LDC1000/LDC1001/LDC1041/LDC1051 Evaluation Module

User's Guide



Literature Number: SNAU150B September 2013–Revised November 2019



LDC1000/LDC1001/LDC1041/LDC1051 Evaluation Module

1.1 Overview

The LDC10xx Evaluation Module is designed to provide an example LC tank and coil structure application which interfaces to a host computer. The module can be used independently of the GUI by the on-board embedded LED, which demonstrates threshold detection.



Figure 1-1. Evaluation Module

The EVM includes an example PCB sensor which is a 2 layer, 23 turn, 14mm diameter inductor with a 100pF 1% NP0 capacitor connected in parallel to form an LC tank.

The EVM is perforated at two locations to provide the option to interface to various system configurations. The first perforation, between the coil and the LDC10xx, can be used to snap off the PCB coil and connect a custom coil. The second perforation is between the LDC10xx and the MSP430, and provides the option to connect the LDC10xx and the sensor to a different system or to use multiple sensors in one system for prototyping.



Figure 1-2. LDC1000+Sensor

When the evaluation module first powers up from the USB port, it will flash a series of green and red LED lights to indicate self-test. When the self-test is finished, the green LED indicates the status of the LDC10xx INTB pin. When the INTB pin is asserted, the green LED is lit. By default, INTB is configured for threshold detection.

1.2 Sensing Solutions EVM GUI

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The Sensing Solutions EVM GUI provides direct device register access, user-friendly configuration, and data streaming.



1.2.1 System Requirements

The host machine is required for device configuration and data streaming. The following steps are necessary to prepare the EVM for the GUI:

- · The GUI and EVM driver must be installed on a host computer
- The EVM must be connected to a full speed USB port (USB 1.0 or above)

The Sensing Solutions EVM GUI supports the following operating systems (both 32-bit and 64-bit):

- Windows XP
- Windows 7
- Windows 8 and 8.1
- Windows 10

1.2.2 Installation Instructions

The Sensing Solutions GUI and EVM driver installer is packaged in a zip file. Follow these steps to install the software:

- 1. Download the software ZIP file from the EVM tool page
- 2. Extract the downloaded ZIP file
- 3. Run the included executable
- 4. If prompted by the User Account Control about making changes to the computer, click "Yes"

2	Do yo chang	u want to allow Jes to this comp	the following program to make uter?
		Program name: Verified publisher: File origin:	SensingSolutionsGUI-1.8.8-windows-instal Texas Instruments, Inc. Hard drive on this computer
🕑 si	how <u>d</u> eta	ils	Yes No

Figure 1-3. User Account Control Prompt

5. After the setup wizard starts, click "Next"

3



👽 Setup	
	Setup - Sensing Solutions EVM GUI
	Welcome to the Sensing Solutions EVM GUI Setup Wizard.
	< Back Next > Cancel

Figure 1-4. Software Installer Wizard

6. Read the license agreement, select "I accept the agreement", and click "Next"

🗣 Setup	
License Agreement	
Please read the following Lic agreement before continuin	ense Agreement. You must accept the terms of this g with the installation.
Source and Binary Code	Internal Use License Agreement
IMPORTANT PLEASE CARE WHICH IS LEGALLY BINDI WHETHER YOU ACCEPT AND READ AND AGREE UNLESS: YOUR OWN BENEFIT AND P BOUND BY THESE TERMS;	FULLY READ THE FOLLOWING LICENSE AGREEMENT, NG. AFTER YOU READ IT, YOU WILL BE ASKED AGREE TO ITS TERMS. DO NOT CLICK I HAVE (1) YOU WILL USE THE LICENSED MATERIALS FOR ERSONALLY ACCEPT, AGREE TO AND INTEND TO BE OR (2) YOU ARE AUTHORIZED TO. AND INTEND TO
Do vou accept this license?	I accept the agreement
	I do not accept the agreement
BitRock Installer	
	< Back Next > Cancel

Figure 1-5. Software Installer License Agreement

4



5

7. Use the preselected installation directory and click "Next"

🗣 Setup			
Installation Directory			
Please specify the directory where Sensing Solutions EVM GUI will be installed.			
Installation Directory C:\ti\Sensing Solutions EVM	GUI-1.8.8		
BitRock Installer			
	Back Next > Cancel		

Figure 1-6. Software Installation Directory

8. Start the installation by clicking "Next"



[#] Setup		
Ready to Install		
Setup is now ready to begin	installing Sensing Solutions	EVM GUI on your computer.
tRock Installer		
	< Bac	ck Next > Cancel

Figure 1-7. Software Installer Ready

9. Wait for the installation to complete



Figure 1-8. Software Installer In Progress



10. When the "Device Driver Installation Wizard" appears, click "Next" to install the EVM driver



Figure 1-9. Device Driver Installer Wizard

11. Wait for the driver installation to complete



The drivers are now installing	
Please wait while the	e drivers install. This may take some time to complete.

Figure 1-10. Device Driver Installer In Progress

12. After the driver installation is completed, click "Finish"





Figure 1-11. Device Driver Installer Completed

13. Click "Finish" to complete the installation

Setup	
	Completing the Sensing Solutions EVM GUI Setup Wizard
	Setup has finished installing Sensing Solutions EVM GUI on your computer.
	< Back Finish Cancel





1.2.3 Starting the GUI

Follow these steps to start the GUI:

- 1. Select the Windows start menu
- 2. Select "All programs"
- 3. Select "Texas Instruments"
- 4. Select "Sensing Solutions EVM GUI"
- 5. Click "Sensing Solutions EVM GUI"
- 6. Splash screen will appear for at least two seconds

OneUI: Server	
	Consing Colutions
	Sensing Solutions
	EVM GUI Tool
	TEXAS INSTRUMENTS
	Copyright 2015. Texas Instruments Incorporated. All rights reserved.

Figure 1-13. Splash Screen

7. After the splash screen is displayed the main window will open



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0 📓	neUl Application	۲.
	MENU Sensing Solutions EVM GUI v1.8.8	
	Introduction to Inductive Sensing	
	Inductive sensing is a highly reliable solution for detecting the position of conductive materials using a simple wire wound coil, PCB coil, or spring. By configuring the coil and target shape, inductive sensing can be applied to many different applications that require proximity measurement, rotational and linear position sensing, as well as simple event counting.	
	Overall reliability is improved and system cost is reduced with the integration of multiple channels making this an attractive solution for metal buttons, motor position, bill counting, lens position, and many other applications.	
	Introduction to Capacitive Sensing	
	Capacitive sensing is a high-resolution, low-cost contactless sensing technique that can be applied to a variety of applications such as liquid level sensing, proximity sensing, gesture recognition, ice/rain detection and collision avoidance.	
	The sensor in a capacitive sensing system is any conductor, such as copper on PCB, conductive ink or a piece of metal, allowing for low cost and highly flexible system design. This conductor acts as a proximity sensor or liquid level sensor depending on the use case.	
	Introduction to Humidity Sensing	
	Humidity affects many properties of air, and of materials in contact with air. Water vapor is a key agent in both weather and climate, and it is an important atmospheric greenhouse gas. Humidity measurements are used wherever there is a need to prevent condensation, corrosion, mold, warping or other spoilage of products. This is highly relevant for foods, pharmaceuticals, chemicals, fuels, wood, paper, and many other products. Air-conditioning systems in buildings often control humidity, and significant energy goes into cooling the air to remove water vapor. Humidity measurements are necessary to maintain comfortable environmental conditions. An accurate humidity sensor can work in synergy with heating and cooling systems to reduce a building energy footprint.	
	Benefits of TI technology and the FDC2x14 and FDC2x12 Families	
	Not connected SSP EVM disconnected TEXAS INSTRUMENTS	*

Figure 1-14. Introduction Page

1.2.4 Navigating the GUI

To navigate to different pages of the GUI follow these steps:

1. Click "Menu" in the upper left corner



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S OneUI Application	<u>د</u>
MENU Sensing Solutions EVM GUI v1.8.8	
Introduction to Inductive Sensing	4
Inductive sensing is a highly reliable solution for detecting the position of conductive materials using a simple wire wound coil, PCB coil, or spring. By configuring the coil and target shape, inductive sensing can be applied to many different applications that require proximity measurement, rotational and linear position sensing, as well as simple event counting.	
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Introduction to Humidity Sensing	
Humidity affects many properties of air, and of materials in contact with air. Water vapor is a key agent in both weather and climate, and it is an important atmospheric greenhouse gas. Humidity measurements are used wherever there is a need to prevent condensation, corrosion, mold, warping or other spoilage of products. This is highly relevant for foods, pharmaceuticals, chemicals, fuels, wood, paper, and many other products. Air-conditioning systems in buildings often control humidity, and significant energy goes into cooling the air to remove water vapor. Humidity measurements are necessary to maintain comfortable environmental conditions. An accurate humidity sensor can work in synergy with heating and cooling systems to reduce a building energy footprint.	
Benefits of TI technology and the FDC2x14 and FDC2x12 Families	
Not connected SSP EVM disconnected	*

Figure 1-15. Mouse Hovered Over Menu Button

2. Select the desired page from the menu shown on the left

Search Constant Const	
	Sensing Solutions EVM GUI v1.8.8
Introduction	ing
Device	ble solution for detecting the position of conductive materials using a simple wire wound coil, PCB coil, or spring. By configuring the coil and target shape, inductive different applications that require proximity measurement, rotational and linear position sensing, as well as simple event counting.
EVM	system cost is reduced with the integration of multiple channels making this an attractive solution for metal buttons, motor position, bill counting, lens position, and
🖋 Registers	
Configuration	nsing
🛃 Data Streaming	lution, low-cost contactless sensing technique that can be applied to a variety of applications such as liquid level sensing, proximity sensing, gesture recognition, oidance.
1 Firmware	g system is any conductor, such as copper on PCB, conductive ink or a piece of metal, allowing for low cost and highly flexible system design. This conductor acts as sensor depending on the use case.
	ing
	of air, and of materials in contact with air. Water vapor is a key agent in both weather and climate, and it is an important atmospheric greenhouse gas. Humidity er there is a need to prevent condensation, corrosion, mold, warping or other spoilage of products. This is highly relevant for foods, pharmaceuticals, chemicals, her products. Air-conditioning systems in buildings often control humidity, and significant energy goes into cooling the air to remove water vapor. Humidity maintain comfortable environmental conditions. An accurate humidity sensor can work in synergy with heating and cooling systems to reduce a building energy
	the FDC2x14 and FDC2x12 Families
Not connected SSP EVM	disconnected



1.2.5 Connecting the EVM

Follow these steps to connect the EVM to the GUI:

- 1. Attach the EVM to the computer via USB
- 2. The GUI always shows the connection status on the bottom left corner of the GUI

Sa On	eUI Application	×
	MENU Sensing Solutions EVM GUI v1.8.8	
	Introduction to Inductive Sensing	+
	Inductive sensing is a highly reliable solution for detecting the position of conductive materials using a simple wire wound coil, PCB coil, or spring. By configuring the coil and target shape, inductive sensing can be applied to many different applications that require proximity measurement, rotational and linear position sensing, as well as simple event counting.	
	Overall reliability is improved and system cost is reduced with the integration of multiple channels making this an attractive solution for metal buttons, motor position, bill counting, lens position, and many other applications.	
	Introduction to Capacitive Sensing	
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	The sensor in a capacitive sensing system is any conductor, such as copper on PCB, conductive ink or a piece of metal, allowing for low cost and highly flexible system design. This conductor acts as a proximity sensor or liquid level sensor depending on the use case.	- 0
	Introduction to Humidity Sensing	
Humidity affects many properties of air, and of materials in contact with air. Water vapor is a key agent in both weather and climate, and it is an important atmospheric greenhouse gas. H measurements are used wherever there is a need to prevent condensation, corrosion, mold, warping or other spoilage of products. This is highly relevant for foods, pharmaceuticals, che fuels, wood, paper, and many other products. Air-conditioning systems in buildings often control humidity, and significant energy goes into cooling the air to remove water vapor. Humidity measurements are necessary to maintain comfortable environmental conditions. An accurate humidity sensor can work in synergy with heating and cooling systems to reduce a building of footprint.		
	Benefits of TI technology and the FDC2x14 and FDC2x12 Families	
	 EMI resistant solution: Narrow band architecture eliminates unwanted noise and interferences enabling EMI-resistant proximity sensor and gesture recognition applications. Fast sensor excitation rate with wide frequency range: Allows sensing of all liquids including conductive ones such as detergent, soap, and ink and allows flexibility in sensor design. 	•
0 (Connected SSP EVM connected - LDC1000	S

Figure 1-17. EVM Connected to GUI

1.2.6 Configuring the EVM Using the Register Page

The register page allows users to control the device directly with the register values. The user may also use this page to read the currect register values on the device.

1.2.6.1 Automatically Update GUI Register Values Using Auto-Read

Autoread will periodically request the register values on the device. Click the dropdown box next to "Auto Read" to select the update interval.



CneUI Application										_ 0 _ X
	IL									v1.8.8
Registers										
Auto Read Off Off Every 1/4 sec Every 1 sec Every 1 sec Every 1 sec Every 5 sec Every 5 sec Every 1 se										
Register	Address	Current Value				В	lits			
			7	6	5	4	3	2	1	0
DEVICE_ID	0x00	0x80	1	0	0	0	0	0	0	0
RP_MAX	0x01	0x0e	0	0	0	0	1	1	1	0
RP_MIN	0x02	0x3a	0	0	1	1	1	0	1	0
WATCHDOG_TIMER_FREQ	0x03	0x94	1	0	0	1	0	1	0	0
LDC_CONFIG	0x04	0x17	0	0	0	1	0	1	1	1
CLOCK_CONFIG	0x05	0x02	0	0	0	0	0	0	1	0
COMPARATOR_THRESH_HIGH_LSB	0x06	0x50	0	1	0	1	0	0	0	0
COMPARATOR_THRESH_HIGH_MSB	0x07	0x14	0	0	0	1	0	1	0	0
COMPARATOR_THRESH_LOW_LSB	0x08	0xc0	1	1	0	0	0	0	0	0
COMPARATOR_THRESH_LOW_MSB	0x09	0x12	0	0	0	1	0	0	1	0
INTB_PIN_CONFIG	0x0A	0x04	0	0	0	0	0	1	0	0
POWER_CONFIG	0x0B	0x01	0	0	0	0	0	0	0	1
STATUS	0x20	0x60	0	1	1	0	0	0	0	0
Connected Wrote registers: RP_MAX							Į į	Texas	s Inst	RUMENTS

Figure 1-18. Selecting Auto-Read Interval on Register Page

1.2.6.2 Manually Update Device Register Values

There are two methods to change register values: update the entire register value or change a single bit within the register. The recommended update mode is always "Immediate" and not "Deferred". To update register values, follow these steps.

1. Double-click the current value of the register that needs to be changed. The text will turn into an editable text box

MENU Sensing Se	olutions EVM GUI								V	1.8.8
Write Register 9 Read Register Update Mo	de: Immediate 🔻									
egister	Address	Current Value				B	lits			
			7	6	5	4	3	2	1	0
EVICE_ID	0x00	0x80	1	0	0	0	0	0	0	0
P_MAX	0x01	0x0e <u>I</u>	0	0	0	0	1	1	1	0
P_MIN	0x02	0x3a	0	0	1	1	1	0	1	0
ATCHDOG_TIMER_FREQ	0x03	0x94	1	0	0	1	0	1	0	0
DC_CONFIG	0x04	0x17	0	0	0	1	0	1	1	1
LOCK_CONFIG	0x05	0x02	0	0	0	0	0	0	1	0
OMPARATOR_THRESH_HIGH_LSB	0x06	0x50	0	1	0	1	0	0	0	0
OMPARATOR_THRESH_HIGH_MSB	0x07	0x14	0	0	0	1	0	1	0	0
OMPARATOR_THRESH_LOW_LSB	0x08	0xc0	1	1	0	0	0	0	0	0
OMPARATOR_THRESH_LOW_MSB	0x09	0x12	0	0	0	1	0	0	1	0
ITB_PIN_CONFIG	0x0A	0x04	0	0	0	0	0	1	0	0
OWER_CONFIG	0x0B	0x01	0	0	0	0	0	0	0	1
TATUS	0x20	0x60	0	1	1	0	0	0	0	0
ROXIMITY_LSB	0x21	0xd8	1	1	0	1	1	0	0	0
ROXIMITY_MSB	0x22	0x22	0	0	1	0	0	0	1	0
REQ_COUNT_LSB	0x23	0x48	0	1	0	0	1	0	0	0
REQ_COUNT_MID_BYTE	0x24	0x0d	0	0	0	0	1	1	0	1
REQ_COUNT_MSB	0x25	0x0	0	0	0	0	0	0	0	0

Figure 1-19. Selecting a Register's Current Value for Editting on Register Page

2. Type the new hexadecimal value into the box and click enter. The text box changes to normal text and the GUI will send a command to the EVM to update the device register

To change individual bit values rather that entire register values follow these steps.

1. Hover the mouse over the desired bit to change



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MENU Sensing Solution	ns EVM GUI									v1.8.8
Write Register Kead Register Update Mode: Imm	ediate 🔻									
Register	Address	Current Value				E	lits			
			7	6	5	4	3	2	1	0
DEVICE_ID	0x00	0x80	1	0	0	0	0	0	0	0
RP_MAX	0x01	0x8e	1	0	0	0	1	1	1	0
RP_MIN	0x02	0x3a	CD0	0	1	1	1	0	1	0
WATCHDOG_TIMER_FREQ	0x03	0x94	1	0	0	1	0	1	0	0
LDC_CONFIG	0x04	0x17	0	0	0	1	0	1	1	1
CLOCK_CONFIG	0x05	0x02	0	0	0	0	0	0	1	0
COMPARATOR_THRESH_HIGH_LSB	0x06	0x50	0	1	0	1	0	0	0	0
COMPARATOR_THRESH_HIGH_MSB	0x07	0x14	0	0	0	1	0	1	0	0
COMPARATOR_THRESH_LOW_LSB	0x08	0xc0	1	1	0	0	0	0	0	0
COMPARATOR_THRESH_LOW_MSB	0x09	0x12	0	0	0	1	Ö	0	1	0
INTB_PIN_CONFIG	0x0A	0x04	0	0	0	0	0	1	0	0
POWER_CONFIG	0x0B	0x01	0	0	0	0	0	0	0	1
STATUS	0x20	0x60	0	1	1	0	0	0	0	0
PROXIMITY_LSB	0x21	0xd8	1	1	0	1	1	0	0	0
PROXIMITY_MSB	0x22	0x22	0	0	1	0	0	0	1	0
FREQ_COUNT_LSB	0x23	0x48	0	1	0	0	1	0	0	0
FREQ_COUNT_MID_BYTE	0x24	0x0d	0	0	0	0	1	1	0	1
FREQ_COUNT_MSB	0x25	0x0	0	0	0	0	0	0	0	0

Figure 1-20. Hovering Mouse Over Register Bit Value on Register Page

2. Double-click the bit to toggle its value and the register's current value will update automatically

1.2.6.3 Reading Register Values without Auto-Read

To read register values follow these steps.

1. Select the register to update by clicking any column of the register row in the table

neUI Application										
MENU Sensing Solutions	S EVM GUI									V1.8.8
Write Register Y Read Register Update Mode: Immed	liate 🔻									
Register	Address	Current Value				E	lits			
			7	6	5	4	3	2	1	0
DEVICE_ID	0x00	0x80	1	0	0	0	0	0	0	0
RP_MAX	0x01	0x0e	0	0	0	0	1	1	1	0
RP_MIN	0x02	0x3a	0	0	1	1	1	0	1	0
WATCHDOG_TIMER_FREQ	0x03	0x94	1	0	0	1	0	1	0	0
LDC_CONFIG	0x04	0x17	0	0	0	1	0	1	1	1
CLOCK_CONFIG	0x05	0x02	0	0	0	0	0	0	1	0
COMPARATOR_THRESH_HIGH_LSB	0x06	0x50	0	1	0	1	0	0	0	0
COMPARATOR_THRESH_HIGH_MSB	0x07	0x14	0	0	0	1	0	1	0	0
COMPARATOR_THRESH_LOW_LSB	0x08	0xc0	1	1	0	0	0	0	0	0
COMPARATOR_THRESH_LOW_MSB	0x09	0x12	0	0	0	1	Ö	0	1	0
INTB_PIN_CONFIG	0x0A	0x04	0	0	0	0	0	1	0	0
POWER_CONFIG	0x0 <mark>B</mark>	0x01	0	0	0	0	0	0	0	1
STATUS	0x20	0x60	0	1	1	0	0	0	0	0
PROXIMITY_LSB	0x21	0xd8	1	1	0	1	1	0	0	0
	0x22	0x22	0	0	1	0	0	0	1	0
FREQ_COUNT_LSB	0x23	0x48	0	1	0	0	1	0	0	0
FREQ_COUNT_MID_BYTE	0x24	0x0d	0	0	0	0	1	1	0	1
FREQ_COUNT_MSB	0x25	0x0	0	0	0	0	0	0	0	0
Connected Read register undefined							- it	TEXAS	s Inst	RUMEN

Figure 1-21. Selecting a Register on Register Page

2. Click the "Read Register" button to update the selected register's current value and bit values in the table

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S On	eUI Application										_ D _X
	MENU Sensing Solutions EVM G	UI									v1.8.8
[Write Register Read Register Update Mode: Immediate										-
	Register	Address	Current Value				В	its			
				7	6	5	4	3	2	1	0
	DEVICE_ID	0x00	0x80	1	0	0	0	0	0	0	0
0.00	RP_MAX	0x01	0x0e	0	0	0	0	1	1	1	0
0008	RP_MIN	0x02	0x3a	0	0	1	1	1	0	1	0
	WATCHDOG_TIMER_FREQ	0x03	0x94	1	0	0	1	0	1	0	0
8	LDC_CONFIG	0x04	0x17	0	0	0	1	0	1	1	1
	CLOCK_CONFIG	0x05	0x02	0	0	0	0	0	0	1	0
3	COMPARATOR_THRESH_HIGH_LSB	0x06	0x50	0	1	0	1	0	0	0	0
	COMPARATOR_THRESH_HIGH_MSB	0x07	0x14	0	0	0	1	0	1	0	0
ŝ	COMPARATOR_THRESH_LOW_LSB	0x08	0xc0	1	1	0	0	0	0	0	0
	COMPARATOR_THRESH_LOW_MSB	0x09	0x12	0	0	0	1	0	0	1	0
	INTB_PIN_CONFIG	0x0A	0x04	0	0	0	0	0	1	0	0
	POWER_CONFIG	0x0B	0x01	0	0	0	0	0	0	0	1
	STATUS	0x20	0x60	0	1	1	0	0	0	0	0
	PROXIMITY_LSB	0x21	0xd8	1	1	0	1	1	0	0	0
	PROXIMITY_MSB	0x22	0x80	1	0	0	0	0	0	0	0
	FREQ_COUNT_LSB	0x23	0x48	0	1	0	0	1	0	0	0
	FREQ_COUNT_MID_BYTE	0x24	0x0d	0	0	0	0	1	1	0	1
	FREQ_COUNT_MSB	0x25	0x0	0	0	0	0	0	0	0	0
•	Connected Read register undefined							Į.	Texas	s Inst	RUMENTS



1.2.6.4 Saving Device Configurations

To save the current register settings of the device follow these steps.

1. Click the button immediately right to the "Auto-Read" selection dropdown



MENU Sensing Solu	tions EVM GUI									v1.8.8
egisters										
Auto Read Off										
Write Register Vpdate Mode:	Address	Current Value				F	lite			
(Vegister	Autos	Current value	7	6	5	4	3	2	1	0
DEVICE_ID	0x00	0x80	1	0	0	0	0	0	0	0
RP_MAX	0x01	0x0e	0	0	0	0	1	1	1	0
RP_MIN	0x02	0x3a	0	0	1	1	1	0	1	0
WATCHDOG_TIMER_FREQ	0x03	0x94	1	0	0	1	0	1	0	0
LDC_CONFIG	0x04	0x17	0	0	0	1	0	1	1	1
CLOCK_CONFIG	0x05	0x02	0	0	0	0	0	0	1	0
COMPARATOR_THRESH_HIGH_LSB	0x06	0x50	0	1	0	1	0	0	0	0
COMPARATOR_THRESH_HIGH_MSB	0x07	0x14	0	0	0	1	0	1	0	0
COMPARATOR_THRESH_LOW_LSB	0x08	0xc0	1	1	0	0	0	0	0	0
COMPARATOR_THRESH_LOW_MSB	0x09	0x12	0	0	0	1	0	0	1	0
INTE PIN CONFIG	0x0A	0x04	0	0	0	0	0	1	0	0
		1200200	0	0	0	0	0	0	0	1
POWER_CONFIG	0x0B	0x01	U				-	-		

Figure 1-23. Save Register Values to File on Register Page

2. Choose a name for the JSON file and the directory to save it within. Then click "Save"

1.2.6.5 Loading Previously Saved Configurations

- To load previously saved register settings from a JSON file follow these steps.
- 1. Click the button furthest right from the "Auto-Read" selection dropdown



OneUI Application										
MENU Sensing Solution	S EVM GUI									71.8.8
Registers										
Auto Read Off										
Write Register Y Read Register Update Mode:	diate •	20000		_	_		24-	_	_	_
Register	Address	Current value	7	6	5	4	3	2	1	0
DEVICE_ID	0x00	0x80	1	0	0	0	0	0	0	0
RP_MAX	0x01	0x0e	0	0	0	0	1	1	1	0
RP_MIN	0x02	0x3a	0	0	1	1	1	0	1	0
WATCHDOG_TIMER_FREQ	0x03	0x94	1	0	0	1	0	1	0	0
LDC_CONFIG	0x04	0x17	0	0	0	1	0	1	1	1
CLOCK_CONFIG	0x05	0x02	0	0	0	0	0	0	1	0
COMPARATOR_THRESH_HIGH_LSB	0x06	0x50	0	1	0	1	0	0	0	0
COMPARATOR_THRESH_HIGH_MSB	0x07	0x14	0	0	0	1	0	1	0	0
COMPARATOR_THRESH_LOW_LSB	0x08	0xc0	1	1	0	0	0	0	0	0
COMPARATOR_THRESH_LOW_MSB	0x09	0x12	0	0	0	1	0	0	1	0
INTB_PIN_CONFIG	0x0A	0x04	0	0	0	0	0	1	0	0
POWER_CONFIG	0x0B	0x01	0	0	0	0	0	0	0	1
STATUS	0x20	0x60	0	1	1	0	0	0	0	0
Connected Registers exported successfully.							j j	TEXA	s Inst	RUMEN

Figure 1-24. Loading Previously Saved Register Values from File on Register Page

2. Select the JSON file with the desired settings and click "Open"

1.2.7 Configuring the EVM Using the Configuration Page

The Sensing Solutions GUI is capable on configuring the device more intuitively than the direct register values. The "Configuration" page provides an easy-to-use tool for updating the device configuration and provides additional information about how the device will perform.



MENU Sensing Solutions EVM CUI urrent Status and Measurements tatus Measurements selection of the point o	OneUI Appl	ication							
trant Status and Measurements Measurements Measurements Measurements Proximity Code Rp (kΩ) Frequency Frequency (MHz) Inductance (MHz) Sampling Rate (Hz) ●	ME	NU	Sensing S	Solutions	EVM GU				
tatus Measurements ctive sensor Oscillator Timeout Poximity Code Rp (kΩ) Frequency Frequency Inductance Sampling Rate (H2) a a b	urrent	Status and Measu	rements						
ctive Sensor Oscillator Timeout Proximity Code R _p (KΩ) Frequency Count Inductance (HHz) Sampling Rate (Hz) 	status		Measuremer	nts					
 8811 0.00000 3395 3.619440 19.335589 1767.3 gisters update rate (100ms minimum, use Data Streaming page for faster rates): 500 ms is GUI automatically puts the device in Standby mode before updating any configuration registers ms	Active Mode	Sensor Oscillator Timeout	Proximity Code	R _p (kΩ)	Frequency Count	Frequency (MHz)	Inductance (uH)	Sampling Rate (Hz)	
egisters update rate (100ms minimum, use Data Streaming page for faster rates): 500 ms is GUI automatically puts the device in Standby mode before updating any configuration registers p Configuration P Configuration P Configuration Comparator Thresholds Threshold Proximity Code KΩ Comparator Status Store Current Measurement Low 4800 0.000 Meausered R _p (KΩ) below threshold Set Low Threshold High 5200 0.000 Meausered R _p (KΩ) above threshold Set High Threshold High 5200 0.000 Meausered R _p (KΩ) above threshold Set High Threshold Profigure Inductance Measurements Nock Configuration External Clock Signal on XIN External Clock Signal on XIN Exter	•	۲	8811	0.000000	3395	3.619440	19.335589	1767.3	
ensor Rp Resistance Register Code Threshold Proximity Code kΩ Comparator Status Store Current Measurement dinimum • 58 14 1	Rp Co	nfiguration	o una comparat	Compar	ator Thre	sholds			
Inimum • 58 Low 4800 0.000 • Meausered R _p (kΩ) below threshold Set Low Threshold taximum 83.111 kΩ • 14 High 5200 0.000 • Meausered R _p (kΩ) below threshold Set Low Threshold configure Inductance Measurements • • 0.000 • Meausered R _p (kΩ) above threshold Set High Threshold configuration Sensor Parameters • • Frequency Counter Configuration External Clock Signal on XIN Minimum Sensor Frequency 0.350537 MHz € Enable Frequency Counter (required for inductance measurement Response Time 6144 • parallel Sensor Capacitance 100 pF Response Time 6144 •	Sensor	R _p Resistance	Register Code	Threshold	Proximity	Code kΩ	1	Comparator Status	Store Current Measurement
Itaximum 83.111 kΩ 14 High 5200 0.000 Meausered R _p (kΩ) above threshold Set High Threshold configure Inductance Measurements Sensor Parameters Frequency Counter Configuration External Clock Signal on XIN External Crystal Across XIN/XOUT Minimum Sensor Frequency Parallel Sensor Capacitance 0.350537 100 MHz € Enable Frequency Counter (required for inductance measuremen Response Time €144 ▼	Minimu	m	58	Low	480	0.000) 😑 Meau	sered $R_p(k\Omega)$ below thresh	Set Low Threshold
Sensor Parameters Frequency Counter Configuration External Clock Signal on XIN Minimum Sensor Frequency 0.350537 MHz Enable Frequency Counter (required for inductance measuremen results) External Crystal Across XIN/XOUT 6 Parallel Sensor Capacitance 100 pF Response Time 6144 •	laximu	im 83.111 kΩ 🔻	14	High	520	0.000) 🔴 Meau	sered $R_p(k\Omega)$ above thresh	old Set High Threshold
Sensor Parameters Frequency Counter Configuration External Clock Signal on XIN Minimum Sensor Frequency 0.350537 MHz									
Iock Configuration Sensor Parameters Frequency Counter Configuration External Clock Signal on XIN Minimum Sensor Frequency 0.350537 MHz External Crystal across XIN/XOUT Parallel Sensor Capacitance 100 pF Parallel Sensor Capacitance 100 pF	onfigu	ire Inductance Mea	surements						
External Clock Signal on XIN Minimum Sensor Frequency 0.350537 MHz	lock	Configuration	Sens	sor Paran	neters		Fre	quency Counter Co	onfiguration
External Crystal across XIN/XOUT Parallel Sensor Capacitance 100 pF Response Time 6144 •	Extern	al Clock Signal on XIN	Minim	um Sensor Fre	equency	0.350537	MHz 🕑 En	able Frequency Counter (re	equired for inductance measureme
	Extern Clock/Cn	al Crystal across XIN/>	OUT Paralle	el Sensor Capa	acitance	100	pF Resp	onse Time 6144 🔻	
	Nocio or	star requercy (wriz)							
Connected Registers exported successfully.	Connec	ted Registers	exported successful	ly.					

Figure 1-25. Sensor Properties and Input Adjustments on Configuration Page

1.2.8 Streaming Measurement Data

The Sensing Solutions GUI and EVM provide a tool to capture, display, and log measurement data. The section describes how to use the data measurement tools from the "Data Streaming" page accessible from the GUI menu.

1.2.8.1 Choosing the Graph and Visible Channels

Select the drop down menu on top of the y-axis to choose the graph to display.



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S OneUI Application				
	VM GUI			v1.8.8
Data Streaming: Start Stop			Show Graph Configu	ration (C) Show Statistics (I)
Data Codes Show: PROXIMITY I FREQ_COUNT I			Select	Log File: 📥 C: \data\data.csv
Frequecy (MHz) Inductance (uH)				
0.6				
0.7				
0.4				
0.5				
0.4				
0.8				
0.2				
0.1				
0.0	2 0.4	0.5 0.6	0.7 0.8	,
🔊 FROXIMITY 🔿 FREQ_COUNT				
0				Range: 64
Connected Registers exported successfully.				Texas Instruments

Figure 1-26. Select the Data Graph on Data Streaming Page

To select which channel measurements are displayed in the graph, check or uncheck the available channels shown next to the graph units. Selecting or not selecting the channels only affects the graph and not the data logged to a file. If a channel is not enabled in the Configuration page it will not appear on the Data Streaming page.

1.2.8.2 Logging Data to a File

Follow these steps to log measurement data to a file.

1. Click the button in the upper right under next to "Click to Select Log File"



S OneUI Application								- 0 X
	utions EVM GUI							v1.8.8
Data Streaming: Start Stop					Show Gra	ph Configuration	n (C) Show	Statistics (I)
Data Codes • Show: PROXIMITY @ FREQ_C	COUNT 🗹					Select Log F	File: 🛓 c: \	data\data.csv
1.0-								
0.9								
0.0								
0.7								
0.6								
0.5								
0.4								
0.9								
0.2								
0.1								
0.0	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
ROXIMITY 😡 FREQ_COUNT								980 1024
,								The star of the
Connected Registers exported successfully.							Texas Ins	TRUMENTS

Figure 1-27. Select Log File Button on Data Streaming Page

- 2. Select a file name and directory to save the data to and then click the "Save" button
- 3. Whenever data streaming is running the data for all channels will be logged to this file. The selected file is shown next to the button.

1.2.8.3 Starting and Stopping Data Streaming

To start data streaming click the "Start" button.



Sensing Solutions EVM GUI

Sa OneUI Application _ 0 <u>_ X</u> v1.8.8 MENU Sensing Solutions EVM GUI Data Streaming: Start Stop Show Graph Configuration (C) Show Statistics (I) ▼ Show: PROXIMITY S FREQ_COUNT Data Codes Select Log File: 📥 C:\data\ldc1000_data.csv 1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0.0 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 ROXIMITY 😞 FREQ_COUNT 1024 Range: 64 TEXAS INSTRUMENTS Registers exported successfully. Connected

Figure 1-28. Start Button on Data Streaming Page

To stop data streaming click the "Stop" button.





Figure 1-29. Stop Button on Data Streaming Page

1.2.8.4 Data Statistics

Click the "Show Statistics" button to view the measurement statistics.



Sensing Solutions EVM GUI

_ 🗆 💌 X Sa OneUI Application v1.8.8 MENU Sensing Solutions EVM GUI Data Streaming: Start Stop Show Graph Configuration (C) Show Statistics (▼ Show: PROXIMITY S FREQ_COUNT Data Codes Select Log File: 📥 C:\data\ldc1000_data.csv 9,000 8,500 8,000 7,500 7,000 6,500 6,000 5,500 5,000 4,500 4,000 3,50 3,000 35,820 35,825 35,830 35,835 35,840 35,845 35,850 35,855 35,860 35,865 35,870 35,875 ROXIMITY 😞 FREQ_COUNT 1024 Range: 64 TEXAS INSTRUMENTS Data streaming started Connected

Figure 1-30. Show Statistics Button on Data Streaming Page

Click the "Hide Statistics" button to hide the measurement statistics.



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Texas Instruments

MENU Sensing Solutions EVM GUI	v1.8.8
ata Streaming: Start Stop	Show Graph Configuration (C) Hide Statistics
ata Codes • Show: PROXIMITY @ FREQ_COUNT @	Statistics Select Log File: 🛓 C:\data\ldc1009_data
s, 000 J	Data Series Current Min Max Delta Average Std. Deviation

e, 600	FREQ_COUNT 3399 3399 3400 1 3399.2 0.4
7,500	Decimals 0 0 0 1 1
6,000	
s, 800 5, 000	
5,800 5,000 4,800	
s, seo s, oeo 4, seo a, seo	
5,500 4,500 4,500 4,500 4,500 4,500 4,500 4,500 4,700 4,700 4,700 4,700 4,700 4,700 4,700 4,700 4,700 4,700 4,700 4,700 4,700 4,700 4,500	

Figure 1-31. Hide Statistics Button on Data Streaming Page

1.2.8.5 Configuring the Graph

To configure the graph, click the "Show Graph Configuration" button.



Sensing Solutions EVM GUI

ILNO		Sensi	ng Soluti	ons EVM	GUI								V1.8.8
Streaming: S	tart Stop								5	Show Graph	Configuratior	n (C) Show	v Statistics
Codes •	Show: PRO	KIMITY 🗹	FREQ_COU	NT 🗹						Select	Log File: 🛓	C:\data\ld	c1000_data
9,000 -													
8,500													
8,000													
7,500													
71000													
6,500													
6,000													
5,500													
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3,000-	1 144 () 141 () 144 () 144 () 147 () 148 ()					ar () can () can () can () can () c							
.,	37,095 3	7,100	37,105	37,110	37,115	37,120	37,125	37,130	37,135	37,140	37,145	37,150	37,155
N PROX	IMITY 🚫 FREQ_O	TRUOT											980
													Range: 6

Figure 1-32. Show Graph Configuration Button on Data Streaming Page



Graph Conii	guration			
Display Fram	e Rate		6	5
16.0 ms = 62.	5 Hz			
New Data Sa	mple Rate			
EVM Outp	ut Rate (II	nfinity ms = 0	.0 Hz)	
Add sample	le to grapi	n every	100	ms
Minimum.		0		
Minimum.		0		
Maximum:		100		
Maximum:	Autoscal	100 e & Lock		
Maximum: Autoscale	Autoscal	100 e & Lock		
Maximum: Autoscale Sample Cour	Autoscal	100 e & Lock		
Maximum: Autoscale Sample Cour Display:	Autoscal	100 e & Lock] ≈ 0.000 s		

Figure 1-33. Graph Configuration Button on Data Streaming Page

The configuration window displays the actual frame rate of the graph, the rate at which data is added to the graph, the vertical scaling, and the sample buffer size. The display rate is the rate at which the graph updates on the computer display and is not configurable. It is automatically optimized by the GUI.

The "New Data Sample Rate" allows the user to choose when new data is added to the graph. Selecting "EVM Output Rate" will display data on the graph as fast as is available from the EVM. This should not be confused with the actual sampling rate of the device on the EVM which could be different. The "Add sample to graph every ... ms" will add a new sample to the graph at the specified rate.

The "Verical Scaling" allows the user to either manually set the minimum and maximum values of the yaxis on the graph or use auto-scaling. The "Autoscale & Lock" button scales the graph based on the data of the current display and then locks those vertical scaling settings.

The "Sample Counts" allows the user to specify the number of samples displayed on the graph and the total number of samples stored in the buffer. Please note the buffer size does not affect data logging to a file.

To hide the configuration window, click the "Hide Graph Configuration" button.



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MENU Sensing Solutions EVM GUI	v1.8.8
Data Streaming: Start Stop	Hide Graph Configuration (C) Show Statistics (I)
Data Codes Show: PROXIMITY OFREQ_COUNT O	Graph Configuration Select Log File: C:\data\ldc1000_data.csv Display Frame Rate
87,800 77,500 70,000 68,800 60,000 50,000 50,000 60,000 50,000 50,000 50,000 50,000 50,000 50,000 50,000 50,000 50,000 50,000 50,000	New Data Sample Rate ● EVM Output Rate (3.15 ms = 317.3 Hz) ● Add sample to graph every 50 ms Vertical Scaling Vertical Left Axis (Y1) Minimum: 0 Maximum: 50 ✓ Autoscale Autoscale & Lock Sample Counts Display: 64 ~ 3.200 s Buffer: 1024 ~ 51.200 s
3,000- 37,845 27,850 27,855 27,860 37,865 27,870 27,875 27,880 37,885 SROXIMITY 🚫 FREQ_COUNT	97,890 97,895 97,900 97,905 000 1024 Range 64

Figure 1-34. Hide Graph Configuration Button on Data Streaming Page

1.2.8.6 Navigating the Data Streaming Buffer

The Sensing Solutions EVM GUI stores a buffer of data samples and then displays a subset of those samples in the graph. The data buffer can be navigated using the horizontal slider below the graph. To adjust the samples displayed in the graph, click either the slider on the left or right side of the green bar and drag it closer or further from the other slider. The number of samples displayed is shown between the left and right sliders in the green bar.

31



Figure 1-35. Changing Number of Samples Displayed in Data Graph

By clicking on the green bar sliders and dragging the mouse left or right, the displayed region of buffered LDC data can be adjusted.

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Sensing Solutions EVM GUI



Figure 1-36. Displaying Previous Data Samples on the Data Streaming Page

1.2.9 Updating the EVM Firmware

To upload new firmware to the EVM, navigate to the "Firmware" page from the GUI menu and follow these steps. The images below show uploading the FDC2214 EVM firmware, but the steps are identical for any LDC, FDC, or HDC EVM when using their respective firmware files.

1. Click the button to select a TI-TXT firmware file



Se OneUI Application	
MENU Sensing Solutions EVM GUI	v1.8.8
Firmware Upgrade	
Select TI-TXT firmware File:	
Connected SSP EVM connected - FDC2214	Texas Instruments

Figure 1-37. Select TI-TXT File Button on Firmware Upload Page

2. Select the firmware file and click "Open"



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9							
ganize 🔻 New fold	der				== •		
Favorites	Name	Date modified	Туре	Size			
📕 Conner, Blair	FDC2x14_LDC13xxRevB_LDC16xxRevB_EVM_Firmware_so	11/5/2015 10:01 AM	File folder				
💻 Desktop	HDC10x0_EVM_Firmware_source	11/5/2015 10:01 AM	File folder				
🔄 Recent Places	FDC2x14_LDC13xxRevB_LDC16xxRevB_EVM_Firmware.txt	6/11/2015 3:34 PM	Text Document	101 KB			
📙 UserData	HDC10x0_EVM_Firmware.txt	6/15/2015 2:08 PM	Text Document	93 KB			
GIT_Repositories							
📙 ti							
👃 Downloads							
🔤 Box Sync							
📙 Blair Conner (P)							
Libraries							
Computer							
SDisk (C:)							
₽ P							
Network							
						-	-

Figure 1-38. Selecting TI-TXT Firmware File for Upload to EVM

3. Click the "Upload Firmware" button



	OneUI Application	- • ×
	MENU Sensing Solutions EVM GUI	v1.8.8
-	Firmware Upgrade	
	Select TI-TXT firmware File: 2:\ti\Sensing Solutions EVM GUI-1.8.8\EVM Firmware\FDC2x14_LDC13xxRevB_LDC16xxRevB_EVM_Firmware.txt	
	Upload Firmware	
	Connected SSP EVM connected - FDC2214 TEXAS INS	STRUMENTS

Figure 1-39. Upload Firmware Button on Firmware Upload Page

4. Wait for the firmware to upload. Do NOT disconnect the EVM from the PC at this time! Also note that the GUI will disconnect from the EVM. The upload process should not take more than one minute. If the upload fails or lasts longer than one minute, unplug the EVM and restart the GUI.

Search ConeUI Application		
■ MENU	Sensing Solutions EVM GUI	v1.8.8
Firmware Upgrad	de	
Select TI-TXT firmw	WARE File: 🔹 C:\ti\Sensing Solutions EVM GUI-1.8.8\EVM Firmware\FDC2x14_LDC13xxRevB_LDC16xxRevB_EVM_Firmware.txt	
Wait for upload to	o complete	
<u></u>	Uploading firmware: Please do NOT disconnect the EVMI	
1		
Not connected	SSP EVM disconnected	Iexas Instruments
	Figure 1-40. Firmware Upload in Progress	



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DneUI Application	- • ×
MENU Sensing Solutions EVM GUI	v1.8.8
Firmware Upgrade	
Select TI-TXT firmware File: 2:\ti\Sensing Solutions EVM GUI-1.8.8\EVM Firmware\FDC2x14_LDC13xxRevB_LDC16xxRevB_EVM_Firmware.txt	
Upload Firmware	
Success	
C3	
Not connected Firmware successsfully updated!	RUMENTS

Figure 1-41. Firmware Upload Success



Chapter 2 SNAU150B–September 2013–Revised November 2019

Schematics

2.1 LDC10xx EVM Schematics



Figure 2-1. EVM Layout



Figure 2-2. Top Layer



Figure 2-3. Bottom Layer



Bill of Materials

Designator	Quantity	Description	Manufacturer	Part Number
C1	1	CAP, CERM, 2.2uF, 10V, +/-10%, X5R, 0603	Kemet	C0603C225K8PACTU
C2	1	CAP CER 10UF 10V 10% X5R 0603	TDK Corporation	C1608X5R1A106K080AC
C3, C5, C11, C12, C16, C19	6	CAP CER 0.1UF 16V 5% X7R 0402	Murata Electronics North America	GRM155R71C104JA88D
C4	1	CAP, CERM, 0.01uF, 25V, +/-5%, C0G/NP0, 0603	TDK	C1608C0G1E103J
C6	1	CAP CER 220PF 50V 1% NP0 0402	TDK Corporation	C1005C0G1H221F050BA
C7	1	CAP, CERM, 2200pF, 50V, +/-10%, X7R, 0603	Kemet	C0603X222K5RACTU
C8, C9	2	CAP CER 18PF 100V 5% NP0 0603	MuRata	GRM1885C2A180JA01D
C10	1	CAP, CERM, 220pF, 50V, +/-1%, C0G/NP0, 0603	AVX	06035A221FAT2A
C13, C15	2	CAP, CERM, 1uF, 10V, +/-10%, X5R, 0402	MuRata	GRM155R61A105KE15D
C14	1	CAP CER 0.056UF 16V 5% X7R 0402	Kemet	C0402C563J4RACTU
C17	1	CAP, CERM, 0.47uF, 10V, +/-10%, X7R, 0603	Kemet	C0603C474K8RACTU
C18	1	CAP CER 20PF 50V 5% NP0 0805	Kemet	C0805C200J5GACTU
C_Tank	1	CAP CER 100PF 50V 1% NP0 0603	AVX Corporation	06035A101FAT2A
D1	1	LED SMARTLED GREEN 570NM 0603	OSRAM Opto Semiconductors Inc	LG L29K-G2J1-24-Z
D2	1	LED 660NM SUPER RED DIFF 0603SMD	Lumex Opto/Components Inc	SML-LX0603SRW-TR
D21	1	Diode, Zener, 5.6V, 500mW, SOD-123	Diodes Inc.	MMSZ5232B-7-F
FID1, FID2, FID3	3	Fiducial mark. There is nothing to buy or mount.	N/A	N/A
J1	1	Connector, USB Type A, 4POS R/A, SMD	Molex	48037-2200
L1	1	INDUCTOR POWER 10UH .45A SMD	TDK Corporation	VLS201610ET-100M
R1, R2	2	RES, 33 ohm, 5%, 0.063W, 0402	Vishay-Dale	CRCW040233R0JNED
R5	1	RES, 33k ohm, 5%, 0.063W, 0402	Vishay-Dale	CRCW040233K0JNED
R6, R7	2	RES 1K OHM 1/10W 5% 0402 SMD	Panasonic Electronic Components	ERJ-2GEJ102X
R20	1	RES,1M ohm, 5%, 0.063W, 0402	Yageo	RC0402JR-071ML



Designator	Quantity	Description	Manufacturer	Part Number
R40	1	RES 1.5K OHM 1/16W 5% 0402 SMD	Vishay Dale	CRCW04021K50JNED
U1	1	Micropower 150 mA Low- Noise Ultra Low-Dropout Regulator, 5-pin SOT-23, Pb-Free	Texas Instruments	LP2985AIM5-3.3/NOPB
U2	1	4-CHANNEL ESD- PROTECTION ARRAY FOR HIGH-SPEED DATA INTERFACES, DRY006A	Texas Instruments	TPD4E004DRY
U3	1	MCU	Texas Instruments	MSP430F5528IRGCR
U4	1	Inductance to Digital Converter	Texas instruments	LDC1000
Y1	1	CRYSTAL 24.000MHZ 18PF SMD	Abracon Corporation	ABMM-24.000MHZ-B2-T
J2	0	TERM BLOCK 2POS 3.81MM PCB HORIZ	FCI	20020327-D021B01LF
J4	0	Header, TH, 100mil, 2x1, Gold plated, 230 mil above insulator	Samtec, Inc.	TSW-102-07-G-S



Revision History

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Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Cł	hanges from A Revision (March 2014) to B Revision	Page
•	Added new part number LDC1001	2
•	Updated GUI instructions to v1.8.8	3
•	Updated Choosing the Graph and Visible Channels section	21

Cł	Changes from Original (September 2013) to A Revision Pag				
•	Added new part numbers LDC1041/LDC1051	. 2			
•	Changed Changed Schematic to Vector graphic for better display	37			

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