Notes:		Unless otherwise noted in the Alternate Part Number or Alternate Manufacturer columns, all parts may be substituted with equivalents.						

7.2 PCB Layouts

Figure 23 and Figure 28 illustrate the PCB layouts.

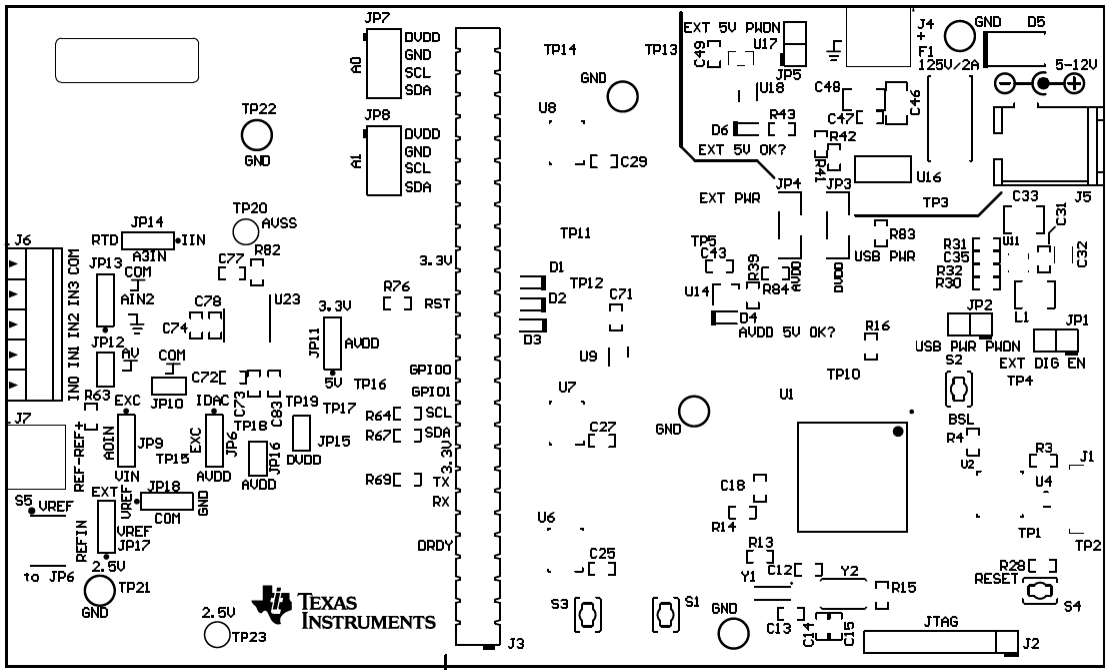


Figure 23. Top Silkscreen

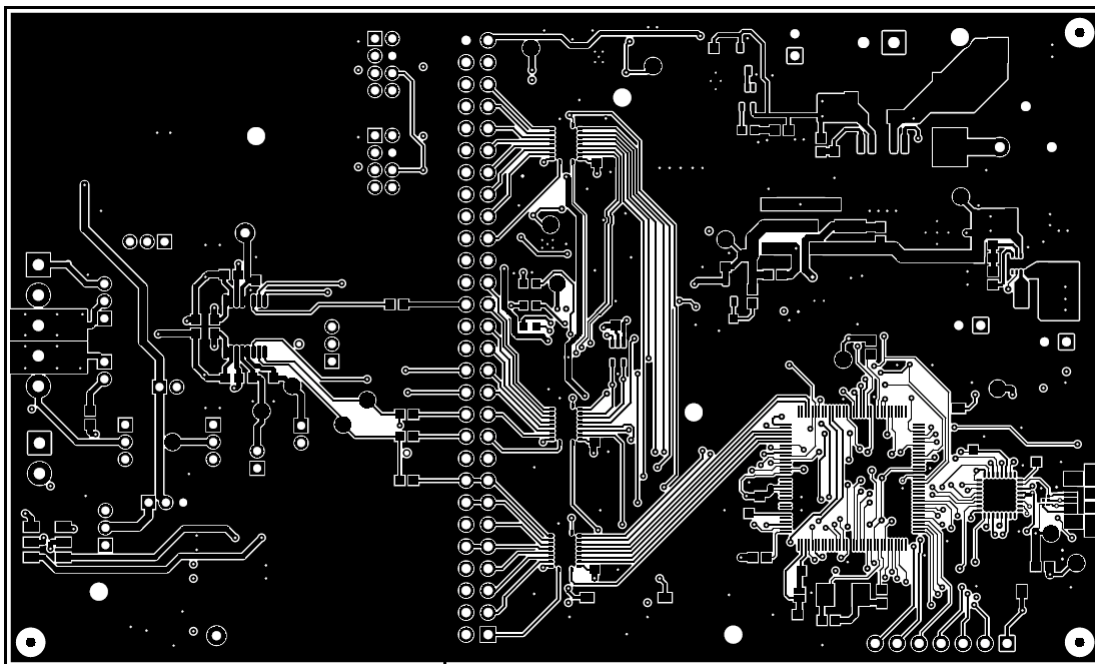


Figure 24. Top Layer (Positive)

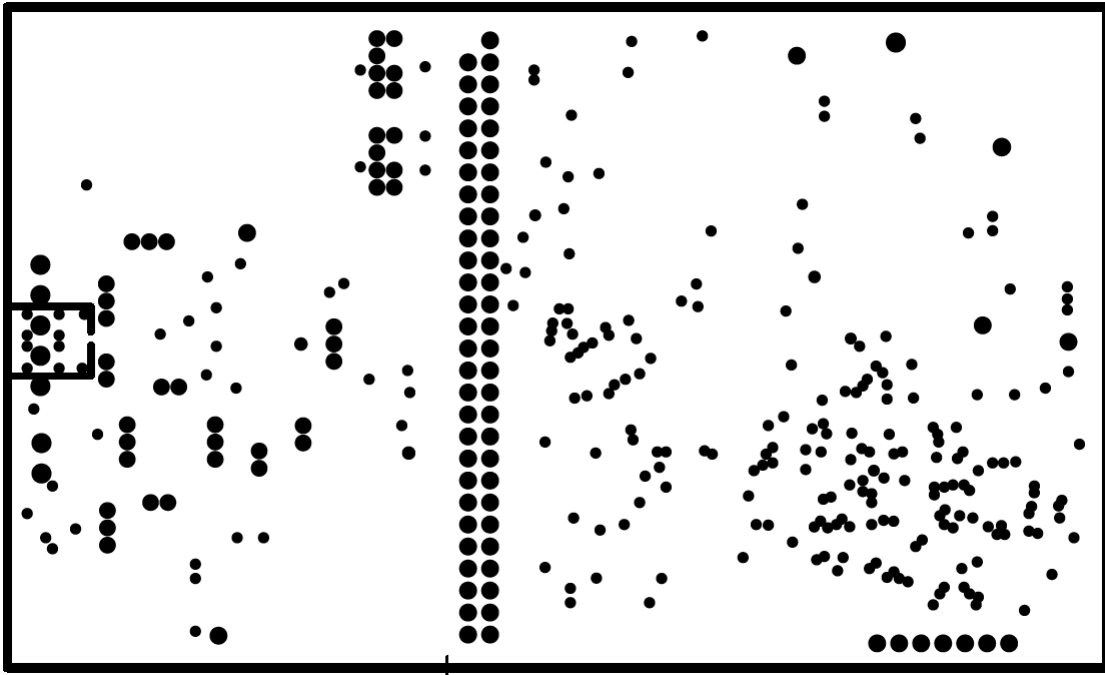


Figure 25. Ground Layer (Negative)

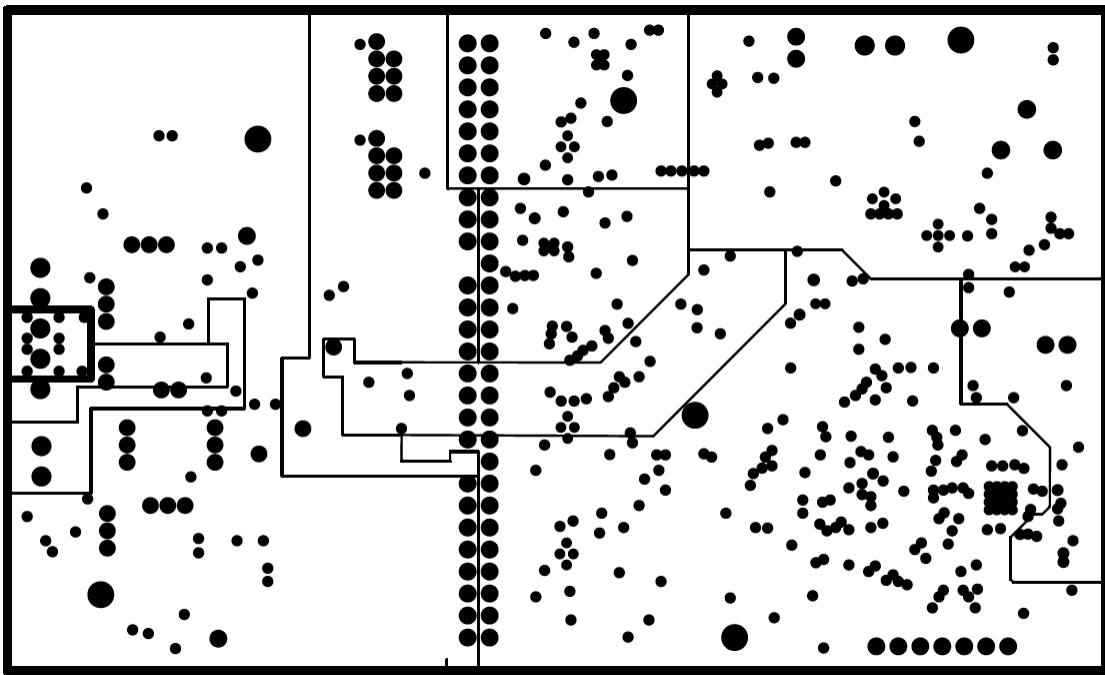


Figure 26. Power Layer (Negative)

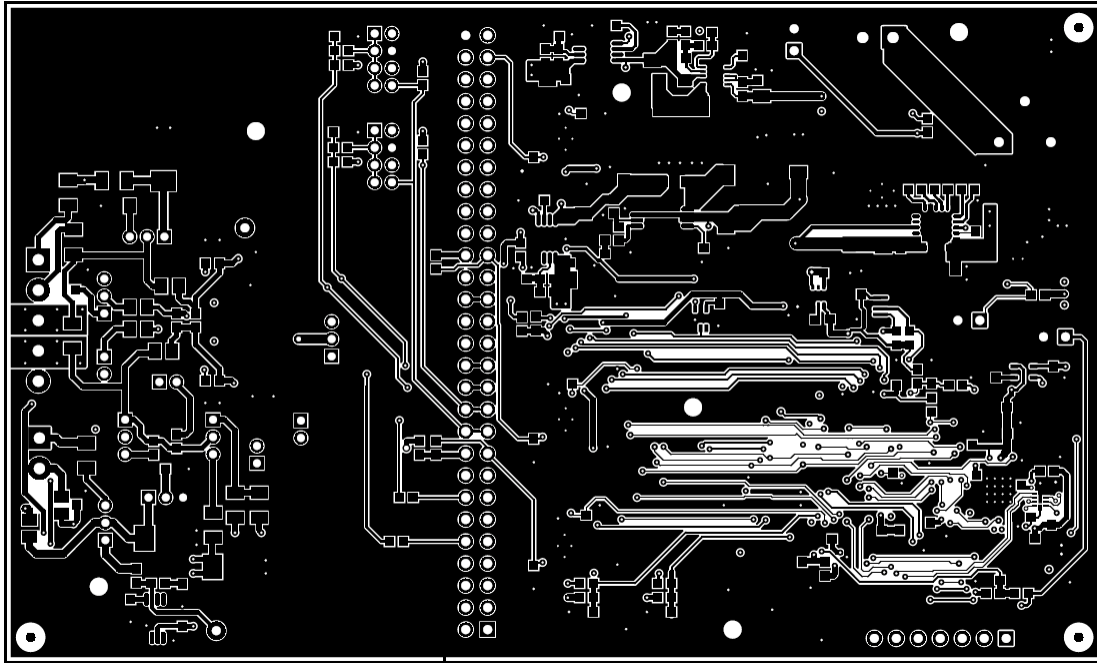


Figure 27. Bottom Layer (Positive)

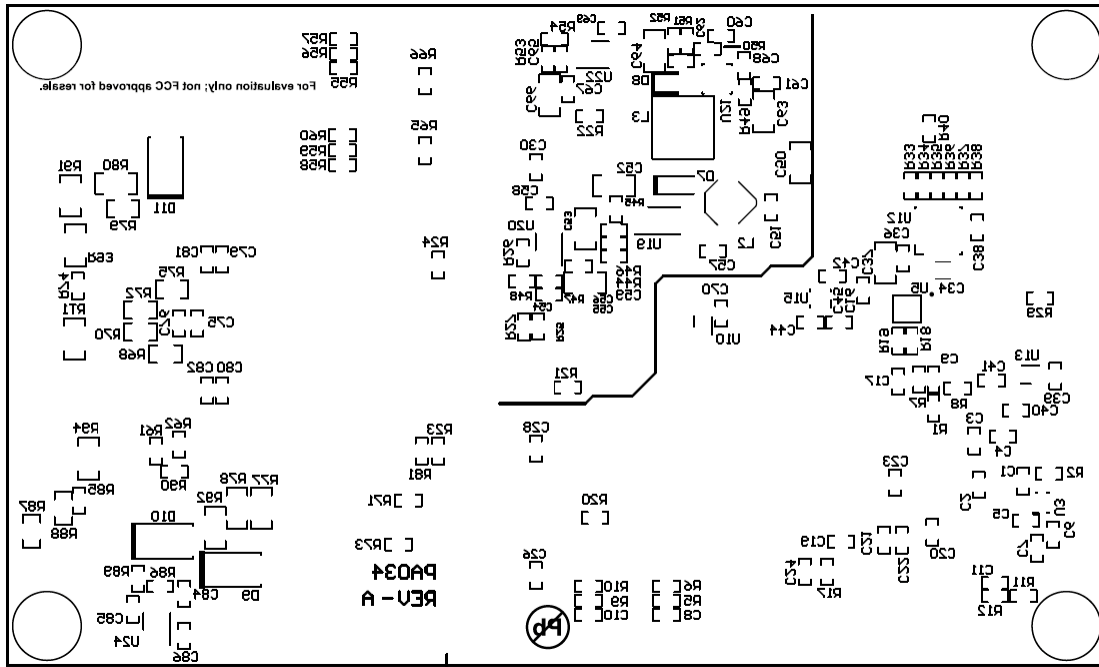


Figure 28. Bottom Silkscreen

7.3 Schematic

Figure 29 through Figure 34 illustrate the EVM schematics.

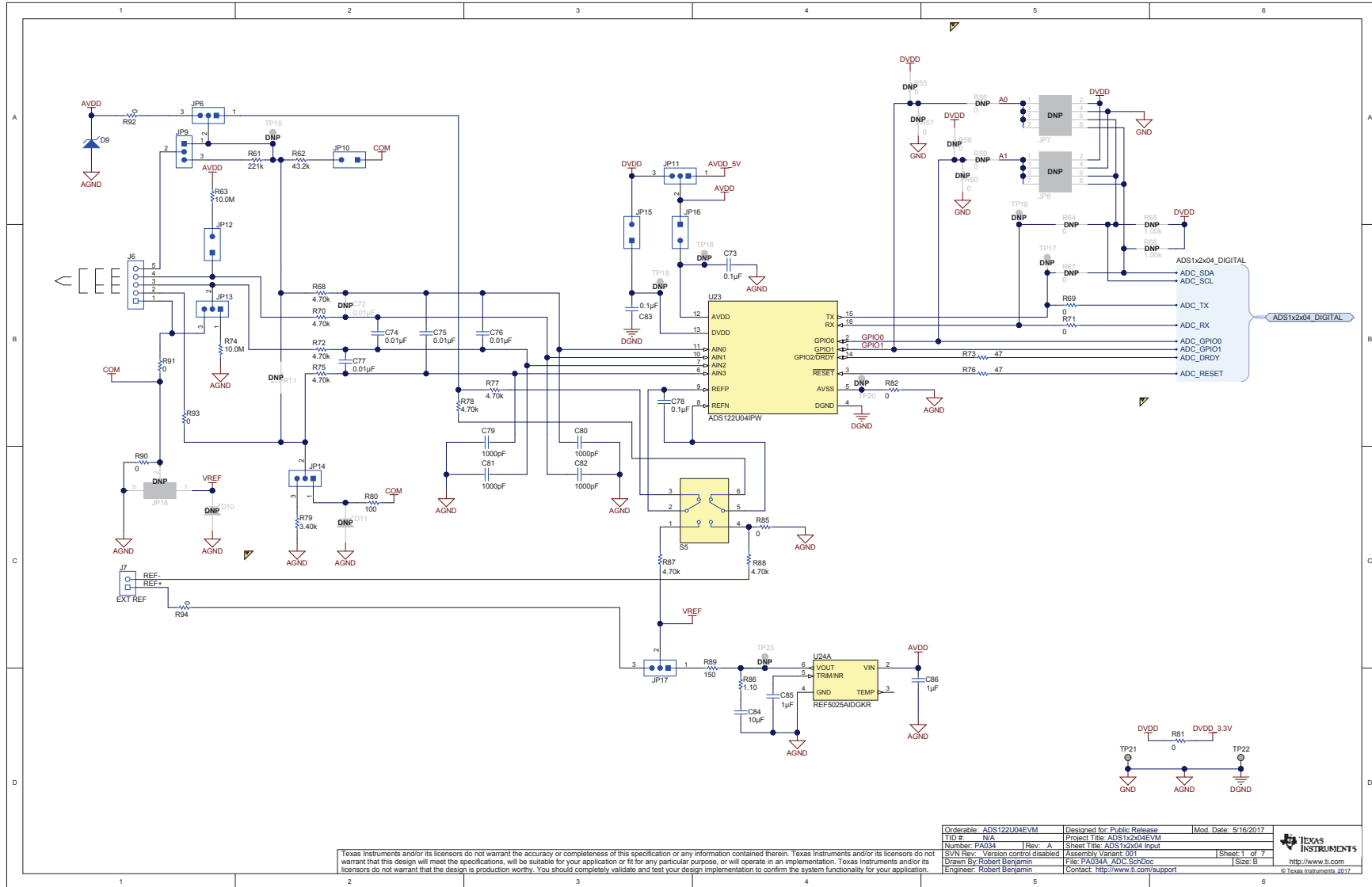


Figure 29. ADS1x2U04EVM ADC Schematic

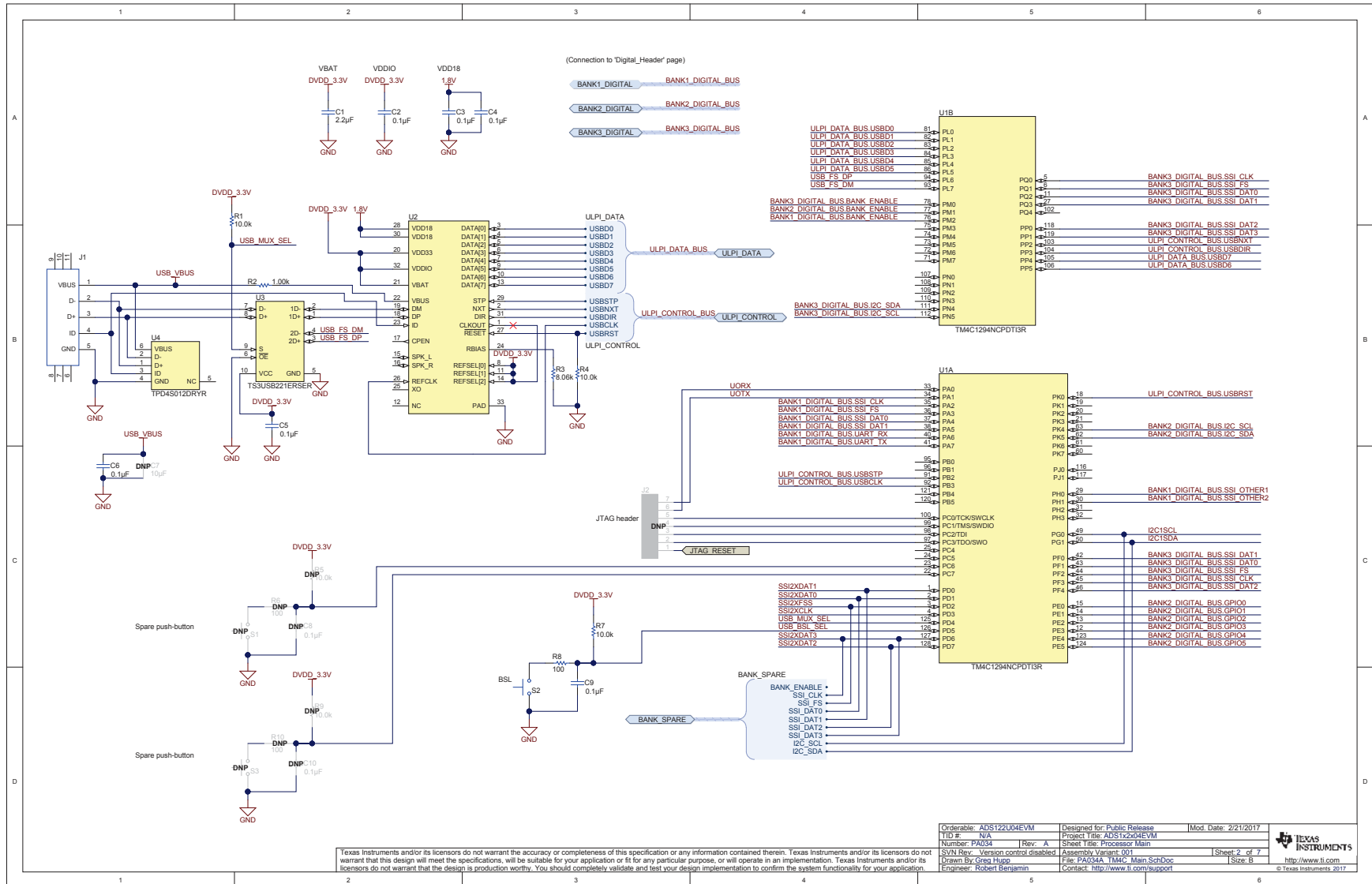


Figure 30. ADS1x2U04EVM Controller Schematic

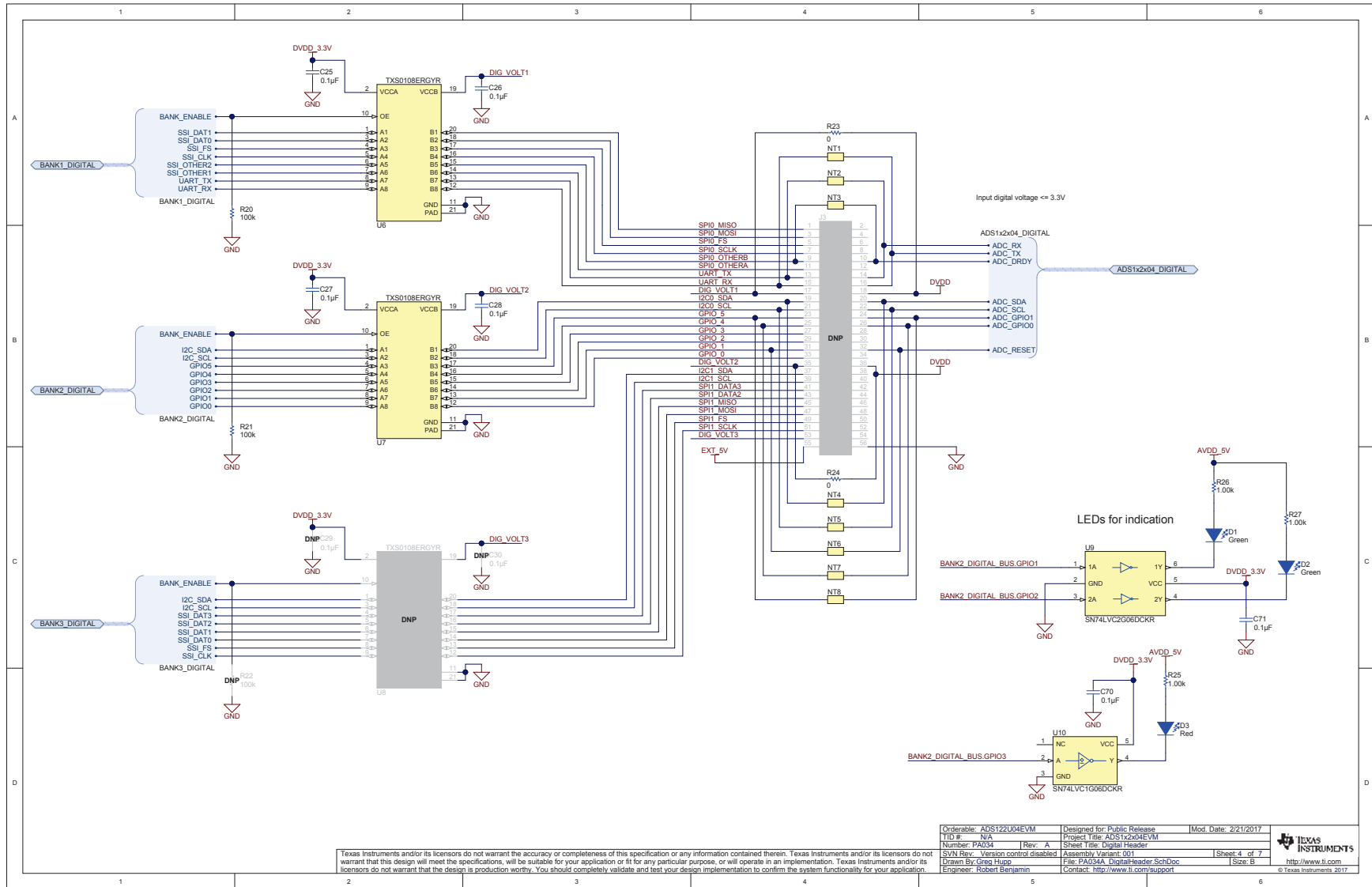


Figure 32. ADS1x2U04EVM Digital Header Schematic

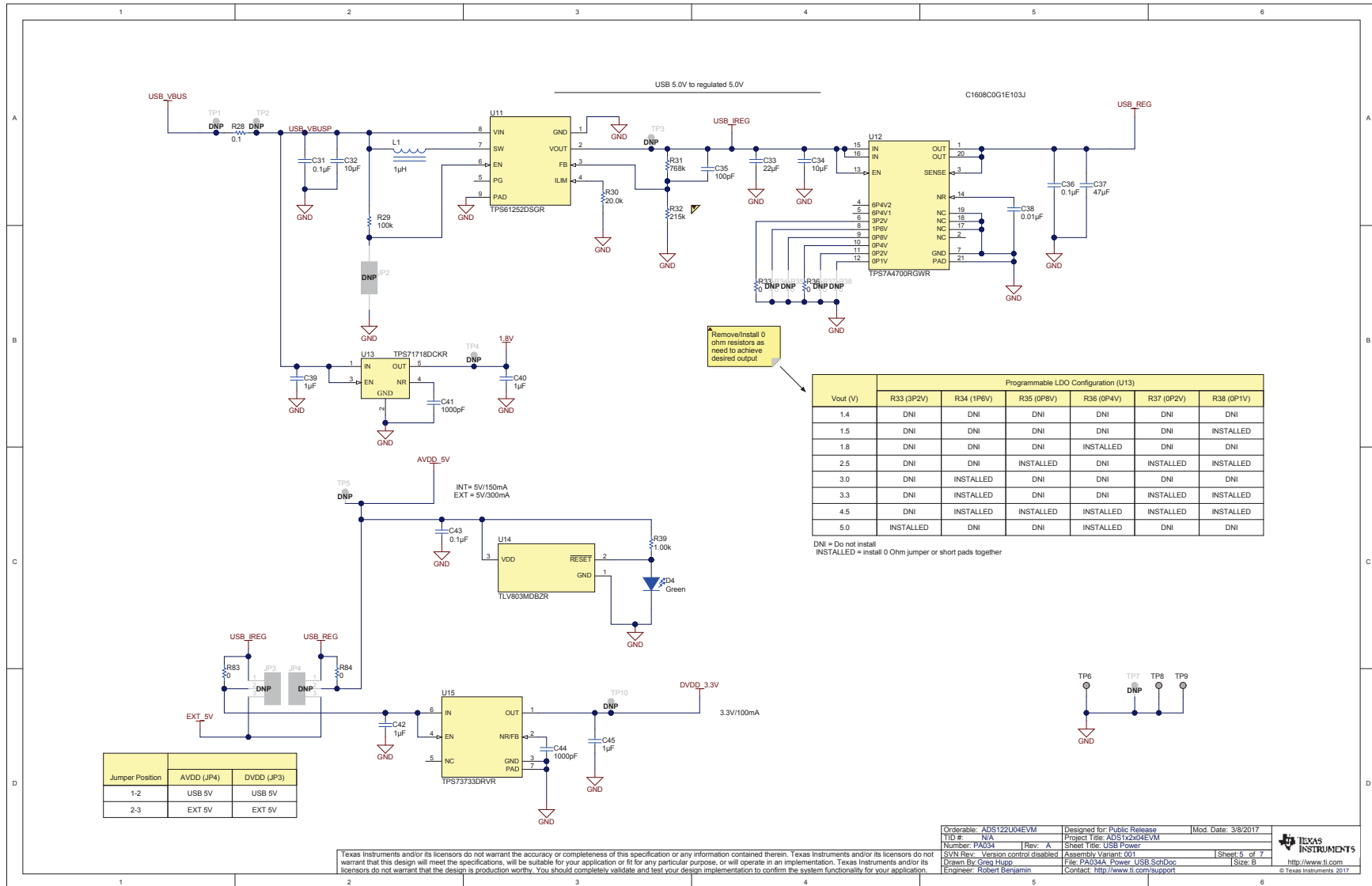


Figure 33. ADS1x2U04EVM Power USB Schematic

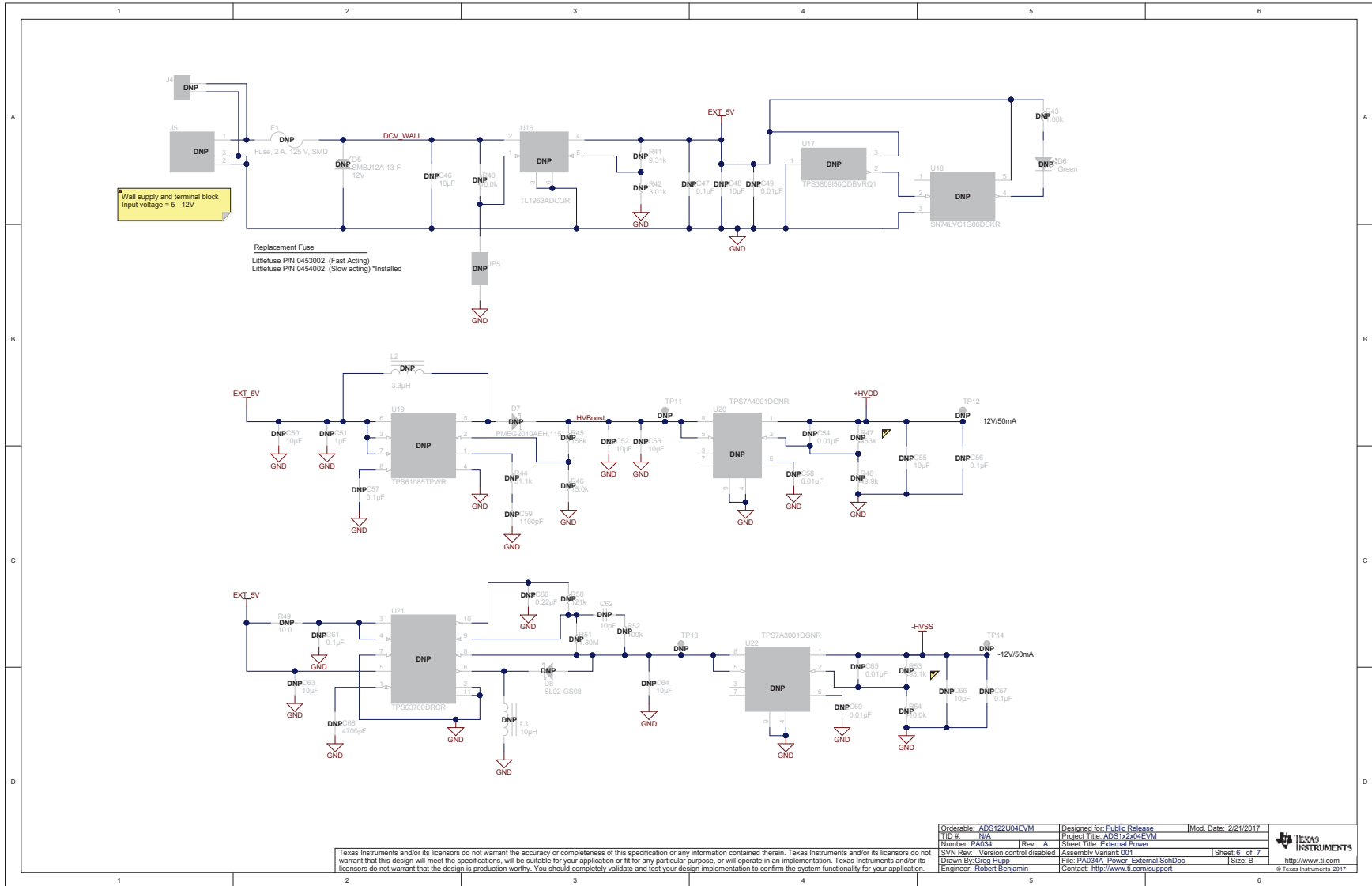


Figure 34. ADS1x2U04EVM Power External Schematic

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3. *Regulatory Notices:*
 - 3.1 *United States*
 - 3.1.1 *Notice applicable to EVMs not FCC-Approved:*

FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.
 - 3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

CAUTION

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

FCC Interference Statement for Class A EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

3.2 Canada

3.2.1 For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

3.3 Japan

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lstds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lstds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive):*

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user 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, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*
- 6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.
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10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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