Application Report
SNOA956–January 2017

LDC0851 – Troubleshooting : Identifying and Fixing Common Setup Issues

ABSTRACT

The LDC0851 is a simple differential inductive switch with a push-pull output that does not require digital programming. LDC0851's unique approach to inductive sensing enables simple and low cost system designs. The LDC0851 stands apart from other LDC devices by being easy to use and solving system level issues like temperature drift.

Unlike other LDC devices, the LDC0851 does not have a digital programming interface, this makes configuring the device a breeze but it limits LDC0851's error reporting abilities. This application report will walk through the steps of identifying and solving setup issues when designing an inductive sensing system with the LDC0851.

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1 LDC0851 Series LC Configuration

LDC0851's unique series LC configuration enables a truly differential inductance measurement. The series LC tank configuration is shown in Figure 1:

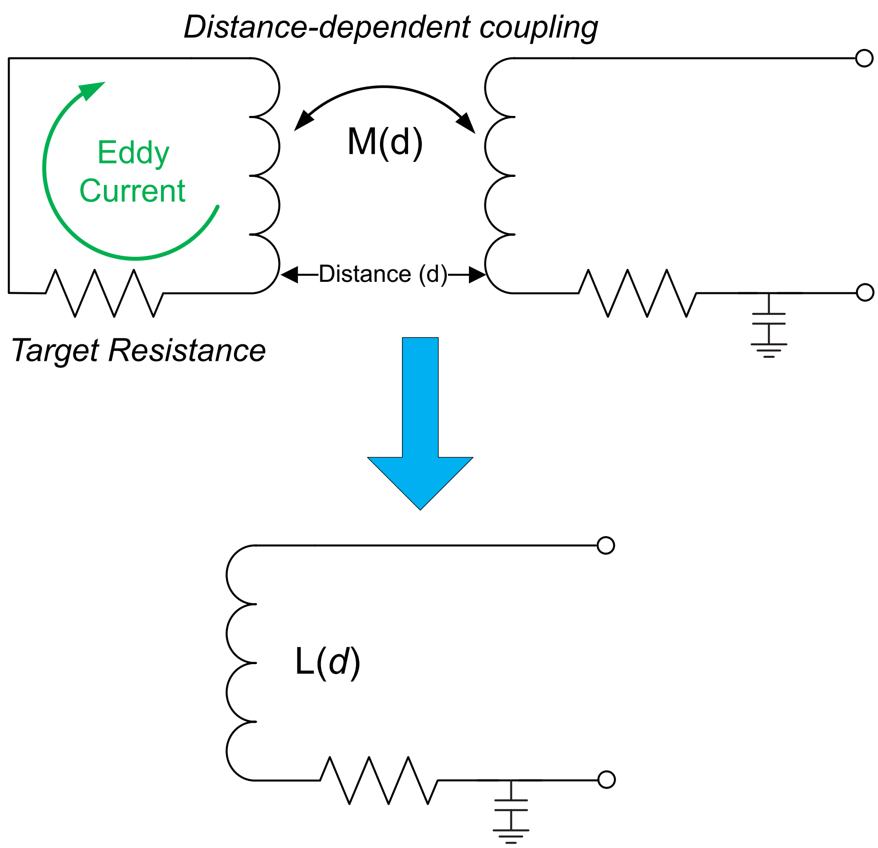


Figure 1. Series LC Configuration in the LDC0851

The series LC configuration uses a shared fixed sensor capacitor for both the sensor tanks resulting in extremely temperature stable measurements.

LDC0851's series LC tank configuration results in a sensor resonant frequency different from all other LDC devices. The sensor resonant frequency for the LDC0851 is given by Equation 1:

$$f_{SENSOR} = \left(\frac{1}{2\pi}\right) \times \sqrt{\frac{2}{L \times C}} \quad (1)$$

The next sections highlight common setup mistakes while working with the LDC0851.

2 Sensor Faults

A sensor fault is a scenario when either one or both of the sensors are disconnected or shorted together.

A sensor fault results in a HIGH signal on the output pin that is unresponsive to proximity events. It is important, however, to remember that the LDC0851 has a normally high output, that is, in addition to the part's output (OUT, Pin 8) staying HIGH in case of a sensor fault it stays high if the part is disabled or if the sense channel inductance is higher than that of the reference channel.

Because a HIGH output on the LDC0851 is not an exclusive indicator of a sensor fault a sure shot method to detect a sensor fault is by probing LSENSE and LREF with respect to ground using an oscilloscope. Scope shots of LREF and LSENSE pins during a sensor fault condition are shown in Figure 2 and Figure 3. For comparison, scope shots of LREF and LSENSE pins during normal operation are shown in Figure 6.

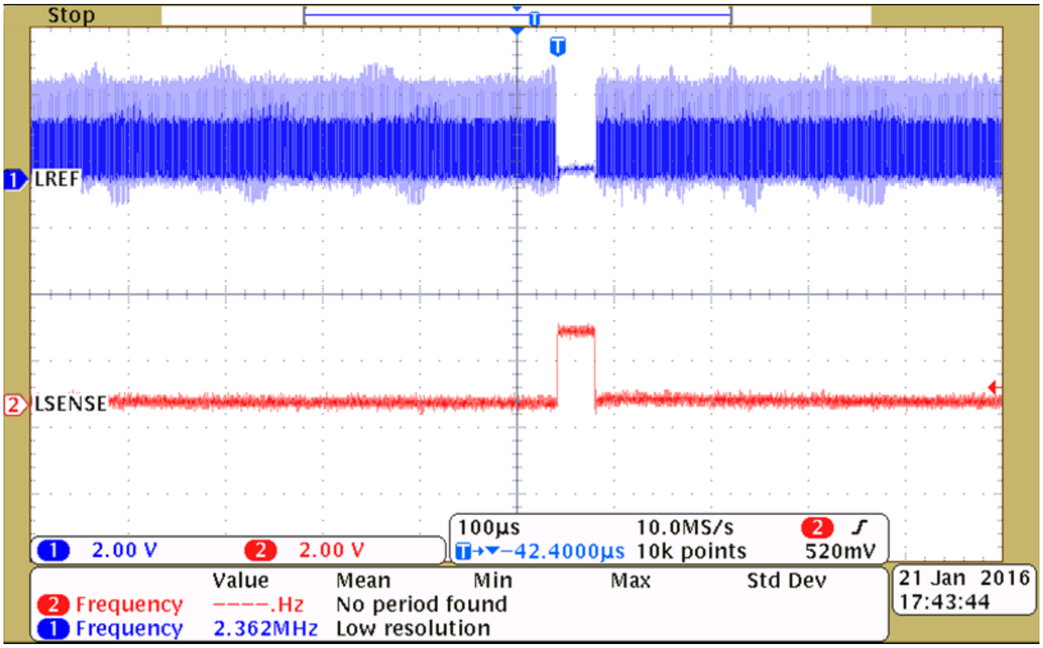


Figure 2. LSENSE Disconnected

LDC0851's sensing cycle starts with sweeping the reference channel first and then moves on to the sense channel. Figure 2 above shows a scenario where the sense channel is disconnected. The scope shot shows continuous sweeps on LREF channel instead of the two sensing channels being muxed. In the scenario shown in Figure 2, the LDC0851 successfully swept the reference channel but detected a fault on the sense channel and restarted the sensing cycle.

Figure 3 shows a scenario where the LREF sensor experienced a sensor fault.

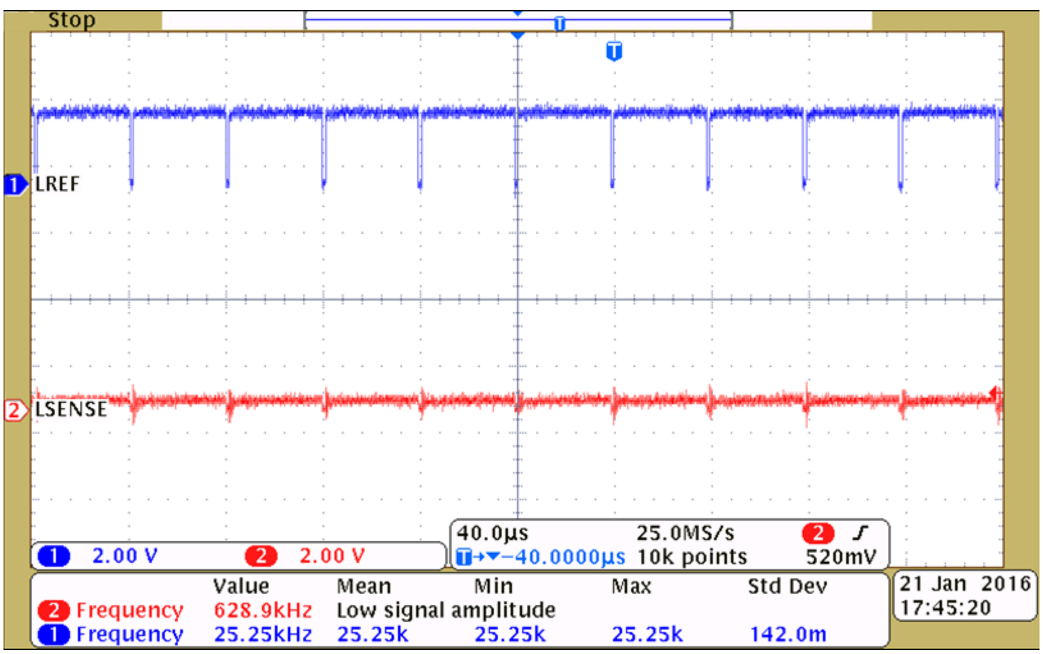


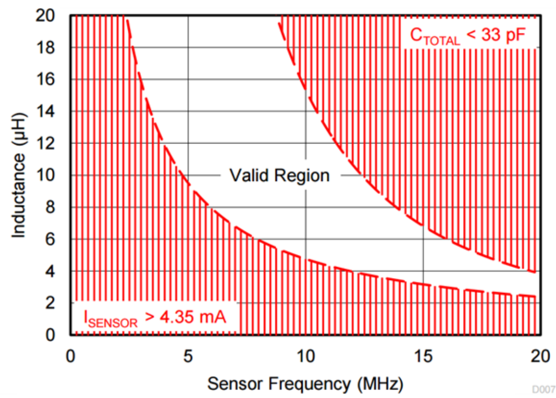
Figure 3. LREF Disconnected

In Figure 3, the LDC0851 is constantly trying to drive the LREF channel but because a sensor fault was detected it never switched to driving the LSENSE channel and restarted the sensing cycle.

Another easy way to recognize sensor faults on the LREF channel is if the LDC0851's dynamic power consumption is negligible. Dynamic Current or Idyn can be calculated by following the steps in *Active Mode* section of the *LDC0851 1.8-3.3V Inductive Switch* data sheet (SNOSCZ7).

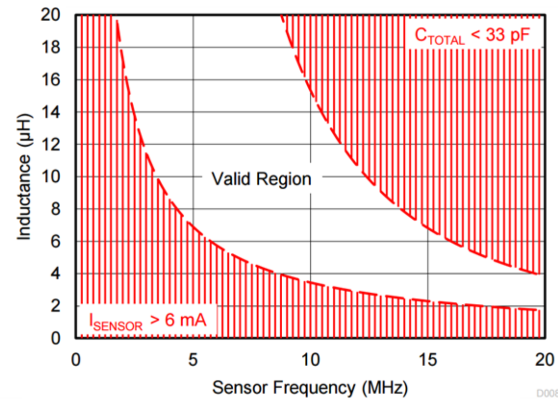
3 Incompatible Sensor

Incompatible sensors use coils with inductance values too low or use fixed sensor capacitors on LCOM with capacitance either too low or high. Sensor inductance and capacitance are limited by the LDC0851's design space shown in Figure 4 and Figure 5:



I_{SENSOR_MAX} = 4.35 mA
Specified for closest target proximity or minimum inductance in the application.

Figure 4. LDC0851 Sensor Design Space for VDD = 1.8 V



I_{SENSOR_MAX} = 6 mA
Specified for closest target proximity or minimum inductance in the application.

Figure 5. LDC0851 Sensor Design Space for VDD = 3.3 V

The LDC0851 may stay in an unresponsive constant HIGH or LOW (OUT, Pin 8) state when the sensor connected falls outside the design space.

A compatible sensor, one within the LDC0851's design space will show the following nominal behavior on LSENSE and LREF (Figure 6):

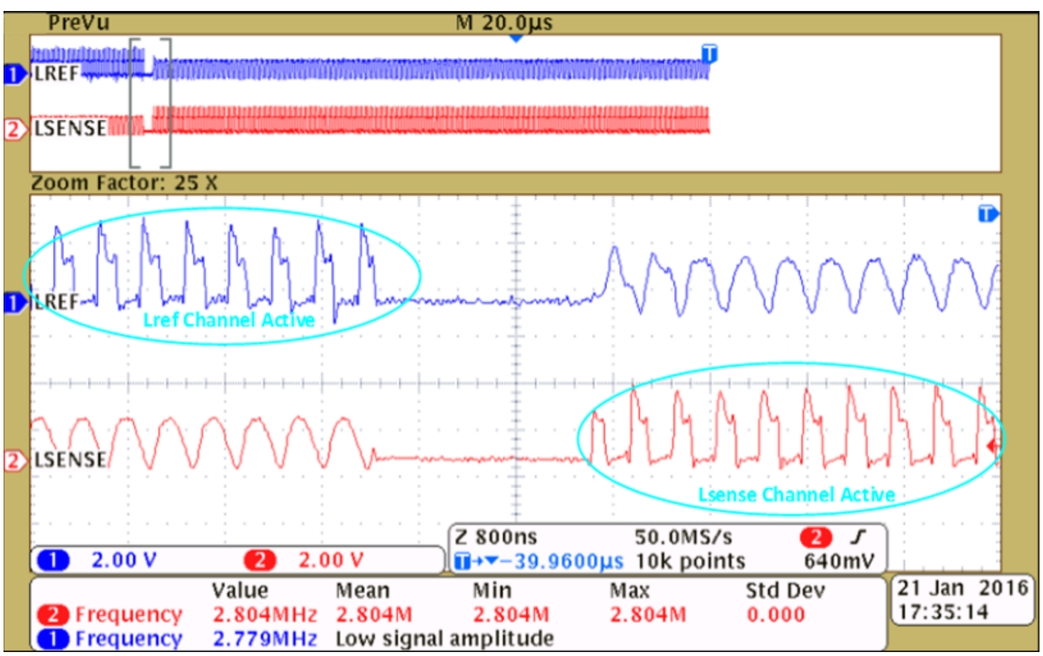


Figure 6. Nominal Waveform, Compatible Sensor

A key thing to note in Figure 6 is that the active waveforms on both the sensing channels roughly resemble a square wave and the sensor resonant frequency is below the typical maximum sensor resonant frequency specified in the datasheet electrical table. An active sensing waveform that resembles a square wave indicates that the sensor connected is well within design space of the LDC0851.

Figure 7 shows a scenario of an incompatible sensor where the sensor inductance is too low.

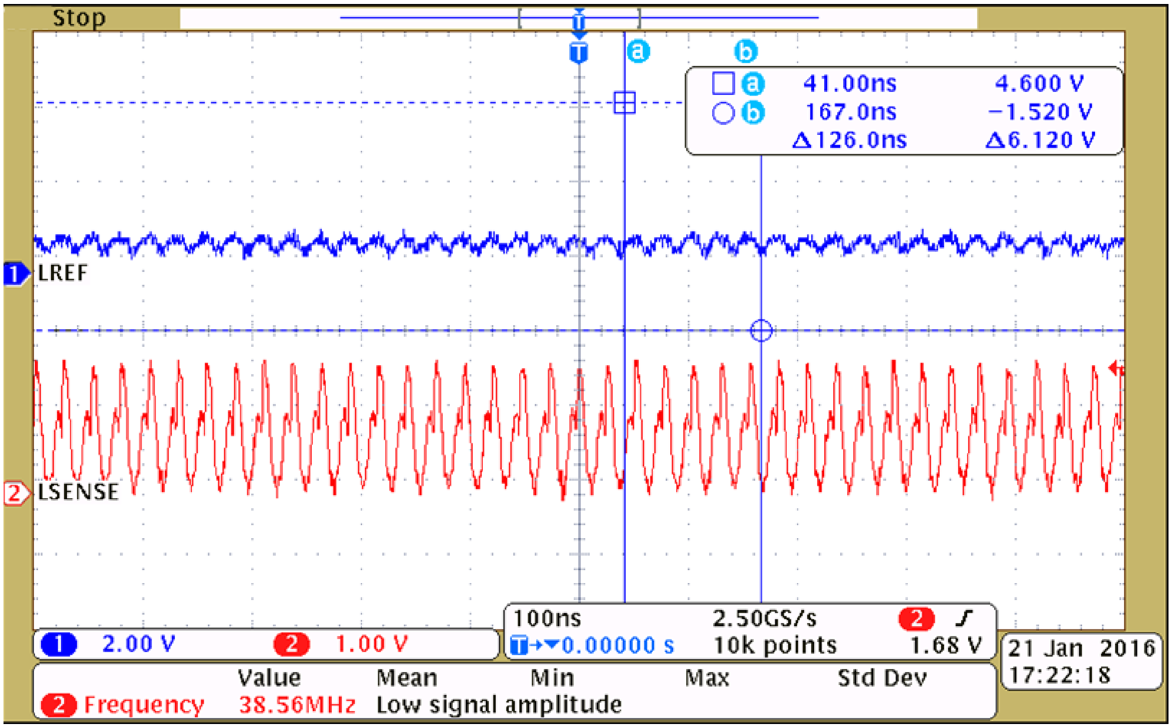


Figure 7. Incompatible Sensor, Sensor Inductance Too Low

The important thing to observe in Figure 7 above is the sensor resonating frequency and shape of the resonating waveform. At 39MHz the Sense sensor is resonating at well beyond the data sheet maximum resonant frequency specification of 19 MHz. In addition to the abnormally high resonating frequency, the shape of the resonating waveform deviates from resembling a square wave to a sinusoidal signal.

Another example of an incompatible sensor configuration is when the sensor capacitor connected is too high. Scope shots of waveforms on LSENSE and LREF in when the sensor capacitance is too high is shown in Figure 8:

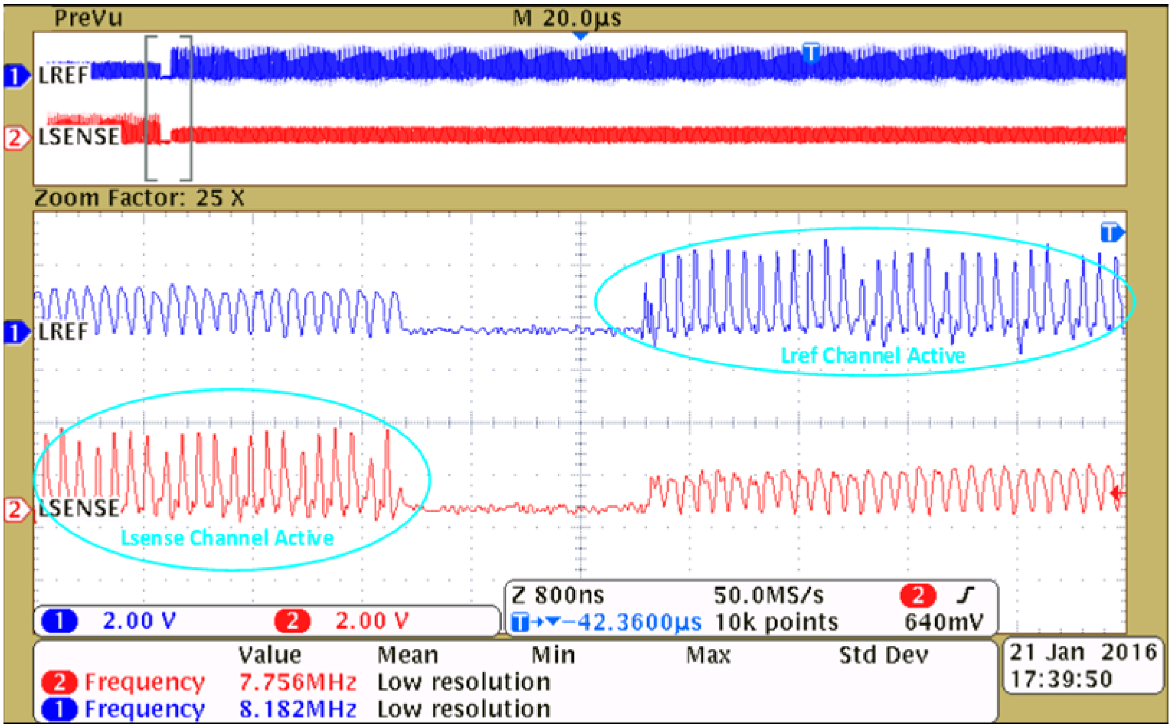


Figure 8. Figure 8: Sensor Capacitance Too High

In the example shown in Figure 8, the resonating waveforms on LSENSE or LREF are almost sinusoidal and very different from the square waveform shown in Figure 6 for a nominal compatible sensor.

For designing sensors that fit the LDC0851 design space and meet the system's sensing needs, refer to the *Number of Turns* and *Multiple Layers* sections in the *LDC Sensor Design* application note (SNOA930).

4 Incorrect Sensor Layout

Stacked coils provide a compact footprint for applications with space constraints. Recommended coil orientation and polarity for stacked coil configuration is shown in Figure 9:

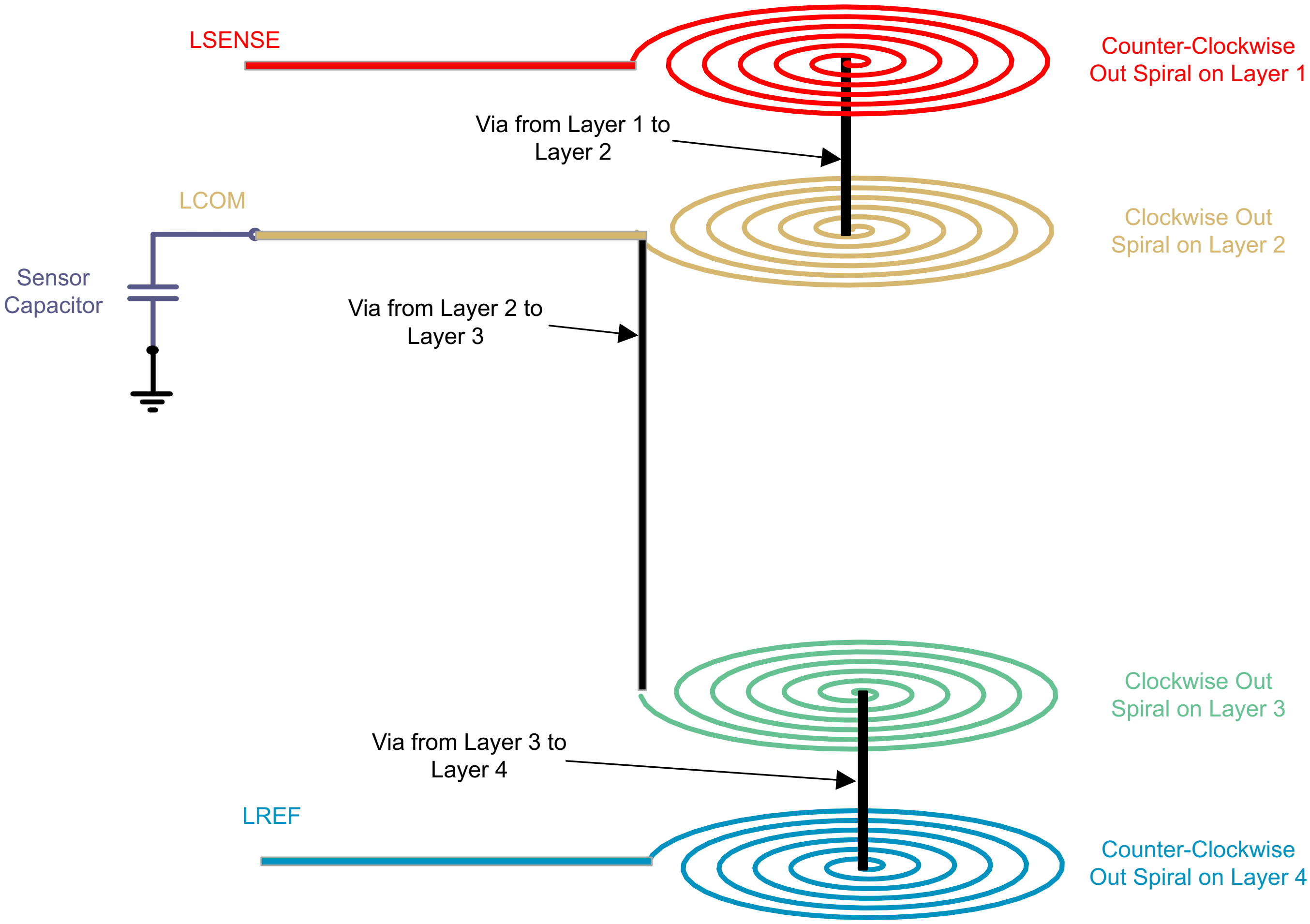


Figure 9. Recommended Stacked Coil Configuration

Incorrectly oriented stacked coils will result in the electromagnetic coupling of the active and inactive channels resulting in erroneous LDC0851 behavior. Incorrectly oriented coils show the following signature behavior:

- Inverted OUT pin behavior, OUT pin stays low when a conductive target is absent but turns HIGH when a conductive target is present.
- Decreased sensing range.
- Resonating frequency that does not follow results from Equation 1.

5 Unresponsive or Incorrect ADJ Code

The ADJ pin on the LDC0851 is used to choose the operating mode and switching distance of the device. The ADJ pin is only sampled during the disable to active mode transition period.

NOTE: It is important to remember that the enable pin needs to be toggled every time a new voltage level corresponding to a new ADJ code is set on the ADJ pin, power cycling the part will obtain the same result.

The approximate switching distance of the LDC0851 in Threshold Adjust Mode is given by Equation 2:

$$d_{switch} = d_{coil} \times n \times \left(1 - \frac{\zeta}{16}\right)$$

where

- dswitch = Switching Distance
- dcoil = Coil Diameter
- ζ = *ADJ code* ($\zeta 1 <= \zeta < 16$)
- n = 0.3 for stacked coil configuration and 0.4 for side by side coil configuration (2)

If the switching distance does not line up with Equation 2 ensure that the voltage level on the ADJ pin matches that given by Equation 3:

$$ADJ_{LEVEL} = \frac{V_{DD}}{32}(\zeta + 1) \quad (3)$$

NOTE: The ADJ level can only be measured at the source and when the ADJ pin is disconnected from it. A voltage meter measuring the ADJ level at the ADJ pin will show incorrect results due to internal circuitry of the device.

In use cases where the enable pin (EN) is tied to VDD, LDC0851 may register an incorrect ADJ code in the case of a slow ramping power supply (ramp rate slower than 4.2 mV/µs). A RC low pass filter can be added to the EN pin in this situation to rectify the problem; this procedure is explained in detail in the *Power Supply Recommendations* section of the *LDC0851 1.8-3.3V Inductive Switch* (SNOSCZ7).

If the ADJ control is still unresponsive ensure that there are no sensor faults and that the sensor falls within LDC0851's design space. Sensor faults were covered in Section 2.

6 Conclusion

This Application Report outlined debugging strategies for common setup issue while working with the LDC0851. The report provided detailed steps for identifying issues in a LDC0851 sensing system and suggested quick fixes.

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