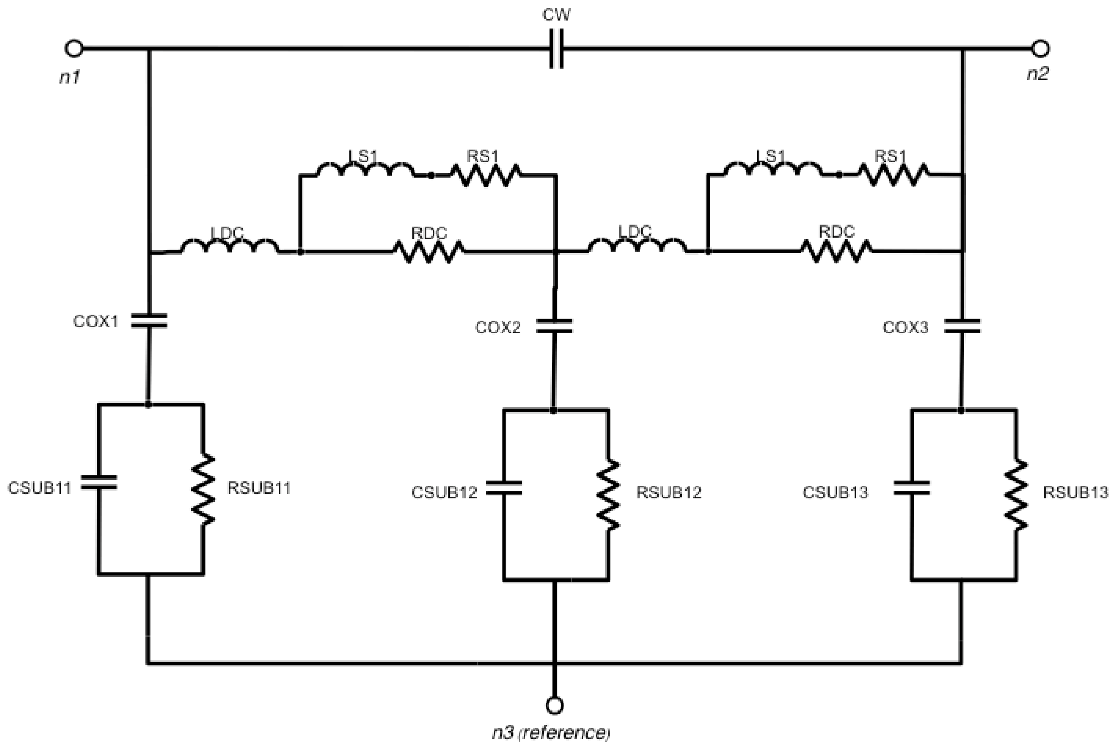


Figure 1: Lumped physical model of a wide-band distributed spiral inductor on silicon.

Form: lspiral:<instance name> n1 n2 n3 <parameter list>
n1, n2, and *n3* are the element terminals.
Terminal n3 is the element's reference terminal.

Parameters:

Parameter	Type	Default value	Required?
rdc: low-frequency series resistance (Ω)	DOUBLE	n/a	yes
ldc: low-frequency series inductance (H)	DOUBLE	n/a	yes
rs1: frequency dependent resistance (Ω)	DOUBLE	n/a	yes
ls1: frequency dependent inductance (H)	DOUBLE	n/a	yes
ms1:mutual inductance between ldc and ls1 (H)	DOUBLE	n/a	yes
cw:capacitance between metal windings of inductor (F)	DOUBLE	n/a	yes
cox1: oxide capacitance (F)	DOUBLE	n/a	yes
csub11: substrate capacitance (F)	DOUBLE	n/a	yes
rsub11: substrate resistivity (Ω)	DOUBLE	n/a	yes
cox2: oxide capacitance (F)	DOUBLE	n/a	yes
csub21: substrate capacitance	DOUBLE	n/a	yes

rsub21: substrate resistivity (Ω)	DOUBLE	n/a	yes
cox3: oxide capacitance (F)	DOUBLE	n/a	yes
csub31: substrate capacitance (F)	DOUBLE	n/a	yes
rsub31: substrate resistivity (Ω)	DOUBLE	n/a	yes

1. cox_n,$rsub_{nm}$ and $csub_{nm}$ are process dependent parameters.
2. The other parameters may obtained analytically or using an appropriate extraction procedure [1], [2].

Example: Planar 9.5-nH spiral inductor [1]

```
lspiral:ls1 1 2 0 rdc=2.778 ldc=4.325e-9 rs1=26e3 ls1=1e-6 ms1=13.61e-9
+ cw=10.00e-15 cox1=19.71e-15 csub11=64.67e-15 rsub11=101 cox2=73.01e-15
+ csub21=10.82e-15 rsub21=457 cox3=15.27e-15 csub31=31.06e-15
+ rsub31=594
```

Details:

Example of transient analysis for a parallel RLC tank using a 9.5-nH planar spiral inductor

netlist file:

```
* lspiral transient analysis
.options verbose
.options gsub11=9.90e-3 gsub21=2.189e-3 gsub31=1.688e-3

.tran2 tstop=1n tstep=4e-13 out_steps=100

isource:isrc 0 1 iac=1m f=8.8GHz

* RLC tank - capacitor value ignores non-idealities
resistor:RL 1 0 r=1k
capacitor:CL 1 0 c={1/(9.5e-9*(8.8GHz*2*pi)**2)}
lspiral:ls1 1 0 0 rdc=2.778 ldc=4.325e-9 rs1=26e3 ls1=1e-6 ms1=13.61e-9
+ cw=10.00e-15 cox1=19.71e-15 csub11=64.67e-15 rsub11={1/gsub11} cox2=73.01e-15
+ csub21=10.82e-15 rsub21={1/gsub21} cox3=15.27e-15 csub31=31.06e-15
+ rsub31={1/gsub31}

.options gnuplot

.options preamble="set title 'Parallel RLC Tank: 9.5-nH Planar spiral inductor'; set zero 1e-15; set
grid; set data style lines;set xlabel 'Time (s)'; set key noautotitles; set ylabel 'Tank Voltage (V)';set
yrange [-0.8:0.8]"

.out plot term "1" vt preamble in "lsp_tr.dat"
```

Figure 2: Transient response of a RLC tank modeled with lspiral

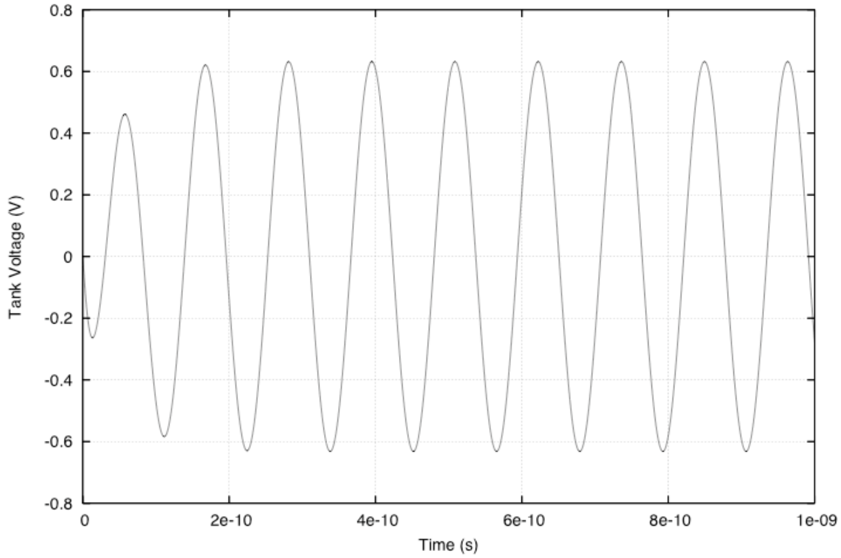
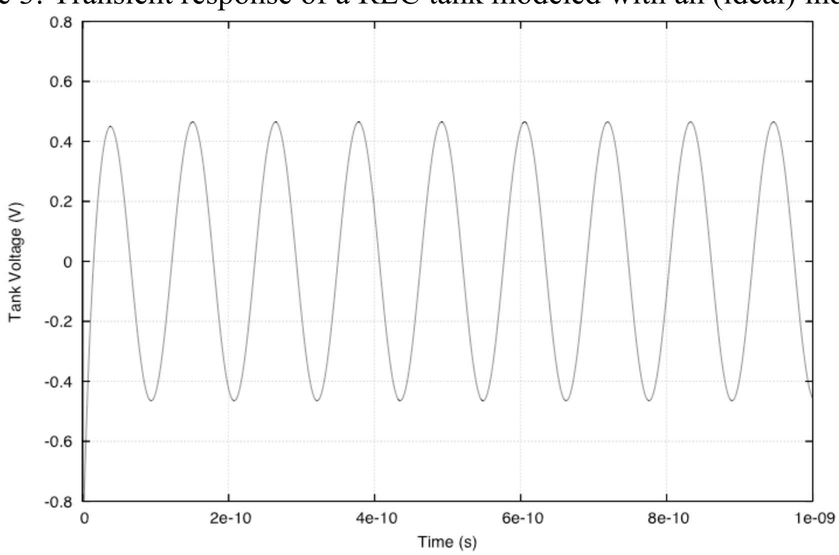


Figure 3: Transient response of a RLC tank modeled with an (ideal) inductor



Example of ac analysis for extracting inductor's quality factor from the short circuit admittance parameter (Y11):

netlist file:

```
* lspiral ac analysis
.options verbose
.options zo=50

vsource:vin 1 0 vdc=0 vac=1
vsource:vprobe 2 0 vdc=0
```

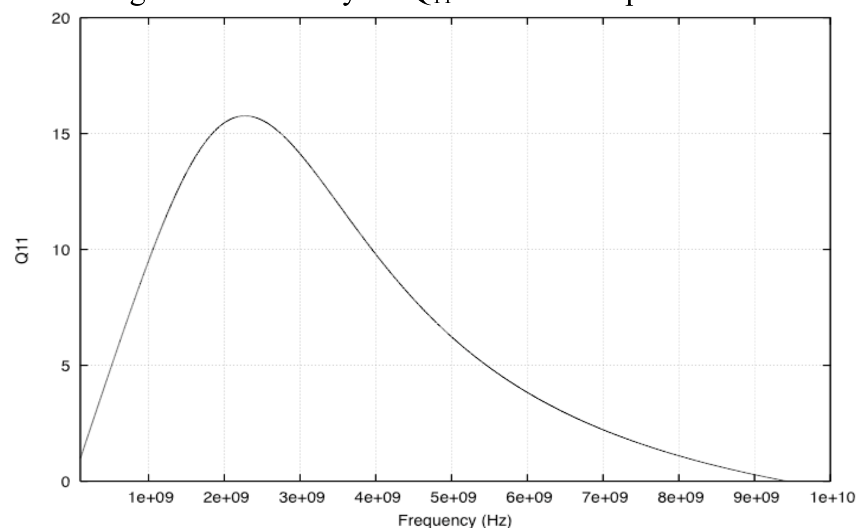
```
.options gsub11=9.90e-3 gsub21=2.189e-3 gsub31=1.688e-3
.ac start=100e6 stop=10GHz n_freqs=10000

lspiral:ls1 1 2 0 rdc=2.778 ldc=4.325e-9 rs1=26e3 ls1=1e-6 ms1=13.61e-9
+ cw=10.00e-15 cox1=19.71e-15 csub11=64.67e-15 rsub11={1/gsub11} cox2=73.01e-15
+ csub21=10.82e-15 rsub21={1/gsub21} cox3=15.27e-15 csub31=31.06e-15
+ rsub31={1/gsub31}

.options gnuplot

.options preamble="set title 'Q11: 9.5-nH Planar spiral inductor'; set zero 1e-15; set grid; set data
style lines;set yrange [0:20]; set ylabel 'Q11';set xrange [100e6:10e9]; set xlabel 'Frequency (Hz)';
set key noautotitles; Q(a,b)=(-b/a)"
.options postamble="using 1:(Q($2,$3))"
* y11 - short output, measure i1/v1
.out plot element "vsource:vin" 0 if -1 mult term "1" vf div postamble preamble in "y11.dat"
```

Figure 4: AC Analysis: Q_{11} for 9.5-nH lspiral model



Credits:

Name	Affiliation	Date	Links
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References:

[1] A comprehensive compact-modeling methodology for spiral inductors in silicon-based RFICs, Watson, A.C.; Melendy, D.; Francis, P.; Kyuwoon Hwang; Weisshaar, A.
Microwave Theory and Techniques, IEEE Transactions on
On page(s): 849- 857, Volume: 52, Issue: 3, March 2004

[2] Frequency-independent equivalent-circuit model for on-chip spiral inductors
Yu Cao; Groves, R.A.; Xuejue Huang; Zamdmer, N.D.; Plouchart, J.-O.; Wachnik, R.A.; Tsu-Jae King; Chenming Hu;
Solid-State Circuits, IEEE Journal of
Volume 38, Issue 3, March 2003 Page(s):419 - 426