ADS1230REF User's Guide

The ADS1230REF is a reference design for the ADS1230 20-bit, delta-sigma analog-to-digital converter (ADC). It contains all the circuitry and user interface elements needed for a weigh-scale digitizer, and is meant as an example of good design for a basic weigh-scale system. The ADS1230REF is also suitable for general evaluation of the ADS1230 device.

The ADS1230REF hardware has the following features:

- ADS1230 ADC
- Connections for load cells or other voltage sources
- Low-side excitation switch on the load cell header connector
- Ample 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 1.1.0 of the firmware includes the following features:

- Weigh-scale mode with two-point calibration
- Complete configuration of the device
- Real-time peak-to-peak and RMS noise calculation
- Autoranging voltage display
- Noise displayed in volts, codes, and bits
- Voltage displayed in volts or codes
- Adjustable averaging mode
- Raw hexadecimal code display
- Simple and fast configuration
- Parameters saved to internal flash memory
- Computer link

Graphical PC software is also provided for histogram display, datalogging, and device control.

We welcome bug reports and suggestions for additional features; please contact the Texas Instruments Precision Analog Applications Group.

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1 Getting Started

A diagram of the ADS1230REF is shown in Figure 1.

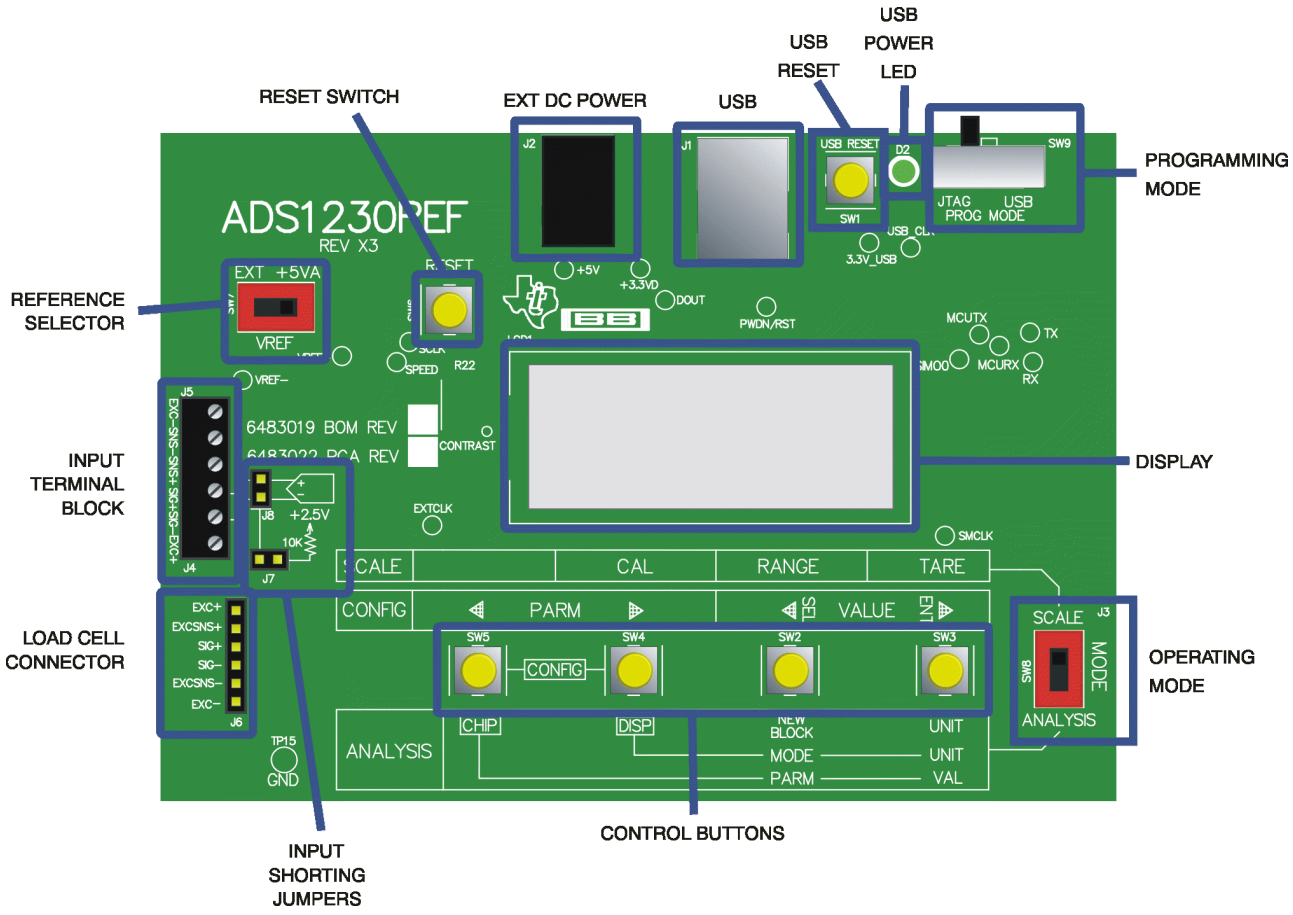


Figure 1. ADS1230REF Controls and Connectors

1.1 Operating Modes

The ADS1230REF operates in one of three modes:

- **Scale mode:** When the mode select switch is in Scale position, the ADS1230REF acts as a basic weigh scale. The scale has tare, range, and calibrate functions, and can display metric (SI) units. Other parameters can be configured in configuration screens. Scale mode is described in detail in Section 2.
- **Analysis mode:** When the mode select switch is in Analysis position, codes are taken directly from the ADS1230 device and various measurements are made upon them. Several measurements are available, including raw display, voltage, RMS noise, and peak-to-peak measurements. The ADS1230 can also be configured directly from this mode. Analysis mode is described in detail in Section 3.
- **Configuration mode:** Parameters governing the operation of the ADS1230REF can be viewed and altered in this mode. Scale and Analysis modes have different options in configuration mode: configuration for Scale mode is described in Section 2.4, and configuration for Analysis mode is described in Section 3.4.

1.2 Controls

The main controls for the ADS1230REF are the four buttons and the mode selection slide-switch (see Figure 1).

The slide-switch selects between weigh-scale (Scale) and Analysis modes. The ADS1230REF switches modes only when it is displaying data. If the switch is changed in a configuration mode, nothing happens until the configuration mode is exited. At that time the ADS1230REF reads the switch and enters the selected mode.

The four buttons have different functions, depending on the operating mode. In Scale mode, the switches have the functions in the box labeled **SCALE**. In Analysis mode, the switches have the functions shown in the box labeled **ANALYSIS**. In configuration mode, the switches have the functions shown in the box labeled **CONFIG**.

The buttons also have different names in different modes. In this document, they are identifed by the respective names they have in the mode under discussion.

1.2.1 Auxiliary Controls

The Reset switch resets the board, except for the USB interface.

The USB Reset switch resets the USB interface. If USB communication fails, pressing **USB Reset** may solve the problem.

The Programming Mode switch is used to update the firmware. For normal operation, it should be set to JTAG.

1.3 Power

To apply power to the ADS1230REF, connect a 9V battery or plug in a 6V–9V ac wall adapter.

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

The ADS1230REF is protected against polarity reversal. If a power source is connected in reverse by mistake, the display remains blank. To prevent damage to the board, do not leave a reversed power source connected for longer than a few seconds.

1.4 Connecting a Load Cell

The ADS1230REF is specifically designed for connection to load cells. Two connectors are provided for this application. 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 terminal block provides connections to the reference input (or power supply) and the header has switched excitation.

1.4.1 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 reference is taken from the power supply.

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

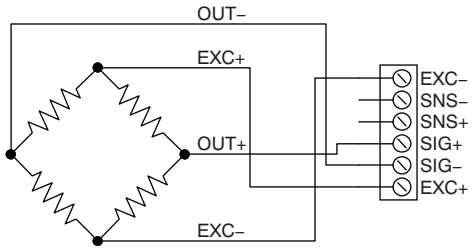


Figure 2. 4-Wire Load Cell to Terminal Block

1.4.2 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's reference is taken from the sense wire returning from the load cell. The sense wire connects to the excitation wire at the bridge sensor.

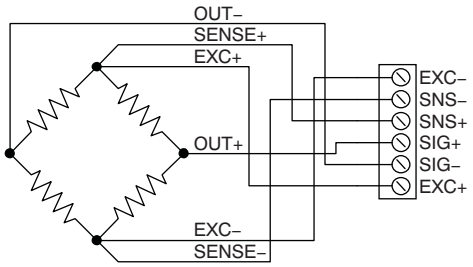


Figure 3. 6-Wire Load Cell to Terminal Block

1.4.3 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.

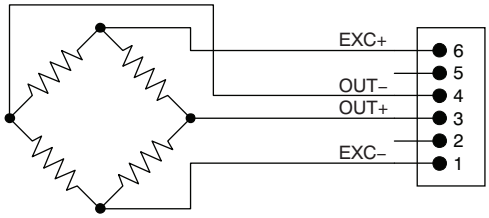


Figure 4. 4-Wire Load Cell to Header

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

1.4.4 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.

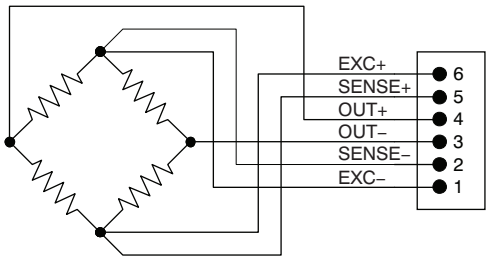


Figure 5. 6-Wire Load Cell to Header

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

1.5 Connecting Other Signal Sources

In general, the ADS1230REF can accurately measure any voltage in the input range of the ADS1230 ADC, as long as the following rules are observed:

- ***Never apply a negative voltage to the inputs of the ADS1230REF.*** The ADS1230 cannot accept negative voltages at its input. Applying negative voltages may damage both the device and the ADS1230REF. (The negative signs used in some signal names indicate inversion, not polarity.)
- For single-ended signals, ground the negative input or connect it to 2.5V. 2.5V is available from a voltage divider by shorting J7; see Section 6.4.5 for details.
- The input range of the amplifier on the ADS1230 does not extend to the supplies. See the ADS1230 data sheet for details.

Note that Scale mode is designed only for use with load cells. Although it can be tested with a voltage source or resistive divider, Scale mode does not, in general, display meaningful data unless a load cell is connected and calibration is performed.

1.6 Connecting an External Clock

To connect an external clock, connect a clock oscillator to the EXTCLK test point. No settings need to be changed; the ADS1230 will automatically use the attached clock.

The clock source must conform to 3.3V TTL or CMOS logic rules.

1.7 Common Tasks

1.7.1 Shorted-Input Noise Test

The noise measurements given in the product data sheet are taken with the inputs shorted to 2.5V. These noise measurements can be replicated on the ADS1230REF with no external hardware. To set up these measurements on the ADS1230REF, perform the following steps:

1. Move the mode switch to Analysis mode.
2. Short jumpers J8 and J7. (These jumpers are located very near the terminal block, and are marked *Input Shorting Jumpers* in Figure 1.)
3. Set up the ADS1230 as desired, as described in the previous sections.
4. Hold down the **DISP** button. The display shows the current display mode. While holding down **DISP**, press the **MODE** button until the word on the left side is `RMS`.
5. While still holding down **DISP**, press the **UNIT** button until the word on the right side is `VOLT`.
6. Release the **DISP** button. The display shows the word `GOT` followed by an increasing number. Once the appropriate number of points is collected, the calculated noise voltage is displayed. This value is the shorted-input RMS noise voltage, input-referred.

The first RMS noise measurement may be incorrect as a result of device settling. The second measurement is generally correct.

For a detailed description of Analysis mode, see Section 3.

1.7.2 Measuring Mass

The following items are required to measure mass with the ADS1230REF:

- A load cell, connected as described in Section 1.4
- An object of known mass within the load cell range

To avoid performing calibration on each power-up, you can save the calibration settings to flash memory. See Section 3.4.1 for details.

Obtaining a calibration weight:

Before the ADS1230REF can display the mass of an object, it must measure the output of the load cell for a previously known mass. The known mass can be adjusted.

At power-up, the ADS1230REF expects a 5kg mass. If this mass is not available, or if the load cell range is not compatible with this mass, the calibration mass can be changed in the following manner:

1. Determine the mass of the calibration weight. The most accurate way to determine the mass is to weigh the calibration object on an accurately calibrated scale. If the weight is precalibrated, its given mass can be used, although this approach is not generally as accurate. (Note that the accuracy of the ADS1230REF as a scale directly depends on the accuracy to which the calibration weight can be measured.)
2. Switch the mode switch to SCALE mode.
3. Press the **ENT** and **SEL** buttons simultaneously. The ADS1230REF enters configuration mode.
4. Use the **PARM** buttons to select the screen which shows `UNIT =`. This screen allows you to select the units used for the calibration mass. If the units shown are not correct, adjust them using the **VALUE** buttons.
5. Use the **PARM** buttons to select the screen that shows `CW=` followed by the calibration mass. On this screen, you can adjust each digit of the calibration mass separately. Select the digit using the **PARM** buttons. The currently-selected digit flashes, and can be adjusted using the **VALUE** buttons.
6. Adjust the calibration mass to match the mass of the calibration weight.
7. Press the **VALUE** buttons simultaneously to exit the configuration mode.

Preparing Scale mode:

Do the following steps to set up the scale mode:

1. Connect the load cell.
2. If the input shorting jumpers J8 and J7 are connected, disconnect them (see Figure 1).
3. Obtain a weight of known mass.
4. If the mass of the weight is not equal to the configured calibration mass, adjust the calibration mass as described above.
5. Move the mode switch to **SCALE** position. If calibration has not been performed, the display reads `NO CAL`.
6. Press the **CAL** button, and follow the calibration procedure given in Section 2.3.

If the calibration is performed properly, and the load cell is connected correctly, the ADS1230REF will measure the mass of an object placed on the load cell (provided that the mass of the object is within the device range).

Weigh scale mode is described in detail in Section 2.

2 Weigh Scale Mode

In weigh scale mode, the ADS1230REF displays mass.(1) Mass is displayed in either SI or avoirdupois units based on the voltage received from a load cell.

The ADS1230REF operates in Scale mode when the mode switch is set to the Scale position.

To accurately calculate mass, the ADS1230REF must have calibration information for the load cell. When scale mode is first entered, the ADS1230REF displays `NO CAL`, because the ADS1230REF has no calibration data when it is powered on.

By default, mass is calculated from the average of four successive readings from the ADC. The number of points for averaging can be adjusted, and averaging can be turned off.

(1) Load cells do not measure mass directly; they output a voltage proportional to the weight of an object. The mass of an object can be accurately inferred from this voltage as long as a calibration is accurately performed, the downward force of gravity remains constant (as it does if the load cell is not moved to a different altitude), and the tilt of the load cell does not change; if either of the latter conditions change, a new calibration must be performed.

2.1 Display

Weigh scale mode can display mass in these uints: µg (displayed as *ug*), g, kg, pounds (*lb*), stone (*st*), and ounces (*oz*).[2]

Internally, mass is measured in grams, and calibration factors are stored in grams. At display time, grams are converted to the desired display unit using the conversion factors given in Table 1.

[2] The avoirdupois units used by the ADS1230REF are equal in the imperial and U. S. customary systems.

Table 1. Unit Conversion Factors and Display Formats

Unit	Multiplier	Format
micrograms (µg)	10^6	*nnn.nnnug*
milligrams (mg)	1000	*nnn.nnnmg*
grams (g)	1	*nnn.nnng*
kilograms (kg)	10^{-3}	*nnn.nnnkg*
ounces (oz)	0.035274	*nnn.nnnoz*
pounds (lb)	0.0022046	*nnn.nnnlb*
stone (st)	157.473×10^{-6}	*nnstnn.nn*

The display format for *stone* differs from the format used for the other units. One stone is equal to fourteen pounds; weight in stone is commonly expressed as a number of stone followed by a number of pounds. On the ADS1230REF, two digits are shown for stone, followed by *st*, followed by pounds displayed to two decimal places.

2.1.1 Calculation of Mass

Mass is calculated from ADC code using the formula:

$$w = mc + w_{zs} - w_t$$

where:

- ***w*** = mass
- ***c*** = the ADC code
- $\boldsymbol{w_t}$ = t are weight
- ***m***, $\boldsymbol{w_{zs}}$, ***wt*** = values determined in the calibration process

m is a calibration constant, and is calculated using Equation 1:

$$m = \frac{w_{fs}}{c_{fs} - c_{zs}} \quad (1)$$

where w_{fs} is the user-specified calibration mass, c_{fs} is the ADC code taken with the calibration mass applied, and c_{zs} is the ADC measurement taken with no load.

$\mathbf{w_{zs}}$, the zero-scale mass, is calculated from m and c_{zs} using Equation 2:

$$w_{zs} = -mc_{zs} \quad (2)$$

2.2 Button Functions

2.2.1 TARE

The tare function allows the mass of a substance to be measured separately from the mass of its container. When the **TARE** button is pressed, the scale measures the mass and records it. This reading is subtracted from each subsequent measurement.

The recorded tare value can be reset to zero by holding the **TARE** button down for at least one second. When the tare value is to be reset, the display reads `TARE OFF`.

Tare is also reset following a calibration.

2.2.2 RANGE

The **RANGE** button changes the units or range of the display. **RANGE** cycles through all available units; see Section 2.1 for details. When the **RANGE** button is depressed, it displays the selected unit.

2.2.3 CAL

Pressing CAL initiates the two-point calibration sequence. See Section 2.3 for details.

2.3 Calibration

Two-point calibration is performed by pressing the **CAL** button. When this button is pressed, the board executes the following command sequence:

1. The board scrolls the message, `REMOVE WEIGHT`.
2. The user removes all weight from the load cell and presses any button.
3. The board measures the load cell voltage and records it as the zero point.
4. The board scrolls the message `PLACE CAL WEIGHT`.
5. The user places a weight on the load cell and presses any button. The weight should have the mass that was selected in the configuration mode.
6. The board measures the load cell voltage and records it as the calibration weight.

New calibration data is lost when power is removed. To prevent this data loss, calibration data can be saved, with other board settings, to flash memory. See Section 3.4.1 for details.

2.4 Configuration

The parameters for Scale mode can be adjusted in the configuration mode.

To enter configuration mode, press the **VALUE** buttons simultaneously. The four buttons then assume the functions shown in the CONFIG box. To exit Configuration mode, press the **VALUE** buttons simultaneously again. This function does not cause parameters to be adjusted, because 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 items are labelled as words with a question mark. To enter these or to execute the command, press **SEL** or **ENT**.

All parameters in the analysis and scale configuration menus are independent, including the parameters found in both modes.

Table 2 summarizes the available parameters.

Table 2. Parameters in Configuration Mode

Parameter	Display	Value Range	Description
Display units	UNIT=	µg, mg, g, kg, lb, st, oz	Display units
Averages	AVGS=	2–128	Number of points to average
ADC speed	SPD=	FAST, SLOW	Acquisition rate
Calibration mass	CW=	0–99.9 in various units	Calibration mass and unit
Offset calibration	OCAL?	—	Offset calibration; see text
Save parameters	SAVE?	—	Save parameters; see text
Version number	V1.1.0	—	Firmware version number display

2.4.1 Parameters

Display units: The units to use when displaying mass. Available units are µg (displayed as ug), mg, g, kg, ounces (oz), pounds, (lb), and stone (st). See Section 2.1 for details.

Averages: Number of points to use when reading weight. The choices available are 2, 4, 8, 10, 16, 32, 50, 64, 100, and 128. The default is 50.

ADC speed: This parameter selects between the two data rates on the ADS1230, which are called *high-speed* and *low-speed*. When high-speed mode is selected, FAST is shown; for low-speed mode, SLOW is shown.(1)

The actual data rate of the ADS1230 depends on the frequency of the master clock, f_{CLK}. In fast mode, the data rate is f_{CLK}/61440; in slow mode, the data rate is f_{CLK}/491520. See the ADS1230 data sheet for further information.

The default setting is low-speed mode.

Calibration weight: This parameter gives the expected mass of the calibration weight used in the calibration procedure (Section 2.3). The calibration mass can be given in any of the available units, in three significant figures. The unit is independent of the display unit.

Each digit in the mass is adjusted separately. The currently-selected digit flashes, and can be adjusted with the **VALUE** buttons. The **PARM** buttons are used to select the digit. The unit is adjusted in the same manner, and flashes when selected.

When the unit is changed, the value changes to the equivalent mass in the new unit.

Offset calibration: This screen has the same function as it does in Analysis mode. See Calibration section 2.3 for information.

Save parameters: This screen allows the settings of the ADS1230REF to be stored in flash memory. It functions the same as it does in Analysis mode. When **ENT** or **SEL** is pressed on this screen, the ADS1230REF saves its settings to flash memory. These settings are loaded from flash memory when the board is reset or powered on. All operating parameters are saved, including scale calibration settings, voltage reference, display mode, and units.

Version number: This screen displays the version number of the ADS1230REF firmware.

(1) The ADS1230REF cannot detect the frequency of the ADS1230 master clock, so it cannot display the actual data rate of the ADS1230 device.

3 Analysis Mode

In Analysis mode, the ADS1230REF analyzes code output from the ADS1230 and displays it in different ways. Table 3 summarizes the numerous display modes available, together with example displays.

Table 3. Modes and Example Displays

	Hex Code	Dec Code	Voltage	ENOB
Raw	1992E9H	+1676001	+499.488M	n/a
RMS	n/a	+5.789	+17.495N	+23.18BIT
Peak-to-Peak	n/a	+31.256	+90.293N	+21.92BIT
Averaged	n/a	+1676001	+499.488M	n/a

The ADS1230REF operates in Analysis mode when the mode switch is set to the **ANALYSIS** position. The default Analysis mode is RAW HEX.

To change measurement types, hold down **DISP** and press **MODE**. This function cycles through the four available measurement types. When **DISP** is released, the newly selected measurement is made. To change units, press **UNIT**. This option cycles through the available units for the active measurement type. This procedure can also be done while **DISP** is depressed; in that case, the new unit is shown by name on the display. The measurement modes are described in detail in Section 3.2.

The ADS1230 itself can be configured directly from this mode, as described in Section 3.1.

3.1 Switch Functions

NEW BLOCK: Pressing this switch 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 switch down allows the settings of the ADS1230 to be changed, using the **PARM (NEW BLOCK)** and **VAL (UNIT)** buttons.

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

The gain setting is displayed as `GAIN=` followed by the gain setting. Gains of 64 and 128 are available.

Data rate is shown on the display as `SPD=FAST` or `SPD=SLOW`. See ADC speed in the Parameters section for further information.

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

3.2 Measurement Modes

Raw: In this measurement, codes are read from the ADS1230 and displayed. No processing or analysis is done on the sample stream. Data can be displayed as hexadecimal codes, decimal codes, or volts.

Voltage is calculated according to Equation 3:

$$V = \frac{x}{2^{24} - 1} \bullet \frac{V_{REF}}{A} \quad (3)$$

Where:

- A is the converter gain (64 or 128), determined from the programmed gain setting
- v_{REF} is the voltage at the converter reference input
- x is the ADC decimal code

v_{REF} is adjustable from Configuration mode. By default, it is 5V.

The voltage display is autoranging. All ranges are shown with six significant figures having three decimal places. The ranges are given in Table 4.

Table 4. 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 ADS1230, and an RMS noise calculation is performed on them using the standard-deviation formula (given in Equation 4):

$$s_N = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - x)^2} \tag{4}$$

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

ENOB: E is calculated using Equation 5:

$$E = \begin{cases} 24 - \log_2 s_N : s_N \neq 0 \\ 24 : s_N = 0 \end{cases} \tag{5}$$

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

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

The number of codes used in the calculation is selected in Configuration mode; 50 codes are used in laboratory characterization, so this value is the default.

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 are 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 is calculated. The result can be displayed in decimal codes or volts. (Hexadecimal is not available because the result may be fractional.) Volts are calculated as in raw mode.

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

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

3.4 Configuration

To enter Configuration mode, press the **VALUE** buttons simultaneously. The four buttons then assume the functions shown in the CONFIG box. To exit Configuration mode, press the **VALUE** buttons simultaneously again. This operation does not cause parameters to be adjusted; 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 items are labelled as words with a question mark. To enter these items or to execute the command, press **SEL** or **ENT**.

Although a few of the parameters in the Analysis and Scale configuration menus are the same, the settings are kept separate between the modes.

Table 5 summarizes the available parameters.

Table 5. Parameters in Analysis Mode

Parameter	Display	Value Range	Description
Averages	AVG=	2–128	Number of points for average, peak-to-peak, and RMS modes
Voltage Reference	VREF=	0.5–5.0	Voltage used in various calculations
Power-down mode	PDWN?	—	Power-down mode; see text
Offset calibration	OCAL?	—	Offset calibration; see text
Save parameters	SAVE?	—	Save parameters; see text
Version number	V1.0.0	—	Firmware version number display

3.4.1 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 setting is 50.

Voltage reference: To convert voltages to codes, the ADS1230REF requires the voltage reference level. Since this level cannot be measured, it must be selected manually. This parameter allows the reference level to be set.

Each digit of the voltage reference is selected and adjusted separately. Use the **PARM** buttons to select a digit, and the **VALUE** buttons to adjust it. The selected digit flashes.

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; the default value for this parameter is 5.0V.

Power-down mode: When **ENT** or **SEL** is pressed on this screen, the ADS1230REF causes the ADS1230 to enter power-down mode. This action occurs by pulling the $\overline{\text{PDWN}}$ line low. While the $\overline{\text{PDWN}}$ line is low, the display reads POWER DN. When a button is pressed from this display, the ADS1230REF powers the converter on and returns to the analysis display, exiting configuration mode.

This mode can be used to test the current consumption of the board when the ADS1230 is powered down.

Offset calibration: When **ENT** or **SEL** is pressed on this screen, the ADS1230REF initiates a hardware offset calibration on the ADS1230 by providing two extra shift clock cycles on the next data read cycle, as described in the ADS1230 data sheet.

When **ENT** or **SEL** is pressed, the display briefly shows OK, indicating that calibration was performed.

Offset calibration is performed when the ADS1230REF is powered on, but is not automatically performed at any other time.

Version number: This screen displays the version number of the ADS1230REF firmware.

4 Using the PC Software

The ADS1230REF 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 a Microsoft Windows® platform. In Windows, the program communicates with the ADS1230REF using a *virtual COM port* driver that causes the USB connection to appear to Windows as a normal serial port. The necessary driver is installed with the EVM software.

4.1 Installation and Setup

The ADS1230REF software is distributed in an installer program called `ADS123x-setup-withLVRT-1.1.1.exe` (the version number in the file name may differ), distributed on the CD-ROM or available from Texas Instruments. To install the software, execute this program. The program guides you through the installation process.

Note the following points:

- The installer installs two packages: the ADS123xREF program itself, and the TI Virtual COM Port driver.
- If any version of the ADS123xREF program is already installed, the installer uninstalls it and quits. You must run the installer again to complete the installation.
- If the Virtual COM Port driver is already installed, the installer offers to uninstall it. Do ***not*** uninstall it; cancel this part of the installation.

The installer displays messages reminding you of these points.

4.1.1 First Time Connection of the ADS123xREF

If the ADS1230REF has never been connected to your computer before, Windows detects the device as *unknown hardware* and takes you through a series of dialogs to install the correct driver. Accept the default settings; the driver is present and only needs to be copied to the correct location. If the driver is successfully installed, Windows does not issue this prompt again.

On some computers, if the board is connected to a different USB port, the operating system detects the board as *new hardware*. If this action occurs, proceed through the new hardware dialogs as usual, and allow Windows to *reinstall* the driver.

4.2 The Display

The ADS1230REF software has a single display; see Figure 6 for a typical display. The major elements of the display discussed next.

Strip chart: This feature displays a scrolling graph of data received from the board.

Histogram: A sliding histogram of data received from the board is also displayed. 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 also adjustable here.

Recording section: This feature controls recording of data to a file.

Device control section: This section allows device parameters to be adjusted.

Status display: This display shows messages indicating the current state of the program.

Acquire button: This button starts and stops the running acquisition of data.

4.3 Starting the Program

When the program launches, a screen similar to that shown in Figure 6 appears. Immediately after launch, the program searches all available serial ports for the board. To do this step, it opens every available serial port in turn, testing it to see if there is an ADS1230REF connected. The program uses the first ADS1230REF it finds.

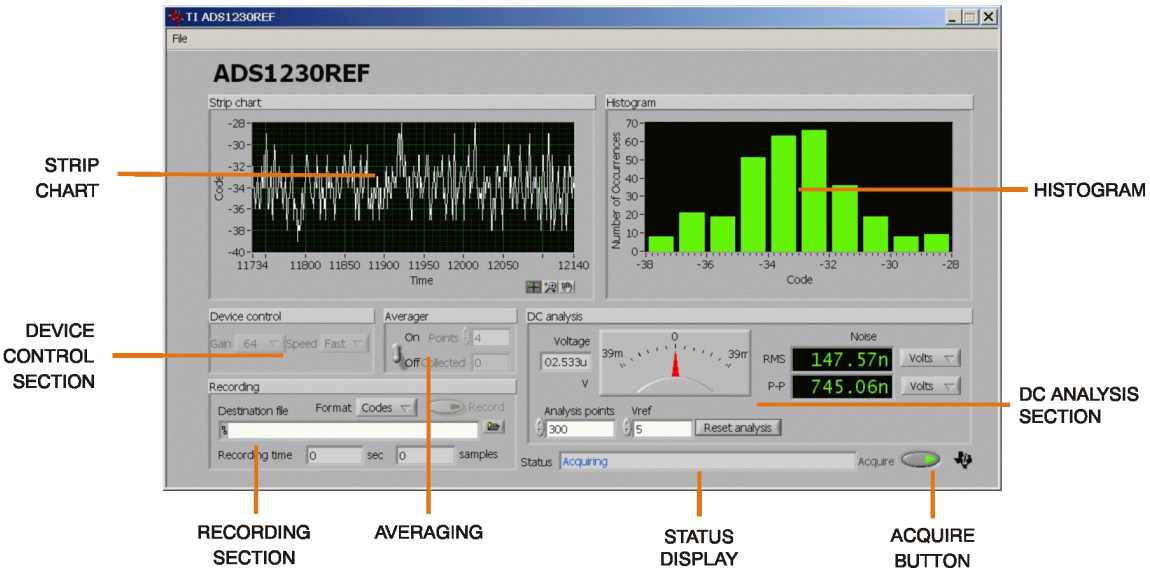


Figure 6. ADS1230REF PC Software Display

Although this procedure is conceptually simple, it may not go as smoothly as expected. The following process ensures that the board is found correctly. Note that Steps 1–3 can be done in any order.

Step 1. Apply power to the ADS1230REF.

Step 2. Plug in the USB connector.

Step 3. Start the program.

Step 4. Watch the status display. It reads *Scanning* followed by the name of the serial port being tested. When the board is found, the display reads *Idle*. Until a board is found, the display cycles through every port, spending approximately one second on each port.

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

Note: If the board is never detected, it is still possible (and safe) to exit the program during the search process. If the board does not respond, pressing the USB Reset switch (SW1) may help.

4.4 Analysis or Record Mode

The program will operate in analysis mode or record mode. Both modes acquire the data and update the displays, but record mode also writes the result to the selected file.

4.5 Adjusting Device Parameters

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

4.6 Acquiring Data

To start receiving and analyzing data from the board, click the **Acquire** button, located in the lower right-hand corner of the display. The program begins 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 while Analysis occurs.

4.6.1 Averaging

The PC software can process data collected from the board using a sliding-window averager. The controls for the averager are found in the *Averager* box.

To turn the averager on, use the **Averaging** switch. The number of points averaged is set by the *Points* control, and the number of points currently collected is shown in the *Collected* box.

When the averager is turned on, it is cleared. To reset the averager, turn it off and then on again.

The histogram displays an integer representation of the averaged data. Note that when selecting a high number of averages, the integer results might include only one code; the histogram for that case will be blank. The strip chart display shows both the full precision result of the averages and the integer version, as illustrated in Figure 7.

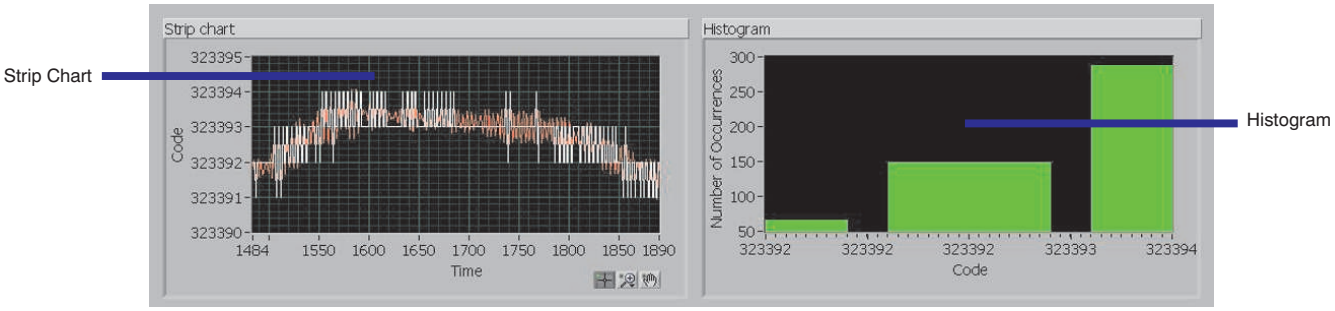


Figure 7. ADS1230REF Average Data

4.6.2 Block Analysis Length

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 (or averaged) samples.

The number of samples used is set using the *Analysis points* control. By default, this number 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, 0s are substituted for the samples not yet received.

In Analysis mode, the analysis can be reset using the button marked *Reset analysis*. This function 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.

4.6.3 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 in the ADS1230REF firmware, as described in Section 3.2. Each calculation can be displayed in units of volts, codes, or bits, as on the board. See Section 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 control also controls the histogram length.

4.6.4 Displaying Volts

When units of volts are displayed, the program must have a value for the reference voltage applied to the ADS1230 to properly calculate the voltage. Because this voltage cannot be measured using the ADS1230REF, 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 the different level, so that voltage calculations are performed correctly.

The *Vref* control also affects voltages recorded in *Record* mode.

4.6.5 Block Acquisition

To enable the program to run reliably on slower computers, results are not calculated each time a sample is received. Instead, groups of samples are collected and added to an analysis buffer that is processed as it becomes full. This processing delay is timed so that the display updates at least every 0.75 seconds.

4.7 Data Recording

The ADS1230REF 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 these steps to record data to a file:

Step 1. Select or create a destination file. Either type the file path directly into the *Destination file* control, or click the small open folder icon to the right of the control to open a dialog box from which a file can be selected. If the selected file exists already, the program will display a warning. Otherwise, type the name of the file that you wish to create.

Step 2. Select a data format. Samples can be recorded as raw (decimal) codes or as volts. In both cases, the data are written to the file as ASCII data, and the file is a text file.

Step 3. Click the *Record* button. The program begins to collect and analyze data from the board, as well as write it to the selected file. As recording proceeds, the recording time indicators are updated.

Step 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 stops and a message displays in the status box.

Recording time is not measured, but calculated from the number of samples collected. The speed is 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 change does not affect the data file, except that samples continue to be collected with the different settings.

In Recording mode, analysis proceeds as in Analysis mode; Recording mode is identical to Analysis mode, except that data is written to a file. See the previous section 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.

4.7.1 File Format

Data files begin with a header that contains the text *collected from ADS1230REF*, the time of recording, and the speed and gain. Following this header, values are written in either volts or raw codes, with one value per line. Line separators are in 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; it is therefore important that this value be correct.

5 Serial Console

The ADS1230REF provides a console mode that can be used with any Windows terminal emulation program, such as Hyperterm™. In Windows, this configuration is done through the Virtual COM Port driver supplied with the EVM software, causing the ADS1230REF to appear in Windows as an extra serial port.

5.1 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 specific 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:

```
ADS1230REF 1.1.0c
(c)2005-2007 Texas Instruments
1230>
```

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

The command prompt is always `1230>` . 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 6. 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 6. Console Mode Commands

COMMAND	FORMAT	OPERATION
P	`P [0,1]`	Set PGA
R	`R [F,S]`	Set data rate
K	`K`	Perform offset calibration
V	`V`	Show 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.

5.2 Command Reference

5.2.1 P—Set PGA

This command sets the gain of the ADS1230 PGA, according to these parameters:

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

5.2.2 R—Set Data Rate

This command sets the speed of the ADS1230 according to these parameters:

- `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.

5.2.3 K—Perform Offset Calibration

Initiates an offset calibration on the ADS1230, using the method described in the datasheet.

5.2.4 V—Show Version

Displays a message containing the firmware version and copyright notice.

5.2.5 S—Start Streaming

When **S** is issued, the ADS1230REF begins printing raw output codes from the ADS1230 in hexadecimal format, separated by new lines. The device iterates continuously until a character is received from the serial port.

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

5.2.6 D—Collect One Sample

Issuing the **D** command causes the ADS1230REF to report the latest collected sample from the ADS1230. The sample is displayed in raw hexadecimal.

5.2.7 C—Set Channel

This command has no effect on the ADS1230 since there is only one channel.

- C0—set to channel 0
- C—(with no arguments) prints the current channel, always CHAN=0

5.2.8 Q—Query Parameters

Q causes the ADS1230REF to issue a coded string summarizing the current settings. The format of the string is:

```
P[0,1]R[F,S]OIC0
```

followed by a carriage-return and linefeed.

6 Hardware

A block diagram of the ADS1230REF is shown in Figure 8. The schematic and layout drawings are given in Appendix A.

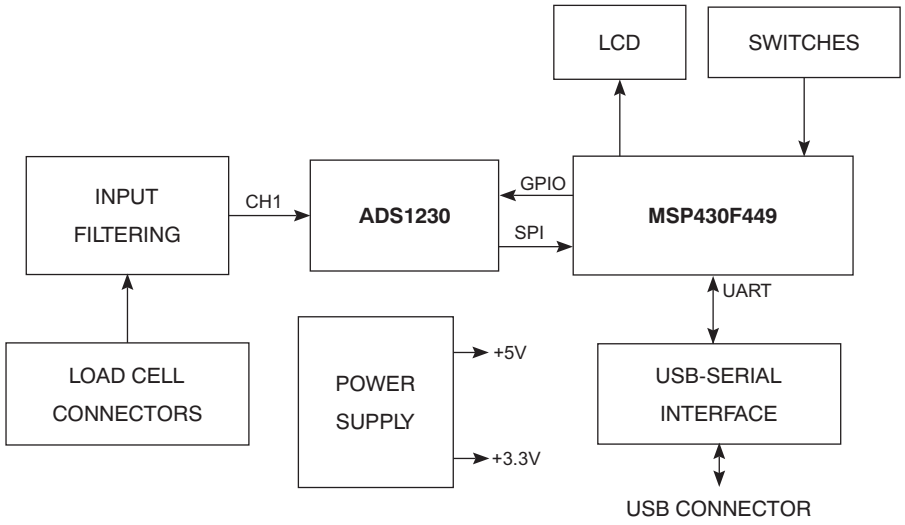


Figure 8. ADS1230REF Hardware Block Diagram

6.1 Microcontroller

The ADS1230REF uses the MSP430F449 microcontroller. This device provides an LCD controller, hardware SPI and UART interfaces, and a multiplier. The latter is important because the firmware must perform many multiplications.

6.2 Power Supply

The ADS1230REF operates from +5VDC and +3.3VDC. These supplies are generated by linear regulators U1 and U2. Input power comes from either wall-adapter connector J2, or battery connector BT1. J2 is switched; when a connector is plugged in, BT1 is disconnected.

Noise is important because the ADS1230 voltage reference is typically taken from the power supply. The supplies are heavily bypassed to reduce noise.

6.3 User Interface

The ADS1230REF user interface consists of the display and switches SW2–5 and SW8. Switches are connected to interrupt-capable GPIOs on the microcontroller, allowing them to wake the microcontroller from sleep mode.

6.4 ADC Section

The ADC section consists of the ADS1230 device itself and ancillary circuitry.

All signals on the ADS1230 are filtered by pass-through capacitors that help to reject electromagnetic interference (EMI), radio frequency interference (RFI), and noise generated by the digital circuitry.

6.4.1 Input Circuitry

The ADS1230REF is designed to connect to resistive bridge sensors, particularly load cells. The input channel is filtered by pass-through capacitors C46 and C47 and differential capacitor C7. Common-mode capacitors C32 and C29 provide additional RF rejection.

6.4.2 Load Cell Header

The load cell header, J6, 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's pinout is given in Table 7. For connection examples, see Section 1.4.3 and Section 1.4.4.

Table 7. 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
4	SIG–	Input for negative load cell output
5	EXCSNS–	Negative sense; connected to external negative reference input
6	EXC–	Negative excitation; connected to ground through switch U7

6.4.3 Input Terminal Block

The input terminal block consists of J4 and J5. It provides connections to all of the analog inputs on the ADS1230, and connections to the ADS1230REF voltage reference network.

The terminal block pinout is given in Table 8.

Table 8. Terminal Block Pinout

TERMINAL NAME	FUNCTION
EXC–	Negative excitation connected to ground through SW7
SNS–	Inverting excitation sense input
SNS+	Noninverting excitation sense input
SIG+	Noninverting input
SIG–	Inverting input
EXC+	Positive excitation output (+5V) or positive reference input

6.4.4 Voltage Reference

The ADS1230REF is designed to operate either ratiometrically or with an external reference. The two modes are selected using switch SW7.

In the EXT position, the ADS1230 reference inputs are taken from the load cell connectors. In the +5VA position, the ADS1230 positive reference input comes from the 5V analog supply, and the negative reference input is connected to ground.

After the switch is placed a filtering network that consists of resistors R14 and R15, bulk capacitor C4, pass-through capacitors C44 and C45, and filtering capacitors C28, C30, and C31.

6.4.5 Input Shorting Jumpers

The shorted-input noise test for the ADS1230 is best performed with both inputs connected to 2.5V. To make this test easy to perform, jumpers J7 and J8 are provided.

Jumper J8 shorts the inputs together. Jumper J7 connects the inverting input to a voltage divider made from R25 and R26, dividing the power supply by 2. This voltage divider electrically resembles an ideal bridge sensor.

6.5 USB Interface

The USB interface can be used for firmware download or data communications. Its role in firmware download is discussed in Section 6.6.

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 that causes the device to appear as a serial port on the host PC.

The USB interface is powered separately from the rest of the ADS1230REF; it takes power from the USB line, through linear regulator U3.

The serial port side of U4 is connected to the microcontroller UART signals. To keep the power domains separate, and to keep the USB and microcontroller sides from inadvertently powering each other, the UART is connected through isolators U8 and U9.

6.6 Programming Connections

The MSP430 can be programmed via the dedicated JTAG port or the serial bootstrap loader.

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.

To allow firmware to be downloaded through USB, U4 is connected to the microcontroller bootstrap loader pins. The DTR and RTS pins are connected to the RST and TCK inputs on the microcontroller to allow the serial bootstrap loader to operate. These lines are not isolated; instead, they are switched through SW9, which also connects USB ground and power to the microcontroller ground and power. Normally this switch is open; it is only switched on when firmware is to be downloaded through USB. This feature also protects the microcontroller from unknown states on these pins at power-up.

Appendix A Schematic and Layout

The printed circuit board (PCB) layouts for the top and bottom sides of the ADS1230REF are shown in Figure A-1 and Figure A-2, respectively. Schematics for the ADS1230REF are shown in Section A.3. The bill of materials is provided in Table A-1.

A.1 Bill of Materials

Table A-1. ADS1230REF Bill of Materials

Reference Designator	Description	Manufacturer	Mfg. Part Number
R23, R24	0 1/16W 1% Chip Resistor	Panasonic	ERJ-3GEY0R00V
R17	20 1/4W 5% Chip Resistor	Panasonic	ERJ-8GEYJ200V
R2, R3	33 1/10W 5% Chip Resistor	Panasonic	ERJ-3GEYJ330V
R12–R15	100 1/10W 5% Chip Resistor	Panasonic	ERJ-3GEYJ101V
R11	220 1/10W 5% Chip Resistor	Panasonic	ERJ-3GEYJ221V
R1	1.5K 1/10W 5% Chip Resistor	Panasonic	ERJ-3GEYJ152V
R4–R10, R16	10K 1/10W 5% Chip Resistor	Panasonic	ERJ-3GEYJ103V
R25, R26	20K 1/16W 1% Chip Resistor	Panasonic	ERJ-3EKF2002V
R18, R30	47K 1/10W 5% Chip Resistor	Panasonic	ERJ-3GEYJ473V
R22	200k Potentiometer 200kΩ, 1/4in SQ	Bourns	3362U-1-204LF
R19-R21	221k 1/16W 1% Chip Resistor	Panasonic	ERJ-3EKF2213V
C1, C2, C16, C17	22pF 50V Ceramic Chip Capacitor, ±0.5pF, NPO	TDK	C1608C0G1H220J
C29, C30, C31, C32	100pF 16V PPS Film Chip Capacitor, 2%	Panasonic	ECH-U1C101GX5
C38, C40–C43	100pF Filter High Frequency, 100pF	Murata	NFM21CC101U1H3D
C5, C11, C13–C15	0.01µF 50V Ceramic Chip Capacitor, ±10%, X7R	TDK	C1608X7R1H103K
C12, C21, C33–C36	0.1µF 50V Ceramic Chip Capacitor, ±10%, X7R	TDK	C1608X7R1H104K
C6, C7	0.1µF 16V PPS Film Chip Capacitor, 2%	Panasonic	ECH-U1C104GX5
C9, C10, C22	1µF 16V Ceramic Chip Capacitor, ±10%, X7R	TDK	C1608X7R1C105K
C37, C44–C47	1µF Filter High-Frequency, 1.0µF	Murata	NFM21PC105B1C3D
C23–C28	2.2µF 6.3V Ceramic Chip Capacitor, ±20%, X5R	TDK	C1608X5R0J225M
C3	4.7µF 16V Ceramic Chip Capacitor, +80/-20%, Y5V	TDK	C2012Y5V1C475Z
C8, C18–C20	10µF 16V Ceramic Chip Capacitor, ±20%, X7R	TDK	C3216X7R1C106M
C4	100µF 10V Tantalum Chip Capacitor, ±10%	Kemet	T494D107K010AT
U6	Analog-to-Digital Converter	Texas Instruments	ADS1230IPW
U5	Microcontroller	Texas Instruments	MSP430F449IPZ
U2, U3	Linear Voltage Regulator, +3.3V	Texas Instruments	TPS77133DGKG4
U1	Linear Voltage Regulator, +5V	Texas Instruments	TPS76350DBVG4

Table A-1. ADS1230REF Bill of Materials (continued)

Reference Designator	Description	Manufacturer	Mfg. Part Number
U4	USB to Serial Converter	Texas Instruments	TUSB3410VFG4
U7	Analog Switch, SPST	Texas Instruments	TS5A3166DCKR
U8, U9	Digital Isolator	Texas Instruments	ISO721DG4
U10, U11	Inverter, Single Gate	Texas Instruments	SN74LVC1G04DBVRG4
BT1 (+)	9 Volt Battery Clip Female	Keystone Electronics	594
BT1 (–)	9 Volt Battery Clip Male	Keystone Electronics	593
J1	USB Type B Socket	Mill-Max	897-43-004-90- 000000
J2	2.5mm Power Jack	CUI	PJ-102BH
J6	1 X 6 Header	Samtec	TSW-106-07-G-S
J7, J8	1 X 2 Header	Samtec	TSW-102-07-G-S
J4	3.5mm PCB Terminal Block, 4-position	On Shore Technology	ED555/4DS
J5	3.5mm PCB Terminal Block, 2-position	On Shore Technology	ED555/2DS
N/A	ADS1230 REF PCB	Texas Instruments	6483020
D1	30V, 200mA Schottky Diode	Fairchild Semiconductor	BAT54
D2	Green LED, SMD	Lumex	SSL-LX3052GD
L1	Ferrite Bead Core, 4A 100MHz	Panasonic	EXC-ML20A390U
LCD1	8-Character LCD Display, TN Type	Varitronix	VIM878-DP-RC-S-LV
SW1–SW6	Push-button Switch	ITT	KSA1MZIILFT
SW7	DPDT Slide Switch, Top Actuator	NKK	SS22SDP2
SW8	SPDT Slide Switch, Top Actuator	NKK	SS12SDP2
SW9	4PDT Slide Switch, RA Actuator	E-Switch	EG4208
TP15	Testpoint	Keystone Electronics	5011
X1	12MHz Quartz Crystal	Citizen	CS10-12.000MABJUT
X2	32.678kHz Quartz Crystal	Epson	C-002RX 32.7680KE: PBFREE

A.2 PCB Layout

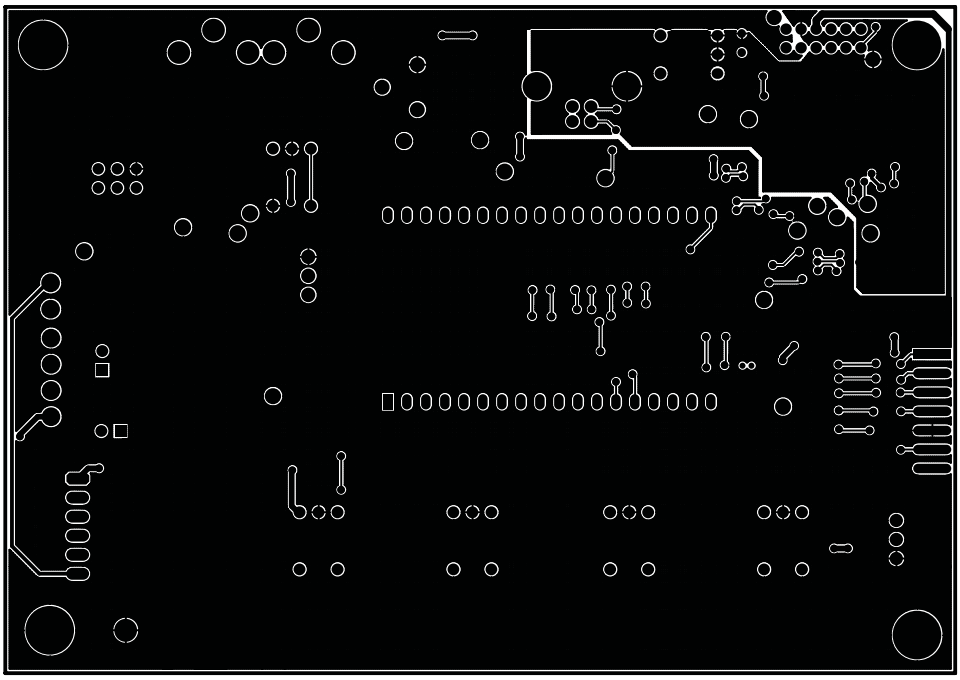


Figure A-1. ADS1230REF PCB—Top Side

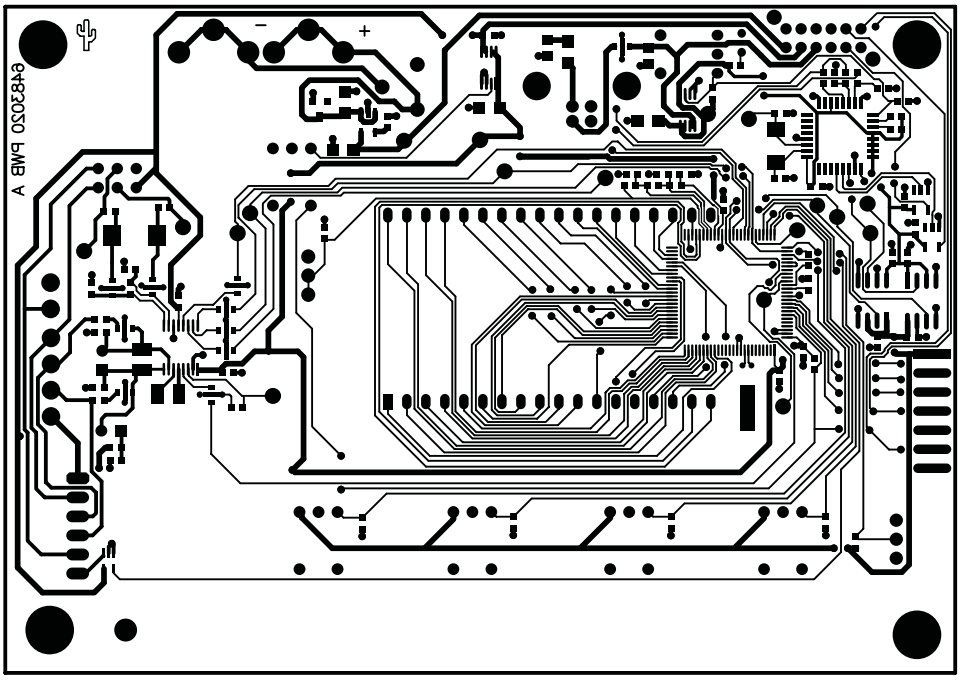


Figure A-2. ADS1230REF PCB—Bottom Side

A.3 Schematics

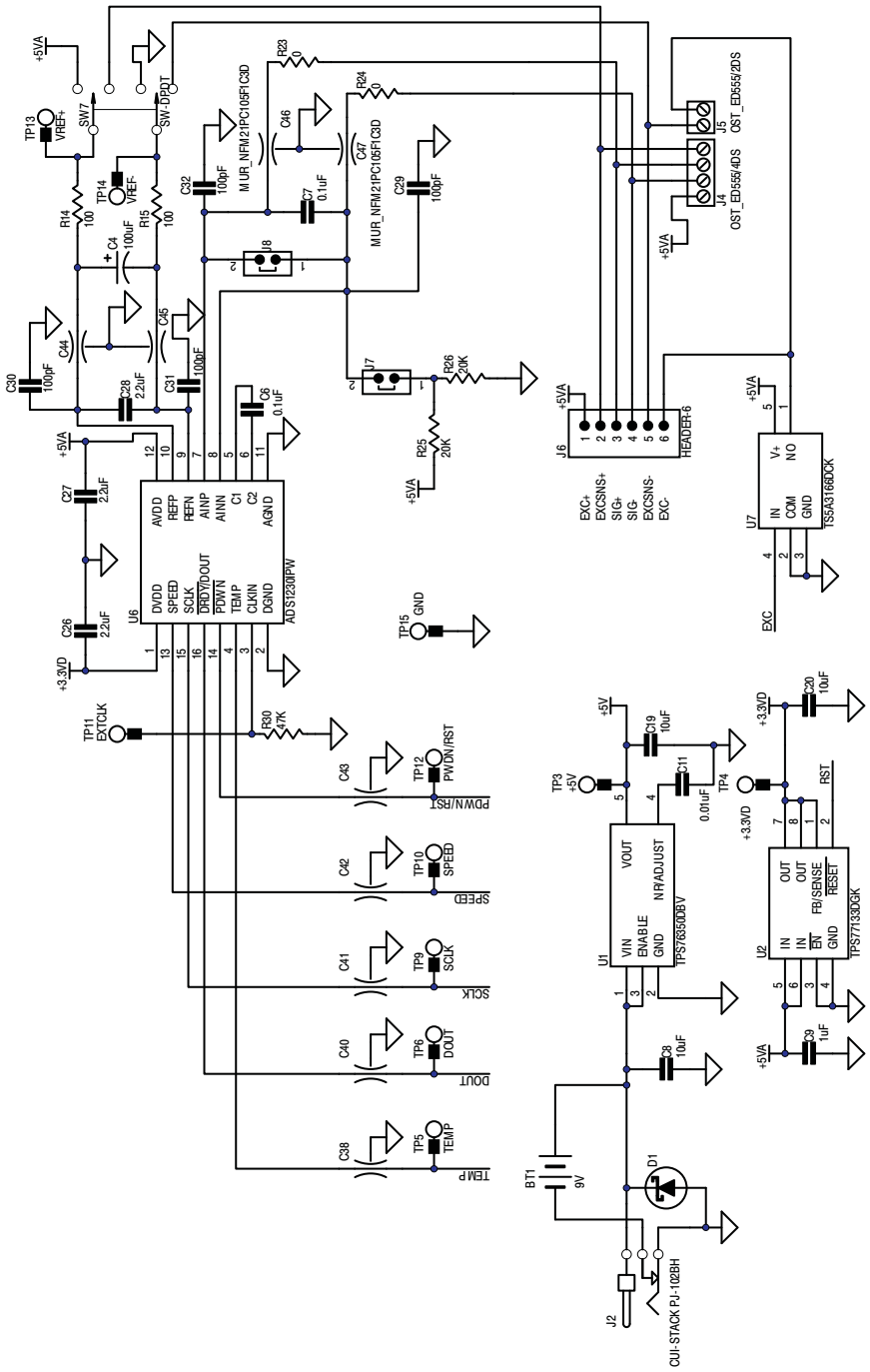


Figure A-3. ADS1230REF Schematic—ADC

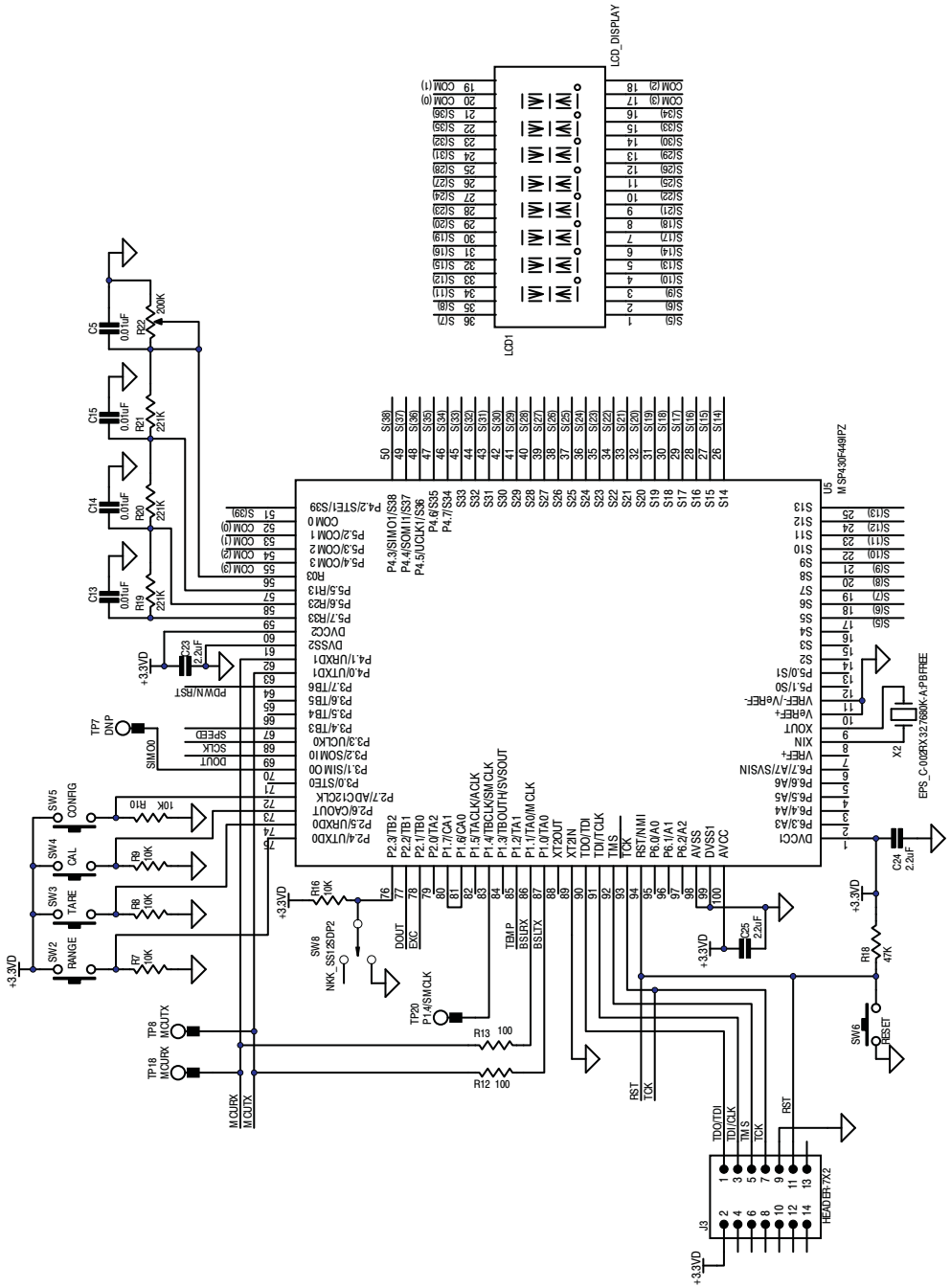


Figure A-4. ADS1230REF Schematic—MCU

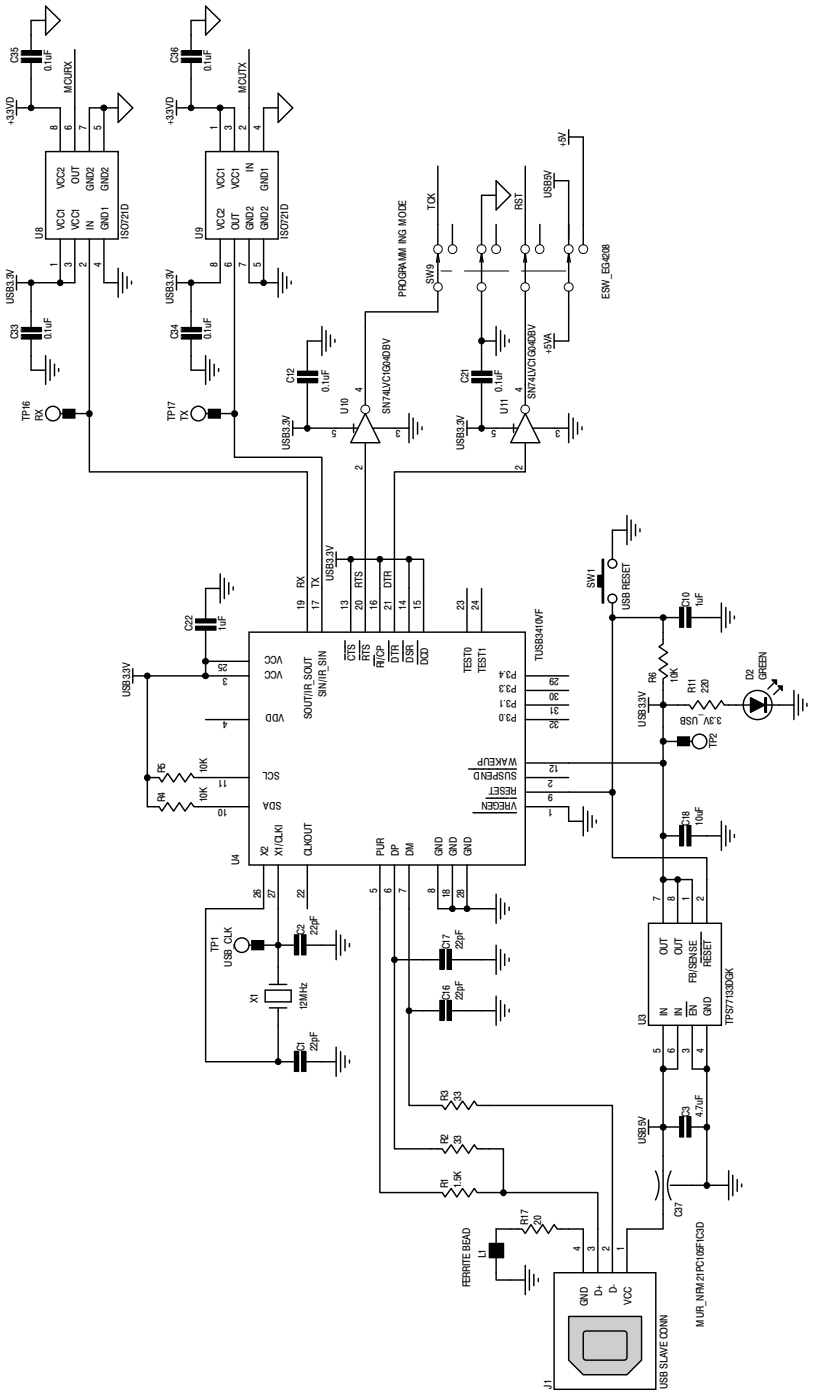


Figure A-5. ADS1230REF Schematic—USB

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EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 0V to 9V and the output voltage range of 0V to 5V.

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

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During normal operation, some circuit components may have case temperatures greater than +30°C. The EVM is designed to operate properly with certain components above +50°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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