

# How You Can Use the LDC Racetrack Inductor Designer Tool



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In my previous post, I introduced the LDC calculator tool, which you can download [here](#). It can calculate a number of useful parameters for an Inductive Sensing application.

LDC devices use inductors to sense the movement of conductive targets. At TI, we commonly use spiral traces routed on a printed circuit board (PCB) to form sensing inductors. [WEBENCH® Coil Designer](#) is a useful online tool that can help you design a sensor inductor and also generate a layout.

The racetrack inductor designer tool is another useful designer in the LDC tools spreadsheet. While the racetrack inductor designer only calculates sensor parameters and does not generate a layout, it is quick to use. Simply click Racetrack Inductor Designer on the Contents tab of the LDC calculator tool, or click the Racetrack\_Inductor\_Designer tab, as shown in [Figure 1](#). You'll wind up on the tab shown in [Figure 2](#).

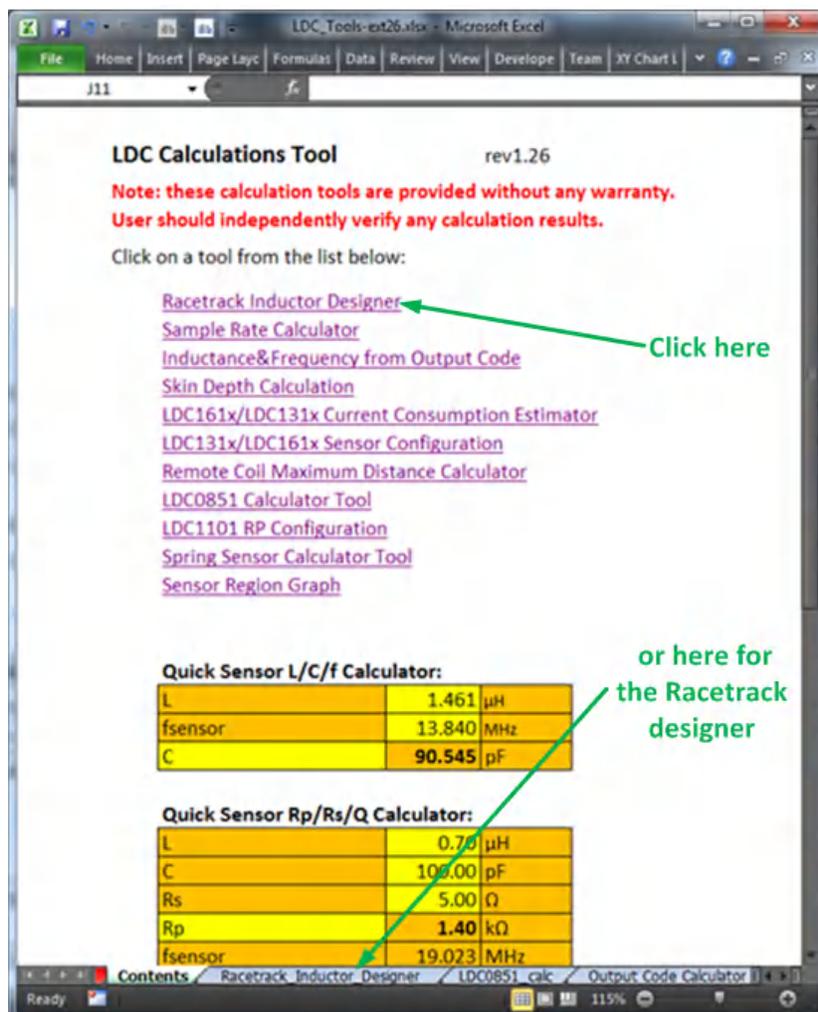
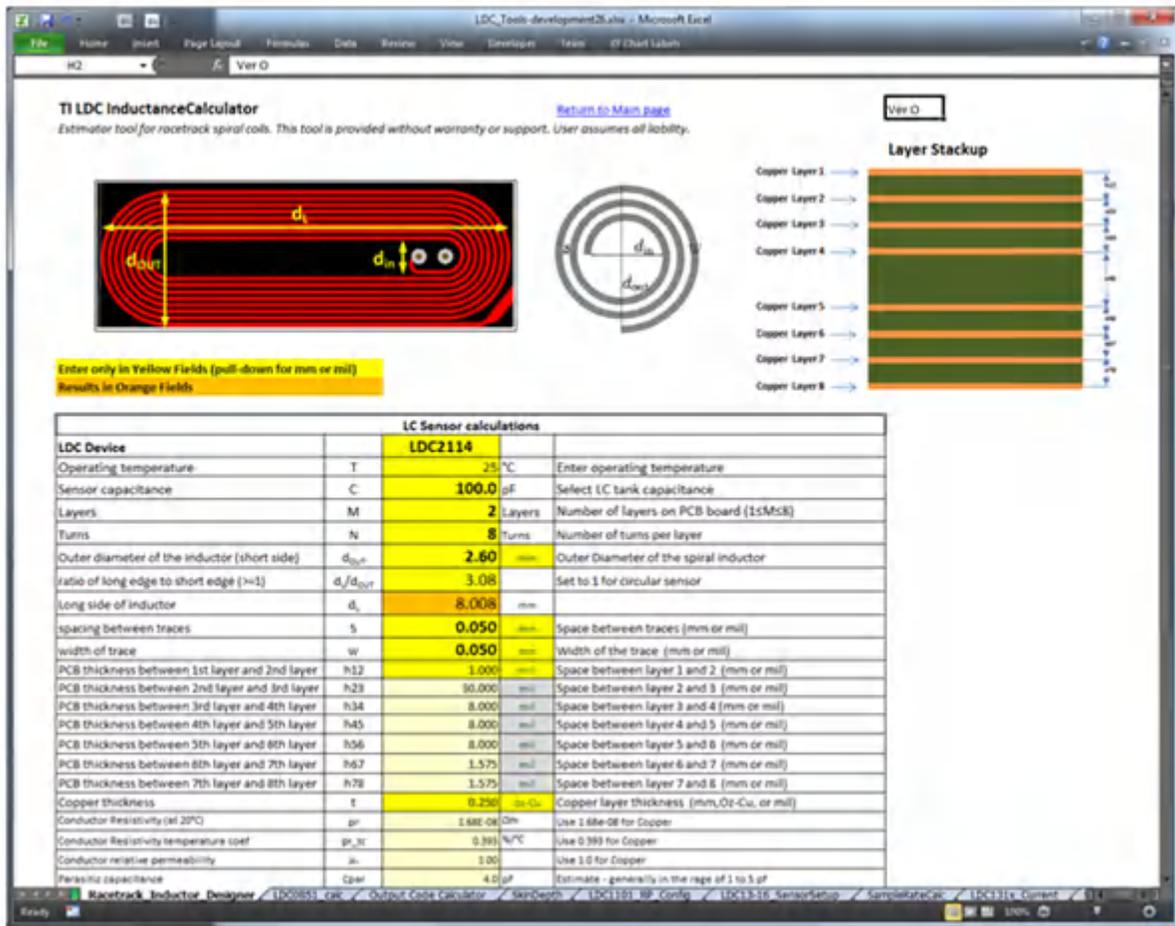


Figure 1. Accessing the Racetrack Inductor Designer



**Figure 2. Racetrack Coil Designer Tool**

The LDC calculator tool is pretty accurate – typically a physical sensor will be within 10% of the calculations. For racetrack-shaped sensors, however, the accuracy may degrade when the ratio of the long side to the short side is greater than 4.

The first step in the process to design a sensor is to determine the PCB manufacturing limitations. [Table 1](#) shows an example of limits from one PCB manufacturer.

**Table 1. Sensor Fabrication Parameters**

Sensor Parameter	Value	Comments
PCB minimum trace width/space	0.125 mm (5 mil)	Fabrication limitation
Via minimum pad size	0.6 mm (24 mil)	Fabrication limitation
Via minimum hole size	0.25 mm (10 mil)	Fabrication limitation
Sensor minimum inner diameter	0.825 mm (21 mil)	0.6 mm + 2 × 0.125 mm One via pad + two trace spaces
Stack-up thickness between layers	0.80 mm (32 mil)	Desired PCB thickness
Copper thickness	0.5-1.0 oz-Cu	

You now need to know a few system limitations – what is the maximum possible size of the sensor, and how close the target can be to the sensor. I've summarized the values for an example system in [Table 2](#).

**Table 2. Sensor Parameters**

Sensor Parameter	Value	Comments
Maximum sensor diameter	9mm (315mil)	Mechanical constraint
Target closest distance	1.8mm	Based on system mechanicals

For this example, I will use the LDC1612 and comply with the limitations from [Table 1](#) and [Table 2](#). [Figure 3](#) shows the calculating region of the racetrack coil designer. I placed a number to the left of each parameter so you can follow me as I walk through each setting below.

LC Sensor calculations			
<b>1</b>	<b>LDC Device</b>		<b>LDC1612/4</b>
	Operating temperature	T	25 °C
<b>10</b>	Sensor capacitance	C	<b>550.0</b> pF
<b>5</b>	Layers	M	<b>2</b> Layers
<b>8</b>	Turns	N	<b>11</b> Turns
<b>6</b>	Outer diameter of the inductor (short side)	$d_{OUT}$	<b>7.00</b> mm
<b>7</b>	ratio of long edge to short edge ( $\geq 1$ )	$d_L/d_{OUT}$	<b>1.00</b>
	Long side of inductor	$d_L$	<b>7.000</b> mm
<b>2</b>	spacing between traces	S	<b>5.000</b> mil
	width of trace	w	<b>5.000</b> mil
<b>3</b>	PCB thickness between 1st layer and 2nd layer	h12	32.000 mil
	PCB thickness between 2nd layer and 3rd layer	h23	30.000 mil
<b>4</b>	Copper thickness	t	1.000 oz-Cu
	Coil Fill Ratio	$d_{in}/d_{out}$	<b>0.20</b>
	Inductor inner diameter	$d_{in}$	<b>1.412</b> mm
	Self inductance per layer	L	0.447 $\mu$ H
	<b>Total Inductance with no target</b>	$L_{TOTAL}$	<b>1.415</b> $\mu$ H
	<b>Sensor Operating Frequency no target</b>	$f_{RES}$	<b>5.683</b> MHz
	<b>Rp with no Target</b>	$R_p$	<b>1.29</b> k $\Omega$
	Q factor	Q	<b>25.35</b>
	Self resonant frequency (estimated)	SRF	66.887 MHz
<b>9</b>	<b>Target Distance</b>	D	<b>0.500</b> mm
	<b>Sensor Inductance from Target Interaction</b>	$L'$	<b>0.665</b> $\mu$ H
	<b>Sensor Frequency with Target Interaction</b>	$f_{RES}'$	<b>8.325</b> MHz
	<b>Rp with Target Interaction</b>	$R_p'$	<b>0.55</b> k $\Omega$
	<b>Q Factor with target</b>	$Q'$	<b>15.7</b>

**Figure 3. Sequence to Enter Parameters**

Next, follow these steps to calculate a basic sensor design:

1. Select the appropriate LDC device – for this application, the LDC1612/4 (the LDC1612 and LDC1614 share the same limitations on sensor drive).
2. Set the spacing between traces and the width of traces to the 0.125 mm (5 mil) manufacturer’s minimum.
3. Set the spacing between layers to 32 mil.
4. Use 1oz-CU, which is the thickest copper available, for better performance.
5. Set the number of layers – usually two or four. Since this PCB is going to be two layers, set the number of layers to two.
6. Enter the outer diameter of the inductor – 9mm is the maximum size for this example.
7. Set the ratio to 1.0 for a circular-shaped sensor. Values larger than 1 will have a racetrack shape. The racetrack shape has higher inductance but a lower Q than a circular sensor. For many applications like Metal Touch buttons, a racetrack shape fits the available area better and enables smaller buttons than a circular sensor.
8. Set the number of turns. If you set it to more than 16 turns, you will be below the minimum inner diameter of 0.825mm from [Table 1](#). If you set the number of turns to 13, the coil fill ratio is close to the optimum value of ~0.3. (The 0.3 coil fill ratio is optimal for most applications, although Metal Touch applications perform better with lower values.)
9. Calculate the effect of the target on the sensor by setting the distance to the target. Set the target distance to 1.80mm, which is the spacing between the sensor and the metal surface.
10. Adjust the sensor capacitor so that  $f_{RES}$ ,  $R_P$ , and  $Q$  are within the LDC1614’s design space constraints. The calculator tool will indicate any parameters that are outside the design space with a red warning label on the appropriate parameter, as shown in [Figure 4](#).

Target Distance	D	1.800 mm	For aluminum target of at least 5 skin depths
Sensor Inductance from Target Interaction	$L'$	2.291 $\mu$ H	
Sensor Frequency with Target Interaction	$f_{RES}'$	10.027 MHz	fsensor is too high - increase L or C
Rp with Target Interaction	$R_p'$	5.57 k $\Omega$	
Q Factor with target	Q'	38.6	

**Figure 4. Example Error Warning Generated by the Calculator Tool**

After entering your numbers, you may need to adjust the number of turns or the sensor capacitance. After trying several settings, I wound up with the values shown in [Table 3](#). I chose 130 pF for the sensor capacitor so that I could safely use a 10% tolerance part.

**Table 3. Resulting Parameters**

Sensor Parameter	Value
Sensor capacitance	130 pF
Layers	2
Turns	14
Outer diameter	9.0 mm
Ratio of long edge to short edge	1
Spacing between traces	5 mil
Width of trace	5 mil
PCB thickness	32 mil
Copper thickness	1.0 oz-Cu

Because the sensor’s electrical parameters change when the target is close, you need to verify that the sensor is still within the valid operating range of the LDC when this occurs. With the closest target distance of 1.8 mm, my sensor has the electrical specifications shown in [Table 4](#), which are within the LDC1614’s operating region.

**Table 4. Sensor Parameters Due to Target Interaction**

Sensor Inductance from Target Interaction	$L'$	<b>2.380<math>\mu</math>H</b>
Sensor Frequency with Target Interaction	$f_{RES}'$	<b>9.049MHz</b>
Rp with Target Interaction	$R_P'$	<b>4.90k<math>\Omega</math></b>
Q Factor with Target	$Q'$	<b>36.3</b>

The LDC tool spreadsheet has a lot more uses. In my next post, I’ll review the LDC0851 calculator tab.

### Additional Resources

- Check out the [“Sensor Design for Inductive Sensing Applications Using LDC”](#).
- To learn more about metal touch applications, download the [“Inductive Sensing Touch-On-Metal Buttons Design Guide.”](#)
- Read other [inductive sensing blog posts](#).

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