ADS1232REF User's Guide

The ADS1232REF is a reference design for the ADS1232 24-bit delta-sigma analog-to-digital converter (ADC). It contains the complete circuitry and user interface needed for a weigh-scale digitizer, and is meant as an example of good design for a basic weigh-scale system. It is also suitable for general evaluation of the ADS1232 device. Additionally, performance results obtained are applicable to the ADS1234, which performs identically.

The ADS1232REF hardware has the following features:

- ADS1232 ADC
- Connections for load cells and other voltage sources
- Low-side excitation switchable on the load cell header connector
- Complete EMI/RFI suppression between the ADC and rest of design
- Eight-digit starburst LCD readout
- USB connection for firmware updates and remote control
- Designed for very low power consumption
- Battery (9V) or wall power

Version 0.2.x of the firmware does not display or calculate weight; this capability is planned for a later release. Version 0.2.0 of the firmware includes the following features:

- Complete configuration of the device
- Real-time peak-to-peak and RMS noise calculation
- Autoranging voltage display
- Noise displayable in volts, codes, and bits
- Voltage displayable in volts or codes
- Adjustable averaging mode
- Raw hexadecimal code display
- Simple and fast configuration
- Computer link
- Companion PC software for histogram display, datalogging, and device control

The following features are planned for future releases:

- Weigh-scale mode with two-point calibration
- Temperature display

We welcome bug reports and suggestions for additional features; please contact the TI Data Acquisition Applications Group.

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1 Getting Started

1.1 Board Overview

Figure 1 shows a diagram of the ADS1232REF.

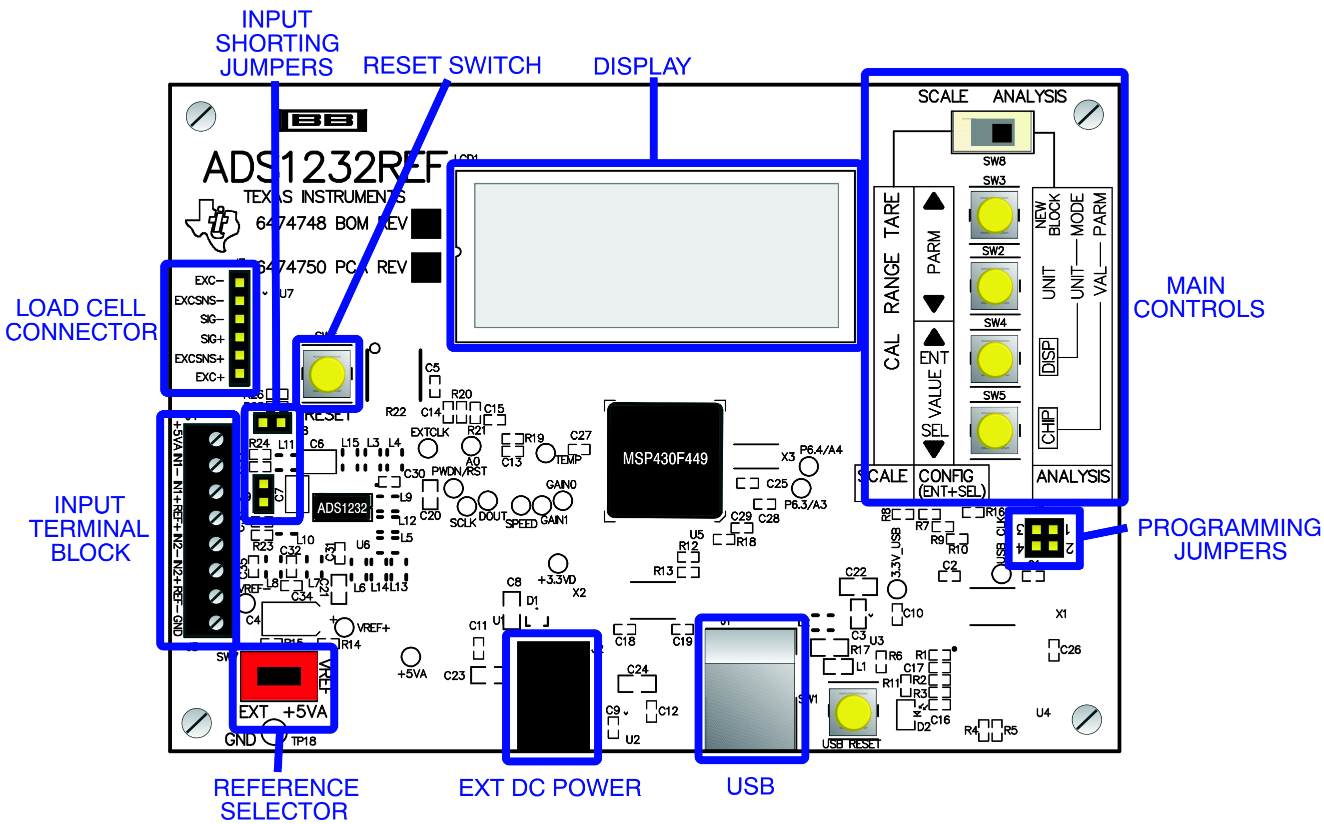


Figure 1. ADS1232REF Controls and Connectors

1.2 Powering the Board

To turn the board on, connect a 9V battery or plug in 6V-9V wall AC adapter.

AC adapters must be tip positive / sleeve negative. When an AC adapter is plugged in, the board always draws power from it, and not from the battery.

The ADS1232REF is protected against polarity reversal. If you connect a power source in reverse by mistake, the display will not come on. To prevent damage to the board, do not leave a reversed power source connected for longer than a few seconds.

1.3 Connecting a Load Cell

The ADS1232REF is specifically designed for connection to load cells; two connectors are provided for this purpose. The terminal block is used for load cells having stripped wire connections; the load cell header is for load cells having a header connector. The connectors differ in that the terminal block provides connections to a reference input, power supply, and both channels, while the header has switched excitation.

1.3.1 Connecting a 4-Wire Load Cell to the Terminal Block

Figure 2 shows the connection of a 4-wire load cell to the terminal block. In this configuration, the load cell is excited by the +5V power supply, and the ADC's reference is taken from the power supply.

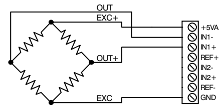


Figure 2. 4-Wire Load Cell to Terminal Block

For this configuration, the reference select switch must be in the +5VA position.

1.3.2 Connecting a 6-Wire Load Cell to the Terminal Block

Figure 3 shows the connection of a 6-wire load cell to the terminal block. In this configuration, the load cell is excited by the +5V power supply, and the ADC reference is taken from the sense wire returning from the load cell. The sense wire connects to the excitation wire at the bridge sensor.

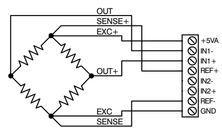


Figure 3. 6-Wire Load Cell to Terminal Block

For this configuration, the reference select switch should be in the EXT position for best performance. The +5V position also works, but may not perform as well.

1.3.3 Connecting a 4-Wire Load Cell to the Header

Figure 4 shows the connection of a 4-wire load cell to the header. In this configuration, the load cell is excited by the +5V power supply, and the ADC reference is taken from the power supply.

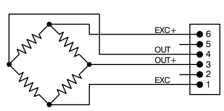


Figure 4. 4-Wire Load Cell to Header

For this configuration, the reference select switch must be in the +5VA position; the EXT position will not work.

1.3.4 Connecting a 6-Wire Load Cell to the Header

Figure 5 shows the connection of a 6-wire load cell to the header. In this configuration, the load cell is excited by the +5V power supply, and the ADC reference is taken from the sense wire returning from the load cell. The sense wire connects to the excitation wire at the bridge sensor.

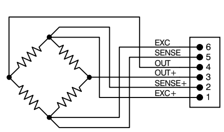


Figure 5. 6-Wire Load Cell to Header

For this configuration, the reference select switch should be in the EXT position for best performance. The +5V position also works, but may not perform as well.

1.4 Connecting Other Sources

In general, the ADS1232 can measure any voltage in the device's input range, as long as the following points are observed:

- ***Never supply a negative voltage to the ADS1232REF.*** The ADS1232 cannot accept negative input voltages. Supplying negative voltages may damage both the device and the ADS1232REF board.
- Two channels are available. Be sure to switch to the correct channel.
- For single-ended signals, ground the negative input or connect it to 2.5V. A weak 2.5V is available from a voltage divider by shorting J8; see Section 5.4.5 for details.
- The input range of the amplifier on the ADS1232 does not extend to the supplies. See the ADS1232 data sheet for details.

1.5 Configuring the ADS1232REF

When the ADS1232REF is first powered up, it sets the ADS1232 gain to 1, the speed to slow (10SPS), and the channel to 1.

To change any of these settings, hold down the button marked **CHIP** and, while holding the button down, press either **PARM** or **VAL** (the top two buttons). *PARM* chooses the parameter to be adjusted, and *VAL* changes the parameter value. Settings take effect once CHIP is released.

For load cell measurement, the ADS1232 is typically set to low speed, with a gain of 128.

1.6 Shorted-Input Noise Test

The noise measurements given in the datasheet are taken with the inputs shorted to 2.5V. To set up these measurements on the ADS1232REF, do the following:

1. Short jumpers J8 and J9. These jumpers are located very near to the terminal block, and are marked *Input Shorting Jumpers* in Figure 1.
2. Set up the ADS1232 as desired, as described in Section 1.5.
3. Hold down the **DISP** button. You will see something like *RAW HEX* on the display. While holding down DISP, press the **MODE** button until the left word reads *RMS*.
4. While still holding down DISP, press the **UNIT** button until the right word reads *VOLT*.
5. Release the DISP button. On the display, you will see the word *GOT* followed by an increasing number. Eventually, you will see a voltage displayed. This voltage is the shorted-input RMS noise voltage, input-referred.

The first RMS noise measurement may be incorrect because of device settling. The second measurement will generally be correct.

There are other modes you can use. See Section 2 for a complete description of these modes.

2 Using the ADS1232REF

2.1 Operating Modes

The ADS1232REF operates in one of two modes:

- **Analysis mode:** Codes are taken directly from the ADS1232 and various measurements are made upon these codes. Several measurements are available, including raw display, voltage, RMS noise, and peak-to-peak measurements. The ADS1232 can also be configured directly from this mode.
- **Configuration mode:** Parameters governing the operation of the ADS1232REF can be viewed and altered in this mode.

Analysis mode is described in detail in Section 2.3. Configuration mode is described in detail in Section 2.4.

Future versions of the firmware will feature a third mode, which will allow the ADS1232REF to operate as a weigh scale.

2.2 Controls

The primary controls for the ADS1232REF are the four buttons and slide-switch at the right side of the board.

The four buttons have different functions depending on the operating mode. In firmware version 0.2.x, there are two modes: Configuration and Analysis. In Analysis mode, the switches have the functions shown in the box labelled **ANALYSIS**. In configuration mode, the switches have the functions shown in the box labelled **CONFIG**.

The slide switch selects between weigh-scale and analysis modes. In firmware version 0.2.x, weigh-scale mode is not available, and the switch has no effect.

Since the switches can have multiple names, we will call them by the name they have in the mode under discussion.

2.3 Analysis Mode

In Analysis mode, the ADS1232REF analyzes code output from the ADS1232. Numerous display modes are available, as seen in Table 1, together with example displays.

Table 1. Modes and Example Displays

	HEX CODE	DEC CODE	DISPLAY	ENOB
Raw	1992E9H	+1676001	+499.488M	n/a
RMS	n/a	+5.789	+17.495N	+2318BIT
Peak-to-Peak	n/a	+31.256	+90.293N	+21.92BIT
Averaged	n/a	+1676001	+499.488M	n/a

The default analysis mode is RAW HEX.

To change measurement types, hold down DISP and press MODE. This sequence cycles through the four available measurement types. When DISP is released, the newly selected measurement is made. To change units, press UNIT. This cycles through the available units for the active measurement type. This process can also be done while DISP is held down; in that case, the new unit is shown by name on the display.

Measurement modes are described in detail in Section 2.3.2.

The ADS1232 itself can be configured directly from this mode, as described in Section 2.3.1.

2.3.1 Switch Functions

NEW BLOCK—Pressing this button resets the collection process for the RMS, peak-to-peak, and averaged measurements.

UNIT—Cycles between available units. Not all units are available in all modes.

DISP—When this switch is pressed, the display shows the current measurement mode and unit. While DISP is still pressed, pressing NEW BLOCK / MODE cycles through the available measurement modes.

CHIP—Holding this button down allows the settings of the ADS1232 to be changed, using the PARM (NEW BLOCK) and VAL (UNIT) buttons.

Pressing PARM while DISP is held down cycles through the available parameters, which are *gain*, *data rate*, and *active channel*.

The gain setting is displayed as **GAIN=** followed by the gain setting. 1, 2, 64 and 128 are the gain settings available.

Data rate is shown on the display as **SPD=FAST** or **SPD=SLOW**.

Channel is shown as **CHANNEL** followed by the active channel number, which can be 1 or 2.

If any of these parameters are changed during a multisample measurement, the measurement is restarted.

2.3.2 Measurement Modes

Raw: In this measurement, codes are read from the ADS1232 and displayed. No processing or analysis is done on the sample stream. Data can be displayed as hexadecimal codes, decimal codes, or volts.

Volts are calculated in the following manner:

$$v = \frac{x}{2^{24} - 1} \frac{v_{REF}}{A} \qquad (1)$$

where ***A*** is the converter gain (1, 2, 64 or 128) and $v\upsilon_{REF}$ is the voltage at the converter's reference input. A is determined from the programmed gain setting.

The value used for $v\upsilon_{REF}$ is adjustable from Configuration mode. It is typically 5, and defaults to this value.

The voltage display is auto-ranging. All ranges are shown with six significant figures having three decimal places. The ranges are given in Table 2.

Table 2. Voltage Display Ranges

	VOLTAGE RANGE	DISPLAY SUFFIX
Nanovolts	< 1μV	n
Microvolts	< 1mV	u
Millivolts	< 1V	m
Volts	≥ 1V	V

RMS noise: In this mode, a number of codes are read from the ADS1232, and an RMS noise calculation is performed on them, using the standard-deviation formula in Equation 2:

$$s_N = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (x_i - \bar{x})^2} \qquad (2)$$

The result can be displayed as decimal codes, volts, or effective bits (ENOB). For decimal codes, s_N is displayed directly. (Hexadecimal is not available since s_N is generally fractional.) For volts, s_N is converted to a voltage as in raw mode.

ENOB *E* is calculated using Equation 3:

$$E = \begin{cases} 24 - \log_2 s_N & : s_N \neq 0 \\ 24 & : s_N \neq 0 \end{cases} \qquad (3)$$

The zero case is needed when a string of equal codes is read, which can happen when the converter is clipping.

Since this measurement requires a number of codes to be read before a calculation can be made, during the first run the display shows the word *GOT* followed by the number of samples collected. This output happens when the mode is first entered, when the converter configuration is changed, or when **NEW BLOCK** is pressed.

The number of codes used in the calculation is selectable in Configuration mode. 50 is the number of codes used in laboratory characterization and is the default value.

Peak-to-peak noise: In this mode, a number of codes are collected, and the absolute value of the difference between the minimum and maximum is calculated. The result can be displayed in decimal or hexadecimal codes, volts, or noise-free bits (ENOB). Volts is calculated as in raw mode; ENOB is calculated in the same way as in RMS mode.

The number of codes used in the calculation is selectable in Configuration mode.

Averaged: In this mode, a number of codes are collected, and the average value is calculated. The result can be displayed in decimal codes or volts. (Hexadecimal is not available since the result is generally fractional.) Volts are calculated as in raw mode.

The number of codes used in the calculation is selectable in Configuration mode.

2.3.3 Progress Graph

The row of apostrophes at the top of the display are used to indicate measurement progress. In Raw mode, the apostrophe moves across the display when data is being received from the converter. The apostrophe moves once for every eight samples collected from the ADC.

In block collection modes, the apostrophes become a bar graph. As the collection of a block proceeds, the bargraph increases. When the bar graph reaches all the way to the right, the new result is generated and collection restarts.

2.4 Configuration Mode

Various aspects of the ADS1232REF can be set in Configuration mode.

To enter Configuration mode, hold down CHIP and press DISP. Once this key sequence is done, the four buttons assume the functions shown in the CONFIG box. To exit Configuration mode, hold down CHIP and press DISP. This sequence will not cause parameters to be adjusted, since only button releases are detected in Configuration mode.

Configuration mode contains a number of adjustable parameters. To scroll through the available parameters, use the PARM buttons. To change the parameter values, use the VALUE buttons.

Some items in Configuration mode are not parameters, but commands or gateways to a submenu. These are labelled as words with a question mark. To enter these gateways or to execute the command, press SEL.

Table 3 summarizes the available parameters.

Table 3. Parameters in Configuration Mode

PARAMETER	DISPLAY	VALUE RANGE	DESCRIPTION
Averages	AVG=	2 – 128	Number of points for average, peak-to-peak, and RMS modes
ADC Clock source	CLK=	INT, EXT	Clock source for ADC: internal or external
Voltage reference	VREF=	0.5 – 5.0	Voltage used in various calculations
Debug mode	DEBUG?	n/a	Submenu for Debug mode
Version number	V0.2.0	n/a	Firmware version number display

2.4.1 Configuration Mode Parameters

Averages: Number of points to use in Averaged, RMS noise, and Peak-Peak calculations. The choices available are 2, 4, 8, 10, 16, 32, 50, 64, and 128. The default number is 50.

ADC clock source: The ADS1232REF can supply an external clock derived from a crystal, or it can allow the ADS1232 to use its internal clock source. This parameter selects which clock is used.

On the ADS1232REF, the external clock is supplied from the microcontroller main internal clock, which is generated by a digital frequency-locked loop and runs at approximately 7.99MHz. The device therefore operates at a faster rate compared to the internal clock, which operates at approximately 4.91MHz, allowing the faster data rate to be evaluated.

The external clock also allows the ADS1232 sensitivity to clock jitter to be evaluated, since the FLL clock exhibits a high amount of jitter.

Internal clock mode is affected by holding the clock line low. See the ADS1232 data sheet for details.

Voltage reference: To convert voltages to codes, the ADS1232REF requires the voltage reference level. Since this cannot be measured, it must be selected manually. This parameter allows the reference level to be set.

This parameter does not affect the actual voltage reference used. If it is incorrect, voltage calculations will be wrong.

The voltage reference is typically the +5V rail, so the default value for this parameter is 5.0V.

Debug mode: Pressing SEL from this screen enters a diagnostic mode. To exit this mode, press SEL again.

Version number: This screen displays the version number of the ADS1232REF firmware.

3 Using the PC Software

The ADS1232REF is supplied with software that performs various analyses on data received from the board via the USB connection. It also provides a means of recording received data to a file. The program currently runs only on Microsoft Windows™ platforms of Windows2000 or higher.**CHECK THIS.**

On Windows, the program communicates with the ADS1232REF using a virtual COM port driver that causes the USB connection to appear as a normal serial port to the Windows operating systems. The necessary driver is installed with the EVM software.

3.1 Installation and Setup

The ADS1232REF software is distributed by means of an installer program called **ads1232ref_1-0-0_install.exe** . To install the software, run this program. The program will guide you through the installation process.(1)

The following conditions should be noted:

- The installer installs two packages: the ADS1232REF program itself, and the TI Virtual COM Port driver.
- If any version of the ADS1232REF program is already installed, the installer will uninstall it and quit. You must run the installer again to complete the installation.
- If the Virtual COM Port driver is already installed, the installer will offer to uninstall it. *Do not uninstall it*: simply cancel that part of the installation.
- The installer displays messages reminding you of these conditions.

(1) The version number is embedded, and may differ.

3.1.1 Connecting the ADS1232REF for the First Time

If you have never connected the ADS1232REF before, Windows will detect the device as unknown hardware and take you through a series of dialogs that installs the correct driver on the system. Accept the default settings, because the driver is present and only needs to be copied to the correct location. If all goes properly, Windows will not issue this prompt again.

You may need to press the **USB Reset** switch to make this work properly; see Connection Failures 3.1.2 for details.

3.1.2 Connection Failures

When you first connect the ADS1232REF, Windows typically does not properly detect the device. This occurrence is the result of a problem in the USB interface circuit; it is not the result of any problem in the installation or operating system.

If Windows displays a message to the effect that a device has failed to connect properly, pressing the USB Reset switch should fix the problem.

3.2 Software Display

The ADS1232REF software has a single display. A picture of the display in a typical state is shown in Figure 6. The major elements of the display are listed below:

- **Strip chart.** This chart displays a scrolling graph of data received from the board.
- **Histogram.** A sliding histogram of data received from the board. The number of points used in the analysis is adjustable.
- **DC analysis section.** The results of RMS noise analysis, peak-to-peak analysis, and a running voltage number are shown in this section. The number of analysis points and the reference voltage used for voltage calculations are adjustable here.

- **Recording section.** This element controls recording of data to a file.
- **Device control section.** Device parameters are adjustable here.
- **Status display.** This element shows messages indicating the current state of the program.
- **Acquire button.** This element starts and stops the running acquisition of data.

3.3 Starting the Program

When the program launches, you will see the screen shown in Figure 6. Immediately after launch, the program searches all available serial ports for the board. To perform this search, it opens every available serial port in turn, testing it to see if there is an ADS1232REF connected. The program uses the first ADS1232REF it finds.

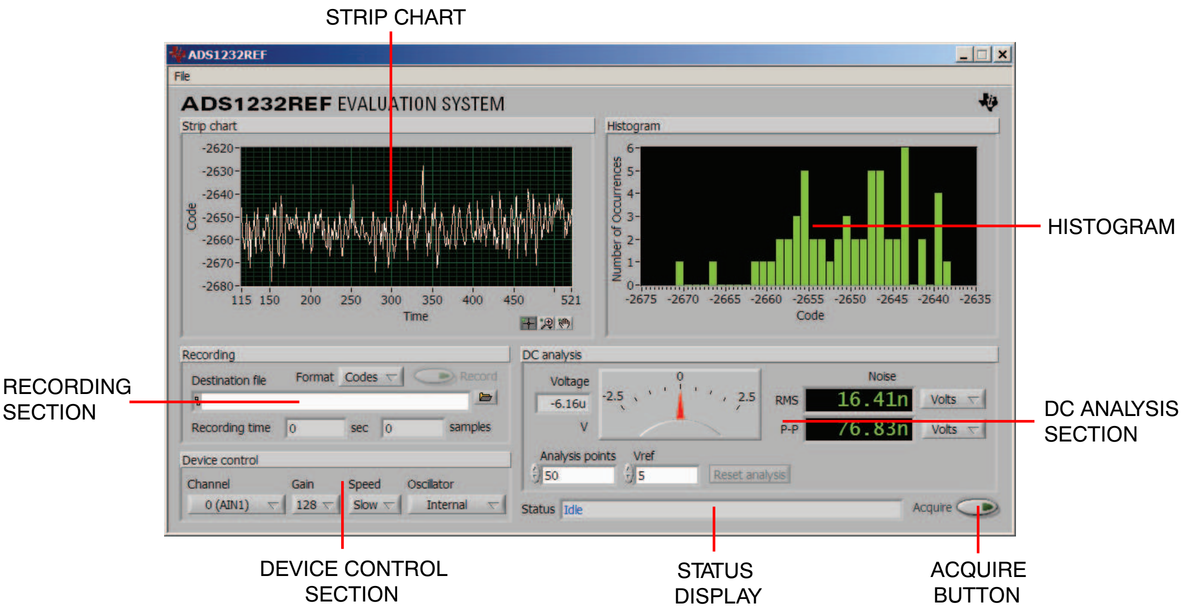


Figure 6. ADS1232REF Software Display

Although this is a conceptually simple process, it may not go as smoothly as expected. The following process will ensure that the board is found correctly. Note that steps 1-3 can be done in any order:

1. Apply power to the ADS1232REF.
2. Plug in the USB connector.
3. Start the program.
4. Watch the status display. It will read *Scanning* followed by the name of the serial port being tested. When the board is found, the display will read *Idle*. Until a board is found, the display cycles through every port, spending approximately one second on each port.
5. If the board is not found, press **USB RESET**.

The last step is required because it often happens that the ADS1232REF USB interface does not properly register with Windows when it is first plugged in. Pressing USB RESET on the ADS1232REF, which is the button located next to the USB connector, forces Windows to re-register the board. Once this re-registration is done, the board's new serial port will be added to the list of available ports, and it will be found. It may take a complete cycle before the program detects the new serial port.

Once the board is detected, the program enters *Idle* state and is ready for use.

Note that even if the board is never detected, it is still possible (and safe) to exit the program during the search process.

3.4 Adjusting Device Parameters

To adjust device parameters, use the four controls in the *Device control* box. Each control corresponds to a setting that can be made from the board itself.

When the program enters Idle mode, it queries the ADS1232REF for the current state of each control, and updates them as necessary. This query is only made when Idle mode is entered. Changes made from the board are not reflected until a transition into Idle mode occurs. This transition occurs after Recording or Analysis modes are stopped, or after the program first finds a board.

3.5 Analysis

To start receiving and analyzing data from the board, click the button marked **Acquire**, located in the lower right hand corner of the display. The program will begin to receive data from the board, displaying the results in near-real time.

It is not possible for the program to adjust board parameters in Analysis mode. For this reason, the board controls are disabled and dimmed when Analysis is occurring.

However, it is possible to make parameter adjustments from the board itself, using the LCD and buttons, while the program is in Analysis mode. If this type of adjustment is done, it may invalidate the results seen in Analysis mode. To resynchronize the program and board, stop Analysis, which causes the program to query the board for its current parameters.

3.5.1 Controlling the Analysis

The histogram, RMS, and peak-to-peak calculations require a set of samples. These calculations are updated with every group of samples received, and are performed on a block of the most recently acquired samples.

The number of samples used is set using the **Analysis points** control. By default, this value is 50, but can be changed at any time. This value also controls the RMS and peak-to-peak noise analysis lengths.

If the number of samples collected is not yet equal to the number of samples specified by the Analysis points control, zeros are substituted for the samples not yet received.

In Analysis mode, the analysis can be reset using the button marked **Reset analysis**. This clears the internal analysis buffer. This button cannot be used outside of Analysis and Recording modes.

Analysis is automatically reset when Analysis and Recording modes are entered.

3.5.2 RMS and Peak-to-Peak Noise Analysis

The RMS and peak-to-peak noise analysis calculations are performed in exactly the same way as they are on the board, as described in Section 2.3.2. Each can be displayed in units of volts, codes, or bits, as on the board. See Section 2.3.2 for detailed descriptions of the calculations.

The number of samples used in each calculation is set using the Analysis points control. By default, this number is 50, but can be changed at any time. This number also controls the histogram length.

3.5.3 Voltage Conversion

When units of volts are displayed, the program must have a value for the reference voltage applied to the ADS1232 to properly calculate the voltage. Because this voltage cannot be measured using the ADS1232REF, it is set manually using the **Vref** control.

The value of Vref defaults to 5V, because the reference is normally taken from the 5V power supply. If a different reference voltage level is used, the value of Vref should be changed to reflect this different reference, so that voltage calculations are performed correctly. The Vref control also affects voltages recorded in Record mode.

3.5.4 About Block Acquisition

To enable the program to run reliably on slower computers, results are not calculated in real time. Instead, groups of samples are received and added to the analysis buffers, which are then analyzed. This block processing occurs approximately 1.33 times per second, and is timed by the number of samples received from the board. Block processing is why the display does not update smoothly, but only every 0.75 seconds.

3.6 Data Recording

The ADS1232REF software can record incoming samples to a text file. This file can be loaded into other programs for analysis. Data recording is performed using the controls in the **Recording** box. Follow this procedure to record data to a file:

1. Select a destination file. The file does not need to exist. Either type the file path directly into the *Destination file* control, or click the small open folder icon to the right of the control. This icon opens a dialog box from which a file can be selected. If the selected file exists already, the program will display a warning.
2. Select a data recording format. The samples can be recorded as raw (decimal) codes or as volts. In both cases these are written to the file as ASCII, and the file is a text file.
3. Click the **Record** button. The program begins to collect and analyze data from the board, but also writes it to the selected file. As recording proceeds, the recording time indicators are updated.
4. Click **Record** again to stop the recording when the desired amount of data has been collected.

The selected file is not opened or created until recording begins. If an error occurs at that time, recording will be cancelled and a message will be displayed in the status box.

Recording time is not measured, but calculated from the number of samples collected. The speed and oscillator fields are used to determine the amount of time for each sample. If the data rate is changed at the board, the recording time will be incorrect. This does not affect the data file, except that samples continue to be collected with the different settings.

In Recording mode, analysis proceeds as it does in Analysis mode; Recording mode is identical to Analysis mode, except that data is written to a file. See the Analysis 2.3 for documentation on Analysis mode. When Recording mode begins, if the selected file exists, it is erased and overwritten. The pre-existence of the file is checked only when a new file is selected.

3.6.1 File Format

Recorded data files begin with a header containing the time of recording, the software version, and the name of the program. Following this header, values are written in either volts or raw codes, with one value per line. Line separators are DOS format, consisting of a carriage return and a line feed. This format can be examined in a text editor and loaded or imported into most other software, including spreadsheets.

Voltages are calculated using the reference voltage given in the Vref control; therefore, it is important that this value is correct.

4 Serial Console

The ADS1232REF provides a console mode that can be used with any Windows terminal emulation program, such as Hyperterm. On a Windows-based PC, this emulation is done through the Virtual COM Port driver supplied with the EVM software, which causes the ADS1232REF to appear in Windows as an extra serial port.

4.1 Using the Console

To use the console, load a terminal emulation program and connect to the EVM serial port using the following parameters:

- Baud rate: 115200
- Data bits: 8
- Parity: none

- Stop bits: 1
- Flow control: none
- Local echo: off
- Terminal emulation: ANSI or VT100

Setting up the terminal program is beyond the scope of this document; see the terminal program documentation for details.

To locate the serial port, try higher port numbers first. When the board first starts, it outputs the following message:

```
ADS1232REF 0.2.0 (c)2005 Texas Instruments
1232>
```

Pressing **Reset** causes the board to output this message.

The command prompt is always `1232>`. Commands are entered at this prompt. Commands consist of one letter possibly followed by arguments. The format of the arguments depends on the command. Commands are case insensitive. Upper-case characters are printed here, but lower-case characters also work.

The available commands are listed in Table 4. In this table, values in brackets indicate a range or list of possible characters. A dash (**–**) indicates a range, and commas (**,**) indicate a list.

Table 4. Console Mode Commands

COMMAND	FORMAT	OPERATION
P	`P [0 - 3]`	Set PGA
R	`R [F,S]`	Set data rate
O	`O [E,I]`	Set clock source
C	`C [0,1,T]`	Set input channel
V	`V`	Set firmware version
S	`S`	Start streaming
D	`D`	Read data once
Q	`Q`	Query parameters

Console mode does not interrupt standalone operation. It is always available, even when the standalone mode is in use. However, if parameters are changed using both the console and standalone modes, parameters may become out of sync.

4.2 Command Reference

4.2.1 P—Set PGA

This command sets the gain of the ADS1232 PGA in the following manner:

- `P0`— sets gain to 1
- `P1`—sets gain to 2
- `P2`— sets gain to 64
- `P3`— sets gain to 128
- `P`—(with no argument) prints the current gain setting

4.2.2 R—Set Data Rate

This command sets the speed mode of the ADS1232 PGA in the following manner:

- `RF`— sets rate to fast
- `RS`—sets rate to slow

- R—(with no argument) prints the current data rate setting

Note that the actual data rate depends on the frequency of the device clock.

4.2.3 O—Set Clock Source

This command sets the clock source of the ADS1232 PGA in the following manner:

- OI— sets clock source to internal
- OE—sets clock source to external
- O—(with no argument) prints the current clock source setting

On the ADS1232REF, the external clock source is supplied by the microcontroller, and operates at approximately 7.99MHz.

The internal clock source is generated by the ADS1232 itself and is nominally 4.9152MHz. See the ADS1232 data sheet for more information on the internal clock source.

4.2.4 C—Set Channel

This command sets the channel of the ADS1232 PGA in the following manner:

- C0— sets input channel to AIN1
- C1—sets input channel to AIN2
- CT—sets input channel to temperature
- C—(with no argument) prints the current channel setting

4.2.5 V—Show Version

Displays a message containing the firmware version and copyright notice.

4.2.6 S—Start Streaming

When **S** is issued, the ADS1232REF begins printing raw output codes from the ADS1232 in hexadecimal format, separated by new lines. It does this continuously until a character is received from the serial port.

S is used primarily by the EVM software for data collection.

4.2.7 D—Collect One Sample

Issuing **D** causes the ADS1232REF to report the latest collected sample from the ADS1232. The sample is displayed in raw hexadecimal.

4.2.8 Q—Query Parameters

Q causes the ADS1232REF to issue a coded string summarising the current settings. The format of the string is:

```
P[0-3]R[F,S]O[E,I]C[0,1,T]¡CR¡LF
```

5 Hardware

A block diagram of the ADS1232REF is shown in Figure 7. The schematic and layout drawings are given in Section 6 at the end of this document.

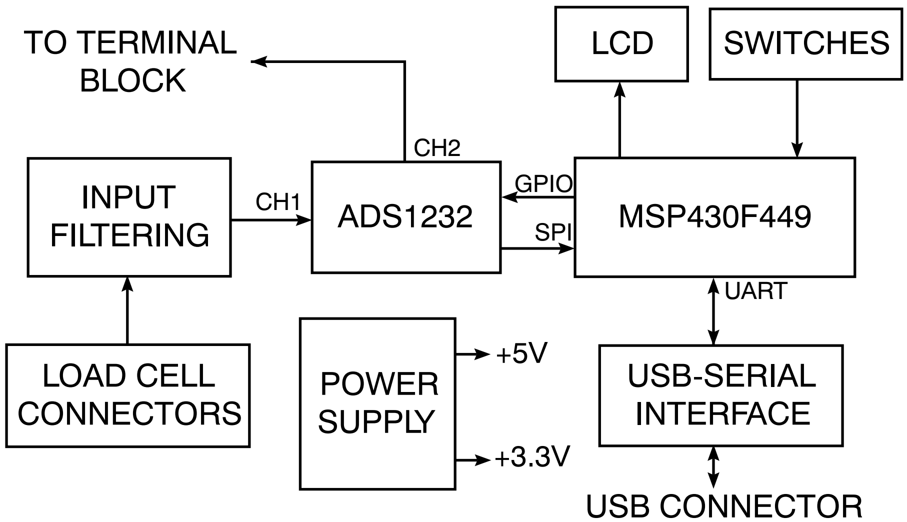


Figure 7. ADS1232REF Hardware Block Diagram

5.1 *Microcontroller*

The ADS1232REF is based around the MSP430F449 microcontroller. This device provides ample ROM and sufficient RAM for the firmware to operate, an LCD controller, hardware SPI™ and UART interfaces, and a multiplier. The latter is important since the firmware must perform many multiplications.

5.2 *Power Supply*

The ADS1232REF operates from +5VDC and +3.3VDC. These supplies are generated by linear regulators U1 and U2. Input power comes from either wall-adaptor connector J2, or battery connector BT1. J2 is switched; when a connector is plugged in, BT2 is disconnected.

Noise is important because the ADS1232 voltage reference is typically taken from the power supply. The supplies are heavily bypassed to reduce noise.

5.3 *User Interface*

The ADS1232REF user interface consists of LCD LCD1 and switches SW2–5 and SW8. Switches are connected to interrupt-capable GPIO on the microcontroller, which allows them to wake the microcontroller from sleep mode.

5.4 *ADC Section*

The ADC section is the functional heart of the ADS1232REF; it consists of the ADS1232 device itself and ancillary circuitry.

All signals on the ADS1232 except for the channel 2 inputs are filtered by pass-through capacitors, which help to reject EMI, RFI, and noise generated by the digital circuitry.

5.4.1 Input Circuitry

The ADS1232REF is designed to connect to resistive bridge sensors, particularly load cells. The ADS1232 has two channels; channel 2 is a direct connection and has no filtering.

Channel 1 is the primary connection for load cells. It is filtered by pass-through capacitors L10 and L11 and differential capacitor C7. Common-mode capacitors C33 and C36 provide additional RF rejection.

5.4.2 Load Cell Header

The load cell header, J7, provides a convenient terminal for load cells having a properly fitted header connector. It provides excitation and sense connections. The negative excitation line is connected to ground through analog switch U7, which is controlled by the microcontroller. This arrangement allows for sleep-and-convert control, which can reduce self-heating in the load cell and conserve power.

The load cell connector pinout is given in Table 5. For connection examples, see Section 1.3.3 and Section 1.3.4.

Table 5. Load Cell Header Pinout

PIN NO.	PIN NAME	FUNCTION
1	EXC+	Positive excitation; connected to +5VA
2	EXCSNS+	Positive sense; connected to external positive reference input
3	SIG+	Input for positive load cell output; connected to ADC channel 1
4	SIG–	Input for negative load cell output; connected to ADC channel 2
5	EXCSNS–	Negative sense; connected to external negative reference input
6	EXC–	Negative excitation; connected to ground through switch U7

5.4.3 Input Terminal Block

The input terminal block consists of J4 and J5. It provides connections to all of the analog inputs on the ADS1232, and connections to the ADS1232REF voltage reference network. Unlike the load cell header, there are no dedicated excitation outputs; instead, connections to ground and the 5V supply are provided, and neither is switched. Also unlike the header, channel 2 inputs are available on the terminal block.

The terminal block pinout is given in Table 6.

Table 6. Terminal Block Pinout

TERMINAL NAME	FUNCTION
+5VA	5V analog power supply output
IN1–	Channel 1 negative input
IN1+	Channel 1 positive input
REF+	Positive reference input
IN2–	Channel 2 negative input
IN2+	Channel 2 positive input
REF–	Negative reference input
GND	Board ground

5.4.4 Voltage Reference

The ADS1232REF is designed to operate either ratiometrically or with an external reference. The two modes are selected using switch SW7.

In the EXT position, the ADS1232 reference inputs are taken from the load cell connectors. In the INT position, the ADS1232 positive reference input comes from the 5V analog supply, and the negative reference input is connected to ground.

After the switch is a filtering network consisting of resistors R14 and R15, bulk capacitor C4, pass-through capacitors L7 and L8, and filtering capacitors C32, C34, and C35.

5.4.5 Input-Shorting Jumpers

The shorted-input noise test for the ADS1232 is best performed with both inputs connected to 2.5V. To make this test easy to perform, jumpers J8 and J9 are provided.

Jumper J8 shorts the inputs together. Jumper J9 connects the negative input to a voltage divider made from R25 and R26, which divide the power supply by 2.

Although the output impedance of this voltage divider is relatively high, it is negligible compared to the input impedance of the ADS1232, and is sufficient for the shorted-input test. Furthermore, since the voltage divider electrically resembles a bridge sensor, it is a reasonable simulation of how the device will behave when connected to an idled bridge sensor.

5.5 USB Interface

The USB interface can be used for firmware download or data communications. Its role in firmware download is discussed in Section 5.6.

The USB interface consists of USB-to-serial converter U4, a Texas Instruments TUSB3410. This device incorporates a USB interface module, a microcontroller, and a 16550-type UART. Driver software is available which causes the device to appear as a serial port on the host PC.

The USB interface is powered separately from the rest of the ADS1232REF; it takes power from the USB line, through linear regulator U3. The serial port side is connected to the microcontroller UART input, and also to the bootstrap loader port. DTR and RTS pins are connected to the TEST and RESET inputs on the microcontroller to allow the serial bootstrap loader to operate.

The DTR and RTS pins are connected through jumper J6, to prevent the interface chip from holding the RESET and TEST lines low when it is unpowered.

5.6 Programming Connections

The MSP430 can be programmed via the dedicated JTAG port or the serial bootstrap loader. Access to the bootstrap loader is provided through the USB interface, which is connected to the bootstrap loader port as well as the normal UART port.

The TEST and RESET lines must be controlled by the PC host for bootstrap loading; these are connected to the DTR and RTS outputs on the USB interface device. Unfortunately, this device will pull these lines low when it is unpowered, so jumper J6 provides means to disconnect these lines when the USB interface is not in use.

The JTAG connector is not factory installed. The footprint is similar to an edge-card pattern, and accepts a standard dual-row 0.100in header mounted on the side of the board. This header is compatible with MSP430 parallel port JTAG adaptors.

6 Schematic and Layout

The printed circuit board (PCB) layouts for the top and bottom sides of the ADS1232REF are shown in Figure 8 and Figure 9, respectively. The schematic for the ADS1232REF is shown in Appendix A.

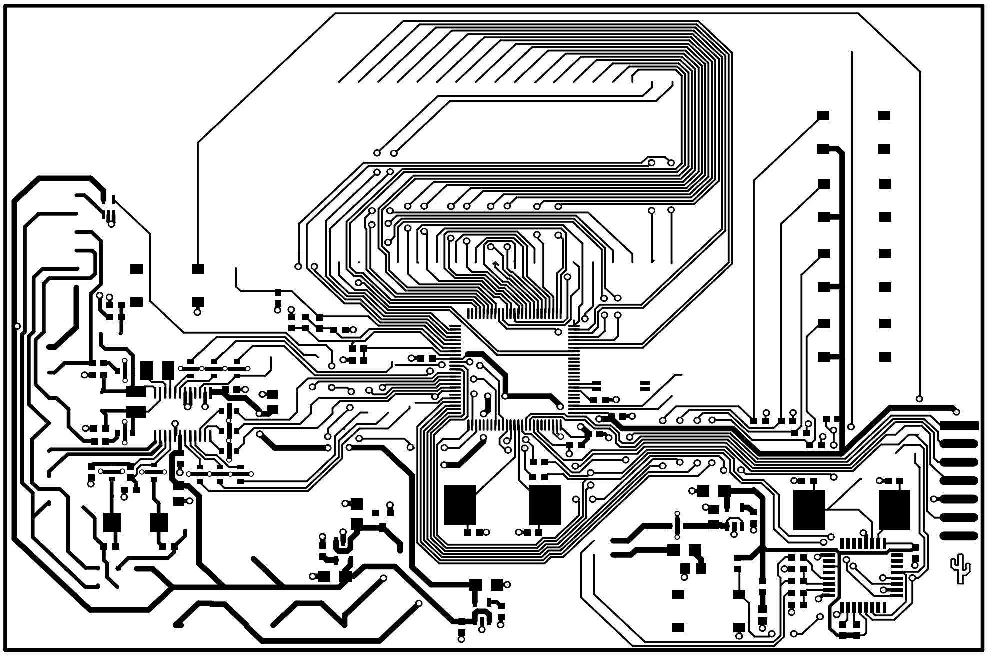


Figure 8. ADS1232REF PCB—Top Side

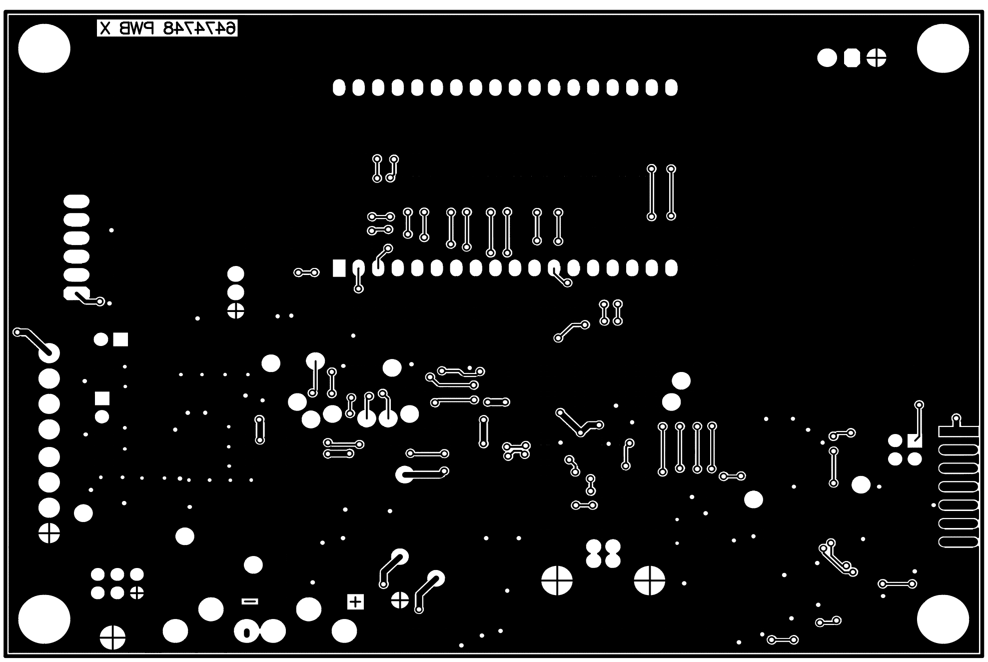
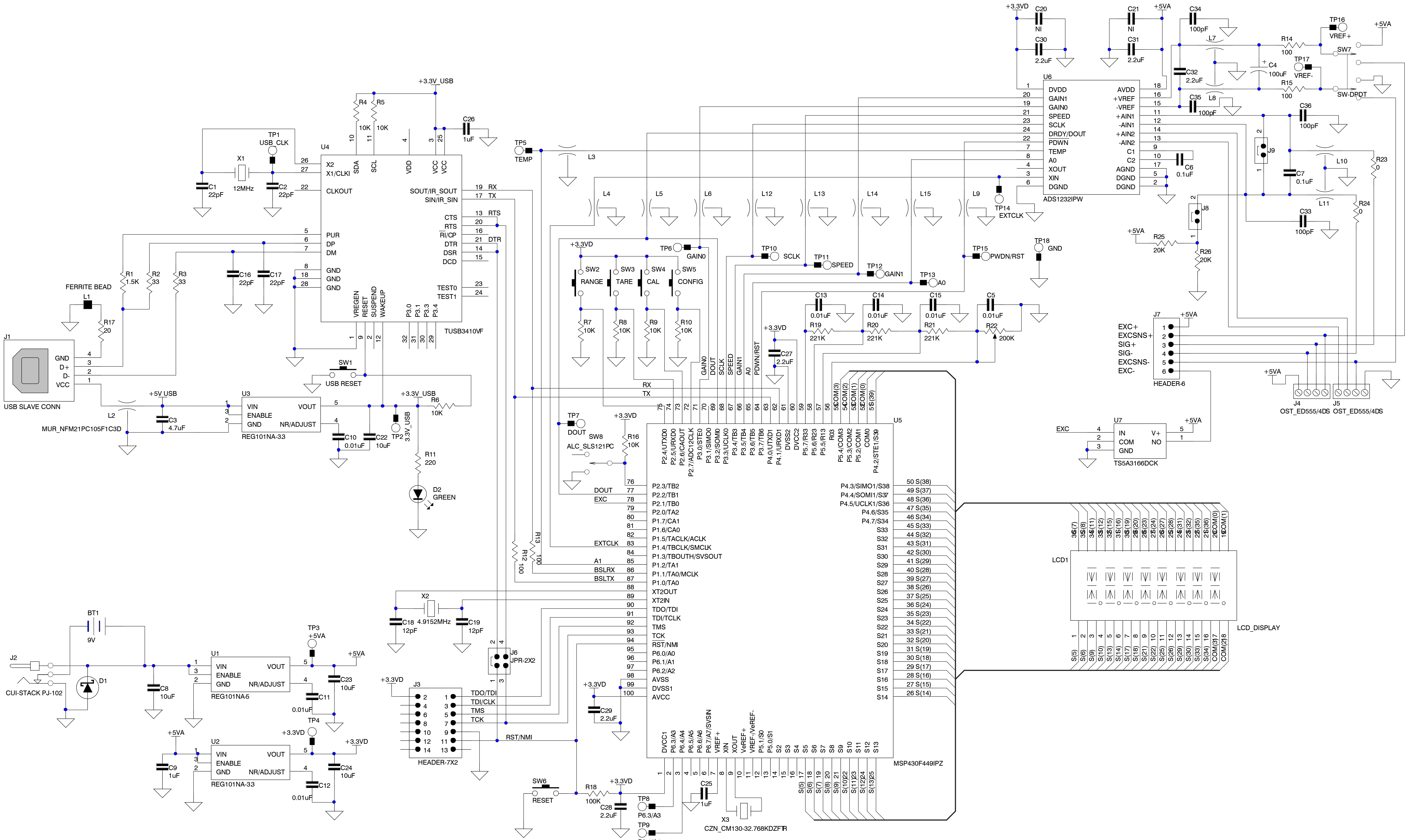


Figure 9. ADS1232REF PCB—Bottom Side

Appendix A ADS1232REF Schematic


U4
TUSB3410VF
X1
12MHz
TP1
USB_CLK
C1
22pF
C2
22pF
R4
10K
R5
10K
+3.3V_USB
C26
1uF
SOUT/IR_SOUT
SIN/IR_SIN
CLKOUT
PUR
DP
DM
GND
CTS
RTS
RI/CP
DTR
DSR
DCD
TEST0
TEST1
VREGEN
RESET
SUSPEND
WAKEUP
RX
TX
FERRITE BEAD
L1
R17
20
R1
1.5K
R2
33
R3
33
C16
22pF
C17
22pF
J1
USB SLAVE CONN
GND
D+
D-
VCC
SW1
USB RESET
L2
MUR_NFM21PC105F1C3D
+5V_USB
C3
4.7uF
U3
REG101NA-33
VIN
ENABLE
VOUT
NR/ADJUST
C10
0.01uF
C22
10uF
TP2
3.3V_USB
R6
10K
R11
220
D2
GREEN
BT1
9V
J2
CUI-STACK PJ-102
D1
C8
10uF
U1
REG101NA-5
TP3
+5VA
C23
10uF
C11
0.01uF
TP4
+3.3VD
U2
REG101NA-33
C9
1uF
C24
10uF
C12
0.01uF
J3
HEADER-7X2
TDO/TDI
TDI/CLK
TMS
TCK
RST/NMI
J6
JPR-2X2
X2
4.9152MHz
C18
12pF
C19
12pF
R12
100
R13
100
SW6
RESET
R18
100K
C28
2.2uF
TP8
P6.3/A3
TP9
P6.4/A4
C25
1uF
X3
CZN_CM130-32.768KDZFTR
TP5
TEMP
L3
L4
L5
L6
L12
L13
L14
L15
L9
TP14
EXTCLK
TP6
GAIN0
TP10
SCLK
TP11
SPEED
TP12
GAIN1
TP13
A0
TP15
PWDN/RST
TP18
GND
SW2
RANGE
SW3
TARE
SW4
CAL
SW5
CONFIG
R7
10K
R8
10K
R9
10K
R10
10K
C13
0.01uF
C14
0.01uF
C15
0.01uF
C5
0.01uF
R19
221K
R20
221K
R21
221K
R22
200K
C27
2.2uF
TP7
DOUT
SW8
ALC_SLS121PC
R16
10K
C29
2.2uF
U5
MSP430F449IPZ
P2.3/TB2
P2.2/TB1
P2.1/TB0
P2.0/TA2
P1.7/CA1
P1.6/CA0
P1.5/TACLK/ACLK
P1.4/TBCLK/SMCLK
P1.3/TBOUTH/SVSOUT
P1.2/TA1
P1.1/TA0/MCLK
P1.0/TA0
XT2OUT
XT2IN
TDO/TDI
TDI/TCLK
TMS
TCK
RST/NMI
P6.0/A0
P6.1/A1
P6.2/A2
AVSS
DVSS1
AVCC
DOUT
EXC
EXTCLK
A1
BSLRX
BSLTX
P4.3/SIMO1/S38
P4.4/SOMI1/S37
P4.5/UCLK1/S36
P4.6/S35
P4.7/S34
U6
ADS1232IPW
DVDD
GAIN1
GAIN0
SPEED
SCLK
DRDY/DOUT
PDWN
TEMP
A0
XOUT
XIN
DGND
AVDD
+VREF
-VREF
+AIN1
-AIN1
+AIN2
-AIN2
C1
C2
AGND
C20
NI
C30
2.2uF
C21
NI
C31
2.2uF
+5VA
C34
100pF
C32
2.2uF
L7
C4
100uF
R14
100
R15
100
TP16
VREF+
TP17
VREF-
SW7
SW-DPDT
C35
100pF
L8
C36
100pF
C6
0.1uF
J9
C7
0.1uF
L10
L11
R23
0
R24
0
J8
C33
100pF
R25
20K
R26
20K
J7
HEADER-6
EXC+
EXCSNS+
SIG+
SIG-
EXCSNS-
EXC-
J4
OST_ED555/4DS
J5
OST_ED555/4DS
U7
TS5A3166DCK
IN
COM
GND
V+
NO
LCD1
LCD_DISPLAY

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