Inductance Calulation of Different Shapes

This sheet is used to design planar spiral inductors used on RFICs.

The expressions are from this paper in the IEEE Journal of Solid State Circuits, 10th October 1999, pages 1419-1424. Paper attached. This paper presents several equations, two are caculated here, a **modified Wheeler**, and a **Current Sheet Approximation**. These are calculated here for the two common planar inductor types.

The main advantage of this is a starting point for a field solver. I was expecting these to be more accurate, not sure why this is. I am very sure din is ok. Still a useful sheet.

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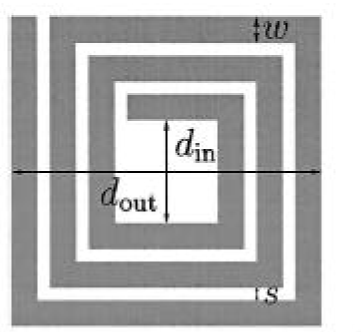
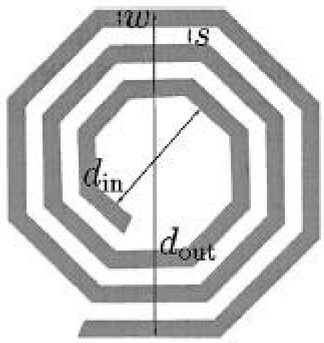
:robat Docume



(a)



(b)

The range of dout is from 100 to 480um; w is from 2 to 0.3*dout; s is from 2um to 3*w; din is from 0.1 to 0.9*dout. Total inductance from 0.5 to 100nH

$\mu m := \frac{m}{10^6}$ $\quad \mu_0 := 4 \cdot \pi \cdot 10^{-7} \cdot \frac{newton}{amp^2}$ $\quad nH := \frac{H}{10^9}$ $\quad mOhm := \frac{ohm}{10^3}$ $\quad freq := 1 \times 10^9 \cdot Hz$

$resistivity := 10 \cdot mOhm$

$d_{in}(d_{out}, n, w, s) := d_{out} - 2 \cdot w - halfturn(n) \cdot (w + s)$

$halfturn(n) := floor[2(n - 0.25)] - 1$

$$d_{avg}(d_{out}, n, w, s) := \frac{d_{in}(d_{out}, n, w, s) + d_{out}}{2}$$

$d_{in}(11\mu m, 2.25, 1\mu m, 1\mu m) = 3\,\mu m$

$d_{in}(300\mu m, 2.25, 20\mu m, 10\mu m) = 170\,\mu m$

$$\rho(d_{out}, n, w, s) := \frac{d_{out} - d_{in}(d_{out}, n, w, s)}{d_{out} + d_{in}(d_{out}, n, w, s)}$$

$\rho(321\mu m, 3.75, 16.5\mu m, 1.9\mu m) = 0.288$

Calculation of Approximate Resistance

$$resistance(d_{out}, n, w, s) := \frac{d_{avg}(d_{out}, n, w, s) \cdot \pi \cdot resistivity}{w}$$

The resistance is calculated simply as the average circumference * n * resistivity. This is very crude and ignores corner affects, but will try to allow Q to be plotted.... (it fails).

$resistance(339\mu m, 3.75, 10\mu m, 1.9\mu m) = 0.921\,ohm$

Square inductor (a) Calculation

$K_{a1} := 2.34$ $K_{a2} := 2.75$

$$L_{smw}(d_{out}, n, w, s) := K_{a1} \cdot \mu_0 \cdot \frac{n^2 d_{avg}(d_{out}, n, w, s)}{1 + K_{a2} \cdot \rho(d_{out}, n, w, s)}$$

$L_{smw}(321\mu m, 3.75, 16.5\mu m, 1.9\mu m) = 5.76\,nH$ #10, measured 6.1nH

$L_{smw}(339\mu m, 5.75, 10\mu m, 1.9\mu m) = 15.33\,nH$ #15, measured 16.2nH

$L_{smw}(400\mu m, 3.75, 31.6\mu m, 1.9\mu m) = 4.7\,nH$ #14, measured 4.9nH

$C_{a1} := 1.27$ $C_{a2} := 2.07$ $C_{a3} := 0.18$ $C_{a4} := 0.13$

$$L_{scsa}(d_{out}, n, w, s) := \frac{\mu_0 \cdot n^2 \cdot d_{avg}(d_{out}, n, w, s)\, C_{a1}}{2} \cdot \left(\ln\left(\frac{C_{a2}}{\rho(d_{out}, n, w, s)} \right) + C_{a3} \cdot \rho(d_{out}, n, w, s) + C_{a4} \cdot \rho(d_{out}, n, w, s)^2 \right)$$

$L_{scsa}(321\mu m, 3.75, 16.5\mu m, 1.9\mu m) = 5.7\,nH$ #10, measured 6.1nH

$L_{scsa}(339\mu m, 5.75, 10\mu m, 1.9\mu m) = 15.2\,nH$ #15, measured 16.2nH

$L_{scsa}(400\mu m, 3.75, 31.6\mu m, 1.9\mu m) = 4.67\,nH$ #14, measured 4.9nH

Hexagon inductor (c) Calculation

$K_{c1} := 2.33$ $K_{c2} := 3.82$

$$L_{hmw}(d_{out}, n, w, s) := K_{c1} \cdot \mu_0 \cdot \frac{n^2 d_{avg}(d_{out}, n, w, s)}{1 + K_{c2} \cdot \rho(d_{out}, n, w, s)}$$

$L_{hmw}(346\mu m, 4, 18\mu m, 2\mu m) = 5.95\,nH$ #55, measured 7.5nH

$L_{hmw}(326\mu m, 5, 8\mu m, 12\mu m) = 7.22\,nH$ #58, measured 7.2nH

$C_{c1} := 1.09$ $C_{c2} := 2.23$ $C_{c3} := 0.0$ $C_{c4} := 0.17$

$$L_{hcsa}(d_{out}, n, w, s) := \frac{\mu_0 \cdot n^2 \cdot d_{avg}(d_{out}, n, w, s)\, C_{c1}}{2} \cdot \left(\ln\left(\frac{C_{c2}}{\rho(d_{out}, n, w, s)} \right) + C_{c3} \cdot \rho(d_{out}, n, w, s) + C_{c4} \cdot \rho(d_{out}, n, w, s)^2 \right)$$

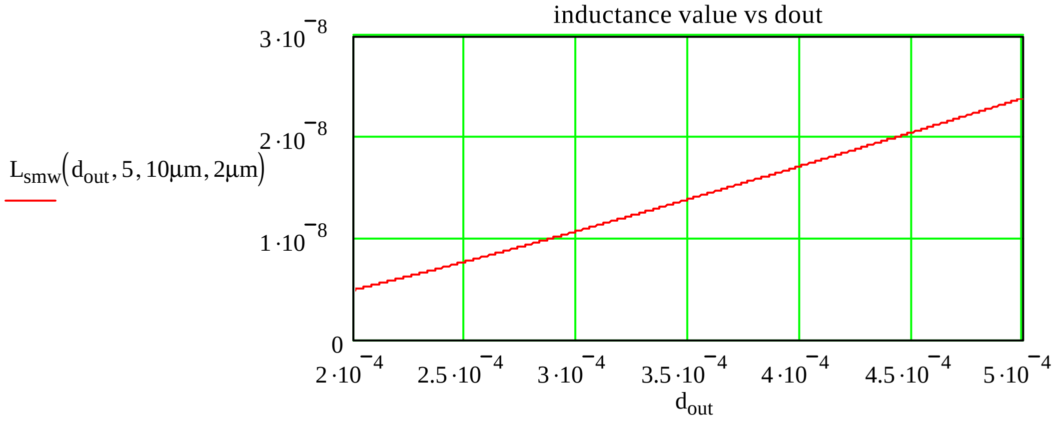
$L_{hcsa}(346\mu m, 4, 18\mu m, 2\mu m) = 6.02\,nH$ #55, measured 7.5nH

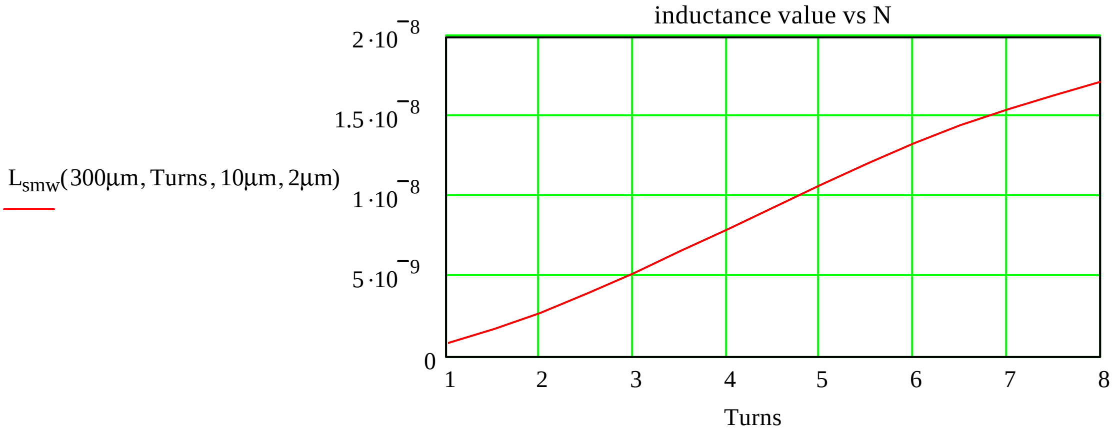
$L_{hcsa}(326\mu m, 5, 8\mu m, 12\mu m) = 7.42\,nH$ #58, measured 7.2nH

Plots of Square inductor

$Turns := 1, 1.5 .. 8$

The inductance varies more or less linearly with outside diameter and turns





The Q is clearly not correct, and is should be about 20. This is because the conducted losses are only part of the story (a small part) and the induced losses into the substrate are more important. To be updated.