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EVAL-ADMX2001EBZ LCR Meter Demo/Evaluation Board

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This page applies to hardware revision B (ADMX2001B) and may not apply to past or future revisions.

The EVAL-ADMX2001EBZ is an easy-to-use evaluation and development board that enables convenient access to the functionality of the ADMX2001 Precision Impedance Analyzer Measurement Module.

1. BNC connectors can interface to common LCR meter test probes and fixtures
2. UART interface can be used with USB-to-UART cables to interface to host PC
3. Trigger and clock synchronization signals are available through SMA connectors that simplify the connection to standard test equipment
4. Arduino-style headers allow the user to develop embedded code with boards like the SDP-K1
5. Power jack accepts various input voltages from ac/dc power adapters that can supply +5V to +12V

Evaluation Kit Contents

1. EVAL-ADMX2001EBZ board
2. UART to USB cable (TTL-232R-RPI)
3. Universal power adapter with 12VDC output
4. LCR meter test clips

Additional Equipment Required

1. **ADMX2001** High-Performance Precision Impedance Analyzer Measurement Module

Optional Equipment

1. LCR meter accessories. Available from various test and measurement manufacturers, for example:
   1. Keysight's Impedance Measurement Accessories
   2. B+K Precision TL89S1 SMD Test Fixture
   3. B+K Precision TL89F1 4-Terminal Test Fixture for leaded components
2. Calibration Standards and Accessories
   1. IET Labs (former General Radio products)
   2. Keysight 42090A Open Termination
   3. Keysight 42091A Short Termination
   4. Keysight 42030A Four Terminal Pair Standard Resistor Set
   5. Keysight 16380A Standard Air Capacitor Set (1pF to 1000pF)
   6. Keysight 16380C Capacitance Standard Set (0.01uF to 10uF)
3. LCR Meter for verification and calibration transfer
   1. Keysight E4980A Precision LCR Meter

Quick Start

There are five simple steps to start evaluating the ADMX2001:

1. Driver Installation
2. Terminal Emulator Installation
3. Basic hardware setup
4. Open a session through the terminal emulator (e.g. TeraTerm)
5. Perform basic measurements

These steps are explained in detail in the following sections.

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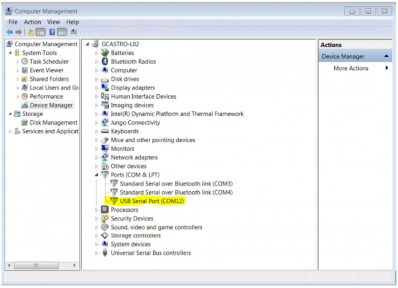
1. Driver Installation

The default communication interface to EVAL-ADMX2001EBZ is via its UART port. When using the UART to USB cable included with the evaluation board (TTL-232R-RPI), FTDI's Virtual COM Power (VCP) drivers must be downloaded from their website located at https://www.ftdichip.com/Drivers/VCP.htm

Installation steps:

1. Download the driver for the host OS version from https://www.ftdichip.com/Drivers/VCP.htm
    1. Note: for detailed instructions, visit https://www.ftdichip.com/Support/Documents/InstallGuides.htm
2. Unzip the files
3. Open the Device Manager
4. Right Click on the Other Device (TTL232R) and select "Update Driver Software…"
5. Click on "Browse my computer for driver software"
6. In the next dialog window, specify the location where the drivers have been saved and click on "Next"
7. The installation should take a few seconds. After the installation has finished, a completion screen is displayed. Click "Close".
8. Note: The steps above only install the USB controller. To install the virtual com port layer, the above steps need to be repeated (as described below)
9. Open the Device Manager and right click again on the other device (TTLR232). Select "Update Driver Software…"
10. Click on "Browse my computer for driver software"
11. In the next dialog window, specify the location where the drivers have been saved and click on "Next"
12. The installation should take a few seconds. After the installation has finished, a completion screen is displayed. Click "Close".
13. **Connect the USB to UART cable to the PC**
14. In the Device Manager window, verify that the USB Serial Port is displayed under "Ports (COM & LPT)" and that a serial port identifier has been assigned as shown below



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2. Terminal Emulator Installation

To communicate with ADMX2001 via its command-line interface and UART, a terminal emulator like TeraTerm is recommended. Visit the URL below to download TeraTerm:

https://osdn.net/projects/ttssh2/releases/

Download and run the latest stable release. Follow the on-screen instructions.

Alternatives like PuTTY can also be used, but some customers have had issues with PuTTY where the terminal window does not open.

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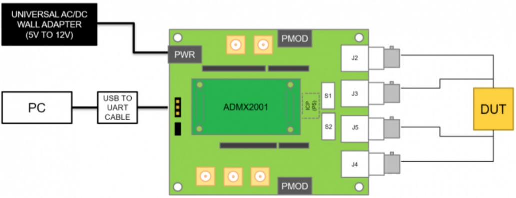
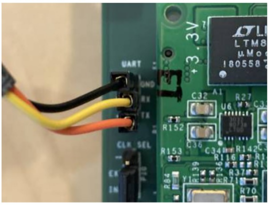
3. Basic Hardware Setup

The following figure shows the basic connections required for evaluating the ADMX2001.



1. Insert the ADMX2001 module into the EVAL-ADMX2001EBZ board in the location shown above

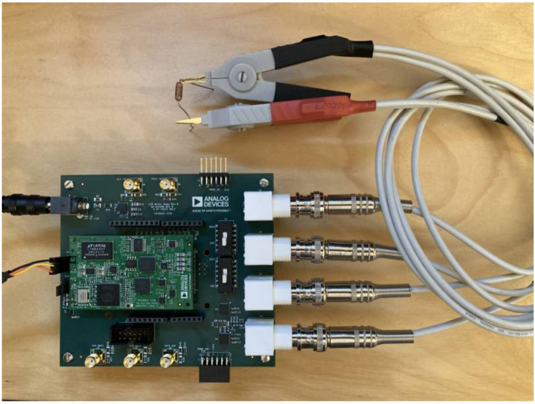
2. Connect the power adapter to the power jack and to the ac outlet
3. Connect the UART to USB cable to the UART terminals TX-->TX, RX-->RX and GND-->GND



4. Ensure that the CLK_SEL jumper is set to INT (internal clock)
5. Use the test leads to connect to the device under test (DUT)

*The switches S1 and S2 must be set to DUT and GND respectively to connect the ADMX2001 to the BNC terminals.

When the ADMX2001 powers on, it automatically performs a self test. The bi-color LED on the underside of the board will turn green if the board boots and passes the self test, or yellow if the self test fails. In order to pass the self test, the switches S1 and S2 must be set to OPEN and GND. Alternatively, if S1 and S2 are in the DUT and GND position, the test leads must be connected in the 'open' configuration to pass the self test. The board will still function without passing the self test. The status of the self test can be seen by running the command 'selftest', and 'selftest run' will rerun the self test.



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4. Opening a Session via TeraTerm

After installing TeraTerm, open the program and choose Serial connection. Select the COM port identified earlier in Device Manager. Click OK. Then choose the dropdown labeled Setup, click Serial port, and ensure that the COM port is set, Speed=115200, Data=8 bits, Parity=none, Stop bits=1 bits, Flow control=none. Click New setting. Optionally, choose Setup→Save setup. Save the file to the default directory. Now, when launching TeraTerm, it will automatically try to connect with the saved settings.

Make sure the hardware is properly installed and that power is available to the board via the 12V power adapter. TeraTerm should now be connected to the board. To check:

- Press ENTER to display the AMDX2001> prompt
- Type `*idn` and press ENTER to display the firmware version
- Type `help` and press ENTER to see a list of commands supported by ADMX2001.

For a complete list of ADMX2001 configuration parameters please refer to the ADMX2001 Configuration Parameters section in this page. For a complete command set reference, please refer to the Command Set Reference section in this page.

Please note that closing the TeraTerm window does not reset the ADMX2001 settings from the last session.

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5. Performing Basic Measurements

Upon opening a session with TeraTerm, the ADMX2001 is ready to perform impedance measurements.

> The measurements reported by the module will not be accurate unless it has been calibrated. For detailed instructions on how to calibrate the module, please refer to the Calibration Procedure section in this user guide.

By default, the module is set to perform single-point measurements with a 1VRMS signal (1.41 signal magnitude) at 1kHz, and no dc offset. To initiate a measurement type the `z` command at the prompt and press ENTER.

Example

Perform a capacitance measurement in parallel with an equivalent resistor (Cp-Rp) at 100kHz with a 1V amplitude sine. Return 5 readings, where each is an average of 10 samples.

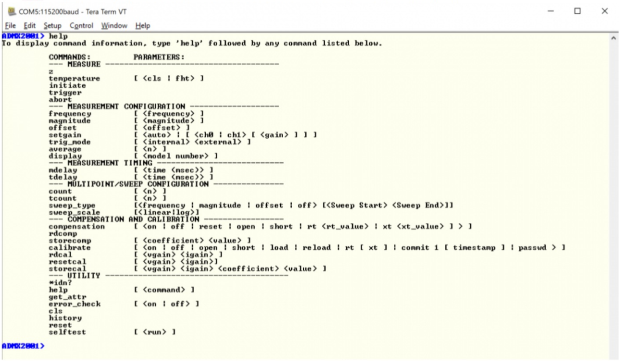
```
ADMX2001> frequency 100
frequency = 100.0000kHz
ADMX2001> display 9
Measurement model: 9 - Capacitance and equivalent parallel resistance (Cp,Rp)
ADMX2001> magnitude 1
magnitude = 1.0000
ADMX2001> average 10
average = 10
ADMX2001> count 5
sampleCount = 5
ADMX2001> z
0,5.677640e-13,8.062763e+07
1,5.668012e-13,8.305672e+07
2,5.675237e-13,8.208995e+07
3,5.673763e-13,8.276912e+07
4,5.683635e-13,8.463327e+07
ADMX2001>
```

The order in which the commands are entered is not important.

By default, auto-range is selected. To disable the auto-ranging function, use the `setgain` command to select a specific measurement range for the voltage (ch0) or current (ch1) measurement channels.

Using the Online Help in the Command-Line Interface

The `help` command will display all the commands available to the user from the command-line interface (CLI).



```
ADMX2001> help
To display command information, type 'help' followed by any command listed below.

          COMMANDS:         PARAMETERS:
          --- MEASURE -------------------------------------
          z
          temperature       [ <cls | fht> ]
          initiate
          trigger
          abort
          --- MEASUREMENT CONFIGURATION -------------------
          frequency         [ <frequency> ]
          magnitude         [ <magnitude> ]
          offset            [ <offset> ]
          setgain           [ <auto> | [ <ch0 | ch1> [ <gain> ] ] ]
          trig_mode         [ <internal> <external> ]
          average           [ <n> ]
          display           [ <model number> ]
          --- MEASUREMENT TIMING ---------------------------
          mdelay            [ <time (msec)> ]
          tdelay            [ <time (msec)> ]
          --- MULTIPOINT/SWEEP CONFIGURATION ---------------
          count             [ <n> ]
          tcount            [ <n> ]
          sweep_type        [<frequency | magnitude | offset | off> [<Sweep Start> <Sweep End>]]
          sweep_scale       [<linear|log>]
          --- COMPENSATION AND CALIBRATION -----------------
          compensation      [ <on | off | reset | open | short | rt <rt_value> | xt <xt_value> ] > ]
          rdcomp
          storecomp         [ <coefficient> <value> ]
          calibrate         [ <on | off | open | short | load | reload | rt [ xt ] | commit 1 [ timestamp ] | passwd > ]
          rdcal             [ <vgain> <igain> ]
          resetcal          [ <vgain> <igain>]
          storecal          [ <vgain> <igain> <coefficient> <value> ]
          --- UTILITY ----------------------------------------
          *idn?
          help              [ <command> ]
          get_attr
          error_check       [ <on | off> ]
          cls
          history
          reset
          selftest          [ <run> ]

ADMX2001>
```

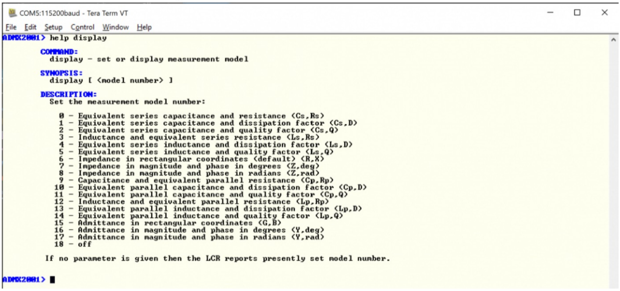
To get help for any command, simply type

```
ADMX2001>help <command>
```

For example, to get help with how to select different measurement display formats, type

```
ADMX2001>help display
```

Which should show a similar screen to the picture shown below


COM5:115200baud - Tera Term VT
File Edit Setup Control Window Help

```
ADMX2001> help display

        COMMAND:
          display - set or display measurement model

        SYNOPSIS:
          display [ <model number> ]

        DESCRIPTION:
          Set the measurement model number:

            0 - Equivalent series capacitance and resistance (Cs,Rs)
            1 - Equivalent series capacitance and dissipation factor (Cs,D)
            2 - Equivalent series capacitance and quality factor (Cs,Q)
            3 - Inductance and equivalent series resistance (Ls,Rs)
            4 - Equivalent series inductance and dissipation factor (Ls,D)
            5 - Equivalent series inductance and quality factor (Ls,Q)
            6 - Impedance in rectangular coordinates (default) (R,X)
            7 - Impedance in magnitude and phase in degrees (Z,deg)
            8 - Impedance in magnitude and phase in radians (Z,rad)
            9 - Capacitance and equivalent parallel resistance (Cp,Rp)
           10 - Equivalent parallel capacitance and dissipation factor (Cp,D)
           11 - Equivalent parallel capacitance and quality factor (Cp,Q)
           12 - Inductance and equivalent parallel resistance (Lp,Rp)
           13 - Equivalent parallel inductance and dissipation factor (Lp,D)
           14 - Equivalent parallel inductance and quality factor (Lp,Q)
           15 - Admittance in rectangular coordinates (G,B)
           16 - Admittance in magnitude and phase in degrees (Y,deg)
           17 - Admittance in magnitude and phase in radians (Y,rad)
           18 - off

         If no parameter is given then the LCR reports presently set model number.


ADMX2001> █
```

Useful Hints

Selecting a Measurement Range

By default, the ADMX2001 is in auto-ranging mode, which will optimize the measurement gain of the voltage and current measurement channels, depending on the frequency and magnitude of the test signal.

> The auto-ranging algorithm will only be applied to the conditions of the first measurement. When performing frequency sweeps, the impedance of the device under test will change and could fall outside of the measurement range selected by the initial measurement conditions.

In some cases, the user may want to select a specific measurement range. The measurement range is mostly affected by the transimpedance of channel 1 and the test signal magnitude. It is recommended to select the transimpedance value that is smaller than the expected value of the impedance under test, but larger than the next transimpedance selection.

For example, if the DUT's expected impedance value is 2kΩ, enter the following in the command line prompt

```
ADMX2001> setgain ch1 1
  Current meas gain = 1
```

The command `setgain ch1` will set the transimpedance of the L_CUR input (channel 1) to 1kΩ. It is not recommended to use the 10kΩ value since this could exceed the input channel measurement capabilities and return incorrect readings.

The transimpedance values available are listed below.

Ch1 Gain	Measurement Range	Max. Input Current	Transimpedance
0	100Ω	25mA	49.9Ω
1	1kΩ	2.5mA	499Ω
2	10kΩ	250uA	4.99kΩ
3	100kΩ	25uA	49.9kΩ

The command `setgain ch0` modifies the input voltage range of channel 0 (between terminals H_POT and L_POT). This is less common, but it can be used to improve measurement sensitivity if the impedance under test is smaller than the lead impedance or less than 100Ω. It can also be used if the magnitude of the test signal is small. This can be the case with sensitive loads, or when the test frequency is high.

Available voltage gain values for channel 0 are listed below.

Ch0 Gain	Gain Factor	Input Voltage Range
0	1	2.5V
1	2	1.25V
2	4	625mV
3	8	31.3mV

Typing the command `setgain` will display the gain of both input channels and whether or not autoranging is enabled.

```
ADMX2001> setgain
Autorange enabled
voltGain = 1
currGain = 3
ADMX2001>
```

To turn autoranging back on after setting a manual range type `setgain auto`

Even though 16 gain combinations are possible, most measurements can be performed with the 7 combinations shown in the table below.

Ch0 Gain	Ch1 Gain	Impedance Measurement Range
3	0	< 10Ω
2	0	< 25Ω
1	0	< 50Ω
0	0	100Ω to 1kΩ
0	1	1kΩ to 10kΩ
0	2	10kΩ to 100kΩ
0	3	> 100kΩ

These are the same ranges that the autoranging algorithm uses. The following section show how to estimate the impedance value of the DUT to determine the measurement range.

Estimating the Impedance and Admittance of Capacitive and Inductive Devices

Impedance is defined as the opposition to the flow of alternating current. Admittance is the reciprocal of impedance, or how easy is for alternating current to flow. Electrical components such as resistors, capacitors and inductors have a direct relationship between their value and the expected impedance (Z):

$Z = X = -1/(2\pi fC)$ for capacitors
$Z = X = 2\pi fL$ for inductors
$Z = R$ for resistors

Where f is the frequency of the signal; C, L, and R are the component values in Farads, Henrys and Ohms respectively. R represents resistance and X reactance. For admittance (Y):

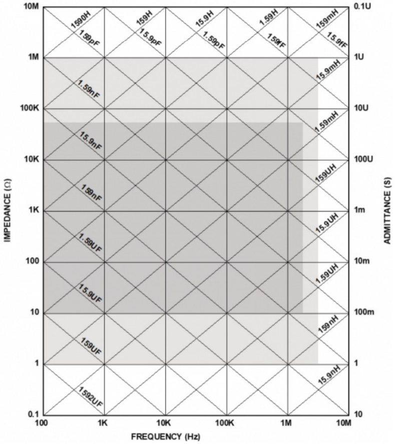
$Y = B = 2\pi fC$ for capacitors
$Y = B = -1/(2\pi fL)$ for inductors
$Y = G = 1/R$ for resistors

Where f is the frequency of the signal; C, L, and R are the component values in Farads, Henrys and Ohms respectively. G represents conductivity and B susceptance.

All components, regardless of their construction, will show a combination of resistive (conductive) and reactive (susceptive) properties. These properties can be expressed in form of ideal electrical components combined either in series or parallel. At any given frequency, impedance/admittance can be expressed as a combination of the reactive element (capacitor or inductor) and a resistive element. The total impedance or admittance magnitude can be obtained by calculating the square-root of the sum of squares (RSS) of the two components or

$|Z| = \mathrm{sqrt}(R*R + X*X)$
$|Y| = \mathrm{sqrt}(G*G + B*B)$

To determine the best measurement range for measurement, it is necessary to estimate the impedance or admittance of the device under test at the frequency of measurement using the equations above. A simpler method to obtain an approximate value based on the expected capacitance or inductance value is through the reactance chart shown below.



To find the approximate impedance or admittance value for a capacitor or inductor, find the closest expected value assigned to the diagonal lines and find its equivalent impedance/admittance value on the vertical axis at the frequency of interest (on the horizontal axis).

Reducing Measurement Noise

The `average` command determines how many samples are averaged for each reading returned. Averaging reduces noise and is helpful in applications that require to detect small changes in a value or when the impedance component of interest is small in comparison to the total impedance magnitude (e.g. ESR of capacitors). The default is set to 1, which means that no averaging is done.

Averaging increases the time required to return a reading. Values greater than 200 have been observed to have little effect in reducing measurement noise and have a notorious impact on measurement speed.

Improving Measurement Precision

To ensure precise and accurate measurements, impedance measurements should be performed with appropriate test fixtures. Measurement leads can introduce additional errors due to parasitic impedances that will vary depending on mechanical configuration.

The test leads included with the EVAL-ADMX2001EBZ kit can introduce fluctuations of a few picofarads depending on their position. This effect becomes more noticeable with test frequencies higher than 100kHz.

To ensure repeatable and stable measurements, custom-made fixtures that minimize impedance fluctuations due to mechanical configuration are recommended. For example, to test surface-mount components, fixtures like the B+K Precision TL89S1 or the Keysight 16034G are recommended. For a full list of recommended accessories, please refer to the Recommended Accessories Section at the beginning of this user guide.

Performing Parametric Sweeps

The ADMX2001 can automatically perform measurements that sweep different measurement parameters such as

- Frequency, common in EIS applications (Electrical Impedance Spectroscopy). The frequency increments can be linear or logarithmic.
- DC bias, common in C-V measurements for semiconductor devices
- Magnitude

By default, the sweep function is off. To enable parametric sweeps, use the `sweep_type` command and specify the sweep type. The command also requires to enter the start and end points of the sweep. The number of points is determined by the `count` command.

Example

Perform an 11-point logarithmic frequency sweep from 100kHz to 1MHz.

```
ADMX2001> count 11
sampleCount = 11
ADMX2001> sweep_type frequency 100 1000
Frequency
sweepStart = +100.0000KHz
sweepEnd = +1000.0000KHz
ADMX2001> sweep_scale log
Sweep scale is log
ADMX2001> z
1.000000e+05,5.683433e-13,8.149236e+07
1.258925e+05,5.704062e-13,4.727518e+07
1.584893e+05,5.674423e-13,2.989029e+07
1.995262e+05,5.652225e-13,1.917354e+07
2.511886e+05,5.622380e-13,1.233886e+07
3.162278e+05,5.577508e-13,8.082886e+06
3.981072e+05,5.490229e-13,5.611289e+06
5.011872e+05,5.421543e-13,3.547964e+06
6.309573e+05,5.299540e-13,2.360688e+06
7.943282e+05,5.136760e-13,1.624230e+06
1.000000e+06,4.798023e-13,1.411488e+06
ADMX2001>
```

When sweeping parameters, the first value printed will be the swept parameter, followed by the measurement in the display format selected.

Performing DC Resistance Measurements

The DC resistance measurement function can be easily selected by setting the test frequency to zero. In DC mode, since the AC test signal is disabled, the DC offset must be used to generate the test signal. Due to the hardware design, saturation may not be detected if the DC offset is positive; set the DC offset to a negative value to prevent this.

```
ADMX2001> frequency 0
DC Resistance mode enabled
ADMX2001> offset -1
Offset = -1.0000
ADMX2001> z
0,4.995231e+01
ADMX2001>
```

In the DC resistance mode, only the dc resistance value is returned.

Optimizing Measurement Timing

The commands `mdelay` (measurement delay) and `tdelay` (trigger delay) can be used to control the settling time between measurements.

- The measurement delay or `mdelay` is only observed during sweeps and multiple measurements controlled by the “count” command.
- Trigger delay is only observed after trigger events controlled by the “tcount” command. This is useful when using ADMX2001 with external scanning cards or multiplexers, to allow proper debounce and settling time.

To setup `mdelay` and `tdelay` , simply enter the command followed by a value in milliseconds.

Plotting Measurement Data

When acquiring multiple measurements or performing sweeps, it is useful to plot the results to observe trends or characteristics of the device under test. TeraTerm allows the user to save a log by going to File→Log, which can then be copy and pasted into a *.csv file that can be opened by spreadsheet applications such as Microsoft Excel®. The log file must be saved BEFORE taking any measurements.

To plot the acquired data in Microsoft Excel, follow the steps below:

1. Go to File→Log, and save the log file.
2. Configure the ADMX2001 and run the `z` command to acquire the desired measurements
3. Open the log file with a text editor (notepad.exe for example).
4. Save the file with any name but make sure the extension is *.csv
5. Close the file and open Excel
6. Open the file from its location
7. Select the data to plot and insert a scatter plot to visualize the data

---

Calibration Procedure

A few milliseconds after power up, the ADMX2001 is ready to perform measurements. However, any readings and their units are scaled and assigned using nominal circuit parameters. Measurement accuracy can only be evaluated after performing calibration on the module with an external calibration source with certified traceability.

There are three basic calibration steps involved in calibrating the module: open calibration, short calibration, and load calibration. The first two correct the module and test lead parasitics. The latter provides traceability to an external source. The calibration steps must be performed in the order open→short→load. Open and load calibration are the most important.

Each measurement front-end configuration (ch0 and ch1 gain combination) needs to be calibrated separately. If calibration is performed for only one gain combination, calibration needs to be carried out again if the front-end configuration changes. There are a total of 16 possible gain combinations based on the 4 gain and transimpedance ranges for channel 0 and channel 1 respectively.

If the user calibrates at a specific gain and frequency, then changes the frequency and calibrates again, the user will overwrite the result of the first calibration.

1. Calibration is for a specific frequency. Measurements taken at a different frequency may be out of tolerance. Always calibrate as near as possible to the intended test frequency.
2. Short calibration can be performed only when channel 1 is set to 0 or 1. When channel 1 is in gain 1, the magnitude of the source must be less than 0.2Vp.
3. Autoranging during calibration must be disabled.

To calibrate the module in a specific gain combination, follow the steps below:

1. Select the desired measurement configuration
2. Set the averaging to 200 samples and tdelay to 200ms (to allow sufficient settling time)
3. Connect the H_POT and H_CUR terminal together and the L_POT and L_CUR terminals together to form two separate connection pairs
    1. For better results, use Keysight 42090A Open Termination
4. Run the `calibrate open` command
5. Connect all the measurement terminals together
    1. For better results, use Keysight 42091A Short Termination
6. Run the `calibrate short` command
7. Connect a known impedance between the measurement leads
8. Run the `calibrate rt <value1> xt <value2>` command where `<value1>` is the true value of the resistive component of the calibration impedance and `<value 2>` is the true value of the reactive component.
    1. For best results, a standard resistor set like the Keysight 42030A can be used

Resistors, capacitors or inductors can be used for calibration. High-quality resistors (e.g, thin film or metal film), air capacitors and gas-filled capacitors tend to provide the best results. Alternatively, ceramic capacitors C0G/NP0 type can be used as well. The true value of these components must be determined with traceable measurements from another meter, such as the Keysight E4980A.

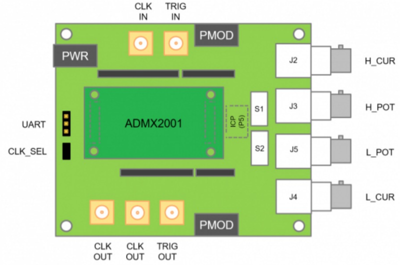
After completing the steps above, calibration coefficients are generated and stored in RAM. These coefficients will be applied to any subsequent measurements, but will be lost after a power cycle or reset of the module. To store the coefficients in non-volatile memory (flash) the command `calibration commit <timestamp>` must be executed, where `timestamp` is the unix timestamp of the last calibration. The unix timestamp is the number of seconds elapsed since 01/01/1970. For example:

```
ADMX2001>calibrate commit 1689959855
```

This will store the calibration coefficients in the RAM to the flash, and set the date and time stamp of the calibration to 07/21/23 at 05:17 UTC.

To help ensure calibration integrity, the calibration coefficients stored in flash are password protected. The default password is `Analog123` and must be entered after running `calibrate commit` to save the coefficients. The password can be changed with the `calibrate password` command. Maximum password length is 12 characters.

EVAL-ADMX2001EBZ Terminal Description



Terminal Name	**Description**
H_CUR	Signal source terminal. It generates the excitation required for measurement. This terminal can source up to +/-5V @ 50mA
H_POT	Voltage sense terminal. Connect to H_CUR at the device under test (DUT)
L_POT	Voltage sense terminal. Connect to L_CUR at the device under test (DUT)
L_CUR	Current sense terminal. Return path for the excitation signal. Connect to the opposite end of the DUT as H_CUR
UART TX	UART transmitter pin. Connect to TX pin on the UART to USB cable
UART RX	UART receiver pin. Connect to RX pin on the UART to USB cable
UART GND	UART ground. Connect to ground pin on the UART to USB cable
CLK_SEL	Jumper selection of internal or external clock. Set to internal for default operation
TRIG_IN	Trigger input. Use for hardware-timed acquisition only, otherwise leave disconnected (future expansion)
TRIG_OUT	Measurement complete trigger out (future expansion)
CLK_IN	External clock input. Use a LVCMOS 50MHz clock signal and set CLK_SEL to EXT position
CLK_OUT	Clock output. These two terminals have a buffered replica of the 50MHz master clock
PMOD	Master and slave PMOD terminals for SPI port (future expansion)

*Arduino headers currently reserved for future expansion

Support

For support or general questions, reach out to admx-support@analog.com.

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