Application Report
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Performing L Measurements from LDC DRDY Timing

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ABSTRACT

TI's LDC100x and LDC1101 devices measure the resonant frequency of an LC tank to determine the inductance of a sensor. Some applications require higher measurement resolution than the LDC100x or even LDC1101 can provide. With proper configuration of the LDC, an external time measurement device can be used for improved inductance measurement resolution.

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Trademarks

1 Performing L Measurements from LDC DRDY Timing

The LDC100x and LDC1101 can be configured to issue a DRDY pulse when a conversion completes. The conversion time off these LDCs is a function of the sensor frequency:

$$\text{Conversion Time(s)} = \frac{\text{RESPONSE\_TIME}}{3 \times f_{\text{SENSOR}}}$$

where

- f_{SENSOR} is the sensor resonant frequency
- RESPONSE_TIME is the programmed response time in register 0x04 (1)

For example, with a RESPONSE_TIME = 6144 and f_{SENSOR} = 1 MHz, the conversion interval is 2.048 ms. An LDC100x with a reference frequency of 8 MHz has an L conversion output code of 16384.

The timing resolution is $1/f_{\text{REFERENCE}}$. A higher reference frequency corresponds to a higher timing resolution.

Table 1. Timing Resolution

	LDC100x	LDC1101
Maximum Reference Frequency	8 MHz	16 MHz
Best timing resolution	125 ns	62.5 ns

When the LDC is configured to report DRDY (for the LDC100x, register 0x0A:bits[2:0] = b'100, for the LDC1101, register 0x0A = 0x84), the LDC asserts the INTB signal on the completion of each conversion.

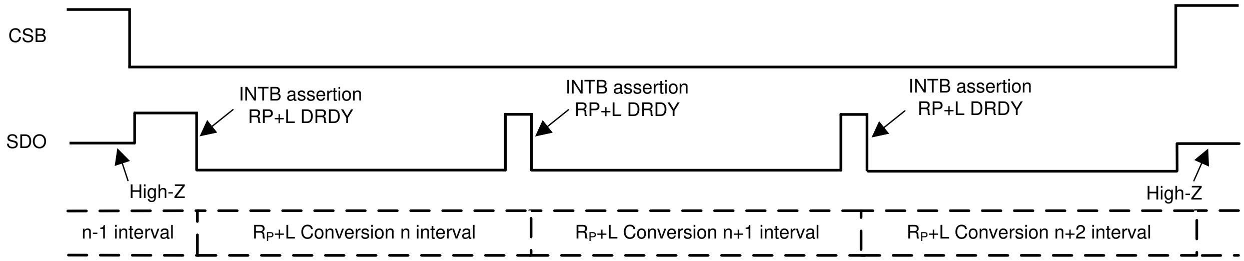

Figure 1. LDC1101 DRDY Signal Output on SDO Pin

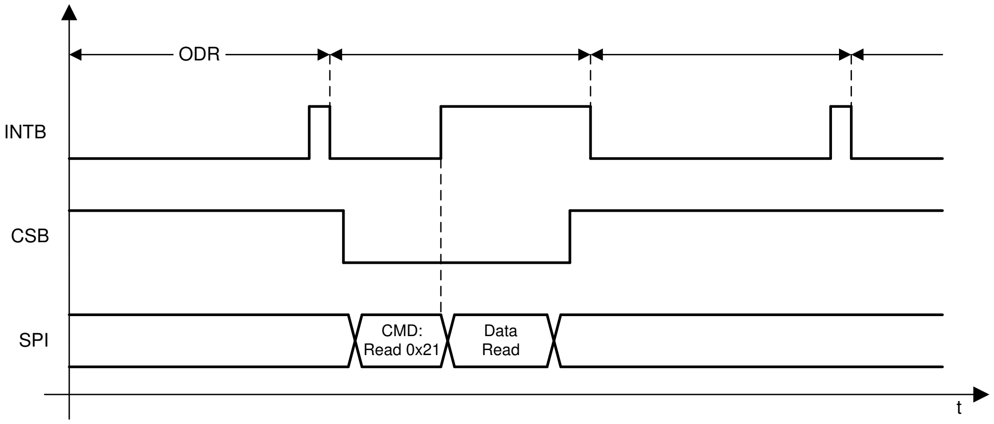

Figure 2. LDC100x DRDY Signal Output on INTB Pin

The time between successive DRDY assertions correspond to the conversion interval, which is a function of the sensor frequency. Directly measuring the time between DRDY assertions can actually be used to accurately measure the sensor frequency.

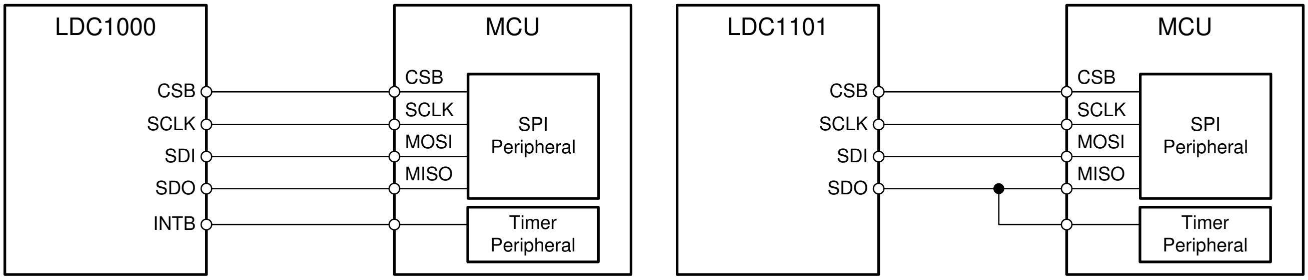

Figure 3. MCU Connections

Many MCUs have a timing peripheral which can measure events to a higher resolution than provided by the LDC. In addition, some MCU timer peripherals can be configured to measure the interval between several pulses; this can be used to measure the sensor frequency over a longer interval than the LDC can be configured to. When measuring frequency, longer measurement intervals can provide a higher resolution measurement.

Measuring the time between DRDY assertions can therefore be used to determine the sensor frequency by:

$$f_{\text{SENSOR}} = \frac{\#\text{pulses} \times \text{RESPONSE\_TIME}}{3 \times \text{MCU\_Measured\_time}}$$

where

- f_{SENSOR} is the sensor resonant frequency
- RESPONSE_TIME is the programmed response time in register 0x04
- #pulses is the number of DRDY assertions that have occurred (2)

For example, if four DRDY assertions were measured over a duration of 3.75 ms when the LDC is configured with a RESPONSE_TIME of 6144, then the sensor frequency is 2.185 MHz.

For many applications, computing the actual sensor frequency is usually not necessary to determining the target position; usually the equation of interest is the application specific equation:

$$\text{position}_{\text{target}} = f(\text{output\_code}) \quad (3)$$

In this case, the output_code is the MCU_Measured_time.

Also, it may be necessary for some MCUs to manage the timer peripheral interrupt servicing to ensure that another ISR does not affect the sensor frequency measurement.

2 Other Timing Measurement Approaches

An LDC can be connected to a TDC7200 for even higher resolution inductance measurements – up to 50 ps timestamp resolution. In this arrangement, the TDC7200 is set to MODE2, and the START input is connected to an MCU GPIO, which is used to initiate a measurement.

The LDC100x is configured to output DRDYB pulses on the INTB pin by setting register 0x0A to 0x04. The TDC7200 is configured to timestamp when it gets a falling edge on the STOP pin.

The LDC100x has its INTB pin connected to the TDC7200 STOP pin, while the LDC1101 has its SDO pin connected to the TDC7200 STOP pin.

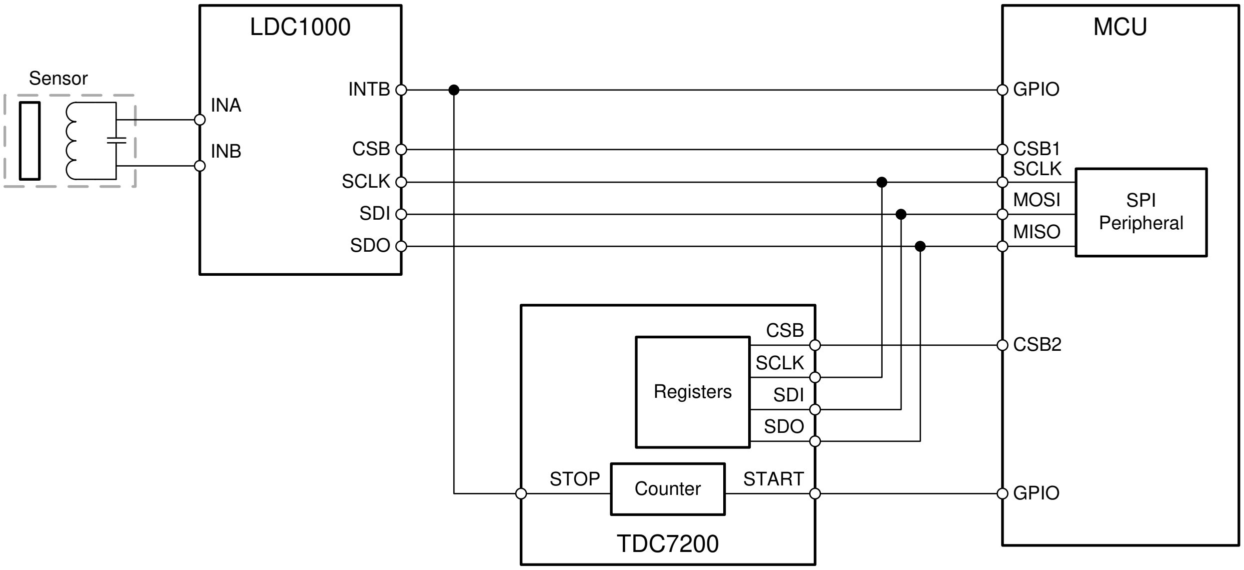

Figure 4. LDC100x and TDC7200 Connections

When a high-resolution L measurement is desired, the LDC100x is enabled, and the MCU sends a START pulse to the TDC7200. Note that the MCU needs to ensure that t1 is at least 250 ns, so it monitors the INTB pin and only sends the START pulse at a permitted time. After five conversion cycles of the LDC, the TDC7200 timestamps are read back.

The sensor frequency is then: f_{SENSOR} = RESPONSE_TIME/ 12*(t5-t1)

Where tX are the timestamps indicated in Figure 5. Alternatively, users can calculate the frequency for each tX-tX-1 and average the four measurements. Using a lower value for the LDC RESPONSE_TIME setting is acceptable.

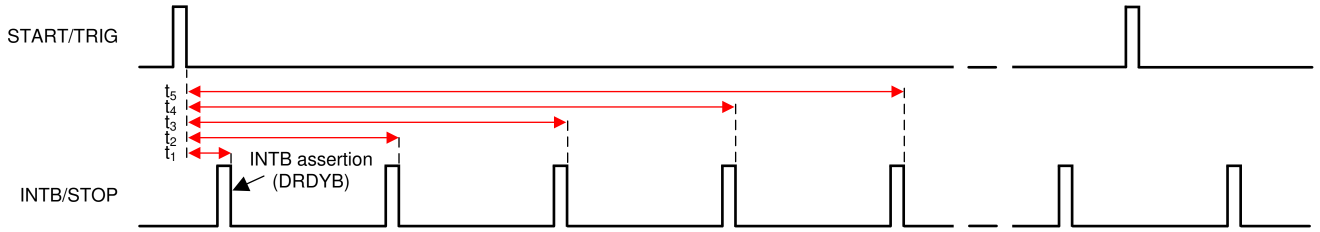

Figure 5. Timing Diagram

The TDC7200 has a maximum measurement time of 8 ms with an 8-MHz reference when using Mode 2. This introduces a limitation for the minimum sensor frequency based on the device configuration, as listed in Table 1.

Table 2. Minimum LDC Sensor Frequency for Various LDC and TDC Configurations

LDC RESPONSE_TIME	**192**	**384**	**768**	**1536**	**3072**	**6144**
5 TDC Stop Events	32 kHz	64 kHz	128 kHz	256 kHz	512 kHz	1.024 MHz
4 TDC Stop Events	24 kHz	48 kHz	96 kHz	192 kHz	384 kHz	768 kHz
3 TDC Stop Events	16 kHz	32 kHz	64 kHz	128 kHz	256 kHz	512 kHz
2 TDC Stop Events	8 kHz	16 kHz	32 kHz	64 kHz	128 kHz	256 kHz

3 Use with the LDC1101

For the LDC1101, this technique is often not necessary, as the LDC1101 supports a 16-MHz reference clock versus the 8-MHz reference on the LDC100x. In addition, the LDC1101's LHR (High-resolution inductance mode) measurements have an effective reference frequency of 32 MHz (when the external reference frequency is set to the maximum supported 16MHz).

4 Circuit Implementation Recommendations

If the TBCLK pin (the CLKIN pin for the LDC1101) is not used, it must be grounded.

For the LDC1101, it is recommended to use the L-only measurement mode, which is detailed in the LDC1101 data sheet.

Because the INTB signal is being used to directly measure the sensor frequency, the schematic and layout of this trace must be designed to maintain signal integrity. The trace must have a continuous ground plane underneath to maintain constant impedance. Minimize the number of vias and minimize the parasitic capacitance on the INTB (or SDO pin for the LDC1101) for the highest slew rate.

If the DRDYB signal is routed to both the TDC7200 and an MCU, route the trace as a continuous path rather than splitting the trace as a Y connection.

5 Summary

Some LDC applications require higher resolution than the reference frequency of the LDC can provide. Using an external time measurement device is one method to consider.

Revision History

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

Changes from Original (November 2015) to A Revision	Page
• Changed LDC1000 to LDC100x throughout	1
• Updated app report for clarity throughout	1

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