LDC1101EVM User Guide

User's Guide

Literature Number: SNOU137
May 2015

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Introduction

The Texas Instruments LDC1101 evaluation module (EVM) helps designers evaluate the operation and performance of the LDC1101 Inductance to Digital Converter. The EVM contains a low cost MSP430F5528 microcontroller which comes with pre-loaded firmware to communicate with LabVIEW™ based PC controller software.

The EVM contains one LDC1101 soldered onto the EVM PCB.

Device and Package Configurations

Device	IC	Package
U1	LDC1101	VSON-10

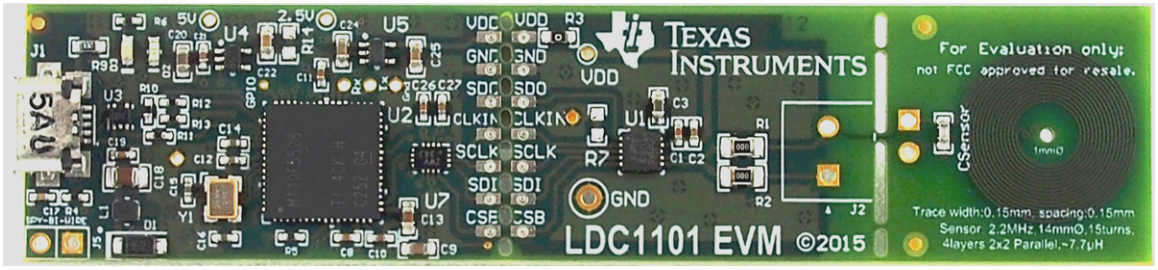

Figure 1-1. LDC1101EVM

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EVM Features and Connections

This section describes the connectors on the LDC1101EVM and how to properly connect, set up and use the LDC1101. The EVM block diagram is shown below.

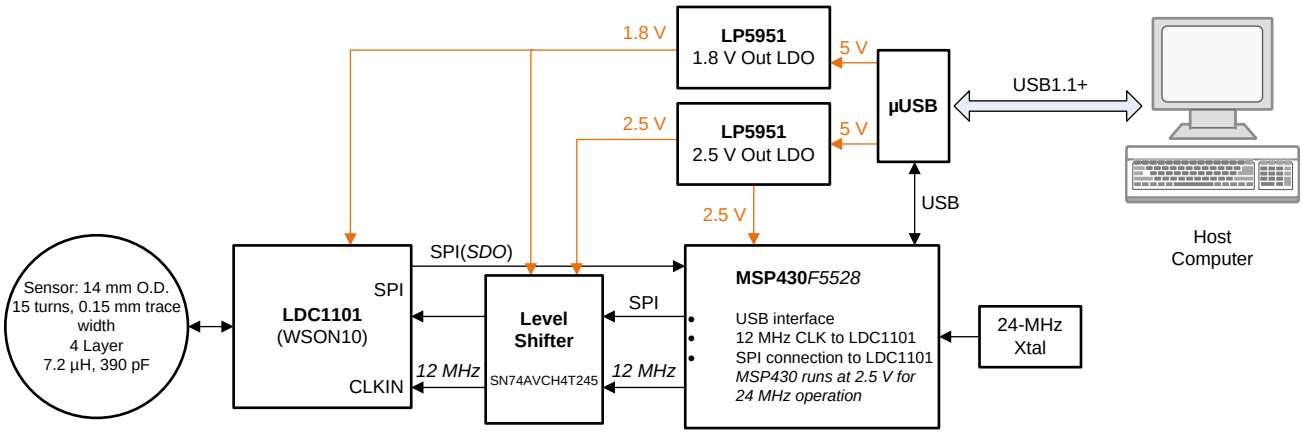

Figure 2-1. EVM Block Diagram

2.1 Connector Description

EVM Connections

Connector	Type	Functionality
J1	Micro-USB connector	Provides power and control via PC USB connection
J2	Phoenix Connector 1727010 (not installed)	Provides convenient screw-terminal adapter for connecting various sensors
J5	100mil header (not installed)	SPY-Bi-Wire connection for Code Composer Studio support.
Break-Away Header	7pin 100mil spaced pads	The EVM can be separated at this point for remote placement of the LDC1101 or to use a different MCU. Provides power and control interface for the LDC1101.
VDD	Via	LDC1101 VDD supply voltage test point
GND	Via	Ground test point

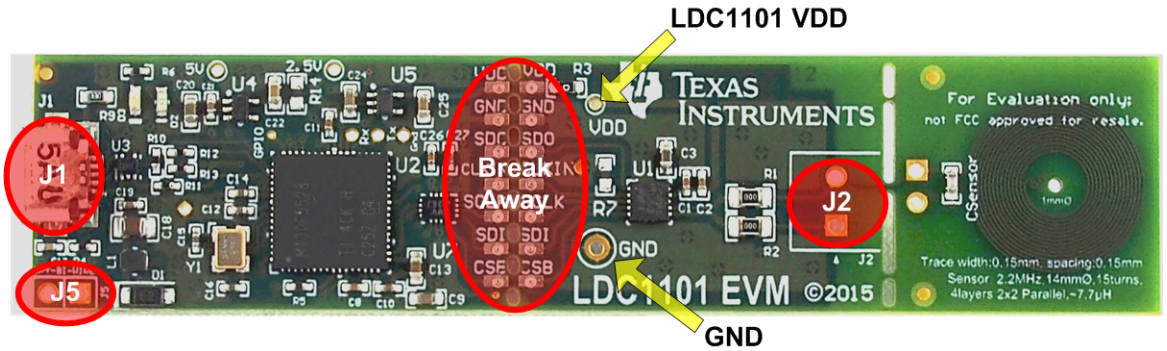

Figure 2-2. Connector Locations

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2.2 EVM Interface

The LDC1101EVM is powered via the USB connection on J1. Use a micro-USB to USB-A cable to connect the EVM to a PC. The LDC1101EVM draws its supply current from the USB port. Do not use a passive USB hub with the EVM.

When powered on, the LDC1101EVM performs a quick self-test; if the LDC1101EVM is working properly and the default EVM sensor is connected, the Green LED will illuminate. If the sensor is different, then the Red LED will illuminate. When connected to the GUI, the Red LED is used to indicate data streaming.

LED Indicator Behavior with GUI

LED	Color	Functionality
D2	Green	Indicates MCU is powered and the default sensor (or a similar sensor) is connected.
D3	Red	Indicates LDC1101 is in streaming mode, transferring conversion results to host when illuminated.

2.3 Break-Away Sections

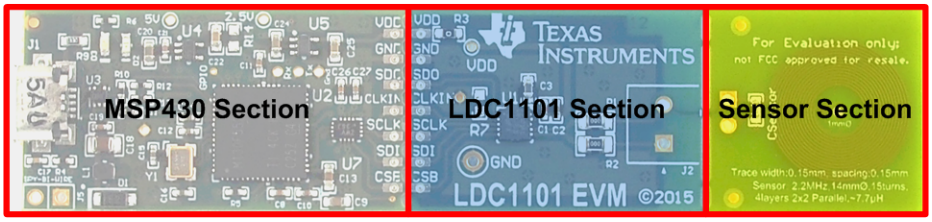

Figure 2-3. EVM Break-Away Sections

The LDC1101 EVM can be broken into 3 discrete sections – a sensor section, which contains the sensor, an LDC1101 section, and an MSP430 section which includes the USB interface section.

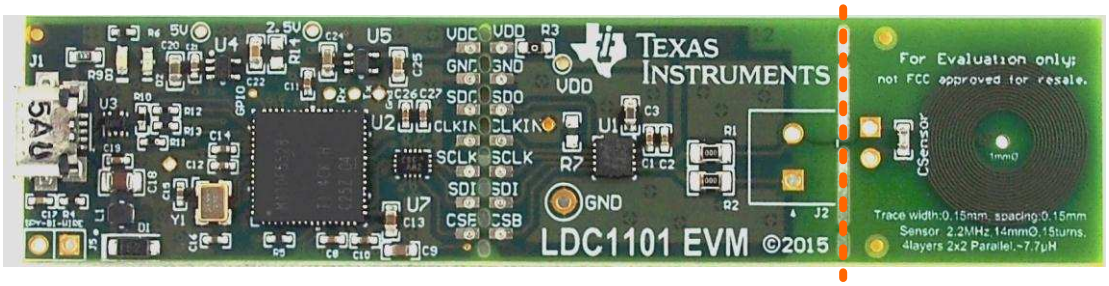

Figure 2-4. Break-Away Sensor

Break-Away Sensor Section

The sensor section of the LDC1101EVM can be broken along the indicated line to separate the sensor from the LDC1101 IC. A two pin header is available for connecting the LDC1101 to alternative inductive sensors. If the cable connection between the sensor and the LDC1101EVM is longer than 2cm, use twisted pair or coaxial cable to connect the sensor to the LDC1101 section.

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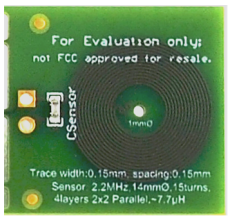

Figure 2-5. Default Inductive Sensor Section

The included sensor is a 4 layer circular coil with 2 parallel inductor paths. This is done to reduce the parasitic series resistance (R_S) of the sensor for improved parallel resonant impedance (R_P) measurement range. J3, a pair of 100mil separated thru-holes, is included for remote connection of the sensor.

A 1mm diameter un-plated thru-hole in the sensor center is available for mounting or alignment to an external assembly.

LDC1101EVM Sensor Parameters

Parameter	EVM Sensor Value
Outer Diameter	551 mils (14.0 mm)
Inner Diameter	191 mils (4.86 mm)
Number of turns	15
Trace Width	6 mils (0.152 mm)
Trace Spacing	6 mils (0.152 mm)
Number of layers	4
Trace Thickness	1 oz-cu (35 µm)
Inductance@ 3 MHz	7.2 µH
Sensor Capacitance	390 pF
f_{SENSOR} (no target)	3.0 MHz
R_S @ 3 MHz (no target)	1.8 Ω
R_P @ 3 MHz (no target)	10.3 kΩ
Q@ 3 MHz	29
Approx. CPARASITIC	3 pF
SRF	33 MHz

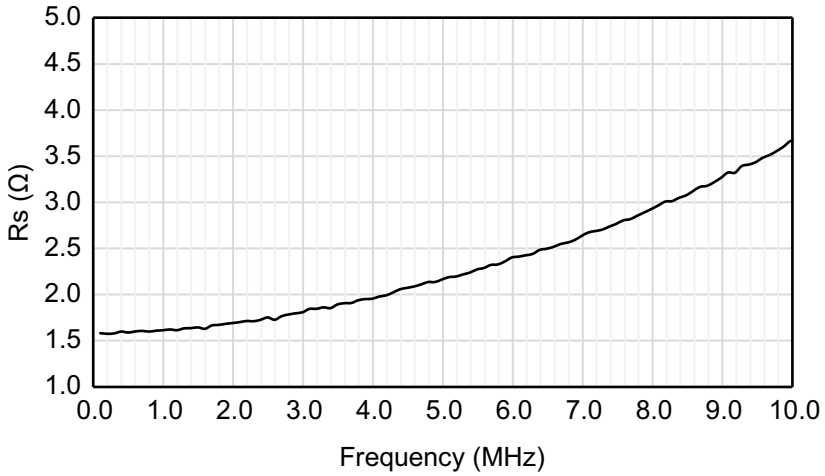

Figure 2-6. LDC1101EVM Default Sensor Resistance Variation

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LDC1101 Recommended Register Settings for EVM Sensor

Register Address	Value
0x01	0x36
0x02	0xDD
0x03	0xFD
0x04	0xCX (set lower nibble based on desired response time)

Sensor Configuration Options

Component footprints are available for a variety of configuration connections.

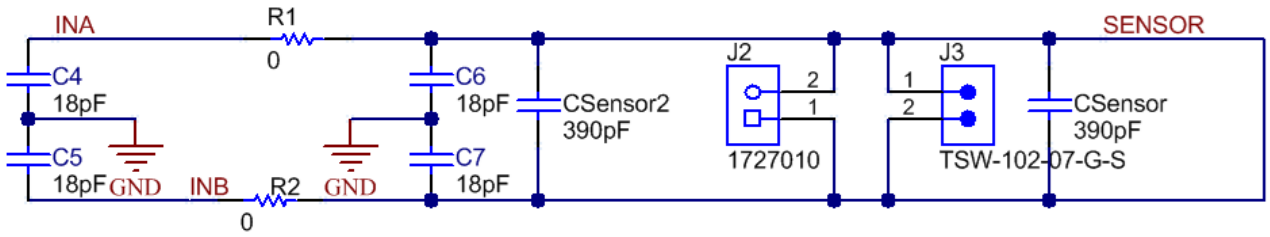

Figure 2-7. Sensor Configuration Options

When operating in an electrically noisy environment or with extended distances to a remote sensor, it may be necessary to populate C4+C5 to improve the measurement ENOB. The components are left unpopulated by default, and the footprints are located on the bottom of the PCB. For additional noise suppression, R1 & R2 can be removed and a common-mode choke (e.g. SRF3216-222Y) can be placed into those two footprints.

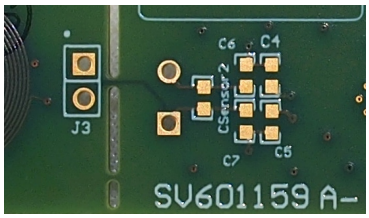

Figure 2-8. Unpopulated Footprints on EVM Bottom

In the rare case where EMI interference is caused by the LDC1101, it may be mitigated by populating C6+C7 with capacitors that are approximately 10% of the value of C_{SENSOR}. The components are left unpopulated by default, and the footprints are located on the bottom of the PCB.

For some sensors, such as wire-wound inductors, it may not be easy to connect a sensor capacitor. A second capacitor footprint – $C_{SENSOR2}$ - is included for such a situation. This is left unpopulated by default, with the footprint located on the bottom of the PCB.

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For remote sensor usage it is recommended to use twisted pair or coaxial cable for the connection to the LDC1101 section of the PCB as shown in Figure 2-9. The maximum distance that a sensor can be located is a function of the sensor frequency, sensor Q, and level of environmental interference. Refer to the Remote Sensor Calculator tool in the LDC Tools Spreadsheet (http://www.ti.com/lit/zip/slyc137) to evaluate maximum sensor distances.

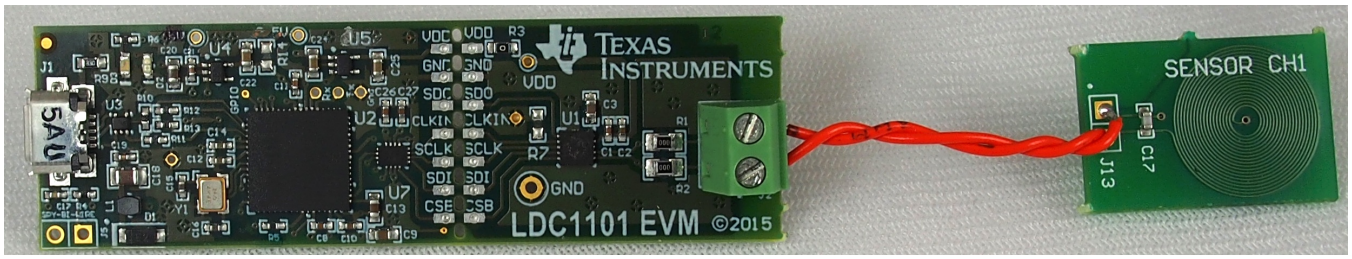

Figure 2-9. Remote Sensor with Twisted Pair Connection

Break-Away MSP430 Section

The MSP430 section of the LDC1101EVM can be broken along the indicated line to separate the MSP430 from the LDC1101 IC. A 7 position 100mil spacing connector can be used for connecting the LDC1101 to the MSP430, or another MCU if necessary. The interface pins on the connector are labeled for proper functionality.

This connector can also be used to supply an external clock input to the LDC1101. If necessary, R7, a 0603 footprint for a 50Ω termination resistor, is present next to the LDC1101. R7 is not populated by default. A ground via is also next to the CLKIN pad for connections using coaxial or twisted pair.

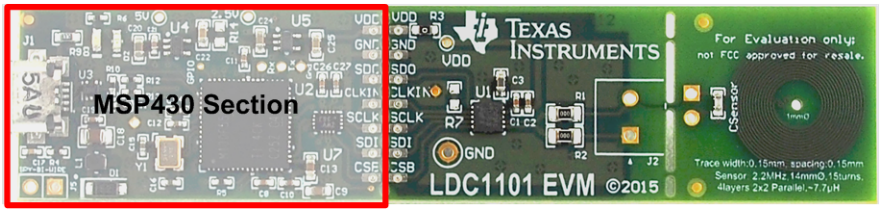

Figure 2-10. MSP430 Section

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LDC1101EVM PC Software (GUI)

The LDC1101EVM uses PC-based application software for device configuration and to retrieve conversion results. The LDC1101 EVM software can be used to evaluate the performance and functionality of the LDC1101 in a simple and flexible GUI configuration. The controls provided correspond to various register fields of the LDC1101 or EVM features (e.g. the RPMIN field setting for the LDC1101).

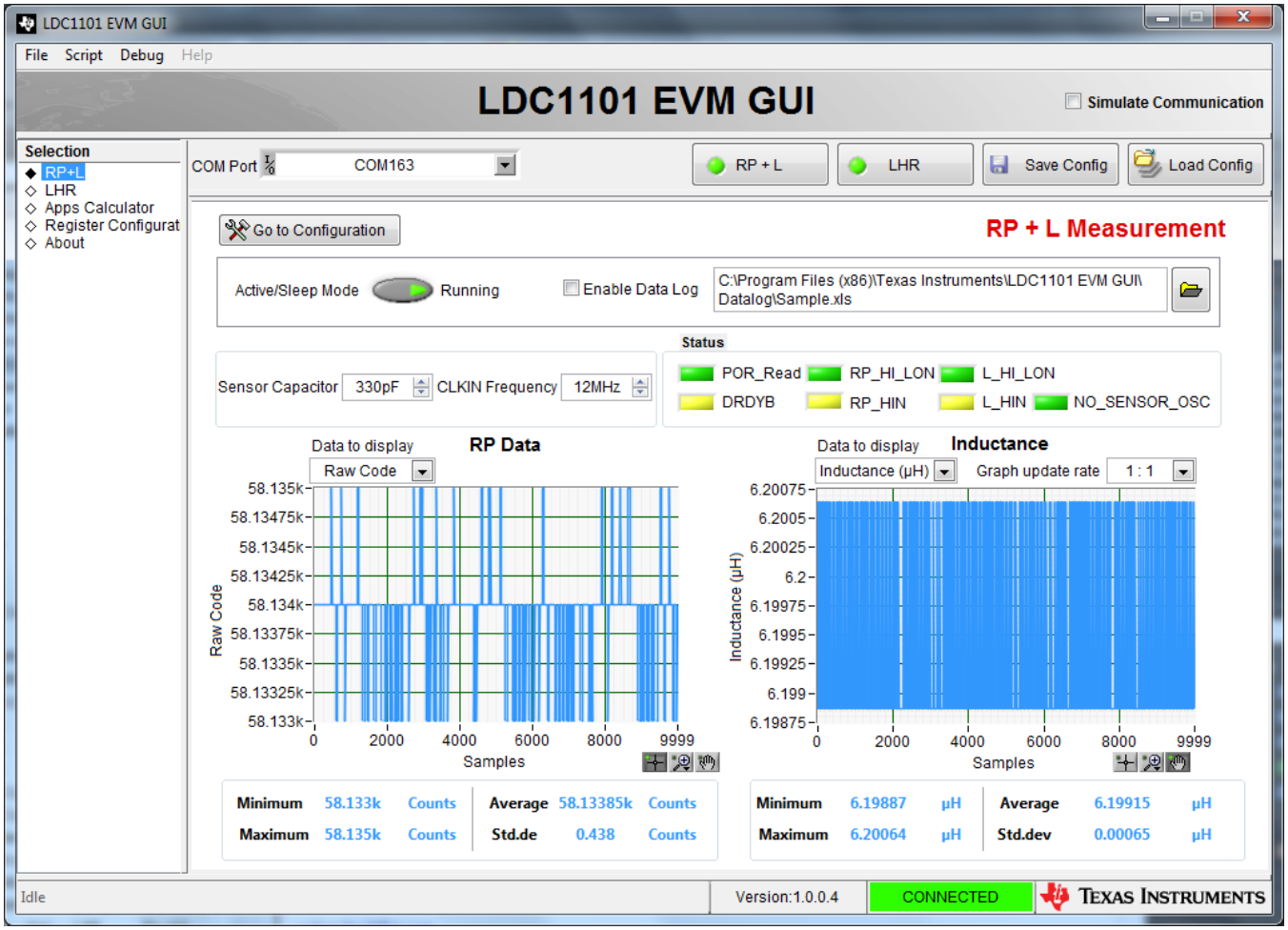

Figure 3-1. LDC1101EVM GUI

3.1 Host Platform Requirements

The LDC1101EVM GUI can run on:

- Windows XP
- Windows 7 (32 & 64 Bit)
- Windows 8 (32 & 64 Bit)

Other platforms are not supported and may not properly operate.

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3.2 Software Installation

Download the latest version of LDC1101EVM GUI software from http://www.ti.com/product/LDC1101. The software must be installed before connecting the LDC1101 to your PC.

To install the LDC1101EVM software:

- Connect to http://www.ti.com/products/LDC1101, and then scroll down to the Software Section to download the latest LDC1101 software.
- Unzip the downloaded file and run the installer file, named "**Texas Instruments LDC1101 EVM GUI Setup.exe**"

The installer will run through a standard Windows program install process. By default, the installer places the control application into **C:\Program Files (x86)\Texas Instruments\LDC1101 EVM GUI**. During the install, the install location can be changed if desired, at the step shown below.

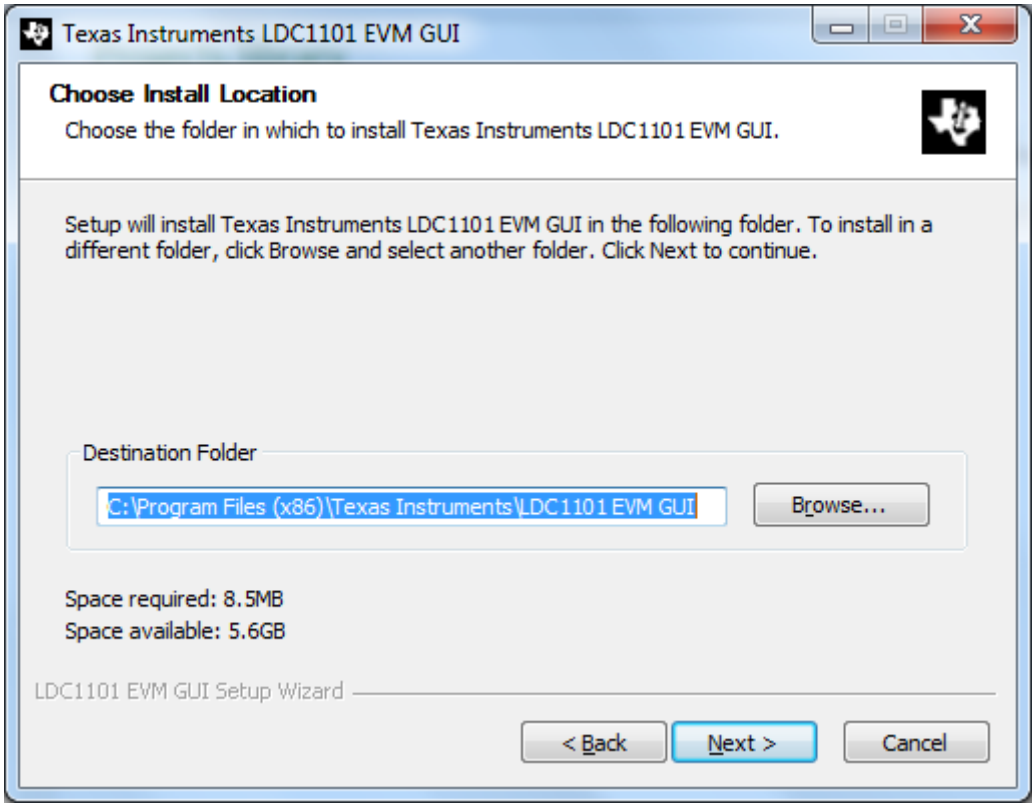

Figure 3-2. Choose Install Location

A shortcut to the application will be available in the Start Menu and on the Desktop.

After installation, connect the LDC1101EVM to the computer with a micro-USB cable. The PC will install the communication driver the first time the board is connected to the PC.

When the Found New Hardware Wizard appears, select the "No, not this time", as the driver is already on the computer.

During installation, the PC may warn that the driver is not compatible. This warning can be ignored; simply press the "Continue Anyway" button to complete the installation. This will associate a COM Port with the EVM.

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3.3 Software Launch

Launch the LDC1101EVM Software from either the Start Menu or the Desktop Icon:

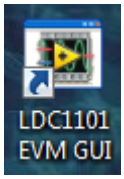

Figure 3-3. Desktop Icon

After the GUI starts, plug in the EVM to an available USB port.

3.4 Connecting the GUI to the EVM

The LDC1101GUI uses a virtual COM port to communicate with the LDC1101EVM through USB.

At the top of the GUI, use the pull-down menu to select the appropriate COM port for communication with the EVM. The GUI verifies the port connection before enabling the interface.

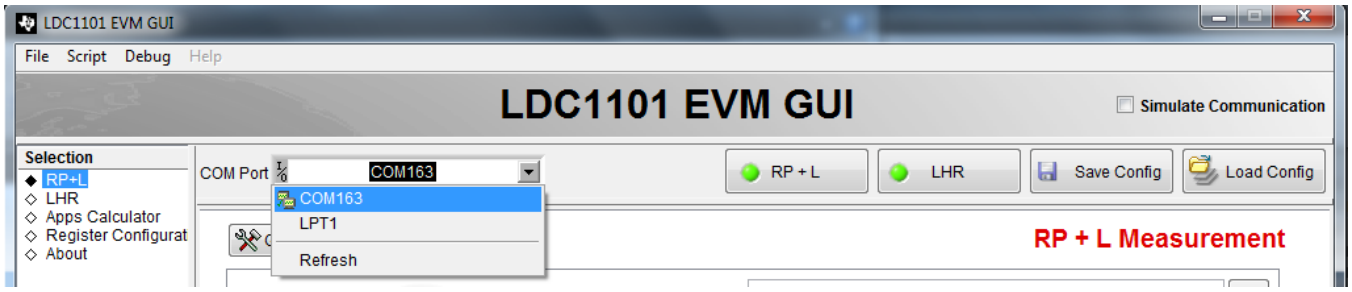

Figure 3-4. COM Port Selection

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On systems which have a large number of installed COM ports, it may not be obvious which COM port is assigned to the EVM. To determine the correct COM port, open the Windows Device Manager and find the COM port named “EVM” under Ports (COM & LPT). In the example below, the LDC1101EVM can be seen on port 89.

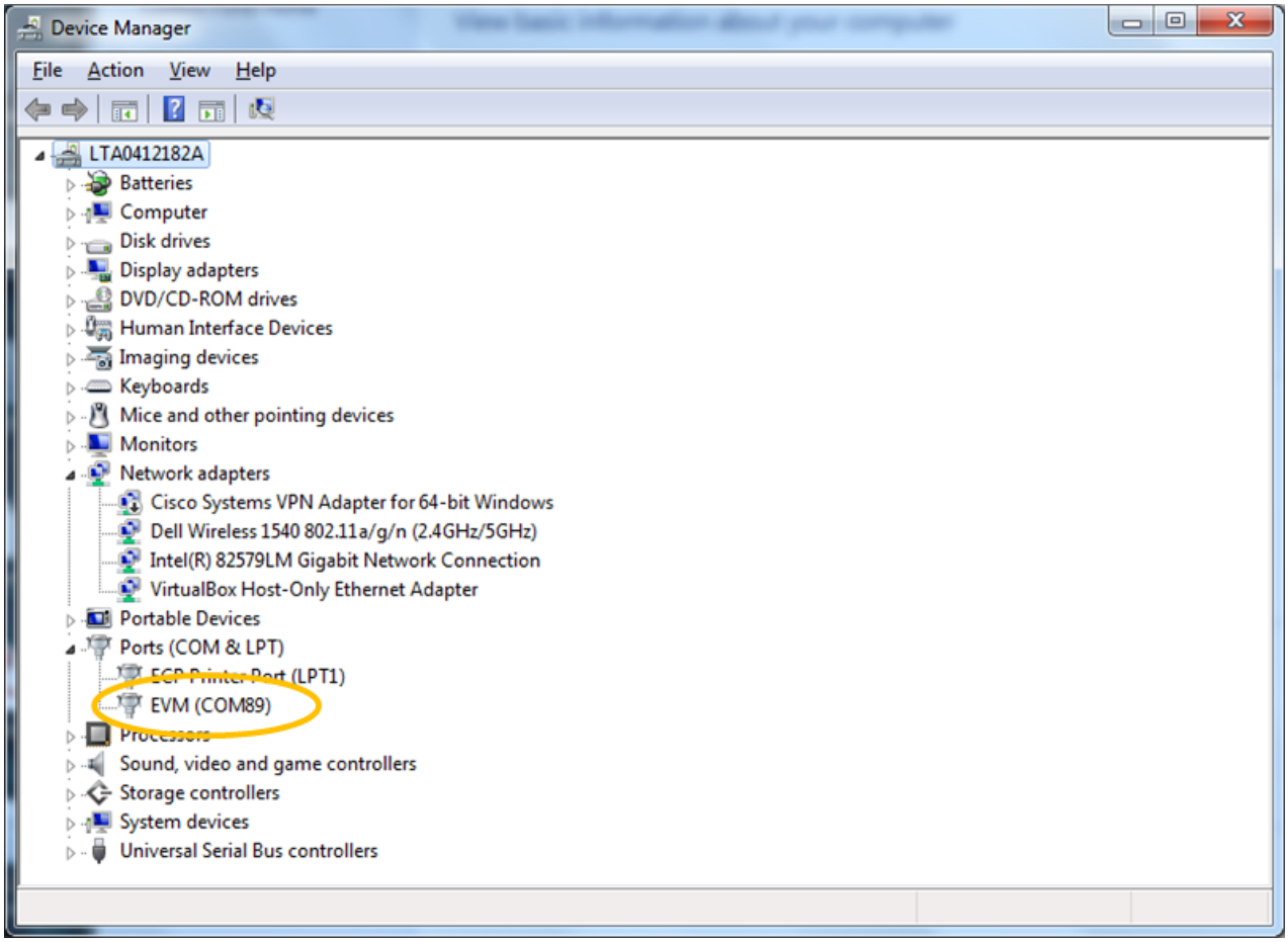

Figure 3-5. EVM COM Port

At the bottom right of the GUI is the connection status indicator – it changes from “NOT CONNECTED” to “CONNECTED” as appropriate.

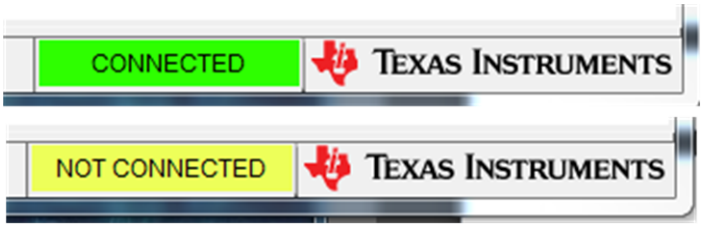

Figure 3-6. EVM Connected/Not Connected Indication

When the software starts up, it reads all the registers of the LDC1101.

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3.5 Software Operation

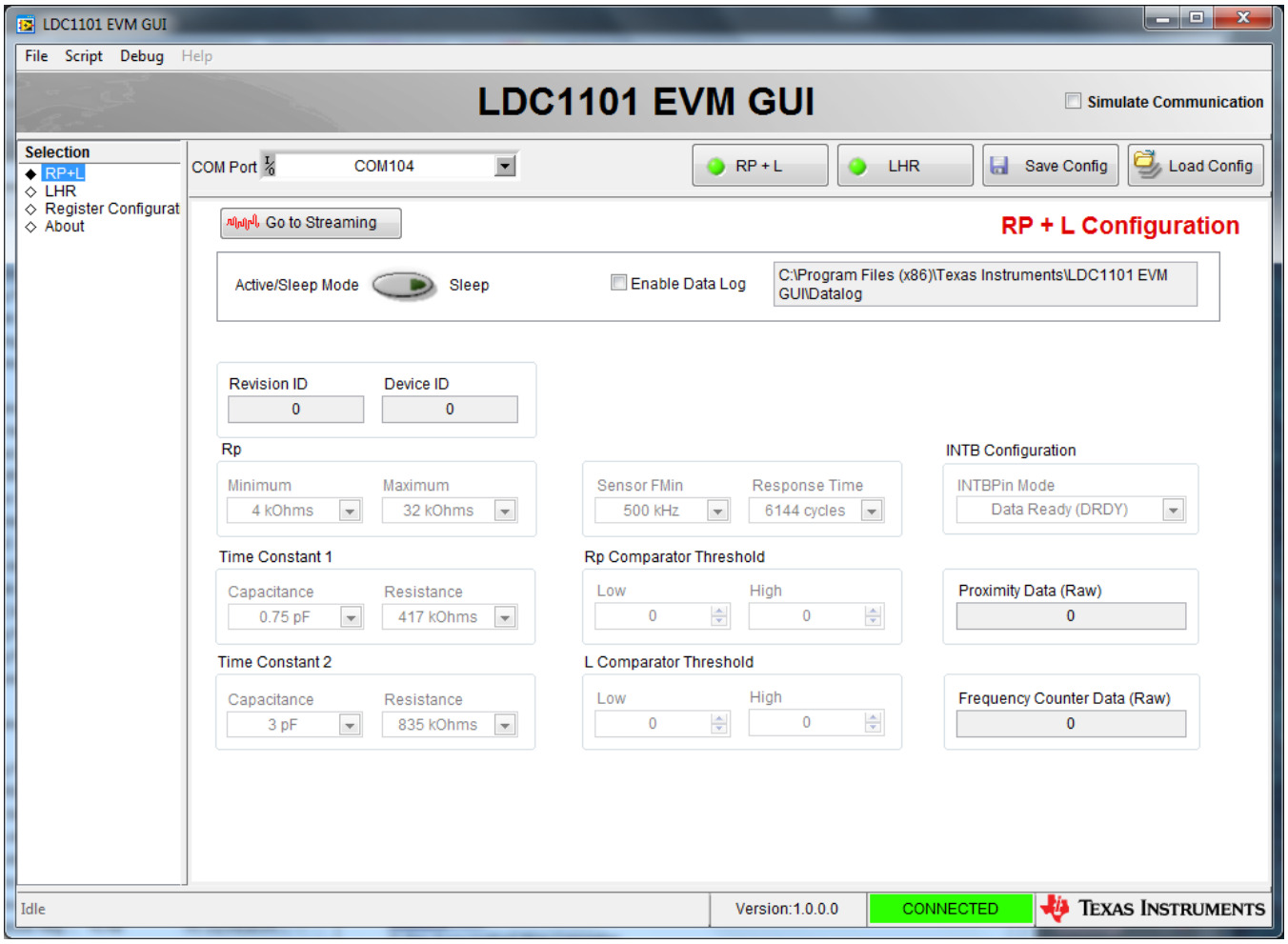

Figure 3-7. LDC1101EVM GUI

The top left section of the GUI is used to select the operating pages, which are the primary sections of the GUI. Simply click on the label corresponding to the desired page. The pages of the LDC1101 GUI are:

- **RP+L Page** – this configures and executes R_P and Inductance (L) measurements
- **LHR Page** – this configures and executes High Resolution Inductance (LHR) measurements
- **Apps Calculator** – this is a tool to configure the LDC1101 R_P measurement settings.
- **Register Configuration Page** – this provides direct reading and writing of LDC1101 registers
- **About Page** – provides information on the GUI Software and information on an attached LDC1101EVM

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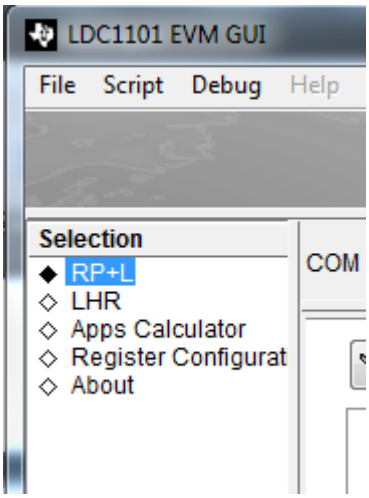

Figure 3-8. Page Selection

3.6 Active/Sleep Mode

The Active/Sleep Mode control changes the operating mode of the LDC1101; pressing the button toggles between Sleep mode and Active mode. While in Sleep Mode the device can be configured with the desired settings; it is recommended to make all device configuration changes in Sleep Mode.

In Active mode, the device is continuously converting and any enabled output plots are updated.

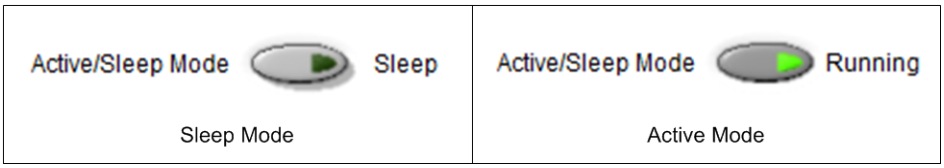

Figure 3-9. Sleep Mode/Active Mode

3.7 Sensor Configuration

The CLKIN Frequency should be set to 12MHz unless the frequency is changed using an external clock source.

The default sensor comes with a sensor capacitance of 390pF; if the sensor capacitance is physically changed then modify the Sensor Capacitor control setting to match the new capacitor value.

Figure 3-10. Sensor Configuration with changed Sensor Capacitor

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3.8 RP+L Page

The RP+L page allows for configuration of R_P & Inductance measurements and plots conversion results. The Streaming section displays the conversion results on two graphs. The left graph is the R_P Data graph and the right graph contains the Inductance graph.

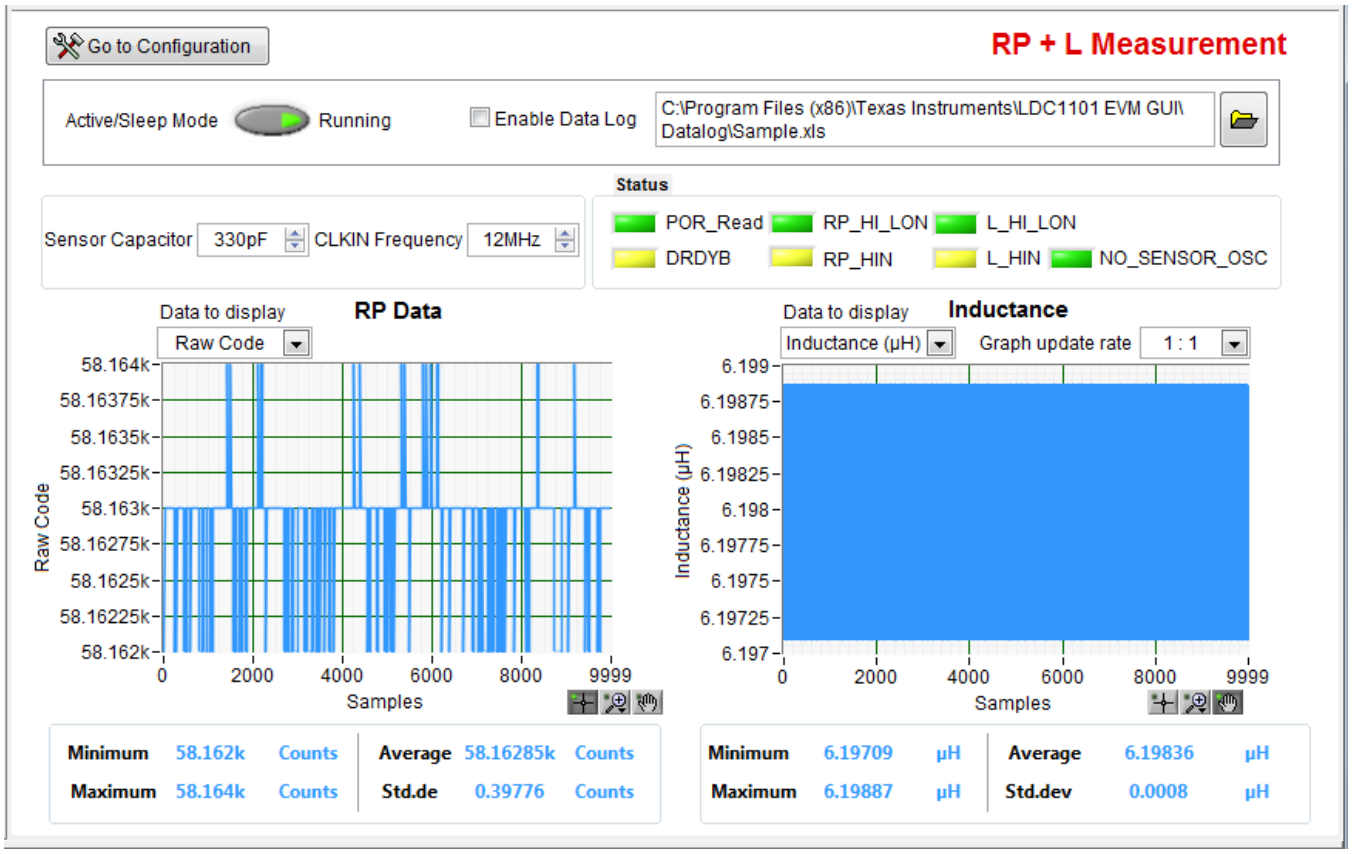

Figure 3-11. LDC1101EVM Control Software: RP+L Page Streaming

Refer to Section 3.12 for information on the features and usage of the graphing areas.

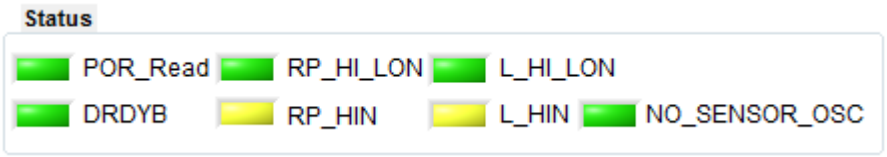

Figure 3-12. RP+L Status

The LDC1101 Status Register (address 0x20) returns information on the measurement status. This status is reported as a set of colored indicators in the Status Section, where Green indicates the condition was not reported (the corresponding bit = 0).

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Register STATUS - Address 0x20

Bit	Bit Field Name	Description
7	NO_SENSOR_OSC	**Sensor Oscillation Not Present Error**
		Indicates that the sensor has stopped oscillating. This error may also be produced if the MIN_FREQ is set to too high a value.
		b0: Error condition was not detected
		b1: LDC1101 has not detected the sensor oscillation.
6	DRDYB	**New Data Ready**
		b0: New conversion data is available.
		b1: No new conversion data is available.
5	RP_HIN	**RP_DATA High Threshold Comparator**
		Note this field will latch a high value.
		b0: RP_DATA measurement has exceeded RP_THRESH_HI
		b1: RP_DATA measurement has not exceeded RP_THRESH_HI
4	RP_HI_LON	**RP_DATA Hysteresis Comparator**
		b0: RP_DATA measurement has gone below RP_THRESH_LO.
		b1: RP_DATA measurement has gone above RP_THRESH_HI.
3	L_HIN	**L_DATA High Threshold Comparator**
		Note this field will latch a high value.
		b0: L_DATA measurement has exceeded L_THRESH_HI
		b1: L_DATA measurement has not exceeded L_THRESH_HI
2	L_HI_LON	**L_DATA Hysteresis Comparator**
		b0: L_DATA measurement has gone below L_THRESH_LO.
		b1: L_DATA measurement has gone above L_THRESH_HI.
0	POR_READ	**Device in Power-On-Reset**
		Indicates the device is in process of resetting. Note that the device cannot accept any configuration changes until reset is complete. Wait until POR_READ = 0 before changing any device configuration.
		b0: Device is not in reset.
		b1: Device is currently in reset; wait until POR_READ = 0.

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While on the Streaming view, press the “Go to Configuration” button to modify the RP+L device settings. The page will change and appear as below. Press the “Go to Streaming” button to return to the Streaming view.

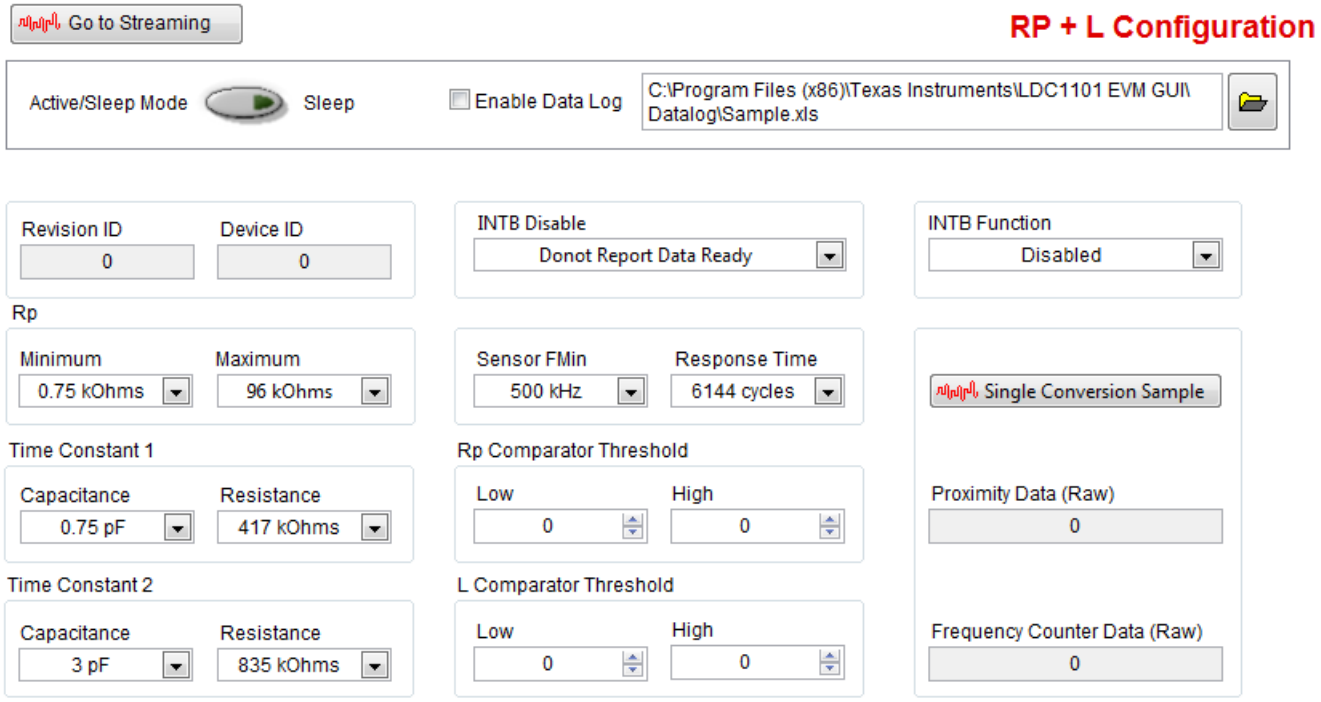

Figure 3-13. RP+L Page Measurement Configuration

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RP+L Configuration Controls

Control	Function	Recommended Setting for LDC1101EVM sensor	LDC1101 Register Field
RP Minimum	Sets the maximum current drive. For higher loss coils, or if there is a larger amount of conductive material in the vicinity of the sensor, this setting may need to be decreased.	1.5 kΩ	RP_MIN
RP Maximum	Sets the minimum current drive. For low-loss coils without a large amount of conductive materials, it may need to be increased; setting to “Disable” will set the LDC1101 RPMAX_DIS.	12 kΩ	RP_MAX + RPMAX_DIS
Time Constant 1 Capacitance	Sets Time Constant 1 capacitance.	6.0 pF	CINT1
Time Constant 1 Resistance	Sets Time Constant 1 resistance.	41.6kΩ	RINT1
Time Constant 2 Capacitance	Sets Time Constant 2 capacitance.	24 pF	CINT2
Time Constant 2 Resistance	Sets Time Constant 2 resistance.	49 kΩ	RINT2
Sensor Fmin	Set the Minimum Sensor Frequency. This is used for checking if oscillation has died.	2.7 MHz	MIN_FREQ
Response Time	Adjusts the measurement resolution and measurement time. A higher value response time setting has higher measurement resolution and lower sample rate	-	RESP_TIME
RP Comparator Low	The LDC1101 can compare the RP conversion result against a high and low threshold. This control is provided for completeness, although the functionality is not available with the GUI.	-	RP_THRESH_LO
RP Comparator High		-	RP_THRESH_HI
L Comparator Low	The LDC1101 can compare the L conversion result against a high and low threshold. This control is provided for completeness, although the functionality is not available with the GUI.	-	L_THRESH_LO
L Comparator High		-	L_THRESH_HI
INTB Function	This control configures the INTB functionality; this feature is not used as the LDC1101 FW periodically polls the conversion results.	-	INTB2SDO
Single Conversion Sample	Returns a single conversion result		

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3.9 LHR Page

The LHR Page allows for configuration of the High Resolution Inductance measurements and plots conversion results. The Streaming section displays conversion result on a graph.

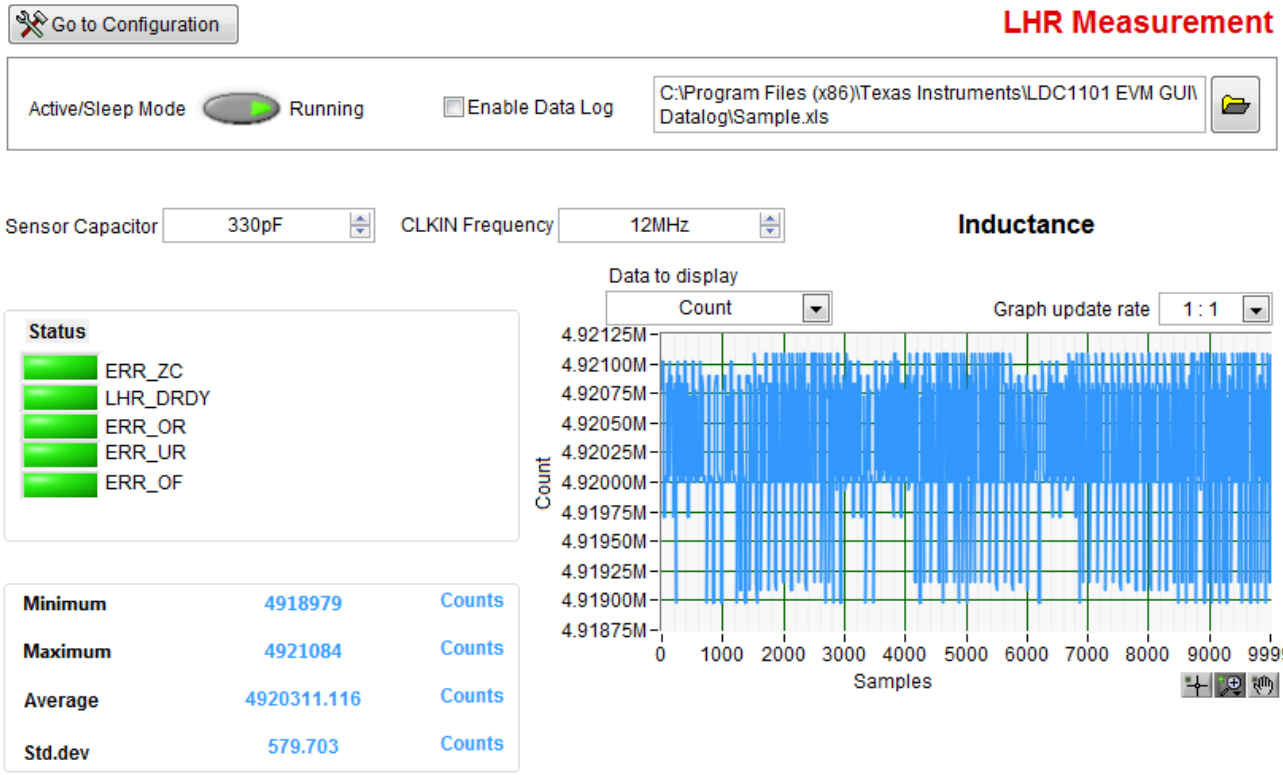

Figure 3-14. LDC1101 Control Software: LHR Page Streaming

Refer to Section 3.13 for information on the features and usage of the graphing area.

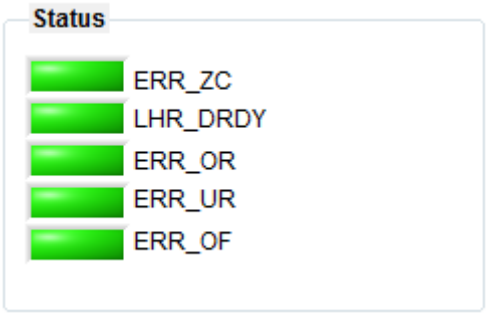

Figure 3-15. LHR Status

The LDC1101 LHR_Status Register (address 0x3B) returns information on LHR measurement status. The status is reported as a set of colored indicators in the Status section, where Green indicates the condition was not reported (the corresponding bit = 0).

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Register LHR_STATUS - Address 0x3B

Bit	Bit Field Name	Description
4	ERR_ZC	**Zero Count Error**
		Zero count errors indicate that no cycles of the sensor occurred in the programmed measurement interval. This indicates either a sensor error or the sensor frequency is too low.
		b0: No Zero Count error has occurred since the last read of the STATUS register.
		b1: A Zero Count error has occurred.
3	ERR_OR	**Conversion Over-range Error**
		Conversion over-range errors indicate that the sensor frequency exceeded the reference frequency.
		b0: No Conversion Over-range error has occurred since the last read of the STATUS register.
		b1: A Conversion Over-range error has occurred.
2	ERR_UR	**Conversion Under-range Error**
		Conversion under-range errors indicate that the output code is negative; this occurs when programmed LHR offset register value is too large.
		b0: No Conversion Under-range error has occurred since the last read of the STATUS register.
		b1: A Conversion Under-range error has occurred.
1	ERR_OF	**Conversion Over-flow Error**
		Conversion over-flow errors indicate that the sensor frequency is too close to the reference frequency.
		b0: No Conversion Over-flow error has occurred since the last read of the STATUS register.
		b1: A Conversion Over-flow error has occurred.
0	LHR_DRDY	b0: No unread conversion data is available.
		b1: Unread conversion data is available.

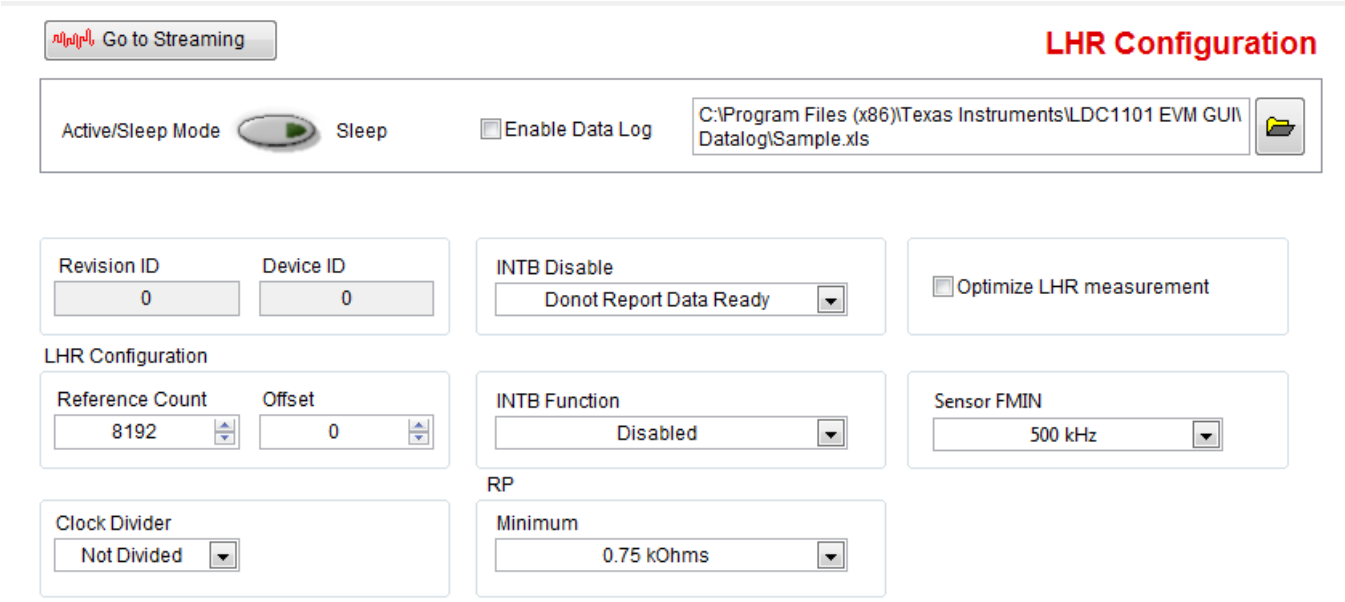

Figure 3-16. LDC1101EVM LHR Configuration

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The GUI controls provide the following functions:

LHR Configuration Controls

Control	Function	Recommended LDC1101 Setting	LDC1101 Register Field
RP Minimum	Sets the maximum current drive.	4kΩ	RP_MIN
	For higher loss coils, or if there is a larger amount of conductive material in the vicinity of the sensor, this setting may need to be decreased.		
	If the Optimize LHR measurement is set, then only the RP_MIN setting is used to control sensor signal amplitude.		
Optimize LHR measurement	Disables R_P measurement sensor modulation. This can improve L measurement accuracy.	Enabled	D_CONFIG + ALT_CONFIG
Reference Count	Set the LHR mode reference count – which is the number of reference clock cycles used to measure the sensor frequency. The higher this number, the higher the resolution of the frequency, although the measurement will take longer.	>1000	LHR_REF_COUNT
Offset	Sets the LHR mode offset count – this value is subtracted off of the measurement.	0	LHR_OFFSET
Clock Divider	Set LHR Sensor Divider. Only necessary when $f_{SENSOR} > f_{REFERENCE}$.	Not divided	SENSOR_DIV
	This control is included only to provide comprehensive configuration control, as the LDC1101EVM Reference frequency of 12MHz is greater than the maximum sensor frequency of 10MHz.		
Reference Frequency Source	Used to bring LDC1101 out of shutdown.	Normal	SHUTDOWN
	This control is included only to provide comprehensive configuration control and is not necessary for EVM functionality.		
INTB Disable	Set INTB reporting.	Do Not Report DRDY	INTB_FUNC
	This control is included only to provide comprehensive configuration control and is not necessary for EVM functionality.		

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3.10 Datalogging Conversion Results

The LDC1101EVM GUI can save conversion results to a file for later evaluation with other applications. To start saving data, simply check the “Enable Data Log” check box – a window will pop-up asking for the location to save the file. While the default extension is an “xls” file, the save format is tab-delimitated ASCII text. If the file is opened in Excel, Excel may issue a warning that the file is corrupt, but it will still properly open the output file.

To stop saving, simply un-check the “Enable Data Log” check box.

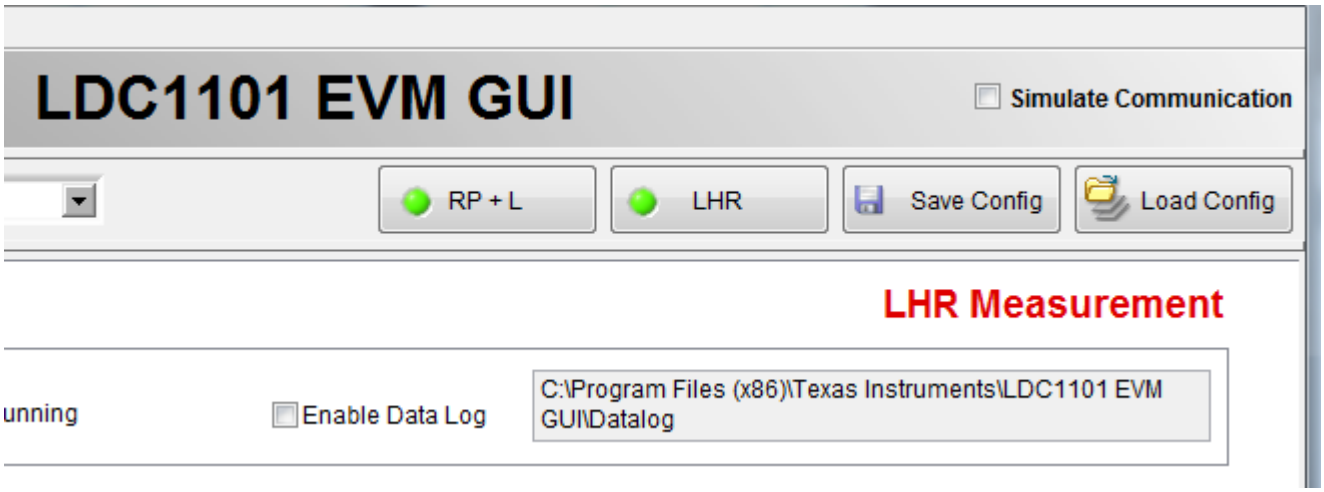

Figure 3-17. Datalogging

The file data structure is formatted as columns of data, with a header at the beginning of the file which indicates the column data. The columns are separated by tabs.

```
Time Stamp    RP Raw Code    RP Min    Rp Max    RP (Ohms)    Fref(Hz)    C(pF)    L count    L
calculated (uH)
    Fref(Hz)    C(pF)    Offset    LHR Count    LHR calculated (uH)

11/17/2014 11:35 AM    0    0    0    0    0    0    0    0    12000000.0    330.0    0
5219578    5.507225

11/17/2014 11:35 AM    0    0    0    0    0    0    0    0    12000000.0    330.0    0
5219578    5.507225

11/17/2014 11:35 AM    0    0    0    0    0    0    0    0    12000000.0    330.0    0
4846751    6.387078
```

3.11 Configuration Saving and Loading

The Save Config and Load Config buttons enable saving the programmed register settings. After configuring the register settings to the desired values (which is the same as setting the configuration controls to the desired settings), simply press the Save Config Button. Enter a filename for the save file. The file data is formatted as ASCII text.

To retrieve the configuration at a later time (e.g. after restarting the GUI), press the Load Config button and select the desired configuration file.

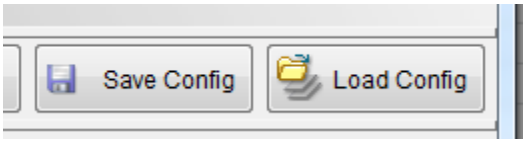

Figure 3-18. Save Config and Load Config Buttons

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3.12 Plot Display Controls and Options

Right-clicking on a plot opens the plot control options, as shown in Figure 3-19 below.

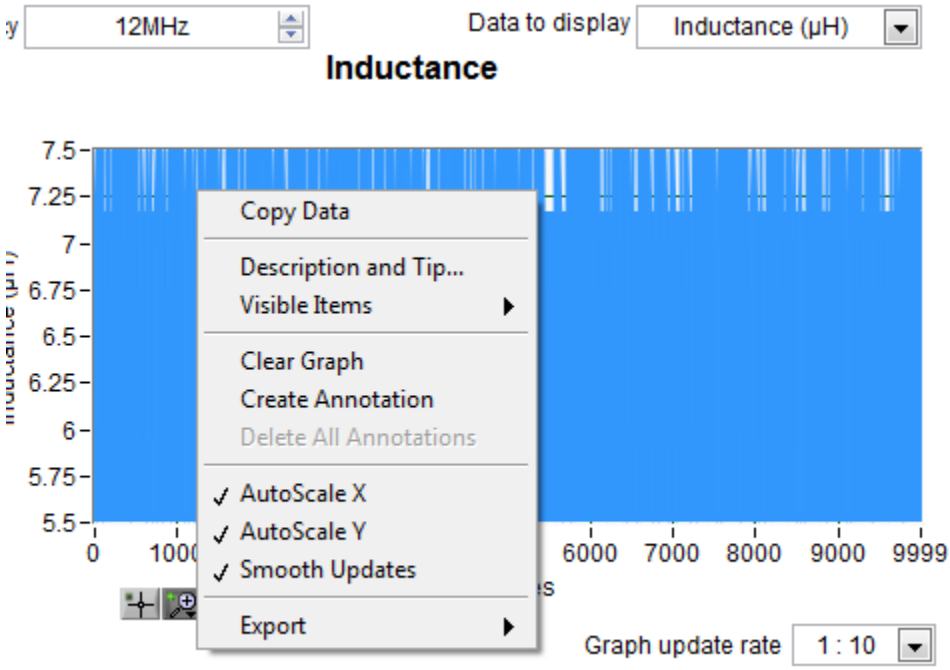

Figure 3-19. Graph Right-Click Menu

3.12.1 AutoScale

The graph can automatically scale the Y axis to only show range of data variation.

3.12.2 Graph Data Export

Plotted data currently shown on the Graph can be exported as an image file, as clipboard data or Excel data. If the data is exported to Excel, then the data will be inserted into a temporary workbook. Clipboard data is exported as ascii text. Both clipboard data and Excel data will have a header at the top, and a maximum of 10k samples of data available.

Note that this feature is independent of the Datalogging functionality described in Section 3.10.

3.12.3 Graph Update

To the bottom right of the plot is the Graph Update rate setting. If the graph rate is updating too quickly, change the update rate to slow down the graph. For example, selecting the 1:10 rate setting will reduce the plotting speed by a factor of 10x.

3.13 R_P Apps Calculator Page

This page is used to calculate appropriate settings for the RPMIN, RPMAX, C1, C2, R1, and R2 LDC1101 settings for a sensor. Setting these parameters are necessary for optimal R_P measurements. The LDC1101EVM does not need to be connected to determine the appropriate settings for a sensor.

Use of the Apps Calculator is simple:

1. Enter the C_{SENSOR}, L_{SENSOR}, and the sensor R_S.
2. Select the largest value possible for C1 and C2; if the settings are not recommended, the bar underneath the control will turn red.

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3. The L variation is used to compensate for target interaction with the sensor. If the target movement causes a maximum shift in inductance of 20%, then enter (1-20%), or 0.8 into the Lvariation field.
4. Adjust the RPvariation – this factor is used to compensate for eddy current losses. This factor is generally quite small and should be 1.02 or less, as the majority of the R_P shift with target position is due to the sensor frequency shifts.

Once a setup is configured, if an LDC1101EVM is connected, press the Update Registers button to write the appropriate values to the LDC1101 registers.

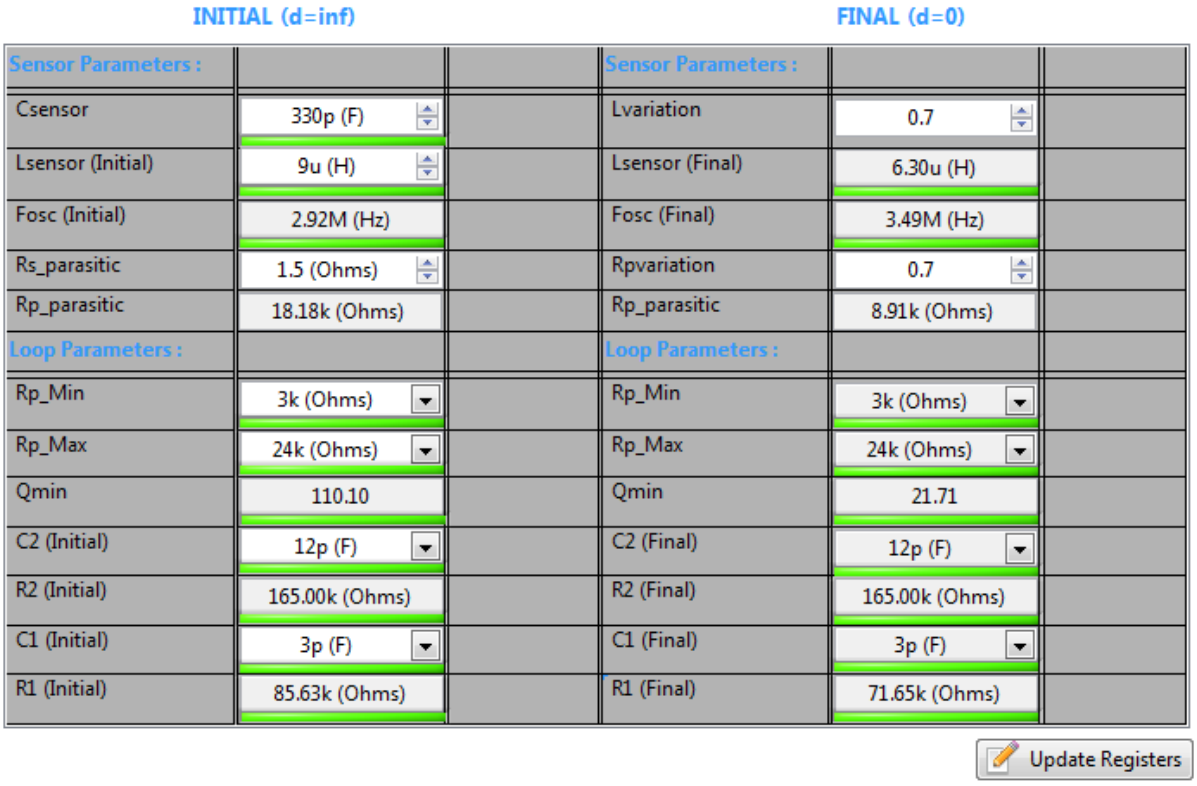

Figure 3-20. Apps Calculator to Configure R_P Measurements

3.14 Direct Register Access Page

If desired, the LDC1101 registers can be viewed and directly modified on the Register Map page of the GUI. The register names, addresses, and current values are displayed in a table format in the middle of the window, and the Write register or Read Register allow for direct manipulation of the registers. Care should be taken to ensure that any write commands are correct and are not writing any incorrect values into the reserved fields.

To set a register, first select the desired register, and then fill in the desired hex value into the Write Data field. Once the data is entered, press the “Write Register” button to update the selected register.

The current configuration can be saved by pressing the “Save Config” button to store the configuration, and the “Load Config” button will restore a previously saved configuration. The files can be read by an ASCII file editor.

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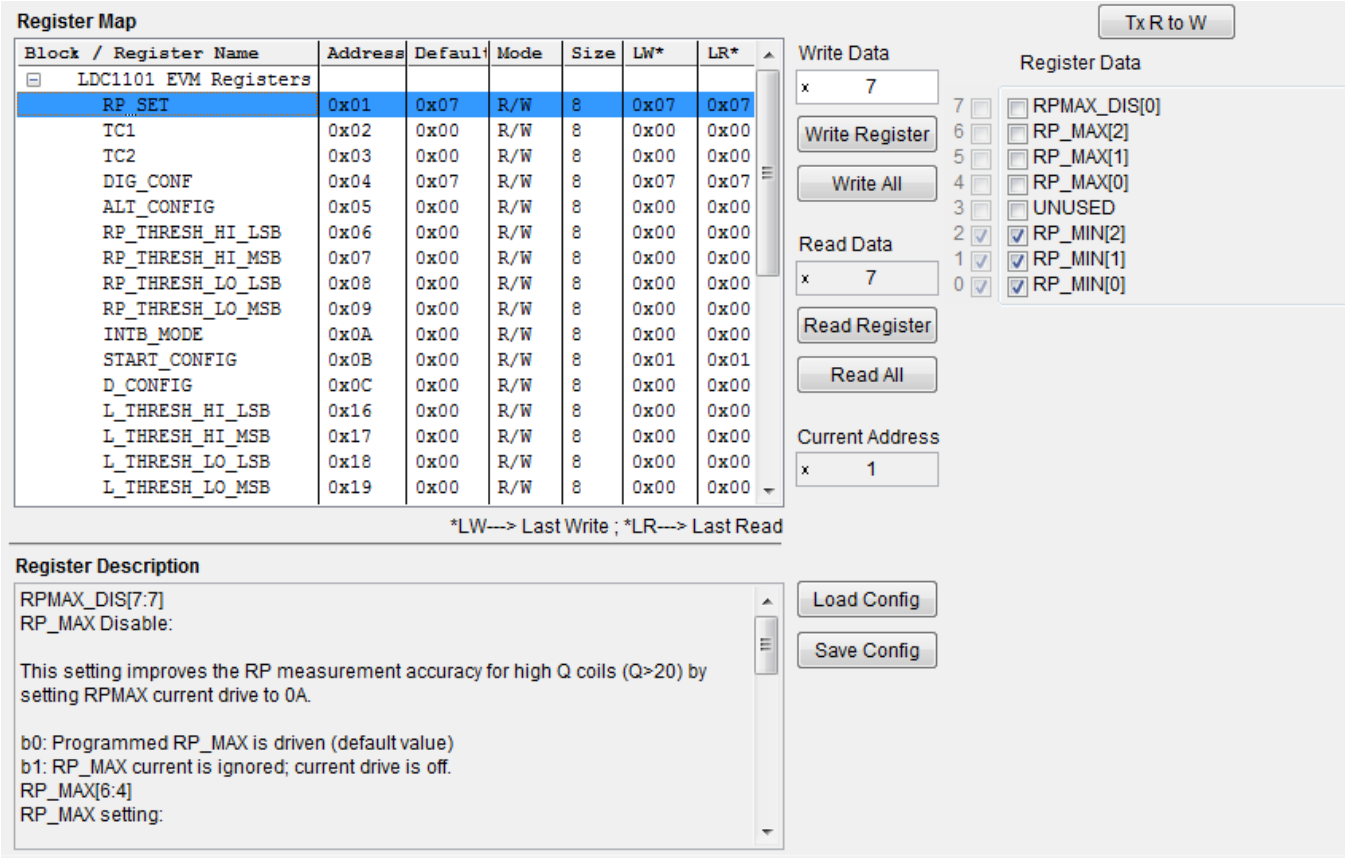

Figure 3-21. LDC1101 Control Software: Register Map Page

In the Register Map table, all of the LDC1101 registers are listed, along with the address, default setting, the Last Written value (LW column), and the Last Read value (LR column).

At the bottom left of the Register Map page, the Register Description section of the page provides information on each field in the register.

To the right of the Register Map table are the register read and write controls. Enter a desired Hex value to program the register value, or click on the desired fields farther to the right. Press the Write Register button to update the LDC1101 with the new value. The LW column in the Register table for the selected register will update to reflect the new value written.

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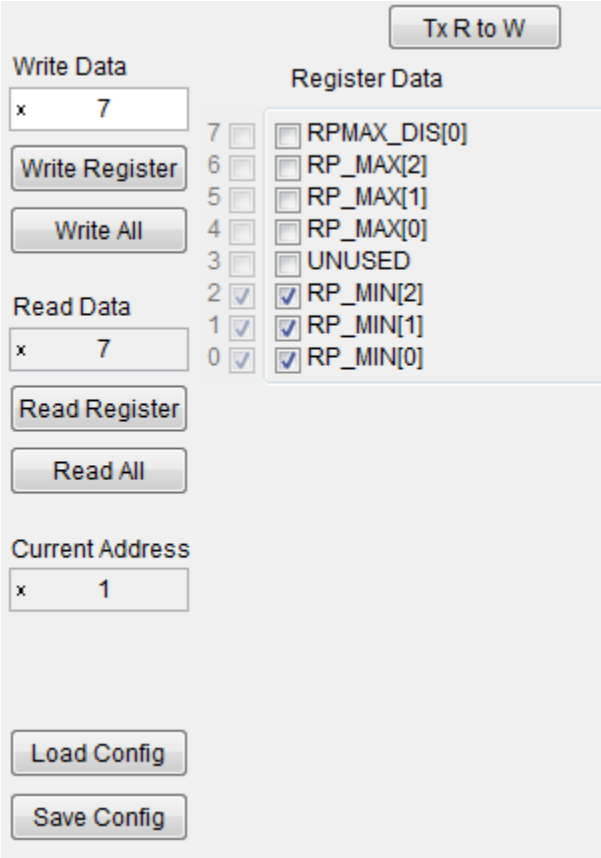

Figure 3-22. Register Read/Write Controls

3.15 EVM FW Protocol

The EVM communicates with the PC using a Com port interface running on USB. Interfacing the LDC1101EVM with PC based tools which can manage Com port communications is feasible. Setting a data rate of 115200 baud, 8 data bits, 1 stop bit with no parity and no flow control are recommended com port settings. Note that the EVM returns values in binary format and not ASCII. For example, the EVM may return the value of 0x00, which is not printable as an ASCII character.

Example: Setting Register 0x31 to 0x6B:

First, take the set Register command, 0x02, as ASCII characters ‘0’ and ‘2’ in array positions 0 and 1. Append the register address, 0x31, as ‘3’ and ‘1’ into positions 2 and 3, followed by the write data, 0x6B, formatted as ‘6’ and ‘B’ into positions 4 and 5.

The resulting string “02316B”, followed by a carriage return, then a line feed.

The EVM response is an array of 8bit integers:

Position	0	1	2	3	4	5	6	7
Value	0x00	0x6B	0x00	0x00	0x00	0x00	0x00	0x00

Where [00] corresponds to a return value of 0x00 and is not a printable ASCII character. The desired return value is in position 1 (starting count from 0), and is the byte value of 0x6B, which appears as “k”, when displayed in an ASCII interface.

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FW Protocol

Command	Command Value (Hex)	Parameters	Return Value
SPI Byte Write	0x02	2,3: SPI Address	1: Data Byte write confirmation
		4,5: SPI Data byte	
SPI Byte Read	0x03	2,3: SPI Address	4: Data Byte read back
Enable BSL	0x04	none	none
Stream Convert data	0x06	2,3: SPI Address	4kbyte integer array. Refer to Table 3-1 for structure.
		SPI Address 0x20: Stream RP+L conversion results	
		SPI Address 0x38: Stream LHR conversion results	
Stop Conversion Stream	0x07		
Read FW Version	0x09	none	6,7,8,9: FW version

Table 3-1. Streaming Data Structure

Position	RP+L Streaming	LHR Streaming
0	Contents of Register 0x20 (RP_STATUS)	Contents of Register 0x3B (LHR_STATUS)
1	Contents of Register 0x22 (RP_DATA_MSB)	Contents of Register 0x3A (LHR_DATA_MSB)
2	Contents of Register 0x21 (RP_DATA_LSB)	Contents of Register 0x39 (LHR_DATA_MID)
3	Contents of Register 0x24 (L_DATA_MSB)	Contents of Register 0x38 (LHR_DATA_LSB)
4	Contents of Register 0x23 (L_DATA_LSB)	0x5A
5	0x5A	Sample Index
6	Sample Index	0x5A
7	0x5A	0x5A

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EVM Design - Board Layout

Layer Usage

Layer	Functionality
Top	Signals, Components, and ground-fill
Mid-layer 1	Ground
Mid-layer 2	Signals and section transition routing
Bottom	MSP430 Power and optional components

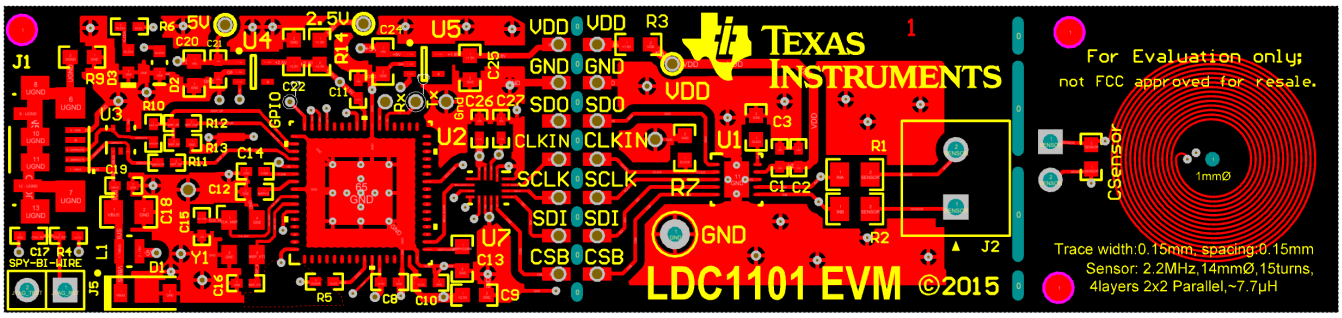

Figure 4-1. Top Layer Routing

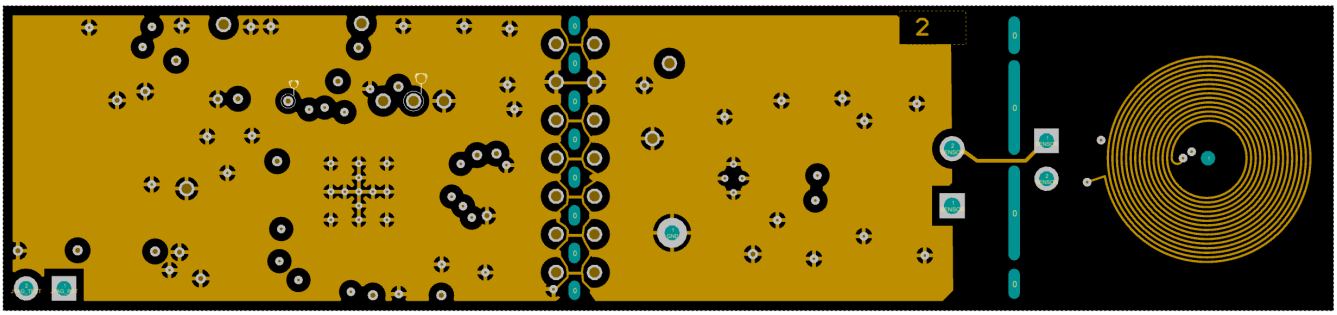

Figure 4-2. Mid-Layer 1 Routing

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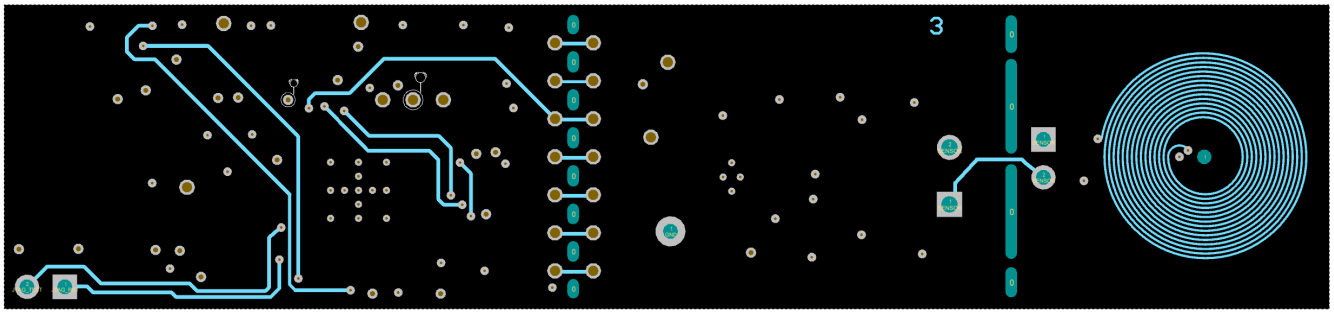

Figure 4-3. Mid-Layer 2 Routing

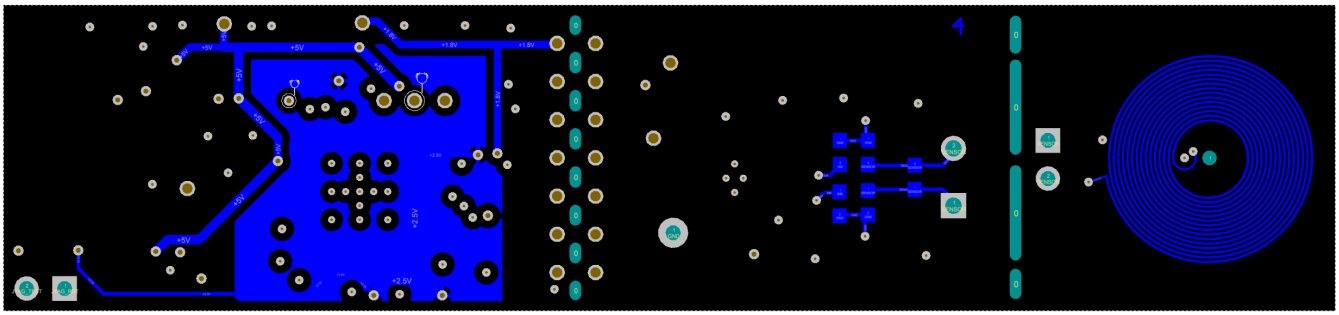

Figure 4-4. Bottom Layer Routing

EVM Design - Schematic

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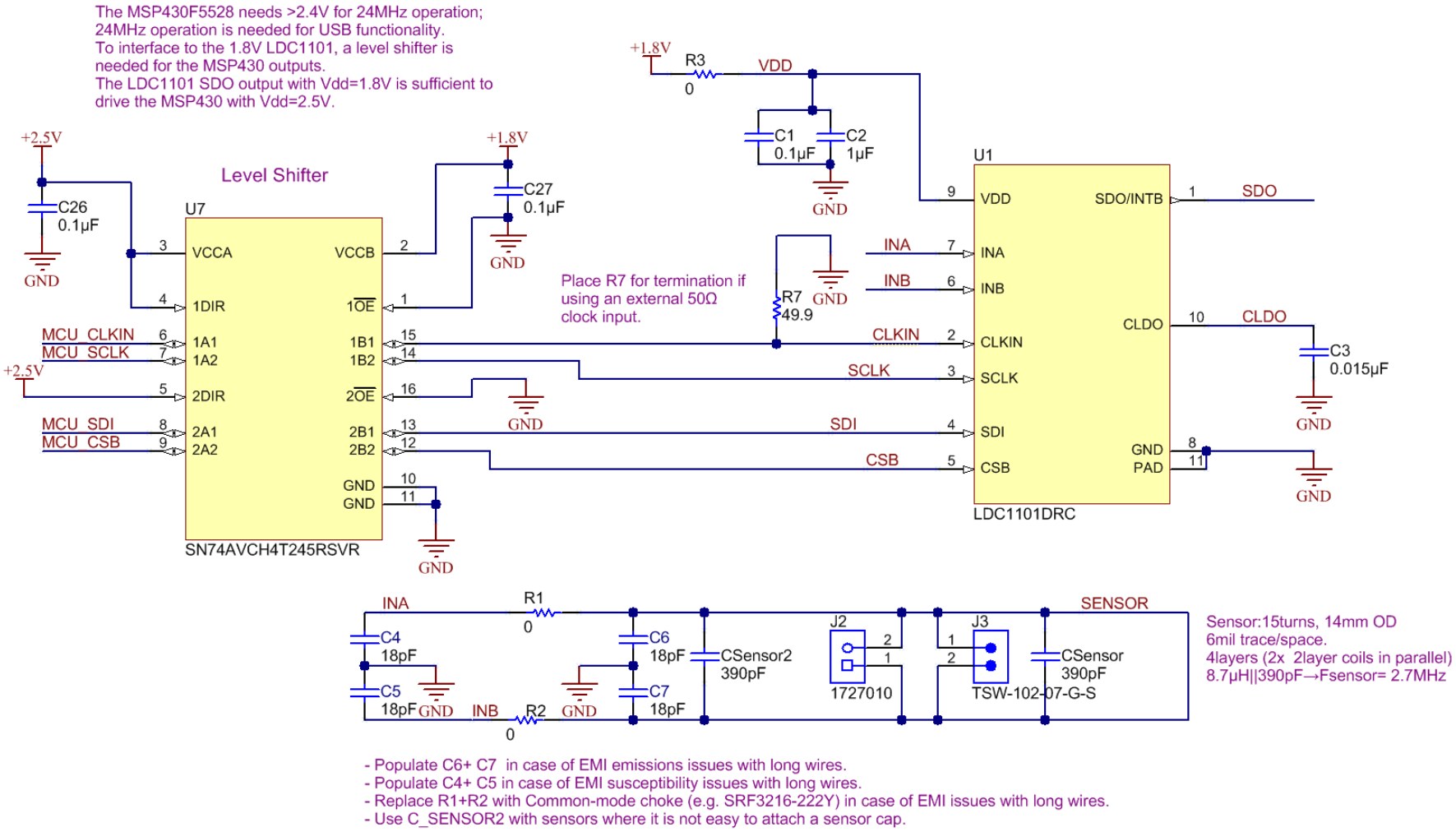

Figure 5-1. LDC1101, Sensor, and Level Shifter Schematic

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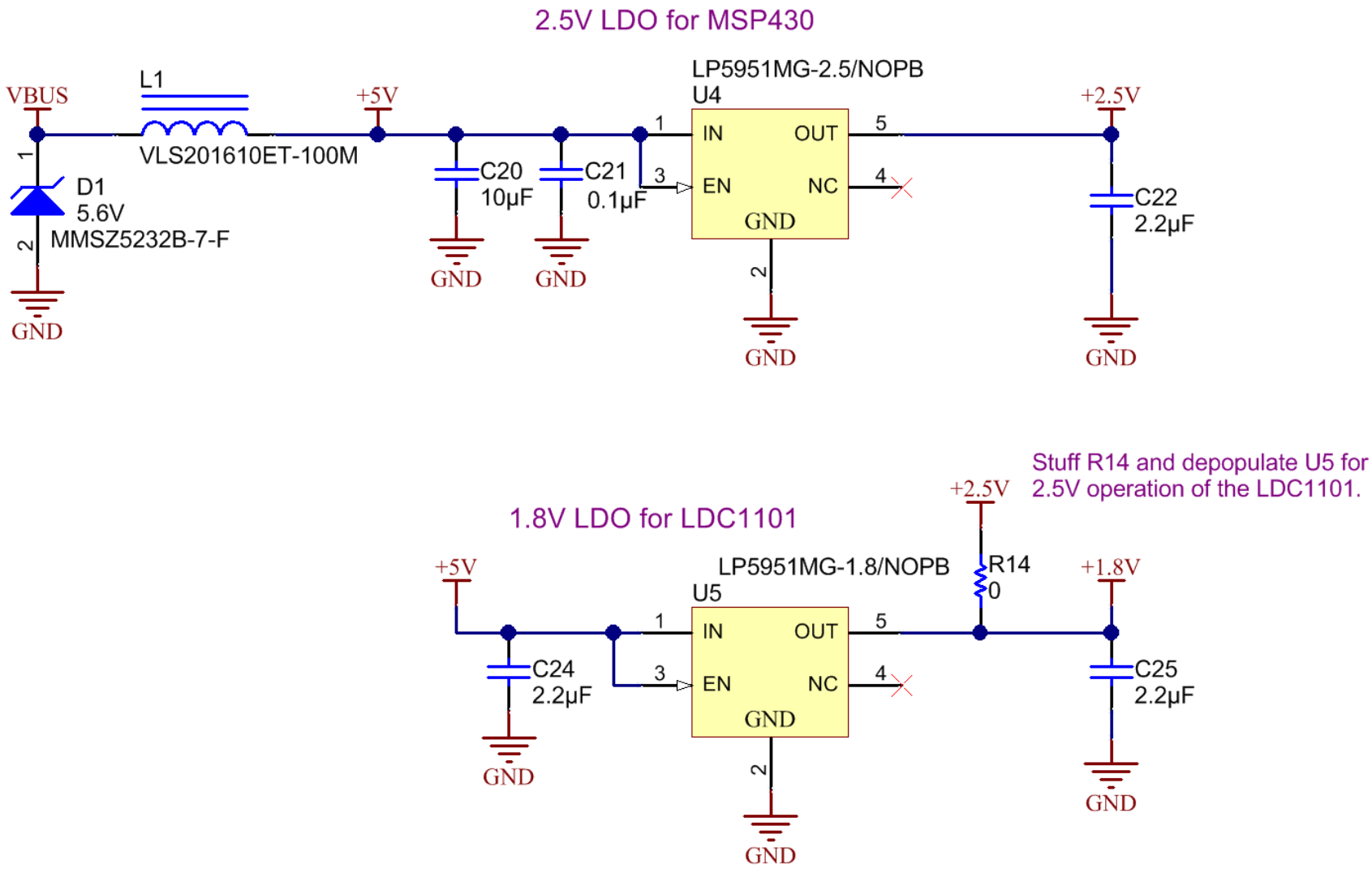

Figure 5-2. Power Conditioning Schematic

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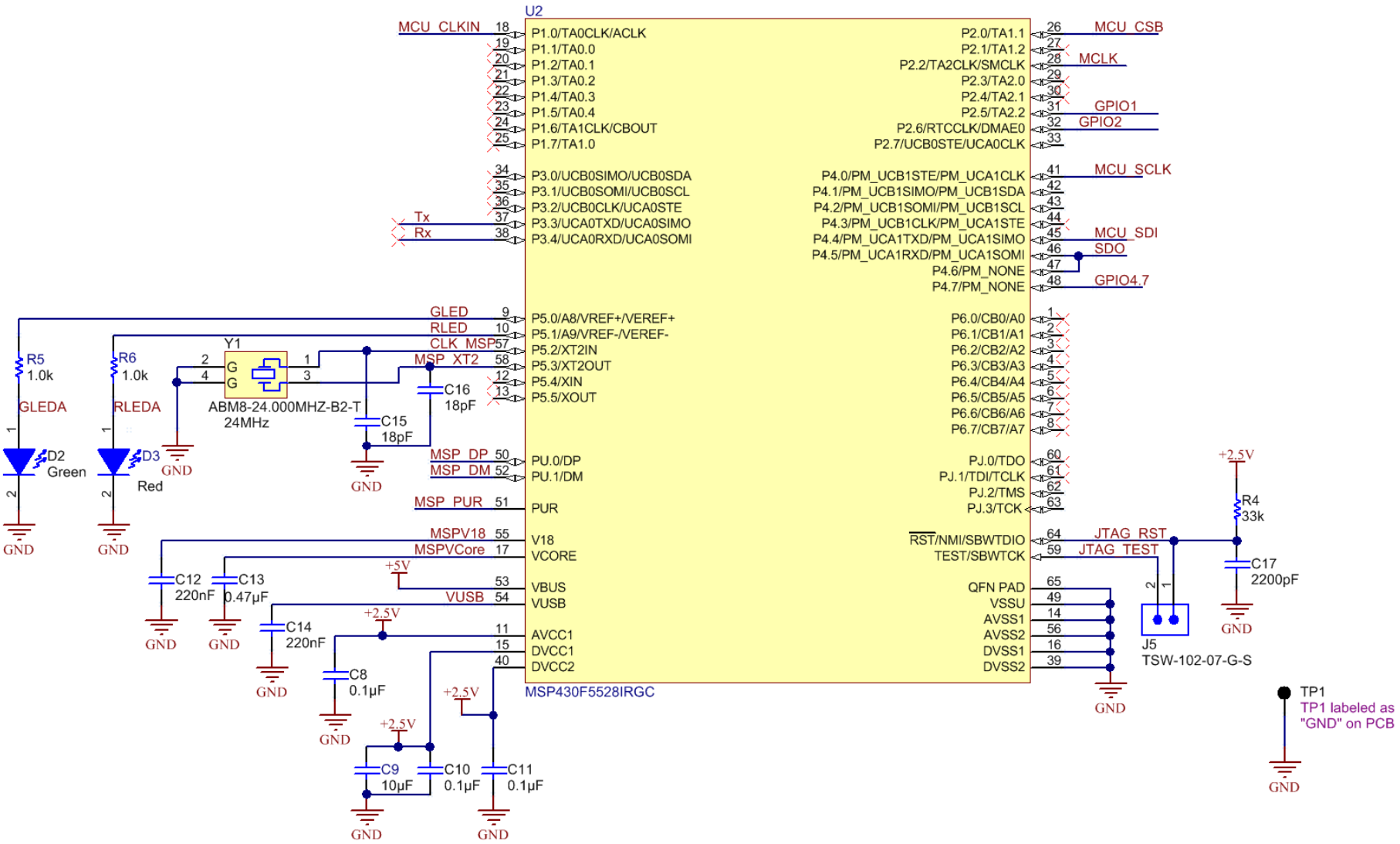

Figure 5-3. MCU Schematic

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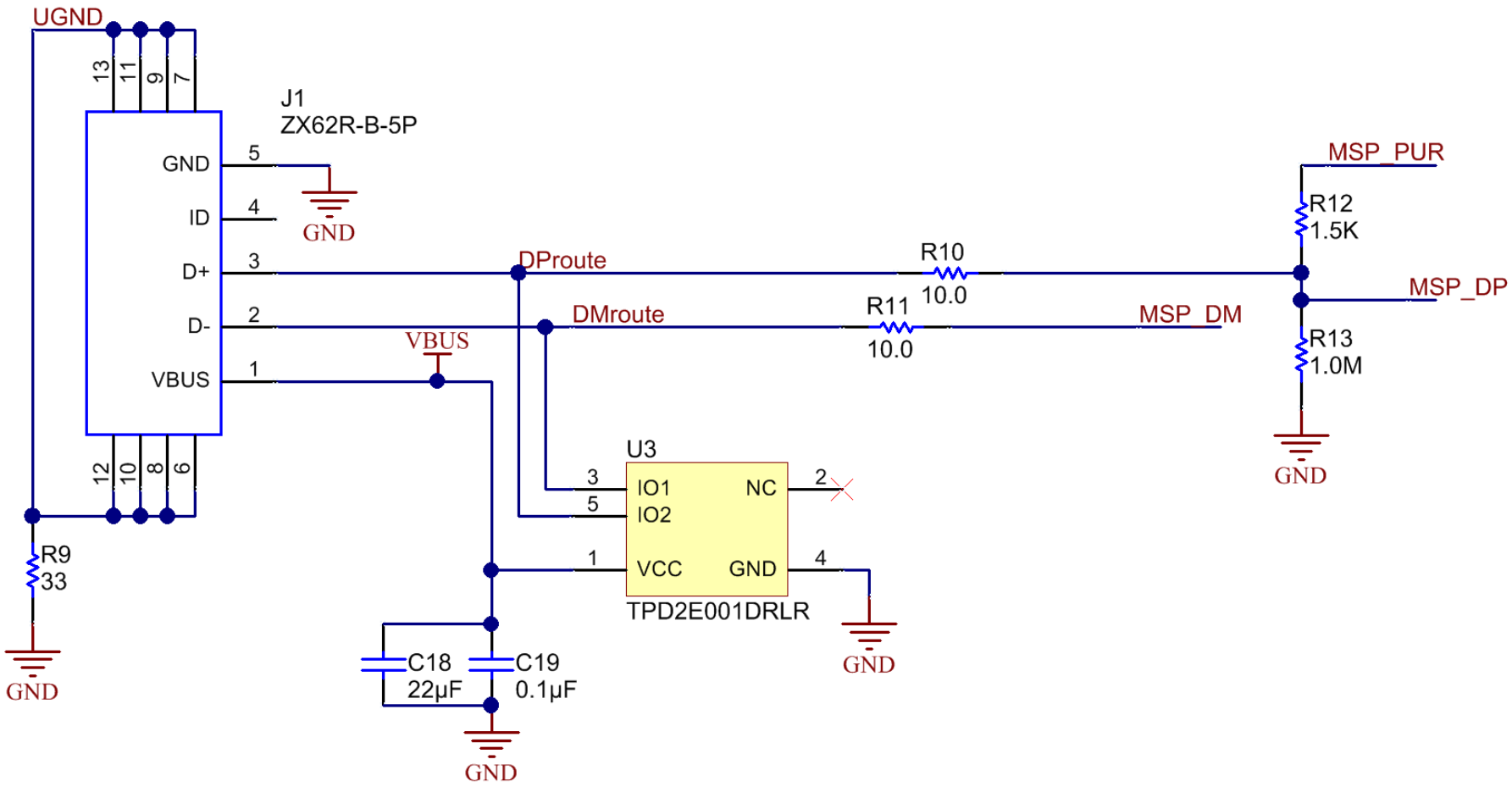

Figure 5-4. USB Connection Schematic

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EVM Bill of Materials

Item #	Designator	Part Number	Manufacturer	Description
1	!PCB1	SV601159	Any	Printed Circuit Board
2	C1, C8, C10, C11, C19, C21, C26, C27	C1005X7R1H104K050BB	TDK	CAP, CERM, 0.1 µF, 50 V, +/- 10%, X7R, 0402
3	C12, C14	C1005X7R1A224K050BB	TDK Corporation	CAP, CERM, 220nF, 10V, 10%, X7R, 0402
4	C13	C0603C474K8RACTU	Kemet	CAP, CERM, 0.47uF, 10V, +/-10%, X7R, 0603
5	C15, C16	GRM1555C1H180JA01D	MuRata	CAP, CERM, 18 pF, 50 V, +/- 5%, C0G/NP0, 0402
6	C17	C1005X7R1H222K	TDK	CAP, CERM, 2200 pF, 50 V, +/- 10%, X7R, 0402
7	C18	C2012X5R1C226K125AC	TDK	CAP, CERM, 22uF, 16V, +/-10%, X5R, 0805
8	C2	GRM155R61A105KE15D	MuRata	CAP, CERM, 1uF, 10V, +/-10%, X5R, 0402
9	C22, C24, C25	C0603C225K8PACTU	Kemet	CAP, CERM, 2.2uF, 10V, +/-10%, X5R, 0603
10	C3	C0603C153J3GACTU	Kemet	CAP, CERM, 0.015 µF, 25 V, +/- 5%, ,NP0 0603
11	C4, C5, C6, C7	GRM1885C2A180JA01D	MuRata	CAP, CERM, 18pF, 100V, +/-5%, C0G/NP0, 0603
12	C9, C20	C1608X5R1A106M	TDK	CAP, CERM, 10uF, 10V, +/-20%, X5R, 0603, CAP, CERM, 10 µF, 10 V, +/- 20%, X5R, 0603
13	Csensor, Csensor2	CC0603FRNPO9BN391	Yageo America	CAP, CERM, 390 pF, 50 V, +/- 1%, C0G/NP0, 0603
14	D1	MMSZ5232B-7-F	Diodes Inc.	Diode, Zener, 5.6V, 500mW, SOD-123
15	D2	LG L29K-G2J1-24-Z	OSRAM	LED, Green, SMD
16	D3	SML-LX0603SRW-TR	Lumex	LED, Super Red, SMD
17	J1	ZX62R-B-5P	Hirose Electric Co. Ltd.	Connector, Receptacle, Micro-USB Type B, SMT
18	J2	1727010	Phoenix Contact	Conn Term Block, 2POS, 3.81mm, TH
19	J3, J5	TSW-102-07-G-S	Samtec, Inc.	Header, TH, 100mil, 2x1, Gold plated, 230 mil above insulator
20	L1	VLS201610ET-100M	TDK	Inductor, Shielded, Ferrite, 10 µH, 0.4 A, 1.38 ohm, SMD
21	LBL1	THT-14-423-10	Brady	Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll
22	R1, R2	CRCW08050000Z0EA	Vishay-Dale	RES, 0 ohm, 5%, 0.125W, 0805
23	R10, R11	CRCW040210R0FKED	Vishay-Dale	RES, 10.0, 1%, 0.063 W, 0402
24	R12	ERJ-2GEJ152X	Panasonic	RES, 1.5k ohm, 5%, 0.10W, 0402
25	R13	CRCW04021M00JNED	Vishay-Dale	RES, 1.0 M, 5%, 0.063 W, 0402
26	R14	CRCW06030000Z0EA	Vishay-Dale	RES, 0 ohm, 5%, 0.1W, 0603
27	R3	CRCW06030000Z0EA	Vishay-Dale	RES, 0 ohm, 5%, 0.1W, 0603
28	R4	CRCW040233K0JNED	Vishay-Dale	RES, 33k ohm, 5%, 0.063W, 0402
29	R5, R6	CRCW04021K00JNED	Vishay-Dale	RES, 1.0k ohm, 5%, 0.063W, 0402
30	R7	RT0603BRD0749R9L	Yageo America	RES, 49.9, 0.1%, 0.1 W, 0603
31	R9	CRCW060333R0JNEA	Vishay-Dale	RES, 33 ohm, 5%, 0.1W, 0603
32	TP1	5001	Keystone	Test Point, Miniature, Black, TH
33	U1	LDC1101DRC	Texas Instruments	1.8V High Resolution Inductance to Digital Converter, DRC0010J
34	U2	MSP430F5528IRGC	Texas Instruments	Mixed Signal MicroController, RGC0064B

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Item #	Designator	Part Number	Manufacturer	Description
36	U3	TPD2E001DRLR	Texas Instruments	Low-Capacitance + / - 15 kV ESD-Protection Array for High-Speed Data Interfaces, 2 Channels, -40 to +85 degC, 5-pin SOT (DRL), Green (RoHS & no Sb/Br)
37	U4	LP5951MG-2.5/NOPB	Texas Instruments	Micropower, 150mA Low-Dropout CMOS Voltage Regulator, 5-pin SC-70, Pb-Free
38	U5	LP5951MG-1.8/NOPB	Texas Instruments	Micropower, 150mA Low-Dropout CMOS Voltage Regulator, 5-pin SC-70, Pb-Free
39	U7	SN74AVCH4T245RSVR	Texas Instruments	4-Bit Dual-Supply Bus Transceiver with Configurable Voltage Translation and 3-State Outputs, RSV0016A
40	Y1	ABM8-24.000MHZ-B2-T	Abracon Corportation	Crystal, 24.000MHz, 18pF, SMD

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Revision History

DATE	REVISION	NOTES
May 2015	*	Initial release.

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STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

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   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms and conditions that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms and conditions do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for any defects that are caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 *Regulatory Notices:*

   3.1 *United States*

      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

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

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      CAUTION

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

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

      FCC Interference Statement for Class A EVM devices

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

FCC Interference Statement for Class B EVM devices

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

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

3.2 *Canada*

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

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

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

Concerning EVMs Including Detachable Antennas:

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

Concernant les EVMs avec antennes détachables

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

3.3 *Japan*

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

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

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

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

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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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4 *EVM Use Restrictions and Warnings:*

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

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

4.3 *Safety-Related Warnings and Restrictions:*

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

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

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

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

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