

# LDC1000 电感数字转换器

## 1 特性

- 无磁体操作
- 亚微米高精度
- 可调节感测范围（通过线圈设计实现）
- 系统成本较低
- 支持远程放置传感器（在恶劣环境中对 LDC 去耦合）
- 高耐用性（通过非接触式操作实现）
- 不易受到环境干扰因素的影响（诸如污垢、灰尘、水、油）
- 电源电压范围（模拟）：4.75V 至 5.25V
- 电源电压范围 (I/O): 1.8V 至 5.25V
- 电源电流（不含 LC 振荡电路）：1.7mA
- $R_p$  分辨率：16 位
- L 分辨率：24 位
- LC 频率范围：5kHz 至 5MHz

## 2 应用

- 位置感测
- 运动感测
- 轮齿计数
- 流量计
- 按钮开关
- 多功能打印机
- 数码照相机
- 医疗设备

## 3 说明

电感感测是一种遥控的、短程感测技术，此项技术能够在灰尘、污垢、油和潮湿环境中实现导体目标的低成本、高分辨率感测，这使得它在恶劣环境中非常可靠。通过使用可在印刷电路板 (PCB) 上被创建为一个感测元件的线圈，LDC1000 可实现超低成本系统解决方案。

电感感测技术可对线性位置或角位置、位移、运动、压缩、振动、金属成分及其他应用进行高精度测量，广泛应用于汽车、消费类产品、计算机、工业、医疗和通信等市场领域。与同类感测技术相比，电感感测的性能更为优异，可靠性和灵活性更高并且系统成本更低。

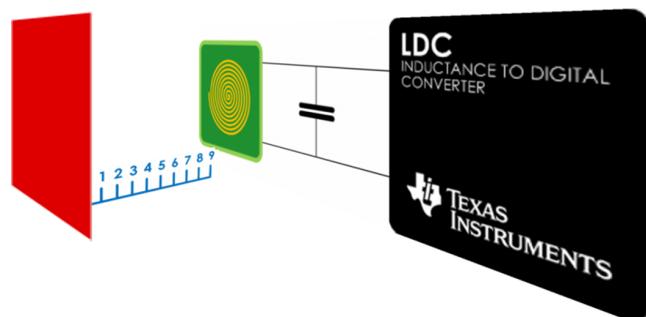
LDC1000 是世界上第一个电感数字转换器，从而在一个低功耗、小封装尺寸解决方案内提供电感感测的优势。此产品采用一个小外形尺寸无引线 (SON)-16 封装，并且提供了几种运行模式。其串行外设接口 (SPI) 简化了与微控制器 (MCU) 的连接方式。

### 器件信息<sup>(1)</sup>

部件号	封装	封装尺寸（标称值）
LDC1000	WSON (16)	5.00mm x 4.00mm

(1) 如需了解所有可用封装，请参见数据表末尾的可订购产品目录。

### 轴距感测应用



An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

English Data Sheet: [SNOSCX2](#)

## 目录

1	特性 .....	1	7.4	Device Functional Modes .....	13
2	应用 .....	1	7.5	Programming .....	16
3	说明 .....	1	7.6	Register Maps .....	18
4	修订历史记录 .....	2	8	<b>Application and Implementation .....</b>	24
5	<b>Pin Configuration and Functions .....</b>	4	8.1	Application Information .....	24
6	<b>Specifications .....</b>	5	8.2	Typical Application .....	25
6.1	Absolute Maximum Ratings .....	5	9	<b>Power Supply Recommendations .....</b>	28
6.2	ESD Ratings .....	5	10	<b>Layout .....</b>	28
6.3	Recommended Operating Condition .....	5	10.1	Layout Guidelines .....	28
6.4	Thermal Information .....	5	10.2	Layout Example .....	29
6.5	Electrical Characteristics .....	6	11	器件和文档支持 .....	30
6.6	Timing Requirements .....	7	11.1	文档支持 (如果适用) .....	30
6.7	Typical Characteristics .....	8	11.2	社区资源 .....	30
7	<b>Detailed Description .....</b>	9	11.3	商标 .....	30
7.1	Overview .....	9	11.4	静电放电警告 .....	30
7.2	Functional Block Diagram .....	9	11.5	Glossary .....	30
7.3	Feature Description .....	9	12	机械、封装和可订购信息 .....	30

## 4 修订历史记录

## Changes from Revision B (March 2015) to Revision C

Page

•	Changed XOUT pin description to clarify proper crystal connection .....	4
•	Added instructions on proper DAP connection .....	4
•	Added conditions for L measurement resolution .....	6
•	Changed TYP to NOM .....	7
•	Changed Some descriptions of device functionality for better clarity and consistency .....	9
•	Changed RP Conversion equation for clarity .....	12
•	Added extended SPI transaction figure for clarity .....	17
•	Changed Register maps to include Clock Configuration and Threshold Registers .....	18
•	Changed description of Min Sensor frequency for clarity .....	21
•	Added documentation of registers 0x05, 0x06, and 0x08 .....	21
•	Changed description of OSC Status to include possible causes .....	23
•	Changed some details on Application Information for improved clarity and consistency .....	24
•	Deleted lateral and rotation images from example applications, as example application details axial sensing configuration .....	25
•	Changed details of example design for improved clarity .....	26

## Changes from Revision A (December 2013) to Revision B

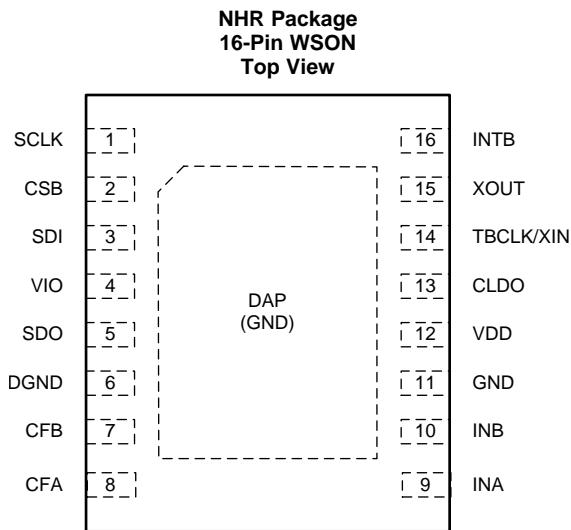
Page

•	已添加 ESD 额定值表, 特性描述部分, 器件功能模式, 应用和实施部分, 电源相关建议部分, 布局部分, 器件和文档支持部分以及机械、封装和可订购信息部分 .....	1
•	Changed SCLK Pin type from DO to DI .....	4
•	Added L Res value to Electrical Characteristics .....	6
•	Added Measuring Inductance With LDC1000 subsection to Feature Description .....	12
•	Changed Frequency Counter Data values in Register Description table .....	18

**Changes from Original (September 2013) to Revision A****Page**

- Changed SCLK to CSB ..... [7](#)

## 5 Pin Configuration and Functions



### Pin Functions

PIN		TYPE <sup>(1)</sup>	DESCRIPTION
NAME	NO.		
SCLK	1	DI	SPI clock input. SCLK is used to clock-out/clock-in the data from/into the chip
CSB	2	DI	SPI CSB. Multiple devices can be connected on the same SPI bus with each device having a dedicated CSB connection to the MCU so that each device can be uniquely selected.
SDI	3	DI	SPI Slave Data In (Master Out Slave In). This should be connected to the Master Out Slave In of the master
VIO	4	P	Digital IO Supply
DGND	6	P	Digital ground
SDO	5	DO	SPI Slave Data Out (Master In Slave Out).It is Hi-Z when CSB is high
CFB	7	A	LDC filter capacitor
CFA	8	A	LDC filter capacitor
INA	9	A	External LC Tank. Connected to external LC tank
INB	10	A	External LC Tank. Connected to external LC tank
GND	11	P	Analog ground
VDD	12	P	Analog supply
CLDO	13	A	LDO bypass capacitor. A 56 nF capacitor should be connected from this pin to GND
TBCLK/XI N	14	DI/A	External time-base clock/XTAL. Either an external clock or crystal can be connected.
XOUT	15	A	XTAL. Crystal out. When using a crystal, a crystal should be connected across XIN and XOUT. When not using a crystal, this pin should be left floating.
INTB	16	DO	Configurable interrupt output.
DAP	17	P	Connect to GND for improved thermal performance. <sup>(2)</sup>

(1) DO: Digital Output, DI: Digital Input, P: Power, A: Analog

(2) There is an internal electrical connection between the exposed Die Attach Pad (DAP) and the GND pin of the device. Although the DAP can be left floating, for best performance the DAP should be connected to the same potential as the device's GND pin. Do not use the DAP as the primary ground for the device. The device GND pin must always be connected to ground.

## 6 Specifications

### 6.1 Absolute Maximum Ratings<sup>(1)</sup>

	MIN	MAX	UNIT
Analog Supply Voltage ( $V_{DD}$ – GND)		6	V
IO Supply Voltage ( $V_{IO}$ – GND)		6	V
Voltage on any Analog Pin	-0.3	$V_{DD} + 0.3$	V
Voltage on any Digital Pin	-0.3	$V_{IO} + 0.3$	V
Input Current on INA and INB		8	mA
Junction Temperature, $T_J$ <sup>(2)</sup>		150	°C
Storage temperature, $T_{stg}$	-65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) The maximum power dissipation is a function of  $T_{J(MAX)}$ ,  $R_{\theta JA}$ , and the ambient temperature,  $T_A$ . The maximum allowable power dissipation at any ambient temperature is  $P_{DMAX} = (T_{J(MAX)} - T_A) / R_{\theta JA}$ . All numbers apply for packages soldered directly onto a PC board. The package thermal impedance is calculated in accordance with JESD 51-7.

### 6.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±1000	V
	Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>	±250	

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Condition<sup>(1)</sup>

	MIN	NOM	MAX	UNIT
Analog Supply Voltage ( $V_{DD}$ – GND)	4.75	5.25		V
IO Supply Voltage ( $V_{IO}$ – GND)	1.8	5.25		V
$V_{DD}$ - $V_{IO}$	≥0			V
Operating Temperature, $T_A$	-40		125	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

### 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>	LDC1000	UNIT	
	NHR (WSON)		
	16-PINS		
$R_{\theta JA}$	Junction-to-ambient thermal resistance <sup>(2)</sup>	28	°C/W

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).
- (2) The maximum power dissipation is a function of  $T_{J(MAX)}$ ,  $R_{\theta JA}$ , and the ambient temperature,  $T_A$ . The maximum allowable power dissipation at any ambient temperature is  $P_{DMAX} = (T_{J(MAX)} - T_A) / R_{\theta JA}$ . All numbers apply for packages soldered directly onto a PC board. The package thermal impedance is calculated in accordance with JESD 51-7.

## 6.5 Electrical Characteristics

Unless otherwise specified, all limits ensured for  $T_A = T_J = 25^\circ\text{C}$ ,  $V_{DD} = 5.0\text{ V}$ ,  $V_{IO} = 3.3\text{ V}$ <sup>(1)(2)</sup>

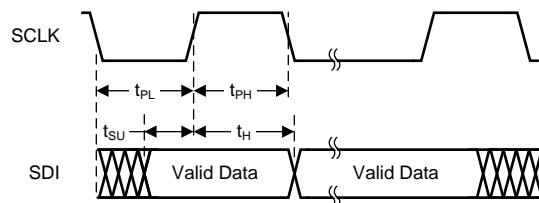
PARAMETER	TEST CONDITIONS	MIN <sup>(3)</sup>	TYP <sup>(4)</sup>	MAX <sup>(3)</sup>	UNIT	
<b>POWER</b>						
$V_{DD}$	Analog Supply Voltage	4.75	5	5.25	V	
$V_{IO}$	IO Supply Voltage	$V_{IO} \leq V_{DD}$	1.8	3.3	5.25	V
$I_{DD}$	Supply Current on VDD pin	PWR_MODE = 1, no sensor connected		1.7	2.3	mA
$I_{VIO}$	IO Supply Current	Static current		14	$\mu\text{A}$	
$I_{DD\_LP}$	Standby Mode Supply Current on VDD pin	PWR_MODE = 0, no sensor connected		250	$\mu\text{A}$	
$t_{START}$	Start-Up Time	From POR to ready-to-convert. Crystal not used for frequency counter		2	ms	
<b>LDC</b>						
$f_{SENSOR\_MIN}$	Minimum sensor frequency		5		kHz	
$f_{SENSOR\_MAX}$	Maximum sensor frequency		5		MHz	
$A_{SENSOR\_MIN}$	Minimum sensor amplitude		1		$V_{PP}$	
$A_{SENSOR\_MAX}$	Maximum sensor amplitude		4		$V_{PP}$	
$t_{REC}$	Recovery time	Oscillation start-up time after $R_P$ under-range condition	10		$1/f_{sensor}$	
$R_P\_MIN$	Minimum Sensor $R_P$ Range		798		$\Omega$	
$R_P\_MAX$	Maximum Sensor $R_P$ Range		3.93		$M\Omega$	
$R_P\_RES$	$R_P$ Measurement Resolution		16		Bits	
L Res	Inductance Measurement Resolution	RESPONSE_TIME = b111 (6144), $f_{EXT} = 8\text{ MHz}$ , $f_{SENSOR} = 5\text{ kHz}$	24		Bits	
$t_S\_MIN$	Minimum Response Time	Minimum programmable settling time of digital filter	$192/f_{SE}$ NSOR		s	
$t_S\_MAX$	Maximum Response Time	Maximum programmable settling time of digital filter	$6144/f_S$ ENSOR		s	
<b>EXTERNAL CLOCK/CRYSTAL FOR FREQUENCY COUNTER</b>						
Crystal	Frequency		8		MHz	
	Startup time		30		ms	
External Clock	Frequency		8		MHz	
	Clock Input High Voltage			$V_{IO}$	V	
<b>DIGITAL I/O CHARACTERISTICS</b>						
$V_{IH}$	Logic 1 Input Voltage		$0.8 \times V_{IO}$		V	
$V_{IL}$	Logic 0 Input Voltage		$0.2 \times V_{IO}$		V	
$V_{OH}$	Logic 1 Output Voltage	$I_{SOURCE}=400\text{ }\mu\text{A}$	$V_{IO}-0.3$		V	
$V_{OL}$	Logic 0 Output Voltage	$I_{SINK}=400\text{ }\mu\text{A}$	0.3		V	
$I_{IOHL}$	Digital IO Leakage Current		-500	500	nA	

- Electrical Characteristics** table values apply only for factory testing conditions at the temperature indicated. Factory testing conditions result in very limited self-heating of the device such that  $T_J = T_A$ . No specification of parametric performance is indicated in the electrical tables under conditions of internal self-heating where  $T_J > T_A$ . **Absolute Maximum Ratings** indicate junction temperature limits beyond which the device may be permanently degraded, either mechanically or electrically.
- The maximum power dissipation is a function of  $T_{J(MAX)}$ ,  $R_{\theta JA}$ , and the ambient temperature,  $T_A$ . The maximum allowable power dissipation at any ambient temperature is  $P_{DMAX} = (T_{J(MAX)} - T_A)/R_{\theta JA}$ . All numbers apply for packages soldered directly onto a PC board. The package thermal impedance is calculated in accordance with JESD 51-7.
- Limits are specified by testing, design, or statistical analysis at  $25^\circ\text{C}$ . Limits over the operating temperature range are specified through correlations using statistical quality control (SQC) method.
- Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration. The typical values are not tested and are not specified on shipped production material.

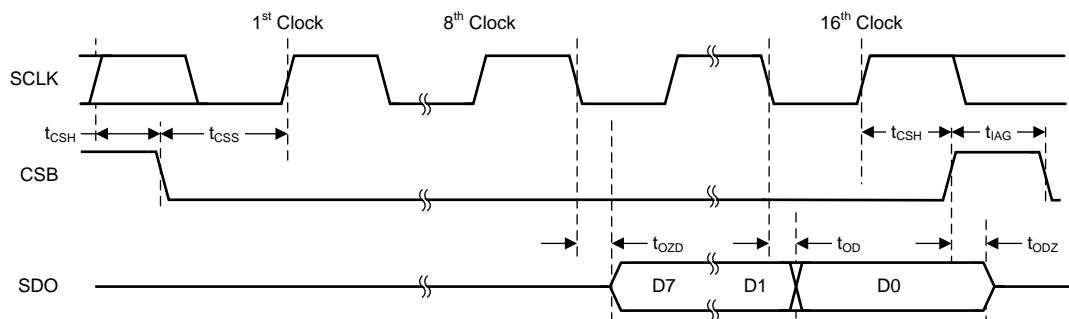
## 6.6 Timing Requirements

Unless otherwise noted, all limits specified at  $TA = 25^\circ\text{C}$ ,  $VDD=5.0$ ,  $VIO=3.3$ , 10 pF capacitive load in parallel with a 10 k $\Omega$  load on SDO. Specified by design; not production tested.

			MIN	NOM	MAX	UNIT
$f_{SCLK}$	Serial Clock Frequency				4	MHz
$t_{PH}$	SCLK Pulse Width High	$f_{SCLK} = 4 \text{ MHz}$	0.4 / $f_{SCLK}$			s
$t_{PL}$	SCLK Pulse Width Low	$f_{SCLK} = 4 \text{ MHz}$	0.4 / $f_{SCLK}$			s
$t_{SU}$	SDI Setup Time		10			ns
$t_H$	SDI Hold Time		10			ns
$t_{ODZ}$	SDO Driven-to-Tristate Time	Measured at 10% / 90% point		20		ns
$t_{OZD}$	SDO Tristate-to-Driven Time	Measured at 10% / 90% point		20		ns
$t_{OD}$	SDO Output Delay Time			20		ns
$t_{CSS}$	CSB Setup Time		20			ns
$t_{CSH}$	CSB Hold Time		20			ns
$t_{IAG}$	Inter-Access Gap		100			ns
$t_{DRDYB}$	Data ready pulse width	Data ready pulse at every 1 / ODR if no data is read	1 / $f_{\text{sensor}}$			s

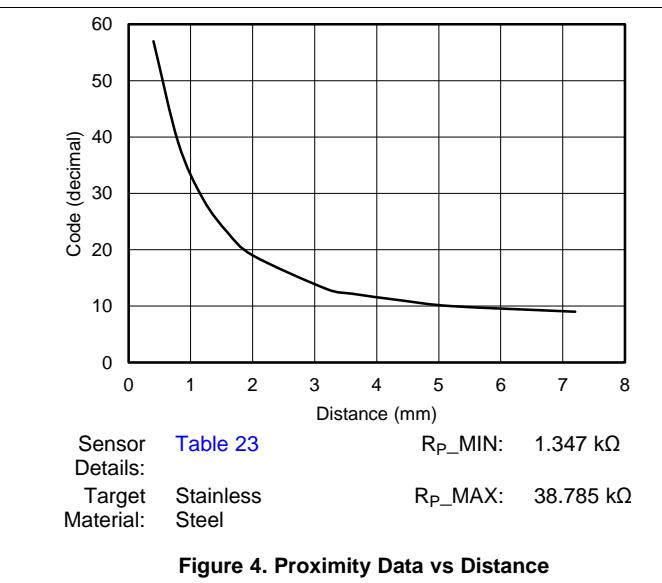
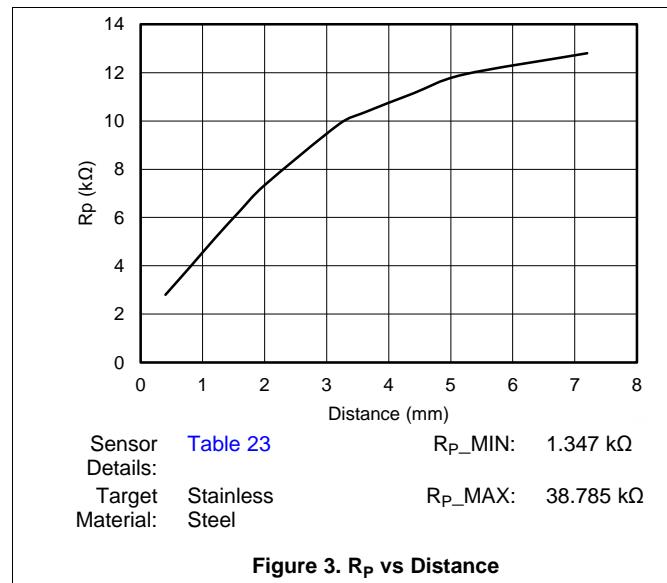


**Figure 1. Write Timing Diagram**



**Figure 2. Read Timing Diagram**

## 6.7 Typical Characteristics



## 7 Detailed Description

### 7.1 Overview

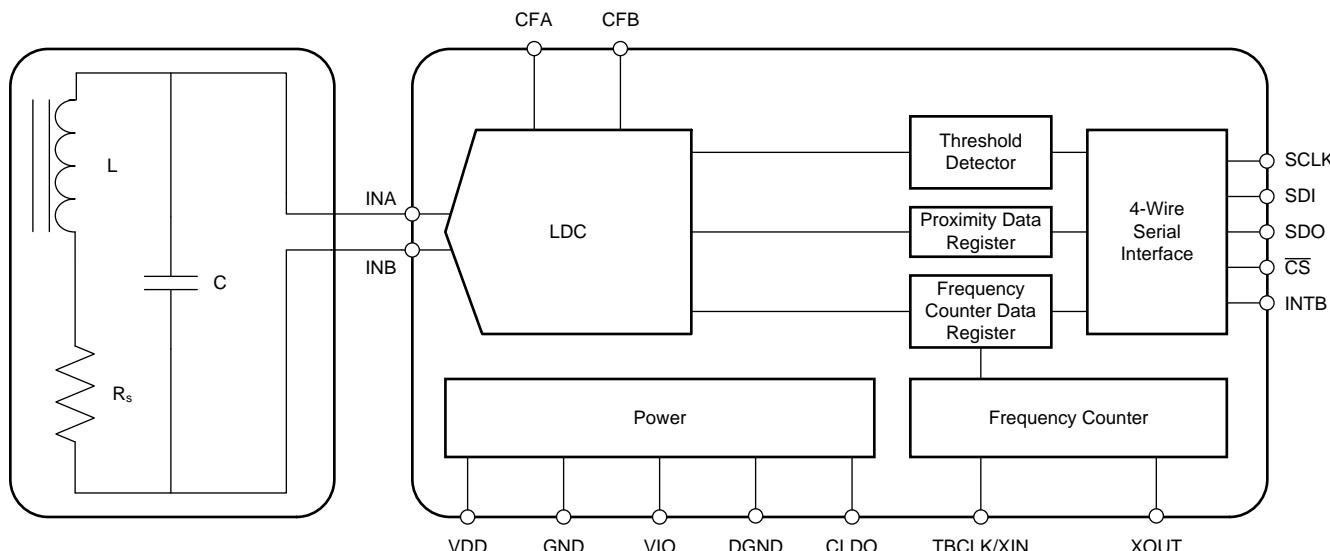
The LDC1000 is an Inductance-to-Digital Converter that measures the parallel impedance of an LC resonator. It accomplishes this task by regulating the oscillation amplitude in a closed-loop configuration to a constant level, while monitoring the energy dissipated by the resonator. By monitoring the amount of power injected into the resonator, the LDC1000 can determine the value of  $R_p$ ; it returns this as a digital value which is inversely proportional to  $R_p$ .

The threshold detector block provides a comparator with hysteresis. With the threshold registers programmed and comparator enabled, proximity data register is compared with threshold registers and INTB pin indicates the output.

The device has a simple 4-wire SPI interface. The INTB pin provides multiple functions which are programmable with SPI.

The device has separate supplies for Analog and I/O, with analog operating at 5 V and I/O at 1.8-5 V. The integrated LDO needs a 56 nF capacitor connected from CLDO pin to GND.

### 7.2 Functional Block Diagram

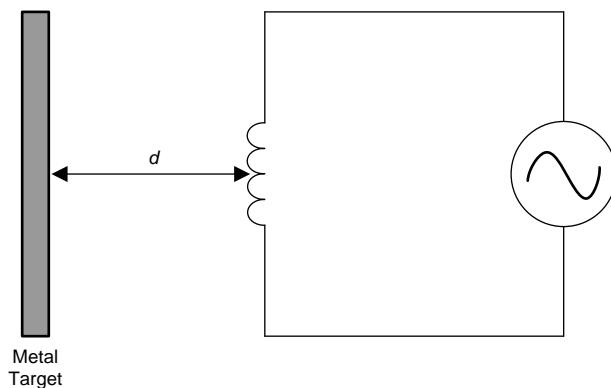


### 7.3 Feature Description

#### 7.3.1 Inductive Sensing

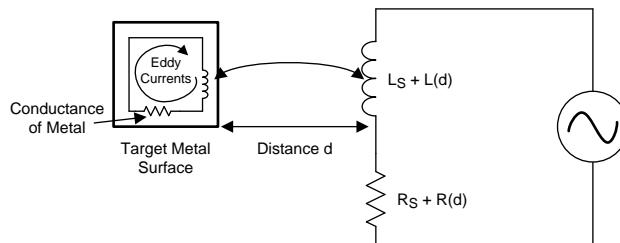
An AC current flowing through an inductor will generate an AC magnetic field. If a conductive material, such as a metal target, is brought into the vicinity of the coil, this magnetic field will induce circulating currents (eddy currents) on the surface of the target. These eddy currents are a function of the distance, size, and composition of the target. The eddy currents then generate their own magnetic field, which opposes the original field generated by the coil. This mechanism is best compared to a transformer, where the coil is the primary core and the eddy current is the secondary core. The inductive coupling between both cores depends on distance and shape. Hence the resistance and inductance of the secondary core (eddy current), shows up as a distant dependent resistive and inductive component on the primary side (coil). The figures (Figure 5 to Figure 8) below show a simplified circuit model.

## Feature Description (continued)



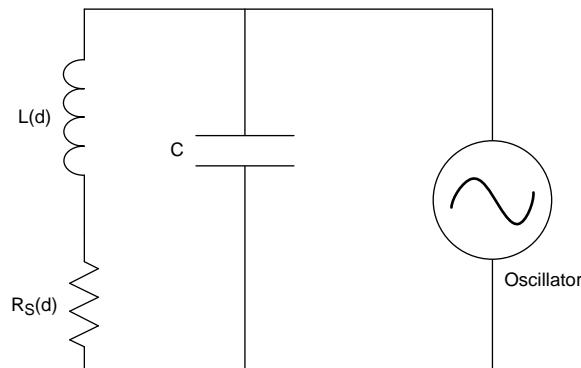
**Figure 5. Inductor With a Metal Target**

Eddy currents generated on the surface of the target can be modeled as a transformer as shown in [Figure 6](#). The coupling between the primary and secondary coils is a function of the distance and the conductor's characteristics. In [Figure 6](#), the inductance  $L_S$  is the coil's inductance, and  $R_S$  is the coil's parasitic series resistance. The inductance  $L(d)$ , which is a function of sensor to target distance,  $d$ , is the coupled inductance of the metal target. Likewise,  $R(d)$  is the parasitic resistance of the eddy currents and is also a function of distance.



**Figure 6. Metal Target Modeled as L and R With Circulating Eddy Currents**

Generating an alternating magnetic field with just an inductor will consume a large amount of power. This power consumption can be reduced by adding a parallel capacitor, turning it into a resonator as shown in [Figure 7](#). In this manner the power consumption is reduced to the eddy and inductor losses  $R_S+R(d)$  only.

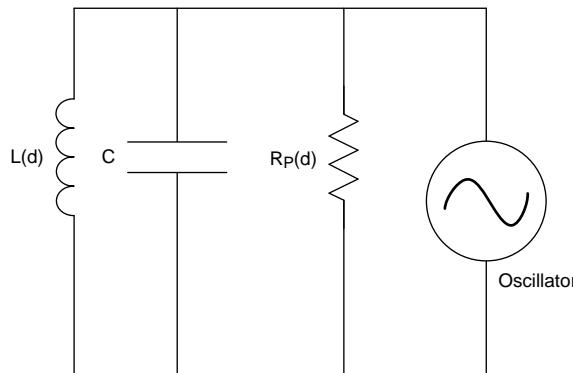


**Figure 7. LC Tank Connected to Oscillator**

## Feature Description (continued)

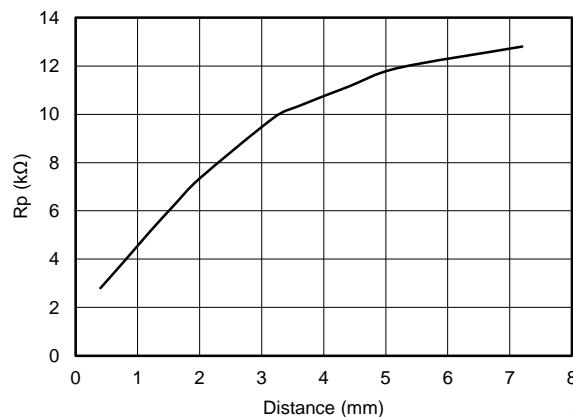
The LDC1000 doesn't measure the series resistance directly; instead it measures the equivalent parallel resonance impedance  $R_p$  (see [Figure 8](#)). This representation is equivalent to the one shown in [Figure 8](#), where the parallel resonance impedance  $R_p(d)$  is given by:

$$R_p(d) = \frac{L_s + L(d)}{[R_s + R(d)] \times C} \quad (1)$$



**Figure 8. Equivalent Resistance of  $R_s$  in Parallel With LC Tank**

[Figure 9](#) below shows the variation in  $R_p$  as a function of distance for a 14 mm diameter PCB coil (refer to Sensor Details: [Table 23](#)). The target in this example is a section of a 2 mm thick stainless steel disk.



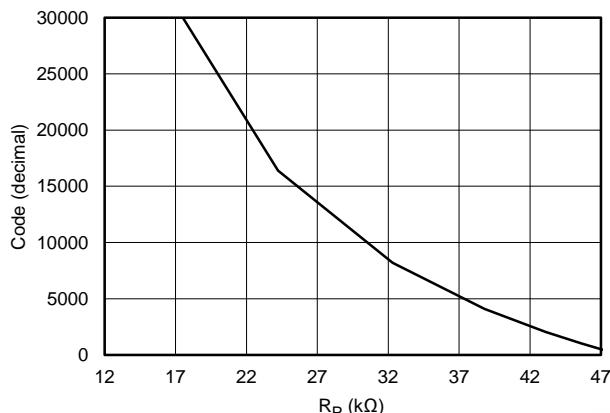
**Figure 9. Typical  $R_p$  vs Distance With 14-mm PCB Coil**

### 7.3.2 Measuring $R_p$ With LDC1000

The LDC1000 supports a wide range of LC combinations, with oscillation frequencies ranging from 5 kHz to 5 MHz and  $R_p$  ranging from 798 Ω to 3.93 MΩ. This range of  $R_p$  can be viewed as the maximum input range of an ADC. As illustrated in [Figure 9](#), the range of  $R_p$  is typically much smaller than the maximum input range supported by the LDC1000. To get better resolution in the desired sensing range, the LDC1000 offers a programmable input range through the  $R_p\_MIN$  and  $R_p\_MAX$  registers. Refer to [Calculation of  \$R\_p\\_MIN\$  and  \$R\_p\\_MAX\$](#)  for information on setting these registers.

When the resonance impedance  $R_p$  of the sensor drops below the programmed  $R_p\_MIN$ , the  $R_p$  output of the LDC will clip at its full scale output. This situation could, for example, happen when a target comes too close to the coil.

## Feature Description (continued)



**Figure 10. Transfer Characteristics of LDC1000 With R<sub>P</sub>\_MIN = 16.160 kΩ and R<sub>P</sub>\_MAX = 48.481 kΩ**

The resonance impedance can be calculated from the digital output code as follows:

$$R_P = \frac{R_P\_MAX \times R_P\_MIN}{[R_P\_MIN \times (1 - Y)] + (R_P\_MAX \times Y)}$$

Where:

- R<sub>P</sub> = Measured sensor parallel resistance in kΩ.
- R<sub>P</sub>\_MIN is the resistance (in kΩ) selected in register 0x02
- R<sub>P</sub>\_MAX is the resistance (in kΩ) selected in register 0x01
- Y = Proximity Data  $\div 2^{15}$
- Proximity data is the LDC R<sub>P</sub> output = (Contents of Register 0x22)  $\times 2^8$  + (Contents of register 0x21). (2)

**Example:** If Proximity data (address 0x22:0x21) is 5000, R<sub>P</sub>\_MIN is 2.394 kΩ, and R<sub>P</sub>\_MAX is 38.785 kΩ, the resonance impedance is given by:

$$Y = 5000/2^{15} = 0.1526$$

$$R_P = (38785 \times 2394) \div (2394 \times (1 - 0.1526) + 38785 \times 0.1526) = (92851290 \div (2028.675 + 5918.591))$$

$$R_P = 11.683 \text{ kΩ}$$

### 7.3.3 Measuring Inductance With LDC1000

LDC1000 measures the sensor's frequency of oscillation using a frequency counter. The frequency counter timing is set by an external clock applied on TBCLK pin. The sensor frequency can be calculated from the frequency counter register value (see registers 0x23 through 0x25) as follows:

$$f_{SENSOR} = \frac{f_{EXT} \times \text{RESPONSE\_TIME}}{3 \times \text{FCOUNT}}$$

Where:

- f<sub>SENSOR</sub> is the measured sensor frequency
- f<sub>EXT</sub> is the frequency of the external clock.
- FCOUNT is the value obtained from the Frequency Counter Data registers (address 0x23,0x24,0x25).
- RESPONSE\_TIME is the programmed response time (set in the LDC configuration register, address 0x04). (3)

## Feature Description (continued)

The sensor inductance can be determined by:

$$L = \frac{1}{C \times (2\pi \times f_{\text{SENSOR}})^2}$$

where

- C is the parallel sensor capacitance
- $f_{\text{SENSOR}}$  is the sensor frequency calculated in [Equation 3](#) (4)

**Example:** If  $f_{\text{EXT}} = 6\text{MHz}$ ,  $\text{RESPONSE\_TIME} = 6144$ ,  $C = 100\text{ pF}$  and measured  $\text{Fcount} = 3000$  (dec) (address  $0x23$  through  $0x25$ )

$$f_{\text{sensor}} = (1/3) \times (6000000/3000) \times (6144) = 4.096\text{ MHz}$$

$$L = \frac{1}{C \times (2\pi \times f_{\text{SENSOR}})^2}$$

Now using,

The sensor inductance  $L = 15.098\text{ }\mu\text{H}$ .

The accuracy of a measurement largely depends upon the frequency of the external time-base clock (TBCLK). A higher frequency will provide better measurement accuracy. The maximum supported frequency is 8 MHz.

## 7.4 Device Functional Modes

### 7.4.1 Power Modes

The LDC1000 has two power modes:

- Active Mode: In this mode the LDC1000 is performing conversions. Changing any device configuration settings except PWR\_MODE or INTB\_MODE when the LDC1000 is in active mode is not recommended. This mode is selected when PWR\_MODE = 1.
- Standby Mode: This is the default mode on device power-up. In the mode the LDC1000 power consumption is lower than when in Active mode, however the LDC1000 is not performing conversions. The device's SPI is enabled and the device should be configured in this mode. This mode is selected when PWR\_MODE = 0.

### 7.4.2 INTB Pin Modes

The INTB pin is a configurable output pin which can be used to drive an interrupt on an MCU. This mode is selected by setting INTB\_MODE. The LDC1000 provides three different modes on INTB pin:

1. Comparator Mode
2. Wake-Up Mode
3. DRDY Mode

LDC1000 has a built-in High and Low trigger threshold which registers as a comparator with programmable hysteresis or a special mode which can be used to wake up an MCU. These modes are explained in detail below.

#### 7.4.2.1 Comparator Mode

In the Comparator mode, the INTB pin is asserted or deasserted when the proximity register value increases above Threshold High or decreases below Threshold Low registers respectively. In this mode, the LDC1000 essentially behaves as a proximity switch with programmable hysteresis.

## Device Functional Modes (continued)

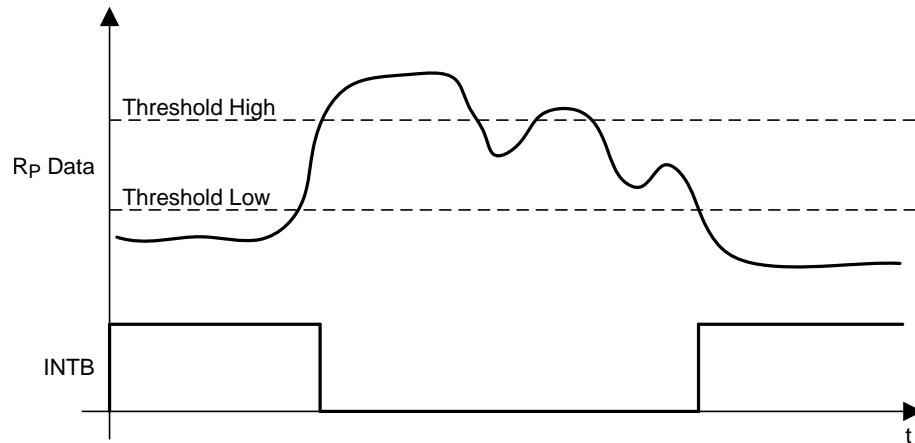


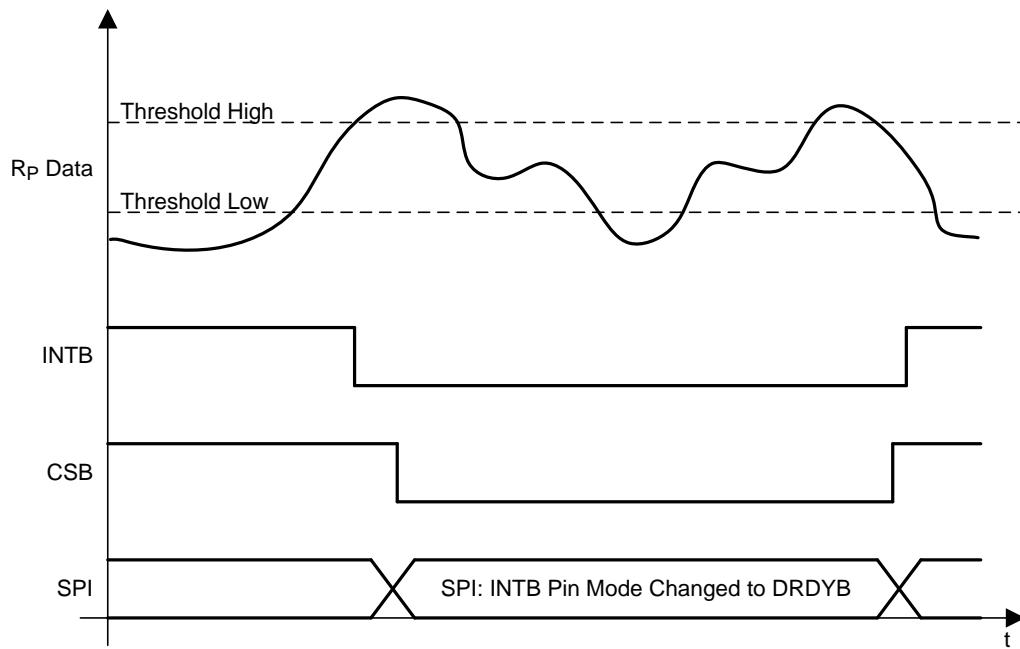
Figure 11. Behavior of INTB Pin in Comparator Mode

## Device Functional Modes (continued)

### 7.4.2.2 Wake-Up Mode

In Wake-up mode, the INTB pin is asserted when proximity register value increases above Threshold High and deasserted when wake-up mode is disabled in INTB pin mode register.

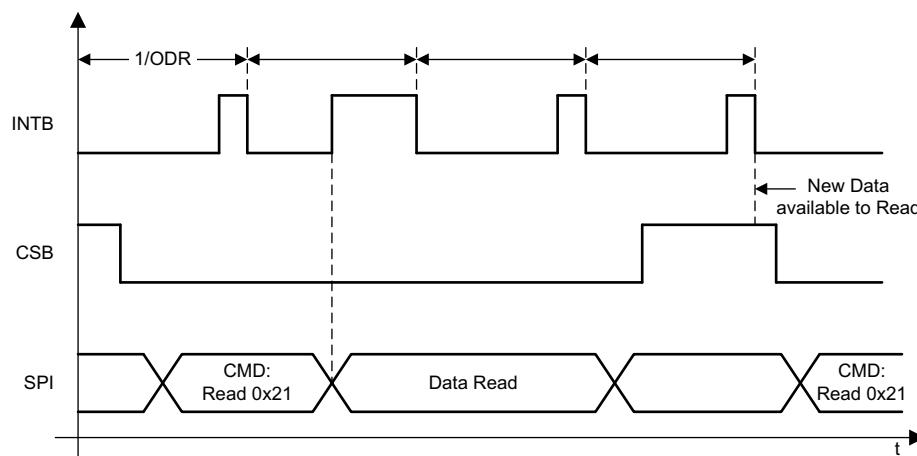
This mode can be used to wake up an MCU which is asleep, to conserve power.



**Figure 12. Behavior of INTB Pin in Wake-Up Mode**

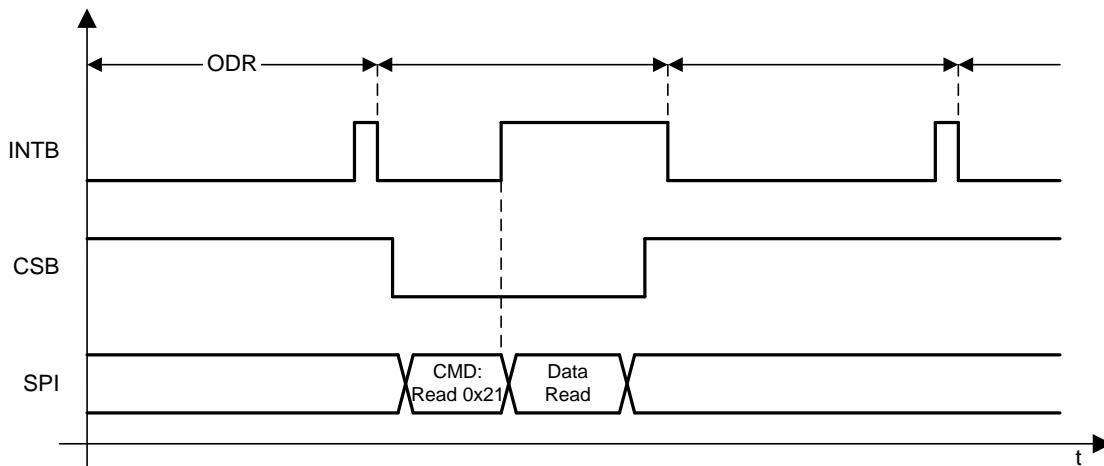
### 7.4.2.3 DRDY Mode

In DRDY mode, the INTB pin is asserted every time the conversion data is available and deasserted once the read command on register 0x21 is registered internally; if the read is in progress, the pin is pulsed instead. It is recommended to configure this setting after PWR\_MODE has been set to 1 (the LDC1000 is in Active Mode).



**Figure 13. Behavior of INTB pin in DRDY Mode With SPI Extending Beyond Subsequent Conversions**

## Device Functional Modes (continued)



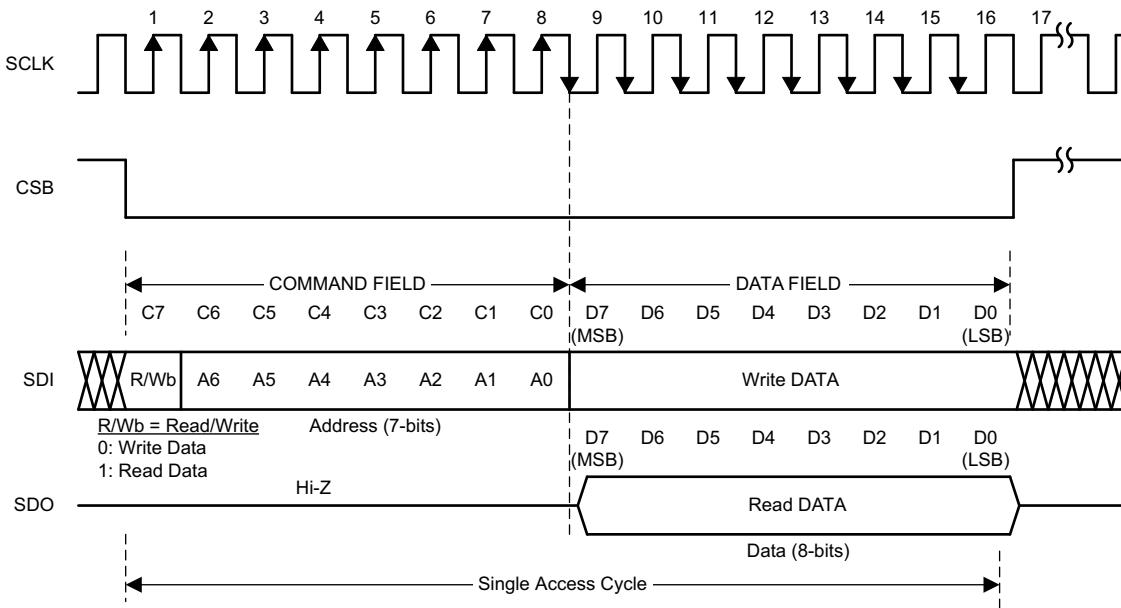
**Figure 14. Behavior of INTB Pin in DRDY Mode With SPI Reading the Data Within Subsequent Conversion**

## 7.5 Programming

The LDC1000 uses a 4-wire SPI to access control and data registers. The LDC1000 is a SPI slave device and does not initiate any transactions.

### 7.5.1 SPI Description

A typical serial interface transaction begins with an 8-bit instruction, which is comprised of a read/write bit (MSB, R=1) and a 7-bit address of the register, followed by a Data field which is typically 8 bits. However, the data field can be extended to a multiple of 8 bits by providing sufficient SPI clocks. Refer to the [Extended SPI Transactions](#) section below.



**Figure 15. Serial Interface Protocol**

## Programming (continued)

Each assertion of chip select bar (CSB) starts a new register access. The R/Wb bit in the command field configures the direction of the access; a value of 0 indicates a write operation and a value of 1 indicates a read operation. All output data is driven on the falling edge of the serial clock (SCLK), and all input data is sampled on the rising edge of the serial clock (SCLK). Data is written into the register on the rising edge of the 16th clock. It is required to deassert CSB after the 16th clock; if CSB is deasserted before the 16th clock, no data write will occur.

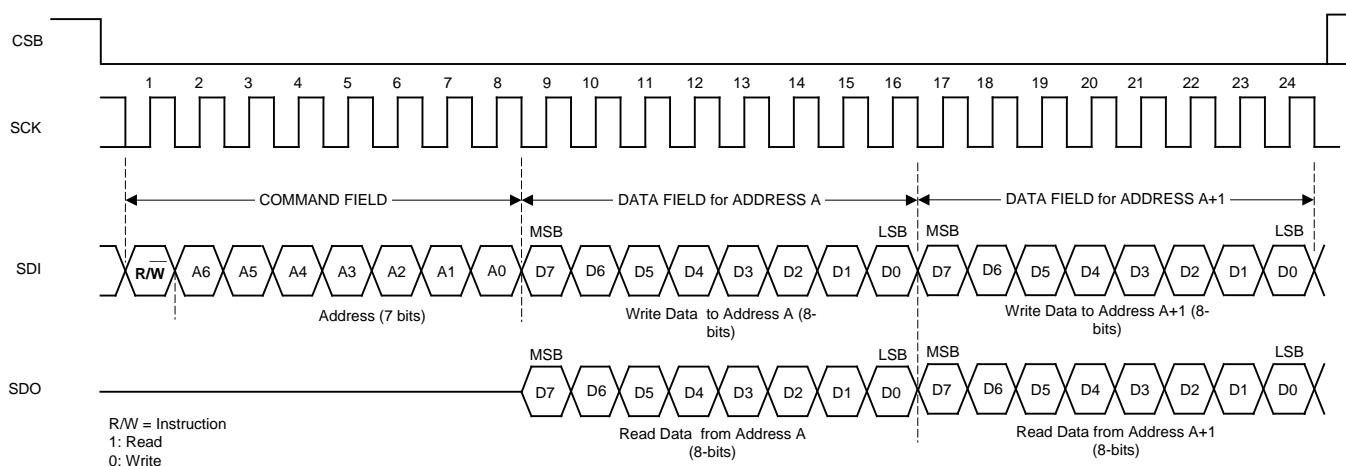
The LDC1000 utilizes a 4-wire SPI interface to access control and data registers. The LDC1000 is an SPI slave device and does not initiate any transactions.

### 7.5.1.1 Extended SPI Transactions

A SPI transaction may be extended to multiple registers by keeping the CSB asserted for more than 16 pulses on SCLK. In this mode, the register addresses increment automatically. CSB must be remain asserted during  $8*(1+N)$  clock cycles of SCLK, where N is the amount of bytes to write or read during the transaction.

During an extended read access, SDO outputs the register contents every 8 clock cycles after the initial 8 clocks of the command field. During an extended write access, the data is written to the registers every 8 clock cycles after the initial 8 clocks of the command field.

Extended transactions can be used to read 16 bits of Proximity data and 24 bits of frequency data all in one SPI transaction by initiating a read from register 0x21.



**Figure 16. Extended SPI Transaction**

## 7.6 Register Maps

**Table 1. Register Description<sup>(1)(2)(3)</sup>**

Register Name	Address	Direction	Default	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0								
Device ID	0x00	RO	0x84	Device ID															
R <sub>P</sub> _MAX	0x01	R/W	0x0E	R <sub>P</sub> Maximum															
R <sub>P</sub> _MIN	0x02	R/W	0x14	R <sub>P</sub> Minimum															
Watchdog Timer Frequency	0x03	R/W	0x45	Min Sensor Frequency															
LDC Configuration	0x04	R/W	0x1B	Reserved (000)			Amplitude			RESPONSE_TIME									
Clock Configuration	0x05	R/W	0x01	Reserved (00'0000)							CLK_SE	CLK_PD							
Comparator Threshold High LSB	0x06	R/W	0xFF	Threshold High LSB															
Comparator Threshold High MSB	0x07	R/W	0xFF	Threshold High MSB															
Comparator Threshold Low LSB	0x08	R/W	0x00	Threshold Low LSB															
Comparator Threshold Low MSB	0x09	R/W	0x00	Threshold Low MSB															
INTB pin Configuration	0x0A	R/W	0x00	Reserved (0'0000)							INTB_MODE								
Power Configuration	0x0B	R/W	0x00	Reserved (000'0000)									PWR_MODE						
Status	0x20	RO		OSC Dead	DRDY	Wake-up	Compa	ra	tor	Don't Care									
Proximity	0x21	RO		Proximity Data[ 7:0] Data LSB															
Proximity	0x22	RO		Proximity Data [15:8] Data MSB															
Frequency Counter Data LSB	0x23	RO		FCOUNT LSB															
Frequency Counter Data Mid-Byte	0x24	RO		FCOUNT Mid Byte															
Frequency Counter Data MSB	0x25	RO		FCOUNT MSB															

(1) Values of register fields which are unused should be set to default values only.  
 (2) Registers 0x01 through 0x05 are Read Only when the part is awake (PWR\_MODE bit is SET)  
 (3) R/W: Read/Write. RO: Read Only. WO: Write Only.

**Table 2. Revision ID**

Address = 0x00, Default=0x80, Direction=RO		
Bit Field	Field Name	Description
7:0	Revision ID	Revision ID of Silicon.

**Table 3.  $R_P$ \_MAX**

Address = 0x01, Default=0x0E, Direction=R/W		
Bit Field	Field Name	Description
7:0	$R_P$ Maximum	Maximum Sensor $R_P$ that LDC1000 needs to measure. Configures the input dynamic range of LDC1000. See <a href="#">Table 4</a> for register settings.

**Table 4. Register Settings for  $R_P$ \_MAX**

Register setting	$R_P$ Maximum Sensor Drive (k $\Omega$ )
0x00	3926.991
0x01	3141.593
0x02	2243.995
0x03	1745.329
0x04	1308.997
0x05	981.748
0x06	747.998
0x07	581.776
0x08	436.332
0x09	349.066
0x0A	249.333
0x0B	193.926
0x0C	145.444
0x0D	109.083
0x0E	83.111
0x0F	64.642
0x10	48.481
0x11	38.785
0x12	27.704
0x13	21.547
0x14	16.160
0x15	12.120
0x16	9.235
0x17	7.182
0x18	5.387
0x19	4.309
0x1A	3.078
0x1B	2.394
0x1C	1.796
0x1D	1.347
0x1E	1.026
0x1F	0.798

**Table 5.  $R_P$ \_MIN**

Address = 0x02, Default=0x14, Direction=R/W		
Bit Field	Field Name	Description
7:0	$R_P$ Minimum	Minimum Sensor $R_P$ that LDC1000 needs to measure. Configures the input dynamic range of LDC1000. See <a href="#">Table 6</a> for register settings. <sup>(1)</sup>

(1) This register needs a mandatory write as it defaults to 0x14.

Table 6. Register Settings for  $R_P$ \_MIN

Register setting	$R_P$ Minimum Sensor Drive (k $\Omega$ )
0x20	3926.991
0x21	3141.593
0x22	2243.995
0x23	1745.329
0x24	1308.997
0x25	981.748
0x26	747.998
0x27	581.776
0x28	436.332
0x29	349.066
0x2A	249.333
0x2B	193.926
0x2C	145.444
0x2D	109.083
0x2E	83.111
0x2F	64.642
0x30	48.481
0x31	38.785
0x32	27.704
0x33	21.547
0x34	16.160
0x35	12.120
0x36	9.235
0x37	7.182
0x38	5.387
0x39	4.309
0x3A	3.078
0x3B	2.394
0x3C	1.796
0x3D	1.347
0x3E	1.026
0x3F	0.798

**Table 7. Watchdog Timer Frequency**

Address = 0x03, Default=0x45, Direction=R/W		
Bit Field	Field Name	Description
7:0	Min Sensor Frequency	<p>Sets the watchdog timer. The Watchdog timer should be set based on the lowest sensor frequency. If this field is set to too high a value, then the LDC1000 may incorrectly determine a sensor oscillation timeout.</p> $M = 68.94 \times \log_{10} \left( \frac{f_{\text{SENSOR}}}{2500} \right)$ <p>where:</p> <ul style="list-style-type: none"> <li>• <math>f_{\text{SENSOR}}</math> is the sensor frequency</li> <li>• M is the register value to program for Min Sensor Frequency.</li> </ul> <p>Example: With a Sensor frequency is 1 MHz Min Sensor Frequency=68.94*log<sub>10</sub>(1×10<sup>6</sup>/2500)=Round to nearest integer(179.38) = 179</p>

**Table 8. LDC Configuration**

Address = 0x04, Default=0x1B, Direction=R/W		
Bit Field	Field Name	Description
7:5	Reserved	Reserved to 000
4:3	Amplitude	<p>Sets the oscillation amplitude</p> <p>00:1V 01:2V 10:4V <b>11:Reserved</b></p>
2:0	RESPONSE_TIME	<p>000: Reserved 001: Reserved 010: 192 <b>011: 384</b> 100: 768 101: 1536 110: 3072 111: 6144</p>

**Table 9. Clock Configuration**

Address = 0x05, Default=0x01, Direction=R/W		
Bit Field	Field Name	Description
7:2	Reserved	Reserved to 00'0000.
1	CLK_SEL	<p>Select Clock input type for L measurements.</p> <p><b>0: Clock input on XIN pin</b> 1: Crystal connected across XIN/XOUT pins.</p>
0	CLK_PD	<p>Crystal Power Down.</p> <p>0: Crystal drive enabled.</p> <p><b>1: Crystal drive is disabled. Use this setting to reduce power consumption with a crystal input when device is in Standby mode. Use this setting for clock input.</b></p>

**Table 10. Comparator Threshold High LSB**

Address = 0x06, Default=0xFF, Direction=R/W		
Bit Field	Field Name	Description
7:0	Threshold High	Threshold High Register LSB. Combine with contents of register 0x07 to set upper threshold.

**Table 11. Comparator Threshold High MSB**

Address = 0x07, Default=0xFF, Direction=R/W		
Bit Field	Field Name	Description
7:0	Threshold High	Threshold High Register MSB.

**Table 12. Comparator Threshold Low LSB**

Address = 0x08, Default=0x00, Direction=R/W		
Bit Field	Field Name	Description
7:0	Threshold Low	Threshold Low Register LSB. Combine with contents of register 0x09 to set lower threshold.

**Table 13. Comparator Threshold Low MSB**

Address = 0x09, Default=0x00, Direction=R/W		
Bit Field	Field Name	Description
7:0	Threshold Low	Threshold Low Register MSB.

**Table 14. INTB pin Configuration**

Address = 0x0A, Default=0x00, Direction=R/W		
Bit Field	Field Name	Description
7:3	Reserved	Reserved to 00'000
2:0	INTB_MODE	<b>000: All modes disabled.</b> No signal output on INTB pin. 001: Wake-up Enabled on INTB pin 010: INTB pin indicates the status of Comparator output 100: DRDY Enabled on INTB pin All other combinations are Reserved

**Table 15. Power Configuration**

Address = 0x0B, Default=0x00, Direction=R/W		
Bit Field	Field Name	Description
7:1	Reserved	Reserved to 000'0000.
0	PWR_MODE	<b>0:Standby mode:</b> LDC1000 is in a lower power mode but not actively converting. It is recommended to configure the LDC1000 while in this mode. 1:Active Mode. Conversion is Enabled Refer to <a href="#">Power Modes</a> for more details.

**Table 16. Status**

Address = 0x20, Default=NA, Direction=RO		
Bit Field	Field Name	Description
7	OSC Status	1:Indicates sensor oscillation timeout. This can be caused by a sensor with an $R_P$ below $R_P_{MIN}$ or setting Min Sensor Frequency too high. 0:Sensor oscillation timeout not detected.
6	Data Ready	1:No new data available 0:Data is ready to be read
5	Wake-up	1:Wake-up disabled 0:Wake-up triggered. Proximity data is more than Threshold High value.
4	Comparator	1:Proximity data is less than Threshold Low value 0:Proximity data is more than Threshold High value
3:0	Don't Care	

It is recommended to read register 0x21 immediately after any read of register 0x20.

**Table 17. Proximity Data LSB**

Address = 0x21, Default=NA, Direction=RO		
Bit Field	Field Name	Description
7:0	Proximity Data[7:0]	Least Significant Byte of Proximity Data

Conversion data is updated to the proximity register only when a read is initiated on 0x21 register. If the read is delayed between subsequent conversions, these registers are not updated until another read is initiated on 0x21.

**Table 18. Proximity Data MSB**

Address = 0x22, Default=NA, Direction=RO		
Bit Field	Field Name	Description
7:0	Proximity data [15:8]	Most Significant Byte of Proximity data

**Table 19. Frequency Counter LSB**

Address = 0x23, Default=NA, Direction=RO		
Bit Field	Field Name	Description
7:0	FCOUNT LSB (FCOUNT[7:0])	LSB of Frequency Counter. Sensor frequency can be calculated using the output data rate. Please refer to the <a href="#">Measuring Inductance With LDC1000</a> .

**Table 20. Frequency Counter Mid-Byte**

Address = 0x24, Default=NA, Direction=RO		
Bit Field	Field Name	Description
7:0	FCOUNT Mid byte (FCOUNT[15:8])	Middle Byte of Output data rate

**Table 21. Frequency Counter MSB**

Address = 0x25, Default=NA, Direction=RO		
Bit Field	Field Name	Description
7:0	FCOUNT MSB (FCOUNT[23:16])	MSB of Output data rate

## 8 Application and Implementation

### NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 8.1 Application Information

#### 8.1.1 Calculation of $R_P\_MIN$ and $R_P\_MAX$

Different sensing applications may have a different range of the resonance impedance  $R_P$  to measure. The LDC1000 measurement range of  $R_P$  is controlled by setting 2 registers –  $R_P\_MIN$  and  $R_P\_MAX$ . For a given application,  $R_P$  must never be outside the range set by these register values, otherwise the measured value will be clipped. For optimal sensor resolution, the range of  $R_P\_MIN$  to  $R_P\_MAX$  should not be unnecessarily large. The following procedure is recommended to determine the  $R_P\_MIN$  and  $R_P\_MAX$  register values.

##### 8.1.1.1 $R_P\_MAX$

$R_P\_MAX$  sets the upper limit of the LDC1000 resonant impedance input range.

- Configure the sensor such that the eddy current losses are minimized. As an example, for a proximity sensing application, set the distance between the sensor and the target to the maximum sensing distance.
- Measure the sensor impedance  $R_P$  using an impedance analyzer.
- Multiply  $R_P$  by 2 and use the next higher value from [Table 7](#).

Note that setting  $R_P\_MAX$  to a value not listed in [Table 7](#) can result in indeterminate behavior.

##### 8.1.1.2 $R_P\_MIN$

$R_P\_MIN$  sets the lower limit of the LDC1000 resonant impedance input range.

- Configure the sensor such that the eddy current losses are maximized. As an example, for a proximity sensing application, set the distance between the sensor and the metal target to the minimum sensing distance.
- Measure the sensor impedance  $R_P$  using an impedance analyzer.
- Divide the  $R_P$  value by 2 and then select the next lower  $R_P$  value from [Table 10](#).

Note that setting  $R_P\_MIN$  to a value not listed on [Table 10](#) can result in indeterminate behavior. In addition,  $R_P\_MIN$  powers on with a default value of 0x14 which must be changed to a value from [Table 10](#) prior to powering on the LDC.

#### 8.1.2 Output Data Rate

The output data rate of (or the conversion time) LDC1000 depends on the sensor frequency,  $f_{SENSOR}$  and RESPONSE\_TIME field in LDC Configuration register(Address:0x04). The maximum sample rate requires a RESPONSE\_TIME setting of 192 and a sensor frequency of 5MHz.

$$SR = \frac{3 \times f_{SENSOR}}{\text{RESPONSE\_TIME}} \quad (6)$$

#### 8.1.3 Choosing Filter Capacitor (CFA and CFB Pins)

The filter capacitor is critical to the operation of the LDC1000. The capacitor should be low leakage, temperature stable, and it must not generate any piezoelectric noise (the dielectrics of many capacitors exhibit piezoelectric characteristics and any such noise is coupled directly through  $R_P$  into the converter). The optimal capacitance values range from 20 pF to 100 nF. The value of the capacitor is based on the time constant and resonating frequency of the sensor.

## Application Information (continued)

If a ceramic capacitor is used, then a C0G (or NP0) grade dielectric is recommended; the voltage rating should be  $\geq 10$  V. The traces connecting CFA and CFB to the capacitor should be as short as possible to minimize any parasitics.

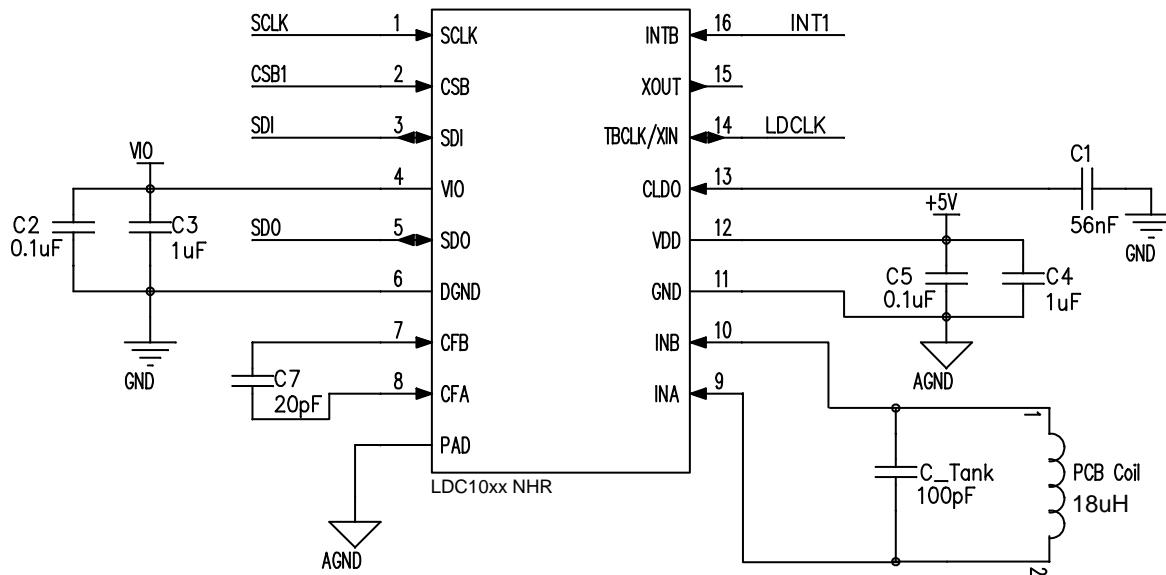
For optimal performance, the chosen filter capacitor, connected between pins CFA and CFB, needs to be as small as possible, but large enough such that the active filter does not saturate. The size of this capacitor depends on the time constant of the sense coil, which is given by  $L/R_S$ , ( $L$ =inductance,  $R_S$ =series resistance of the inductor at oscillation frequency). The larger this time constant, the larger filter capacitor is required. Hence, this time constant reaches its maximum when there is no target present in front of the sensor.

The following procedure can be used to find the optimal filter capacitance:

1. Start with a large filter capacitor. For a ferrite core coil, 10 nF is usually large enough. For an air coil or PCB coil, 100 pF is usually large enough.
2. Power on the LDC1000 and set the desired register values. Minimize the eddy currents losses, by minimizing the amount of conductive target covering the sensor. For an axial sensing application, the target should be at the farthest distance from coil. For a lateral or angular position sensing application, the target coverage of the coil should be minimized.
3. Observe the signal on the CFB pin using a scope. Because this node is very sensitive to capacitive loading, it is recommended to use an active probe. As an alternative, a passive probe with a 1 k $\Omega$  series resistance between the tip and the CFB pin can be used. The time scale of the scope should be set so that 10-100 cycles of the sensor oscillation frequency are visible. For example, if the sensor frequency is 1 MHz, the timescale per division of the oscilloscope should be set to 0.1ms.
4. Vary the values of the filter capacitor until that the signal observed on the CFB pin has an amplitude of approximate 1 V<sub>PP</sub>. This signal scales linearly with the reciprocal of the filter capacitance. For example, if a 100 pF filter capacitor is applied and the signal observed on the CFB pin has a peak-to-peak value of 200 mV, the desired 1 V<sub>PP</sub> value is obtained using a 200 mV / 1 V \* 100 pF = 20 pF filter capacitor.

## 8.2 Typical Application

### 8.2.1 Axial Distance Sensing Using a PCB Sensor With LDC1000



**Figure 17. Typical Application Schematic, LDC1000**

## Typical Application (continued)

### 8.2.1.1 Design Requirements

For this design example, use the following as the input parameters.

**Table 22. Design Parameters**

DESIGN PARAMETER	EXAMPLE VALUE
Minimum sensing distance	1 mm
Maximum sensing distance	7 mm
Sample rate	28 KSPS
Number of PCB layers for sensor	2 layers with 62 mil (1.8mm) PCB thickness
Sensor Diameter	551 mil (14 mm)

### 8.2.1.2 Detailed Design Procedure

#### 8.2.1.2.1 Sensor and Target

In this example, consider a PCB sensor with the below characteristics:

**Table 23. Sensor Characteristics**

PARAMETER	VALUE
Thickness of PCB copper	1 Oz-Cu (35μm)
Coil shape	Circular
Number of turns	23
Trace thickness	4 mil (0.102mm)
Trace spacing	4 mil (0.102mm)
PCB core material	FR4
$R_p$ @ 1 mm target-sensor distance	5 kΩ
$R_p$ @ 7 mm target-sensor distance	12.5 kΩ
Nominal sensor Inductance	18 μH

The target is a stainless steel disk of 15mm diameter and has a thickness of 1mm.

#### 8.2.1.2.2 Calculating Sensor Capacitor

Sensor frequency depends on various factors in the application. For this example, one of the design parameters is a sample rate of 28 KSPS, which requires the sensor frequency as calculated below:

$$SR = \frac{3 \times f_{SENSOR}}{RESPONSE\_TIME} \quad (7)$$

With an LDC1000 RESPONSE\_TIME setting of 384 and output data rate specification of 28 KSPS, the sensor frequency would have to be 3.6 MHz.

Now, using the below formula, the sensor capacitor is calculated to be 108 pF with the sensor inductance of 18 μH. A 100 pF sensor capacitor will slightly increase the sensor frequency to 3.75 MHz, and provide a sample rate of 29.3 KSPS.

$$L = \frac{1}{C \times (2\pi \times f_{SENSOR})^2} \quad (8)$$

As the target interacts with the sensor inductance, the apparent inductance will decrease. When the target is at the 1mm minimum distance for this application, the maximum interaction will occur, and the sensor frequency will increase to 3.95 MHz.

### 8.2.1.2.3 Choosing Filter Capacitor

Using the steps given in [Choosing Filter Capacitor \(CFA and CFB Pins\)](#), the filter capacitor for the example sensor is 20 pF. The waveform below shows the pattern on CFB pin with 100 pF and 20 pF filter capacitor. Notice that the timescale of scope traces is sufficient to view the waveform over many cycles of the sensor oscillation.

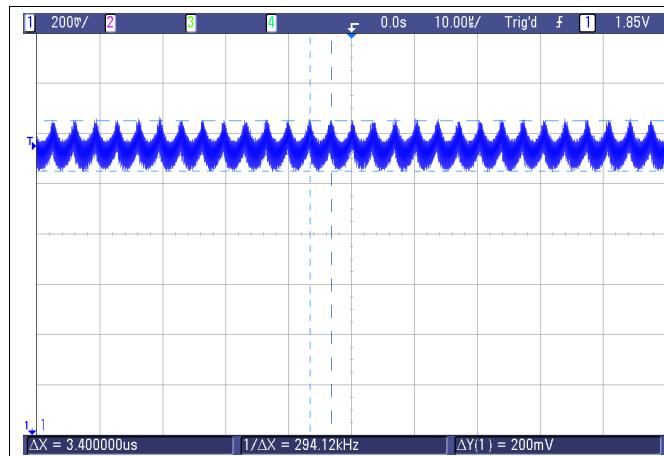


Figure 18. Waveform on CFB With 100 pF

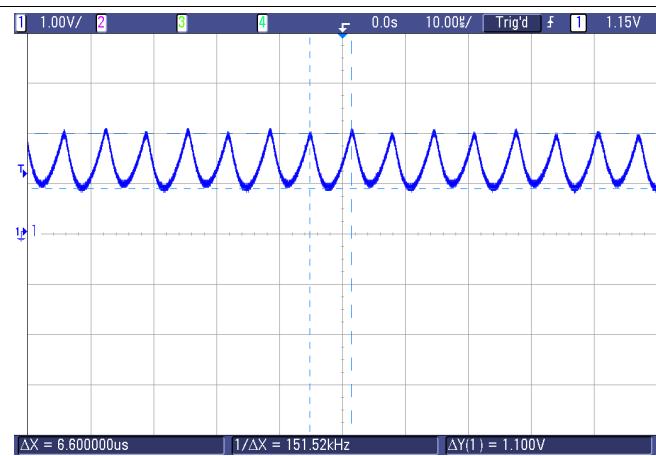


Figure 19. Waveform on CFB With 20 pF

### 8.2.1.2.4 Setting R<sub>P</sub>\_MIN and R<sub>P</sub>\_MAX

Calculating value for R<sub>P</sub>\_MAX Register : R<sub>P</sub> at 8 mm is 12.5 kΩ, 12500×2 = 25000. In [Table 7](#), then 27.704 kΩ is the nearest value larger than 25 kΩ; this corresponds to R<sub>P</sub>\_MAX setting of 0x12.

Calculating value for R<sub>P</sub>\_MIN Register : R<sub>P</sub> at 1mm is 5 kΩ, 5000/2 = 2500. In [Table 6](#), 2.394 kΩ is the nearest value lower than 2.5 kΩ; this corresponds to R<sub>P</sub>\_MIN setting of 0x3B.

### 8.2.1.2.5 Calculating Minimum Sensor Frequency

Using

$$M = 68.94 \times \log_{10} \left( \frac{f_{\text{SENSOR}}}{2500} \right) \quad (9)$$

M is 218.96, which rounds to 219 decimal. This value should be written into Watchdog Timer Register (address 0x03).

The LDC1000 includes a watchdog which monitors the sensor oscillation and flags an error in the STATUS register if no transitions occur on the sensor in a given time window. The time window is controlled by the Min Frequency setting. If the Min Sensor Frequency is programmed for too high a frequency, the watchdog will erroneously indicate that the sensor has stopped oscillating. If the Min Sensor Frequency is set too low, then the LDC1000 will take a longer time to detect if the sensor oscillation has stopped.

### 8.2.1.3 Application Curve



**Figure 20.  $R_P$  vs Distance**

## 9 Power Supply Recommendations

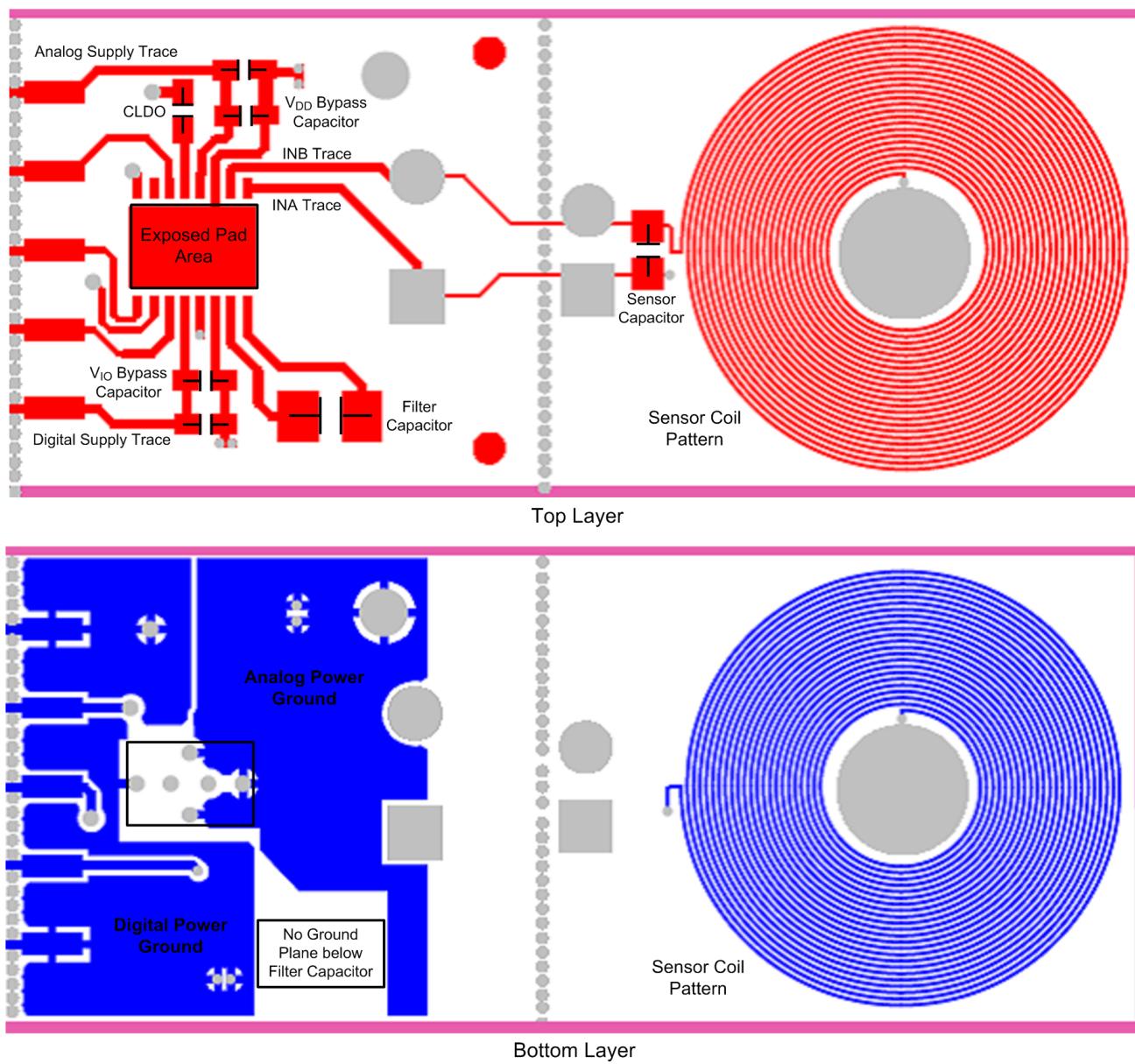
The LDC1000 is designed to operate from an analog supply range of 4.75 V to 5.25 V and digital I/O supply range of 1.8 V to 5.25 V. The analog supply voltage should be greater than or equal to the digital supply voltage for proper operation of the device. The supply voltage should be well regulated. If the supply is located more than a few centimeters from the LDC1000, additional bulk capacitance may be required in addition to the ceramic bypass capacitors. A capacitor with a value of 10  $\mu$ F is usually sufficient.

## 10 Layout

### 10.1 Layout Guidelines

- The VDD and VIO pin should be bypassed to ground with a low ESR ceramic bypass capacitor. The typical recommended bypass capacitance is 0.1  $\mu$ F ceramic with a X5R or X7R dielectric. Some applications may require additional supply bypassing for optimal LDC1000 operation; for these applications the smallest-valued capacitor should be placed closest to the corresponding supply pin.
- The optimum placement is closest to the VDD/VIO and GND/DGND pins of the device. Take care to minimize the loop area formed by the bypass capacitor connection, the VDD/VIO pin, and the GND/DGND pin of the IC. See [Figure 21](#) for a PCB layout example.
- The CLDO pin should be bypassed to digital ground (DGND) with a 56 nF ceramic bypass capacitor.
- The filter capacitor selected for the application using the procedure described in section [Choosing Filter Capacitor \(CFA and CFB Pins\)](#) is connected between CFA and CFB pins. Place the filter capacitor close to the CFA and CFB pins. Do not use any ground or power plane below the capacitor and the trace connecting the capacitor and the CFA /CFB pins.
- Use of separate ground planes for GND and DGND is recommended with a star connection. See [Figure 21](#) for a PCB layout example.
- The sensor capacitor should be a C0G capacitor placed as close as possible to the sensor coil. Refer to [LDC Sensor Design App Note](#) for more details.

## 10.2 Layout Example



**Figure 21. LDC1000 Board Layout**

## 11 器件和文档支持

### 11.1 文档支持（如果适用）

#### 11.1.1 相关文档

应用报告《IC 封装热指标》，[SPRA953](#)

《LDC 传感设计应用笔记》，[SNOA930](#)

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### 11.5 Glossary

[SLYZ022 — TI Glossary.](#)

This glossary lists and explains terms, acronyms, and definitions.

## 12 机械、封装和可订购信息

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DLP® 产品	<a href="http://www.dlp.com">www.dlp.com</a>
DSP - 数字信号处理器	<a href="http://www.ti.com.cn/dsp">www.ti.com.cn/dsp</a>
时钟和计时器	<a href="http://www.ti.com.cn/clockandtimers">www.ti.com.cn/clockandtimers</a>
接口	<a href="http://www.ti.com.cn/interface">www.ti.com.cn/interface</a>
逻辑	<a href="http://www.ti.com.cn/logic">www.ti.com.cn/logic</a>
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Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LDC1000NHRJ	NRND	WSON	NHR	16	4500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LDC1000	
LDC1000NHRR	NRND	WSON	NHR	16	1000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LDC1000	
LDC1000NHRT	NRND	WSON	NHR	16	250	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LDC1000	

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(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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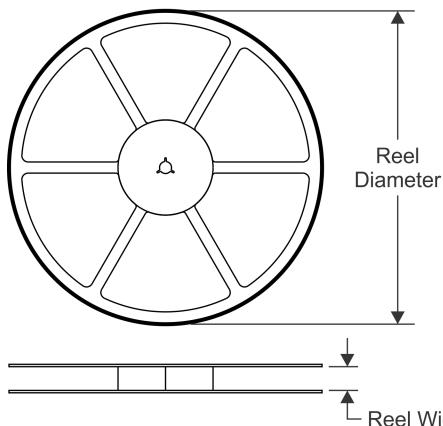
- Automotive: [LDC1000-Q1](#)

NOTE: Qualified Version Definitions:

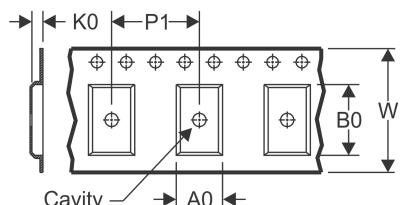
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

## TAPE AND REEL INFORMATION

## REEL DIMENSIONS

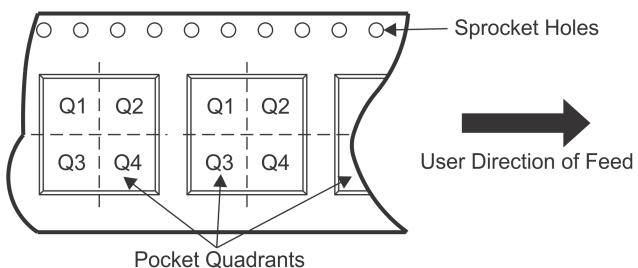


## TAPE DIMENSIONS



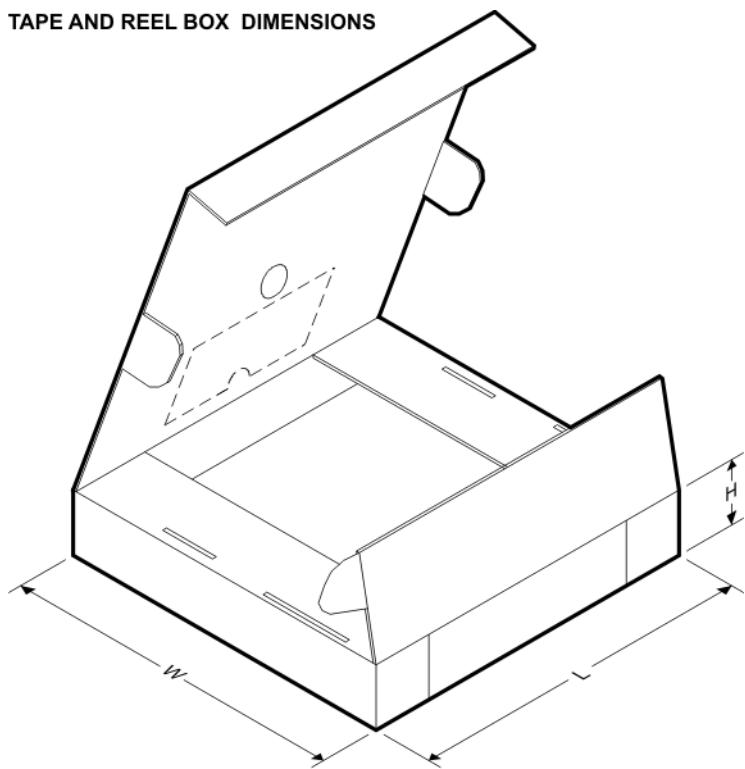
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

## QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



\*All dimensions are nominal

All dimensions are nominal													
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant	
LDC1000NHRJ	WSON	NHR	16	4500	330.0	12.4	4.3	5.3	1.3	8.0	12.0	Q1	
LDC1000NHRR	WSON	NHR	16	1000	178.0	12.4	4.3	5.3	1.3	8.0	12.0	Q1	
LDC1000NHRT	WSON	NHR	16	250	178.0	12.4	4.3	5.3	1.3	8.0	12.0	Q1	

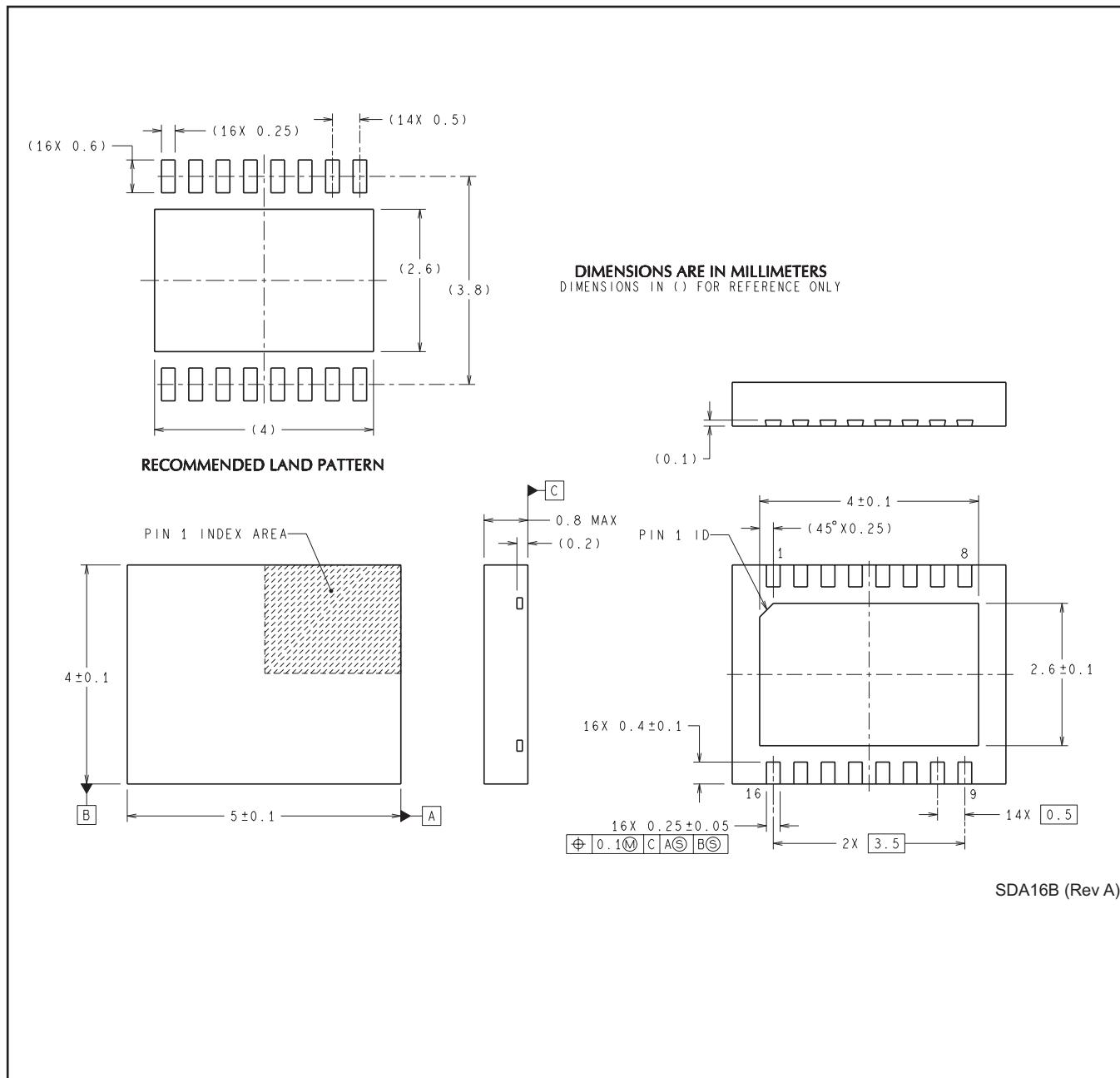
**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LDC1000NHRJ	WSON	NHR	16	4500	367.0	367.0	35.0
LDC1000NHRR	WSON	NHR	16	1000	210.0	185.0	35.0
LDC1000NHRT	WSON	NHR	16	250	210.0	185.0	35.0

## MECHANICAL DATA

NHR0016B



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邮寄地址：上海市浦东新区世纪大道 1568 号中建大厦 32 楼，邮政编码：200122  
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