Agilent Technologies

Distributed Components

May 2003

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Agilent Technologies
395 Page Mill Road
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Contents

Chapter 1: Finline Components

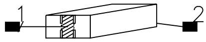
Finline Model Basis

For each finline component, the model is a rectangular waveguide with the cutoff frequency and the dielectric constant at cutoff modified by the dielectric slab and conducting strip. Conductor and dielectric losses are not included.

Spectral domain numerical results provide the basis for *unilateral* and *bilateral* finlines. The quoted accuracy, with respect to spectral domain, are ±0.6 percent for equivalent dielectric constant at cutoff and cutoff wavelength for unilateral finline and ±0.1 percent for phase velocity of bilateral finline. The equations for *insulated* finlines are analytical curve-fits to numerical results of transmission line matrix analysis (TLM). The cited accuracy for equivalent dielectric constant and cutoff frequency is 0.6 percent compared to the TLM results. All accuracies are for parameter values within the range of usage.

BFINL (Bilateral Finline)

Symbol



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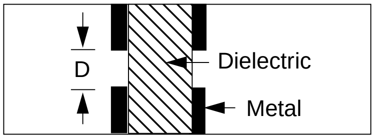


Parameters

Subst = substrate instance name

D = width of gap, in specified units

L = length of finline, in specified units

Temp = physical temperature, in °C

Range of Usage

$$\frac{B}{32} \leq D \leq B$$

$$\frac{A}{64} \leq S \leq \frac{A}{8}$$

where

D = gap width
A = inside enclosure width (from associated FSUB)
B = inside enclosure height (from associated FSUB)
S = thickness of substrate (from associated FSUB)

Notes/Equations

1. Refer to "Finline Model Basis" on page 1-1 at the beginning of this chapter.
2. For time-domain analysis, the frequency-domain analytical model is used.
3. This component has no default artwork associated with it.

References

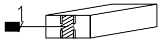
[1] P. Pramanick and P. Bhartia, “Accurate Analysis Equations and Synthesis Technique for Unilateral Finlines,” *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-33, No. 1, pp. 24-30, Jan. 1985.

[2] P. Pramanick and P. Bhartia, “Simple Formulae for Dispersion in Bilateral Fin-Lines,” *AEU*, Vol. 39, No. 6, pp. 383-386, 1985.

[3] P. Pramanick and P. Bhartia, “Accurate Analysis and Synthesis Equations for Insulated Fin-Lines, *AEU*, Vol. 39, No. 1, pp. 31-36, 1985.

BFINLT (Bilateral Finline Termination)

Symbol



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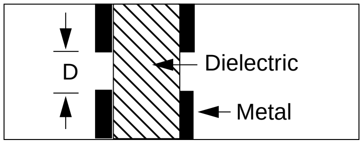


Parameters

Subst = substrate instance name

D = width of gap, in specified units

Temp = physical temperature, in °C

Range of Usage

$$\frac{B}{32} \le D \le B$$

$$\frac{A}{64} \le S \le \frac{A}{8}$$

where

D = gap width
A = inside enclosure width (from associated FSUB)
B = inside enclosure height (from associated FSUB)
S = thickness of substrate (from associated FSUB)

Notes/Equations

1. Refer to "Finline Model Basis" on page 1-1 at the beginning of this chapter.
2. For time-domain analysis, the frequency-domain analytical model is used.
3. This component has no default artwork associated with it.

References

[1] P. Pramanick and P. Bhartia, "Accurate Analysis Equations and Synthesis Technique for Unilateral Finlines," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-33, No. 1, pp. 24-30, Jan. 1985.

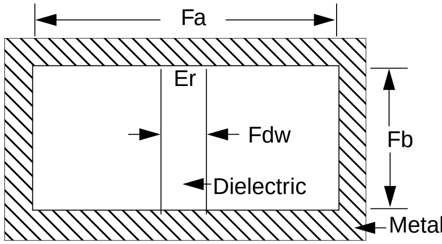
4. P. Pramanick and P. Bhartia, “Simple Formulae for Dispersion in Bilateral Fin-Lines,” *AEU*, Vol. 39, No. 6, pp. 383-386, 1985.

5. P. Pramanick and P. Bhartia, “Accurate Analysis and Synthesis Equations for Insulated Fin-Lines, *AEU*, Vol. 39, No. 1, pp. 31-36, 1985.

FSUB (Finline Substrate)

Symbol

Illustration



Parameters

Er = substrate dielectric constant

Fdw = thickness of slab, in specified units

Fa = inside width of enclosure, in specified units

Fb = inside height of enclosure, in specified units

Cond = conductor conductivity, in Siemens/meter

Range of Usage

Er ≥ 1.0
Fdw > 0
Fa > 0
Fb > 0
Cond ≥ 0

Notes/Equations

1. Refer to the section "Finline Model Basis" on page 1-1 at the beginning of this chapter.
2. FSUB is required for all finline components.

References

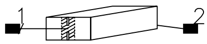
[1] P. Pramanick and P. Bhartia, “Accurate Analysis Equations and Synthesis Technique for Unilateral Finlines,” *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-33, No. 1, pp. 24-30, Jan. 1985.

[2] P. Pramanick and P. Bhartia, “Simple Formulae for Dispersion in Bilateral Fin-Lines,” *AEU*, Vol. 39, No. 6, pp. 383-386, 1985.

[3] P. Pramanick and P. Bhartia, “Accurate Analysis and Synthesis Equations for Insulated Fin-Lines, *AEU*, Vol. 39, No. 1, pp. 31-36, 1985.

IFINL (Insulated Finline)

Symbol



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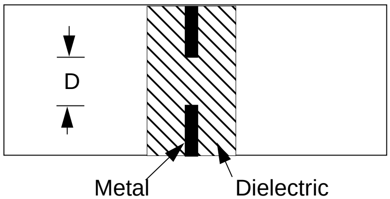


Parameters

Subst = substrate instance name

D = width of gap, in specified units

L = length of finline, in specified units

Temp = physical temperature, in °C

Range of Usage

$$\frac{B}{32} \le D \le B$$

$$\frac{A}{64} \le S \le \frac{A}{4}$$

where

D = gap width
A = inside enclosure width (from associated FSUB)
B = inside enclosure height (from associated FSUB)
S = thickness of substrate (from associated FSUB)

Notes/Equations

1. Refer to the section "Finline Model Basis" on page 1-1 at the beginning of this chapter.

2. For time-domain analysis, the frequency-domain analytical model is used.

3. This component has no default artwork associated with it.

References

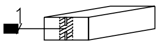
[1] P. Pramanick and P. Bhartia, “Accurate Analysis Equations and Synthesis Technique for Unilateral Finlines,” *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-33, No. 1, pp. 24-30, January 1985.

[2] P. Pramanick, and P. Bhartia, “Simple Formulae for Dispersion in Bilateral Fin-Lines,” *AEU*, Vol. 39, No. 6, pp. 383-386, 1985.

[3] P. Pramanick and P. Bhartia, “Accurate Analysis and Synthesis Equations for Insulated Fin-Lines,” *AEU*, Vol. 39, No. 1, pp. 31-36, 1985.

IFINLT (Insulated Finline Termination)

Symbol



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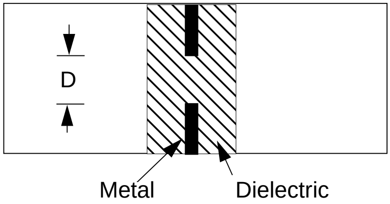


Parameters

Subst = substrate instance name

D = width of gap, in specified units

Temp = physical temperature, in °C

Range of Usage

$$\frac{B}{32} \leq D \leq B$$

$$\frac{A}{64} \leq S \leq \frac{A}{4}$$

where

D = gap width
A = inside enclosure width (from associated FSUB)
B = inside enclosure height (from associated FSUB)
S = thickness of substrate (from associated FSUB)

Notes/Equations

1. Refer to the section “Finline Model Basis” on page 1-1 at the beginning of this chapter.
2. For time-domain analysis, the frequency-domain analytical model is used.
3. This component has no default artwork associated with it.

References

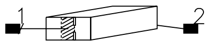
[1] P. Pramanick and P. Bhartia, “Accurate Analysis Equations and Synthesis Technique for Unilateral Finlines,” *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-33, No. 1, pp. 24-30, January 1985.

[2] P. Pramanick and P. Bhartia, “Simple Formulae for Dispersion in Bilateral Fin-Lines,” *AEU*, Vol. 39, No. 6, pp. 383-386, 1985.

[3] P. Pramanick and P. Bhartia, “Accurate Analysis and Synthesis Equations for Insulated Fin-Lines, *AEU*, Vol. 39, No. 1, pp. 31-36, 1985.

UFINL (Unilateral Finline)

Symbol



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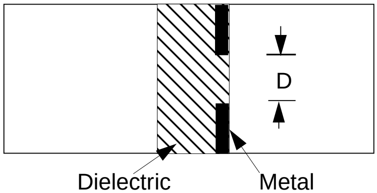


Parameters

Subst = substrate instance name

D = width of gap, in specified units

L = length of finline, in specified units

Temp = physical temperature, in °C

Range of Usage

$$\frac{B}{32} \le D \le B$$

$$\frac{A}{64} \le S \le \frac{A}{4}$$

where

D = gap width
A = inside enclosure width (from associated FSUB)
B = inside enclosure height (from associated FSUB)
S = thickness of substrate (from associated FSUB)

Notes/Equations

1. Refer to the section “Finline Model Basis” on page 1-1 at the beginning of this chapter.
2. For time-domain analysis, the frequency-domain analytical model is used.
3. This component has no default artwork associated with it.

References

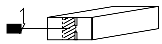
[1] P. Pramanick and P. Bhartia, “Accurate Analysis Equations and Synthesis Technique for Unilateral Finlines,” *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-33, No. 1, pp. 24-30, January 1985.

[2] P. Pramanick and P. Bhartia, “Simple Formulae for Dispersion in Bilateral Fin-Lines,” *AEU*, Vol. 39, No. 6, pp. 383-386, 1985.

[3] P. Pramanick and P. Bhartia, “Accurate Analysis and Synthesis Equations for Insulated Fin-Lines, *AEU*, Vol. 39, No. 1, pp. 31-36, 1985.

UFINLT (Unilateral Finline Termination)

Symbol



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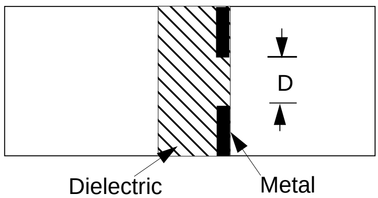


Parameters

Subst = substrate instance name

D = width of gap, in specified units

Temp = physical temperature, in °C

Range of Usage

$$\frac{B}{32} \leq D \leq B$$

$$\frac{A}{64} \leq S \leq \frac{A}{4}$$

where

D = gap width
A = inside enclosure width (from associated FSUB)
B = inside enclosure height (from associated FSUB)
S = thickness of substrate (from associated FSUB)

Notes/Equations

1. Refer to the section “Finline Model Basis” on page 1-1 at the beginning of this chapter.
2. For time-domain analysis, the frequency-domain analytical model is used.
3. This component has no default artwork associated with it.

References

[1] P. Pramanick and P. Bhartia, “Accurate Analysis Equations and Synthesis Technique for Unilateral Finlines,” *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-33, No. 1, pp. 24-30, January 1985.

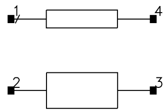
[2] P. Pramanick and P. Bhartia, “Simple Formulae for Dispersion in Bilateral Fin-Lines,” *AEU*, Vol. 39, No. 6, pp. 383-386, 1985.

[3] P. Pramanick and P. Bhartia, “Accurate Analysis and Synthesis Equations for Insulated Fin-Lines, *AEU*, Vol. 39, No. 1, pp. 31-36, 1985.

Chapter 2: Microstrip Components

MACLIN (Microstrip Asymmetric Coupled Lines)

Symbol



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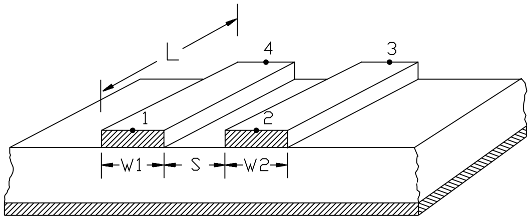


Parameters

Subst = microstrip substrate name

W1 = width of conductor 1, in specified units

W2 = width of conductor 2, in specified units

S = conductor spacing, in specified units

L = conductor length, in specified units

Temp = physical temperature, in °C

WA = (ADS Layout option) width of line that connects to pin 1

WB = (ADS Layout option) width of line that connects to pin 2

WC = (ADS Layout option) width of line that connects to pin 3

WD = (ADS Layout option) width of line that connects to pin 4

Range of Usage

$1 \le Er \le 18$
$T \ge 0$
$0.01 \times H \le W1 \le 100.0 \times H$
$0.01 \times H \le W2 \le 100.0 \times H$
$0.1 \times H \le S \le 10.0 \times H$
Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)

T = conductor thickness (from associated Subst)

Simulation frequency $\leq \frac{25}{H(mm)}$ (GHz)

W1 > 0, W2 > 0, S > 0, L > 0 for layout

WA ≥ 0, WB ≥ 0, WC ≥ 0, WD ≥ 0

Notes/Equations

1. The frequency-domain analytical model is a distributed, coupled-line model. The even- and odd-mode characteristics of the microstrip lines are calculated using the formula developed by Kirschning and Jansen for parallel coupled microstrip lines, and the formula developed by Hammerstad and Jensen for single microstrip line. Dispersion of the effective dielectric constant is included. The per-unit-length coupling capacitances are then derived for the asymmetric case using a model developed for Agilent by Vijai Tripathi. The even- and odd-mode impedance and admittance matrices are calculated based on the coupling capacitances. The result is used to calculate the network parameters of the distributed, coupled-line model by Tripathi's method. Conductor losses are ignored.

2. To turn off noise contribution, set Temp to −273.15°C.

3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

4. In generating a layout, adjacent transmission lines will be lined up with the inner edges of the conductor strips; if the connecting transmission lines are narrower than the coupled lines, they will be centered on the conductor strips.

References

[1] V. K. Tripathi, “Asymmetric Coupled Transmission Lines in an Inhomogeneous Medium,” *MTT-23*, September 1975.

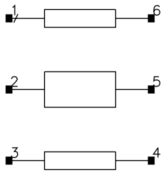
[2] V. K. Tripathi and Y. K. Chin. “Analysis of the General Nonsymmetrical Directional Coupler with Arbitrary Terminations,” *Proceedings of the IEEE*, Vol. 129, December 1982, p. 360.

[3] M. Kirschning and R. H. Jansen. “Accurate Wide-Range Design Equations for the Frequency-Dependent Characteristic of Parallel Coupled Microstrip Lines,” *MTT-32*, January 1984 (with corrections by Agilent).

[4] E. Hammerstad and O. Jensen. “Accurate Models for Microstrip Computer-Aided Design,” *MTT Symposium Digest*, 1980, pp. 407-409.

MACLIN3 (Microstrip 3-Conductor Asymmetric Coupled Lines)

Symbol



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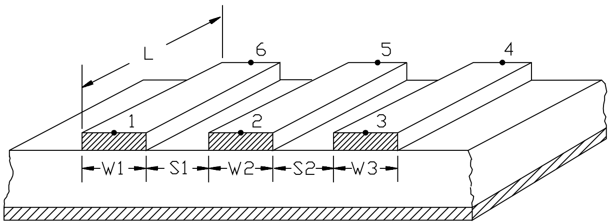


Parameters

Subst = microstrip substrate name

W1 = width of conductor 1, in specified units

W2 = width of conductor 2, in specified units

W3 = width of conductor 3, in specified units

S1 = spacing between conductors 1 and 2, in specified units

S2 = spacing between conductors 2 and 3, in specified units

L = conductor length, in specified units

Temp = physical temperature, in °C

WA = (ADS Layout option) width of line that connects to pin 1

WB = (ADS Layout option) width of line that connects to pin 2

WC = (ADS Layout option) width of line that connects to pin 3

WD = (ADS Layout option) width of line that connects to pin 4

Range of Usage

$0.01 \times H \leq W1 \leq 100.0 \times H$
$0.01 \times H \leq W2 \leq 100.0 \times H$

$0.01 \times H \leq W3 \leq 100.0 \times H$
$0.1 \times H \leq S1 \leq 10.0 \times H$
$0.1 \times H \leq S2 \leq 10.0 \times H$
$1.01 \leq Er \leq 18$
$T \geq 0$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
T = conductor thickness (from associated Subst)

$$\text{Simulation frequency} \leq \frac{25}{H(mm)} \quad \text{(GHz)}$$

W1 > 0, W2 > 0, W3 > 0, S1 > 0, S2 > 0, L > 0 for layout
WA ≥ 0, WB ≥ 0, WC≥ 0, WD ≥ 0

Notes/Equations

1. The frequency-domain analytical model is a distributed, coupled-line model. The even- and odd-mode characteristics of the microstrip lines are calculated using the formula developed by Kirschning and Jansen for parallel coupled microstrip lines, and the formula developed by Hammerstad and Jensen for single microstrip line. The per-unit-length coupling capacitances are then derived for the asymmetric case using a model developed for Agilent by Vijai Tripathi. The even- and odd-mode impedance and admittance matrices are calculated based on the coupling capacitances. The result is used to calculate the network parameters of the distributed, coupled-line model by Tripathi's method. Conductor loss and dispersion are ignored.

2. To turn off noise contribution, set Temp to –273.15°C.

3. In generating a layout, adjacent transmission lines will be lined up with inner edges of the conductor strips at pins 1, 3, 4 and 6. If the connecting transmission lines are narrower than the coupled lines, they will be centered on the conductor strips. At pins 2 and 5, the assumption is that the abutting transmission lines are narrower or the same width as the center coupled line.

References

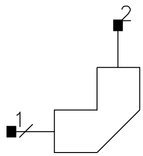
[1] V. K. Tripathi “On the Analysis of Symmetrical Three-Line Microstrip Circuits,” *MTT-25*, September 1977.

[2] M. Kirschning and R. H. Jansen. “Accurate Wide-Range Design Equations for the Frequency-Dependent Characteristic of Parallel Coupled Microstrip Lines,” *MTT-32*, January 1984 (with corrections by Agilent).

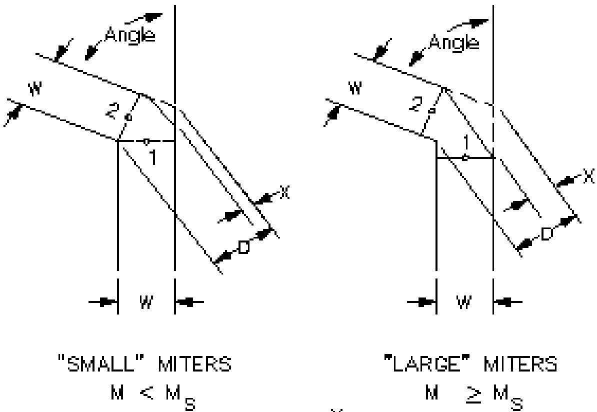
[3] E. Hammerstad and O. Jensen. “Accurate Models for Microstrip Computer-Aided Design,” *MTT Symposium Digest*, 1980, pp. 407-409.

MBEND (Microstrip Bend (Arbitrary Angle/Miter))

Symbol



Illustration



$$M = \frac{X}{D}$$

$$M_S = \mathrm{Sin}^2\left(\frac{\mathrm{Angle}}{2}\right)$$

Parameters

Subst = microstrip substrate name

W = conductor width, in specified units

Angle = angle of bend, in degrees

M = miter fraction (M=X/D)

Temp = physical temperature, in °C

Range of Usage

$1 \le Er \le 128$
$-90° \le Angle \le 90°$

$$0.01 \le \frac{W}{H} \le 100$$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
W ≥ 0   for layout
Angle = any value for layout

Notes/Equations

1. For the unmitered, 90° condition, the frequency-domain analytical model is the lumped component, right-angle bend model proposed by Gupta et al. Otherwise, the lumped component model proposed by Jansen is used. The Hammerstad and Jensen microstrip formulas are used to calculate reference plane shifts in the Jansen model. Dispersion and conductor loss are not included in the model.
2. For right-angle bends, use MBEND2, MBEND3, or MCORN.
3. Two possible reference plane locations are available:
   - Small miters where the reference planes line up with the inner corner of the bend, or
   - Large miters where the reference planes line up with the corner between the connecting strip and the mitered section
4. To turn off noise contribution, set Temp to –273.15°C.
5. In layout, a positive value for Angle draws a bend in the counterclockwise direction from pin 1 to 2; a negative value for Angle draws a bend in the clockwise direction.

References

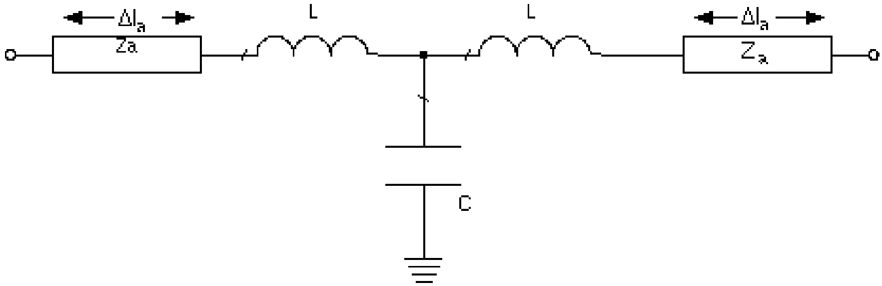
[1] M. Kirschning, R. H. Jansen, and N. H. L. Koster. “Measurement and Computer-Aided Modeling of Microstrip Discontinuities by an Improved Resonator Method,” *1983 IEEE MTT-S International Microwave Symposium Digest*, May 1983, pp. 495-497.

[2] R. H. Jansen, “Probleme des Entwarfs und der Messtechnik von Planaren Schaltungen,” *1. Teil, NTZ*, Vol 34, July 1981, pp. 412-417.

[3] E. Hammerstad and O. Jensen, “Accurate Models for Microstrip Computer-Aided Design,” *MTT Symposium Digest*, 1980, pp. 407-409.

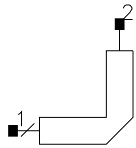
[4] K. C. Gupta, R. Garg, and R. Chadha, *Computer-Aided Design of Microwave Circuits*, 1981, p. 195.

Equivalent Circuit

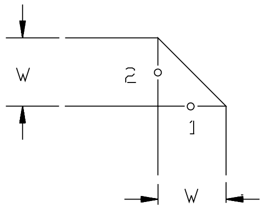


MBEND2 (90-degree Microstrip Bend (Mitered))

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = conductor width, in specified units

Temp = physical temperature, in °C

Range of Usage

$0.2 \le \frac{W}{H} \le 6.0$

$2.36 \le Er \le 10.4$

Simulation frequency $\le \frac{12}{H(mm)}$ (GHz)

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
W ≥ 0 for layout

Notes/Equations

1. The frequency-domain model is an empirically-based analytical model that consists of a static, lumped, equivalent circuit. The equivalent circuit parameters are calculated based on the expressions developed by Kirschning, Jansen and Koster according to the following formula.

$$\frac{C}{H} = \frac{W}{H}\left[7.6\varepsilon_r + 3.8 + \frac{W}{H}(3.93\varepsilon_r + 0.62)\right] \quad \mathrm{pF/m}$$

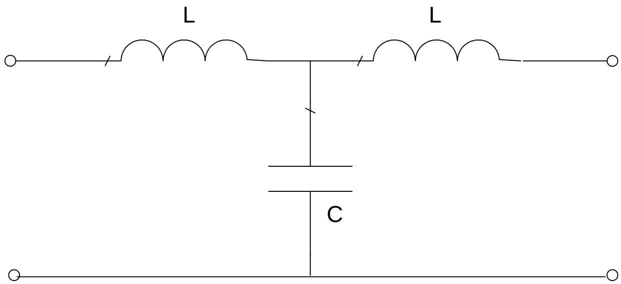
$$\frac{L}{H} = 441.2712\left\{1 - 1.062\exp\left[-0.177\left(\frac{W}{H}\right)^{0.947}\right]\right\} \quad \mathrm{nH/m}$$

2. To turn off noise contribution, set Temp to –273.15°C.

References

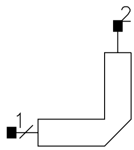
[1] M. Kirschning, R. H. Jansen, and N. H. L. Koster. “Measurement and Computer-Aided Modeling of Microstrip Discontinuities by an Improved Resonator Method,” *1983 IEEE MTT-S International Microwave Symposium Digest*, May 1983, pp. 495-497.

Equivalent Circuit

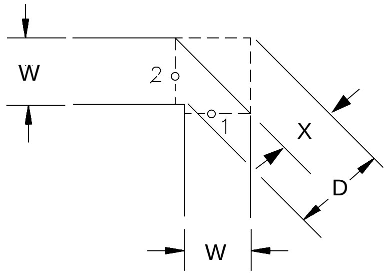


MBEND3 (90-degree Microstrip Bend (Optimally Mitered))

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = conductor width, in specified units

Temp = physical temperature, in °C

Range of Usage

$0.5 \le \frac{W}{H} \le 2.75$

$2.5 \le Er \le 25$

Simulation frequency $\le \frac{15}{H(mm)}$ (GHz)

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
$W \ge 0$ for layout

Notes/Equations

1. The frequency-domain model is an empirically based, analytical model. The optimal chamfered bend dimensions are calculated based on the expression developed by Douville and James. The resulting bend is modeled as a matched

transmission line of length, $2\Delta l_o$. This length is calculated from curve fits to the graphical data given in the references. In addition, dispersion is accounted for in the transmission line model. Conductor losses are ignored.

2. Optimum miter is given by:

$$\frac{X}{D} = 0.52 + 0.65 \times e^{(-1.35 \times (W/H))}$$

where

H = substrate thickness

3. To turn off noise contribution, set Temp to –273.15°C.

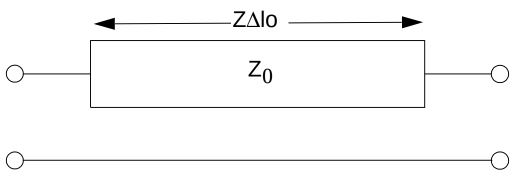
References

[1]. R. J. P. Douville and D. S. James, “Experimental Characterization of Microstrip Bends and Their Frequency Dependent Behavior,” *1973 IEEE Conference Digest*, October 1973, pp. 24-25.

[2] R. J. P. Douville and D. S. James, “Experimental Study of Symmetric Microstrip Bends and Their Compensation,” *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-26, March 1978, pp. 175-181.

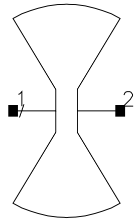
[3] Reinmut K. Hoffman, *Handbook of Microwave Integrated Circuits*, Artech House, 1987, pp. 267-309.

Equivalent Circuit

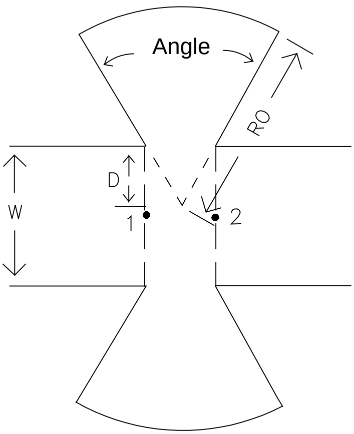


MBSTUB (Microstrip Butterfly Stub)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = width of feed line, in specified units

Ro = outer radius of circular sector, in specified units

Angle = angle subtended by circular sector, in degrees

D = insertion depth of circular sector in feed line, in specified units

Temp = physical temperature, in °C

Range of Usage

$$0.01 \le \frac{W}{H} \le 100$$

$$Ro > \frac{D}{\cos(Angle/2)}$$

Angle < 90

where

H = substrate thickness (from associated Subst)

Notes/Equations

1. The frequency-domain analytical model accounts for conductor and dielectric losses.
2. It is assumed that only TM_{on} radial modes are excited. This requires Angle to be less than 90 degrees.
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
4. To turn off noise contribution, set Temp to –273.15°C.

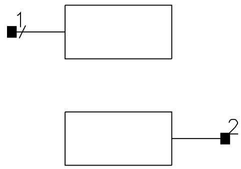
References

[1] F. Giannini, M. Ruggieri, and J. Vrba, "Shunt-Connected Microstrip Radial Stubs," *IEEE Transaction, Microwave Theory and Techniques,* Vol. MTT-34, No. 3, March 1986, pp. 363-366.

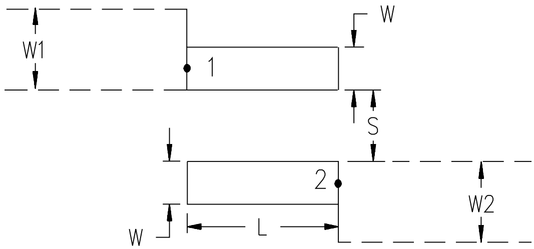
[2] F. Giannini, R. Sorrentino, and J. Vrba, "Planar Circuit Analysis of Microstrip Radial Stub," *IEEE Transaction, Microwave Theory and Techniques,* Vol. MTT-32, No. 12, December 1984, pp. 1652-1655.

MCFIL (Microstrip Coupled-Line Filter Section)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = line width, in specified units

S = spacing between lines, in specified units

L = line length, in specified units

Temp = physical temperature, in °C

W1 = (ADS Layout option) width of line that connects to pin 1

W2 = (ADS Layout option) width of line that connects to pin 2

Range of Usage

$$0.1 \le \frac{W}{H} \le 10$$

$$0.1 \le \frac{S}{H} \le 10$$

$$1 \le Er \le 18$$

$$\text{Simulation frequency} \le \frac{25}{H(mm)} \quad \text{(GHz)}$$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
W ≥ 0, S ≥ 0, L ≥ 0 for layout
W1 ≥ 0, W2 ≥ 0

Notes/Equations

1. The frequency-domain analytical model is a distributed, coupled-line model. The per-unit-length coupling capacitances are calculated using the formula developed by Kirschning and Jansen for parallel coupled microstrip lines, and the formula developed by Hammerstad and Jensen for single microstrip line. Dispersion, end effect, and conductor loss are included. The even- and odd-mode line impedances are calculated based on the coupling capacitances and conductor losses. The result is used to calculate the network parameters of the distributed, coupled-line model.
2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
3. To turn off noise contribution, set Temp to –273.15°C.
4. In generating a layout, adjacent transmission lines will be lined up with the inner edges of the conductor strips. If the connecting transmission lines are narrower than the coupled lines, they will be centered on the conductor strips.

References

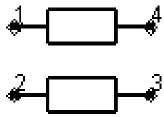
[1] R. Garg and I. J. Bahl. “Characteristics of Coupled Microstriplines,” *MTT-27*, July 1979.

[2] M. Kirschning and R. H. Jansen. “Accurate Wide-Range Design Equations for the Frequency-Dependent Characteristic of Parallel Coupled Microstrip Lines,” *MTT-32,* January 1984 (with corrections by Agilent).

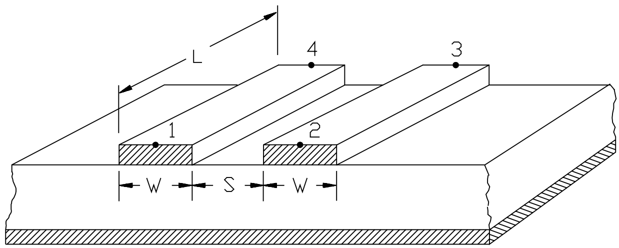
[3] E. Hammerstad and O. Jensen. “Accurate Models for Microstrip Computer-Aided Design,” *MTT Symposium Digest*, 1980, pp. 407-409

MCLIN (Microstrip Coupled Lines)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = line width, in specified units

S = space between lines, in specified units

L = line length, in specified units

Temp = physical temperature, in °C

W1 = (ADS Layout option) width of line that connects to pin 1

W2 = (ADS Layout option) width of line that connects to pin 2

W3 = (ADS Layout option) width of line that connects to pin 3

W4 = (ADS Layout option) width of line that connects to pin 4

Range of Usage

$0.01 \times H \le W \le 100.0 \times H$
$0.1 \times H \le S \le 10.0 \times H$
$1 \le Er \le 18$
$T \ge 0$

$$\text{Simulation frequency} \le \frac{25}{H(mm)} \quad \text{(GHz)}$$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
T = conductor thickness (from associated Subst)
W   0, S≥ 0, L ≥ 0   for layout
W1 ≥ 0, W2 ≥ 0, W3 ≥ 0, W4 ≥ 0

Notes/Equations

1. The frequency-domain analytical model is a distributed, coupled-line model. The per-unit-length coupling capacitances are calculated using the formula developed by Kirschning and Jansen for parallel coupled microstrip lines, and the formula developed by Hammerstad and Jensen for single microstrip line. Dispersion and conductor loss are included. The even- and odd-mode line impedances are calculated based on the coupling capacitances and conductor losses. The result is used to calculate the network parameters of the distributed, coupled-line model.

2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

3. To turn off noise contribution, set Temp to –273.15°C.

4. In generating a layout, adjacent transmission lines will be lined up with the inner edges of the conductor strips. If the connecting transmission lines are narrower than the coupled lines, they will be centered on the conductor strips.

References

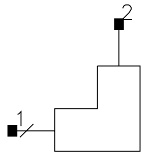
[1] R. Garg and I. J. Bahl. “Characteristics of Coupled Microstriplines,” *MTT-27*, July 1979.

[2] M. Kirschning and R. H. Jansen. “Accurate Wide-Range Design Equations for the Frequency-Dependent Characteristic of Parallel Coupled Microstrip Lines,” *MTT-32*, January 1984 (with corrections by Agilent).

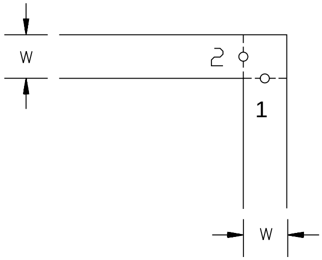
[3] E. Hammerstad and O. Jensen, “Accurate Models for Microstrip Computer-Aided Design,” *MTT Symposium Digest*, 1980, pp. 407-409.

MCORN (90-degree Microstrip Bend (Unmitered))

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = conductor width, in specified units

Temp = physical temperature, in °C

Range of Usage

$$0.2 \le \frac{W}{H} \le 6.0$$

$$2.36 \le Er \le 10.4$$

$$\text{Simulation frequency} \le \frac{12}{H(mm)} \text{ (GHz)}$$

where

Er = dielectric constant
H = substrate thickness

Notes/Equations

1. The frequency-domain model is an empirically based, analytical model which consists of a static, lumped, equivalent circuit. The equivalent circuit

parameters are calculated based on the expressions developed by Kirschning, Jansen and Koster according to the following formula.

$$\frac{C}{H} = \frac{W}{H}\left[2.6\varepsilon_r + 5.64 + \frac{W}{H}(10.35\varepsilon_r + 2.5)\right] \quad \text{pF/m}$$

$$\frac{L}{H} = 220.6356\left\{1 - 1.35\exp\left[-0.18\left(\frac{W}{H}\right)^{1.39}\right]\right\} \quad \text{nH/m}$$

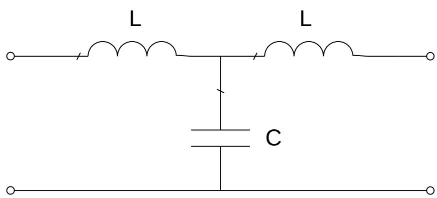
2. To turn off noise contribution, set Temp to –273.15°C.

References

[1] M. Kirschning, R. H. Jansen, and N. H. L. Koster. "Measurement and Computer-Aided Modeling of Microstrip Discontinuities by an Improved Resonator Method," *1983 IEEE MTT-S International Microwave Symposium Digest*, May 1983, pp. 495-497.

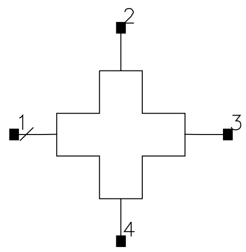
[2] N. Marcuvitz, *Waveguide Handbook*, McGraw-Hill, New York, 1951, pp. 312-313.

Equivalent Circuit

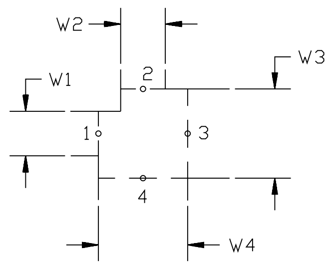


MCROS (Microstrip Cross-Junction)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W1 = conductor width of line at pin 1, in specified units

W2 = conductor width of line at pin 2, in specified units

W3 = conductor width of line at pin 3, in specified units

W4 = conductor width of line at pin 4, in specified units

Range of Usage

$0.25 \leq W_i/H \leq 8$

where

H = substrate thickness (from associated Subst)
$Er \leq 50$

Notes/Equations

1. This microstrip cross model is derived by curve fitting the results of microstrip cross simulations of an Agilent internal electromagnetic field solver. The new

microstrip cross model can be applied to the most commonly used substrates including duriod, alumina, and GaAs. The range of validity of the model is further extended for use in microwave and RF circuit design applications.

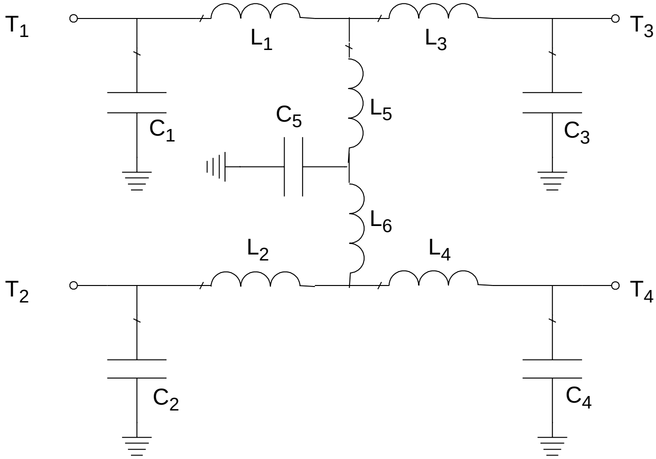
The inductance equations are invariant to the relative dielectric constant on the substrate. Dispersion and conductor loss are not included.

2. To turn off noise contribution, set Temp to –273.15°C.
3. In layout, all pins are centered at the corresponding edges.

References

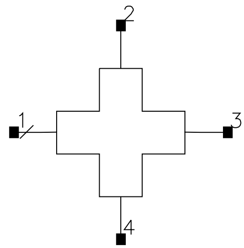
[1] K. C. Gupta, R. Garg, and R. Chadha. *Computer-Aided Design of Microwave Circuits,* Artech House, 1981, pp. 197-199.

Equivalent Circuit

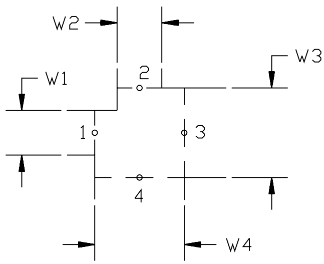


MCROSO (Alternate Libra Microstrip Cross-Junction)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W1 = conductor width of line at pin 1, in specified units

W2 = conductor width of line at pin 2, in specified units

W3 = conductor width of line at pin 3, in specified units

W4 = conductor width of line at pin 4, in specified units

Temp = physical temperature, in °C

Range of Usage

$0.4 \le W_i/H \le 2.5$

where

H = substrate thickness (from associated Subst)

Notes/Equations

1. The frequency-domain model is an empirically based, analytical model that consists of a static, lumped, equivalent circuit. The equivalent circuit parameters are calculated based on the expressions developed by Gupta et al. The capacitance equations are modified to take into account the relative dielectric constant of the material according to the following formula.

$$ {}_x(\varepsilon_r = \varepsilon_r^{sub}) = C_x(\varepsilon_r = 9.9)\left[\frac{Z_o(\varepsilon_r = 9.9,\ w = Wx)}{Z_o(\varepsilon_r = \varepsilon_r^{sub},\ w = Wx)}\right]\sqrt{\frac{\varepsilon_{eff}(\varepsilon_r = \varepsilon_r^{sub},\ w = Wx)}{\varepsilon_{eff}(\varepsilon_r = 9.9,\ w = Wx)}} $$

   The inductance equations are invariant to the relative dielectric constant on the substrate. Dispersion and conductor loss are not included.

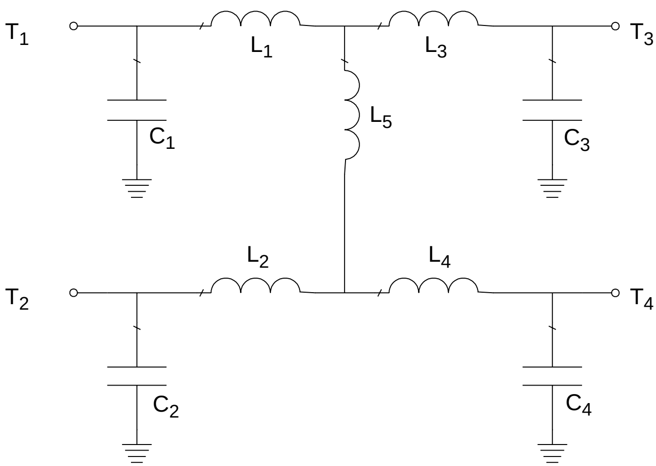
2. To turn off noise contribution, set Temp to –273.15°C.

3. In layout, all pins are centered at the corresponding edges.

References

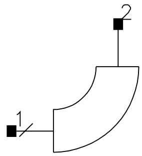
[1] K. C. Gupta, R. Garg, and R. Chadha. *Computer-Aided Design of Microwave Circuits*, Artech House, 1981, pp. 197-199.

Equivalent Circuit

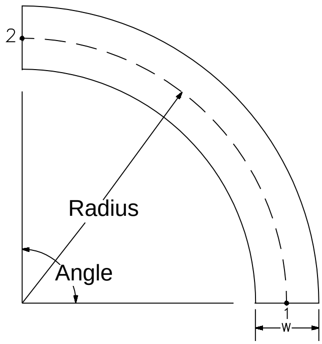


MCURVE (Microstrip Curved Bend)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = conductor width, in specified units

Angle = angle subtended by the bend, in degrees

Radius = radius (measured to strip centerline), in specified units

Temp = physical temperature, in °C

Range of Usage

$0.01 \times H \leq W \leq 100 \times H$
$-180° \leq Angle \leq 180°$
$Radius \geq W/2$

where

H = substrate thickness (from associated Subst)

Notes/Equations

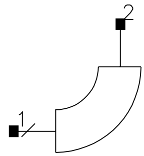
1. The microstrip curved bend is modeled in the frequency domain as an equivalent piece of straight microstrip line. The microstrip line is modeled using the MLIN component, including conductor loss, dielectric loss and dispersion. A correction for finite line thickness is applied to the line width.

   The length of the equivalent straight microstrip section is equal to the product of the centerline radius and the angle in radians.

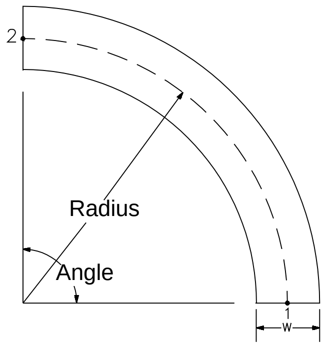
2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
3. To turn off noise contribution, set Temp to –273.15°C.
4. In layout, a positive value for Angle specifies a counterclockwise curvature; a negative value specifies a clockwise curvature.

MCURVE2 (Microstrip Curved Bend)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = conductor width, in specified units

Angle = angle of bend, in degrees

Radius = radius (measured to strip centerline), in specified units

NMode = number of modes (refer to notes)

Temp = physical temperature, in °C

Range of Usage

$0.01 \times H \leq W \leq 100 \times H$
$-360° \leq Angle \leq 360°$
$W \leq Radius \leq 100 \times W$
NMode = 0, 1, 2 ...

where

H = substrate thickness (from associated Subst)

Notes/Equations

1. The frequency-domain analytical model is based on a magnetic wall waveguide model developed by Weisshaar and Tripathi. The model includes the effect of higher order modes of propagation. Conductor loss, dielectric loss, and dispersion of both effective dielectric constant and characteristic impedance are also included.
2. NMode=1 or, at most, NMode=2 should provide satisfactory accuracy. Increasing NMode for improving accuracy results in significantly increased simulation time and additional memory requirements.
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
4. To turn off noise contribution, set Temp to −273.15°C.
5. In layout, a positive value for Angle specifies a counterclockwise curvature; a negative value specifies a clockwise curvature.

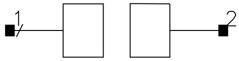
References

[1] A. Weisshaar, S. Luo, M. Thorburn, V. K. Tripathi, M. Goldfarb, J. L. Lee, and E. Reese. “Modeling of Radial Microstrip Bends,” *IEEE MTT-S International Microwave Symposium Digest*, Vol. III, May 1990, pp. 1051-1054.

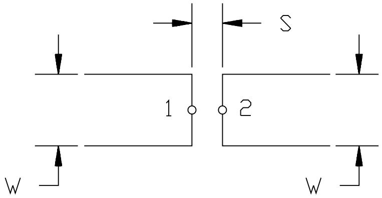
[2] A. Weisshaar and V. K. Tripathi. “Perturbation Analysis and Modeling of Curved Microstrip Bends,” *IEEE Transactions on Microwave Theory and Techniques*, Vol. 38, No. 10, October 1990, pp. 1449-1454.

MGAP (Microstrip Gap)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = conductor width, in specified units

S = length of gap (spacing), in specified units

Temp = physical temperature, in °C

Range of Usage

$1 \le Er \le 15$

$0.1 \le \frac{W}{H} \le 3.0$

$0.2 \le \frac{S}{H}$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)

Notes/Equations

1. The frequency-domain model is an empirically based, analytical model that consists of a lumped component, equivalent circuit. The equivalent circuit parameters are calculated based on the expressions developed by Kirschning, Jansen and Koster. Dispersion is included in the capacitance calculations.

2. This new version of the MGAP component improves the simulation accuracy of gap capacitance.

3. To turn off noise contribution, set Temp to –273.15°C.

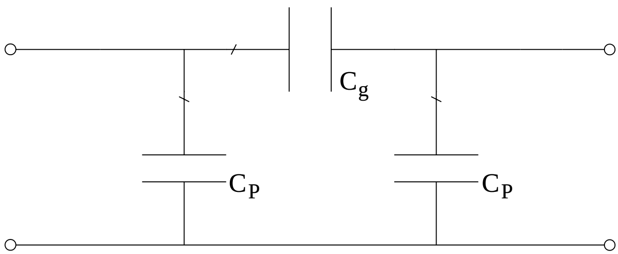
References

[1] E. Hammerstad, "Computer Aided Design of Microstrip Couplers with Accurate Discontinuity Models," *IEEE MTT-S International Microwave Symposium Digest*, June 1981, pp. 54-56 (with modifications).

[2] M. Kirschning, Jansen, R.H., and Koster, N. H. L. "Measurement and Computer-Aided Modeling of Microstrip Discontinuities by an Improved Resonator Method," *IEEE MTT-S International Microwave Symposium Digest*, May 1983, pp. 495-497.

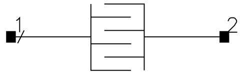
[3] N. H. L Koster and R. H. Jansen. "The Equivalent Circuit of the Asymmetrical Series Gap in Microstrip and Suspended Substrate Lines," *IEEE Trans. on Microwave Theory and Techniques*, Vol. MTT-30, Aug. 1982, pp. 1273-1279.

Equivalent Circuit

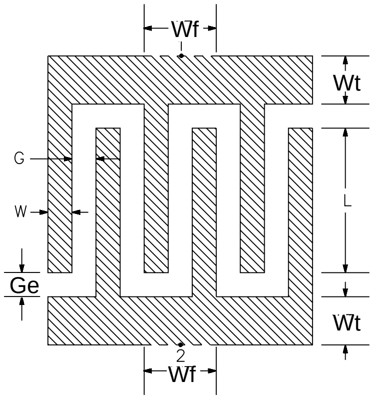


MICAP1 (Microstrip Interdigital Capacitor (2-port))

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = finger width, in specified units

G = gap between fingers, in specified units

Ge = gap at end of fingers, in specified units

L = length of overlapped region, in specified units

Np = number of finger pairs (an integer)

Wt = width of interconnect, in specified units

Wf = width of feedline, in specified units

Temp = physical temperature, in °C

Range of Usage

Er ≤ 12.5
T ≤ 0.015 × H

$0.05 \times H \le W \le 0.8 \times H$
$0.025 \times H \le G \le 0.45 \times H$

$$\text{Simulation frequency} \le \frac{2.4}{H(mm)} \text{ (GHz)}$$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
T = conductor thickness (from associated Subst)

Notes/Equations

1. The frequency-domain analytical model is a distributed, coupled-line model developed for Agilent by William J. Getsinger. (References [1], [2], and [3] are supplemental.)

   The digits of the structure are assumed to be part of an infinite array excited on an even- and odd-mode basis. Each component in this array is a unit cell bounded by magnetic walls. The model calculates the per-unit-length admittance and impedance matrices (even and odd modes) for each cell. This calculation is based on the even and odd mode capacitances, the conductor loss and the substrate dielectric loss. The capacitances are calculated by a conformal mapping technique. Conductor losses are calculated using Wheeler's method. Corrections for finite strip thickness and end effects are included. Network parameters of the transmission line model of each cell are calculated from the admittance and impedance matrices. The cells are combined to from the complete model including end effects. Microstrip dispersion effects are included in this model.

2. This component is intended for series connection.

3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

4. To turn off noise contribution, set Temp to –273.15°C.

References

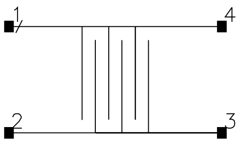
[1] G. Alley, “Interdigital Capacitors and Their Application to Lumped-Element Microwave Integrated Circuits,” *IEEE Trans. MTT-18*, December 1970, pp. 1028-1033 (with additions by Agilent).

[2] R. Esfandiari, D. Maku, and M. Siracusa, “Design of Interdigitated Capacitors and Their Application to Gallium-Arsenide Monolithic Filters,” *IEEE Trans. MTT*, Vol. 31, No. 1, January 1983, pp. 57-64.

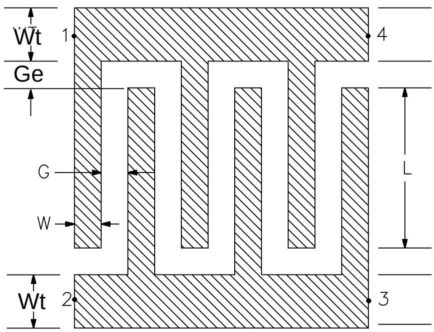
[3] X. Y. She and Y. L. Chow. “Interdigital microstrip capacitor as a four-port network,” *IEEE Proceedings*, Pt. H, Vol. 133, 1986, pp. 191-197.

MICAP2 (Microstrip Interdigital Capacitor (4-port))

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = finger width, in specified units

G = gap between fingers, in specified units

Ge = gap at end of fingers, in specified units

L = length of overlapped region, in specified units

Np = number of finger pairs (an integer)

Wt = width of interconnect, in specified units

Temp = physical temperature, in °C

Range of Usage

$Er \leq 12.5$
$T \leq 0.015 \times H$
$0.05 \times H \leq W \leq 0.8 \times H$
$0.025 \times H \leq G \leq 0.45 \times H$

$$\text{Simulation frequency} \le \frac{2.4}{H(mm)} \text{ (GHz)}$$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
T = conductor thickness (from associated Subst)

Notes/Equations

1. The frequency-domain analytical model is a distributed, coupled-line model developed for Agilent by William J. Getsinger. (References [1], [2], and [3] are supplemental.)

   The digits of the structure are assumed to be part of an infinite array excited on an even- and odd-mode basis. Each component in this array is a unit cell bounded by magnetic walls. The model calculates the per-unit-length admittance and impedance matrices (even and odd modes) for each cell. This calculation is based on the even and odd mode capacitances, the conductor loss and the substrate dielectric loss. The capacitances are calculated by a conformal mapping technique. Conductor losses are calculated using Wheeler's method. Corrections for finite strip thickness and end effects are included. Network parameters of the transmission line model of each cell are calculated from the admittance and impedance matrices. The cells are combined to from the complete model including end effects. Microstrip dispersion effects are include in this model.

2. This component is used when a cascade configuration is not appropriate.

3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

4. To turn off noise contribution, set Temp to –273.15°C.

References

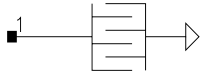
[1] G. Alley, “Interdigital Capacitors and Their Application to Lumped-Element Microwave Integrated Circuits,” *IEEE Trans. MTT-18*, December 1970, pp. 1028-1033 (with additions by Agilent).

[2] R. Esfandiari, D. Maku and M. Siracusa. “Design of Interdigitated Capacitors and Their Application to Gallium-Arsenide Monolithic Filters,” *IEEE Trans. MTT*, Vol. 31, No. 1, January 1983, pp. 57-64.

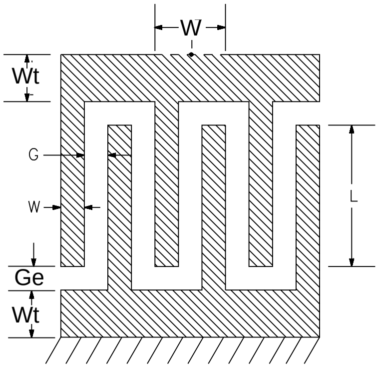
[3] X. Y. She and Y. L. Chow. “Interdigital microstrip capacitor as a four-port network,” *IEEE Proceedings*, Pt. H, Vol. 133, 1986, pp. 191-197.

MICAP3 (Microstrip Interdigital Capacitor (1-port))

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = finger width, in specified units

G = gap between fingers, in specified units

Ge = gap at end of fingers, in specified units

L = length of overlapped region, in specified units

Np = number of finger pairs (an integer)

Wt = width of interconnect, in specified units

Wf = width of the feedline, in specified units

Temp = physical temperature, in °C

Range of Usage

$Er \leq 12.5$
$T \leq 0.015 \times H$
$0.05 \times H \leq W \leq 0.8 \times H$
$0.025 \times H \leq G \leq 0.45 \times H$

$$\text{Simulation frequency} \le \frac{2.4}{H(mm)} \text{ (GHz)}$$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
T = conductor thickness (from associated Subst)

Notes/Equations

1. The frequency-domain analytical model is a distributed, coupled-line model developed for Agilent by William J. Getsinger. (References [1], [2], and [3] are supplemental.)

   The digits of the structure are assumed to be part of an infinite array excited on an even- and odd-mode basis. Each component in this array is a unit cell bounded by magnetic walls. The model calculates the per-unit-length admittance and impedance matrices (even and odd modes) for each cell. This calculation is based on the even and odd mode capacitances, the conductor loss and the substrate dielectric loss. The capacitances are calculated by a conformal mapping technique. Conductor losses are calculated using Wheeler's method. Corrections for finite strip thickness and end effects are included. Network parameters of the transmission line model of each cell are calculated from the admittance and impedance matrices. The cells are combined to from the complete model including end effects. Microstrip dispersion effects are included in this model.

2. This is a 1-port configuration of MICAP1 for use where one side of the interdigital capacitor is connected to ground.

3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

4. To turn off noise contribution, set Temp to –273.15°C.

5. Proper grounding must be added manually in the layout. The implied ground plane is drawn on the layer mapped to the Hole parameter in the MSUB component. The ground plane is for modeling in Momentum and is not modeled separately in the circuit simulator.

References

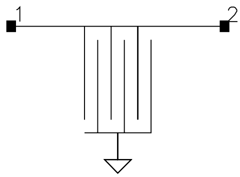
[1] G. Alley, “Interdigital Capacitors and Their Application to Lumped-Element Microwave Integrated Circuits,” *IEEE Trans. MTT-18*, December 1970, pp. 1028-1033 (with additions by Agilent).

[2] R. Esfandiari, D. Maku and M. Siracusa. “Design of Interdigitated Capacitors and Their Application to Gallium-Arsenide Monolithic Filters,” *IEEE Trans. MTT*, Vol. 31, No. 1, pp. 57-64, January 1983.

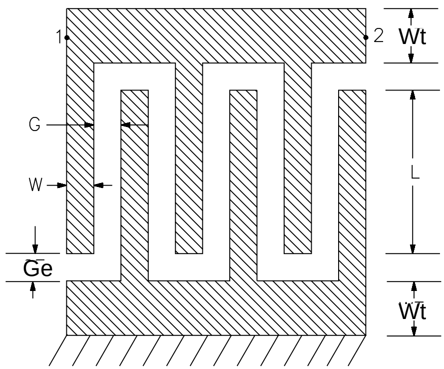
[3] X. Y. She and Y. L. Chow. “Interdigital microstrip capacitor as a four-port network,” *IEEE Proceedings*, Pt. H, Vol. 133, 1986, pp. 191-197.

MICAP4 (Microstrip Interdigital Capacitor (Grounded 2-port))

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = finger width, in specified units

G = gap between fingers, in specified units

Ge = gap at end of fingers, in specified units

L = length of overlapped region, in specified units

Np = number of finger pairs (an integer)

Wt = width of interconnect, in specified units

Temp = physical temperature, in °C

Range of Usage

$Er \leq 12.5$
$T \leq 0.015 \times H$

$0.05 \times H \leq W \leq 0.8 \times H$
$0.025 \times H \leq G \leq 0.45 \times H$

$$\text{Simulation frequency} \leq \frac{2.4}{H(mm)} \text{ (GHz)}$$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
T = conductor thickness (from associated Subst)

Notes/Equations

1. The frequency-domain analytical model is a distributed, coupled-line model developed for Agilent by William J. Getsinger. References [1], [2], and [3] are supplemental.

   The digits of the structure are assumed to be part of an infinite array excited on an even- and odd-mode basis. Each component in this array is a unit cell bounded by magnetic walls. The model calculates the per-unit-length admittance and impedance matrices (even and odd modes) for each cell. This calculation is based on the even and odd mode capacitances, the conductor loss and the substrate dielectric loss. The capacitances are calculated by a conformal mapping technique. Conductor losses are calculated using Wheeler's method. Corrections for finite strip thickness and end effects are included. Network parameters of the transmission line model of each cell are calculated from the admittance and impedance matrices. The cells are combined to from the complete model including end effects. Microstrip dispersion effects are included in this model.

2. This is a 2-port configuration of MICAP2 intended for use where one side of the interdigital capacitor is connected to ground and the other side does not have a simple single connection point.

3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

4. To turn off noise contribution, set Temp to –273.15°C.

5. Proper grounding must be added manually in the layout. The implied ground plane is drawn on the layer mapped to the Hole parameter in the MSUB component. The ground plane is for modeling in Momentum and is not modeled separately in the circuit simulator.

References

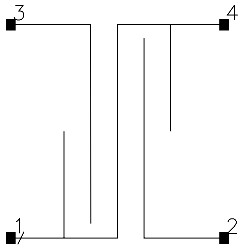
[1] G. Alley, “Interdigital Capacitors and Their Application to Lumped-Element Microwave Integrated Circuits,” *IEEE Trans. MTT-18*, December 1970, pp. 1028-1033 (with additions by Agilent).

[2] R. Esfandiari, D. Maku, and M. Siracusa. “Design of Interdigitated Capacitors and Their Application to Gallium-Arsenide Monolithic Filters,” *IEEE Trans. MTT*, Vol. 31, No. 1, pp. 57-64, January 1983.

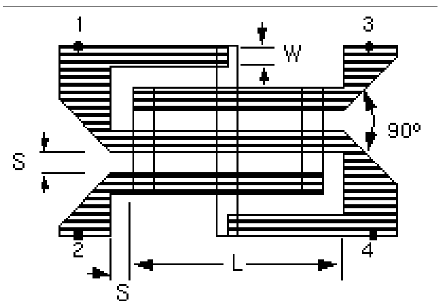
[3] X. Y. She and Y. L. Chow. “Interdigital microstrip capacitor as a four-port network,” *IEEE Proceedings*, Pt. H, Vol. 133, 1986, pp. 191-197.

MLANG (Microstrip Lange Coupler)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = finger width, in specified units

S = conductor spacing, in specified units

L = conductor length, in specified units

Temp = physical temperature, in °C

W1 = (ADS Layout option) width of transmission lines that connect to pins 1, 2, 3, 4

Range of Usage

$1 \le Er \le 18$

$$0.01 \le \frac{W}{H} \le 10$$

$$0.01 \le \frac{S}{H} \le 10$$

$$\text{Simulation frequency} \le \frac{25}{H(mm)} \quad \text{(GHz)}$$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
$(3W + 2S) \ge W1 \ge 0$ for proper layout

Notes/Equations

1. The frequency-domain analytical model is a distributed, coupled-line model. Even- and odd-mode capacitances are calculated for each unit-cell of the interdigitated structure. Alternate fingers are assumed to be at the same potential. Only coupling between adjacent fingers is included in the model.

   The per-unit-length coupling capacitances are calculated using the formula developed by Kirschning and Jansen for parallel coupled microstrip lines, and the formula developed by Hammerstad and Jensen for single microstrip line.

   Dispersion and conductor loss are included. The even- and odd-mode line impedances are calculated based on the coupling capacitances and conductor losses. This result is used to calculate the network parameters of the distributed, coupled-line model.

2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

3. To turn off noise contribution, set Temp to −273.15°C.

4. The conductor drawn on the layer mapped to the Cond2 parameter, as well as the transition drawn on the layer to the Diel2 parameter, in the MSUB component are for the purpose of modeling in Momentum. They are not modeled separately in the circuit simulator.

References

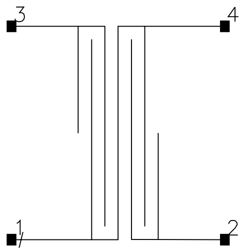
[1] W. H. Childs, “A 3-dB Interdigitated Coupler on Fused Silica,” *IEEE MTT Symposium Digest*, 1977.

[2] E. Hammerstad and O. Jensen, “Accurate Models for Microstrip Computer-Aided Design,” *MTT Symposium Digest*, 1980, pp. 407-409.

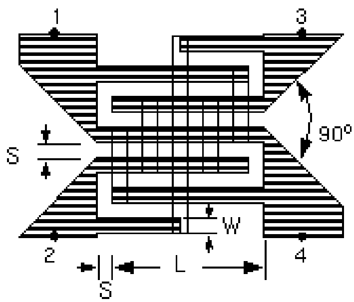
[3] M. Kirschning and R. H. Jansen, “Accurate Wide-Range Design Equations for the Frequency-Dependent Characteristics of Parallel Coupled Microstrip Lines,” *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-32, January 1984, pp. 83-89.

MLANG6 (Microstrip Lange Coupler (6-Fingered))

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = conductor width, in specified units

S = conductor spacing, in specified units

L = conductor length, in specified units

Temp = physical temperature, in °C

W1 = (ADS Layout option) width of transmission lines that connect to pins 1, 2, 3, 4

Range of Usage

$1 \le Er \le 18$

$$0.01 < \frac{W}{H} < 10$$

$$0.01 < \frac{S}{H} < 10$$

$$\text{Simulation frequency} \leq \frac{25}{H(mm)} \text{ (GHz)}$$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
(3W + 2S) ≥ W1 ≥ 0 for proper layout

Notes/Equations

1. The frequency-domain analytical model is a distributed, coupled-line model. Even- and odd-mode capacitances are calculated for each unit-cell of the interdigitated structure. Alternate fingers are assumed to be at the same potential. Only coupling between adjacent fingers is included in the model.

   The per-unit-length coupling capacitances are calculated using the formula developed by Kirschning and Jansen for parallel coupled microstrip lines, and the formula developed by Hammerstad and Jensen for single microstrip line.

   Dispersion and conductor loss are included. The even- and odd-mode line impedances are calculated based on the coupling capacitances and conductor losses. This result is used to calculate the network parameters of the distributed, coupled-line model.

2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

3. To turn off noise contribution, set Temp to –273.15°C.

4. W1 is a layout-only parameter and does not affect the simulation results.

5. The conductor drawn on the layer mapped to the Cond2 parameter, as well as the transition drawn on the layer to the Diel2 parameter, in the MSUB component are for the purpose of modeling in Momentum. They are not modeled separately in the circuit simulator.

References

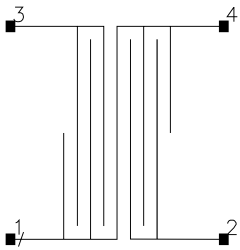
[1] W. H. Childs, “A 3-dB Interdigitated Coupler on Fused Silica,” *IEEE MTT Symposium Digest*, 1977.

[2] E. Hammerstad and O. Jensen, “Accurate Models for Microstrip Computer-Aided Design,” *MTT Symposium Digest*, 1980, pp. 407-409.

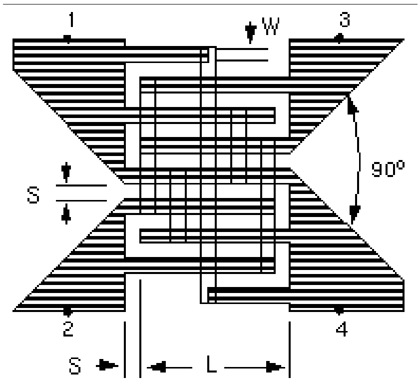
6. M. Kirschning and R. H. Jansen, “Accurate Wide-Range Design Equations for the Frequency-Dependent Characteristics of Parallel Coupled Microstrip Lines,” *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-32, January 1984, pp. 83-89.

MLANG8 (Microstrip Lange Coupler (8-Fingered))

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = conductor width, in specified units

S = conductor spacing, in specified units

L = conductor length, in specified units

Temp = physical temperature, in °C

W1 = (ADS Layout option) width of transmission lines that connect to pins 1, 2, 3, 4

Range of Usage

$1 \le Er \le 18$

$0.01 \le \frac{W}{H} \le 10$

$$0.01 \le \frac{S}{H} \le 10$$

$$\text{Simulation frequency} \le \frac{25}{H(mm)} \text{ (GHz)}$$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
(5W + 4S) ≥ W1≥ 0 for proper layout

Notes/Equations

1. The frequency-domain analytical model is a distributed, coupled-line model. Even- and odd-mode capacitances are calculated for each unit-cell of the interdigitated structure. Alternate fingers are assumed to be at the same potential. Only coupling between adjacent fingers is included in the model.

   The per-unit-length coupling capacitances are calculated using the formula developed by Kirschning and Jansen for parallel coupled microstrip lines, and the formula developed by Hammerstad and Jensen for single microstrip line.

   Dispersion and conductor loss are included. The even- and odd-mode line impedances are calculated based on the coupling capacitances and conductor losses. This result is used to calculate the network parameters of the distributed, coupled-line model.

2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
3. To turn off noise contribution, set Temp to –273.15°C.
4. W1 is a layout-only parameter and does not affect the simulation results.
5. The conductor drawn on the layer mapped to the Cond2 parameter, as well as the transition drawn on the layer to the Diel2 parameter, in the MSUB component are for the purpose of modeling in Momentum. They are not modeled separately in the circuit simulator.

References

[1] W. H. Childs, "A 3-dB Interdigitated Coupler on Fused Silica," *IEEE MTT Symposium Digest*, 1977.

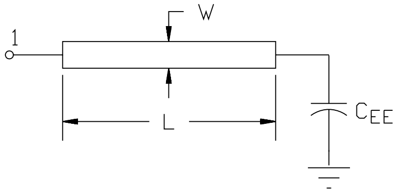
[2] E. Hammerstad and O. Jensen, "Accurate Models for Microstrip Computer-Aided Design," *MTT Symposium Digest*, 1980, pp. 407-409.

[3] M. Kirschning and R. H. Jansen, “Accurate Wide-Range Design Equations for the Frequency-Dependent Characteristics of Parallel Coupled Microstrip Lines,” *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-32, January 1984, pp. 83-89.

MLEF (Microstrip Line Open-End Effect)

Symbol

Illustration



Parameters

Subst = microstrip substrate name

W = line width, in specified units

L = line length, in specified units

Wall1 = distance from near edge of strip H to first sidewall

Wall2 = distance from near edge of strip H to second sidewall

Temp = physical temperature, in °C

Range of Usage

$2 \leq Er \leq 50$

$$\frac{W}{H} \geq 0.2$$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)

Notes/Equations

1. The open-end effect in microstrip is modeled in the frequency domain as an extension to the length of the microstrip stub. The microstrip is modeled using the MLIN component, including conductor loss, dielectric loss and dispersion. A correction for finite line thickness is applied to the line width. The length of the microstrip extension, dl, is based on the formula developed by Kirschning,

Jansen and Koster. Fringing at the open end of the line is calculated and included in the model.

2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

3. To turn off noise contribution, set Temp to –273.15°C.

4. When the Hu parameter of the substrate is less than $100 \times$ Thickness_of_substrate, the impedance calculation will not be properly done if WALL1 and WALL2 are left blank.

5. Wall1 and Wall2 must satisfy the following constraints:

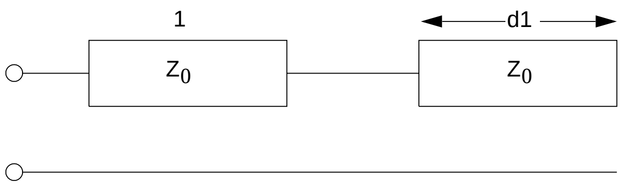
   Min(Wall1) > 1/2 × Maximum(Metal_Width, Substrate_Thickness)

   Min(Wall2) > 1/2 × Maximum(Metal_Width, Substrate_Thickness)

References

[1] M. Kirschning, R. H. Jansen, and N. H. L. Koster. "Accurate Model for Open-End Effect of Microstrip Lines," *Electronics Letters*, Vol. 17, No. 3, February 5, 1981, pp. 123-125.

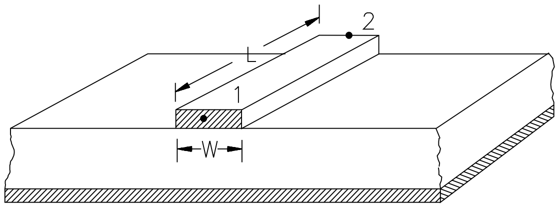
Equivalent Circuit



MLIN (Microstrip Line)

Symbol

Illustration



Parameters

Subst = microstrip substrate name

W = line width, in specified units

L = line length, in specified units

Wall1 = distance from near edge of strip H to first sidewall

Wall2 = distance from near edge of strip H to second sidewall

Temp = physical temperature, in °C

Mod = choice of dispersion formula

Range of Usage

$1 \le ER \le 128$

$$0.01 \le \frac{W}{H} \le 100$$

where

ER = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)

Recommended Range for different dispersion models

Kirschning and Jansen:

$1 \leq Er \leq 20$

$0.1 \times H \leq W \leq 100 \times H$

Kobayashi:

$1 \leq Er \leq 128$

$0.1 \times H \leq W \leq 10 \times H$

$0 \leq H \leq 0.13 \times \lambda$

Yamashita:

$2 \leq Er \leq 16$

$0.05 \times H \leq W \leq 16 \times H$

where

λ = wavelength

freq ≤ 100 GHz

Notes/Equation

1. The frequency-domain analytical model uses the Kirschning and Jansen formula to calculate the static impedance, Z_o, and effective dielectric constant, $\varepsilon_{eff.}$. The attenuation factor, α, is calculated using the incremental inductance rule by Wheeler. The frequency dependence of the skin effect is included in the conductor loss calculation. Dielectric loss is also included in the loss calculation.
2. Dispersion effects are included using either the improved version of the Kirschning and Jansen model, the Kobayashi model, or the Yamashita model, depending on the choice specified in Mod. The program defaults to using the Kirschning and Jansen formula.
3. For time-domain analysis, an impulse response obtained from the frequency analytical model is used.
4. To turn off noise contribution, set Temp to –273.15°C.
5. When the Hu parameter of the substrate is less than $100 \times H$, the enclosure effect will not be properly calculated if Wall1 and Wall2 are left blank.
6. Wall1 and Wall2 must satisfy the following constraints:

$\text{Min(Wall1)} > 1/2 \times \text{Maximum(W, H)}$

$\text{Min(Wall2)} > 1/2 \times \text{Maximum(W, H)}$

References

[1] W. J. Getsinger, "Measurement and Modeling of the Apparent Characteristic Impedance of Microstrip," *MTT-31*, August 1983.

[2] E. Hammerstad and O. Jensen, "Accurate Models for Microstrip Computer-aided Design," *MTT Symposium Digest*, 1980.

[3] M. Kirschning and R.H. Jansen, "Accurate Model for Effective Dielectric Constant of Microstrip and Validity up in Millimeter-Wave Frequencies", *Electron*. Lett, Vol. 18 March 18, 1982, pp. 272-273.

[4] M. Kobayashi , "Frequency Dependent Characteristics of Microstrips on Ansiotropic Substrates", *IEEE Trans*., Vol. MTT-30, November 1983, pp. 89-92.

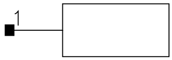
[5] M. Kobayashi, "A Dispersion Formula Satisfying Recent Requirements in Microstrip CAD", *IEEE Trans*., Vol. MTT-36, August 1990, pp. 1246-1370.

[6] E. Yamashita, K. Atshi and T. Hirachata, "Microstrip Dispersion in a Wide Frequency Range", *IEEE Trans*., Vol. MTT-29, June 1981, pp. 610-611.

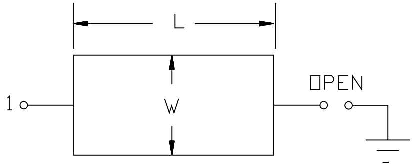
[7] H. A. Wheeler, "Formulas for the Skin Effect," *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

MLOC (Microstrip Open-Circuited Stub)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = line width, in specified units

L = line length, in specified units

Wall1 = distance from near edge of strip to first sidewall

Wall2 = distance from near edge of strip to second sidewall

Temp = physical temperature, in °C

Mod = choice of dispersion formula

Range of Usage

$1 \le Er \le 128$

$$0.01 \le \frac{W}{H} \le 100$$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)

Recommended Range for different dispersion models

Kirschning and Jansen:

$1 \le Er \le 20$

$0.1 \times H \le W \le 100 \times H$

Kobayashi:

$1 \le Er \le 128$

$0.1 \times H \le W \le 10 \times H$

$0 \le H \le 0.13 \times \lambda$

Yamashita:

$2 \le Er \le 16$

$0.05 \times H \le W \le 16 \times H$

where

λ = wavelength

freq $\le$ 100 GHz

Notes/Equations

1. The frequency-domain analytical model uses the Kirschning and Jansen formula to calculate the static impedance, Z_o, and effective dielectric constant, ε_{eff}. The attenuation factor, α, is calculated using the incremental inductance rule by Wheeler. The frequency dependence of the skin effect is included in the conductor loss calculation. Dielectric loss is also included in the loss calculation.
2. Dispersion effects are included using either the improved version of the Kirschning and Jansen model, the Kobayashi model, or the Yamashita model, depending on the choice specified in Mod. The program defaults to using the Kirschning and Jansen formula.
3. For time-domain analysis, an impulse response obtained from the frequency analytical model is used.
4. To turn off noise contribution, set Temp to –273.15°C.
5. When the Hu parameter of the substrate is less than $100 \times H$, the enclosure effect will not be properly calculated if Wall1 and Wall2 are left blank.
6. Wall1 and Wall2 must satisfy the following constraints:

$\text{Min(Wall1)} > 1/2 \times \text{Maximum(W, H)}$

$\text{Min(Wall2)} > 1/2 \times \text{Maximum(W, H)}$

7. End effects are included in the model.

References

[1] W. J. Getsinger, “Measurement and Modeling of the Apparent Characteristic Impedance of Microstrip,” *MTT-31*, August 1983.

[2] E. Hammerstad and O. Jensen, “Accurate Models for Microstrip Computer-aided Design,” *MTT Symposium Digest*, 1980.

[3] M. Kirschning and R.H. Jansen, “Accurate Model for Effective Dielectric Constant of Microstrip and Validity up in Millimeter-Wave Frequencies”, *Electron*. Lett, Vol. 18 March 18, 1982, pp. 272-273.

[4] Kobayashi, M., “Frequency Dependent Characteristics of Microstrips on Ansiotropic Substrates”, *IEEE Trans*., Vol. MTT-30, November 1983, pp. 89-92.

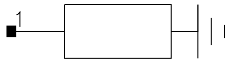
[5] Kobayashi, M., “A Dispersion Formula Satisfying Recent Requirements in Microstrip CAD”, *IEEE Trans*., Vol. MTT-36, August 1990, pp. 1246-1370.

[6] Yamashita, E., K. Atshi and T. Hirachata, “Microstrip Dispersion in a Wide Frequency Range”, *IEEE Trans*., Vol. MTT-29, June 1981, pp. 610-611.

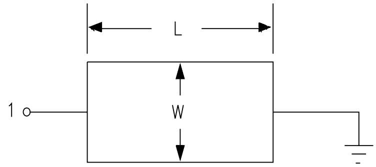
[7] H. A. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

MLSC (Microstrip Short-Circuited Stub)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = line width, in specified units

L = line length, in specified units

Wall1 = distance from near edge of strip to first sidewall

Wall2 = distance from near edge of strip to second sidewall

Temp = physical temperature, in °C

Mod = choice of dispersion formula

Range of Usage

$1 \leq Er \leq 128$

$$0.01 \leq \frac{W}{H} \leq 100$$

where

Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)

Recommended Range for different dispersion models

Kirschning and Jansen:

$1 \leq Er \leq 20$

$0.1 \times H \leq W \leq 100 \times H$

Kobayashi:

$1 \leq Er \leq 128$

$0.1 \times H \leq W \leq 10 \times H$

$0 \leq H \leq 0.13 \times \lambda$

Yamashita:

$2 \leq Er \leq 16$

$0.05 \times H \leq W \leq 16 \times H$

where

λ = wavelength

freq $\leq$ 100 GHz

Notes/Equations

1. The frequency-domain analytical model uses the Kirschning and Jansen formula to calculate the static impedance, Z_o, and effective dielectric constant, $\varepsilon_{eff.}$. The attenuation factor, α, is calculated using the incremental inductance rule by Wheeler. The frequency dependence of the skin effect is included in the conductor loss calculation. Dielectric loss is also included in the loss calculation.
2. Dispersion effects are included using either the improved version of the Kirschning and Jansen model, the Kobayashi model, or the Yamashita model, depending on the choice specified in Mod. The program defaults to using the Kirschning and Jansen formula.
3. For time-domain analysis, an impulse response obtained from the frequency analytical model is used.
4. To turn off noise contribution, set Temp to –273.15°C.
5. When the Hu parameter of the substrate is less than $100 \times H$, the enclosure effect will not be properly calculated if Wall1 and Wall2 are left blank. Hu and

H respectively cover the height and substrate thickness specified in the associated substrate.

6. Wall1 and Wall2 must satisfy the following constraints:

   $\mathrm{Min(Wall1)} > 1/2 \times \mathrm{Maximum(W, H)}$

   $\mathrm{Min(Wall2)} > 1/2 \times \mathrm{Maximum(W, H)}$

   where H is the substrate thickness specified in the associated substrate.

7. End effects are included in the model.

References

[1] W. J. Getsinger, “Measurement and Modeling of the Apparent Characteristic Impedance of Microstrip,” *MTT-31*, August 1983.

[2] E. Hammerstad and O. Jensen, “Accurate Models for Microstrip Computer-aided Design,” *MTT Symposium Digest*, 1980.

[3] M. Kirschning and R.H. Jansen, “Accurate Model for Effective Dielectric Constant of Microstrip and Validity up in Millimeter-Wave Frequencies”, *Electron*. Lett, Vol. 18 March 18, 1982, pp. 272-273.

[4] Kobayashi, M., “Frequency Dependent Characteristics of Microstrips on Ansiotropic Substrates”, *IEEE Trans*., Vol. MTT-30, November 1983, pp. 89-92.

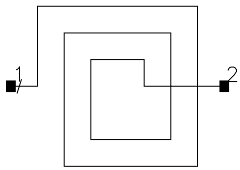
[5] Kobayashi, M., “A Dispersion Formula Satisfying Recent Requirements in Microstrip CAD”, *IEEE Trans*., Vol. MTT-36, August 1990, pp. 1246-1370.

[6] Yamashita, E., K. Atshi and T. Hirachata, “Microstrip Dispersion in a Wide Frequency Range”, *IEEE Trans*., Vol. MTT-29, June 1981, pp. 610-611.

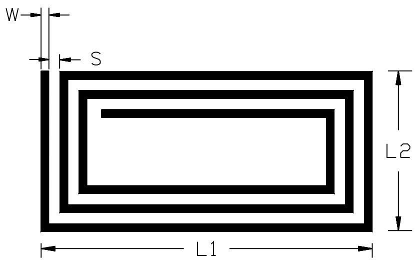
[7] H. A. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

MRIND (Microstrip Rectangular Inductor)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

N = number of turns (need not be an integer)

L1 = length of second outermost segment (see illustration), in specified units

L2 = length of outermost segment (see illustration), in specified units

W = conductor width, in specified units

S = conductor spacing, in specified units

Temp = physical temperature, in °C

W1 = (ADS Layout option) width of line that connects to pin 1

W2 = (ADS Layout option) width of line that connects to pin 2

Range of Usage

$W > 0$; $S > 0$; $T > 0$
$N \leq 8$ (or the highest number of turns that will fit, given W, S, L1 and L2)
$L1 > 2 \times N \times W + (2 \times N\text{-}1) \times S$
$L2 > 2 \times N \times W + (2 \times N\text{-}1) \times S$

$W + S \geq 0.01 \times H$
$T/W < 0.5$
$T/S < 0.5$
$N > 0.25$ turns

where

S = conductor spacing
T = conductor thickness (from associated Subst)
H = substrate thickness (from associated Subst)

Notes/Equations

1. The number of turns (N) is adjusted to the nearest quarter turn. This component does not include a connection (such as an air-bridge) from the center of the inductor to the outside.

2. The frequency-domain analytical model for this component has been developed for Agilent by William J. Getsinger. Results published in the references listed at the end of these notes were used in the development of this model.

3. Each segment of the spiral is modeled as a lumped C-L-C π-section with mutual inductive coupling to all other parallel segments including those of an image spiral. The image spiral accounts for the effects of the microstrip ground plane. The inductive calculations include the end-effects and differing lengths of coupled segments. The capacitive components account for capacitance to ground, coupling to the parallel adjacent segments, and the coupling to the next parallel segments beyond the adjacent, on both sides.

   The frequency dependence of the skin effect is included in the conductor loss calculation. A smooth transition is provided from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the loss calculation.

4. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

5. To turn off noise contribution, set Temp to –273.15°C.

6. In layout, the number of turns is rounded to the nearest quarter-turn. The connection will align at the inside edge at pin 1 and the outside edge at pin 2, unless $W1 < W$ or $W2 > W$, in which case the conductors are centered.

References

[1] C. Hoer and C. Love, “Exact inductance equations for rectangular conductors with applications to more complicated geometrics,” *Journal of Research of NBS*, Vol. 69C, No. 2, April-June 1965, pp. 127-137.

[2] N. Marcuvitz, *Waveguide Handbook*, McGraw-Hill, New York, 1951, sections 5.11 and 5.28.

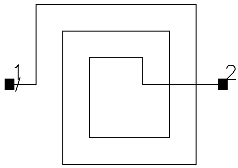
[3] V. Ghoshal and L. Smith, “Skin effects in narrow copper microstrip at 77K,” *IEEE Trans. on Microwave Theory and Tech.*, Vol. 36, December 1988.

[4] H. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, Sept. 1941, pp. 412-424.

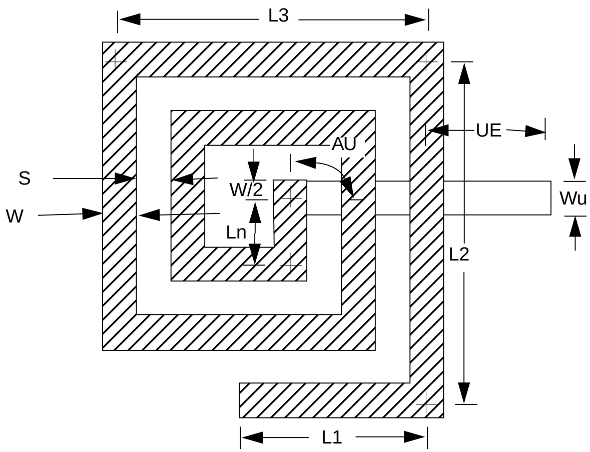
[5] K. Gupta, R. Garg and I. Bahl, *Microstrip lines and slotlines*, Artech House, Dedham, MA, section 2.4.5.

MRINDELA (Elevated Microstrip Rectangular Inductor)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

Ns = number of segments

L1 = length of first segment, in specified units

L2 = length of second segment, in specified units

L3 = length of third segment, in specified units

Ln = length of last segment, in specified units

W = conductor width, in specified units

S = conductor spacing, in specified units

Hi = elevation of inductor above substrate, in specified units

Ti = thickness of conductors, in specified units (T parameter in MSUB is ignored)

Ri = resistivity (relative to gold) of conductors

Sx = spacing limit between support posts, in specified units (0 to ignore posts)

Cc = coefficient for capacitance of corner support posts (ratio of actual post cross-sectional area to W^2)

Cs = coefficient for capacitance of support posts along segment (ratio of actual post cross-sectional area to W^2)

Wu = width of underpass strip conductor, in specified units

Au = angle of departure from innermost segment, in degrees

UE = extension of underpass beyond inductor, in specified units

Temp = physical temperature, in °C

Range of Usage

W > 0
S > 0
Sx > 2W
Au = 0°, 45°, or 90°
Au must be 90° if last segment (Ln) is less than full length
$\frac{W+S}{2} \leq Ln \leq Lnmax$ where Lnmax is the *full length* of the last segment (refer to Note 4)
Ti ≤ W and Ti ≤ S

Notes/Equations

1. The inductor is elevated in air above the substrate with a bridge connection that is in the form of an underpass strip conductor. Effects of support posts are included. Support posts are assumed to exist at each corner, plus along the segments, depending on the value of Sx.

2. The frequency-domain analytical model for this component has been developed for Agilent by William J. Getsinger. Results published in the references listed at the end of these notes were used in the development of this model.

3. Each segment of the spiral is modeled as a lumped C-L-C π-section with mutual inductive coupling to all other parallel segments including those of an image spiral. The image spiral accounts for the effects of the microstrip ground plane.

The inductive calculations include the end-effects and differing lengths of coupled segments. The capacitive components account for capacitance to ground, coupling to the parallel adjacent segments, and the coupling to the next parallel segments beyond the adjacent, on both sides.

The frequency dependence of the skin effect is included in the conductor loss calculation. A smooth transition is provided from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the loss calculation.

4. The underpass conductor (bridge) connects to the innermost segment and crosses the inductor from underneath the spiral. The bridge is capacatively coupled to each segment of the spiral that it crosses.
5. If Ln is set to 0, it is assumed to have *full length*. The *full length* (Lnmax) is such that the spacing from the contact reference point to the inner edge of the fourth-from-last segment is S+W/2.

   If Ns is even: $Lnmax = L2 - (Ns - 2) \times (W + S)/2$
   If Ns is odd: $Lnmax = L3 - (Ns - 3) \times (W + S)/2$
6. If Wu=0, the effect of the underpass strip conductor is not simulated.
7. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
8. To turn off noise contribution, set Temp to −273.15°C.
9. In layout, spiral segments are drawn on the layer mapped to the Cond2 parameter of the MSUB component; support posts are drawn on the layer mapped to the Cond1 parameter of the MSUB component.

   For layout purposes the last segment (Ln) is drawn such that it extends a distance of W/2 beyond the contact reference point. This allows for a square region of size W×W, on which the contact to the underpass is centered.

   Inductor segments to airbridge/underpass transition are drawn on the layer mapped to the diel2 layer. The transition is only for the purpose of modeling in Momentum and is not taken into account in the circuit simulator.

   For the transition at pin 2, if the angle of the airbridge/underpass is 0 or 45, the width of the transition is the width of the airbridge/underpass; if the angle of the airbridge/underpass is 90, the width of the transition is the width of the inductor segment.

References

[1] C. Hoer and C. Love, “Exact inductance equations for rectangular conductors with applications to more complicated geometrics,” *Journal of Research of NBS*, Vol. 69C, No. 2, April-June 1965, pp. 127-137.

[2] N. Marcuvitz, *Waveguide Handbook*, McGraw-Hill, New York, 1951, sections 5.11 and 5.28.

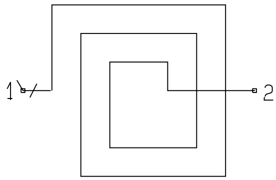
[3] V. Ghoshal and L. Smith, “Skin effects in narrow copper microstrip at 77K,” *IEEE Trans. on Microwave Theory and Tech.*, Vol. 36, December 1988.

[4] H. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, Sept. 1941, pp. 412-424.

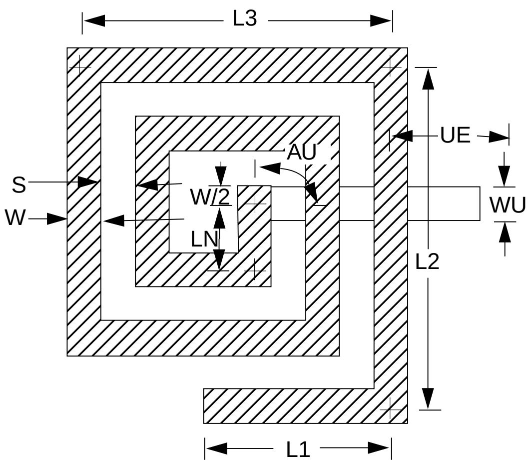
[5] K. Gupta, R. Garg and I. Bahl, *Microstrip lines and slotlines*, Artech House, Dedham, MA, section 2.4.5.

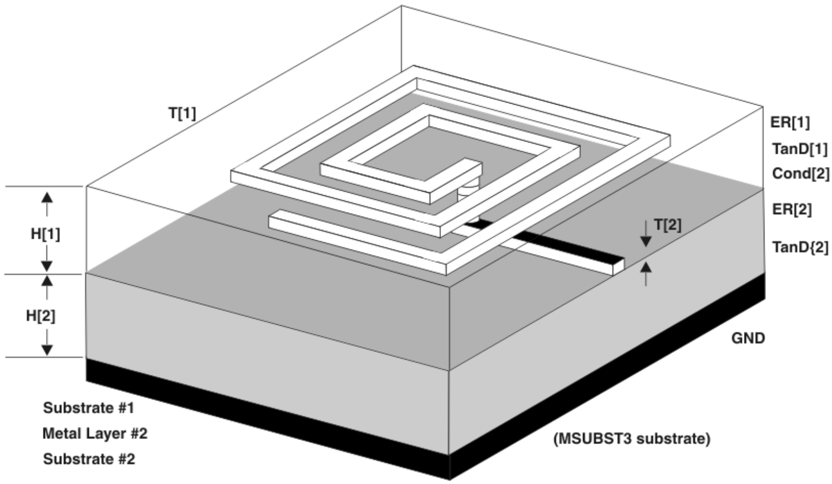
MRINDELM (Elevated Microstrip Rectangular Inductor (3-Layer Substrate))

Symbol



Illustrations





Parameters

Subst = microstrip substrate name

Ns = number of segments

L1 = length of first segment, in length units

L2 = length of second segment, in length units

L3 = length of third segment, in length units

Ln = length of last segment, in specified units

W = conductor width, in specified units

S = conductor spacing, in specified units

WU = width of underpass conductor, in length units

AU = angle of departure from innermost segment, in angle units

UE = extension of underpass beyond inductor, in length units

Temp = physical temperature, in °C

Range of Usage (including data item parameters)

W > 0
S > 0

AU = 0°, 45°, or 90°
AU must be 90° if last segment (LN) is less than full length

$$\frac{W+S}{2} \le LN \le LNmax$$

where LNmax is the *full length* of the last segment (refer to Note 5)
MSUBST3 substrate thickness H (1) > metal thickness T (1)

Notes/Equations

1. The inductor is elevated above a second substrate, as described by MSUBST3. The bridge connection is in the form of an underpass strip conductor that is printed on the bottom substrate (described by MSUBST3).
2. The frequency-domain analytical model for this element has been developed for Agilent by William J. Getsinger. Results published in the references listed at the end of these notes were used in the development of this model.
3. Each segment of the spiral is modeled as a lumped C-L-C π-section with mutual inductive coupling to all other parallel segments including those of an image spiral. The image spiral accounts for the effects of the microstrip ground plane. The inductive calculations include the end-effects and differing lengths of coupled segments. The capacitive elements account for capacitance to ground, coupling to the parallel adjacent segments, and the coupling to the next parallel segments beyond the adjacent, on both sides.

   The frequency dependence of the skin effect is included in the conductor loss calculation. A smooth transition is provided from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the loss calculation.
4. The underpass conductor (bridge) connects to the innermost segment and crosses the inductor from underneath the spiral. The bridge is capacatively coupled to each segment of the spiral that it crosses.
5. If LN is set to zero, it is assumed to have *full length*. The *full length* (LNmax) is such that the spacing from the contact reference point to the inner edge of the fourth-from-last segment is S+W/2.

   If NS is even: LNmax = L2 – (NS – 2) × (W + S)/2
   If NS is odd: LNmax = L3 – (NS – 3) × (W + S)/2
6. If WU=0, the effect of the underpass strip conductor is not simulated.
7. For transient analysis, microstrip inductors are modeled using a lumped RLC circuit.

8. For convolution analysis, the frequency-domain analytical model is used.
9. In Layout, the spiral inductor is mapped to the layer assigned to the LayerName[1] parameter of the MSUBST3 component referenced by the MRINDELM component. The underpass is mapped to the layer assigned to the LayerName[2] parameter of the MBSUBST3 component referenced by the MRINDELM component.

   For layout purposes the last segment (LN) is drawn such that it extends a distance of W/2 beyond the contact reference point. This allows for a square region of size W×W, on which the contact to the underpass is centered.

   The inductor segments to air-bridge/underpass transition is mapped to the layer assigned to the LayerViaName[1] parameter of the MSUBST3 component referenced in the MRINDELM component. The transition is only for the purpose of modeling in Momentum and is not taken into account in the circuit simulator.

   For the transition at pin 2, if the angle of the air-bridge/underpass is 0 or 45, the width of the transition is the width of the air-bridge/underpass; if the angle of the air-bridge/underpass is 90, the width of the transition is the width of the inductor segment.

References

[1] C. Hoer and C. Love, “Exact inductance equations for rectangular conductors with applications to more complicated geometrics,” *Journal of Research of NBS*, Vol. 69C, No. 2, April-June 1965, pp. 127-137.

[2] N. Marcuvitz, *Waveguide Handbook*, McGraw-Hill, New York, 1951, sections 5.11 and 5.28.

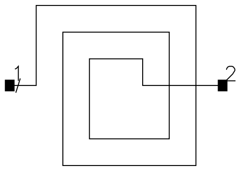
[3] V. Ghoshal and L. Smith, “Skin effects in narrow copper microstrip at 77K,” *IEEE Trans. on Microwave Theory and Tech.*, Vol. 36, December 1988.

[4] H. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, Sept. 1941, pp. 412-424.

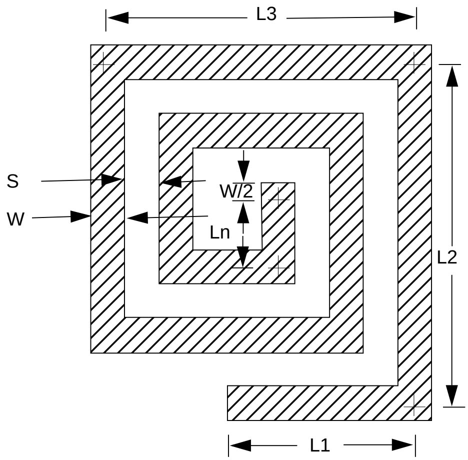
[5] K. Gupta, R. Garg and I. Bahl, *Microstrip lines and slotlines*, Artech House, Dedham, MA, section 2.4.5.

MRINDNBR (Microstrip Rectangular Inductor (No Bridge))

Symbol



Illustration



Parameters

Subst = microstrip substrate name

Ns = number of segments

L1 = length of first segment, in specified units

L2 = length of second segment, in specified units

L3 = length of third segment, in specified units

Ln = length of last segment, in specified units

W = conductor width, in specified units

S = conductor spacing, in specified units

Temp = physical temperature, in °C

Range of Usage

W > 0
S > 0

$$\frac{W+S}{2} \leq Ln \leq Lnmax$$

where
Lnmax is the *full length* of the last segment (refer to Note 3)

Notes/Equations

1. This component model is the same as that for MRIND. As with MRIND, this component does not include a connection (such as an airbridge) from the enter of the inductor to the outside.

2. The frequency-domain analytical model for this component has been developed for Agilent by William J. Getsinger. Results published in the references listed at the end of these notes were used in the development of this model.

3. Each segment of the spiral is modeled as a lumped C-L-C π-section with mutual inductive coupling to all other parallel segments including those of an image spiral. The image spiral accounts for the effects of the microstrip ground plane. The inductive calculations include the end-effects and differing lengths of coupled segments. The capacitive components account for capacitance to ground, coupling to the parallel adjacent segments, and the coupling to the next parallel segments beyond the adjacent, on both sides.

   The frequency dependence of the skin effect is included in the conductor loss calculation. A smooth transition is provided from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the loss calculation.

4. If Ln is set to zero, it is assumed to have *full length*. The *full length* (Lnmax) is such that the spacing from the contact reference point to the inner edge of the fourth-from-last segment is S+W/2.

   If Ns is even: Lnmax = L2 – (Ns – 2) × (W + S)/2
   If Ns is odd: Lnmax = L3 – (Ns – 3) × (W + S)/2

5. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

6. To turn off noise contribution, set Temp to –273.15°C.

7. For layout purposes, the last segment (Ln) is drawn such that it extends a distance of W/2 beyond the contact reference point. This allows for a square region of size W×W, on which the contact to the inner pin is centered.

References

[1] C. Hoer and C. Love, “Exact inductance equations for rectangular conductors with applications to more complicated geometrics,” *Journal of Research of NBS*, Vol. 69C, No. 2, April-June 1965, pp. 127-137.

[2] N. Marcuvitz, *Waveguide Handbook*, McGraw-Hill, New York, 1951, sections 5.11 and 5.28.

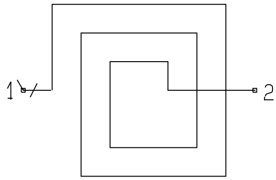
[3] V. Ghoshal and L. Smith, “Skin effects in narrow copper microstrip at 77K,” *IEEE Trans. on Microwave Theory and Tech.*, Vol. 36, December 1988.

[4] H. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, Sept. 1941, pp. 412-424.

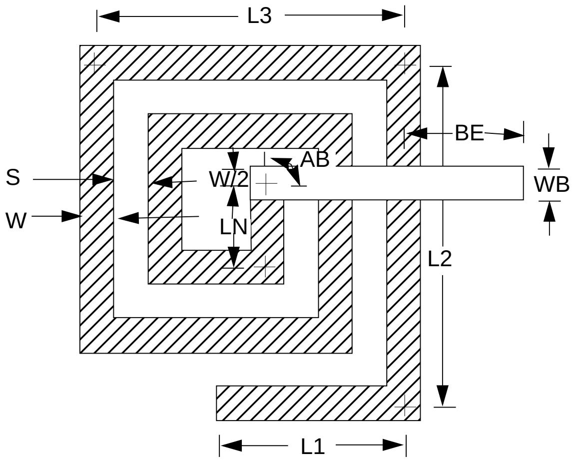
[5] K. Gupta, R. Garg and I. Bahl, *Microstrip lines and slotlines*, Artech House, Dedham, MA, section 2.4.5.

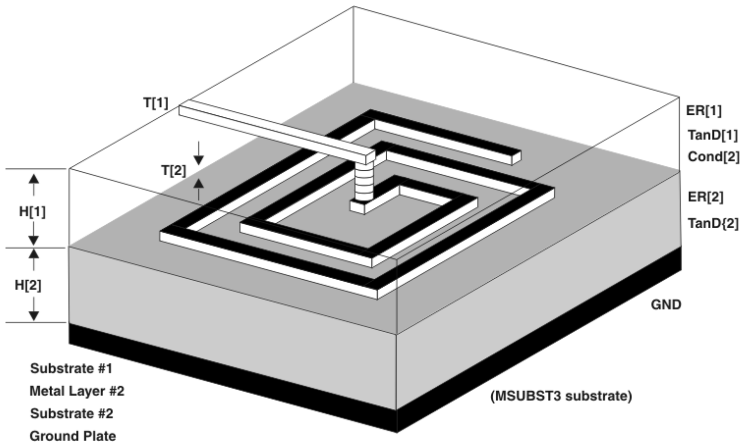
MRINDSBR (Microstrip Rectangular Inductor (Strip Bridge, 3-Layer Substrate))

Symbol



Illustrations





Parameters

Subst = microstrip substrate name

Ns = number of segments

L1 = length of first segment, in length units

L2 = length of second segment, in length units

L3 = length of third segment, in length units

Ln = length of last segment, in length units

W = conductor width, in length units

S = conductor spacing, in length units

WB = width of bridge strip conductor, in length units

AB = angle of departure from innermost segment, in angle units

BE = extension of bridge beyond inductor, in length units

Temp = physical temperature, in °C

Range of Usage (including data item parameters)

W > 0
S > 0
AB = 0°, 45°, or 90°
AB must be 90° if last segment is less than full length

$$\frac{W+S}{2} \leq LN \leq LNmax$$

where
LNmax is the *full length* of the last segment (refer to Note 5)

Notes/Equations

1. The inductor is modeled as printed on the substrate described by MSUBST3. The bridge strip is modeled as printed on a dielectric that is described by MSUBST3.

2. The frequency-domain analytical model for this element has been developed for Agilent by William J. Getsinger. Results published in the references listed at the end of these notes were used in the development of this model.

3. Each segment of the spiral is modeled as a lumped C-L-C π-section with mutual inductive coupling to all other parallel segments including those of an image

spiral. The image spiral accounts for the effects of the microstrip ground plane. The inductive calculations include the end-effects and differing lengths of coupled segments. The capacitive elements account for capacitance to ground, coupling to the parallel adjacent segments, and the coupling to the next parallel segments beyond the adjacent, on both sides.

The frequency dependence of the skin effect is included in the conductor loss calculation. A smooth transition is provided from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the loss calculation.

4. The bridge conductor connects to the innermost segment and crosses the spiral from the top. The bridge is capacitively coupled to each segment of the spiral that it crosses.
5. If LN is set to zero, it is assumed to have *full length*. The *full length* (LNmax) is such that the spacing from the contact reference point to the inner edge of the fourth-from-last segment is S+W/2.

   If NS is even: LNmax = L2 – (NS – 2)×(W + S)/2
   If NS is odd: LNmax = L3 – (NS – 3)×(W + S)/2
6. If WB=0, the effect of the bridge strip conductor is not simulated.
7. For transient analysis, microstrip inductors are modeled using a lumped RLC circuit.
8. For convolution analysis, the frequency-domain analytical model is used.
9. In Layout, the spiral inductor is mapped to the layer assigned to the LayerName[2] parameter of the MSUBST3 component referenced by the MRINDSBR component. The strip bridge is mapped to the layer assigned to the LayerName[1] parameter of the MBSUBST3 component referenced by the MRINDSBR component.

   For layout purposes, the last segment (LN) is drawn such that it extends a distance of W/2 beyond the contact reference point. This allows for a square region of size W×W, on which the contact to the bridge is connected.

   The inductor segments to air-bridge/underpass transition is mapped to the layer assigned to the LayerViaName[1] parameter of the MSUBST3 component. referenced by the MRINDSBR component. The transition is only for the purpose of modeling in Momentum and is not taken into account in the circuit simulator.

For the transition at pin 2, if the angle of the air-bridge/underpass is 0 or 45°, the width of the transition is the width of the air-bridge/underpass; if the angle of the air-bridge/underpass is 90°, the width of the transition is the width of the inductor segment.

References

[1] C. Hoer and C. Love, "Exact inductance equations for rectangular conductors with applications to more complicated geometrics," *Journal of Research of NBS*, Vol. 69C, No. 2, April-June 1965, pp. 127-137.

[2] N. Marcuvitz, *Waveguide Handbook*, McGraw-Hill, New York, 1951, sections 5.11 and 5.28.

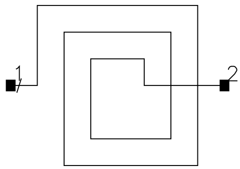
[3] V. Ghoshal and L. Smith, "Skin effects in narrow copper microstrip at 77K," *IEEE Trans. on Microwave Theory and Tech.*, Vol. 36, December 1988.

[4] H. Wheeler, "Formulas for the Skin Effect," *Proc. IRE*, Vol. 30, Sept. 1941, pp. 412-424.

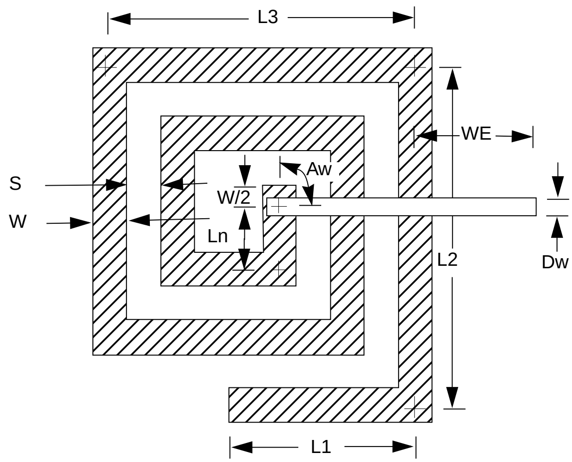
[5] K. Gupta, R. Garg and I. Bahl, *Microstrip lines and slotlines*, Artech House, Dedham, MA, section 2.4.5.

MRINDWBR (Microstrip Rectangular Inductor (Wire Bridge))

Symbol



Illustration



Parameters

Subst = microstrip substrate name

Ns = number of segments

L1 = length of first segment, in length units

L2 = length of second segment, in length units

L3 = length of third segment, in length units

Ln = length of last segment, in length units

W = conductor width, in length units

S = conductor spacing, in length units

WB = width of bridge strip conductor, in length units

AB = angle of departure from innermost segment, in angle units

BE = extension of bridge beyond inductor, in length units

Temp = physical temperature, in °C

Range of Usage

W > 0
S > 0
Aw = 0°, 45°, or 90°
Aw must be 90° if last segment is less than full length

$$\frac{W+S}{2} \le Ln \le Lnmax$$

where
Lnmax is the *full length* of the last segment (refer to Note 3)

Notes/Equations

1. This inductor is modeled as printed on the substrate described by Subst. The airbridge is in the form of a round wire that connects from the center of the spiral to the outside.
2. The frequency-domain analytical model for this component has been developed for Agilent by William J. Getsinger. Results published in the references listed at the end of these notes were used in the development of this model.
3. Each segment of the spiral is modeled as a lumped C-L-C π-section with mutual inductive coupling to all other parallel segments including those of an image spiral. The image spiral accounts for the effects of the microstrip ground plane. The inductive calculations include the end-effects and differing lengths of coupled segments. The capacitive components account for capacitance to ground, coupling to the parallel adjacent segments, and the coupling to the next parallel segments beyond the adjacent, on both sides.

   The frequency dependence of the skin effect is included in the conductor loss calculation. A smooth transition is provided from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the loss calculation.
4. If Ln is set to zero, it is assumed to have *full length*. The *full length* (LNmax) is such that the spacing from the contact reference point to the inner edge of the fourth-from-last segment is S+W/2.

If Ns is even: Lnmax = L2 – (Ns – 2) × (W + S)/2
If Ns is odd: Lnmax = L3 – (Ns – 3) × (W + S)/2

5. If Dw=0, the effect of the wire bridge is not simulated.
6. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
7. To turn off noise contribution, set Temp to –273.15°C.
8. In layout, spiral segments are drawn on the layer mapped to the Cond1 parameter of the MSUB component. The wire bridge is drawn on the *bond* layer.

   For layout purposes the last segment (Ln) is drawn such that it extends a distance of W/2 beyond the contact reference point. This allows for a square region of size W×W, on which the contact to the wire bridge is centered.

   Inductor segments to airbridge/underpass transition are drawn on the layer mapped to the diel2 layer. The transition is only for the purpose of modeling in Momentum and is not taken into account in the circuit simulator.

   For the transition at pin 2, if the angle of the air-bridge/underpass is 0 or 45, the width of the transition is the width of the air-bridge/underpass; if the angle of the air-bridge/underpass is 90, the width of the transition is the width of the inductor segment.

References

[1] C. Hoer and C. Love, “Exact inductance equations for rectangular conductors with applications to more complicated geometrics,” *Journal of Research of NBS*, Vol. 69C, No. 2, April-June 1965, pp. 127-137.

[2] N. Marcuvitz, *Waveguide Handbook*, McGraw-Hill, New York, 1951, sections 5.11 and 5.28.

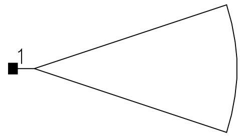
[3] V. Ghoshal and L. Smith, “Skin effects in narrow copper microstrip at 77K,” *IEEE Trans. on Microwave Theory and Tech.*, Vol. 36, December 1988.

[4] H. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, Sept. 1941, pp. 412-424.

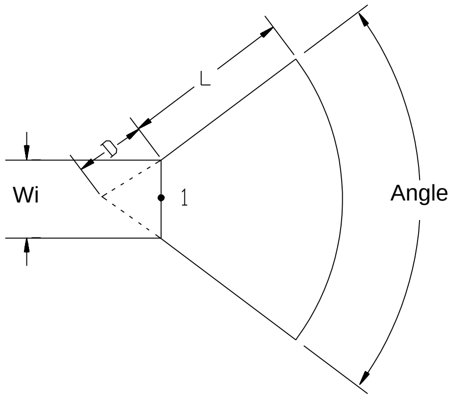
[5] K. Gupta, R. Garg and I. Bahl, *Microstrip lines and slotlines*, Artech House, Dedham, MA, section 2.4.5.

MRSTUB (Microstrip Radial Stub)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

Wi = width of input line, in specified units

L = length of stub, in specified units

Angle = angle subtended by stub, in degrees

Temp = physical temperature, in °C

Range of Usage

$Er \leq 128$
$10° \leq Angle \leq 170°$

$$0.01 \leq \frac{Wi}{H} \leq 100$$

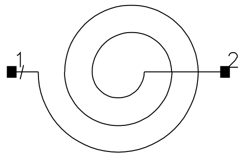
$(L + D) \times$ Angle (radians) $\leq 100 \times H$ (see illustration)
where
  Er = dielectric constant (from associated Subst)
  H = substrate thickness (from associated Subst)

Notes/Equations

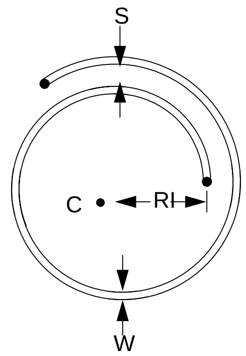
1. The frequency-domain analytical model is a microstrip line macro-model developed by Agilent. The radial stub is constructed from a series of *straight* microstrip sections of various widths that are cascaded together. The microstrip line model is the MLIN model. The number of sections is frequency dependent. Dispersion effects in the microstrip sections are included. The frequency-domain analytical model is lossless.
2. MRSTUB should be used with MTEE or MCROS when used as a stub in shunt with a transmission line.
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
4. To turn off noise contribution, set Temp to –273.15°C.

MSIND (Microstrip Round Spiral Inductor)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

N = number of turns

Ri = inner radius measured to the center of the conductor, in specified units

W = conductor width, in specified units

S = conductor spacing, in specified units

Temp = physical temperature, in °C

W1 = (ADS Layout option) width of strip ending at pin 1

W2 = (ADS Layout option) width of strip ending at pin 2

Range of Usage

Ri> W/2
N > 1

Notes/Equations

1. The frequency-domain analytical model is a low-pass, series R-L and shunt C structure. Each R-L-C section corresponds to one turn of the inductor. The inductor L of each section is calculated using the formulas of Remke and Burdick, which do include ground plane inductance. Formulas given by Pettenpaul and his co-authors are used to calculate the series resistance R. These formulas provide a smooth transition from dc resistance to resistance due to skin effect at high frequencies. The value of the shunt capacitance C is based on coupled transmission line theory. Dielectric losses are not included.
2. Ri is measured to the center of the conductor.
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
4. To turn off noise contribution, set Temp to –273.15°C.

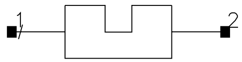
References

[1] E. Pettenpaul, H. Kapusta, A. Weisgerber, H. Mampe, J. Luginsland, and I. Wolff. *CAD Models of Lumped Elements on GaAs up to 18 GHz*, IEEE Transactions on Microwave Theory and Techniques, Vol. 36, No. 2, February 1988, pp. 294-304.

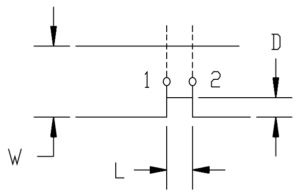
[2] R. L. Remke and G. A. Burdick. *Spiral Inductors for Hybrid and Microwave Applications*, Proc. 24th Electron Components Conference, Washington, D.C., May 1974, pp. 152-161.

MSLIT (Microstrip Slit)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W = width, in specified units

D = depth of slit, in specified units

L = length of slit, in specified units

Temp = physical temperature, in °C

Range of Usage

D $\leq$ (0.9 × W) or (W – 0.01 × H) whichever is smaller

$$L < \frac{\lambda}{10}$$

L $\leq$ H

$$0.01 \leq \frac{W}{H} \leq 100$$

where

λ = wavelength in the dielectric

H = substrate thickness (from associated Subst)

Notes/Equations

1. The frequency-domain analytical model consists of a static, lumped, equivalent circuit. The equivalent circuit parameters are calculated based on the expressions given by Hoefer. The reference plane of the lumped model is at the center of the slit. Two reference plane shifts are added to move the reference plane to the outside edge of the slit, so that they are coincident with the layout

dimensions. These reference plane shifts are modeled using a MLIN microstrip model that includes loss and dispersion. The characteristics of the microstrip lines are calculated based on the constricted width of the slit W-D. The formulas are given below, where Z_o and ε_{eff} are calculated for width W; Z_o and ε_{eff} are calculated for width W-D; and, C_{gap} is the gap capacitance associated with a gap of length L and width 2D (c_o is the velocity of light in air).

$$\frac{\Delta L}{H} = \frac{\pi\mu_0}{2}\left(1 - \frac{Z_o}{Z_o'}\sqrt{\frac{\varepsilon_{eff}}{\varepsilon_{eff}'}}\right)$$

$$C_s = \frac{C_{gap}}{2}$$

$$C_p = \frac{\sqrt{\varepsilon_{eff}'}L}{2c_0Z_0'}$$

2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
3. To turn off noise contribution, set Temp to –273.15°C.

References

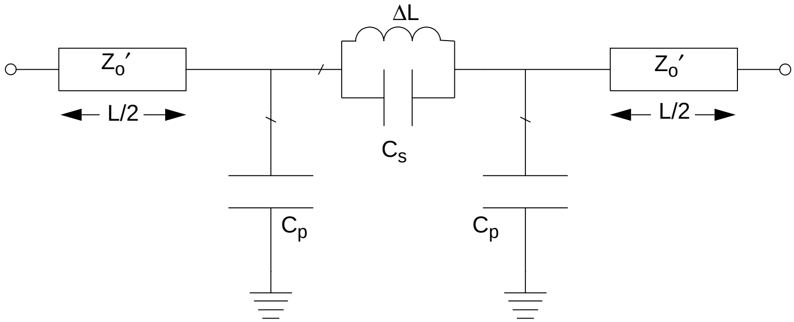
[1] E. Hammerstad, "Computer-Aided Design of Microstrip Couples with Accurate Discontinuity Models," *IEEE MTT Symposium Digest*, June 1981, pp. 54-56.

[2] W. J. R. Hoefer, "Fine Tuning of Microwave Integrated Circuits Through Longitudinal and Transverse Slits of Variable Length," *NTZ* (German), Vol.30, May 1977, pp. 421-424.

[3] W. J. R. Hoefer, "Theoretical and Experimental Characterization of Narrow Transverse Slits in Microstrip," *NTZ (*German), Vol. 30, July 1977, pp. 582-585.

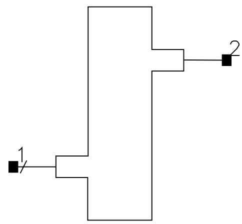
[4] W. J. R. Hoefer, "Equivalent Series Inductivity of a Narrow Transverse Slit in Microstrip," *MTT Transactions*, Vol. MTT- 25, October 1977, pp. 822-824.

Equivalent Circuit

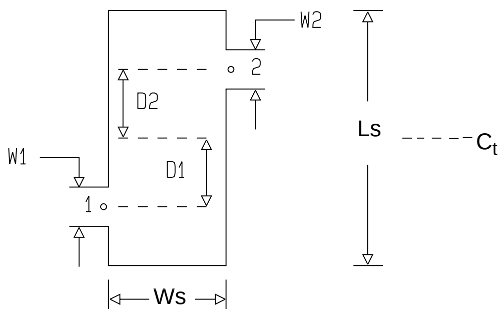


MSOP (Microstrip Symmetric Pair of Open Stubs)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W1 = width of input line, in specified units

D1 = distance between centerlines of input line and stub-pair, in specified units

W2 = width of output line, in specified units

D2 = distance between centerlines of output line and of stub-pair, in specified units

Ws = width of stubs, in specified units

Ls = combined length of stubs, in specified units

Temp = physical temperature, in °C

Range of Usage

$$0.01 \le \frac{W1}{H} \le 100$$

$$0.01 \le \frac{W2}{H} \le 100$$

Ws > 0

Ls > 0

where

H = substrate thickness (from associated Subst)

Notes/Equations

1. The frequency-domain analytical model ignores conductor losses, dielectric losses, and metal thickness.
2. A positive (negative) D1 implies that the input line is below (above) the center of the stub-pair.

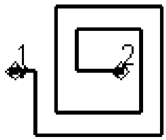
   A positive (negative) D2 implies that the output line is above (below) the center of the stub-pair.
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
4. To turn off noise contribution, set Temp to –273.15°C.

References

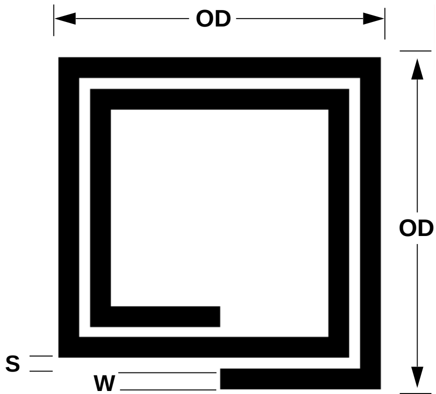
[1] G. D'Inzeo, F. Giannini, C. Sodi, and R. Sorrentino. "Method of Analysis and Filtering Properties of Microwave Planar Networks," *IEEE Transactions on Microwave Theory and Techniques,* Vol. MTT-26, No. 7, July 1978, pp. 467-471.

MSSPLC_MDS (MDS Microstrip Center-Fed Rectangular Spiral Inductor)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

N = number of turns (must be an integer)

W = conductor width, in specified length units

S = conductor spacing, in specified length units

OD = overall dimension, in specified length units

Range of Usage

OD > (2N+1)(W+S)
Er < 50
10 H > W > 0.1 H
10 H > S > 0.1 H
Frequency < 2 fo, where fo is the open-circuit resonant frequency of the inductor
Frequency (GHz) $\times$ H (mm) $\leq$ 25

Notes/Equations

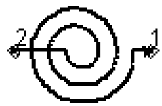
1. Noise that is contributed by this component appears in all simulations.

References

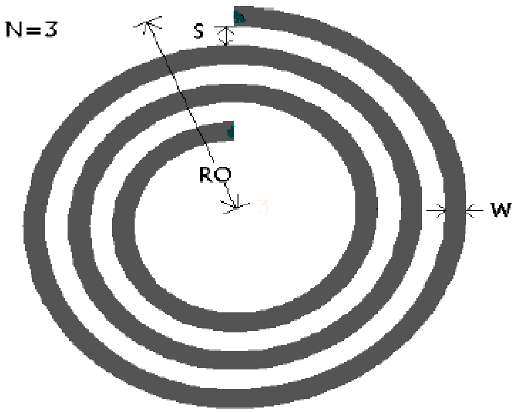
[1] H. Wheeler, “Formulas for the Skin Effect”, *Proc. IRE*, Vol. 30 Sept. 1941, pp. 412-424

MSSPLR_MDS (MDS Microstrip Round Spiral Inductor)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

N = number of turns (must be an integer)

W = conductor width, in specified length units

S = conductor spacing, in specified length units

RO = outer radius, in specified length units

Range of Usage

RO > (N+0.5)(W+S)
1 < Er < 50
10 H > W > 0.1 H
10 H > S > 0.1 H
Frequency < 2 fo, where fo is the open-circuit resonant frequency of the inductor
Frequency (GHz) $\times$ H (mm) $\leq$ 25

Notes/Equations

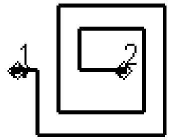
1. Noise that is contributed by this component appears in all simulations.

References

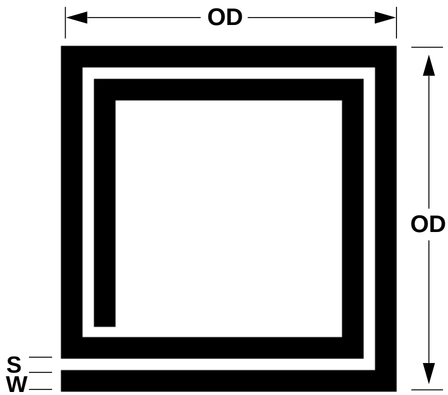
[1] H. Wheeler, “Formulas for the Skin Effect”, *Proc. IRE*, Vol. 30 Sept. 1941, pp. 412-424

MSSPLS_MDS (MDS Microstrip Side-Fed Rectangular Spiral Inductor)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

N = number of turns (must be an integer)

W = conductor width, in specified length units

S = conductor spacing, in specified length units

OD = overall dimension, in specified length units

Range of Usage

OD > (2N+1)(W+S)
Er < 50
10 H > W > 0.1 H
10 H > S > 0.1 H
Frequency < 2 fo, where fo is the open-circuit resonant frequency of the inductor
Frequency (GHz) $\times$ H (mm) $\leq$ 25

Notes/Equations

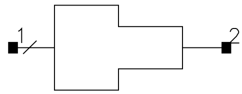
1. Noise that is contributed by this component appears in all simulations.

References

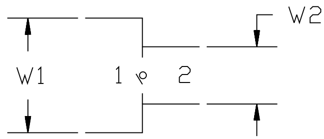
[1] H. Wheeler, “Formulas for the Skin Effect”, *Proc. IRE*, Vol. 30 Sept. 1941, pp. 412-424

MSTEP (Microstrip Step in Width)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W1 = conductor width at pin 1, in specified units

W2 = conductor width at pin 2, in specified units

Temp = physical temperature, in °C

Range of Usage

$$0.01 < \frac{W1}{H} and \frac{W2}{H} < 100$$

where

ER = dielectric constant (from associated Subst)

H = substrate thickness (from associated Subst)

Notes/Equations

1. Although the references listed here have validated the model for ER $\leq$ 10, it does not mean that the model is inaccurate for ER > 10.

2. The frequency-domain analytical model is derived from a TEM (fundamental mode) planar waveguide model of the discontinuity. In the derivation, the planar waveguide model is transformed into a rectangular waveguide model, and the expression for the series inductance, L_s, is formulated based on an analysis of the current concentration at the discontinuity. This formula is documented in *Handbook of Microwave Integrated Circuits* by R. Hoffman. The reference plane shift, Δl, is calculated based on an analysis of the scattered

electric fields at the front edge of the wider conductor. In addition, dispersion is accounted for in the model.

3. To turn off noise contribution, set Temp to –273.15°C.
4. In layout, MSTEP aligns the centerlines of the strips.

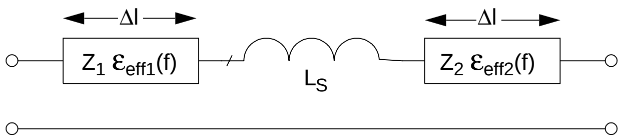
References

[1] R. K. Hoffman, *Handbook of Microwave Integrated Circuits*, Artech House, 1987, pp. 267-309.

[2] G. Kompa, "Design of Stepped Microwave Components," *The Radio and Electronic Engineer*, Vol. 48, No. 1/2, January 1978, pp. 53-63.

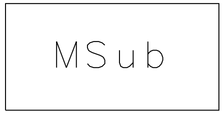
[3] N. H. L. Koster and R. H. Jansen. "The Microstrip Step Discontinuity: A Revised Description," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT 34, No. 2, February 1986, pp. 213-223 (for comparison only).

Equivalent Circuit

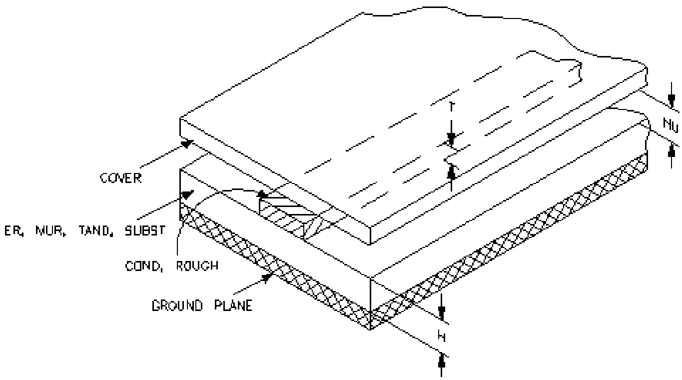


MSUB (Microstrip Substrate)

Symbol



Illustration



Parameters

H = substrate thickness, in specified units

Er = relative dielectric constant

Mur = relative permeability

Cond = conductor conductivity, in Siemens/meter

Hu = cover height

T = conductor thickness, in specified units

TanD = dielectric loss tangent

Rough = conductor surface roughness, in specified units; RMS value; refer to note 6

Cond1 = (ADS Layout option) layer on which the microstrip metallization will be drawn in layout

Cond2 = (ADS Layout option) layer on which the air bridges will be drawn in layout

Diel1 = (ADS Layout option) layer on which the dielectric capacitive areas will be drawn in layout

Diel2 = (ADS Layout option) layer on which the via between Cond and Cond2 masks will be drawn in layout

Hole = (ADS Layout option) layer on which the via layer used for grounding will be drawn in layout

Res = (ADS Layout option) layer on which the resistive mask will be drawn in layout

Netlist Format

Substrate model statements for the ADS circuit simulator may be stored in an external file.

```
model  substratename  MSUB [parm=value]*
```

The model statement starts with the required keyword *model*. It is followed by the *substratename* that will be used by microstrip components to refer to the model. The third parameter indicates the type of model; for this model it is *MSUB*. The rest of the model contains pairs of substrate model parameters and values, separated by an equal sign. The name of the model parameter must appear exactly as shown in the parameters table-these names are case sensitive. Model parameters may appear in any order in the model statement. For more information about the ADS circuit simulator netlist format, including scale factors, subcircuits, variables and equations, refer to Chapter 8, *ADS Simulator Input Syntax* in the *Circuit Simulation* book.

Example:

```
model Msub1 MSUB  H=10 mil Er=9.6 Mur=1 Cond=1.0E50 \
  Hu=3.9e+34 mil T=0 mil Tand=0 Rough=0 mil
```

Notes/Equations

For RFDE Users Information about this model must be provided in a *model* file; refer to the *Netlist Format* section.

---

1. MSUB is required for all microstrip components except MRINDSBR and MRINDELM.
2. Conductor losses are accounted for when Cond < 4.1×10^{17} S/m and T > 10^{-9}. Gold conductivity is 4.1×10^{7} S/m. Rough modifies loss calculations. Conductivity for copper is 5.8×10^{7}.

3. Parameters Cond1, Cond2, Diel1, Diel2, Hole, and Res control the layer on which the Mask layers are drawn. These are layout-only parameters and are not used by the simulator.
4. Microstrip cover height effect is defined in the Hu parameter. MCFIL, MCLIN, MLEF, MLIN, MLOC, and MLSC components support microstrip cover effect (MACLIN and MACLIN3 components do not support this cover effect).
5. When the Hu parameter of the substrate is less than $100 \times$ Thickness_of_substrate, the impedance calculation will not be properly done if Wall1 and Wall2 are left blank.
6. The microstrip cover uses a perturbational technique based on the assumption that a significant portion of energy is in the substrate between the conductor and the lower ground. It assumes that a microstrip line is beneath it. The microstrip cover Hu and the Er parameters were not intended to be used in the limiting case where the configuration of the MLIN with sub and cover converges to a stripline topology. Therefore, Hu must always be taken much larger than H and T.
7. The Rough parameter is used in the following equation in MDS and ADS:

   $$\text{Loss\_factor} = 1 + (2/\pi) \times \text{atan}(\omega \times \text{We} \times \text{Rough}^2)$$

   where atan is arctangent; We is the factor in the surface roughness formula, which is some constant.

   $$\text{We} = 0.7 \times \text{U0} \times \text{Ur} \times \sigma$$

   where

   U0 = magnetic permeability constant
   Ur = relative magnetic permeability
   σ = conductivity constant (4.1e7 for gold)

   So if

   Rough factor = 0, then atan (0) = 0 and so Loss_factor = 1

   If

   Rough factor = large number, then atan (large number) = close to $\pi/2$ and so Loss_factor= $1+ 2/\pi \times (\pi/2) = 2$

   So

   Loss_factor = between 1 to 2 for Rough = from 0 to infinity.

Loss (α for conductor with surface roughness) =
Loss (α for perfectly smooth conductor) $\times$ Loss_factor

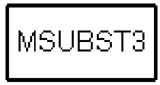
α = Attenuation (nepers/m)

References

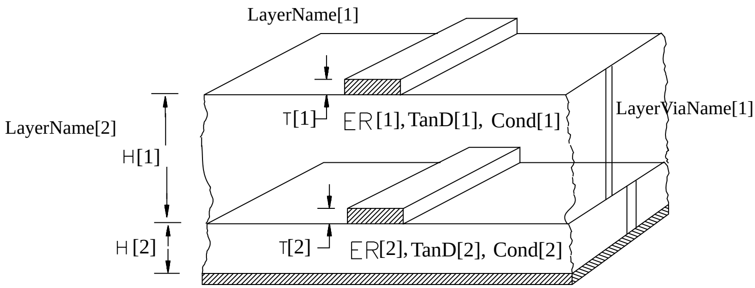
[1] For the Rough parameter: Hammerstead and Bekkadal, Microstrip Handbook, ELAB report STF44 A74169, page 7.

MSUBST3 (Microstrip 3-Layer Substrate)

Symbol



Illustration



Parameters

Er[1] = dielectric constant

H[1] = substrate height, in specified units

TanD[1] = dielectric loss tangent

T[1] = conductor thickness, in specified units

Cond[1] = conductor conductivity, in Siemens/meter

Er[2] = dielectric constant

H[2] = substrate height, in specified units

TanD[2] = dielectric loss tangent

T[2] = conductor thickness, in specified units

Cond[2] = conductor conductivity, in Siemens/meter

LayerName[1] = (ADS Layout option) layout layer to which conductors on the top substrate is mapped. Default is *cond*.

LayerName[2] = (ADS Layout option) layout layer to which conductors on the bottom substrate is mapped. Default is *cond2*.

LayerViaName[1] = (ADS Layout option) layout layer to which the transition between the bridge/underpass is mapped. Default is *diel2*.

Netlist Format

Substrate model statements for the ADS circuit simulator may be stored in an external file.

```
model  substratename  Substrate N=3 [parm=value]*
```

The model statement starts with the required keyword *model*. It is followed by the *substratename* that will be used by microstrip components to refer to the model. The third parameter indicates the type of model; for this model it is *Substrate*. The fourth parameter says that this is a 3-layer substrate. The rest of the model contains pairs of substrate model parameters and values, separated by an equal sign. The name of the model parameter must appear exactly as shown in the parameters table-these names are case sensitive. Model parameters may appear in any order in the model statement. For more information about the ADS circuit simulator netlist format, including scale factors, subcircuits, variables and equations, refer to Chapter 8, *ADS Simulator Input Syntax* in the *Circuit Simulation* book.

Example:

```
model MSubst1 Substrate N=3 \
  Er[1]=4.5 H[1]=10 mil TanD[1]=0 T[1]=0 mil Cond[1]=1.0E+50 \
  Er[2]=4.5 H[2]=10 mil TanD[2]=0 T[2]=0 mil Cond[2]=1.0E+50
```

Notes/Equations

For RFDE Users Information about this model must be provided in a *model* file; refer to the *Netlist Format* section.

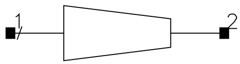
---

1. MSUBST3 is required for MRINDSBR and MRINDELM components. MSUBST3 is not intended for components using a single metal layer. MSUBST3 is intended for MRINDSBR and MRINDELM only and will generate errors if used with other components.

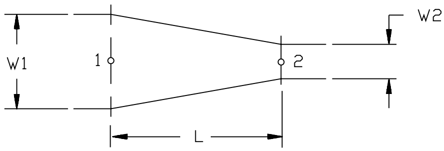
2. Conductor losses are accounted for when Cond < 4.1×10^{17} S/m and T > 10^{-9}. Gold conductivity is 4.1×10^{7} S/m. Rough modifies loss calculations. Conductivity for copper is 5.8×10^{7}.

MTAPER (Microstrip Width Taper)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W1 = conductor width at pin 1, in specified units

W2 = conductor width at pin 2, in specified units

L = line length, in specified units

Temp = physical temperature, in °C

Range of Usage

$Er \leq 128$
$0.01 \times H \leq (W1, W2) \leq 100 \times H$
where
Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)

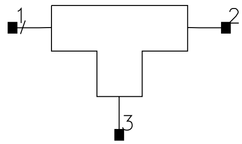
Notes/Equations

1. The frequency-domain analytical model is a microstrip line macro-model developed by Agilent. The taper is constructed from a series of *straight* microstrip sections of various widths that are cascaded together. The microstrip line model is the MLIN model. The number of sections is frequency dependent. Dispersion, conductor loss, and dielectric loss effects are included in the microstrip model.

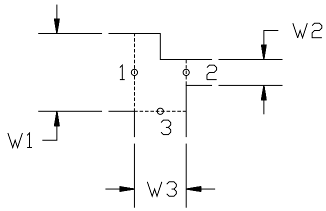
2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

MTEE (Microstrip T-Junction)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W1 = conductor width at pin 1, in specified units

W2 = conductor width at pin 2, in specified units

W3 = conductor width at pin 3, in specified units

Temp = physical temperature, in °C

Range of Usage

$0.05 \times H \leq W1 \leq 20 \times H$
$0.05 \times H \leq W2 \leq 20 \times H$
$0.05 \times H \leq W3 \leq 20 \times H$
$Er \leq 20$
Wlargest/Wsmallest ≤ 5
where
Wlargest, Wsmallest are the largest, smallest width among W2, W2, W3
f(GHz) $\times$ H (mm) $\leq 0.4 \times$ Z0
where
Z0 is the characteristic impedance of the line with Wlargest

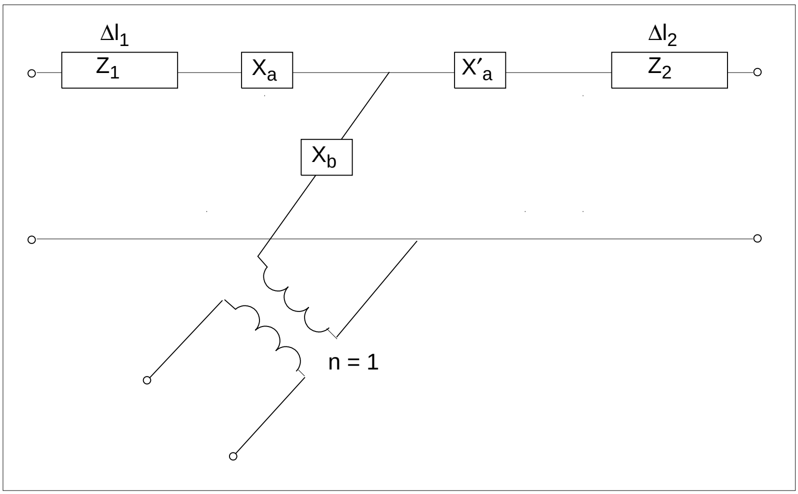
Notes/Equations

1. The frequency-domain model is an empirically based, analytical model. The model modifies E. Hammerstad model formula to calculate the Tee junction discontinuity at the location defined in the reference for wide range validity. A reference plan shift is added to each of the ports to make the reference planes consistent with the layout.
2. The center lines of the strips connected to pins 1 and 2 are assumed to be aligned.
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

References

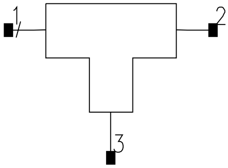
[1] E. Hammerstad, "Computer-Aided Design of Microstrip Couplers Using Accurate Discontinuity Models," *MTT Symposium Digest*, 1981.

Equivalent Circuit

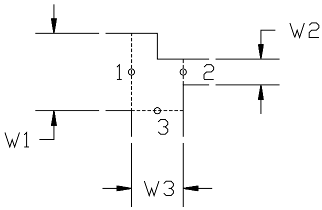


MTEE_ADS (Libra Microstrip T-Junction)

Symbol



Illustration



Parameters

Subst = microstrip substrate name

W1 = conductor width at pin 1, in specified units

W2 = conductor width at pin 2, in specified units

W3 = conductor width at pin 3, in specified units

Temp = physical temperature, in °C

Range of Usage

$W1 + W3 \leq 0.5\lambda$
$W2 + W3 \leq 0.5\lambda$
$0.10 \times H \leq W1 \leq 10 \times H$
$0.10 \times H \leq W2 \leq 10 \times H$
$0.10 \times H \leq W3 \leq 10 \times H$
$Er \leq 128$
where
Er = dielectric constant (from associated Subst)
H = substrate thickness (from associated Subst)
λ = wavelength in the dielectric

Notes/Equations

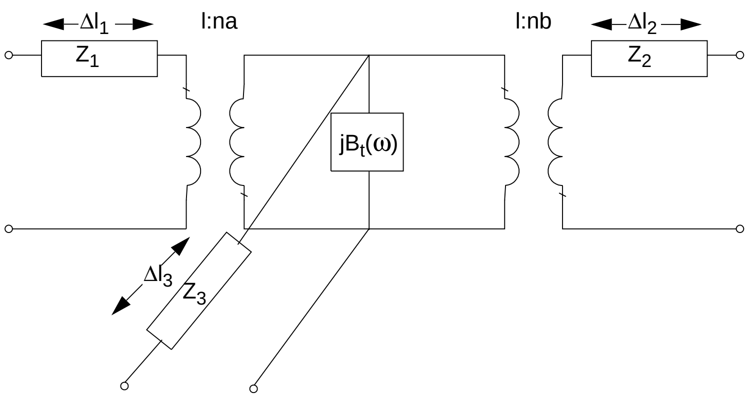
1. The frequency-domain model is an empirically based, analytical model. The model presented by Hammerstad is used to calculate the discontinuity model at the location defined in the reference. A reference plan shift is then added to each of the ports to make the reference planes consistent with the layout. Dispersion is accounted for in both the reference plan shifts and the shunt susceptance calculations using the formulas of Kirschning and Jansen.
2. The center lines of the strips connected to pins 1 and 2 are assumed to be aligned.
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

References

[1] E. Hammerstad, "Computer-Aided Design of Microstrip Couplers Using Accurate Discontinuity Models," *MTT Symposium Digest*, 1981.

[2] M. Kirschning and R. H. Jansen, *Electronics Letters*, January 18, 1982.

Equivalent Circuit



MTFC (Microstrip Thin Film Capacitor)

Symbol

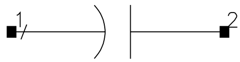
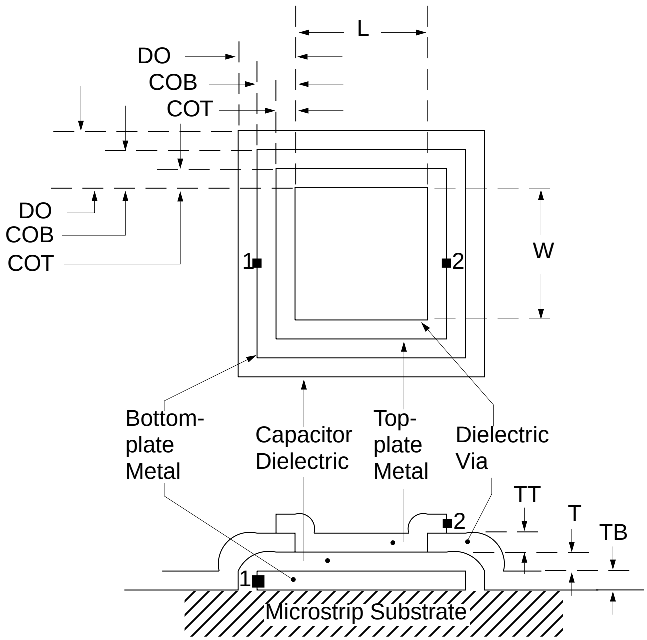


Illustration (Layout):



Parameters

Subst = microstrip substrate name

W = dielectric width common to both metal plates, in specified units

L = dielectric length common to both metal plates, in specified units

CPUA = capacitance per unit area, pf/mm^2

T = thickness of capacitor dielectric, in specified unit

RsT = sheet resistance of top metal plate, in ohms per square

RsB = sheet resistance of bottom metal plate, in ohms per square

TT = thickness of top metal plate, in specified units

TB = thickness of bottom metal plate, in specified units

COB = bottom conductor overlap, in specified units

Temp = physical temperature, in °C

COT = (ADS Layout option) top conductor overlap, in specified units

DO = (ADS Layout option) dielectric overlap, in specified units

Range of Usage

$0.0l \times H \le (W + 2.0 \times COB) \le 100.0 \times H$
$1 \le Er \le 128$
$COB > 0$
$T > 0$
where
H = substrate thickness (from associated Subst)
Er = dielectric constant (from associated Subst)

Notes/Equations

1. This is a distributed MIM capacitor model based on the coupled-transmission-line approach. Conductor loss for both metal plates is calculated from the sheet resistance (skin-effect is not modeled.) Dielectric loss is calculated from the loss tangent. (The TanD specification applies to the dielectric between the two metal plates and not to the MSUB substrate.) Coupling capacitance from both metal plates to the ground plane is accounted for.

2. Thickness of the dielectric T is required for calculating the mutual coupling between the two metal plates. Thickness of the two metal plates, TT and TB, are used for calculating microstrip parameters.

3. The model does not include a connection (such as an air-bridge) from the top metal (pin 2) to the connecting transmission line. It must be included separately by the user for simulation as well as layout purposes.

4. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

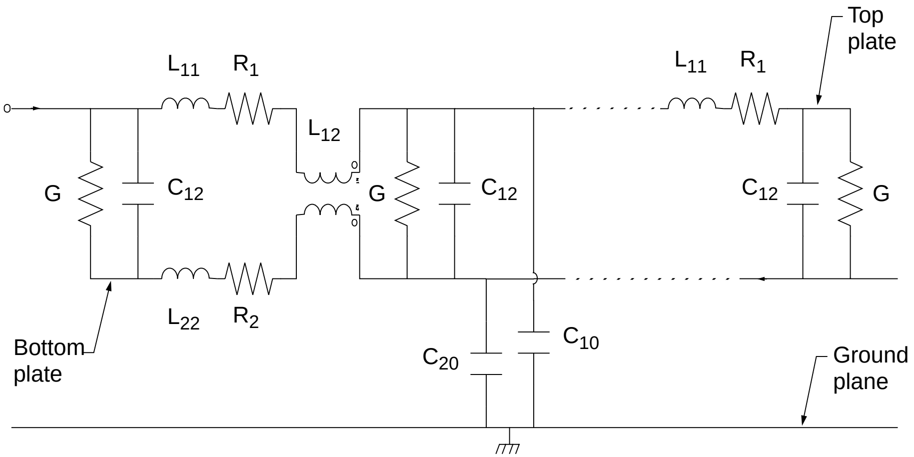
5. To turn off noise contribution, set Temp to –273.15°C.

6. In the layout, the top metal will be on layer *cond2*, the bottom metal on layer *cond*, the capacitor dielectric on layer *diel*, and the dielectric via layer on layer *diel2*.

References

[1] J. P. Mondal, An Experimental Verification of a Simple Distributed Model of MIM Capacitors for MMIC Applications, *IEEE Transactions on Microwave Theory Tech*., Vol. MTT-35, No.4, pp. 403-408, April 1987.

Equivalent Circuit



L_{11} = inductance/unit length of the top plate

L_{22} = inductance/unit length of the bottom plate

L_{12} = mutual inductance between the plates/units length of the capacitor

R_1 = loss resistance/unit length of the top plate

R_2 = loss resistance/unit length of the bottom plate

G = loss conductance of the dielectric/unit length of the capacitor

C_{12} = capacitance/unit length of the capacitor

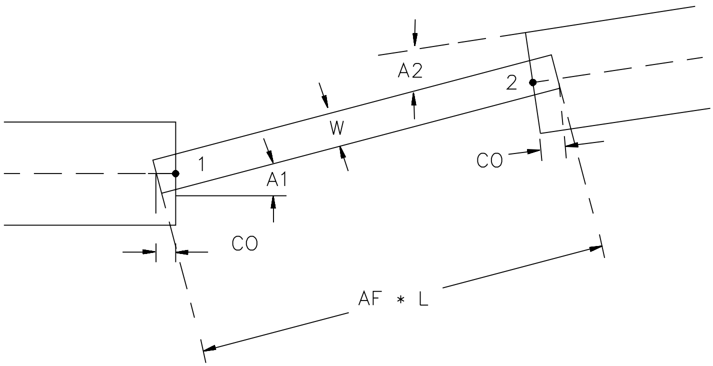
C_{10} = capacitance with respect to ground/unit length of the top plate (due to the substrate effects)

C_{20} = capacitance with respect to ground/unit length of the bottom plate (due to the substrate effects)

RIBBON (Ribbon)

Symbol

Illustration



Parameters

W = conductor width, in specified units

L = conductor length, in specified units

Rho = metal resistivity (relative to gold)

Temp = physical temperature, in °C

AF = (ADS Layout option) arch factor; ratio of distance between bond points to actual ribbon length

CO = (ADS Layout option) conductor overlap; distance from edge connector

A1 = (ADS Layout option) angle of departure from first pin

A2 = (ADS Layout option) angle of departure from second pin

BandLayer = (ADS Layout option) layer on which the wire/ribbon is drawn; default = 6 (bond)

Notes/Equations

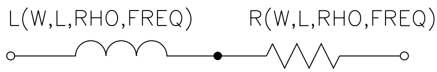
1. Although this component is included in the *Microstrip Components* library, it does not use a microstrip substrate (MSUB).

2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

3. To turn off noise contribution, set Temp to –273.15°C.

4. The ribbon *bond* layer to the *conductor* layer transition is drawn on the *diel2* layer. The width of the *diel2* layer is CO, the conductor offset. If CO is 0, the transition is drawn as a zero width polygon. The transition is only for layout purposes and is not taken into account in the circuit simulator.

Equivalent Circuit



TFC (Thin Film Capacitor)

Symbol

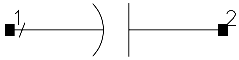
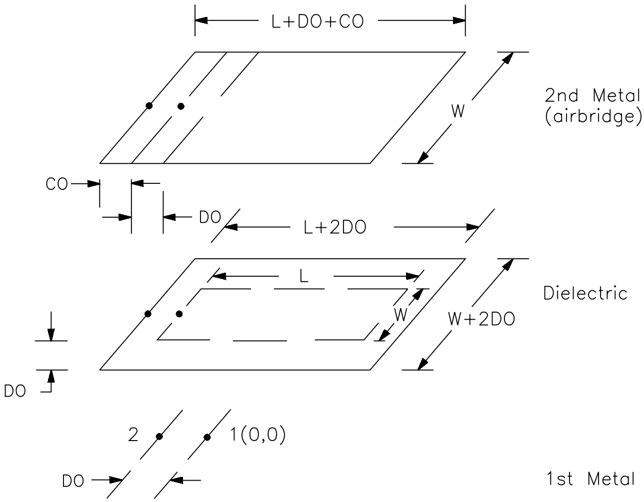


Illustration (Layout)



Parameters

W = conductor width, in specified units

L = conductor length, in specified units

T = dielectric thickness, in specified units

Er = relative dielectric constant

Rho = metal resistivity of conductor (relative to gold)

TanD = dielectric loss tangent value

Temp = physical temperature, in °C

CO = (ADS Layout option) conductor overlap

DO = (ADS Layout option) dielectric overlap

DielLayer = (ADS Layout option) layer on which the dielectric is drawn;
default = 4 (diel)

Cond2Layer = (ADS Layout option) layer on which the airbridge is drawn; default = 2(cond2)

Range of Usage

$1 < Er < 50$
$0.005T < W < 1000T$
$0.01H < W < 100H$

Notes/Equations

1. The frequency-domain analytical model is a series R-C, lumped component network. The conductor losses with skin effect and dielectric losses are modeled by the series resistance. The parallel plate capacitance is modeled by the series capacitance.

2. Although this component is included in the *Microstrip Components* library, it does not use a microstrip substrate (MSUB).

3. For a distributed model, use MTFC instead of TFC.

4. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

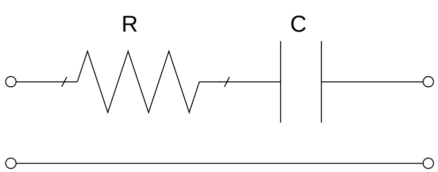
5. To turn off noise contribution, set Temp to –273.15°C.

6. Pins 1 and 2 are on the mask layer *cond* for primary metallization. The top of the capacitor is formed on the *cond2* layer, with the conductor overlapping the connecting line at pin 2 by CO.

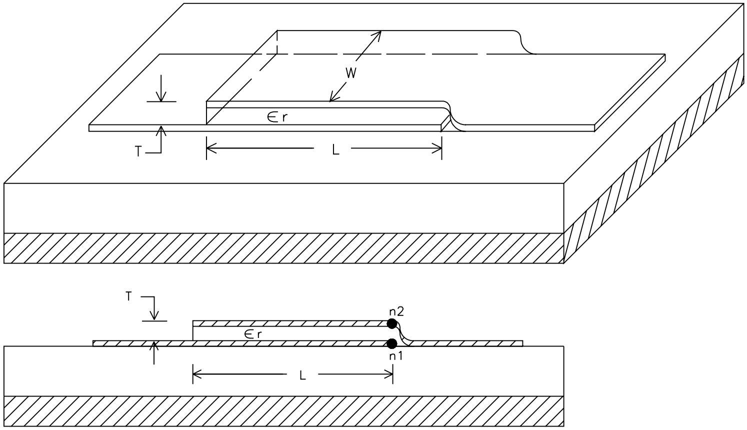
References

[1] K. C. Gupta, R. Garg, R. Chadha, *Computer-Aided Design of Microwave Circuits*, Artech House, 1981, pp. 213-220.

Equivalent Circuit



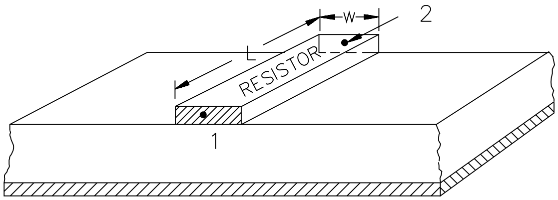
Additional Illustration



TFR (Thin Film Resistor)

Symbol

Illustration



Parameters

Subst = microstrip substrate name

W = conductor width, in specified units

L = conductor length, in specified units

Rs = sheet resistivity, in ohms/square

Freq = frequency for scaling sheet resistivity, in hertz

Temp = physical temperature, in °C

CO = (ADS Layout option) conductor offset; in specified units

Range of Usage

$0.01 \times H \leq W \leq 100 \times H$
where
  H = substrate thickness (from associated Subst)

Notes/Equations

1. The frequency-domain analytical model is a lossy microstrip line model developed by Agilent. The microstrip line model is based on the formula of Hammerstad and Jensen. Conductor loss with skin effect is included; however, dispersion, dielectric loss and thickness correction are not included.

2. If Freq is set to a value other than zero, then Rs is scaled with frequency as follows:

$$Rs(f) = Rs(Freq) \times \sqrt{(f/Freq)} \quad \text{(for microstrip)}$$

If Freq=0, then Rs is constant with respect to frequency. Setting Freq=0 is correct in most cases.

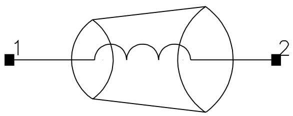
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
4. To turn off noise contribution, set Temp to –273.15°C.

References

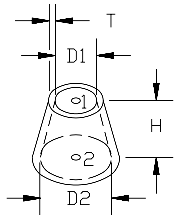
[1] E. Hammerstad and O. Jensen, "Accurate Models for Microstrip Computer-Aided Design," *MTT Symposium Digest*, 1980, pp. 407-409.

VIA (Tapered Via Hole in Microstrip)

Symbol



Illustration



Parameters

D1 = diameter at pin 1, in specified units

D2 = diameter at pin 2, in specified units

H = substrate thickness, in specified units

T = conductor thickness, in specified units

W = (ADS Layout option) width of conductor attached to via hole, in specified units

Cond1Layer = (ADS Layout option) layer on which the top transitional metal is drawn; default = 1 (cond)

HoleLayer = (ADS Layout option) layer on which the Via-hole is drawn; default=5 (hole)

Cond2Layer = (ADS Layout option) layer on which the bottom transitional metal is drawn; default=2 (cond2)

Range of Usage

$H \leq 2 \times$ (greater of D1 or D2)
$H << \lambda$
where λ = wavelength in the dielectric

Notes/Equations

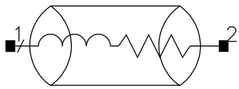
1. The frequency-domain analytical model is a series, lumped inductance as shown in the symbol. Conductor and dielectric losses are not modeled. The model was developed by Vijai K. Tripathi for Agilent.

2. In addition to the two circles on the conducting layers, the artwork includes a circle for the via-hole on the hole layer. The diameter for the via-hole is set by D1, the diameter at pin 1.

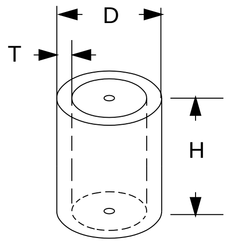
3. Although this component is included in the Microstrip Components library, it does not use a microstrip substrate (MSUB).

VIA2 (Cylindrical Via Hole in Microstrip)

Symbol



Illustration



Parameters

D = diameter at pin 1, in specified units

H = substrate thickness, in specified units

T = conductor thickness, in specified units

Rho = metal resistivity (relative to gold)

W = width of via pad (assumed square), in specified units

Temp = physical temperature, in °C

Cond1Layer = (ADS Layout option) layer on which the top transitional metal is drawn; default = 1 (cond)

HoleLayer = (ADS Layout option) layer on which the Via-hole is drawn; default=5(hole)

Cond2Layer = (ADS Layout option) layer on which the bottom transitional metal is drawn; default=2 (cond2)

Range of Usage

100 μM < H < 635 μM

$$0.2 < \frac{D}{H} < 1.5$$

$$0 \le T < \frac{D}{2}$$

$$1 < \frac{W}{H} < 2.2$$

W > D

where

H = substrate thickness
T = conductor thickness

Notes/Equations

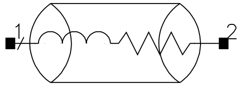
1. The frequency-domain analytical model is a series R-L, lumped component network as shown in the symbol. The model equations are based on the numerical analysis and formula of Goldfarb and Pucel. The conductor loss with skin effect is included in the resistance calculation. The model equations provide a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is not included in the model.
2. Although this component is included in the *Microstrip Components* library, it does not use a microstrip substrate (MSUB).
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
4. To turn off noise contribution, set Temp to –273.15°C.

References

[1] M. Goldfarb and R. Pucel. “Modeling Via Hole Grounds in Microstrip,” *IEEE Microwave and Guided Wave Letters*, Vol. 1, No. 6, June 1991, pp. 135-137.

VIAFC (Via with Full-Circular Pads)

Symbol



Parameters

D = diameter of via hole

H = substrate thickness

T = conductor thickness

Dpad1 = (ADS Layout option) width of pad at pin 1

Dpad2 = (ADS Layout option) width of pad at pin 2

Angle = (ADS Layout option) angle between pads

Cond1Layer = (ADS Layout option) layer on which the top transitional metal is drawn; default = cond1

HoleLayer = (ADS Layout option) layer on which the via hole is drawn, default = hole

Cond2Layer = (ADS Layout option) layer on which the bottom transitional is drawn, default = cond2

StartLayer = (ADS Layout option) layer on which the blind via starts

StopLayer = (ADS Layout option) layer on which the blind via stops

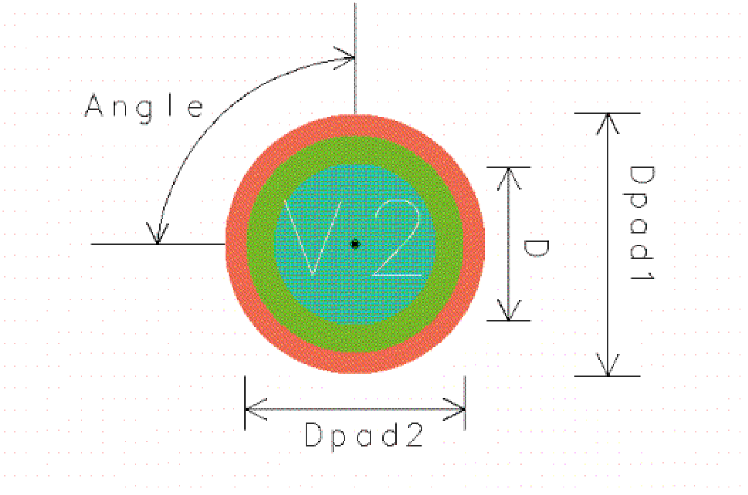
Range of Usage

$H \leq 2 \times D$
$H < \lambda$ where λ is wavelength in the dielectric
Dpad1 > D
Dpad2 > D

Notes

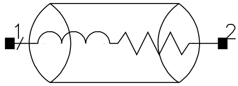
1. This via is similar to VIASC except that the pads are complete circles.

2. Electrical model for this via is the same as VIA in the ADS-equivalent RF library.



VIAHS (Via with Half-Square Pads)

Symbol



Parameters

D = diameter of via hole

H = substrate thickness

T = conductor thickness

Dpad1 = (ADS Layout option) width of pad at pin 1

Dpad2 = (ADS Layout option) width of pad at pin 2

Angle = (ADS Layout option) angle between pads

Cond1Layer = (ADS Layout option) layer on which the top transitional metal is drawn; default = cond1

HoleLayer = (ADS Layout option) layer on which the via hole is drawn, default = hole

Cond2Layer = (ADS Layout option) layer on which the bottom transitional metal is drawn, default = cond2

StartLayer = (ADS Layout option) layer on which the blind via starts

StopLayer = (ADS Layout option) layer on which the blind via stops

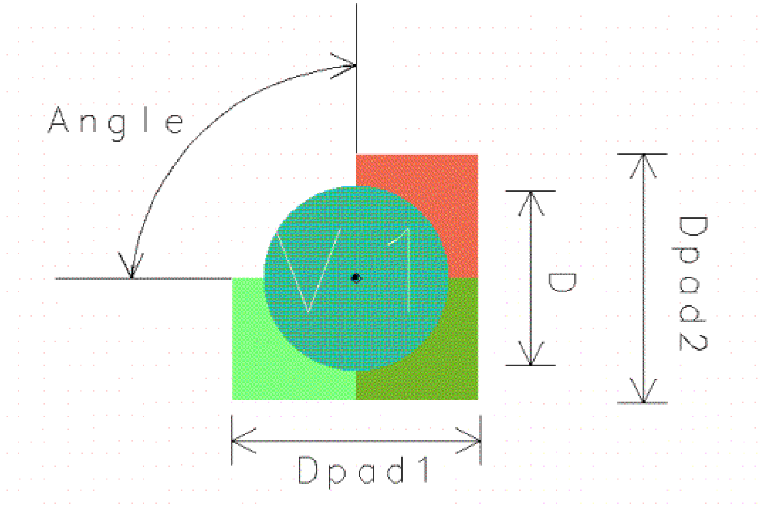
Range of Usage

$H \leq 2 \times D$
$H < \lambda$ where λ is wavelength in the dielectric
Dpad1 > D
Dpad2 > D

Notes

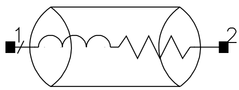
1. This via is similar to the existing VIA component in the ADS-equivalent RF library; but it is more flexible in that the widths of the pads can be different and their orientations can be of arbitrary angles.

2. Electrical model for this via is the same as for VIA in the ADS-equivalent RF library.



VIAQC (Via with Quasi-Circular Pads)

Symbol



Parameters

D = diameter of via hole

H = substrate thickness

T = conductor thickness

W1 = (ADS Layout option) width of transmission line connected to pin 1

W2 = (ADS Layout option) width of transmission line connected to pin 2

Dpad1 = (ADS Layout option) diameter of pad at pin 1

Dpad2 = (ADS Layout option) diameter of pad at pin 2

Angle = (ADS Layout option) angle between pads

Cond1Layer = (ADS Layout option) layer on which the top transitional metal is drawn; default = cond1

HoleLayer = (ADS Layout option) layer on which the via hole is drawn, default = hole

Cond2Layer = (ADS Layout option) layer on which the bottom transitional metal is drawn, default = cond2

StartLayer = (ADS Layout option) layer on which the blind via starts

StopLayer = (ADS Layout option) layer on which the blind via stops

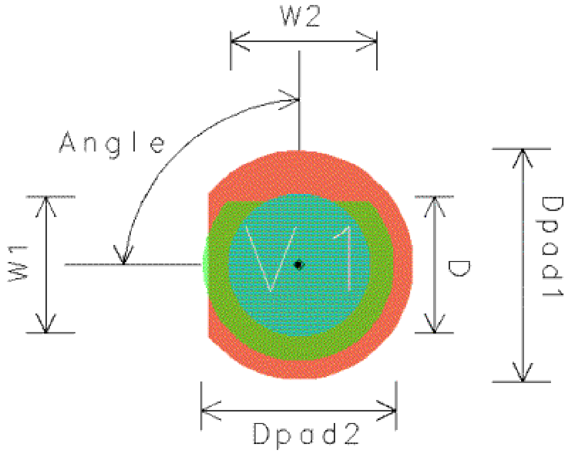
Range of Usage

$H \leq 2 \times D$
$H < \lambda$ where λ is wavelength in the dielectric
Dpad1 > D, W1
Dpad2 > D, W2

Notes

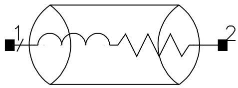
1. This via is similar to VIAHS but the pads are circles with one side being cut off by the connecting transmission lines.

2. Electrical model for this via is the same as for VIA in the ADS-equivalent RF library.



VIASC (Via with Semi-Circular Pads)

Symbol



Parameters

D = diameter of via hole

H = substrate thickness

T = conductor thickness

Dpad1 = (ADS Layout option) width of pad at pin 1

Dpad2 = (ADS Layout option) width of pad at pin 2

Angle = (ADS Layout option) angle between pads

Cond1Layer = (ADS Layout option) layer on which the top transitional metal is drawn; default = cond1

HoleLayer = (ADS Layout option) layer on which the via hole is drawn, default = hole

Cond2Layer = (ADS Layout option) layer on which the bottom transitional metal is drawn, default = cond2

StartLayer = (ADS Layout option) layer on which the blind via starts

StopLayer = (ADS Layout option) layer on which the blind via stops

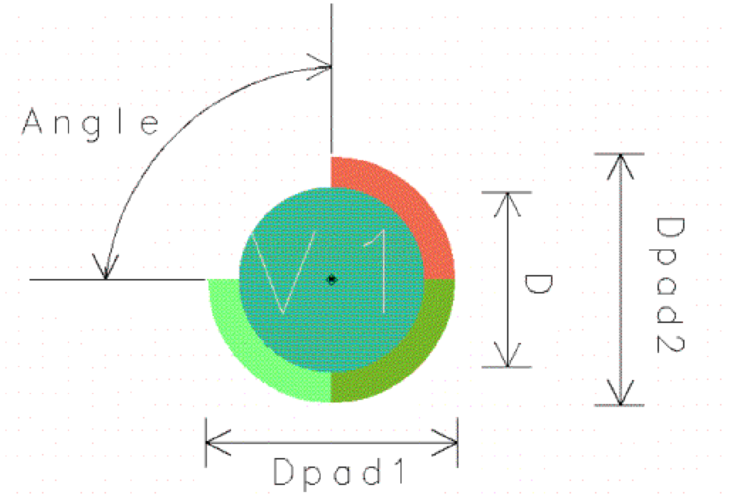
Range of Usage

$H \leq 2 \times D$
$H < \lambda$ where λ is wavelength in the dielectric
Dpad1 > D
Dpad2 > D

Notes

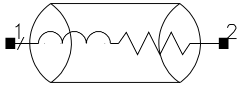
1. This via is similar to VIAHS but the pads are circles with one side being cut off by the connecting transmission lines.

2. Electrical model for this via is the same as for VIA in the ADS-equivalent RF library.



VIASTD (Via with Smooth Tear Drop Pads)

Symbol



Parameters

D = diameter of via hole

H = substrate thickness

T = conductor thickness

W1 = (ADS Layout option) width of transmission line connected to pin 1

W2 = (ADS Layout option) width of transmission line connected to pin 2

L1 = (ADS Layout option) length of tear drop from via hole center to pin 1

L2 = (ADS Layout option) length of tear drop from via hole center to pin 2

Dpad1 = (ADS Layout option) diameter of pad at pin 1

Dpad2 = (ADS Layout option) diameter of pad at pin 2

Angle = (ADS Layout option) angle between pads

Cond1Layer = (ADS Layout option) layer on which the top transitional metal is drawn; default = cond1

HoleLayer = (ADS Layout option) layer on which the via hole is drawn, default = hole

Cond2Layer = (ADS Layout option) layer on which the bottom transitional metal is drawn, default = cond2

StartLayer = (ADS Layout option) layer on which the blind via starts

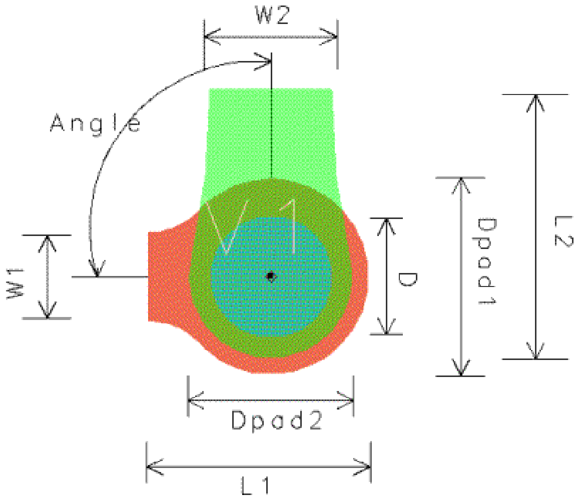
StopLayer = (ADS Layout option) layer on which the blind via stops

Range of Usage

$H \leq 2 \times D$
$H < \lambda$, where λ is wavelength in the dielectric
Dpad1 > D, W1
Dpad2 > D, W2
L1 > 0.5 x Dpad1
L2 > 0.5 x Dpad2

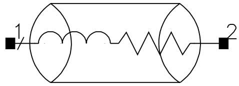
Notes

1. This via is similar to VIATDD but the pads have smooth tear drop shapes. The tear drops are tangential to the connecting transmission lines.
2. Electrical model for this via is the same as for VIA in the ADS-equivalent RF library.



VIATTD (Libra Via Hole in Microstrip with Tear Drop Pads)

Symbol



Parameters

D = diameter of via hole

H = substrate thickness

T = conductor thickness

W1 = (ADS Layout option) width of transmission line connected to pin 1

W2 = (ADS Layout option) width of transmission line connected to pin 2

L1 = (ADS Layout option) length of tear drop from via hole center to pin 1

L2 = (ADS Layout option) length of tear drop from via hole center to pin 2

Dpad1 = (ADS Layout option) diameter of pad at pin 1

Dpad2 = (ADS Layout option) diameter of pad at pin 2

Angle = (ADS Layout option) angle between pads

Cond1Layer = (ADS Layout option) layer on which the top transitional metal is drawn; default = cond1

HoleLayer = (ADS Layout option) layer on which the via hole is drawn, default = hole

Cond2Layer = (ADS Layout option) layer on which the bottom transitional metal is drawn, default = cond2

StartLayer = (ADS Layout option) layer on which the blind via starts

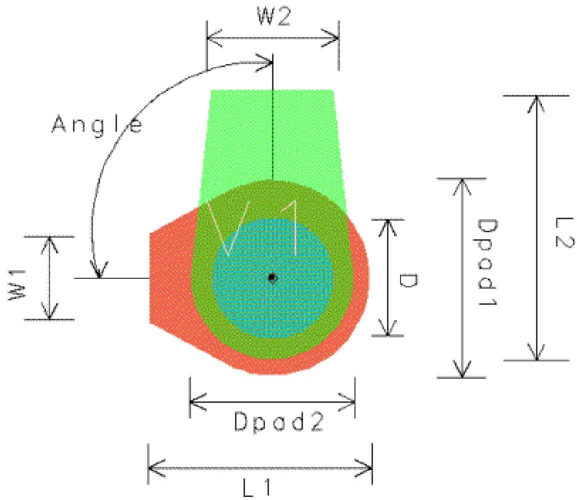
StopLayer = (ADS Layout option) layer on which the blind via stops

Range of Usage

$H \leq 2 \times D$
$H < \lambda$, where λ is wavelength in the dielectric
Dpad1 > D, W1
Dpad2 > D, W2
L1 > 0.5 x Dpad1
L2 > 0.5 x Dpad2

Notes

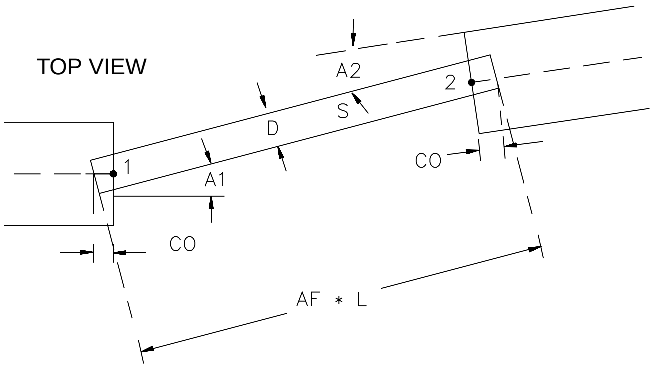
1. This via is similar to VIAHS but the pads have triangular tear drop shapes. The tear drops are not tangential to the connecting transmission lines.
2. Electrical model for this via is the same as for VIA in the ADS-equivalent RF library.



WIRE (Round Wire)

Symbol

Illustration



Parameters

D = wire diameter, in specified units

L = wire length, in specified units

Rho = metal resistivity (relative to gold)

Temp = physical temperature, in °C

AF = (ADS Layout option) arch factor; ratio of distance between two pins to wire length

CO = (ADS Layout option) conductor offset; distance from edge of conductor

A1 = (ADS Layout option) angle of departure from first pin

A2 = (ADS Layout option) angle between direction of first and second pins

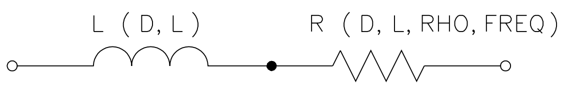
BondLayer = (ADS Layout option) layer on which the wire/ribbon is drawn; default=6 (bond)

Notes/Equations

1. Although this component is included in the *Microstrip Components* library, it does not use a microstrip substrate (MSUB).

2. Wire and Ribbon components serve as air bridges that are parallel to the surface of the substrate. This provides a way to connect the center of MRIND, MRINDNBR, and MSIND components.
3. Bulk resistivity of gold is used for Rho = 2.44 microhm-cm.
4. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
5. To turn off noise contribution, set Temp to –273.15°C.
6. The wire *bond* layer to the *conductor* layer transition is drawn on the *diel2* layer. The width of the *diel2* layer is CO, the conductor offset. If CO is zero, the transition is drawn as a zero width polygon. The transition is only for layout purposes and is not taken into account in the circuit simulator.

Equivalent Circuit



Chapter 3: Multilayer Interconnects

Introduction

Differences between the Multilayer library and the Printed Circuit Board library are described here.

The PCB library was originally developed at the University of Oregon, and was integrated into EEsof’s Libra program in 1992. This library is based on a finite difference method of solving a Poisson equation. It requires the structure to be enclosed in a metal box. It assumes zero-thickness metal. Metal loss is calculated based on Zs. It also requires the dielectric to be uniform. It is included with the purchase of ADS.

The multilayer library was first integrated into MDS in 1994. It is based on method of moments and Green's function method. It handles arbitrary dielectric layers and arbitrary metal thickness. Skin effect resistance matrix is calculated numerically. It has structures such as coupled tapers, coupled bends, coupled cross-overs, and coupled slanted lines. It can be purchased from Agilent as an optional feature.

COMBINE2ML (Combine 2 Coupled-Line Components)

Symbol

Parameters

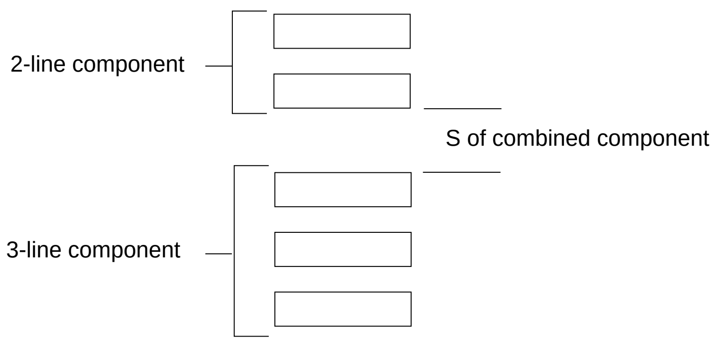
Coupled[1] = first component to be combined

Coupled[2] = second component to be combined

S = spacing between Coupled[1] and Coupled[2]

Notes/Equations

1. Combining coupled-line components allows you to create a component of more coupled lines by combining several individual components into a single component. For example, to create 20 coupled lines, you can combine two 10-line components. Or, use them to combine small sets of lines instead of reinserting components with a greater number of lines.
2. You can combine coupled lines of constant width and spacing, coupled lines with varying width and spacing, and coupled pads and lines. The components to be combined must refer to the same substrate, be parallel, and be of the same length.



COMBINE3ML (Combine 3 Coupled-Line Components)

Symbol

Parameters

Coupled[1] = first component to be combined

Coupled[2] = second component to be combined

Coupled[3] = third component to be combined

S[1] = spacing between Coupled[1] and Coupled[2]

S[2] = spacing between Coupled[2] and Coupled[3]

Notes/Equations

1. Combining coupled-line components allows you to create a component of more coupled lines by combining several individual components into a single component. For example, to create 20 coupled lines, you can combine two 10-line components. Or, use them to combine small sets of lines instead of reinserting components with a greater number of lines.
2. You can combine coupled lines of constant width and spacing, coupled lines with varying width and spacing, and coupled pads and lines. The components to be combined must refer to the same substrate, be parallel, and be of the same length.

COMBINE4ML (Combine 4 Coupled-Line Components)

Symbol

Parameters

Coupled[1] = first component to be combined

Coupled[2] = second component to be combined

Coupled[3] = third component to be combined

Coupled[4] = fourth component to be combined

S[1] = spacing between Coupled[1] and Coupled[2]

S[2] = spacing between Coupled[2] and Coupled[3]

S[3] = spacing between Coupled[3] and Coupled[4]

Notes/Equations

1. Combining coupled-line components allows you to create a component of more coupled lines by combining several individual components into a single component. For example, to create 20 coupled lines, you can combine two 10-line components. Or, use them to combine small sets of lines instead of reinserting components with a greater number of lines.

2. You can combine coupled lines of constant width and spacing, coupled lines with varying width and spacing, and coupled pads and lines. The components to be combined must refer to the same substrate, be parallel, and be of the same length.

COMBINE5ML (Combine 5 Coupled-Line Components)

Symbol

Parameters

Coupled[1] = first component to be combined

Coupled[2] = second component to be combined

Coupled[3] = third component to be combined

Coupled[4] = fourth component to be combined

Coupled[5] = fifth component to be combined

S[1] = spacing between Coupled[1] and Coupled[2]

S[2] = spacing between Coupled[2] and Coupled[3]

S[3] = spacing between Coupled[3] and Coupled[4]

S[4] = spacing between Coupled[4] and Coupled[5]

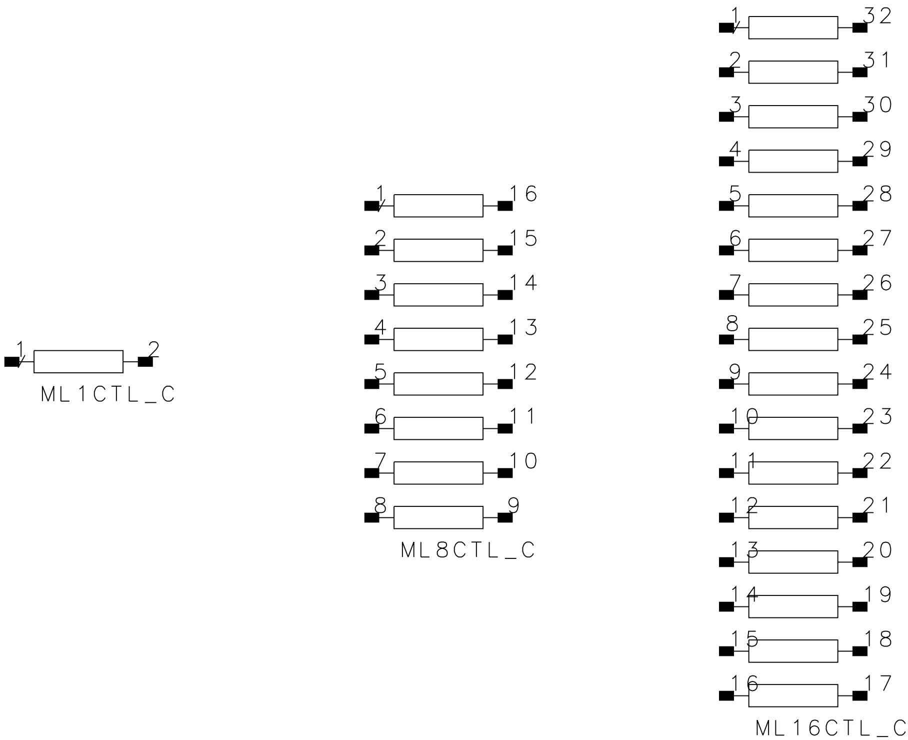
Notes/Equations

1. Combining coupled-line components allows you to create a component of more coupled lines by combining several individual components into a single component. For example, to create 20 coupled lines, you can combine two 10-line components. Or, use them to combine small sets of lines instead of reinserting components with a greater number of lines.

2. You can combine coupled lines of constant width and spacing, coupled lines with varying width and spacing, and coupled pads and lines. The components to be combined must refer to the same substrate, be parallel, and be of the same length.

ML1CTL_C to ML8CTL_C, ML16CTL_C (Coupled Lines, Constant Width and Spacing)

Symbol



Parameters

Subst = substrate name

Length = line length, in specified units

W = width of conductors, in specified units

S = spacing; default: 5.0 mil; also um mm, cm, meter, in

Layer = layer number of all conductors (value type: integer)

RLGC_File = name of RLGC file

Reuse RLGC = yes to reuse the RLGC matrices stored in RLGC_File; no to not reuse. (refer to Note 5)

Range of Usage

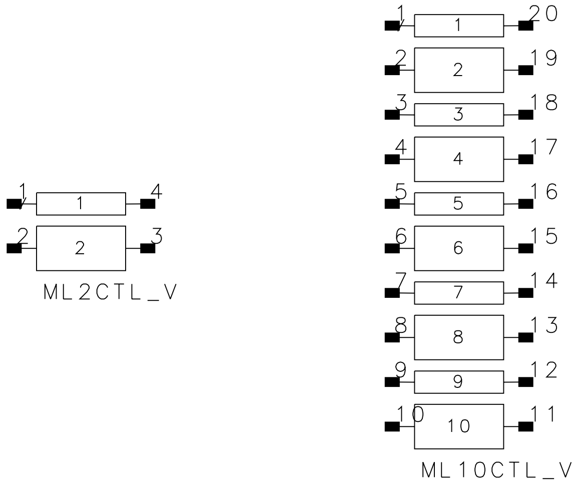
W > 0
S > 0

Notes/Equations

1. Dispersion due to skin effect and dielectric loss is calculated. Dispersion due to inhomogeneous dielectrics is not considered.
2. These models are implemented as the numerical solution of Maxwell's Equations for the two-dimensional cross-section geometry that is defined by the model parameters. Because a new numerical calculation is performed for each unique set of geometric or material parameters, the evaluation of these models may take a few seconds on some platforms. One effect of this implementation is that optimization of any set of the geometric or material parameters for these models may result in a time-consuming analysis. Only one numerical calculation is required for an analysis that is only swept with respect to frequency. The evaluation time for this model is significantly reduced for conductors of 0 thickness.
3. Conductor loss (and its contribution to noise) is *not* considered if conductivity is infinite or conductor thickness is 0.
4. A substrate must be named as the *Subst* parameter and a multilayer interconnect substrate definition that corresponds to this name must appear on the schematic.
5. If Reuse_RLGC is set to *yes*, the RLGC matrices will be read from the file stored on your disk. If you have changed the substrate parameters or transition parameters, setting Reuse_RLGC to yes will cause invalid results. In most cases, a setting of *no* is recommended. If you know that the substrate and transmission parameters are fixed in your simulation, you can set Reuse_RLGC to *yes* to save some computer time, as the RLGC matrices will not be re-calculated.
6. All *n* conductors of the ML*n*CTL_C model lay on the same layer. If the *n* conductors of the coupled lines are assigned to different layers, use the more general ML*n*CTL_V model.

ML2CTL_V to ML10CTL_V (Coupled Lines, Variable Width and Spacing)

Symbol



Parameters

Subst = substrate name

Length = length, in specified units

W[i] = width of ith conductor, in specified units

S(i) = spacing between ith and (i+1)th conductors, in specified units. (refer to note 5)

Layer(i) = layer number of ith conductor (value type: integer)

RLGC_File = name of RLGC file

Reuse RLGC = yes to reuse the RLGC matrices stored in RLGC_File; no to not reuse. (refer to note 6)

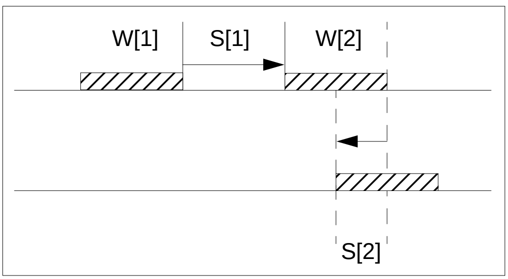
Range of Usage

Length > 0
W > 0

Notes/Equations

1. Dispersion due to skin effect and dielectric loss is calculated. Dispersion due to inhomogeneous dielectrics is not considered.

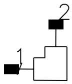
2. These models are implemented as the numerical solution of Maxwell's Equations for the two-dimensional cross-section geometry that is defined by the model parameters. Because a new numerical calculation is performed for each unique set of geometric or material parameters, the evaluation of these models may take a few seconds on some platforms. One effect of this implementation is that optimization of any set of the geometric or material parameters for these models may result in a time-consuming analysis. Only one numerical calculation is required for an analysis that is only swept with respect to frequency. The evaluation time for this model is significantly reduced for conductors of 0 thickness.
3. Conductor loss (and its contribution to noise) is not considered if conductivity is infinite or conductor thickness is 0.
4. A substrate must be named in the Subst field and a multilayer interconnect substrate definition that corresponds to this name must be placed in the schematic.
5. Spacing (S[i] is measured from the right edge of the ith conductor to the left edge of (it1)th conductor. If (it1)th conductor overlays with ith conductor, S[i] will be negative, as illustrated.



6. If Reuse_RLGC is set to *yes*, the RLGC matrices will be read from the file stored on your disk. If you have changed the substrate parameters or transition parameters, setting Reuse_RLGC to yes will cause invalid results. In most cases, a setting of *no* is recommended. If you know that the substrate and transmission parameters are fixed in your simulation, you can set Reuse_RLGC to *yes* to save some computer time, as the RLGC matrices will not be re-calculated.

MLACRNR1 (190-degree Corner, Changing Width)

Symbol



Parameters

Subst = substrate name

W1 = width on one side, in specified units

W2 = width on the other side, in specified units

Layer = layer number of conductor (value type: integer)

Range of Usage

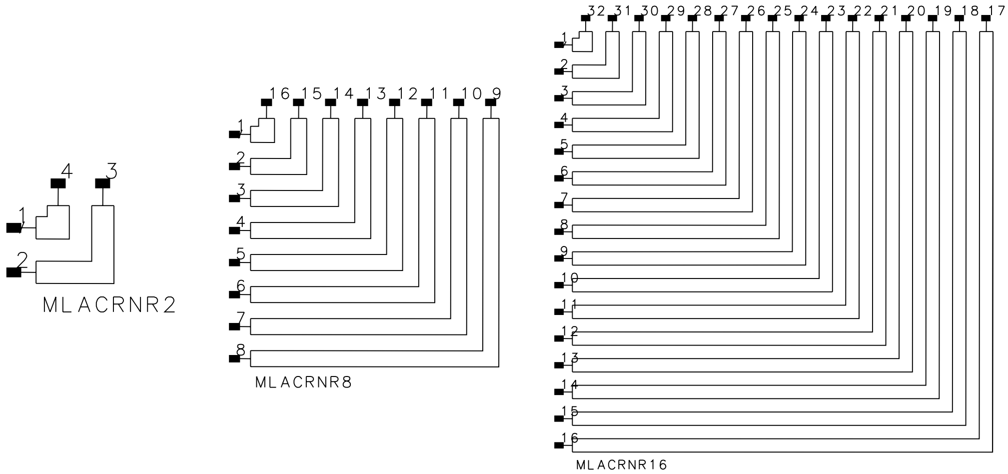
W1 > 0
W2 > 0

Notes/Equations

1. A substrate must be named in the Subst field and a multilayer interconnect substrate definition that corresponds to this name must appear on the circuit page.

MLACRNR2 to MLACRNR8, MLACRNR16 (Coupled 90-deg Corners, Changing Pitch)

Symbol



Parameters

Subst = substrate name

W1 = conductor width on one side, in specified units

S1 = conductor spacing on one side, in specified units

W2 = conductor width on the other side, in specified units

S2 = conductor spacing on the other side, in specified units

Layer = layer number of conductor (value type: integer)

Range of Usage

W1 > 0
W2 > 0

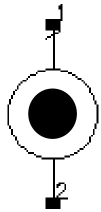
Notes/Equations

1. Coupled line corners are modeled as staggered coupled lines. The discontinuity effect of corners is not modeled.

2. A substrate must be named in the Subst field and a multilayer interconnect substrate definition that corresponds to this name must appear on the circuit page.

MLCLE (Via Clearance)

Symbol



Parameters

Subst = substrate name

DiamClear = clearance diameter, in specified units

DiamPad = pad diameter, in specified units

Layer = layer number of the clearance (value type: integer)

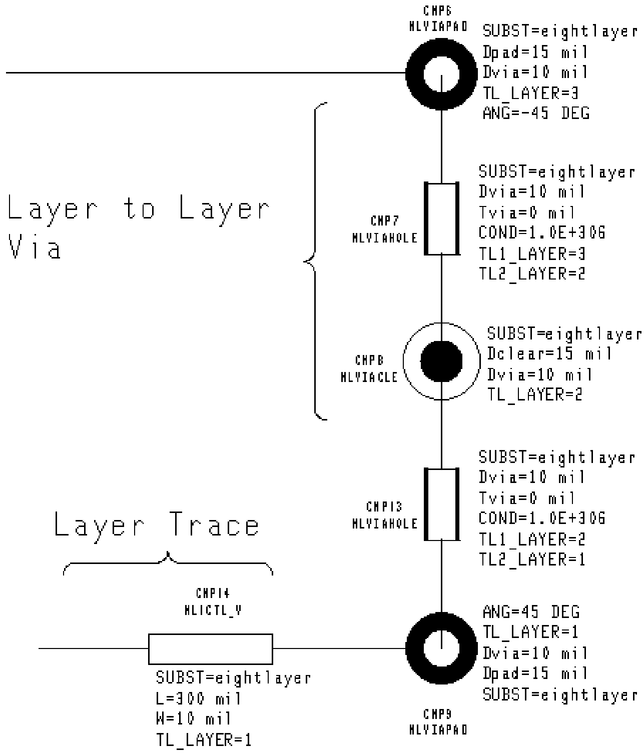
Range of Usage

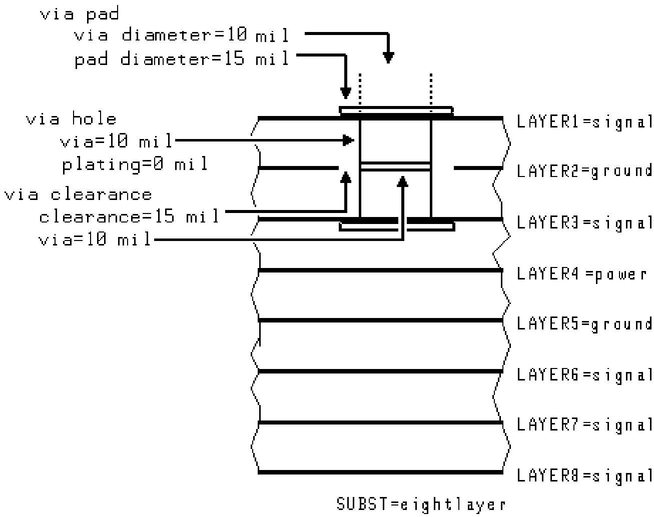
DiamClear > 0
DiamPad > 0
DiamClear > DiamPad

Notes/Equations

1. This component is modeled as a capacitor to ground.
2. A substrate must be named in the Subst field and a multilayer substrate definition that corresponds to this name must appear on the circuit page.
3. A via clearance must be located on a ground layer or a power layer. The pins of MLCLE must be connected to the pins of MLVIAHOLE. MLCLE models the parasitic capacitance between the via hole and the power/ground plane on which MLCLE is located.
4. When MLCLE components are used with MLVIAHOLE components, the inner diameter of the clearance hole (MLCLE parameter DiamPad) must be set equal to the via diameter (MIVIAHOLE parameter DiamVia).

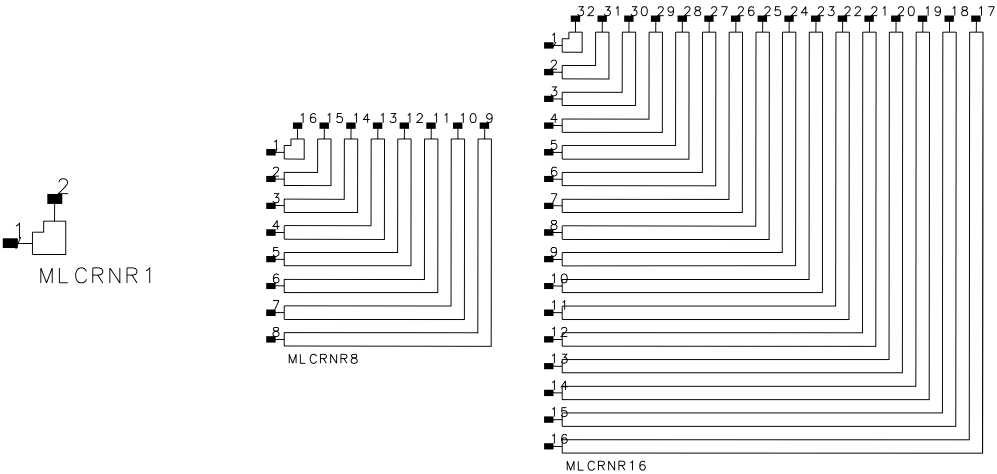
5. A circuit using via components to create a path to multiple board layers is illustrated.




via pad
via diameter=10 mil
pad diameter=15 mil
via hole
via=10 mil
plating=0 mil
via clearance
clearance=15 mil
via=10 mil
LAYER1=signal
LAYER2=ground
LAYER3=signal
LAYER4 =power
LAYER5=ground
LAYER6=signal
LAYER7=signal
LAYER8=signal
SUBST=eightlayer

MLCRNR1 to MLCRNR8, MLCRNR16 (Coupled Angled Corners, Constant Pitch)

Symbol



Parameters

Subst = substrate name

Angle = angle of bend, in degrees

W = width of conductors, in specified units

S = spacing between conductors, in specified unit

layer = layer number of conductor (value type: integer)

Range of Usage

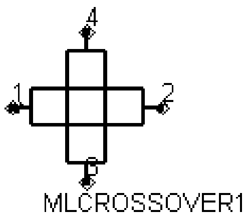
$W > 0$
$S > 0$
$0 \le Angle \le 90°$

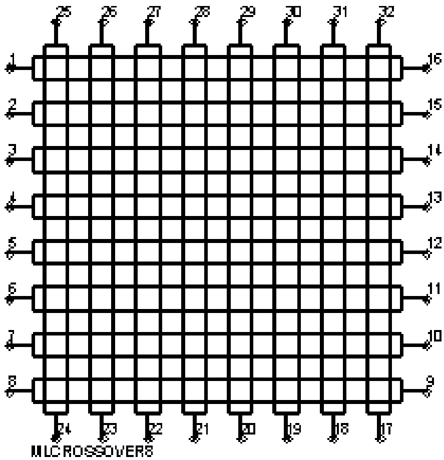
Notes/Equations

1. Coupled line corners are modeled as staggered coupled lines. The discontinuity effect of corners is not modeled.
2. A substrate must be named in the Subst field and a multilayer interconnect substrate definition that corresponds to this name must appear on the circuit page.

MLCROSSOVER1 to MLCROSSOVER8 (1 to 8 Crossovers)

Symbol





Parameters

Subst = substrate name

W_Top = width of top conductors, in specified units

W_Bottom = width of bottom conductors, in specified units

S_Top = spacing between top conductors, in specified units

S_Bottom = spacing between bottom conductors, in specified units

LayerTop = top layer number (value type: integer)

LayerBottom = bottom layer number (value type: integer)

Range of Usage

W_Top > 0
W_Bottom > 0
S_Top > 0
S_Bottom > 0

Notes/Equations

1. An important discontinuity in high-speed digital design is the crossover between two adjacent signal layers. The crossover causes parasitic capacitance, resulting in high-frequency crosstalk. These crossover models are modeled as

coupled lines cascaded with junction coupling capacitors. The models are quasi-static.

2. A substrate must be named in the Subst field and a multilayer interconnect substrate definition that corresponds to this name must appear on the circuit page.

3. Port reference planes are located at the edge of each crossover region, as shown in Figure 3-1. The capacitor is at the junction where a horizontal and vertical line cross.

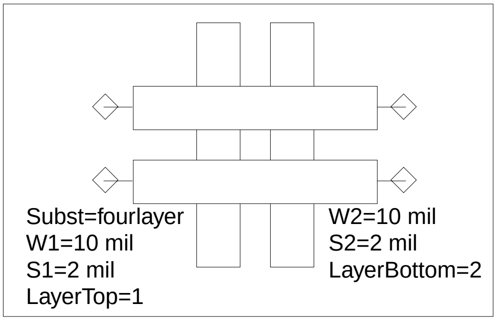
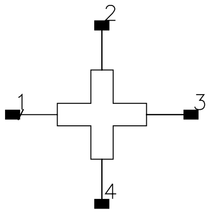


Figure 3-1. Crossover region with port reference planes

MLJCROSS (Cross Junction)

Symbol



Parameters

Subst = substrate name

W1 = width of conductor 1, in specified units

W2 = width of conductor 2, in specified units

W3 = width of conductor 3, in specified units

W4 = width of conductor 4, in specified units

Layer = layer number (value type: integer)

Range of Usage

W1 > 0
W2 > 0
W3 > 0
W4 > 0

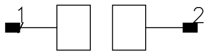
Notes/Equations

1. The cross junction is treated as an ideal connection between pins 1, 2, 3, and 4, and is provided to facilitate interconnections between lines in layout.

2. A substrate must be named in the Subst field and a multilayer interconnect substrate definition that corresponds to this name must appear on the circuit page.

MLJGAP (Open Gap)

Symbol



Parameters

Subst = substrate name

G = width of gap, in specified units

W = width of conductor, in specified units

Layer = layer number (value type: integer)

Range of Usage

G > 0
W > 0

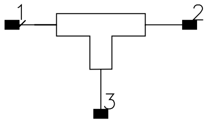
Notes/Equations

1. The gap is treated as an ideal open circuit between pins 1 and 2, and is provided to facilitate layout.

2. A substrate must be named in the Subst field and a multilayer interconnect substrate definition that corresponds to this name must appear on the circuit page.

MLJTEE (Tee Junction)

Symbol



Parameters

Subst = substrate name

W1 = width of conductor 1, in specified units

W2 = width of conductor 2, in specified units

W3 = width of conductor 3, in specified units

Layer = layer number (value type: integer)

Range of Usage

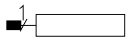
W[n] > 0

Notes/Equations

1. The tee junction is treated as an ideal connection between pins 1, 2, and 3, and is provided to facilitate interconnections between lines oriented at different angles in layout.
2. A substrate must be named in the Subst field and a multilayer interconnect substrate definition that corresponds to this name must appear on the circuit page.

MLOPENSTUB (Open Stub)

Symbol



Parameters

Subst = substrate name

Length = length of conductor, in specified units

W = width of conductor, in specified units

Layer = layer number (value type: integer)

Range of Usage

W > 0
L > 0

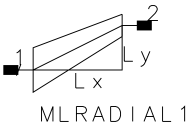
Notes/Equations

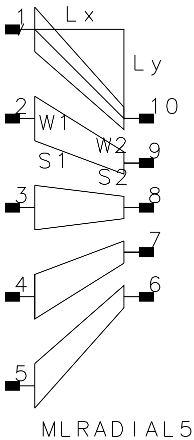
1. If the length of the stub is zero, this component simulates an open-end effect. If the length is greater than zero, this component simulates a length of line and an open-end effect.

2. A substrate must be named in the Subst field and a multilayer interconnect substrate definition that corresponds to this name must appear on the circuit page.

MLRADIAL1 to MLRADIAL5 (Radial Line, Coupled Radial Lines)

Symbol





Parameters

Subst = substrate name

X_Offset = horizontal offset

Y_Offset = vertical offset

W_Left = width of conductor on left side, in specified units

W_Right = width of conductor on right side, in specified units

S_Left = spacing between conductors on left side, in specified units

S_Right = spacing between conductors on right side, in specified units

Layer = layer number of conductor (value type: integer)

Range of Usage

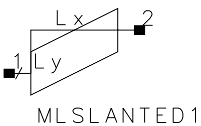
X_Offset > 0
Y_Offset > 0
W_Left > 0
W_Right > 0
S_Left > 0
S_Right > 0

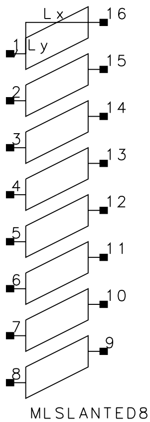
Notes/Equations

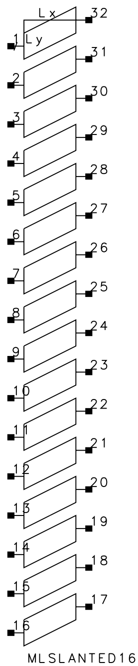
1. Radial lines are modeled as a cascade of uniform coupled line segments. Each segment is implemented as the numerical solution of Maxwell's Equations for the two-dimensional cross-section geometry. For optimization or tuning, zero-thickness conductor is suggested to speed up the run time.
2. A substrate must be named in the Subst field and a multilayer interconnect substrate definition that corresponds to this name must appear on the circuit page.

MLSLANTED1 to MLSLANTED8, MLSLANTED16 (Slanted Line, Slanted Coupled Lines)

Symbol







Parameters

Subst = substrate name

X_Offset = horizontal offset

Y_Offset = vertical offset

W = width of conductors, in specified units

S = spacing between conductors, in specified units

Layer = layer number of conductors (value type: integer)

Range of Usage

X_Offset > 0
Y_Offset > 0

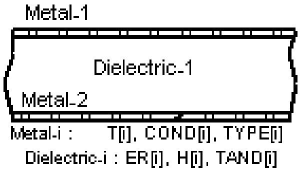
W > 0
S > 0

Notes/Equations

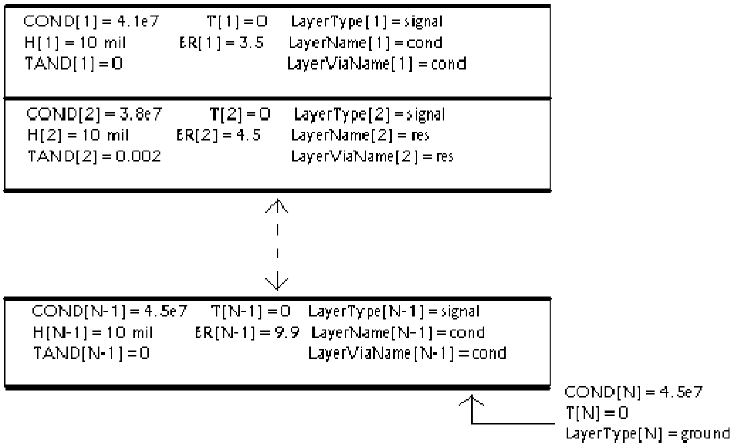
1. Dispersion due to skin effect and dielectric loss is calculated. Dispersion due to inhomogeneous dielectrics is not considered.
2. These models are implemented as the numerical solution of Maxwell's Equations for the two-dimensional cross-section geometry that is defined by the model parameters. Because a new numerical calculation is performed for each unique set of geometric or material parameters, the evaluation of these models may take a few seconds on some platforms. One effect of this implementation is that optimization of any set of the geometric or material parameters for these models may result in a time-consuming analysis. Only one numerical calculation is required for an analysis that is only swept with respect to frequency. The evaluation time for this model is significantly reduced for conductors of 0 thickness.
3. Conductor loss (and its contribution to noise) is *not* considered if conductivity is infinite or conductor thickness is 0.
4. A substrate must be named in the Subst field and a multilayer interconnect substrate definition that corresponds to this name must appear on the circuit page.

MLSUBSTRATE2 to MLSUBSTRATE10, MLSUBSTRATE12, MLSUBSTRATE14, MLSUBSTRATE16, MLSUBSTRATE32, MLSUBSTRATE40 (Dielectric Constant for N Layers)

Symbol



Illustration



Parameters

Er[n] = dielectric constant

H[n] = height of substrate, in specified length units

TanD[n] = dielectric loss tangent

T[n] = metal thickness, in specified units

Cond[n] = conductivity, in conductance per meters

LayerType[n] = type of the metal layer: blank, signal, ground, power

LayerName[n] = layer name (for layout use)

LayerViaName[n] = layer name of the via (for layout use)

Recommended Range of Usage

Er[n] > 0
H[n] > 0
TanD[n] > 0
Cond[n] > 0

Netlist Format

Substrate model statements for the ADS circuit simulator may be stored in an external file.

```
model  substratename  Substrate N=layers [parm=value]*
```

The model statement starts with the required keyword *model*. It is followed by the *substratename* that will be used by multilayer components to refer to the model. The third parameter indicates the type of model; for this model it is *Substrate*. The fourth parameter is the number of layers for this substrate. The number of layers may be any value between 2 and 40. The rest of the model contains pairs of substrate model parameters and values, separated by an equal sign. The name of the model parameter must appear exactly as shown in the parameters table-these names are case sensitive. Model parameters may appear in any order in the model statement. For more information about the ADS circuit simulator netlist format, including scale factors, subcircuits, variables and equations, refer to Chapter 8, *ADS Simulator Input Syntax* in the *Circuit Simulation* book.

Example:

```
model Subst1 Substrate N=2 Er=4.5 H=10 mil TanD=0 \
T[1]=0 mil Cond[1]=1.0E+50 LayerType[1]="signal" \
T[2]=0 mil Cond[2]=1.0E+50 LayerType[2]="ground"
```

Notes/Equations

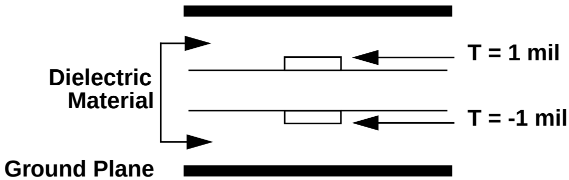
For RFDE Users Information about this model must be provided in a *model* file; refer to the *Netlist Format* section.

---

1. *N*-1 defines the number of dielectric layers being used as a multilayer substrate. The number of dielectric layers supported are N=2, 3, 4, 5, 6, 7, 8, 10, 12, 14, 16, 32 and 40.
2. At least one substrate component must be inserted as part of any multilayer circuit design. The name of the substrate must be inserted in the Subst field of every multilayer interconnect component displaying the field in the circuit.

Substrate names can be up to 10 characters long; they must begin with a letter, not a number or a symbol.

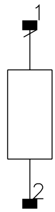
3. If the conductor thickness T[n] is set to zero or if the conductivity Cond[n] is set to infinity, the conductor is assumed to have zero loss. T[n] can be used to specify the position of the trace on a substrate. If T[n] is positive, the trace grows up into the dielectric material; if T[n] is negative, the trace grows down into the material. For ground and power supply layers, assigning T[n] as positive or negative has no effect, as illustrated here.



4. The substrate schematic symbol appears as a cross-section of a substrate. Each layer is labeled, and you can easily set the parameters for each layer. A signal layer has components on it. A power or ground layer is a solid sheet of metal. No components are on this layer other than clearance holes.

MLVIAHOLE (Via Hole)

Symbol



Parameters

Subst = substrate name

DiamVia = via diameter, in specified units

T = via thickness, in specified units

Cond = conductivity

Layer[1] = starting layer number (value type: integer)

Layer[2] = ending layer number (value type: integer)

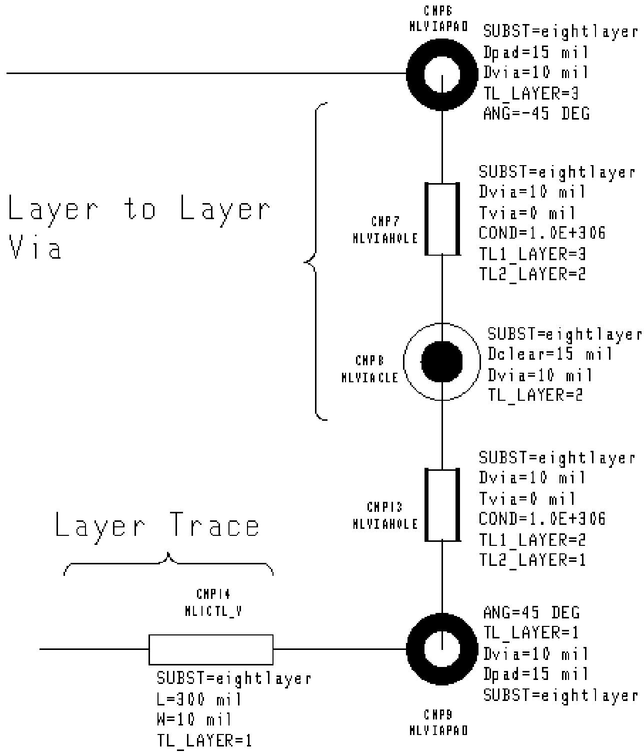
Range of Usage

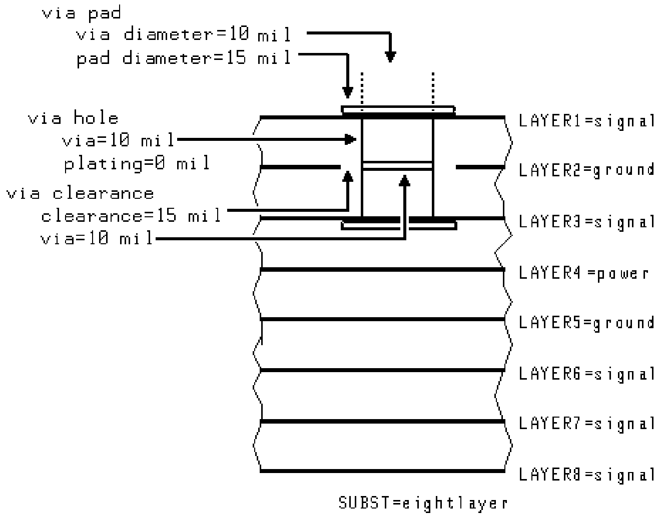
DiamVia > 0
T > 0
Cond > 0

Notes/Equations

1. This component is modeled as an inductor.
2. A substrate must be named in the Subst field and a multilayer substrate definition that corresponds to this name must be placed in the schematic.

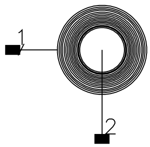
3. Circuit Using Via Components to Create a Path to Multiple Board Layers




via pad
via diameter=10 mil
pad diameter=15 mil
via hole
via=10 mil
plating=0 mil
via clearance
clearance=15 mil
via=10 mil
LAYER1=signal
LAYER2=ground
LAYER3=signal
LAYER4 =power
LAYER5=ground
LAYER6=signal
LAYER7=signal
LAYER8=signal
SUBST=eightlayer

MLVIAPAD (Via Pad)

Symbol



Parameters

Subst = substrate name

DiamVia = via diameter, in specified units

DiamPad = pad diameter, in specified units

Layer = layer number (value type: integer)

Angle = (ADS Layout option) input pin to output pin angle, in degrees

Range of Usage

DiamVia > 0
DiamPad > 0
$-180° \leq$ Angle $\leq +180°$

Notes/Equations

1. This component is modeled as a capacitor to ground.
2. A substrate must be named in the Subst field and a multilayer substrate definition that corresponds to this name must appear on the circuit page.
3. A via pad connects signal trace to a via hole. Pin 1 of MLVIAPAD should be connected to a signal trace. Pin 2 should be connected to a MLVIAHOLE.
4. Angle refers to the angle between two connecting lines and is necessary for performing layout. In Figure 3-2 the angle between the two traces is 90°. The angle parameters of the two pads used in connecting these traces must be specified so that the difference between them is 90°. Therefore, the angle of the first pad may be –45° and the second 45°, or 0° and 90°, respectively.

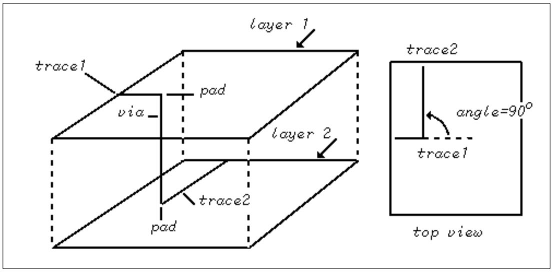
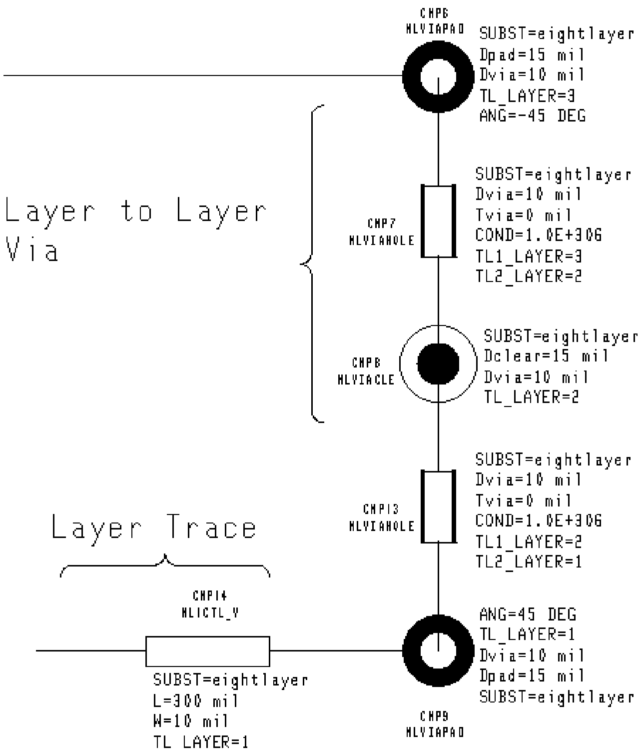
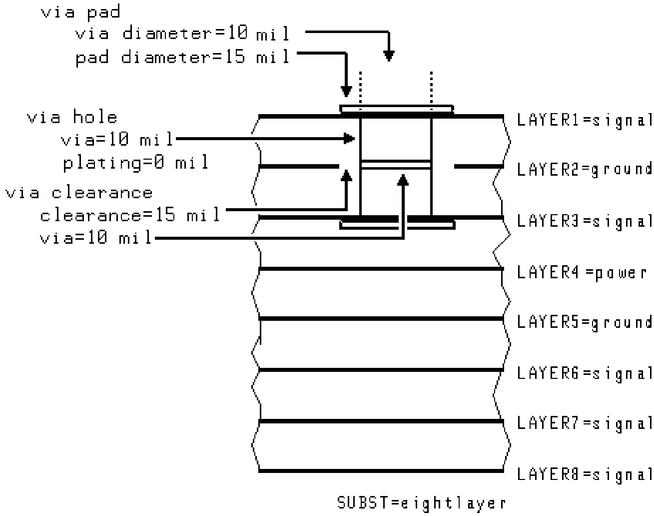


Figure 3-2. 90° angles of connecting lines

5. A circuit using via components to create a path to multiple board layers is shown.




via pad
via diameter=10 mil
pad diameter=15 mil
via hole
via=10 mil
plating=0 mil
via clearance
clearance=15 mil
via=10 mil
LAYER1=signal
LAYER2=ground
LAYER3=signal
LAYER4 =power
LAYER5=ground
LAYER6=signal
LAYER7=signal
LAYER8=signal
SUBST=eightlayer

Chapter 4: Passive RF Circuit Components

AIRIND1 (Aircore Inductor (Wire Diameter))

Symbol

Parameters

N = number of turns

D = diameter of form, in specified units

L = length of form, in specified units

WD = wire diameter, in specified units

Rho = conductor resistivity (relative to copper)

Temp = physical temperature, in °C

Range of Usage

$N \geq 1$
$WD > 0$
$L \geq N \times WD$
$D > 0$

Notes/Equations

1. This component is envisioned as a single-layer coil. Loss is included by calculating total resistance, including skin effect, from the physical dimensions and the resistivity. The resonant frequency is estimated from the physical dimensions.
2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
3. This component has no default artwork associated with it.

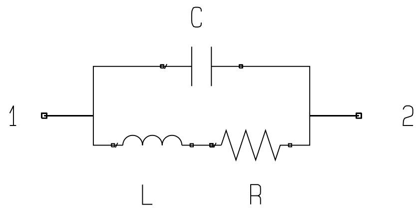
References

[1] Frederick W. Grover, *Inductance Calculations: Working Formulas and Tables,* Dover Publications, Inc., 1962, Chapter 16, pp. 142-162.

[2] R. G. Medhurst, “H.F. Resistance and Self-Capacitance of Single-Layer Solenoids,” *Wireless Engineer,* February 1947, pp. 35-43.

[3] R. G. Medhurst, “H.F. Resistance and Self-Capacitance of Single-Layer Solenoids,” *Wireless Engineer,* March 1947, pp. 80-92.

Equivalent Circuit



AIRIND2 (Aircore Inductor (Wire Gauge))

Symbol

Parameters

N = number of turns

D = diameter of form, in specified units

L = length of form, in specified units

AWG = wire gauge (any value in AWG table)

Rho = conductor resistivity (relative to copper)

Temp = physical temperature, in °C

Range of Usage

$N \geq 1$
$9 \leq AWG \leq 46$
$L \geq N \times WD$, where WD is the wire-diameter
$D > 0$

Notes/Equations

1. This component is envisioned as a single-layer coil. Loss is included by calculating total resistance, including skin effect, from the physical dimensions and the resistivity. The resonant frequency is estimated from the physical dimensions.

2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

3. This component has no default artwork associated with it.

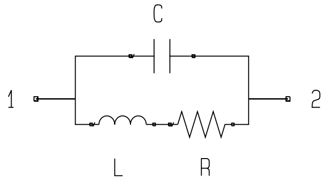
References

1. Frederick W. Grover, *Inductance Calculations: Working Formulas and Tables*, Dover Publications, Inc., 1962, Chapter 16, pp. 142-162.

2. R. G. Medhurst, "H.F. Resistance and Self-Capacitance of Single-Layer Solenoids," *Wireless Engineer*, February 1947, pp. 35-43.

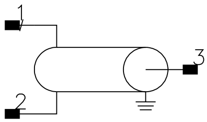
3. R. G. Medhurst, "H.F. Resistance and Self-Capacitance of Single-Layer Solenoids," *Wireless Engineer*, March 1947, pp. 80-92.

Equivalent Circuit



BALUN1 (Balanced-to-Unbalanced Transformer (Ferrite Core))

Symbol



Parameters

Z = characteristic impedance of transmission line, in ohms

Len = physical length of transmission line, in specified units

K = effective dielectric constant

A = attenuation of transmission line, in dB per unit meter

F = frequency for scaling attenuation, in hertz

N = number of turns

AL = inductance index; units in Henry/N^2, where N = number of turns

TanD = dielectric loss tangent

Mur = relative permeability

TanM = magnetic loss tangent

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

Z > 0, Len > 0, AL > 0
K ≥ 1
A ≥ 0
F ≥ 0
N ≥ 1

Notes/Equations

1. This component is a length of transmission line (specified by Z, LEN, K, A and F) coiled around a ferrite core.
2. Choking inductance L_c accounts for low-frequency roll-off and is given by

$L_c = N^2 \times AL$

$A(f) = A \quad (\text{for } F = 0)$

$$A(f) = A(F) \times \sqrt{\left(\frac{f}{F}\right)} \quad (\text{for } F \neq 0)$$

where

f = simulation frequency

F = reference frequency for attenuation

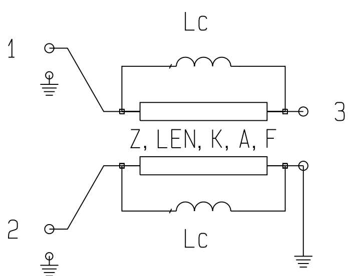
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

4. This component has no default artwork associated with it.

References

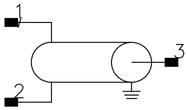
[1] J. Sevick, *Transmission Line Transformers*, 2nd Ed., American Radio Relay League, Newington, CT, 1990.

Equivalent Circuit



BALUN2 (Balanced-to-Unbalanced Transformer (Ferrite Sleeve))

Symbol



Parameters

Z = characteristic impedance of transmission line, in ohms

Len = physical length of transmission line, in specified units

K = effective dielectric constant

A = attenuation of transmission line, in dB per unit meter

F = frequency for scaling attenuation, in hertz

Mu = relative permeability of surrounding sleeve

L = inductance (per meter) of line without sleeve, in henries

TanD = dielectric loss tangent

Mur = relative permeability

TanM = magnetic loss tangent

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

$Z > 0$, $Len > 0$, $Mu > 0$, $L > 0$
$K \geq 1$
$A \geq 0$
$F \geq 0$

Notes/Equations

1. This component is a straight length of transmission line (specified by Z, Len, K, A and F) surrounded by a ferrite sleeve.
2. Choking inductance L_c accounts for low-frequency roll-off and is given by

   $$L_c = Mu \times L \times Len$$

   $$A(f) = A \quad (\text{for } F = 0)$$

$$A(f) = A(F) \times \sqrt{\left(\frac{f}{F}\right)} \quad (\text{for } F \neq 0)$$

where

f = simulation frequency

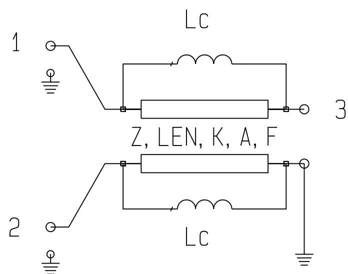
F = reference frequency for attenuation

3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
4. This component has no default artwork associated with it.

References

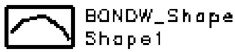
[1] Sevick, Jerry. *Transmission Line Transformers*, 2nd Ed., American Radio Relay League, Newington, CT, 1990.

Equivalent Circuit



BONDW_Shape (Philips/TU Delft Bondwire Parameterized Shape)

Symbol



Parameters

Rw = radius of the bondwires

Gap = horizontal distance between the Start point and the Stop point (ignoring the difference in height)

StartH = Left-hand height above the groundplane

Flip = 1 start height above odd-numbered pins

Flip = 0 start height above even-numbered pins

MaxH = Height above the groundplane

Tilt = for > 0: wire tilts to the right; for = 0: wire tilts slightly to the right; for < 0: wire makes an additional loop to the left

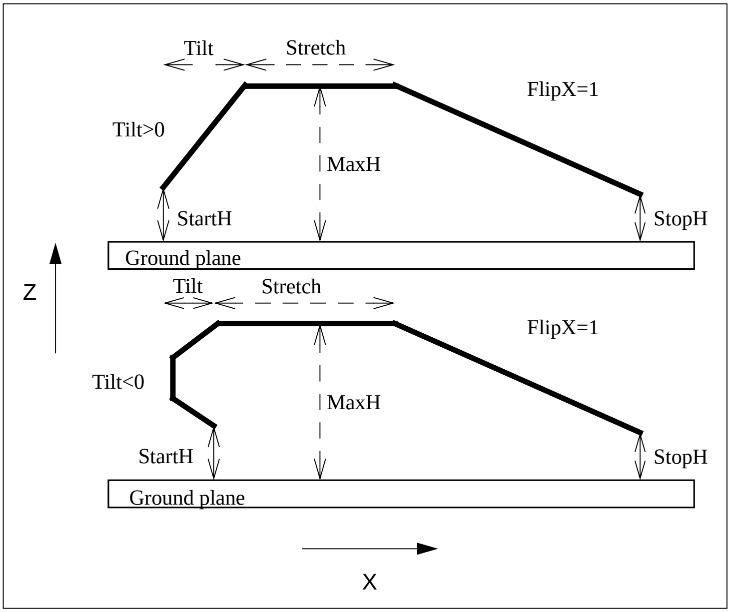
Stretch = Length of the top segment

StopH = Right-hand height above the ground plane

Flip = 1 stop height above odd-numbered pins

Flip = 0 stop height above even-numbered pins

FlipX = 1 or 0 flips the wire geometry between the pins. The pin coordinates remain unchanged.


Tilt
Stretch
FlipX=1
Tilt>0
MaxH
StartH
StopH
Ground plane
Z
Tilt
Stretch
FlipX=1
Tilt<0
MaxH
StartH
StopH
Ground plane
X

Notes

1. This component is not available from the component palette or library browser. To access it, type its exact name (BONDW_shape) into the right entry panel above the viewing area. Press *Enter* on your keyboard. Move the cursor to the viewing area to place the component.
2. The Gap parameter does not allow for wires that are perpendicular to the ground plane.
3. For more details on the use of bondwire components, refer to the Notes and References in the section "BONDW1 (Philips/TU Delft Bondwires Model (1 Wire)" on page 4-15.

Equations

$$X1 = 0$$

$$WX2 = min(Tilt - Rw, -3 \times Rw) \times \mathrm{sgn}(ramp(-Tilt)) + 1/3 \times ramp(max(Tilt, 3 \times Rw))$$

$$WX2 = min(Tilt - Rw, -3 \times Rw) \times \mathrm{sgn}(ramp(-Tilt)) + 1/3 \times ramp(max(Tilt, 3 \times Rw))$$

$$WX3 = min(Tilt - Rw, -3 \times Rw) \times \mathrm{sgn}(ramp(-Tilt)) + 2/3 \times ramp(max(Tilt, 3 \times Rw))$$

$$WX4 = ramp(max(Tilt, 3 \times Rw)) - \mathrm{sgn}(ramp(-Tilt)) \times 3 \times Rw$$

$$WX5 = max(4 \times Rw, abs(Stretch)) + ramp(max(Tilt, 3 \times Rw)) - \mathrm{sgn}(ramp(-Tilt)) \times 3 \times Rw$$

$$WX6 = Gap$$

$$WZ1 = Rw + StartH$$

$$WZ2 = 1/3 \times (MaxH + 2/3 \times (StartH + Rw))$$

$$WZ3 = 1/3 \times MaxH + 1/3 \times (StartH + Rw)$$

$$WZ4 = MaxH$$

$$WZ5 = MaxH$$

$$WZ6 = Rw + StopH$$

$$X1 = 0$$

$$X2 = (FlipX = 1)|_{Gap - WX5}^{WX2}$$

$$X3 = (FlipX = 1)|_{Gap - WX4}^{WX3}$$

$$4 = (FlipX = 1)\Big|_{Gap - WX3}^{WX4}$$

$$5 = (FlipX = 1)\Big|_{Gap - WX2}^{WX5}$$

$$6 = (FlipX = 1)\Big|_{Gap - WX1}^{WX6}$$

$$Y1 = X1$$

$$Y2 = X2$$

$$Y3 = X3$$

$$Y4 = X4$$

$$Y5 = X5$$

$$Z1 = (FlipX = 1)\Big|_{WZ6}^{WZ1}$$

$$Z2 = (FlipX = 1)\Big|_{WZ5}^{WZ2}$$

$$Z3 = (FlipX = 1)\Big|_{WZ4}^{WZ3}$$

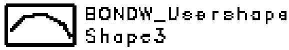
$$Z4 = (FlipX = 1)\Big|_{WZ3}^{WZ4}$$

$$Z5 = (FlipX = 1)\Big|_{WZ2}^{WZ5}$$

$$Z6 = (FlipX = 1)\Big|_{WZ1}^{WZ6}$$

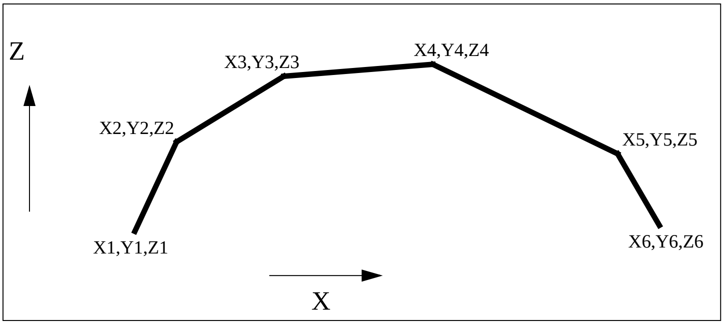
BONDW_Usershape (Philips/TU Delft Bondwire Model with User-Defined Shape)

Symbol



Parameters

X1..Z6 = Equations or values describing the individual segment coordinates



Notes

1. This model generates a bondwire according to user input; virtually any shape is possible.
2. For more details on the use of bondwire components, refer to the Notes and References in the section “BONDW1 (Philips/TU Delft Bondwires Model (1 Wire)” on page 4-15.

BONDW1 (Philips/TU Delft Bondwires Model (1 Wire)

Symbol

Parameters

Radw = Radius of the bondwires

Cond = Conductivity of the bondwires in [S/m]

View = (ADS Layout option) determine top or side view; default: sid

Layer = (ADS Layout option) layer to which the bondwire is drawn; default = cond

SepX = Separation, incrementally added to each Xoffset

SepY = Separation, incrementally added to each Yoffset

Zoffset = Offset added to all Zoffset parameters

W1_Shape = Shape reference (quoted string) for wire 1

W1_Xoffset = X offset for wire 1

W1_Yoffset = Y offset for wire 1

W1_Zoffset = Z offset for wire 1

W1_Angle = Rotation angle of wire 1 with respect to odd-numbered connections

The block W#_Shape..W#_Angle is repeated for each individual wire.

Notes

1. The model is based on Koen Mouthaans model WIRECURVEDARRAY, which includes skin effects as well. The model calculates the effective inductance matrix of a set of mutually coupled bondwires as a function of the geometrical shape in space of the wires. The wire shapes must be linearized into 5 segments. To define the shape you should refer to a shape wire (like a BONDW_Shape or a BONDW_Usershape instance).

2. **Introduction to Bondwire Components**

   The bondwire model is a physics-based model, calculating the self inductances and mutual inductances (the inductance matrix) of coupled bondwires. For the calculatation of these inductances, Neumann's inductance equation is used in combination with the concept of partial inductances [1], [2]. The method of images is used to account for a perfectly conducting groundplane [6]. The DC- and AC-resistance of each wire are included in the model using a zero order approximation.

3. **Bondwire Features and Restrictions**

- Calculation of the self- and mutual inductance of coupled bondwires using Neumann's inductance equation.
- Each bondwire is represented by five straight segments.
- Cartesian (*x,y,z)* coordinates for begin- and endpoints of the segments are entered.
- Segments may not touch or intersect.
- A perfectly conducting groundplane is assumed at z=0.
- Capacitive coupling between bondwires is not accounted for.
- Capacitive coupling to ground is not accounted for.
- Loss, due to radiation is not considered.
- A change in the current distribution due to the proximity of other wires (*proximity effect*) is not included.
- DC losses, due to the finite conductivity of the wires is included.
- AC losses, due to the skin effect, are accounted for in a zero-th order approximation.

4. **Input Parameters of the Model**

In modelling the bondwires, each bondwire is represented by five straight segments. This is illustrated in Figure 4-1, where the SEM photo of a bondwire is shown: on the left two coupled bondwires are shown; on the right, five segments representing the bondwire are shown.

The bondwire model requires the following input parameters:

- radius of the wires (meters)
- conductivity of the wires (Siemens/meter)
- view (top or side)
- layer (cond, cond2, resi, diel, diel2. bond, symbol, text, leads, packages)

• begin point, intermediate points and endpoint of the segments in Cartesian coordinates (meters).

A perfectly conducting groundplane at z=0 is assumed. The presence of this groundplane normally reduces the inductance compared to the case of wires without such a groundplane.

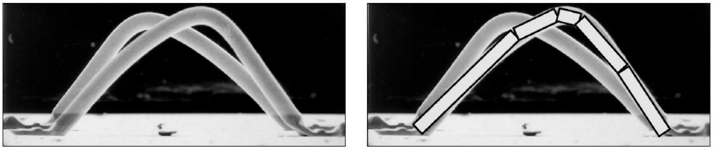


Figure 4-1. Piecewise Approximation of Bondwires
on the right, wire is approximated by straight segments

5. Example Instance

The instance for three wires is shown in Figure 4-2. The symbol BONDW3 defines the number of bondwires and their relative positions.

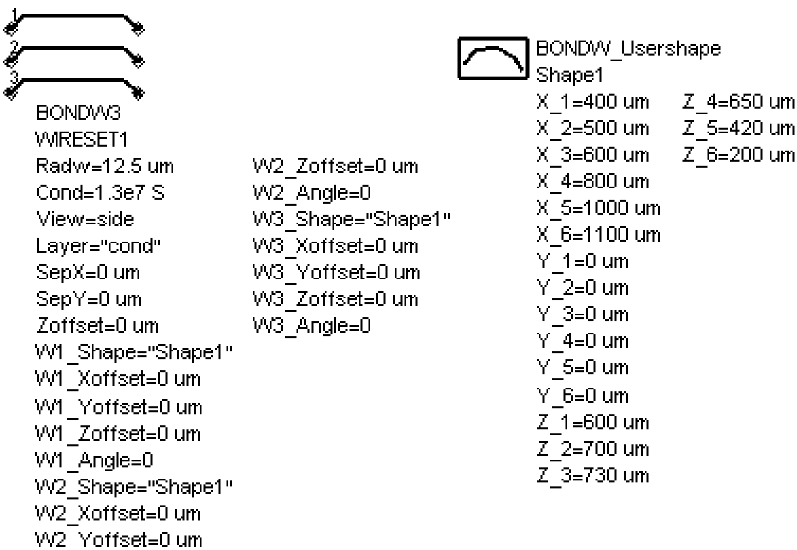


Figure 4-2. Instance of Bondwire Model for Three Wires (BONDW3)

In this example, the input parameters are as follows.

- RW, radius of the wires (meters). If the diameter of a wire is 25 um, the value of RW should be set to 12.5 um.
- COND, conductivity of the wire (Siemens/meter). If the wires have a conductivity of 1.3 10E+7 S/m the value of COND must be set to 1.3E7.
- VIEW set to default side
- LAYER set to default cond
- SepX = 0 is a constant separation in the x direction that is added incrementally to each wire.
- SepY = 200 um is a constant separation in the y direction, which is added incrementally to each wire. In the common case of parallel wires, this is the distance between wires.
- Zoffset = 0 is an offset added to each bondwire coordinates in the z-direction.
- Wi_Shape = “Shape1” defines the shape instance. It can be BONDW_Shape or BONDW_Usershape (as shown in Figure 4-2).
- Wi_Xoffset represents an offset added to each x coordinate of wire i (meters).
- Wi_Yoffset represents an offset added to each x coordinate of wire i (meters).
- Wi_Zoffset represents an offset added to each x coordinate of wire i (meters).
- Wi_Angle represents the rotation from the x direction of the bondwire plane (degrees).

A perfectly conducting groundplane is assumed at the plane z=0.

By choosing the BONDW_Usershape (Shape1 symbol), each wire is divided into 5 segments and the Cartesian coordinates of the begin and endpoints must be entered.

6. **What the Model Calculates**

The model calculates the self and mutual inductances of wires. Capacitive coupling between wires or capacitive coupling to ground is not included, nor is radiation loss included. DC losses, due to the finite conductivity of the wires, is included. AC losses are included using zero-th order approximations for skin effect losses. The effect of proximity effects, when wires are located closely together, on the inductance and resistance is not included in the model. The model assumes a perfectly conducting ground plane at z=0. The presence of this groundplane normally reduces the inductance as compared to the case of wires without such a plane. Possible electromagnetic couplings between wires and other circuit elements are not accounted for. In conclusion, the model calculates the self- and mutual inductance of wires. DC losses are included and AC losses are approximately incorporated.

7. **Restrictions on Input**

The three figures that follow demonstrate forbidden situations.

- Wire segments must be fully located above the groundplane at z=0, as illustrated in Figure 4-3. To guarantee that the wire is fully located above the ground plane, add the wire radius in the BONDW_Shape component.

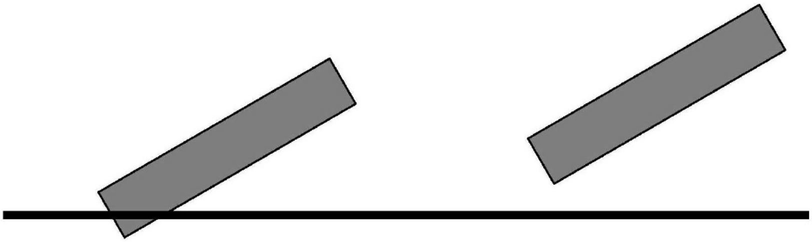


Figure 4-3. Incorrect Application (on the left)
Correct Application (on the right)

- As shown in Figure 4-4, the angle between segments always must be greater than 90 degrees.

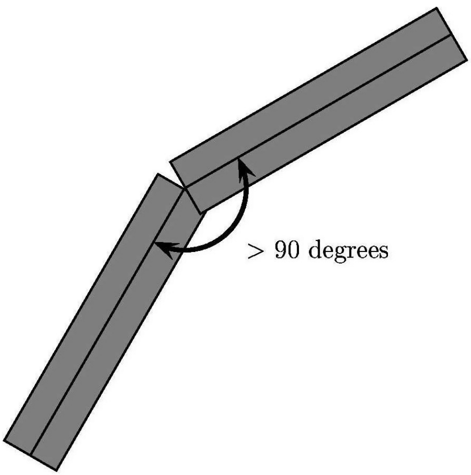


Figure 4-4. 90-degree Angle Not Sufficient

• As shown in Figure 4-5, non-adjacent segments may not touch nor intersect.

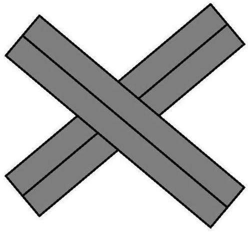


Figure 4-5. Non-adjacent Segments Touching

8. **Example With a Single Bondwire**

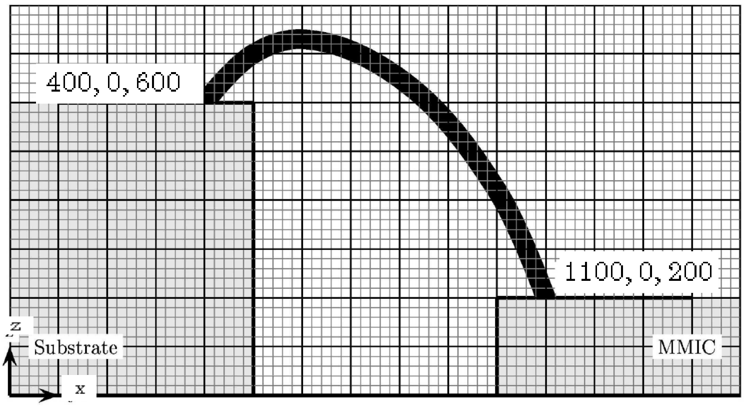


Figure 4-6. Example of a Bondwire Interconnecting a Substrate and a MMIC

For convenience, a grid with a major grid spacing of 100 um is also plotted. Using this grid, starting point, four intermediate points and end point are found as: (400,0,600), (500,0,700), (600,0,730), (800,0,650), (1000,0,420) and (1100,0,200) respectively (all in um). The radius of the wire is 20 um.

The representation of this wire in ADS is shown in Figure 4-7. One wire in ADS uses the points (0,400,600), (0,500,700), (0,600,730), (0,800,650), (0,1000,420) and (0,1100,200) (in um) As a result of the simulation, the inductance is calculated as 0.730 nH.

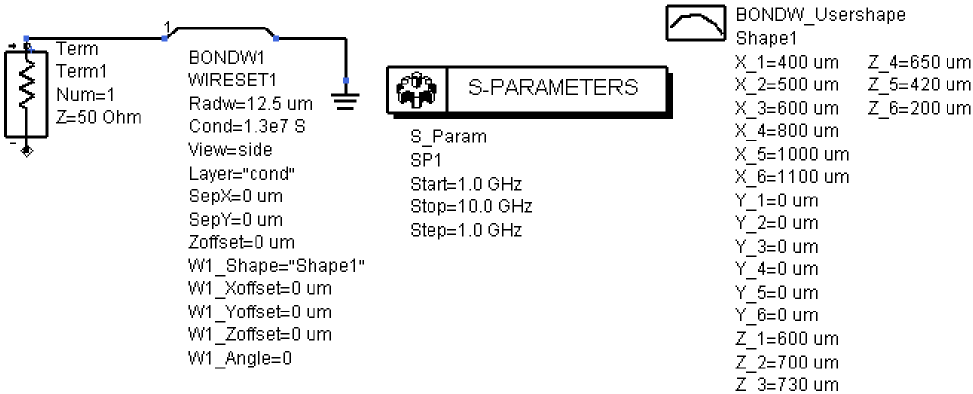


Figure 4-7. Example of Single Bondwire

9. **Example With a Double Bondwire**

As a second example, four bondwires are placed in parallel separated by 200 um. Each bondwire has the shape used in the previous example (Figure 4-7). The representation of the four parallel wires in ADS is shown in Figure 4-8. The inductance of the four parallel wires is calculated to be 278 pH. For simplicity, in this example the four wires were connected in parallel. With the model, it is very easy to calculate mutual inductances in much more complicated situations.

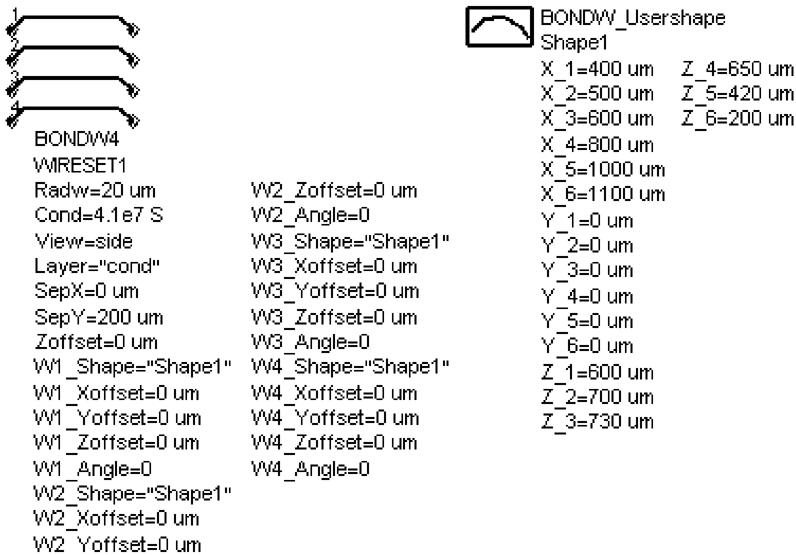


Figure 4-8. Example of Four Wires in ADS

10. **Neumann's Inductance Equation**

The bondwire model calculates the inductance matrix of coupled bondwires using Neumann's inductance equation. The principle of this equation for closed loops is illustrated in Figure 4-9. The mutual inductance $L_{i,j}$ between a closed loop C_i and a closed loop C_j is defined as the ratio between the flux through C_j, due to a current in C_i, and the current in C_i. The figure shows the definition of the mutual inductance between two current carrying loops as the ratio of the magnetic flux in contour C_j and the current in loop i.

In practice, however, bondwires are only part of a loop. To account for this effect, the concept of partial inductances is used [2]. This concept is illustrated in Figure 4-9. This figure illustrates that the model calculates the partial inductance between the bondwires, ignoring possible couplings between the wires and other circuit elements.

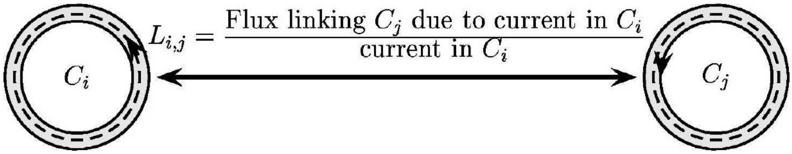


Figure 4-9. Definition of Mutual Inductance

Figure 4-10 shows Current carrying loops formed with network elements. On the left, closed loops are shown using elements such as a capacitor, a resistor and a voltage source. Each loop also has a bondwire. If only the mutual inductance between the wires is of interest, the concept of partial inductance is used [2] where for reasons of simplicity the mutual coupling between the wires and the remaining network elements is assumed negligible. In this case Neumann's inductance equation is not applied to the closed contours, but to the wires only.

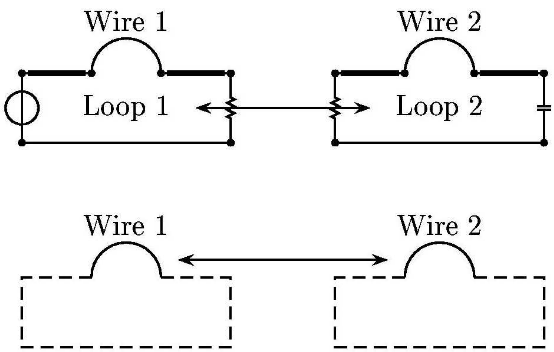


Figure 4-10. Loops Formed with Network Elements

Figure 4-11 shows modelling of bondwires in ADS. Inductive coupling is modelled by the inductance matrix L and resistive losses are modelled by a resistance matrix R.

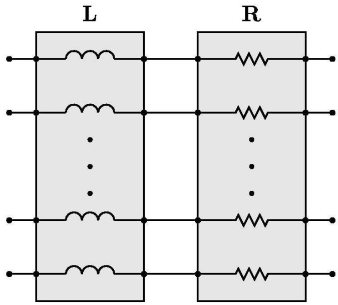


Figure 4-11. Modelling of Bondwires in ADS

11. **Generating Layout**

    The layout can be generated through the ADS Schematic window. After you create and simulate the design, select *Layout* > *Generate/Update Layout*.

12. **Background**

    The bondwire model calculates the self inductances and mutual inductances of coupled bondwires and puts the values into an inductance matrix L. In addition the model calculates the DC resistances and the AC resistances assuming uncoupled bondwires. Changes in the current distribution within a wire due to a nearby located current carrying wire (proximity effect) are not accounted for. The DC and AC resistances are put into a resistance matrix R. The bondwire model is formed by placing the inductance matrix and the resistance matrix in series (Figure 4-11).

    The basic principles of the bondwire model have been tested and verified in HFSS [5], by measurements on test structures [3], and in practical situations [4].

13. **Further Information**

    In the Ph.D. thesis of K. Mouthaan [5], the model and a comparison of the model with rigorous simulations and measurements, are described in detail. To obtain a copy of the dissertation, visit the internet site: *www.DevilsFoot.com*.

References

[1] F. W. Grover, *Inductance Calculations Working Formulas and Tables*. Dover Publications, Inc., New York, 1946.

[2] A.E. Ruehli, “Inductance calculations in a complex integrated circuit environment,” IBM J. *Res. Develop*, pp. 470-481, September 1972.

[3] K. Mouthaan and R. Tinti and M. de Kok and H.C. de Graaff and J.L. Tauritz and J. Slotboom, “Microwave modelling and measurement of the self- and mutual inductance of coupled bondwires,” Proceedings of the 1997 Bipolar/BiCMOS Circuits and Technology Meeting, pp.166-169, September 1997.

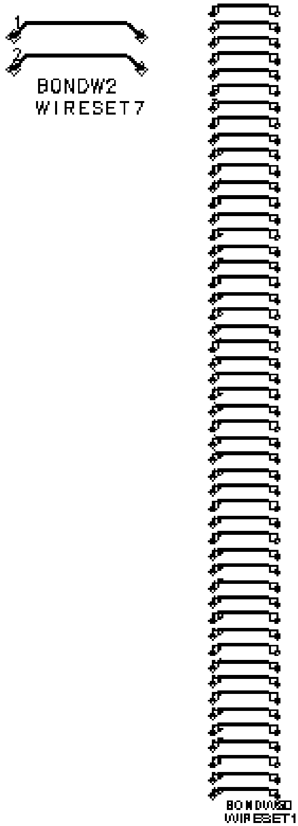
[4] A.O. Harm and K. Mouthaan and E. Aziz and M. Versleijen, “Modelling and Simulation of Hybrid RF Circuits Using a Versatile Compact Bondwire Model,” Proceedings of the European Microwave Conference, pp. 529-534, Oct. 1998. Amsterdam.

[5] K. Mouthaan, *Modelling of RF High Power Bipolar Transistors*. Ph.D. dissertation, ISBN 90-407-2145-9, Delft University of Technology, 2001. To obtain a copy, visit the internet site: http://www.DevilsFoot.com.

[6] L.V. Bewly, Two dimensional fields in Electrical Engineering. Dover publication, Inc., New York, 1963.

BONDW2 to BONDW50 (Philips/TU Delft Bondwires Model (2 to 50 Wires)

Symbol



Parameters

Radw = Radius of the bondwires

Cond = Conductivity of the bondwires in [S/m]

View = (ADS Layout option) determine top or side view; default: side

Layer = (ADS Layout option) layer to which the bondwire is drawn; default = cond

SepX = Separation, incrementally added to each Xoffset

SepY = Separation, incrementally added to each Yoffset

Zoffset = Offset added to all Zoffset parameters

W2_Shape...W20_Shape = Shape reference (quoted string) for wire 1

W2_Xoffset...W20_Xoffset = X offset for wire 1

W2_Yoffset ... W20_Yoffset = Y offset for wire 1

W2_Zoffset...W20_Zoffset= Z offset for wire 1

W2_Angle.. W20_Angle = Angle for wire 1

The block W#_Shape..W#_Angle is repeated for each individual wire

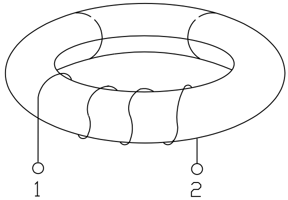
Notes

1. **Important:** Some examples of symbols are provided in ADS in the Passive-RF Circuit component library (N=1,2,3,4,5,6,7,8,9,10, 20). Since the internal model works with any number of bondwires, other symbols can be created. The symbols can be created using the ADS Command Line by selecting *Options* > *Command* from the Main window. Type create_bondwires_symbol(n) where n is the number of bondwires. A file called *bondwires.ael* will appear in your project directory.
2. BONDW11 through BONDW19 and BONDW21 through BONDW50 are not available from the component palette or library browser. To access them from a Schematic window, type the exact component name (such as BONDW12) in the *Component* field above the design area; press *Enter* on your keyboard; move the cursor to the design area and place the component.
3. Limitations
   - Wires must not cross.
   - Wires must be above the ground plane by at least the wire diameter.
   - Wires must not be perpendicular to the groundplane.
4. For more details on the use of bondwire components, refer to the Notes and References in the section “BONDW1 (Philips/TU Delft Bondwires Model (1 Wire)” on page 4-15.

CIND2 (Lossy Toroidal Inductor)

Symbol

Illustration



Parameters

N = number of turns

AL = inductance index, in henries

R = total winding resistance, in ohms

Q = core quality factor

Freq = frequency at which Q is specified, in hertz

Range of Usage

$N \geq 0$
$AL > 0$
$R, Q, F \geq 0$

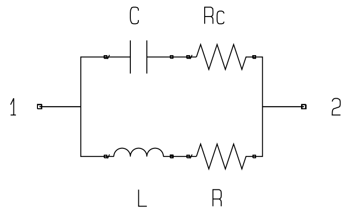
Notes/Equations

1. A value of zero for either Q or F implies that the core is lossless.
2. The equivalent circuit component values are given by the following equations:

L	=	$N2 \times AL$	
C	=	$1 / [(2 \times \pi \times F)2 \times L]$	(for F > 0)
	=	0	(for F = 0)
Rc	=	$1 / [(2 \times \pi \times F) \times C \times Q]$	(for F > 0 and Q > 0)
	=	0	(for F = 0, or Q = 0)

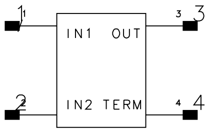
3. This component has no default artwork associated with it.

Equivalent Circuit



HYBCOMB1 (Hybrid Combiner (Ferrite Core))

Symbol



Parameters

ZB = characteristic impedance of balun line, in ohms

LenB = physical length of balun line, in specified unit

KB = effective dielectric constant of balun line

AB = attenuation of balun line, in dB per unit meter

FB = frequency for scaling attenuation of balun line, in hertz

NB = number of turns of balun line

ALB = inductance index for balun line, in henries

ZX = characteristic impedance of transformer line, in ohms

LenX = physical length of transformer line, in specified units

KX = effective dielectric constant of transformer line

AX = attenuation of transformer line, in dB per unit lengt

FX = frequency for scaling attenuation of transformer line, in hertz

NX = number of turns of transformer line

ALX = inductance index for transformer line, in henries

TanD = dielectric loss tangent

Mur = relative permeability

TanM = magnetic loss tangent

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

ZB > 0, LenB > 0, AB ≥ 0, ALB > 0, KB, KX ≥ 1

$ZX > 0$, $LenX > 0$, $AX \geq 0$, $ALX > 0$, $NB, NX \geq 1$

Notes/Equations

1. When used as a combiner, pins 1 and 2 are the input pins and pin 3 is the output pin. The termination at pin 4 is at the discretion of the user.
2. This component is a combination of a balun and a transformer. Both the balun line and the transformer line are coiled around ferrite cores.
3. Choking inductances L_{cx} and L_{cb} account for the low-frequency roll-off and are given by:

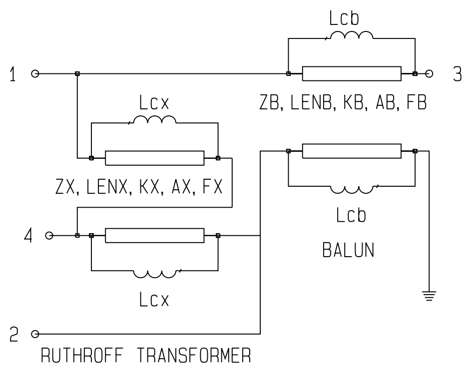
   $L_{cx} = NX^2 \times ALX$

   $L_{cb} = NB^2 \times ALB$
4. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
5. This component has no default artwork associated with it.

References

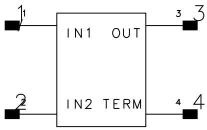
[1] O. Pitzalis Jr. and T. P. M. Couse. "Broadband transformer design for RF transistor power amplifiers," *Proceedings of 1968 Electronic Components Conference*, Washington, D.C., May 1968, pp. 207-216.

Equivalent Circuit



HYBCOMB2 (Hybrid Combiner (Ferrite Sleeve))

Symbol



Parameters

ZB = characteristic impedance of balun line, in ohms

LenB = physical length of balun line, in specified unit

KB = effective dielectric constant of balun line

AB = attenuation of balun line, in dB per unit meter

FB = frequency for scaling attenuation of balun line, in hertz

MUB = relative permeability of ferrite sleeve for balun line

LB = inductance of balun line without the sleeve per unit length, in henries

ZX = characteristic impedance of transformer line, in ohms

LenX = physical length of transformer line, in specified units

KX = effective dielectric constant of transformer line

AX = attenuation of transformer line, in dB per unit lengt

FX = frequency for scaling attenuation of transformer line, in hertz

MUX = relative permeability of ferrite sleeve for transformer line

LX = inductance (per unit length) of transformer line without sleeve, in henries

TanD = dielectric loss tangent

Mur = relative permeability

TanM = magnetic loss tangent

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

$ZB > 0$, $LenB > 0$, $AB \geq 0$, $MUB > 0$, $LB > 0$ $KB, KX \geq 1$

$ZX > 0$, $LenX > 0$, $AX \geq 0$, $MUX > 0$, $LX > 0$

Notes/Equations

1. When used as a combiner, pins 1 and 2 are the input pins and pin 3 is the output pin. The termination at pin 4 is at the discretion of the user.
2. This component is a combination of a balun and a transformer. Both the balun line and the transformer line are surrounded by ferrite sleeves.
3. The choking inductances, L_{cx} and L_{cb}, account for the low-frequency roll-off and are given by

   $$L_{cx} = MUX \times LX \times LenX$$

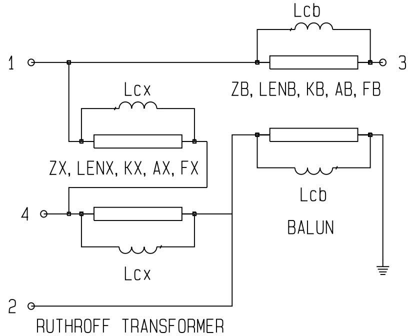
   $$L_{cb} = MUB \times LB \times LenB$$

4. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
5. This component has no default artwork associated with it.

References

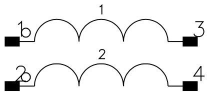
[1] O. Pitzalis Jr. and T. P. M. Couse. "Broadband transformer design for RF transistor power amplifiers," *Proceedings of 1968 Electronic Components Conference*, Washington, D.C., May 1968, pp. 207-216.

Equivalent Circuit



MUC2 (Two Coupled Resistive Coils)

Symbol



Parameters

L1 = self-inductance of coil #1

R1 = resistance of coil #1

L2 = self-inductance of coil #2

R2 = resistance of coil #2

K12 = coupling coefficient between coils 1 and 2

Range of Usage

$L_i > 0$, i = 1, 2

$R_i \geq 0$, i = 1, 2

$-1 < K12 < 1$

Notes/Equations

1. Pin numbers 1_i, 2_i, ... , i correspond to the coupled pins of coil 1, coil 2, ... , coil i, respectively. For example, for MUC2, pin numbers of coil 1 are 1 and 3; pin numbers of coil 2 are 2 and 4.
2. The model is as follows. If V_{ci} denotes voltage across coil *i*, *i*=1, ... , *N* then

$$V_{ci} = (R_i + j\omega L_i) \times I_i + \sum_{\substack{j=1 \\ j \neq i}}^{N} j\omega \times M_{ij} \times I_j$$

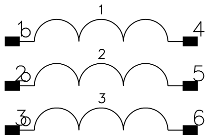
where

$$M_{ij} = K_{ij} \times \sqrt{L_i \times L_j}$$

3. This component has no default artwork associated with it.

MUC3 (Three Coupled Resistive Coils)

Symbol



Parameters

L1 = self-inductance of coil #1

R1 = resistance of coil #1

L2 = self-inductance of coil #2

R2 = resistance of coil #2

L3 = self-inductance of coil #3

R3 = resistance of coil #3

K12 = coupling coefficient between coils 1 and 2

K13 = coupling coefficient between coils 1 and 3

K23 = coupling coefficient between coils 2 and 3

Range of Usage

$L_i > 0$

$R_i \geq 0$

$-1 < K_{ij} < 1$

where

$i \leq i, j \leq 3, i \neq j$

Notes/Equations

1. Pin numbers 1, 2, ... , i correspond to the coupled pins of coil 1, coil 2, ... , coil i, respectively. For example, for MUC3, pin numbers of coil 1 are 1 and 4; pin numbers of coil 2 are 2 and 5, and so on.
2. The model is as follows. If V_{ci} denotes voltage across coil *i*, *i*=1, ... , *N* then

   N

$V_{ci} = (R_i + j\omega L_i) \times I_i + \Sigma\, j\omega \times M_{ij} \times I_j$

$j = 1$

$j \neq i$

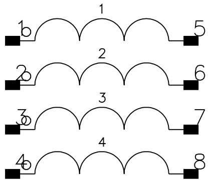
where

$$M_{ij} = K_{ij} \times \sqrt{L_i \times L_j}$$

3. This component has no default artwork associated with it.

MUC4 (Four Coupled Resistive Coils)

Symbol



Parameters

L1 = self-inductance of coil #1

R1 = resistance of coil #1

L2 = self-inductance of coil #2

R2 = resistance of coil #2

L3 = self-inductance of coil #3

R3 = resistance of coil #3

L4 = self-inductance of coil #4

R4 = resistance of coil #4

K12 = coupling coefficient between coils 1 and 2

K13 = coupling coefficient between coils 1 and 3

K14 = coupling coefficient between coils 1 and 4

K23 = coupling coefficient between coils 2 and 3

K24 = coupling coefficient between coils 2 and 4

K34 = coupling coefficient between coils 3 and 4

Range of Usage

$L_i >$

$R_i \geq$

$-1 < K_{ij} < 1$

where

$i \leq i, j \leq 4, i \neq j$

Notes/Equations

1. Pin numbers 1, 2, ... , ni correspond to the coupled pins of coil 1, coil 2, ... , coil i, respectively. For example, for MUC4, pin numbers of coil 1 are 1 and 5; pin numbers of coil 2 are 2 and 6, and so on.
2. The model is as follows. If V_{ci} denotes voltage across coil *i*, *i*=1, ... , *N* then

   $$V_{ci} = (R_i + j\omega L_i) \times I_i + \sum_{\substack{j=1 \\ j \neq i}}^{N} j\omega \times M_{ij} \times I_j$$

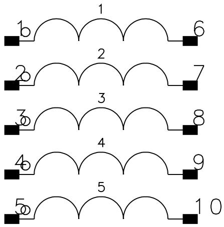
   where

   $$M_{ij} = K_{ij} \times \sqrt{L_i \times L_j}$$

3. This component has no default artwork associated with it.

MUC5 (Five Coupled Resistive Coils)

Symbol



Parameters

L1 = self-inductance of coil #1

R1 = resistance of coil #1

L2 = self-inductance of coil #2

R2 = resistance of coil #2

L3 = self-inductance of coil #3

R3 = resistance of coil #3

L4 = self-inductance of coil #4

R4 = resistance of coil #4

L5 = self-inductance of coil #5

R5 = resistance of coil #5

K12 = coupling coefficient between coils 1 and 2

K13 = coupling coefficient between coils 1 and 3

K14 = coupling coefficient between coils 1 and 4

K15 = coupling coefficient between coils 1 and 5

K23 = coupling coefficient between coils 2 and 3

K24 = coupling coefficient between coils 2 and 4

K25 = coupling coefficient between coils 2 and 5

K34 = coupling coefficient between coils 3 and 4

K35 = coupling coefficient between coils 3 and 5

K45 = coupling coefficient between coils 4 and 5

Range of Usage

$L_i > 0$

$R_i \geq 0$

$-1 < K_{ij} < 1$

where

$i \leq i, j \leq 5, i \neq j$

Notes/Equations

1. Pin numbers 1, 2, ... , i correspond to the coupled pins of coil 1, coil 2, ... , coil i, respectively. For example, for MUC5, pin numbers of coil 1 are 1 and 6, pin numbers of coil 2 are 2 and 7, and so on.
2. The model is as follows. If V_{ci} denotes voltage across coil *i*, *i*=1, ... , *N* then

   $$V_{ci} = (R_i + j\omega L_i) \times I_i + \sum_{\substack{j=1 \\ j \neq i}}^{N} j\omega \times M_{ij} \times I_j$$

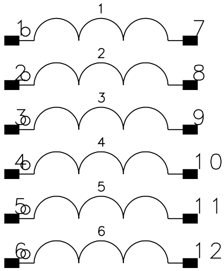
   where

   $$M_{ij} = K_{ij} \times \sqrt{L_i \times L_j}$$

3. This component has no default artwork associated with it.

MUC6 (Six Coupled Resistive Coils)

Symbol



Parameters

L1 = self-inductance of coil #1

R1 = resistance of coil #1

L2 = self-inductance of coil #2

R2 = resistance of coil #2

L3 = self-inductance of coil #3

R3 = resistance of coil #3

L4 = self-inductance of coil #4

R4 = resistance of coil #4

L5 = self-inductance of coil #5

R5 = resistance of coil #5

L6 = self-inductance of coil #6

R6 = resistance of coil #6

K12 = coupling coefficient between coils 1 and 2

K13 = coupling coefficient between coils 1 and 3

K14 = coupling coefficient between coils 1 and 4

K15 = coupling coefficient between coils 1 and 5

K16 = coupling coefficient between coils 1 and 6

K23 = coupling coefficient between coils 2 and 3

K24 = coupling coefficient between coils 2 and 4

K25 = coupling coefficient between coils 2 and 5

K26 = coupling coefficient between coils 2 and 6

K34 = coupling coefficient between coils 3 and 4

K35 = coupling coefficient between coils 3 and 5

K36 = coupling coefficient between coils 3 and 6

K45 = coupling coefficient between coils 4 and 5

K46 = coupling coefficient between coils 4 and 6

K56 = coupling coefficient between coils 5 and 6

Range of Usage

$L_i > 0$
$R_i \geq 0$
$-1 < K_{ij} < 1$
where
$i \leq i, j \leq 6, i \neq j$

Notes/Equations

1. Pin numbers 1, 2, ... , i correspond to the coupled pins of coil 1, coil 2, ... , coil i, respectively. For example, for MUC6, pin numbers of coil 1 are 1 and 7; pin numbers of coil 2 are 2 and 8, and so on.

2. The model is as follows. If V_{ci} denotes voltage across coil *i*, *i*=1, ... , *N* then

$$V_{ci} = (R_i + j\omega L_i) \times I_i + \sum_{\substack{j=1 \\ j \neq i}}^{N} j\omega \times M_{ij} \times I_j$$

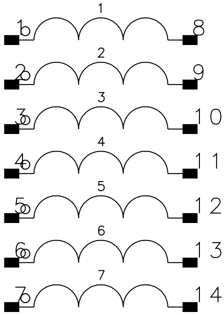
where

$$M_{ij} = K_{ij} \times \sqrt{L_i \times L_j}$$

3. This component has no default artwork associated with it.

MUC7 (Seven Coupled Resistive Coils)

Symbol



Parameters

L1 = self-inductance of coil #1

R1 = resistance of coil #1

L2 = self-inductance of coil #2

R2 = resistance of coil #2

L3 = self-inductance of coil #3

R3 = resistance of coil #3

L4 = self-inductance of coil #4

R4 = resistance of coil #4

L5 = self-inductance of coil #5

R5 = resistance of coil #5

L6 = self-inductance of coil #6

R6 = resistance of coil #6

L7 = self-inductance of coil #7

R7 = resistance of coil #7

K12 = coupling coefficient between coils 1 and 2

K13 = coupling coefficient between coils 1 and 3

K14 = coupling coefficient between coils 1 and 4

K15 = coupling coefficient between coils 1 and 5

K16 = coupling coefficient between coils 1 and 6

K17 = coupling coefficient between coils 1 and 7

K23 = coupling coefficient between coils 2 and 3

K24 = coupling coefficient between coils 2 and 4

K25 = coupling coefficient between coils 2 and 5

K26 = coupling coefficient between coils 2 and 6

K27 = coupling coefficient between coils 2 and 7

K34 = coupling coefficient between coils 3 and 4

K35 = coupling coefficient between coils 3 and 5

K36 = coupling coefficient between coils 3 and 6

K37 = coupling coefficient between coils 3 and 7

K45 = coupling coefficient between coils 4 and 5

K46 = coupling coefficient between coils 4 and 6

K47 = coupling coefficient between coils 4 and 7

K56 = coupling coefficient between coils 5 and 6

K57 = coupling coefficient between coils 5 and 7

K67 = coupling coefficient between coils 6 and 7

Range of Usage

$L_i > 0$

$R_i \geq 0$

$-1 < K_{ij} < 1$

where

$i \leq i, j \leq 7, i \neq j$

Notes/Equations

1. Pin numbers 1, 2, ... , i correspond to the coupled pins of coil 1, coil 2, ... , coil i, respectively. For example, for MUC7, pin numbers of coil 1 are 1 and 8; pin numbers of coil 2 are 2 and 9, and so on.
2. The model is as follows. If V_{ci} denotes voltage across coil i, i=1, ... , N then

   $$V_{ci} = (R_i + j\omega L_i) \times I_i + \sum_{\substack{j=1 \\ j \neq i}}^{N} j\omega \times M_{ij} \times I_j$$

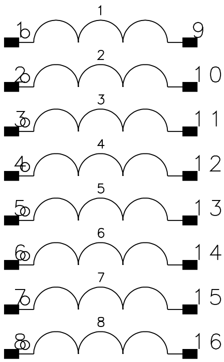
   where

   $$M_{ij} = K_{ij} \times \sqrt{L_i \times L_j}$$

3. This component has no default artwork associated with it.

MUC8 (Eight Coupled Resistive Coils)

Symbol



Parameters

L1 = self-inductance of coil #1

R1 = resistance of coil #1

L2 = self-inductance of coil #2

R2 = resistance of coil #2

L3 = self-inductance of coil #3

R3 = resistance of coil #3

L4 = self-inductance of coil #4

R4 = resistance of coil #4

L5 = self-inductance of coil #5

R5 = resistance of coil #5

L6 = self-inductance of coil #6

R6 = resistance of coil #6

L7 = self-inductance of coil #7

R7 = resistance of coil #7

L8 = self-inductance of coil #8

R8 = resistance of coil #8

K12 = coupling coefficient between coils 1 and 2

K13 = coupling coefficient between coils 1 and 3

K14 = coupling coefficient between coils 1 and 4

K15 = coupling coefficient between coils 1 and 5

K16 = coupling coefficient between coils 1 and 6

K17 = coupling coefficient between coils 1 and 7

K18 = coupling coefficient between coils 1 and 8

K23 = coupling coefficient between coils 2 and 3

K24 = coupling coefficient between coils 2 and 4

K25 = coupling coefficient between coils 2 and 5

K26 = coupling coefficient between coils 2 and 6

K27 = coupling coefficient between coils 2 and 7

K28 = coupling coefficient between coils 2 and 8

K34 = coupling coefficient between coils 3 and 4

K35 = coupling coefficient between coils 3 and 5

K36 = coupling coefficient between coils 3 and 6

K37 = coupling coefficient between coils 3 and 7

K38 = coupling coefficient between coils 3 and 8

K45 = coupling coefficient between coils 4 and 5

K46 = coupling coefficient between coils 4 and 6

K47 = coupling coefficient between coils 4 and 7

K48 = coupling coefficient between coils 4 and 8

K56 = coupling coefficient between coils 5 and 6

K57 = coupling coefficient between coils 5 and 7

K58 = coupling coefficient between coils 5 and 8

K67 = coupling coefficient between coils 6 and 7

K68 = coupling coefficient between coils 6 and 8

K78 = coupling coefficient between coils 7 and 8

Temp = physical temperature

Range of Usage

$L_i > 0$
$R_i \geq 0$
$-1 < K_{ij} < 1$
where
$i \leq i, j \leq 8, i \neq j$

Notes/Equations

1. Pin numbers 1, 2,. ... , ni correspond to the coupled pins of coil 1, coil 2, ... , coil i, respectively. For example, for MUC8, pin numbers of coil 1 are 1 and 9; pin numbers of coil 2 are 2 and 10, and so on.
2. The model is as follows. If V_{ci} denotes voltage across coil *i*, *i*=1, ... , *N* then

   $$V_{ci} = (R_i + j\omega L_i) \times I_i + \sum_{j=1, j \neq i}^{N} j\omega \times M_{ij} \times I_j$$

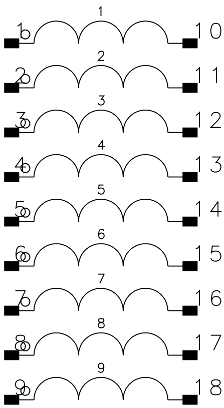
   where

   $$M_{ij} = K_{ij} \times \sqrt{L_i \times L_j}$$

3. This component has no default artwork associated with it.

MUC9 (Nine Coupled Resistive Coils)

Symbol



Parameters

L1 = self-inductance of coil #1

R1 = resistance of coil #1

L2 = self-inductance of coil #2

R2 = resistance of coil #2

L3 = self-inductance of coil #3

R3 = resistance of coil #3

L4 = self-inductance of coil #4

R4 = resistance of coil #4

L5 = self-inductance of coil #5

R5 = resistance of coil #5

L6 = self-inductance of coil #6

R6 = resistance of coil #6

L7 = self-inductance of coil #7

R7 = resistance of coil #7

L8 = self-inductance of coil #8

R8 = resistance of coil #8

L9 = self-inductance of coil #9

R9 = resistance of coil #9

K12 = coupling coefficient between coils 1 and 2

K13 = coupling coefficient between coils 1 and 3

K14 = coupling coefficient between coils 1 and 4

K15 = coupling coefficient between coils 1 and 5

K16 = coupling coefficient between coils 1 and 6

K17 = coupling coefficient between coils 1 and 7

K18 = coupling coefficient between coils 1 and 8

K19 = coupling coefficient between coils 1 and 9

K23 = coupling coefficient between coils 2 and 3

K24 = coupling coefficient between coils 2 and 4

K25 = coupling coefficient between coils 2 and 5

K26 = coupling coefficient between coils 2 and 6

K27 = coupling coefficient between coils 2 and 7

K28 = coupling coefficient between coils 2 and 8

K29 = coupling coefficient between coils 2 and 9

K34 = coupling coefficient between coils 3 and 4

K35 = coupling coefficient between coils 3 and 5

K36 = coupling coefficient between coils 3 and 6

K37 = coupling coefficient between coils 3 and 7

K38 = coupling coefficient between coils 3and 8

K39 = coupling coefficient between coils 3and 9

K45 = coupling coefficient between coils 4 and 5

K46 = coupling coefficient between coils 4 and 6

K47 = coupling coefficient between coils 4 and 7

K48 = coupling coefficient between coils 4 and 8

K49 = coupling coefficient between coils 4 and 9

K56 = coupling coefficient between coils 5 and 6

K57 = coupling coefficient between coils 5 and 7

K58 = coupling coefficient between coils 5 and 8

K59 = coupling coefficient between coils 5 and 9

K67 = coupling coefficient between coils 6 and 7

K68 = coupling coefficient between coils 6 and 8

K69 = coupling coefficient between coils 6 and 9

K78 = coupling coefficient between coils 7 and 8

K79 = coupling coefficient between coils 7 and 9

K89 = coupling coefficient between coils 8 and 9

Temp = physical temperature

Range of Usage

$L_i > 0$
$R_i \geq 0$
$-1 < K_{ij} < 1$
where
$i \leq i, j \leq 9, i \neq j$

Notes/Equations

1. Pin numbers 1, 2, ... , i correspond to the coupled pins of coil 1, coil 2, ... , coil i, respectively. For example, for MUC9, pin numbers of coil 1 are 1 and 10; pin numbers of coil 2 are 2 and 11, and so on.
2. The model is as follows. If V_{ci} denotes voltage across coil *i*, *i*=1, ... , *N* then

$$V_{ci} = (R_i + j\omega L_i) \times I_i + \sum_{\substack{j=1 \\ j \neq i}}^{N} j\omega \times M_{ij} \times I_j$$

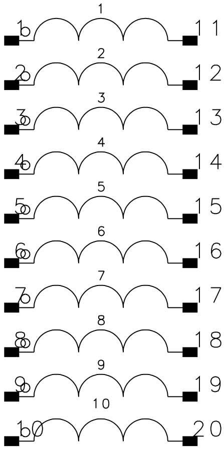
where

$$M_{ij} = K_{ij} \times \sqrt{L_i \times L_j}$$

3. This component has no default artwork associated with it.

MUC10 (Ten Coupled Resistive Coils)

Symbol



Parameters

L1 = self-inductance of coil #1

R1 = resistance of coil #1

L2 = self-inductance of coil #2

R2 = resistance of coil #2

L3 = self-inductance of coil #3

R3 = resistance of coil #3

L4 = self-inductance of coil #4

R4 = resistance of coil #4

L5 = self-inductance of coil #5

R5 = resistance of coil #5

L6 = self-inductance of coil #6

R6 = resistance of coil #6

L7 = self-inductance of coil #7

R7 = resistance of coil #7

L8 = self-inductance of coil #8

R8 = resistance of coil #8

L9 = self-inductance of coil #9

R9 = resistance of coil #9

L10 = self-inductance of coil #10

R10 = resistance of coil #10

K12 = coupling coefficient between coils 1 and 2

K13 = coupling coefficient between coils 1 and 3

K14 = coupling coefficient between coils 1 and 4

K15 = coupling coefficient between coils 1 and 5

K16 = coupling coefficient between coils 1 and 6

K17 = coupling coefficient between coils 1 and 7

K18 = coupling coefficient between coils 1 and 8

K19 = coupling coefficient between coils 1 and 9

K110 = coupling coefficient between coils 1 and 10

K23 = coupling coefficient between coils 2 and 3

K24 = coupling coefficient between coils 2 and 4

K25 = coupling coefficient between coils 2 and 5

K26 = coupling coefficient between coils 2 and 6

K27 = coupling coefficient between coils 2 and 7

K28 = coupling coefficient between coils 2 and 8

K29 = coupling coefficient between coils 2 and 9

K210 = coupling coefficient between coils 2 and 10

K34 = coupling coefficient between coils 3 and 4

K35 = coupling coefficient between coils 3 and 5

K36 = coupling coefficient between coils 3 and 6

K37 = coupling coefficient between coils 3 and 7

K38 = coupling coefficient between coils 3and 8

K39 = coupling coefficient between coils 3and 9

K310 = coupling coefficient between coils 3 and 10

K45 = coupling coefficient between coils 4 and 5

K46 = coupling coefficient between coils 4 and 6

K47 = coupling coefficient between coils 4 and 7

K48 = coupling coefficient between coils 4 and 8

K49 = coupling coefficient between coils 4 and 9

K410 = coupling coefficient between coils 4 and 10

K56 = coupling coefficient between coils 5 and 6

K57 = coupling coefficient between coils 5 and 7

K58 = coupling coefficient between coils 5 and 8

K59 = coupling coefficient between coils 5 and 9

K510 = coupling coefficient between coils 5 and 10

K67 = coupling coefficient between coils 6 and 7

K68 = coupling coefficient between coils 6 and 8

K69 = coupling coefficient between coils 6 and 9

K610 = coupling coefficient between coils 6 and 10

K78 = coupling coefficient between coils 7 and 8

K79 = coupling coefficient between coils 7 and 9

K710 = coupling coefficient between coils 7 and 10

K89 = coupling coefficient between coils 8 and 9

K810 = coupling coefficient between coils 8 and 10

K910 = coupling coefficient between coils 9 and 10

Temp = physical temperature

Range of Usage

$L_i > 0$
$R_i \geq 0$
$-1 < K_{ij} < 1$
where
  $i \leq i, j \leq 10, i \neq j$

Notes/Equations

1. Pin numbers 1, 2, ... , i correspond to the coupled pins of coil 1, coil 2, ... , coil i, respectively. For example, for MUC10, pin numbers of coil 1 are 1 and 11; pin numbers of coil 2 are 2 and 12, and so on.
2. The model is as follows. If V_{ci} denotes voltage across coil *i*, *i*=1, ... , *N* then

   $$V_{ci} = (R_i + j\omega L_i) \times I_i + \sum_{\substack{j=1 \\ j \neq i}}^{N} j\omega \times M_{ij} \times I_j$$

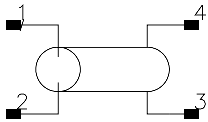
   where

   $$M_{ij} = K_{ij} \times \sqrt{L_i \times L_j}$$

3. This component has no default artwork associated with it.

SAGELIN (Sage Laboratories WIRELINE)

Symbol



Parameters

L = physical length of transmission line, in specified units

BW_Code = code for bandwidth selection: narrow, octave

Notes/Equations

1. The model is a standard hybrid coupler model in which the even- and odd-mode effective dielectric constants are equal (the medium is homogeneous).
2. The quarter-wavelength frequency is calculated as:

   F (MHz) = 1850 / L (inches)
3. Pin designations:

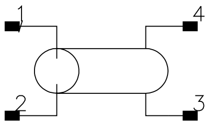
   1 = input
   2 = coupled
   3 = isolated
   4 = direct
4. This component has no default artwork associated with it.

References

[1] *Designers Guide to Wireline & Wirepac*, Sage Laboratories, Inc., 11 Huron Drive, Natick, MA 01760-1314.

SAGEPAC (Sage Laboratories WIREPAC)

Symbol



Parameters

L = physical length of transmission line, in specified units

BW_Code = code for bandwidth selection: narrow, octave

Notes/Equations

1. The model is a standard hybrid coupler model in which the even- and odd-mode effective dielectric constants are equal (the medium is homogeneous).
2. The quarter-wavelength frequency is calculated as:

   F (MHz) = 1970/L(inches)
3. Pin designations:

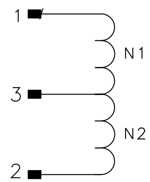
   1= input
   2 = coupled
   3 = isolated
   4 = direct
4. This component has no default artwork associated with it.

References

[1] *Designers Guide to Wireline & Wirepac*, Sage Laboratories, Inc., 11 Huron Drive, Natick, MA 01760-1314.

TAPIND1 (Tapped Aircore Inductor (Wire Diameter))

Symbol



Parameters

N1 = number of turns between pins 1 and 3

N2 = number of turns between pins 2 and 3

D = diameter of coil

L = length of coil

WD = wire diameter

Rho = metal resistivity (relative to copper)

Temp = physical temperature

Range of Usage

$N1 \geq 1$
$N2 \geq 1$
$D > 0$
$L \geq (N1 + N2) \times WD$
$WD > 0$

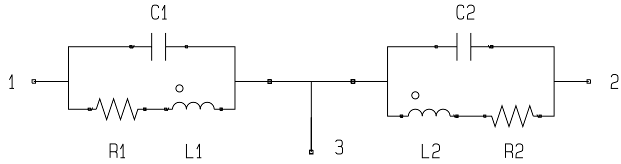
Notes/Equations

1. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
2. This component has no default artwork associated with it.

References

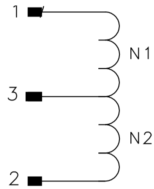
[1] H. Krauss, C. Bostain, and F. Raab. *Solid State Radio Engineering*.

Equivalent Circuit



TAPIND2 (Tapped Aircore Inductor (Wire Gauge))

Symbol



Parameters

N1 = number of turns between pins 1 and 3

N2 = number of turns between pins 2 and 3

D = diameter of coil, in specified units

L = length of coil, in specified units

AWG = wire gauge (any value in AWG table)

Rho = conductor resistivity (relative to copper)

Range of Usage

$N1 \geq 1$
$N2 \geq 1$
$D > 0$
$L \geq (N1 + N2) \times WD$, where WD is the wire diameter
$9 \geq AWG \leq 46$

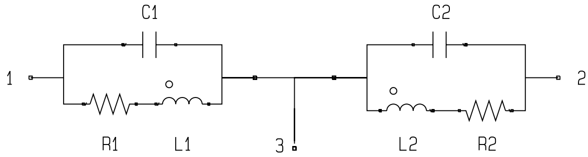
Notes/Equations

1. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
2. This component has no default artwork associated with it.

References

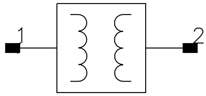
[1] H. Krauss, C. Bostain, and F. Raab. *Solid State Radio Engineering*.

Equivalent Circuit



X9TO1COR (9:1 Transformer with Ferrite Core)

Symbol



Parameters

Z = characteristic impedance of transmission line, in ohms

Len = physical length of transmission line, in specified units

K = effective dielectric constant for transmission lines

A = attenuation of transmission line, in dB per unit meter

F = frequency for scaling attenuation, in hertz

N = number of turns

AL = inductance index, in henries

TanD = dielectric loss tangent

Mur = relative permeability

TanM = magnetic loss tangent

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

Z, Len > 0
A, F, AL ≥ 0
K, N ≥ 1

Notes/Equations

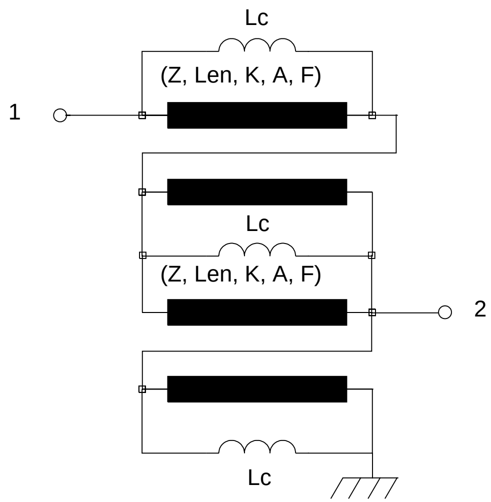
1. This transmission-line transformer comprises TEM transmission lines and *choking* inductances connected as indicated by the Equivalent Circuit illustration that follows.

2. The value of L_c is: $L_c = N^2 \times AL$

3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

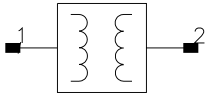
4. This component has no default artwork associated with it.

Equivalent Circuit



X9TO4COR (9:4 Transformer with Ferrite Core)

Symbol



Parameters

Z = characteristic impedance of transmission line, in ohms

Len = physical length of transmission line, in specified units

K = effective dielectric constant for transmission line

A = attenuation of transmission line, in dB per unit meter

F = frequency for scaling attenuation, in hertz

N = number of turns

AL = inductance index, in henries

TanD = dielectric loss tangent

Mur = relative permeability

TanM = magnetic loss tangent

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

Z, Len > 0
A, F, AL ≥ 0
K, N ≥ 1

Notes/Equations

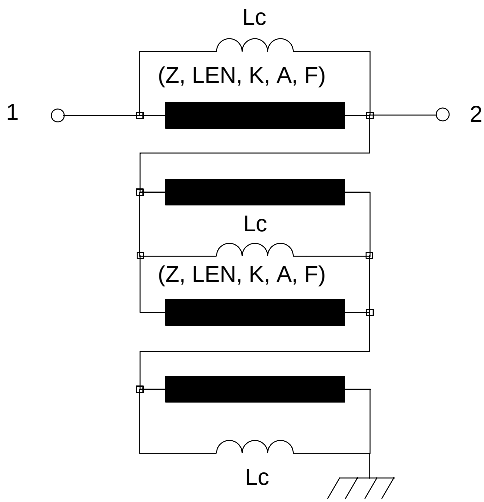
1. This transmission-line transformer comprises TEM transmission lines and *choking* inductances connected as indicated by the Equivalent Circuit illustration that follows.

2. The value of L_c is: $L_c = N^2 \times AL$

3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

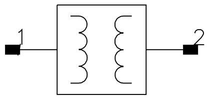
4. This component has no default artwork associated with it.

Equivalent Circuit



X9TO1SLV (9:1 Transformer with Ferrite Sleeve)

Symbol



Parameters

Z = characteristic impedance of transmission line, in ohms

Len = physical length of transmission line, in specified units

K = effective dielectric constant for transmission line

A = attenuation of transmission line, in dB per unit meter

F = frequency for scaling attenuation, in hertz

N = number of turns

AL = inductance index, in henries

TanD = dielectric loss tangent

Mur = relative permeability

TanM = magnetic loss tangent

Sigma = dielectric conductivity

Temp = physical temperature, in °C

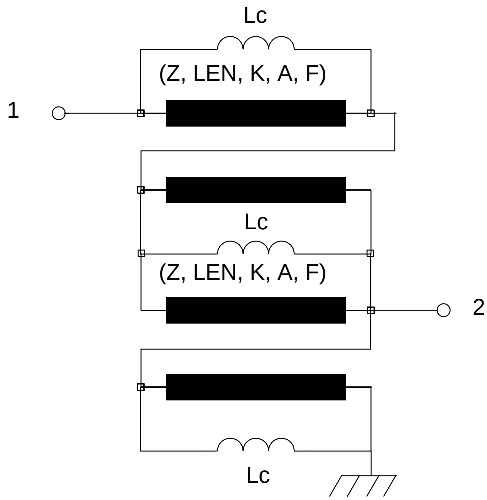
Range of Usage

Z, Len > 0
A, F, AL ≥ 0
K, N ≥ 1

Notes/Equations

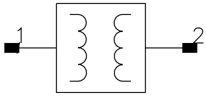
1. This transmission-line transformer comprises TEM transmission lines and *choking* inductances connected as indicated by the Equivalent Circuit illustration that follows.
2. The value of L_c is: $L_c = Mu \times L \times Len$
3. This component has no default artwork associated with it.

Equivalent Circuit



X9TO4SLV (9:4 Transformer with Ferrite Sleeve)

Symbol



Parameters

Z = characteristic impedance of transmission line, in ohms

Len = physical length of transmission line, in specified units

K = effective dielectric constant for transmission lines

A = attenuation of transmission lines, in dB per unit meter

F = frequency for scaling attenuation, in hertz

Mu = relative permeability of surrounding sleeve

L = inductance index (inductance per meter) of the line without the sleeve, in henries

TanD = dielectric loss tangent

Mur = relative permeability

TanM = magnetic loss tangent

Sigma = dielectric conductivity

Temp = physical temperature, in °C

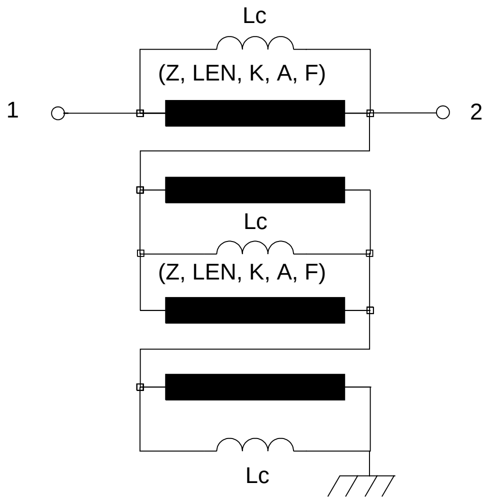
Range of Usage

Z, Len > 0
A, F, AL ≥ 0
K, N ≥ 1

Notes/Equations

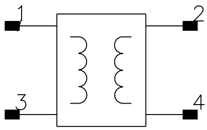
1. This transmission-line transformer comprises TEM transmission lines and *choking* inductances connected as indicated by the Equivalent Circuit illustration that follows.
2. The value of L_c is: $L_c = MU \times L \times Len$
3. This component has no default artwork associated with it.

Equivalent Circuit



XFERTL1 (Transmission Line Transformer (Ferrite Core))

Symbol



Parameters

Z = characteristic impedance of transmission line, in ohms

Len = physical length of transmission line, in specified units

K = effective dielectric constant

A = attenuation of transmission line, in dB per unit length

F = frequency for scaling attenuation, in hertz

N = number of turns

AL = inductance index, in henries

Order = number of transmission lines (must be an integer)

TanD = dielectric loss tangent

Mur = relative permeability

TanM = magnetic loss tangent

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

Z > 0, Len > 0, K ≥ 1, F ≥ 0, A ≥ 0, N ≥ 1, AL > 0, Order ≥ 1

Notes/Equations

1. TEM transmission lines, each specified by Z, Len, K, A and F, are connected in parallel at one end (pins 1 and 3) and in series at the other (pins 2 and 4). The number of lines is equal to Order and the lines are coiled around a ferrite core.

   Transformation ratio = $(\text{Order})^2 : 1$

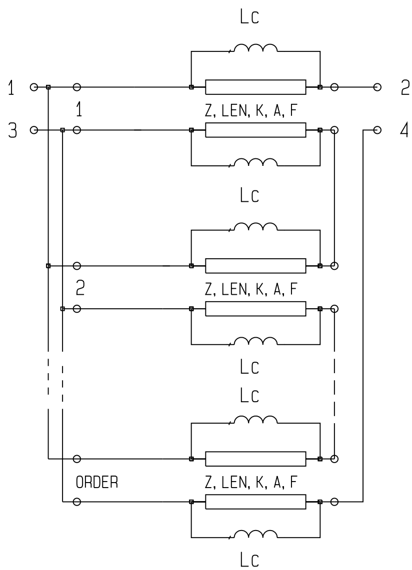
2. The choking inductance L_c accounts for the low-frequency roll-off and is given by $L_c = N^2 \times AL$
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
4. This component has no default artwork associated with it.

References

[1] E. Rotholz, “Transmission-line transformers,” *IEEE Transactions on Microwave Theory and Technology*, Vol. MTT- 29, No.4, April 1981, pp. 327-331.

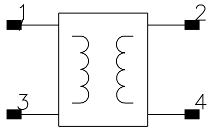
[2] Jerry Sevick, *Transmission Line Transformers*, 2nd Ed., American Radio Relay League, Newington, CT, 1990.

Equivalent Circuit



XFERTL2 (Transmission Line Transformer (Ferrite Sleeve))

Symbol



Parameters

Z = characteristic impedance of transmission line, in ohms

Len = physical length of transmission line, in specified units

K = effective dielectric constant

A = attenuation of transmission line, in dB per unit length

F = frequency for scaling attenuation, in hertz

Mu = relative permeability of surrounding sleeve

L = inductance (per meter) of line without the sleeve, in henries

Order = number of transmission lines (must be an integer)

TanD = dielectric loss tangent

Mur = relative permeability

TanM = magnetic loss tangent

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

$Z > 0$, $Len > 0$, $K \geq 1$, $A \geq 0$, $F \geq 0$, $Mu > 0$, $L > 0$, $Order \geq 1$

Notes/Equations

1. Ideal transmission lines, each specified by Z, Len, K, A and F, are connected in parallel at one end (pins 1 and 3) and in series at the other (pins 2 and 4). The number of lines is equal to Order and the lines are surrounded by a ferrite sleeve.

   Transformation ratio = $(Order)^2 : 1$

2. The choking inductance L_c accounts for the low-frequency roll-off and is given by $L_c = Mu \times L \times Len$

3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

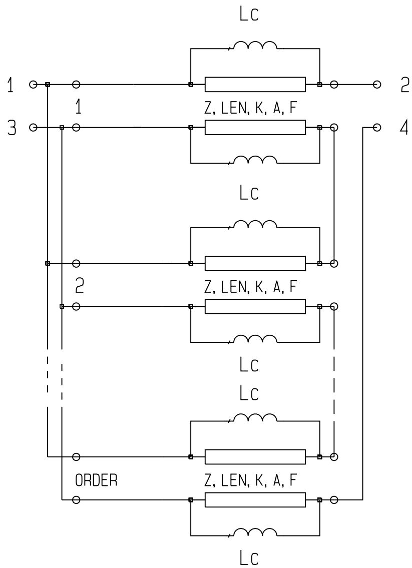
4. This component has no default artwork associated with it.

References

[1] E. Rotholz, "Transmission-line transformers," *IEEE Transactions on Microwave Theory and Technology,* Vol. MTT- 29, No.4, April 1981, pp. 327-331.

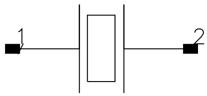
[2] Jerry Sevick, *Transmission Line Transformers*, 2nd Ed., American Radio Relay League, Newington, CT, 1990.

Equivalent Circuit



XTAL1 (Piezoelectric Crystal with Holder)

Symbol



Parameters

C = motional capacitance, in farads

L = motional inductance, in henries

R = motional resistance, in ohms

Cp = static capacitance, in farads

OT = overtone number; Value = 1, 3, or 5

Range of Usage

$C > 0$, $L > 0$

Notes/Equations

1. The motional arm is represented by R, L and C. Cp is the static capacitance associated with the crystal, the electrodes and the crystal enclosure.
2. User inputs are assumed to be the actual values of C and R at the specified overtone. Thus, the values of C_n, R_n, and L_n are, for n any odd integer

   $$C_n = (OT/n)^2 \times C$$
   $$R_n = (n/OT)^2 \times R$$
   $$L_n = L$$

3. The value of N (refer to the equivalent circuit illustration) is

   $$N = (OT + 1) / 2 + 5$$

   that is, N is the set of odd integers {1, 3, 5, ... , OT, OT+2, OT+4, OT+6, OT+8, OT+10}. This means that all odd sub harmonics of OT as well as five odd harmonics above OT are included regardless of the value of OT.
4. This component has no default artwork associated with it.

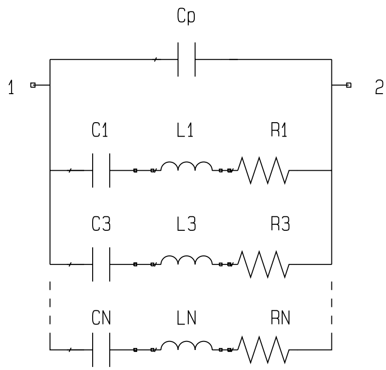
References

[1] Arthur Ballato, "Piezoelectric Resonators," *Design of Crystal and Other Harmonic Oscillators*, Benjamin Parzen, John Wiley & Sons; 1983, Chapter 3, pp. 66-122.

[2] Marvin E. Frerking, *Crystal Oscillator Design and Temperature Compensation*, Van Nostrand Reinhold Company; 1978.

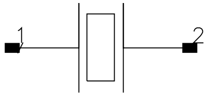
[3] Erich Hafner, "The Piezoelectric Crystal Unit—Definitions and Methods of Measurement," *Proceedings of the IEEE*, Vol. 57, No. 2, pp. 179-201; February 1969.

Equivalent Circuit



XTAL2 (Piezoelectric Crystal with Holder)

Symbol



Parameters

C = motional capacitance, in farads

F = resonant frequency, in hertz

Q = unloaded Q

Cp = static capacitance, in farads

OT = overtone number; Value = 1, 3, or 5

Temp = physical temperature, celsius

Range of Usage

$C > 0$, $F > 0$, $Q > 0$

Notes/Equations

1. The motional arm is represented by R, L and C. Cp is the static capacitance associated with the crystal, the electrodes and the crystal enclosure.

   $L = 1 / [(2 \times \pi \times F)^2 \times C]$
   $R = 1 / [(2 \times \pi \times F) \times C \times Q]$ (for $Q > 0$)
   $R = 0$ (for $Q = 0$)

2. This component has no default artwork associated with it.

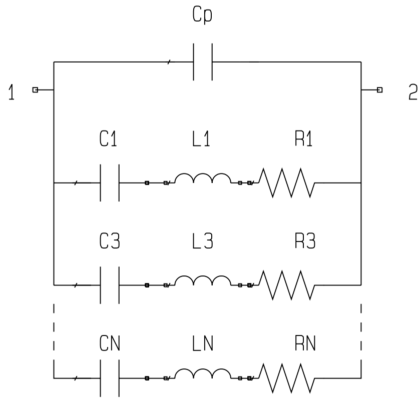
References

[1] Arthur Ballato, "Piezoelectric Resonators," *Design of Crystal and Other Harmonic Oscillators*, Benjamin Parzen, John Wiley & Sons, 1983, Chapter 3, pp. 66-122.

[2] Marvin E. Frerking, *Crystal Oscillator Design and Temperature Compensation*, Van Nostrand Reinhold Company, 1978.

[3] Erich Hafner, "The Piezoelectric Crystal Unit—Definitions and Methods of Measurement," *Proceedings of the IEEE*, Vol. 57, No. 2, February 1969, pp. 179-201.

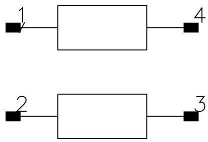
Equivalent Circuit



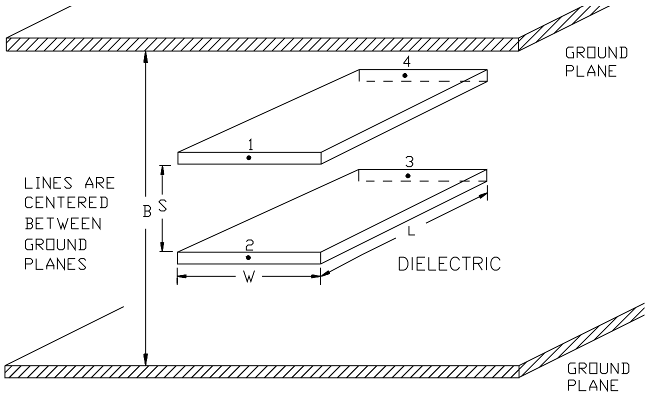
Chapter 5: Stripline Components

SBCLIN (Broadside-Coupled Lines in Stripline)

Symbol



Illustration



Parameters

Subst = substrate instance name

W = conductor width, in specified units

S = conductor spacing, in specified units (refer to Notes 3 and 4)

L = length, in specified units

Temp = physical temperature, in °C

W1 = (ADS Layout option) offset from pin 1 to conductor centerline

W2 = (ADS Layout option) offset from pin 2 to conductor centerline

W3 = (ADS Layout option) offset from pin 3 to conductor centerline

W4 = (ADS Layout option) offset from pin 4 to conductor centerline

P1Layer = (ADS Layout option) layer associated with pin 1 conductor; *cond1*, *cond2*

Range of Usage

$Er \geq 1$

$$\frac{W}{B-S} \geq 0.35$$

$$\frac{S}{B} \leq 0.9$$

$$\frac{W}{S} \geq 0.7$$

where

Er = dielectric constant (from associated SSUB(O))
B = ground plane spacing (from associated SSUB(O))
S = center layer thickness (conductor spacing)

Notes/Equations

1. Conductor thickness correction is applied in the frequency-domain analytical model.
2. Coupled lines are parallel to the ground plane.
3. Components that refer to an SSUBO with S=0 give the same simulation results as if they refer to an otherwise equivalent SSUB.
4. If the Subst parameter refers to an SSUBO, the SSUBO's spacing parameter (S) value is used rather than the component spacing parameter (S). This is true regardless of whether the component's S is set to a real value or to *unspecified*. If it is set to a real value, a warning message is displayed.
5. For coupled-stripline of negligible thickness (T=0), the even- and odd-mode characteristic line impedances are calculated from the exact formula derived by Shelton using conformal mapping. For a stripline of finite thickness, an approximate model developed by William Getsinger for Agilent and based on the formula of Shelton, Cohn, and Wheeler is used to calculate the even- and odd-mode impedances. Additionally, the attenuation formula developed by Wheeler is used. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the model.
6. For time-domain analysis, the frequency-domain analytical model is used.

References

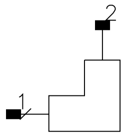
[1] S. B. Cohn, “Thickness Corrections for Capacitive Obstacles and Strip Conductors,” *IRE Trans. Microwave Theory and Techniques*, Vol. MTT-8, November, 1960, pp. 638-644.

[2] J. P. Shelton, “Impedance of Offset Parallel-Coupled Strip Transmission Lines,” *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-14, January, 1966, pp. 7-15.

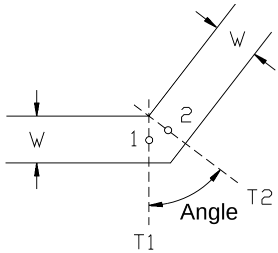
[3] H. A. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

SBEND (Unmitered Stripline Bend)

Symbol



Illustration



Parameters

Subst = substrate (SSUB or SSUBO) instance name

W = conductor width, in specified units

Angle = angle of bend, in degrees

Temp = physical temperature, in °C

Layer = (ADS Layout option) conductor layer number: *cond1*, *cond2*

Range of Usage

$W \geq 0$

Angle = any value in Layout

$15° \leq \text{Angle} \leq 120° \quad (\text{for } \frac{W}{B} \approx 1)$

$0.25 \leq \frac{W}{B} \leq 1.75 \quad (\text{for Angle} = 90°)$

where

B = ground plane spacing (from associated SSUB)

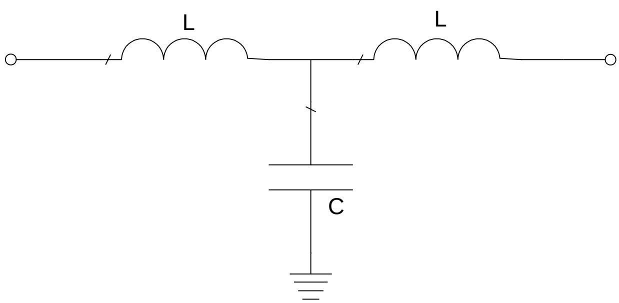
Notes/Equations

1. The frequency-domain analytical model is the static, lumped component model of Altschuler and Oliner. The formulas are based on a theoretical analysis of the E-plane bend in parallel-plate waveguide. Conductor and dielectric losses are not included in the simulation.
2. If the Subst parameter refers to an SSUBO whose spacing parameter S has a non-zero value, the component is considered offset for layout and electromagnetic analysis purposes. For other types of analyses, the offset is ignored.
3. In layout, a positive value for Angle draws a bend in the counterclockwise direction from pin 1 to 2; a negative value for Angle draws a bend in the clockwise direction.

References

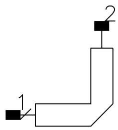
[1] H. M. Altschuler and A. A. Oliner. “Discontinuities in the Center Conductor of Symmetric Strip Transmission Line,” *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-8, May, 1960. (Cf. Section III-H.)

Equivalent Circuit

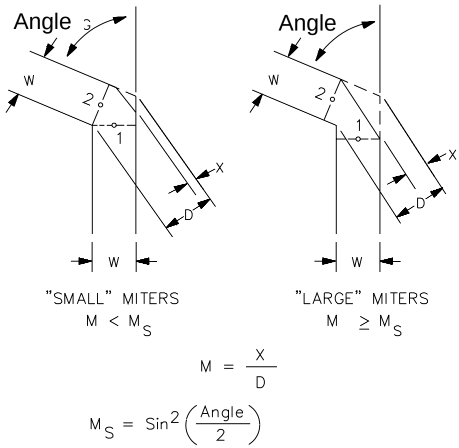


SBEND2 (Stripline Bend -- Arbitrary Angle/Miter)

Symbol



Illustration



Parameters

Subst = substrate (SSUB or SSUBO) instance name

W = conductor width, in specified units

Angle = angle of bend, in degrees

M = miter fraction

Temp = physical temperature, in °C

Layer = (ADS Layout option) conductor layer number: *cond1, cond2*

Range of Usage

$W \leq 5.7 \times B$
$B \leq 0.2 \times \lambda$
$W \leq 0.2 \times \lambda$
$M \leq 0.01 \times$ Angle (degrees)
$M \leq 0.8$

$20° \le$ Angle $\le 150°$
where
B = ground plane spacing (from associated SSUB)
λ = wavelength in the dielectric
$W \ge 0$ for Layout

Notes/Equations

1. The frequency-domain analytical model is a static, lumped component model developed for Agilent by William J. Getsinger. The model is based on the waveguide E-plane parallel-plate model analyzed by J. Schwinger and published in Marcuvitz's book, *Waveguide Handbook*. Based on the work of Oliner, the waveguide model is transformed into its dual stripline model. Conductor and dielectric losses are included in the simulation. Reference plane shifts are added for large miters ($M > M_s$).

2. If the Subst parameter refers to an SSUBO whose spacing parameter S has a non-zero value, the component is considered offset for layout and electromagnetic analysis purposes. For other types of analyses, the offset is ignored.

3. There are two possible reference plane locations available:

   - Small miters where the reference planes line up with the inner corner of the bend.

   - Large miters where the reference planes line up with the corner between the connecting strip and the mitered section.

4. In layout, a positive value for Angle draws a bend in the counterclockwise direction from pin 1 to 2; a negative value for Angle draws a bend in the clockwise direction.

References

[1] H. M. Altschuler and A. A. Oliner. “Discontinuities in the Center Conductor of Symmetric Strip Transmission Line,” *IEEE Transactions on Microwave Theory and Techniques,* Vol. MTT-8, May, 1960. (Cf. Section III-H.)

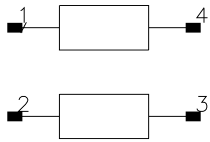
[2] M. Kirschning, R. H. Jansen, and N. H. L. Koster. “Measurement and Computer-Aided Modeling of Microstrip Discontinuities by an Improved Resonator Method,” 1983 IEEE *MTT-S International Microwave Symposium Digest*, May 1983, pp. 495-497.

[3] N. Marcuvitz, *Waveguide Handbook*, McGraw-Hill, 1951, pp. 337-350.

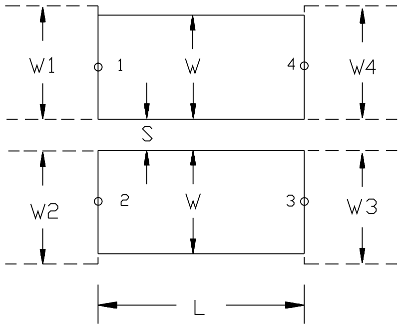
[4] A. Oliner, “Equivalent Circuits For Discontinuities in Balanced Strip Transmission Line,” *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-3, March 1955, pp. 134-143.

SCLIN (Edge-Coupled Lines in Stripline)

Symbol



Illustration



Parameters

Subst = substrate instance name

W = line width, in specified units

S = spacing between lines, in specified units

L = line length, in specified units

Temp = physical temperature, in °C

W1 = (ADS Layout option) width of line that connects to pin 1

W2 = (ADS Layout option) width of line that connects to pin 2

W3 = (ADS Layout option) width of line that connects to pin 3

W4 = (ADS Layout option) width of line that connects to pin 4

Layer = (ADS Layout option) conductor layer number: *cond1*, *cond2*

Range of Usage

$S > 0$
$W \geq 0.35 \times B$ (for $T > 0$)

W > 0 (for T = 0)
T < 0.1 × B
where
B = ground plane spacing (from associated SSUB)
T = conductor thickness (from associated SSUB)

Notes/Equations

1. The frequency-domain analytical model is as follows. For centered coupled-stripline of negligible thickness (T=0), the even- and odd-mode characteristic line impedances are calculated from the exact formula derived by Cohn using conformal mapping. For a centered coupled-stripline of finite thickness, Cohn's approximate formula is used in conjunction with Wheeler's attenuation formula. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the model.
2. If the Subst parameter refers to an SSUBO whose spacing parameter S has a non-zero value, the component is considered offset for layout and electromagnetic analysis purposes. For other types of analyses, the offset is ignored.
3. For time-domain analysis, the frequency-domain analytical model is used.
4. In generating a layout, adjacent transmission lines will be lined up with the inner edges of the conductor strips. If the connecting transmission lines are narrower than the coupled lines, they will be centered on the conductor strips.

References

[1] H. M. Altschuler and A. A. Oliner. "Discontinuities in the Center Conductor of Symmetric Strip Transmission Line," *IEEE Transactions on Microwave Theory and Techniques,* Vol. MTT-8, May, 1960. (Cf. Section III-H.)

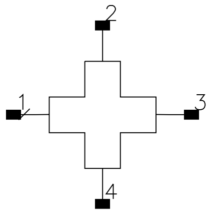
[2] S. B. Cohn. "Shielded Coupled-Strip Transmission Line," IRE Trans. Microwave Theory and Techniques, Vol. MTT-3, October, 1955, pp. 29-38.

[3] K. C. Gupta, R. Garg, and R. Chadha. *Computer-Aided Design of Microwave Circuits*, Artech House, Inc., 1981.

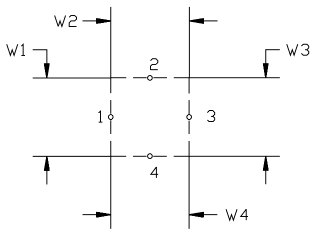
[4] H. A. Wheeler. "Formulas for the Skin Effect," Proc. IRE, Vol. 30, September, 1942, pp. 412-424.

SCROS (Stripline Cross Junction)

Symbol



Illustration



Parameters

Subst = substrate instance name

W1 = conductor width at pin 1, in specified units

W2 = conductor width at pin 2, in specified units

W3 = conductor width at pin 3, in specified units

W4 = conductor width at pin 4, in specified units

Temp = physical temperature, in °C

Layer = (ADS Layout option) conductor layer number: *cond1*, *cond2*

Range of Usage

Simulation frequency (GHz) $\leq \frac{Zo}{B}$

where

Zo = characteristic impedance of the widest strip in ohms

B = ground plane spacing in millimeters

Notes/Equations

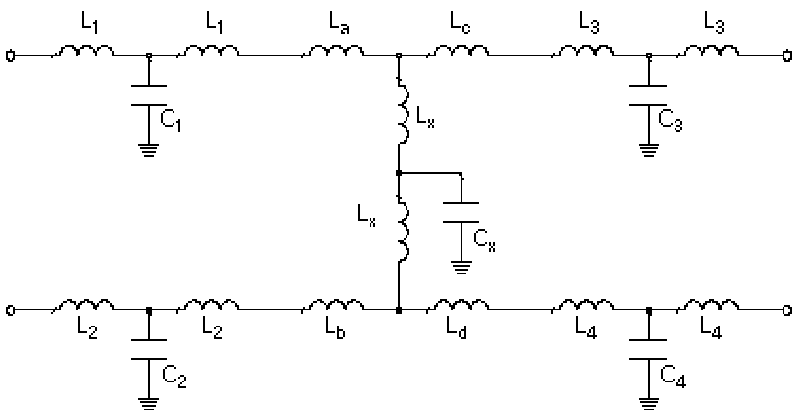
1. The frequency-domain analytical model is a frequency dependent, lumped component model developed for Agilent by William J. Getsinger. The model is an extension of the stripline T-junction model. The T-junction model is based on the waveguide E-plane parallel-plate model analyzed by J. Schwinger and published in Marcuvitz's book, *Waveguide Handbook*. Based on the work of Oliner, the waveguide model is transformed into its dual stripline model. Conductor and dielectric losses are not included in the simulation.
2. If the Subst parameter refers to an SSUBO whose spacing parameter S has a non-zero value, the component is considered offset for layout and electromagnetic analysis purposes. For other types of analyses, the offset is ignored.
3. For time-domain analysis, the frequency-domain analytical model is used.
4. In Layout, all pins are centered at the corresponding edges.

References

[1] N. Marcuvitz. *Waveguide Handbook*, McGraw-Hill, 1951, pp. 337-350.

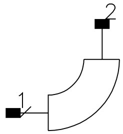
[2] A. Oliner. "Equivalent Circuits For Discontinuities in Balanced Strip Transmission Line," *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-3, March 1955, pp. 134-143.

Equivalent Circuit

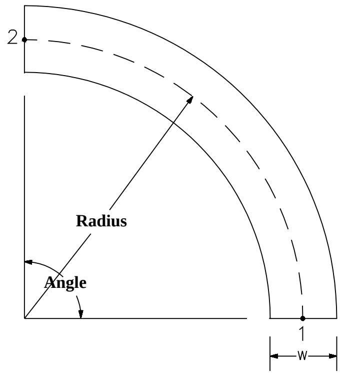


SCURVE (Curved Line in Stripline)

Symbol



Illustration



Parameters

Subst = substrate instance name

W = conductor width, in specified units

Angle = angle subtended by the bend, in degrees

Radius = radius (measured to strip centerline), in specified units

Temp = physical temperature, in °C

Layer = (ADS Layout option) conductor layer number: *cond1*, *cond2*

Range of Usage

$$\text{RAD} \geq \frac{W + B/2}{2}$$

where

B = ground plane spacing (from associated SSUB)

Notes/Equations

1. The frequency-domain analytical model consists of an equivalent piece of straight stripline. The model was developed for Agilent by William J. Getsinger and is based on the waveguide E-plane parallel-plate model analyzed by J. Schwinger and published in Marcuvitz's book, *Waveguide Handbook*. Following the work of Oliner, the waveguide model is transformed into its dual stripline model. Conductor and dielectric losses are included in the simulation. Discontinuity effects accounted for are those due to radius only.
2. If the Subst parameter refers to an SSUBO whose spacing parameter S has a non-zero value, the component is considered offset for layout and electromagnetic analysis purposes. For other types of analyses, the offset is ignored.
3. For time-domain analysis, the frequency-domain analytical model is used.
4. In layout, a positive value for Angle draws a curve in the counterclockwise direction; a negative value draws a curve in the clockwise direction.

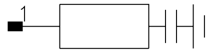
References

[1] N. Marcuvitz. *Waveguide Handbook*, McGraw-Hill, 1951, pp. 337-350.

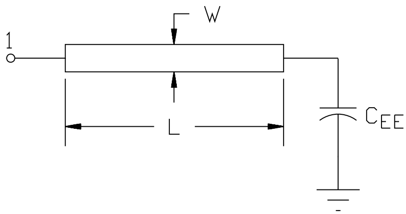
[2] A. Oliner. “Equivalent Circuits For Discontinuities in Balanced Strip Transmission Line,” *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-3, March 1955, pp. 134-143.

SLEF (Stripline Open-End Effect)

Symbol



Illustration



Parameters

Subst = substrate instance name

W = line width, in specified units

L = line length, in specified units

Temp = physical temperature, in °C

Layer = (ADS Layout option) conductor layer number: *cond1*, *cond2*

Range of Usage

$$\frac{W}{B} \geq 0.15$$

$$\frac{T}{B} < 0.1$$

where

B = ground plane spacing (from associated SSUB)

T = conductor thickness (from associated SSUB)

Notes/Equations

1. The frequency-domain analytical model consists of an extension to the length of the stripline stub. The stripline is modeled using the SLIN model for thin (T=0) and thick (T>0) stripline, including conductor and dielectric loss. The length of

the extension of the stripline, dl, is based on the formula developed by Altschuler and Oliner.

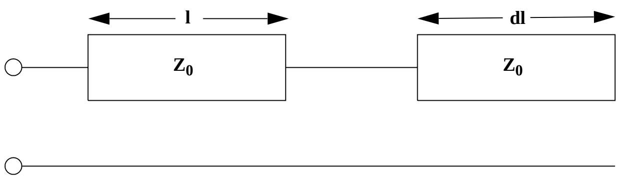
2. If the Subst parameter refers to an SSUBO whose spacing parameter S has a non-zero value, the component is considered offset for layout and electromagnetic analysis purposes. For other types of analyses, the offset is ignored.
3. For time-domain analysis, the frequency-domain analytical model is used.

References

[1] H. M. Altschuler, and A. A. Oliner, "Discontinuities in the Center Conductor of Symmetric Strip Transmission Line," *IRE Trans. Microwave Theory and Techniques*, Vol. MTT-8, May 1960, pp. 328-339.

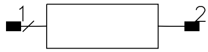
[2] K. C. Gupta, R. Garg, and R. Chadha. *Computer-Aided Design of Microwave Circuits,* Artech House, Inc., 1981.

Equivalent Circuit



SLIN (Stripline)

Symbol



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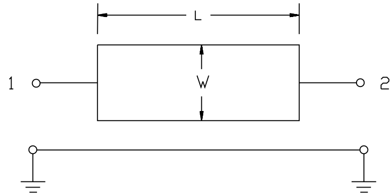


Parameters

Subst = substrate instance name

W = line width, in specified units

L = line length, in specified units

Temp = physical temperature, in °C

Layer = (ADS Layout option) conductor layer number: *cond1*, *cond2*

Range of Usage

W > 0 (for T = 0)

W ≥ 0.35 × B (for T > 0)

T ≤ 0.25 × B

S > 0.9 × B

where

B = ground plane spacing (from associated SSUB)

T = conductor thickness (from associated SSUB)

Notes/Equations

1. The frequency-domain analytical model is as follows. For centered stripline of negligible thickness (T=0), the characteristic line impedance is calculated from the exact formula derived by Cohn using conformal mapping. For a centered stripline of finite thickness, Wheeler's approximate formula for the

characteristic line impedance and attenuation factor are used. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the model.

2. For offset stripline, a model developed by William Getsinger for Agilent and based on the formula of Shelton, Cohn and Wheeler is used. For an offset stripline of negligible thickness (T=0), the characteristic line impedance is calculated from the exact formula derived by Shelton using conformal mapping. For an offset stripline of finite thickness, Shelton's exact formula is combined with Cohn's formula for a centered thick stripline to formulate an approximate formula. Additionally, the attenuation formula developed by Wheeler is used. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the model.
3. If the Subst parameter refers to an SSUBO whose spacing parameter S has a non-zero value, the component is considered offset for simulation and layout purposes. A reference to SSUBO with its spacing parameter S=0 is equivalent to a reference to the SSUB.

References

[1] S. B. Cohn, “Characteristic Impedance of the Shielded-Strip Transmission Line,” *IRE Trans. Microwave Theory and Techniques*, Vol. MTT-2, July, 1954, pp. 52-55.

[2] S. B., Cohn, “Problems in Strip Transmission Lines,” *IRE Trans. Microwave Theory and Techniques*, Vol. MTT-3, March, 1955, pp. 119-126.

[3] K. C. Gupta, R. Garg, and R. Chadha. *Computer-Aided Design of Microwave Circuits*, Artech House, Inc., 1981.

[4] J. P. Shelton, “Impedance of Offset Parallel-Coupled Strip Transmission Lines,” *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-14, January, 1966, pp. 7-15.

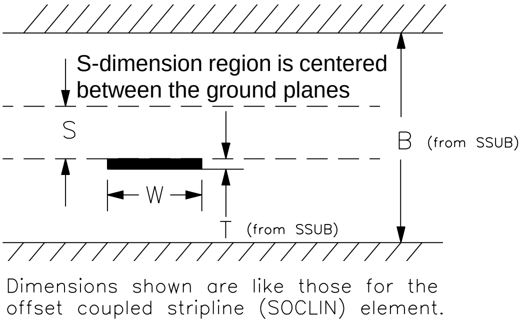
[5] H. A. Wheeler, “Transmission Line Properties of a Stripline Between Parallel Planes,” *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-26, November, 1978, pp. 866-876.

[6] H. A. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

SLINO (Offset Strip Transmission Line)

Symbol

Illustration



Parameters

Subst = substrate instance name

W = line width, in specified units

S = middle dielectric layer thickness, in specified units (refer to Notes 1 and 2)

L = line length, in specified units

Temp = physical temperature, in °C

Layer = (ADS Layout option) conductor layer number: *cond1*, *cond2*

Range of Usage

$$\frac{W}{B + S - T} \geq 0.35$$

where

B = ground plane spacing (from associated SSUB)
T = conductor thickness (from associated SSUB)

Notes/Equations

1. The frequency-domain analytical model is as follows. For offset stripline, a model developed by William Getsinger for negligible thickness (T=0), the characteristic line impedance is calculated from the exact and based on the

formula of Shelton, Cohn and Wheeler is used. For an offset stripline of negligible thickness (T=0), the characteristic line impedance is calculated from the exact formula derived by Shelton using conformal mapping. For an offset stripline of finite thickness, Shelton's exact formula is combined with Cohn's formula for a centered thick stripline to formulate an approximate formula. Additionally, the attenuation formula developed by Wheeler is used. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the model.

2. Components that refer to an SSUBO with S=0 give the same simulation results as if they refer to an otherwise equivalent SSUB.

3. If the Subst parameter refers to an SSUBO, the SSUBO spacing parameter (S) value is used rather than the component spacing parameter (S). This is true regardless of whether the component's S is set to a real value or to *unspecified*. If it is set to a real value, a warning message is displayed. If the Subst parameter refers to an SSUB (rather than to an SSUBO), the component's value for S is used.

4. For time-domain analysis, the frequency-domain analytical model is used.

References

[1] S. B. Cohn, "Characteristic Impedance of the Shielded-Strip Transmission Line," *IRE Trans. Microwave Theory and Techniques*, Vol. MTT-2, July, 1954, pp. 52-55.

[2] S. B. Cohn, "Problems in Strip Transmission Lines," *IRE Trans. Microwave Theory and Techniques*, Vol. MTT-3, March, 1955, pp. 119-126.

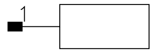
[3] J. P. Shelton, "Impedance of Offset Parallel-Coupled Strip Transmission Lines," *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-14, January, 1966, pp. 7-15.

[4] H. A. Wheeler, "Transmission Line Properties of a Stripline Between Parallel Planes," *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-26, November, 1978, pp. 866-876.

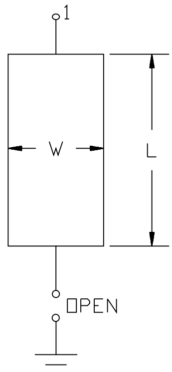
[5] H. A. Wheeler, "Formulas for the Skin Effect," *Proc. IRE, Vol*. 30, September, 1942, pp. 412-424.

SLOC (Stripline Open-Circuited Stub)

Symbol



Illustration



Parameters

Subst = substrate instance name

W= line width, in specified units

L = line length, in specified units

Temp = (physical temperature, in °C

Layer = (ADS Layout option) conductor layer number: *cond1*, *cond2*

Range of Usage

$$\frac{T}{B} \leq 0.25$$

where

B = ground plane spacing (from associated SSUB)

T = conductor thickness (from associated SSUB)

Notes/Equations

1. The frequency-domain analytical model is as follows. For centered stripline of negligible thickness (T=0), the characteristic line impedance is calculated from

the exact formula derived by Cohn using conformal mapping. For a centered stripline of finite thickness, Wheeler's approximate formula for the characteristic line impedance and attenuation factor are used. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the model.

2. For offset stripline, a model developed by William Getsinger for Agilent and based on the formula of Shelton, Cohn and Wheeler is used. For an offset stripline of negligible thickness (T=0), the characteristic line impedance is calculated from the exact formula derived by Shelton using conformal mapping. For an offset stripline of finite thickness, Shelton's exact formula is combined with Cohn's formula for a centered thick stripline to formulate an approximate formula. Additionally, the attenuation formula developed by Wheeler is used. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the model. No end effects are included in the model.
3. If the Subst parameter refers to an SSUBO whose spacing parameter S has a non-zero value, the component is considered offset for simulation and layout purposes. A reference to SSUBO with its spacing parameter S=0 is equivalent to a reference to SSUB.
4. For time-domain analysis, the frequency-domain analytical model is used.

References

[1] S. B. Cohn, "Characteristic Impedance of the Shielded-Strip Transmission Line," *IRE Trans. Microwave Theory and Techniques*, Vol. MTT-2, July, 1954, pp. 52-55.

[2] S. B. Cohn, "Problems in Strip Transmission Lines," *IRE Trans. Microwave Theory and Techniques*, Vol. MTT-3, March, 1955, pp. 119-126.

[3] K. C.Gupta, R. Garg, and R. Chadha. *Computer-Aided Design of Microwave Circuits,* Artech House, Inc., 1981.

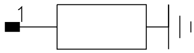
[4] J. P. Shelton, "Impedance of Offset Parallel-Coupled Strip Transmission Lines," *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-14, January, 1966, pp. 7-15.

[5] H. A. Wheeler, "Transmission Line Properties of a Stripline Between Parallel Planes," *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-26, November, 1978, pp. 866-876.

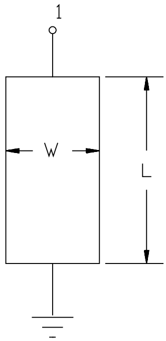
[6] H. A. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

SLSC (Stripline Short-Circuited Stub)

Symbol



Illustration



Parameters

Subst = substrate instance name

W = line width, in specified units

L = line length, in specified units

Temp = physical temperature, in °C

Layer = (ADS Layout option) conductor layer number: cond1, cond2

Range of Usage

$$\frac{T}{B} \leq 0.25$$

where

B = ground plane spacing (from associated SSUB)

T = conductor thickness (from associated SSUB)

Notes/Equations

1. For centered stripline of negligible thickness (T = 0), the characteristic line impedance is calculated from the exact formula derived by Cohn using conformal mapping. For a centered stripline of finite thickness, Wheeler's

approximate formula for the characteristic line impedance and attenuation factor are used. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the model.

2. For offset stripline, a model developed by William Getsinger for Agilent and based on the formula of Shelton, Cohn and Wheeler is used. For an offset stripline of negligible thickness (T=0), the characteristic line impedance is calculated from the exact formula derived by Shelton using conformal mapping. For an offset stripline of finite thickness, Shelton's exact formula is combined with Cohn's formula for a centered thick stripline to formulate an approximate formula. Additionally, the attenuation formula developed by Wheeler is used. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the model. No end effects are included in the model.
3. If the Subst parameter refers to an SSUBO whose spacing parameter S has a non-zero value, the component is considered offset for simulation and layout purposes. A reference to SSUBO with its spacing parameter S=0 is equivalent to a reference to SSUB.
4. For time-domain analysis, the frequency-domain analytical model is used.

References

[1] S. B. Cohn, “Characteristic Impedance of the Shielded-Strip Transmission Line,” IRE Trans. Microwave Theory and Techniques, Vol. MTT-2, July, 1954, pp. 52-55.

[2] S. B. Cohn, “Problems in Strip Transmission Lines,” IRE Trans. Microwave Theory and Techniques, Vol. MTT-3, March, 1955, pp. 119-126.

[3] K. C. Gupta, R. Garg, and R. Chadha. *Computer-Aided Design of Microwave Circuits*, Artech House, Inc., 1981.

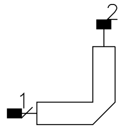
[4] J. P. Shelton, “Impedance of Offset Parallel-Coupled Strip Transmission Lines,” *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-14, January, 1966, pp. 7-15.

[5] H. A. Wheeler, “Transmission Line Properties of a Stripline Between Parallel Planes,” *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-26, November, 1978, pp. 866-876.

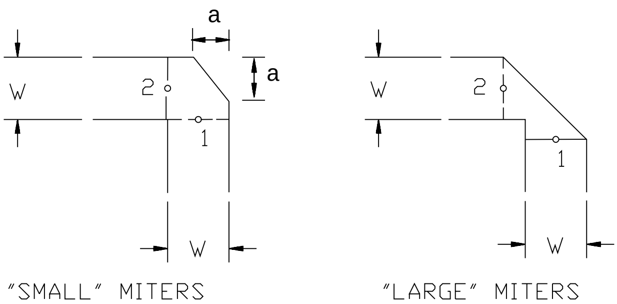
[6] H. A. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

SMITER (90-degree Stripline Bend -- Optimally Mitered)

Symbol



Illustration



Parameters

Subst = substrate instance name

W = conductor width, in specified units

Temp = physical temperature, in °C

Layer = (ADS Layout option) conductor layer number: *cond1*, *cond2*

Range of Usage

$0.2 \times B \leq W \leq 3 \times B$

where

B = ground plane spacing (from associated SSUB)

Notes/Equations

1. The frequency-domain model is an empirically based, analytical model. The chamfered bend is modeled as a matched stripline line of length, $\Delta l_o + l_{ext}$. The effective length of the bend and the optimal chamfered dimension are calculated based on curve fits to empirical data in Matthaei, Young, and Jones. The stripline is modeled using the SLIN model for thin (T=0) and thick (T>0) stripline, including conductor and dielectric loss.

For Δl_o:

If $(W/B \le 0.2)$

$$\Delta l_o/W = 0.56528 + 0.023434 \times (W/B - 0.2)$$

If $(0.2 < W/B \le 3.0)$

$$\Delta l_o/W = 0.56528 + 0.01369 \times (W/B - 0.2)^{0.77684} + 0.01443 \times (W/B - 0.2)^{2.42053}$$

If $(W/B > 3.0)$

$$\Delta l_o/W = 0.770175 + 0.155473 \times (W/B - 3.0)$$

For l_{ext}:

If $(a > W)$

$$l_{ext} = 2 \times (a - W)$$

If $(a \le W)$

$$l_{ext} = 0.0$$

2. If the Subst parameter refers to an SSUBO whose spacing parameter S has a non-zero value, the component is considered offset for layout and electromagnetic analysis purposes. For other types of analyses, the offset is ignored.
3. The artwork is dependent on the parameters given in the SSUB or SSUBO. Layout artwork requires placing a SSUB or SSUBO, prior to placing the component directly in the Layout window.
4. The miter fraction (a/W) is calculated using one of the formulae given below depending on the parameter values.

If $(W/B < 0.2)$,

$$a/W = 1.267472 - 0.35041 \times (W/B - 0.2).$$

If $(0.2 \le W/B \le 1.6)$,

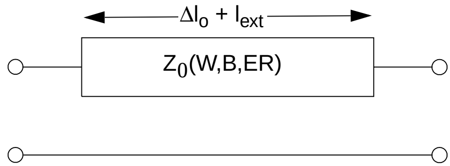
$$a/W = 1.012 + (1.6 - W/B) \times (0.08 + (1.6 - W/B) \times (0.013 + ((1.6 - W/B) \times 0.043))).$$

If $(1.6 \le W/B \le 14.25)$, $a/W = 0.884 + 0.08 \times (3.2 - W/B).$

5. Harlan Howe, Jr, *Stripline Circuit Design*, Artech House, Inc., 1982.

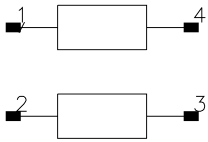
6. G. Matthaei, L. Young, E. M. T. Jones. *Microwave Filters, Impedance-Matching Networks and Coupling Structures*, Artech House, Inc., 1980, pp 203, 206.

Equivalent Circuit

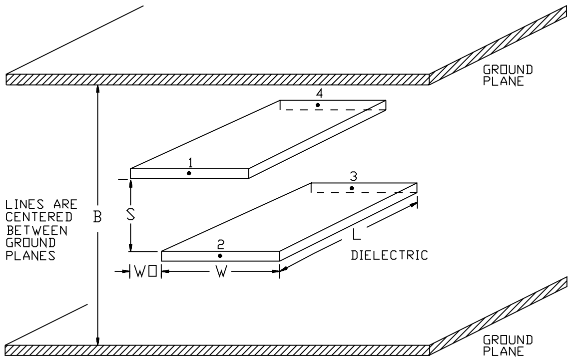


SOCLIN (Offset-Coupled Lines in Stripline)

Symbol



Illustration



Parameters

Subst = substrate instance name

W = conductor width, in specified units

WO = conductor offset, in specified units

S = conductor spacing, in specified units

L = conductor length, in specified units

Temp = physical temperature, in °C

W1 = (ADS Layout option) offset from pin 1 to conductor centerline

W2 = (ADS Layout option) offset from pin 2 to conductor centerline

W3 = (ADS Layout option) offset from pin 3 to conductor centerline

W4 = (ADS Layout option) offset from pin 4 to conductor centerline4

P1Layer = (ADS Layout option) layer associated with pin 1 conductor: *cond1, cond2*

Range of Usage

Er ≥ 1

$$\frac{W}{B-S} \geq 0.35$$

$$\frac{S}{B} \leq 0.9$$

where

B = ground plane spacing (from associated SSUB)

Er = dielectric constant (from associated SSUB)

Notes/Equations

1. The frequency-domain analytical model is as follows. For laterally-offset coupled-stripline of negligible thickness (T=0), the even- and odd-mode characteristic line impedances are calculated from the exact formula derived by Shelton using conformal mapping. For a laterally-offset coupled-stripline of finite thickness, a model developed by William Getsinger for Agilent and based on the formula of Shelton, Cohn and Wheeler is used to calculate the even- and odd-mode impedances. Additionally, the attenuation formula developed by Wheeler is used. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dielectric loss is also included in the model.
2. Coupled lines are parallel to the ground plane.
3. Components that refer to an SSUBO with S=0 give the same simulation results as if they refer to an otherwise equivalent SSUB.
4. If the Subst parameter refers to an SSUBO, the SSUBO spacing parameter (S) value is used rather than the component spacing parameter (S). This is true regardless of whether the component's S is set to a real value or to unspecified. If it is set to a real value, a warning message is displayed. If the Subst parameter refers to an SSUB (rather than to an SSUBO), the component's value for S is used.
5. For time-domain analysis, the frequency-domain analytical model is used.
6. W1, W2, W3 and W4 are layout-only parameters and only affect the electromagnetic simulation results. W1, W2, W3 and W4 cannot exceed W/2.

References

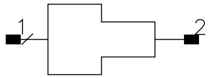
[1] S. B. Cohn, "Thickness Corrections for Capacitive Obstacles and Strip Conductors," *IRE Trans. Microwave Theory and Techniques*, Vol. MTT-8, November, 1960, pp. 638-644.

[2] J. Paul Shelton, Jr. "Impedances of Offset Parallel-Coupled Strip Transmission Lines," *IEEE Transactions On Microwave Theory and Techniques,* Vol. MTT-14, January, 1966, pp. 7-15.

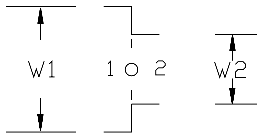
[3] H. A. Wheeler, "Formulas for the Skin Effect," *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424

SSTEP (Stripline Step in Width)

Symbol



Illustration



Parameters

Subst = substrate instance name

W1 = conductor width at pin 1, in specified units

W2 = conductor width at pin 2, in specified units

Temp = physical temperature, in °C

Layer = (ADS Layout option) conductor layer number: *cond1, cond2*

Range of Usage

$$0.1 \le \frac{W2}{W1} \le 10$$

$W1 \le 0.2 \times \lambda$

$W2 = 0.2 \times \lambda$

where

λ = wave length in the dielectric

Notes/Equations

1. The frequency-domain analytical model is the lumped component model of Altschuler and Oliner. The model includes reference plane adjustments to align the *natural* reference plane of the discontinuity with the reference plane of the layout. The SLIN stripline model is used to model these reference plane shifts.

2. If the Subst parameter refers to an SSUBO whose spacing parameter S has a non-zero value, the component is considered offset for layout and

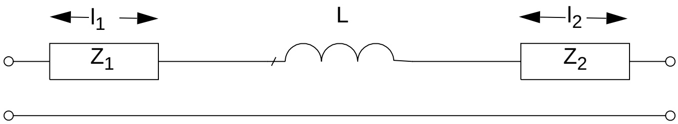
electromagnetic analysis purposes. For other types of analyses, the offset is ignored.

3. In layout, SSTEP aligns the centerlines of the strips.

References

[1] H. M. Altschuler and A. A. Oliner. "Discontinuities in the Center Conductor of Symmetric Strip Transmission Line," *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-8, May 1960. (Cf. Section III-H.)

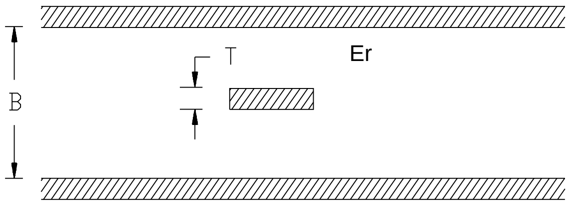
Equivalent Circuit



SSUB (Stripline Substrate)

Symbol

Illustration



Parameters

Er = relative dielectric constant

Mur = relative permeability

B = ground plane spacing, in specified units

T = conductor thickness, in specified units

Cond = conductor conductivity, in Siemens/meter

TanD = dielectric loss tangent

Cond 1 (ADS Layout option) layer to which *cond* is mapped; default = 1 (cond)

Cond2 (ADS Layout option) layer to which *cond2* is mapped; default = 2 (cond2)

Range of Usage

Er ≥ 1.0
B > 0
T ≥ 0

Notes/Equations

1. SSUB sets up stripline substrate parameters for one or more stripline components. Either an SSUB or SSUBO is required for all stripline components. For offset center conductor layers, use SSUBO.

2. Gold conductivity is 4.1×10^7 S/m. Rough modifies loss calculations. Conductivity for copper is 5.8×10^7.

3. The parameters Cond1 and Cond2 control the mask layers on which the conductors are drawn. These are layout-only parameters and are not used by the simulator.

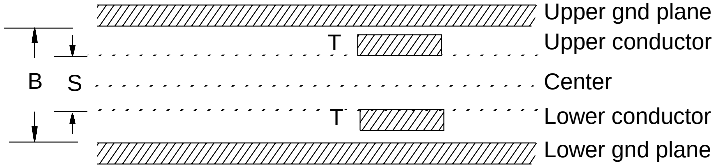
   In the case of SBCLIN and SOCLIN, the component parameter P1Layer identifies the virtual layer (*cond1* or *cond2*) that the conductor associated with pin 1 is drawn on. All other stripline components have a Layer parameter that identifies the virtual layer (*cond1* or *cond2*) on which the conductor is drawn.

   The virtual layer referred to by P1Layer or Layer (*cond1* or *cond2*) is mapped to an actual mask layer by the Cond1 or Cond2 parameter of the appropriate SSUB or SSUBO.

SSUBO (Offset Stripline Substrate)

Symbol

Illustration



Parameters

Er = relative dielectric constant

Mur = relative permeability

S = inter-layer (conductor) spacing, in specified units

B = ground plane spacing around the center, in specified units

T = conductor thickness, in specified units

Cond = conductor conductivity

TanD =dielectric loss tangent

Cond1 = (ADS Layout option) layer to which cond1 is mapped; default = 1 (cond)

Cond2 = (ADS Layout option) layer to which cond2 is mapped; default = 2 (cond2)

Range of Usage

$Er \geq 1.0$
$S \geq 0$
$B > 0$
$T \geq 0$
$S < 0.9 \times B$

Notes/Equations

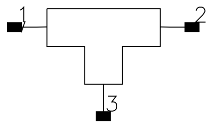
1. This item specifies stripline substrate with two conductor layers located symmetrically between ground planes. It can also be used for specifying stripline substrate with an offset center conductor layer. The only difference

between SSUB and SSUBO is that spacing parameter S is added to SSUBO to support the offset conductor. SSUBO with S=0 is the same as SSUB.

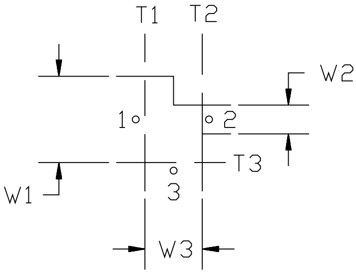
2. A stripline Subst parameter can either refer to an SSUB or an SSUBO. From a simulation viewpoint, reference to SSUBO is meaningful only for the SBCLIN, SOCLIN, SLINO, SLIN, SLOC, SLEF, and SLSC, because the intrinsic models for these components support offset conductor configuration. For all other stripline components, a reference to SSUBO is effectively the same as a reference to SSUB because the spacing parameter of SSUBO is ignored.
3. An SSUBO or an SSUB is required for all stripline components.
4. Cond1 and Cond2 control the mask layers on which the conductors are drawn. These are layout-only parameters and are not used by the simulator.
5. Gold conductivity is 4.1×10^{7} S/m. Rough modifies loss calculations. Conductivity for copper is 5.8×10^{7}.
6. In the case of SBCLIN and SOCLIN, the parameter P1Layer identifies the virtual layer (*cond1* or *cond2*) that the conductor associated with pin 1 is drawn on. All other stripline components have a Layer parameter that identifies the virtual layer (*cond1* or *cond2*) on which the conductor is drawn.
7. The virtual layer referred to by P1Layer or Layer (*cond1* or *cond2*) is mapped to an actual mask layer by the Cond1 or Cond2 parameter of the appropriate SSUB or SSUBO.

STEE (Stripline T-Junction)

Symbol



Illustration



Parameters

Subst = substrate instance name

W1 = conductor width at pin 1, in specified units

W2 = conductor width at pin 2, in specified units

W3 = conductor width at pin 3, in specified units

Temp = physical temperature, in °C

Layer = (ADS Layout option) conductor layer number: *cond1*, *cond2*

Range of Usage

$0.1 \le Z_{01} / Z_{03} \le 2.0$

where

Z_{01} = characteristic impedance of line connected to pin 1

Z_{03} = characteristic impedance of line connected to pin 3

Notes/Equations

1. The frequency-domain analytical model is a frequency dependent, lumped component model developed for Agilent by William J. Getsinger. The model is

based on the waveguide E-plane parallel-plate model analyzed by J. Schwinger and published in Marcuvitz's book, *Waveguide Handbook*. Based on the work of Oliner, the waveguide model is transformed into its dual stripline model. Conductor and dielectric losses are not included in the simulation.

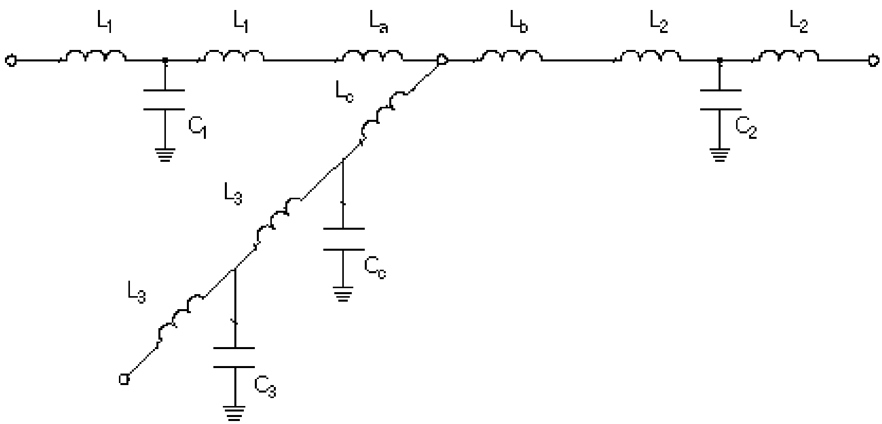
2. If the Subst parameter refers to an SSUBO whose spacing parameter S has a non-zero value, the component is considered offset for layout and electromagnetic analysis purposes. For other types of analyses, the offset is ignored.
3. Model assumes W1 = W2. If W1 $\neq$ W2, then the width is calculated as $\sqrt{(W_1 \times W_2)}$
4. For time-domain analysis, the frequency-domain analytical model is used.

References

[1] N. Marcuvitz, *Waveguide Handbook*, McGraw-Hill, 1951, pp. 337-350.

[2] A. Oliner, “Equivalent Circuits For Discontinuities in Balanced Strip Transmission Line,” *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-3, March 1955, pp. 134-143.

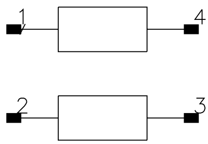
Equivalent Circuit



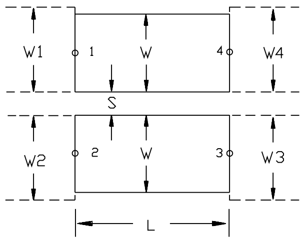
Chapter 6: Suspended Substrate Components

SSCLIN (Suspended Substrate Coupled Lines)

Symbol



Illustration



Parameters

Subst = substrate instance name

W = line width, in specified units

S = line spacing, in specified units

L = line length, in specified units

Temp = physical temperature

W1 = (ADS Layout option) width of line that connects to pin 1

W2 = (ADS Layout option) width of line that connects to pin 2

W3 = (ADS Layout option) width of line that connects to pin 3

W4 = (ADS Layout option) width of line that connects to pin 4

Range of Usage

$Er \geq 1.3$

$Hu \geq H$

$$\frac{H}{100} \leq Hl \leq 100 \times H$$

$$\frac{H}{50} \leq W \leq 50 \times H$$

$$\frac{H}{10} \leq S \leq 10 \times H$$

where

Er = dielectric constant (from SSSUB)

H = substrate thickness (from SSSUB)

Hl = lower ground plane to substrate spacing (from SSSUB)

Hu = upper ground plane to substrate spacing (from SSSUB)

Notes/Equations

1. The frequency-domain analytical model is a non-dispersive static and lossless model. Conductor thickness is ignored.
2. In generating a layout, adjacent transmission lines will be lined up with the inner edges of the conductor strips. If the connecting transmission lines are narrower than the coupled lines, they will be centered on the conductor strips.
3. W1, W2, W3 and W4 are layout-only parameters and do not affect the simulation results.

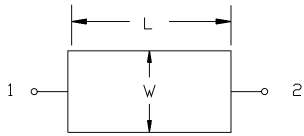
References

[1] John I. Smith, "The Even- and Odd-Mode Capacitance Parameters for Coupled Lines in Suspended Substrate," *IEEE Trans. Microwave Theory and Techniques*, Vol. MTT-19, May 1971, pp. 424-431.

SSLIN (Suspended Substrate Line)

Symbol

Illustration



Parameters

Subst = substrate instance name

W = line width, in specified units

L = line length, in specified units

Temp = physical temperature

Range of Usage

Er ≥ 1.0

Hu ≥ H

$\frac{H}{50} \leq W \leq H$

where

Er = dielectric constant (of the associated substrate)

HU = Height of the cover (of the associated substrate)

H = substrate thickness (of the associated substrate)

Notes/Equations:

1. Conductor loss and dielectric loss are included in the frequency-domain analytical model.

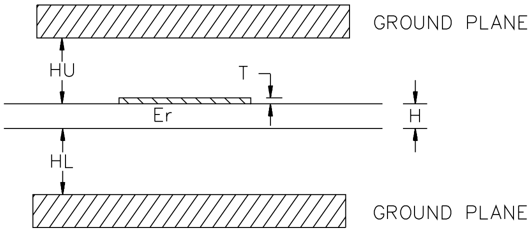
References

[1] A.K. Verma and G. Hassani Sadr, “Unified Dispersion Model for Multilayer Microstrip Line”, *IEEE Trans.*, MYY-40, July 1992.

SSSUB (Suspended Substrate)

Symbol

Illustration



Parameters

Er = relative dielectric constant

Mur = relative permeability

B = ground plane spacing, in specified units

T = conductor thickness, in specified units

Cond = conductor conductivity, in Siemens/meter

TanD = dielectric loss tangent

Cond1 = (ADS Layout option) layer to which cond is mapped; default = 1 (cond)

Cond2 = (ADS Layout option) layer to which cond2 is mapped; default = 2 (cond2)

Range of Usage

$Er \geq 1.3$
$Hu \geq H$
$0.01 \times H \leq Hl \leq 100 \times H$

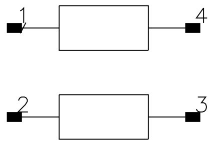
Notes/Equations

1. SSSUB sets up substrate parameters for suspended substrate components and is required for all suspended substrates.
2. Cond1 controls the layer on which the Mask layer is drawn; it is a layout-only parameter and is not used by the simulator.

Chapter 7: Transmission Line Components

CLIN (Ideal Coupled Transmission Lines)

Symbol



Parameters

Ze = even-mode characteristic impedance, in ohms

Zo = odd-mode characteristic impedance, in ohms

E = electrical length, in degrees

F = reference frequency for electrical length, in Hz

Range of Usage

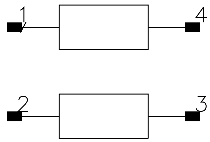
Ze > 0	Ze > Zo	Zo > 0
E ≠ 0	F > 0	

Notes/Equations

1. Odd- and even-mode phase velocities are assumed equal.
2. This component has no default artwork associated with it.

CLINP (Lossy Coupled Transmission Lines)

Symbol



Parameters

Ze = even-mode characteristic impedance, in ohms

Zo = odd-mode characteristic impedance, in ohms

L = physical length, in specified units

Ke = even-mode effective dielectric constant

Ko = odd-mode effective dielectric constant

Ae = even-mode attenuation, in dB per unit meter

Ao = odd-mode attenuation, in dB per unit meter

Temp = physical temperature, in °C

Range of Usage

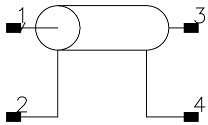
Ze > 0	Ze > Zo	Zo > 0	
Ke > 0	Ko > 0	Ae ≥ 0	Ao ≥ 0

Notes/Equations

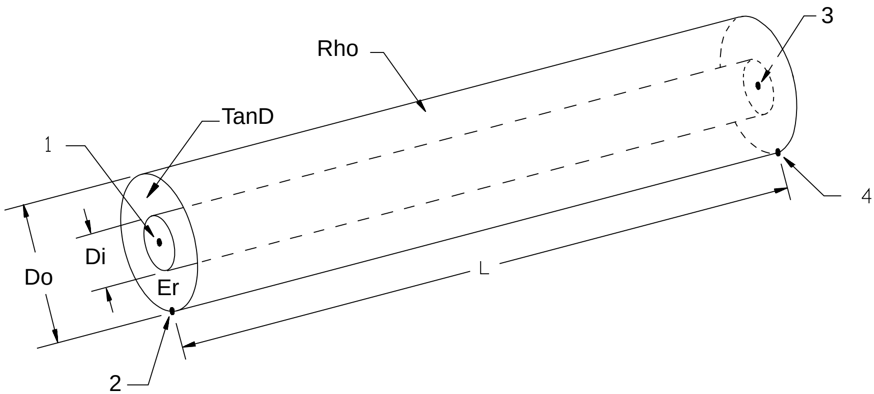
1. This component has no default artwork associated with it.

COAX (Coaxial Cable)

Symbol



Illustration



Parameters

Di = diameter of inner conductor, in specified units

Do = inner diameter of outer conductor, in specified units

L = length, in specified units

Er = dielectric constant of dielectric between inner and outer conductors

TanD = dielectric loss tangent

Rho = conductor resistivity (relative to copper)

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

Dimensions must support only TEM mode.
TanD ≥ 0
Rho ≥ 0
Er ≥ 1

Do > Di

$$\text{Simulation frequency} < \frac{190\ \text{GHz}}{\sqrt{Er} \times [Di(mm) + Do(mm)]}$$

Notes/Equations

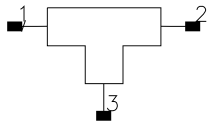
1. This component has no default artwork associated with it.

References

[1] Simon Ramo, John R. Whinnery, and Theodore Van Duzer. *Fields and Waves in Communication Electronics*, John Wiley and Sons, 1984, Table 5.11b, p. 252.

CoaxTee (Coaxial 3-Port T-Junction, Ideal, Lossless)

Symbol



Parameters

Z = line characteristic impedance, in specified units (value type: real, var)

L = length of all T-junction branches, in specified units (value type: real, var)

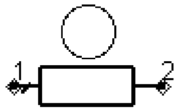
K = effective dielectric constant (value type: real, var)

Range of Usage

Z > 0
L ≥ 0
K ≥ 1.0

DR (Cylindrical Dielectric Resonator Coupled Transmission Line Section)

Symbol



Parameters

Z = Impedance of Coupled Line

K = Coupling Coefficient

Er = Dielectric Constant of the Dielectric Resonator

Mode = Mode of Operation, eg. Mode=1 means TE 01x mode

Qdr = Q-factor of the Dielectric Resonator

Rad = Radius of the Dielectric Resonator

H = Thickness of the Dielectric Resonator

ErL = Dielectric Constant of the Substrate Suspending the Dielectric Resonator

HL = Thickness of the Substrate Suspending the Dielectric Resonator

ErU = Dielectric Constant of the Superstrate Above

HU = Height of the Cover, Measured from the Top of the Dielectric Resonator

Cond = Conductivity of the upper and lower metal plates

Range of Usage

H, HL, HU, Rad, Qdr, Cond > 0
Er > ErL > ErU ≥ 1.0

Notes/Equations

1. The unloaded resonant frequency are calculated using variational technique.

   The unloaded quality factor is determined using:

   $$1/Qu = 1/Qdr + 1/Qcond$$

   where the Qcond is the quality factor due to the finite conductivity of the upper and lower conductor plates.

2. The coupling coefficient is not modeled in this release, due to the proximity effect between the dielectric resonator and the transmission line.

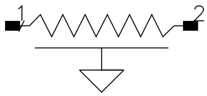
References

[1] T. Itoh and R. S Rudokas, “New method for computing the resonant frequencies of dielectric resonators,” *IEEE Trans.*, MTT-25, pp.52-54, Jan. 1977.

[2] R.K. Mongia, “Resonant Frequency of Cylindrical Dielectric Resonator Placed in an MIC Environment”, *IEEE Trans.*, MTT-38, pp. 802-804, June 1990.

RCLIN (Distributed R-C Network)

Symbol



Parameters

R = series resistance per meter

C = shunt capacitance per meter

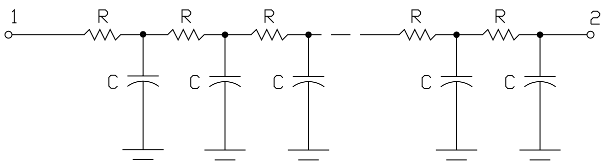
L = length, in specified units

Temp = physical temperature, in °C

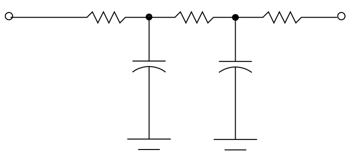
Notes/Equations

1. Total series resistance = R × L; total shunt capacitance = C × L
2. This component has no default artwork associated with it.

Equivalent Circuit

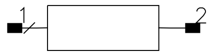


For transient analysis, a simplified lumped model is used, as shown below.

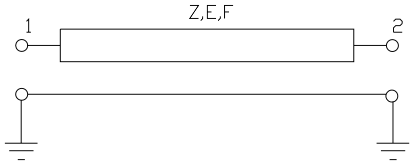


TLIN (Ideal 2-Terminal Transmission Line)

Symbol



Illustration



Parameters

Z = characteristic impedance, in ohms

E = electrical length, in degrees

F = reference frequency for electrical length, in hertz

Range of Usage

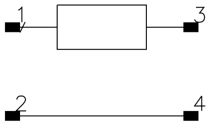
$Z \neq 0$
$F \neq 0$

Notes/Equations

1. This component has no default artwork associated with it.

TLIN4 (Ideal 4-Terminal Transmission Line)

Symbol



Parameters

Z = characteristic impedance, in ohms

E = electrical length, in degrees

F = reference frequency for electrical length, in hertz

Range of Usage

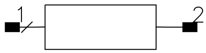
$Z \neq 0$
$F \neq 0$

Notes/Equations

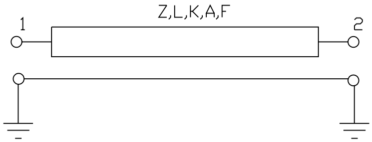
1. This component has no default artwork associated with it.

TLINP (2-Terminal Physical Transmission Line)

Symbol



Illustration



Parameters

Z = characteristic impedance, in ohms

L = physical length, in specified units

K = effective dielectric constant

A = attenuation, in dB per unit meter

F = frequency for scaling attenuation, in hertz

TanD = dielectric loss tangent

Mur = relative permeability

TanM = permeability

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

$Z > 0 \quad K \geq 1 \quad A \geq 0 \quad F \geq 0$

Notes/Equations

1. The A parameter specifies conductor loss only. To specify dielectric loss, specify non-zero value for TanD (to specify a frequency-dependent dielectric loss) or Sigma (to specify a constant dielectric loss).

   Because conductor and dielectric losses can be specified separately, the component is not assumed to be distortionless. Therefore, the actual characteristic impedance of the line may be complex and frequency-dependent.

This may cause reflections in your circuit that would not occur if a distortionless approximation were made.

$A(f) = A \quad (\text{for } F = 0)$

$A(f) = A(F) \times \sqrt{\frac{f}{F}} \quad (\text{for } F \neq 0)$

where

f = simulation frequency

F = reference frequency

2. TanD and Sigma are included in the shunt admittance to ground (g) in the rlgc network (series l, series r, shunt g, shunt c) which is internally in the model. In the model, the admittance g is proportional to the following sum:

   $g \sim Sigma/eps0/K + 2 \times \pi \times freq \times TanD$

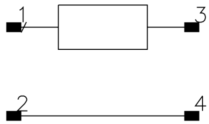
   This means that both Sigma (conductive loss in the substrate) and TanD (loss tangent loss in the substrate) can be defined with the correct frequency dependence (note that the frequency dependency of the Sigma term is different from the frequency dependency of the TanD term in the above sum). However, in practice, the loss in a given substrate is best described using either Sigma or TanD. For example, for a Silicon substrate one can define Sigma and set TanD to 0; for a board material, one can define TanD and set Sigma to 0.

3. For time-domain analysis, the frequency-domain analytical model is used.

4. This component has no default artwork associated with it.

TLINP4 (4-Terminal Physical Transmission Line)

Symbol



Parameters

Z = characteristic impedance, in ohms

L = physical length, in specified units

K = effective dielectric constant

A = attenuation, in dB per unit meter

F = frequency for scaling attenuation, in hertz

TanD = dielectric loss tangent

Mur = relative permeability

TanM = permeability

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

$Z > 0$
$K \geq 1$
$A \geq 0$
$F \geq 0$

Notes/Equations

1. The A parameter specifies conductor loss only. To specify dielectric loss, specify non-zero value for TanD (to specify a frequency-dependent dielectric loss) or Sigma (to specify a constant dielectric loss).
2. Since conductor and dielectric losses can be specified separately, the component is not assumed to be distortionless. Therefore, the actual characteristic impedance of the line may be complex and frequency-dependent. This may cause reflections in your circuit that would not occur if a distortionless approximation were made.

3. A(f) = A (for F = 0)

$$A(f) = A(F) \times \sqrt{\frac{f}{F}} \quad (\text{for } F \neq 0)$$

where

f = simulation frequency

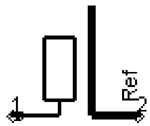
F = reference frequency

4. For time-domain analysis, the frequency-domain analytical model is used.

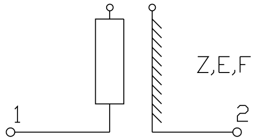
5. This component has no default artwork associated with it.

TLOC (Ideal Transmission Line Open-Circuited Stub)

Symbol



Illustration



Parameters

Z = characteristic impedance, in ohms

E = electrical length, in degrees

F = reference frequency for electrical length, in hertz

Range of Usage

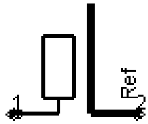
$Z \neq 0$
$F \neq 0$

Notes/Equations

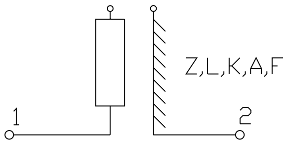
1. This component has no default artwork associated with it.
2. Port 2 should be connected to the system ground reference.

TLPOC (Physical Transmission Line Open-Circuited Stub)

Symbol



Illustration



Parameters

Z = characteristic impedance, in ohms

L = physical length, in specified units

K = effective dielectric constant

A = attenuation, in dB per unit meter

F = frequency for scaling attenuation, in hertz

TanD = dielectric loss tangent

Mur = relative permeability

TanM = permeability

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

$Z > 0$
$K \geq 1$
$A \geq 0$
$F \geq 0$

Notes/Equations

1. The A parameter specifies conductor loss only. To specify dielectric loss, specify non-zero value for TanD (to specify a frequency-dependent dielectric loss) or Sigma (to specify a constant dielectric loss).

2. Since conductor and dielectric losses can be specified separately, the component is not assumed to be distortionless. Therefore, the actual characteristic impedance of the line may be complex and frequency-dependent. This may cause reflections in your circuit that would not occur if a distortionless approximation were made.
3. A(f) = A (for F = 0)

   $$A(f) = A(F) \times \sqrt{\frac{f}{F}} \quad (\text{for } F \neq 0)$$

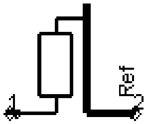
   where

   f = simulation frequency

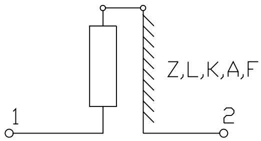
   F = reference frequency
4. For time-domain analysis, the frequency-domain analytical model is used.
5. This component has no default artwork associated with it.

TLPSC (Physical Transmission Line Short-Circuited Stub)

Symbol



Illustration



Parameters

Z = characteristic impedance, in ohms

L = physical length, in specified units

K = effective dielectric constant

A = attenuation, in dB per unit meter

F = frequency for scaling attenuation, in hertz

TanD = dielectric loss tangent

Mur = relative permeability

TanM = permeability

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

$Z > 0$
$K \geq 1$
$A \geq 0$
$F \geq 0$

Notes/Equations

1. The A parameter specifies conductor loss only. To specify dielectric loss, specify non-zero value for TanD (to specify a frequency-dependent dielectric loss) or Sigma (to specify a constant dielectric loss).
2. Because conductor and dielectric losses can be specified separately, the component is not assumed to be distortionless. Therefore, the actual characteristic impedance of the line may be complex and frequency-dependent. This may cause reflections in your circuit that would not occur if a distortionless approximation were made.
3. A(f) = A (for F = 0)

   $$A(f) = A(F) \times \sqrt{\frac{f}{F}} \quad (\text{for } F \neq 0)$$

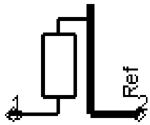
   where

   f = simulation frequency

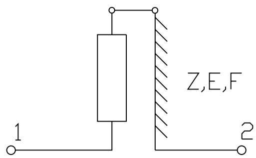
   F = reference frequency
4. For time-domain analysis, the frequency-domain analytical model is used.
5. This component has no default artwork associated with it.

TLSC (Ideal Transmission Line Short-Circuited Stub)

Symbol



Illustration



Parameters

Z = characteristic impedance, in ohms

E = electrical length, in degrees

F = reference frequency for electrical length, in hertz

Range of Usage

$Z \neq 0$
$F \neq 0$

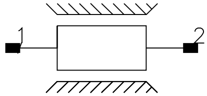
Notes/Equations

1. This component has no default artwork associated with it.
2. Port 2 should be connected to the system ground reference.

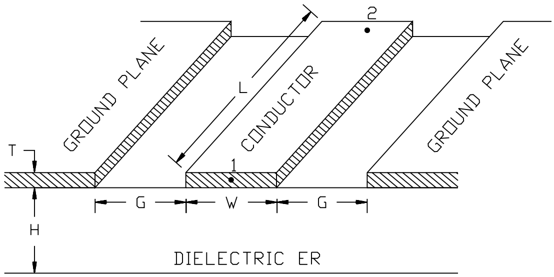
Chapter 8: Waveguide Components

CPW (Coplanar Waveguide)

Symbol



Illustration



Parameters

Subst= substrate instance name

W = center conductor width, in specified units

G = gap (spacing) between center conductor and ground plane, in specified units

L = center conductor length, in specified units

Temp = physical temperature, in °C

Range of Usage

$0.125 \times W \leq G \leq 4.5 \times W$
$W + 2G \leq 20 \times H$
$W > 0$
$G > 0$

Notes/Equations

1. The frequency-domain analytical model for the coplanar waveguide was developed for Agilent by William J. Getsinger and is based on a conformal mapping technique. The resulting formulas for the characteristic line impedance and effective dielectric constant are virtually the same as those published by Ghione and Naldi. However, the formulas are extended to account for conductors of finite thickness, conductor losses and dielectric losses.

The thickness correction is based on a technique proposed by Cohn. The conductor losses are calculated using Wheeler's incremental inductance rule. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dispersion at high frequencies is not included in the model.

2. No lower ground plane is included.
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

References

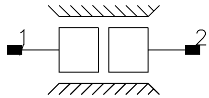
[1] S. B. Cohn, "Thickness Corrections for Capacitive obstacles and Strip Conductors," *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-8, November 1960, pp. 638-644.

[2] G. Ghione and C. Naldi. "Analytical Formulas for Coplanar Lines in Hybrid and Monolithic MICs," *Electronics Letters*, Vol. 20, No. 4, February 16, 1984, pp. 179-181.

[3] H. A. Wheeler, "Formulas for the Skin Effect," *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

CPWCGAP (Coplanar Waveguide, Center-Conductor Gap)

Symbol



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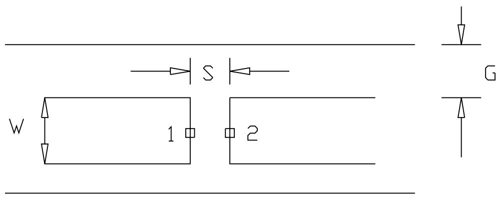


Parameters

Subst = substrate instance name

W = center conductor width, in specified units

G = gap (spacing) between center conductor and ground plane, in specified units

S = gap between end of center conductor and ground plane, in specified units

Temp = physical temperature, in °C

Range of Usage

$W > 0$
$G > 0$
$W \leq S \leq 1.4 \times W$

Notes/Equations

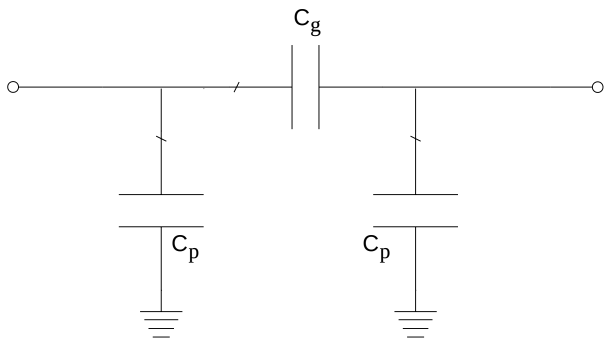
1. The center conductor gap in coplanar waveguide is modeled as a static, lumped component circuit. More specifically, the network is a pi-network with capacitive coupling between the center conductors and fringing capacitance from the center conductors to ground. The value of the capacitances are calculated from formula developed by William Getsinger for Agilent. The formula is based on an analysis of an analogous twin-strip configuration of the coplanar discontinuity as proposed by Getsinger. Additionally, metallization thickness correction is applied.

2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

References

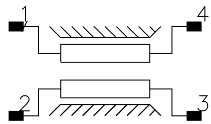
[1] Getsinger, W. J., "Circuit Duals on Planar Transmission Media," *IEEE MTT-S Int'l Microwave Symposium Digest*, 1983, pp. 154-156.

Equivalent Circuit



CPWCPL2 (Coplanar Waveguide Coupler (2 Center Conductors))

Symbol



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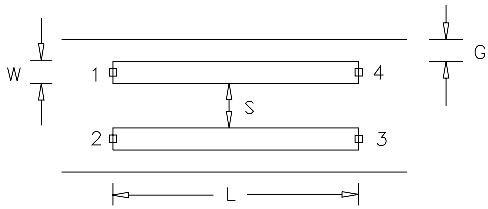


Parameters

Subst = substrate instance name

W = center conductor width, in specified units

G = gap (spacing) between center conductor and ground plane, in specified units

S = gap between end of center conductor and ground plane, in specified units

L = center conductor length, in specified units

Temp = physical temperature, in °C

Range of Usage

W > 0
G > 0
S > 0

Notes/Equations

1. The frequency-domain analytical model for a 2-conductor coupler in coplanar waveguide was developed for Agilent by William J. Getsinger and is based on a conformal mapping technique. The resulting formulas for the even and odd-mode characteristic line impedances and effective dielectric constants include the effects of finite conductor thickness, conductor losses and dielectric losses.

   The thickness correction is based on a technique proposed by Cohn. The conductor losses are calculated using Wheeler's incremental inductance rule.

The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dispersion at high frequencies is not included in the model.

2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

References

[1] Bastida, E. and N. Fanelli. "Interdigital Coplanar Directional Couplers," *Electronic Letters*, Vol. 16, August 14, 1980, pp. 645-646.

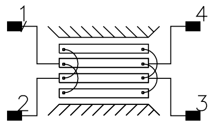
[2] S. B. Cohn, "Thickness Corrections for Capacitive obstacles and Strip Conductors," *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-8, November 1960, pp. 638-644.

[3] C. P. Wen, "Coplanar Waveguide Directional Couplers," *IEEE Transaction - MTT-18*, June 1970, pp. 318-322.

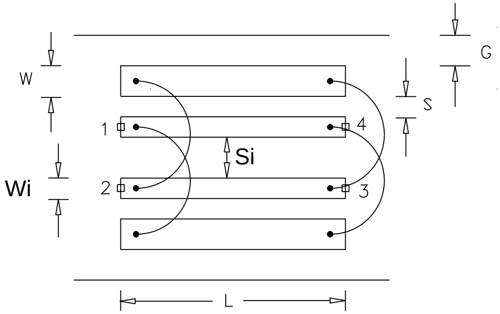
[4] H. A. Wheeler, "Formulas for the Skin Effect," *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

CPWCPL4 (Coplanar Waveguide Coupler (4 Center Conductors))

Symbol



Illustration



Parameters

Subst = substrate instance name

W = width of outer center conductors, in specified units

G = gap (spacing) between center conductors and ground plane, in specified units

S = gap between outer and inner center conductors, in specified units

Wi = width of inner center conductors, in specified units

Si = gap between inner center conductors, in specified units

L = center conductor length, in specified units

Temp = physical temperature, in °C

Range of Usage

W > 0
G > 0
S > 0
Wi > 0
Si > 0

Notes/Equations

1. The frequency-domain analytical model for a 4-conductor coupler in coplanar waveguide was developed for Agilent by William J. Getsinger and is based on a conformal mapping technique. The resulting formulas for the even and odd-mode characteristic line impedances and effective dielectric constants include the effects of finite conductor thickness, conductor losses and dielectric losses.

   The thickness correction is based on a technique proposed by Cohn. The conductor losses are calculated using Wheeler's incremental inductance rule. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dispersion at high frequencies is not included in the model.

2. Alternate center conductors are directly connected at ends of CPWCPL4 coupler.

3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

References

[1] E. Bastida and N. Fanelli. “Interdigital Coplanar Directional Couplers,” *Electronic Letters*, Vol. 16, August 14, 1980, pp. 645-646.

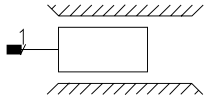
[2] S. B. Cohn, “Thickness Corrections for Capacitive obstacles and Strip Conductors,” *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-8, November 1960, pp. 638-644.

[3] C. P. Wen, “Coplanar Waveguide Directional Couplers,” *IEEE Transaction - MTT-18,* June, 1970, pp. 318-322.

[4] H. A. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

CPWEF (Coplanar Waveguide, Open-End Effect)

Symbol



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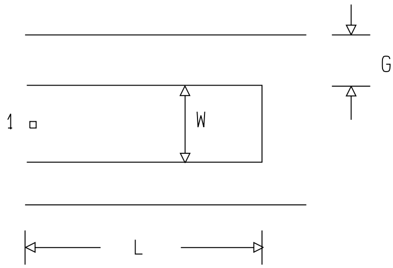


Parameters

Subst = substrate instance name

W = center conductor width, in specified units

G = gap (spacing) between center conductor and ground plane, in specified units

L = center conductor length, in specified units

Temp = physical temperature, in °C

Range of Usage

$W > 0$
$G > 0$
$W + 2 \times G \leq 20 \times H$
$0.125 \times W \leq G \leq 4.5 \times W$

where

H = substrate thickness (from associated CPWSUB)

Notes/Equations

1. The frequency-domain analytical model for the coplanar waveguide was developed for Agilent by William J. Getsinger and is based on a conformal mapping technique. The resulting formulas for the characteristic line impedance and effective dielectric constant are virtually the same as those

published by Ghione and Naldi. However, the formulas are extended to account for conductors of finite thickness, conductor losses and dielectric losses. The thickness correction is based on a technique proposed by Cohn.

The conductor losses are calculated using Wheeler's incremental inductance rule. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dispersion at high frequencies is not included in the model.

2. The end effect of the abruptly terminated line is modeled as a lumped capacitance to ground. The value of the capacitance is calculated from formula developed by William Getsinger for Agilent. The formula is based on an analysis of an analogous twin-strip configuration of the coplanar discontinuity as proposed by Getsinger.
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

References

[1] S. B. Cohn, “Thickness Corrections for Capacitive obstacles and Strip Conductors,” *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-8, November 1960, pp. 638-644.

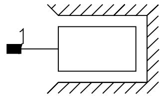
[2] G. Ghione and C. Naldi, “Analytical Formulas for Coplanar Line in Hybrid and Monolithic MICs,” *Electronics Letters*, Vol. 20, No. 4, February 16, 1984, pp. 179-181.

[3] W. J. Getsinger, “Circuit Duals on Planar Transmission Media,” *IEEE MTT-S Int'l Microwave Symposium Digest*, 1983, pp. 154-156.

[4] H. A. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

CPWEGAP (Coplanar Waveguide, End Gap)

Symbol



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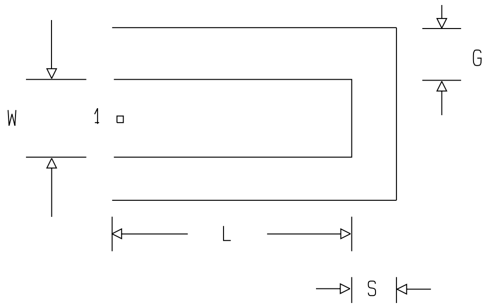


Parameters

Subst = substrate instance name

W = center conductor width, in specified units

G = gap (spacing) between center conductor and ground plane, in specified units

S = gap between end of center conductor and ground plane, in specified units

L = center conductor length, in specified units

Temp = physical temperature, in °C

Range of Usage

$W > 0, G > 0$
$W \leq S \leq 1.4 \times W$
$0.125 \times W \leq G \leq 4.5 \times W$
$W + 2 \times G \leq 20 \times H$

where

H = substrate thickness (from associated CPWSUB)

Notes/Equations

1. The frequency-domain analytical model for the coplanar waveguide was developed for Agilent by William J. Getsinger and is based on a conformal mapping technique. The resulting formulas for the characteristic line impedance and effective dielectric constant are virtually the same as those published by Ghione and Naldi. However, the formulas are extended to account for conductors of finite thickness, conductor losses and dielectric losses. The thickness correction is based on a technique proposed by Cohn. The conductor losses are calculated using Wheeler's incremental inductance rule. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dispersion at high frequencies is not included in the model.
2. The end effect of the abruptly terminated line is modeled as a lumped capacitance to ground. The value of the capacitance is calculated from formula developed by William Getsinger for Agilent. The formula is based on an analysis of an analogous twin-strip configuration of the coplanar discontinuity as proposed by Getsinger.
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

References

[1] S. B. Cohn, “Thickness Corrections for Capacitive obstacles and Strip Conductors,” *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-8, November 1960, pp. 638-644.

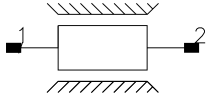
[2] W. J. Getsinger, “Circuit Duals on Planar Transmission Media,” *IEEE MTT-S Int'l Microwave Symposium Digest*, 1983, pp. 154-156.

[3] G. Ghione, and C. Naldi, “Analytical Formulas for Coplanar Line in Hybrid and Monolithic MICs,” *Electronics Letters*, Vol. 20, No. 4, February 16, 1984, pp. 179-181.

[4] H. A. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

CPWG (Coplanar Waveguide with Lower Ground Plane)

Symbol



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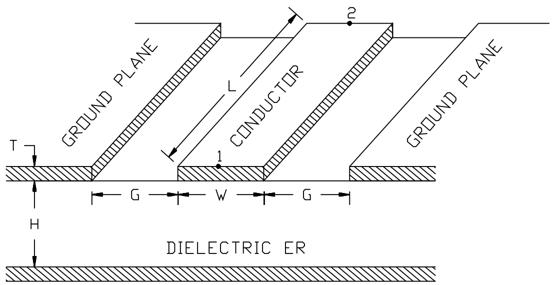


Parameters

Subst = substrate instance name

W = center conductor width, in specified units

G = gap (spacing) between center conductor and ground plane, in specified units

L = center conductor length, in specified units

Temp = physical temperature, in °C

Range of Usage

$0.125 \times W \leq G \leq 4.5 \times W$
$W + 2 \times G \leq 10 \times H$
$W > 0$
$G > 0$

where

H = substrate thickness

Notes/Equations

1. The frequency-domain analytical model for the coplanar waveguide was developed for Agilent by William J. Getsinger and is based on a conformal mapping technique. The resulting formulas for the characteristic line impedance and effective dielectric constant are virtually the same as those

published by Ghione and Naldi. However, the formulas are extended to account for conductors of finite thickness, conductor losses and dielectric losses. The thickness correction is based on a technique proposed by Cohn. The conductor losses are calculated using Wheeler's incremental inductance rule. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dispersion at high frequencies is not included in the model.

2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

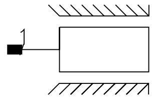
References

[1] G. Ghione and C. Naldi. “Parameters of Coplanar Waveguides with Lower Common Planes,” *Electronics Letters*, Vol. 19, No. 18, September 1, 1983, pp. 734-735.

[2] H. A. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

CPWOC (Coplanar Waveguide, Open-Circuited Stub)

Symbol



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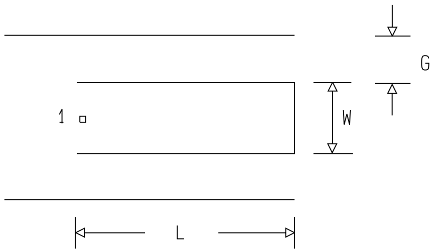


Parameters

Subst = substrate instance name

W = center conductor width, in specified units

G = gap (spacing) between center conductor and ground plane, in specified units

L = center conductor length, in specified units

Temp = physical temperature, in °C

Range of Usage

$W > 0$
$G > 0$
$0.125 \times W \leq G \leq 4.5 \times W$
$W + 2 \times G \leq 20 \times H$

where

H = substrate thickness (from associated CPWSUB)

Notes/Equations

1. The frequency-domain analytical model for the coplanar waveguide was developed for Agilent by William J. Getsinger and is based on a conformal mapping technique. The resulting formulas for the characteristic line impedance and effective dielectric constant are virtually the same as those

published by Ghione and Naldi. However, the formulas are extended to account for conductors of finite thickness, conductor losses and dielectric losses. The thickness correction is based on a technique proposed by Cohn.

The conductor losses are calculated using Wheeler's incremental inductance rule. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dispersion at high frequencies is not included in the model. No end effects are included in the model.

2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

References

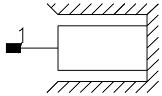
[1] S. B. Cohn, "Thickness Corrections for Capacitive Obstacles and Strip Conductors," *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-8, November 1960, pp. 638-644.

[2] G. Ghione and C. Naldi, "Analytical Formulas for Coplanar Line in Hybrid and Monolithic MICs," *Electronics Letters*, Vol. 20, No. 4, February 16, 1984, pp. 179-181.

[3] H. A. Wheeler, "Formulas for the Skin Effect," *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

CPWSC (Coplanar Waveguide, Short-Circuited Stub)

Symbol



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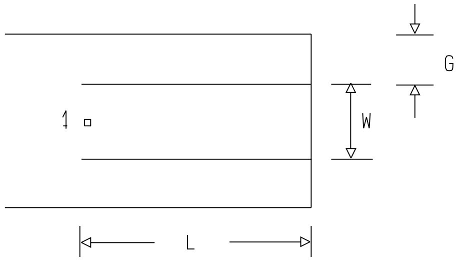


Parameters

Subst = substrate instance name

W = center conductor width, in specified units

G = gap (spacing) between center conductor and ground plane, in specified units

L = center conductor length, in specified units

Temp = physical temperature, in °C

Range of Usage

$W > 0$
$G > 0$
$0.125 \times W \leq G \leq 4.5 \times W$
$W + 2 \times G \leq 20 \times H$

where

H = substrate thickness (from associated CPWSUB)

Notes/Equations

1. The frequency-domain analytical model for the coplanar waveguide was developed for Agilent by William J. Getsinger and is based on a conformal mapping technique. The resulting formulas for the characteristic line impedance and effective dielectric constant are virtually the same as those

published by Ghione and Naldi. However, the formulas are extended to account for conductors of finite thickness, conductor losses and dielectric losses. The thickness correction is based on a technique proposed by Cohn.

The conductor losses are calculated using Wheeler's incremental inductance rule. The attenuation formula provides a smooth transition from dc resistance to resistance due to skin effect at high frequencies. Dispersion at high frequencies is not included in the model.

2. The end effect of the abruptly terminated line is modeled as a lumped inductance to ground. The value of the inductance is calculated from formula developed by William Getsinger for Agilent. The formula is based on an analysis of an analogous twin-strip configuration of the coplanar discontinuity as proposed by Getsinger.
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

References

[1] S. B. Cohn, “Thickness Corrections for Capacitive obstacles and Strip Conductors,” *IRE Trans. on Microwave Theory and Techniques*, Vol. MTT-8, November 1960, pp. 638-644.

[2] W. J. Getsinger, “Circuit Duals on Planar Transmission Media,” *IEEE MTT-S Int'l Microwave Symposium Digest*, 1983, pp. 154-156.

[3] G. Ghione, and C. Naldi, “Analytical Formulas for Coplanar Line in Hybrid and Monolithic MICs,” *Electronics Letters*, Vol. 20, No. 4, February 16, 1984, pp. 179-181.

[4] H. A. Wheeler, “Formulas for the Skin Effect,” *Proc. IRE*, Vol. 30, September, 1942, pp. 412-424.

CPWSUB (Coplanar Waveguide Substrate)

Symbol

Parameters

H = substrate thickness, in specified units

Er = relative dielectric constant

Mur = relative permeability

Cond = conductor conductivity

T = conductor thickness, in specified units

TanD = dielectric loss tangent

Rough = conductor surface roughness, in specified units

Cond1 = (ADS Layout option) layer to which Cond is mapped; default=*cond*

Range of Usage

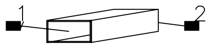
H > 0
Er ≥ 1.0
T ≥ 0

Notes/Equations

1. CPWSUB is required for all coplanar waveguide components.
2. The substrate defined by this component does not have a lower ground plane.
3. Losses are accounted for when Rough > 0 and T > 0. The Rough parameter modifies the loss calculations.
4. Cond1 controls the layer on which the Mask layer is drawn; it is a Layout-only parameter and is not used by the simulator.

RWG (Rectangular Waveguide)

Symbol



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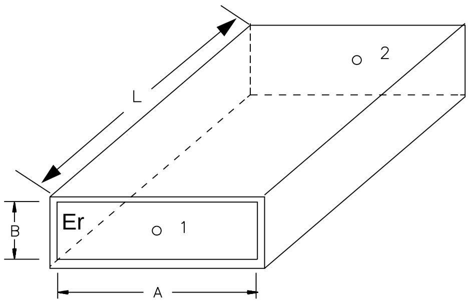


Parameters

A = inside width of enclosure, in specified units

B = inside height of enclosure, in specified units

L = waveguide length, in specified units

Er = relative dielectric constant

Rho = metal resistivity (relative to copper)

TanD = dielectric loss tangent

Mur = relative permeability

TanM = permeability

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

A > B
TE10 and evanescent (below cutoff) modes are supported.

Notes/Equations

1. The power-voltage definition of waveguide impedance is used in the frequency-domain analytical model.

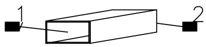
2. Conductor losses can be specified using Rho or TanM or both. Dielectric loss can be specified using TanD or Sigma or both.
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
4. If the values of A and B are such that B > A, then B is assumed to be the width, and A is assumed to be the height.
5. This component has no default artwork associated with it.

References

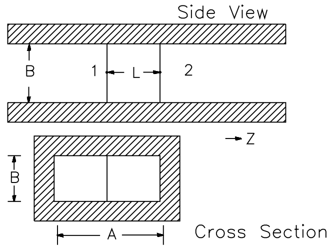
[1] R. Ramo and J. R. Whinnery, *Fields and Waves in Modern Radio*, 2nd Ed., John Wiley and Sons, New York, 1960.

RWGINDF (Rectangular Waveguide Inductive Fin)

Symbol



Illustration



Parameters

A = inside width of enclosure, in specified units

B = inside height of enclosure, in specified units

L = length of the fin, in specified units

Er = relative dielectric constant

Rho = metal resistivity (relative to copper)

TanD =dielectric loss tangent

Mur = relative permeability

TanM = permeability

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

$0.02 \leq L/A \leq 1.1$
B < A/2
TE10 mode only
Simulation frequency > FC

where

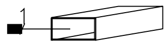
FC = cutoff frequency of waveguide

Notes/Equations

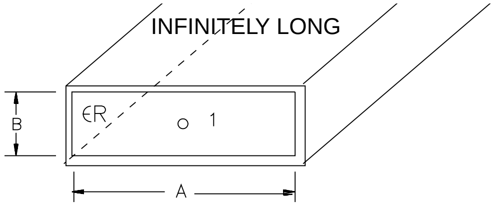
1. Strip is centered between sidewalls of waveguide. Strip contacts top and bottom of waveguide.
2. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
3. This component has no default artwork associated with it.

RWGT (Rectangular Waveguide Termination)

Symbol



Illustration



Parameters

A = inside width of enclosure, in specified units

B = inside height of enclosure, in specified units

Er = relative dielectric constant

Rho = metal resistivity (relative to copper)

TanD = dielectric loss tangent

Mur = relative permeability

TanM = permeability

Sigma = dielectric conductivity

Temp = physical temperature, in °C

Range of Usage

A > B
TE10 and evanescent (below cutoff) modes are supported.

Notes/Equations

1. The power-voltage definition of waveguide impedance is used in the frequency-domain analytical model.
2. Conductor losses can be specified using Rho or TanM or both. Dielectric loss can be specified using TanD or Sigma or both.
3. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

4. If the values of A and B are such that B > A, then B is assumed to be the width, and A is assumed to be the height.
5. This component has no default artwork associated with it.

References

[1] R. Ramo and J. R. Whinnery. *Fields and Waves in Modern Radio*, 2nd Ed., John Wiley and Sons, New York, 1960.

Chapter 9: Printed Circuit Board Components

PCB Model Basis and Limits

The printed circuit board line components available in this library are based on a quasi-static analysis in an enclosed region with stratified layers of a single dielectric.

The dielectric layers and the metal enclosure are specified by PCSUBn (n=1, ... , 7) whereas the coupled lines are specified by PCLINn (n=1, ... , 10). There can be any combination of 1 to 10 conducting strips and 1 to 7 dielectric layers. In other words, for a given PCLINn, its conductors can be associated with any metal layers of a given PCSUBn.

All of the dielectric layers of a PCSUBn have the same dielectric constant. However, each dielectric layer can have a different thickness. There can be an air layer above the top-most dielectric or below the bottom-most dielectric. When an air layer exists, there may be a conductor pattern at the air-dielectric interface. The structure can be open or covered by a conducting shield at the top and at the bottom. The sidewalls are required.

Method of Analysis

The model is that of N coupled TEM transmission lines. Laplace's equation is solved in the plane transverse to the direction of propagation subject to appropriate boundary conditions at the conducting surfaces. Then the solution of Laplace's equation is used to formulate the indefinite admittance matrix for N-coupled TEM transmission lines. The solution of Laplace's equation is by means of finite differences.

The quasi-static solution makes these suitable for use at RF frequencies and for high-speed digital applications.

Because the analysis is quasi-static, the time required for analysis is improved. In contrast to a full-wave analysis, which is expected to be slow, a quasi-static analysis is expected to be relatively fast. Essentially all of the analysis time is required for the solution of the Laplace's equation.

The mesh size used in the finite difference solution of Laplace's equation is the single most important determinant of analysis time for a given structure. Use discretion when specifying the width of the enclosure (parameter W of PCSUBn) and the heights of the upper and lower conducting shields (Hu and Hl parameters of PCSUBn). Specifying large values for these parameters requires a large number of cells for the mesh resulting in longer simulation times. If sidewalls are not actually present then a rough guide is to use a spacing of 10 conductor widths to the sidewalls instead of specifying a large number for the width of enclosure.

Assumptions and Limitations

The conductor thickness is used solely for loss calculations. In the solution of Laplace's equation the conductors are assumed to have zero thickness. Conductor losses are effectively ignored if the thickness is set to zero or if Rho is set to 0. Conductor losses include both dc and skin effect calculations.

The dielectric loss is accounted for by non-zero dielectric conductivity, Sigma. Provision for a frequency-dependent loss tangent component has been made by specification of the TanD parameter, but is not used in the present implementation.

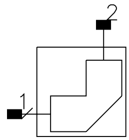
In principle, the aspect ratio (conductor width to dielectric thickness or horizontal spacing between conductors) is unrestricted. In reality, the problem size (and, therefore, calculation time) increases greatly for aspect ratios less than 0.1 or greater than 10. It is highly recommended to keep the aspect ratio within this range.

References

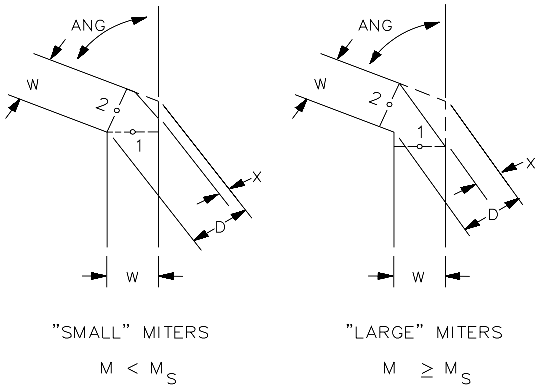
Vijai K. Tripathi and Richard J. Bucolo, “A Simple Network Analog Approach for the Quasi-Static Characteristics of General Lossy, Anisotropic, Layered Structures,” *IEEE Transactions on Microwave Theory and Techniques*, Vol. MTT-33, No. 12, pp. 1458-1464; December 1985.

PCBEND (PCB Bend (Arbitrary Angle/Miter))

Symbol



Illustration



$$M = \frac{X}{D}$$

$$M_S = \sin^2\left(\frac{Angle}{2}\right)$$

Parameters

Subst = printed circuit substrate name (PCSUBi, i=1,2, ... , 7)

W = conductor width, in specified units

CLayer = conductor layer number

Angle = angle of bend, in degrees

M = miter fraction

Temp = physical temperature, in °C

Range of Usage

$W > 0$
$1 \leq CLayer \leq Nlayers+1$
$-90 \leq Angle \leq 90$, degrees

where

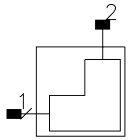
Nlayers = number of layers specified by PCSUBi (i=1,2, ... , 7)

Notes/Equations

1. This component is modeled as an ideal short-circuit between pins 1 and 2. It is provided mainly to facilitate interconnections between PCB lines oriented at different angles in layout.
2. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2, ... , 7) if Hl=0.
3. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).
4. In layout, a positive value for Angle draws a counterclockwise bend from pin 1 to 2; a negative value for Angle draws a clockwise bend.
5. Layout artwork requires placing a PCSUBi(i=1, 2, ... , 7) prior to placing the component directly in the Layout window.

PCCORN (Printed Circuit Corner)

Symbol



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1, 2, ... , 7)

W = conductor width, in specified units

CLayer = conductor layer number

Temp = physical temperature, in °C

Range of Usage

W > 0

1 ≤ CLayer ≤ Nlayers+1

where

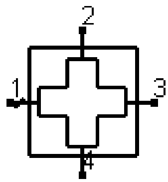
Nlayers = number of layers specified by PCSUBi (i=1, 2, ... , 7)

Notes/Equations

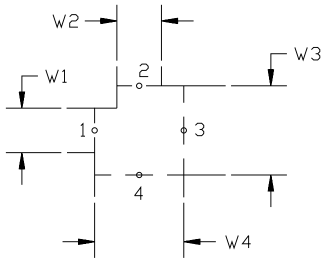
1. This component is treated as an ideal connection between pins 1 and 2, and is provided mainly to facilitate interconnections between PCB lines in layout.
2. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1, 2, ... , 7) if Hl=0.
3. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).
4. Layout artwork requires placing a PCSUBi(i=1, 2, ... , 7) prior to placing the component directly in the Layout window.

PCCROS (Printed Circuit Cross-Junction)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1, 2, ... , 7)

W1 = width at pin 1, in specified units

W2 = width at pin 2, in specified units

W3 = width at pin 3, in specified units

W4 = width at pin 4, in specified units

CLayer = conductor layer number

Temp = physical temperature, in °C

Range of Usage

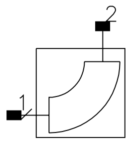
W1 > 0,   W2 > 0,   W3 > 0,   W4 > 0
1 ≤ CLayer ≤ Nlayers+1
where
   Nlayers = number of layers specified by PCSUBi (i=1,2, ... , 7)

Notes/Equations

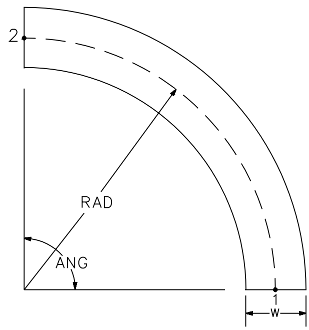
1. This component is treated as an ideal connection between pins 1, 2, 3, and 4, and has been provided mainly to facilitate interconnections among PCB lines in layout.
2. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2, ... , 7) if Hl=0.
3. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).
4. Layout artwork requires placing a PCSUBi (i=1, 2, ... , 7) prior to placing the component directly in the Layout window.

PCCURVE (PCB Curve)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1,2, ... , 7)

W = conductor width, in specified units

CLayer = conductor layer number

Angle = angle subtended by the bend, in degrees

Radius = radius (measured to center of conductor), in specified units

Temp = physical temperature, in °C

Range of Usage

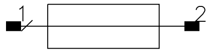
W > 0
1 ≤ CLayer ≤ Nlayers+1
–180 ≤ Angle ≤ 180, degrees
Radius ≥ W/2
where
Nlayers = number of layers specified by PCSUBi (i=1,2, ... , 7)

Notes/Equations

1. This component is modeled as PCLIN1, assuming a single straight line of length Radius×Angle, where Angle is in radians. The single line is assumed to be located halfway between and parallel to the sidewalls. The distance between the sidewalls is given as part of the PCSUBi specification.
2. The distance between the sidewalls is typically the width of the metal enclosure around the PC board. If the metal enclosure is absent, width of the PC board itself can be specified and treated as the distance between the sidewalls. Note, however, that the simulation time increases rapidly as the sidewall distance increases. If the effect of the sidewalls is not important, it is highly recommended to set it to approximately 10 times the line width for this component.
3. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2, ... , 7) if Hl=0.
4. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).
5. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
6. This component has been provided mainly to facilitate interconnections between PCB lines oriented at different angles in layout.
7. In layout, a positive value for Angle specifies a counterclockwise curvature; a negative value specifies a clockwise curvature.
8. Layout artwork requires placing a PCSUBi (i=1, 2, ... , 7) prior to placing the component directly in the Layout window.

PCILC (Printed Circuit Inter-layer Connection)

Symbol



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1,2, ... , 7)

D = diameter of via hole, in specified units

CLayer1 = conductor layer number at pin 1

CLayer2 = conductor layer number at pin 2

Temp = physical temperature, in °C

Ang = (ADS Layout option) angle of orientation at pin 2, in degrees

W1 = (ADS Layout option) width of square pad or diameter of circular pad on CLayer1, in specified units

W2 = (ADS Layout option) width of square pad or diameter of circular pad on CLayer2, in specified units

Type = (ADS Layout option) type of via pad, *square* or *circular*

Range of Usage

1 ≤ CLayer1, CLayer2 ≤ Nlayers+1
where
  Nlayers = number of layers specified by PCSUBi (i= 1,2, ... , 7)

Notes/Equations

1. This component is modeled as an ideal connection between pin 1 and pin 2 and has been provided mainly to facilitate interconnections between PCB components placed on different conductor layers in layout.

2. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2, ... , 7) if Hl=0.

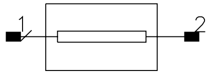
3. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric

layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).

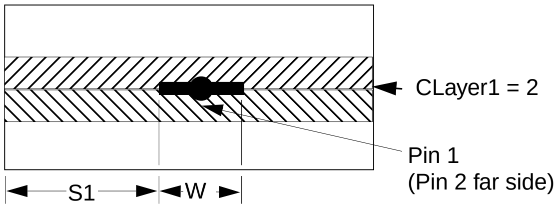
4. Type specifies the type of the via pad. Type=square draws a square pad on CLayer1 and CLayer2; Type=circular draws a circular pad on CLayer1 and CLayer2.
5. Layout artwork requires placing a PCSUBi (i=1, 2, ... , 7) prior to placing the component directly in the Layout window.

PCLIN1 (1 Printed Circuit Line)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1,2, ... , 7)

W = width of line, in specified units

S1 = distance from line to left wall, in specified units

CLayer1 = conductor layer number (value type: integer)

L = length of line, in specified units

Temp = physical temperature, in °C

Range of Usage

W > 0
S1 > 0
1 ≤ CLayer1 ≤ Nlayers+1
where
Nlayers = number of layers specified by PCSUBi (i=1,2, ... , 7)

Notes/Equations

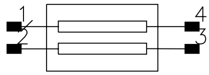
1. The 2-layer illustration shown is only an example. PCSUBi has between 1 and 7 dielectric layers, and any conductor can be placed above or below any dielectric layer. Conductors can overlap if desired.

2. The frequency-domain analytical model for this component is a non-dispersive static model developed by Agilent. Refer to the section "PCB Model Basis and Limits" on page 9-1 at the beginning of this chapter.

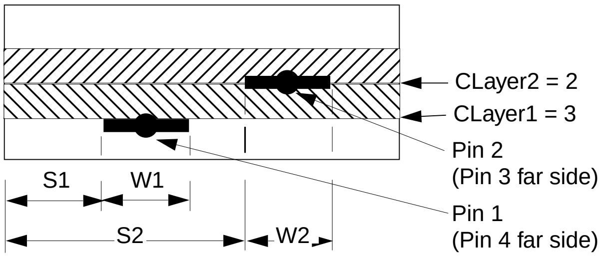
3. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2, ... , 7) if Hl=0.
4. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).
5. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

PCLIN2 (2 Printed Circuit Coupled Lines)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1,2, ... , 7)

W1 = width of line #1, in specified units

S1 = distance from line #1 to left wall, in specified units

CLayer1 = conductor layer number - line #1 (value type: integer)

W2 = width of line #2, in specified units

S2 = distance from line #2 to left wall, in specified units

CLayer2 = conductor layer number - line #2 (value type: integer)

L = length of the lines, in specified units

Temp = physical temperature, in °C

Range of Usage

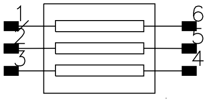
W1 > 0, W2 > 0
S1 > 0, S2 > 0
1 ≤ CLayer1 ≤ Nlayers+1
1 ≤ CLayer2 ≤ Nlayers+1
where
Nlayers = number of layers specified by PCSUBi (i=1,2, ... , 7)

Notes/Equations

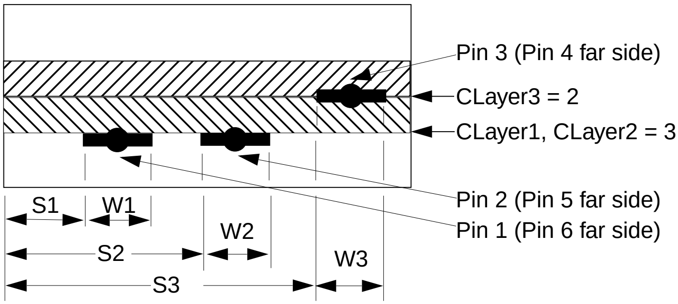
1. The 2-layer illustration shown is only an example. PCSUBi has between 1 and 7 dielectric layers, and any conductor can be placed above or below any dielectric layer. Conductors can overlap if desired.
2. The frequency-domain analytical model for this component is a non-dispersive static model developed by Agilent. Refer to the section "PCB Model Basis and Limits" on page 9-1 at the beginning of this chapter.
3. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2, ... , 7) if Hl=0.
4. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).
5. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

PCLIN3 (3 Printed Circuit Coupled Lines)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1,2, ... , 7)

W1 = width of line #1, in specified units

S1 = distance from line #1 to left wall, in specified units

CLayer1 = conductor layer number - line #1 (value type: integer)

W2 = width of line #2, in specified units

S2 = distance from line #2 to left wall, in specified units

CLayer2 = conductor layer number - line #2 (value type: integer)

W3 = width of line #3, in specified units

S3 = distance from line #3 to left wall, in specified units

CLayer3 = conductor layer number - line #3 (value type: integer)

L = length of the lines, in specified units

Temp = physical temperature, in °C

Range of Usage

W1 > 0,   W2 > 0,   W3 > 0

S1 > 0,   S2 > 0,   S3 > 0

$1 \leq$ CLayer1 $\leq$ Nlayers+1

$1 \leq$ CLayer2 $\leq$ Nlayers+1

$1 \leq$ CLayer3 $\leq$ Nlayers+1

where

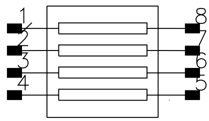
Nlayers = number of layers specified by PCSUBi (i=1,2, ... , 7)

Notes/Equations

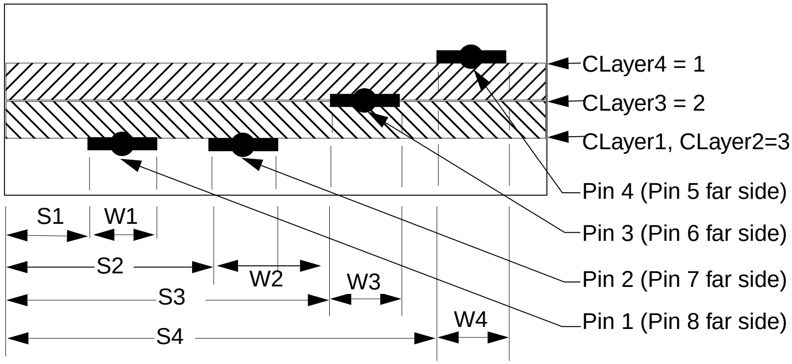
1. The 2-layer illustration shown is only an example. PCSUBi has between 1 and 7 dielectric layers, and any conductor can be placed above or below any dielectric layer. Conductors can overlap if desired.
2. The frequency-domain analytical model for this component is a non-dispersive static model developed by Agilent. Refer to the section "PCB Model Basis and Limits" on page 9-1 at the beginning of this chapter.
3. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2, ... , 7) if Hl=0.
4. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).
5. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

PCLIN4 (4 Printed Circuit Coupled Lines)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1,2, ... , 7)

W1 = width of line #1, in specified units

S1 = distance from line #1 to left wall, in specified units

CLayer1 = conductor layer number - line #1 (value type: integer)

W2 = width of line #2, in specified units

S2 = distance from line #2 to left wall, in specified units

CLayer2 = conductor layer number - line #2 (value type: integer)

W3 = width of line #3, in specified units

S3 = distance from line #3 to left wall, in specified units

CLayer3 = conductor layer number - line #3 (value type: integer)

W4 = width of line #4, in specified units

S4 = distance from line #4 to left wall, in specified units

CLayer4 = conductor layer number - line #4 (value type: integer)

L = length of the lines, in specified units

Temp = physical temperature, in °C

Range of Usage

W1 > 0,   W2 > 0,   W3 > 0,   W4 > 0

S1 > 0,   S2 > 0,   S3 > 0,   S4 > 0

1 ≤ CLayer1 ≤ Nlayers+1

1 ≤ CLayer2 ≤ Nlayers+1

1 ≤ CLayer3 ≤ Nlayers+1

1 ≤ CLayer4 ≤ Nlayers+1

where

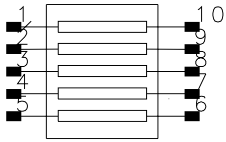
Nlayers = number of layers specified by PCSUBi (i=1,2, ... , 7)

Notes/Equations

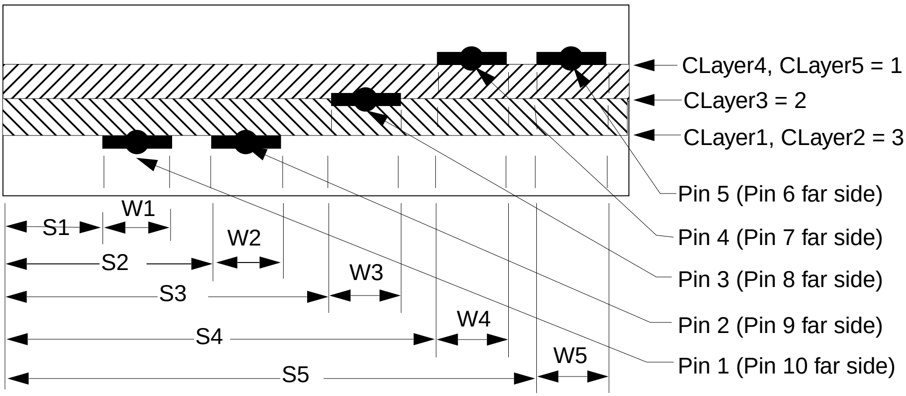
1. The 2-layer illustration shown is only an example. The PCSUBi has between 1 and 7 dielectric layers, and any conductor can be placed above or below any dielectric layer. Conductors can overlap if desired.
2. The frequency-domain analytical model for this component is a non-dispersive static model developed by Agilent. Refer to the section "PCB Model Basis and Limits" on page 9-1 at the beginning of this chapter.
3. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2, ... , 7) if Hl=0.
4. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).
5. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

PCLIN5 (5 Printed Circuit Coupled Lines)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1, 2, ... , 7)

W1 = width of line #1, in specified units

S1 = distance from line #1 to left wall, in specified units

CLayer1 = conductor layer number - line #1 (value type: integer)

W2 = width of line #2, in specified units

S2 = distance from line #2 to left wall, in specified units

CLayer2 = conductor layer number - line #2 (value type: integer)

W3 = width of line #3, in specified units

S3 = distance from line #3 to left wall, in specified units

CLayer3 = conductor layer number - line #3 (value type: integer)

W4 = width of line #4, in specified units

S4 = distance from line #4 to left wall, in specified units

CLayer4 = conductor layer number - line #4 (value type: integer)

W5 = width of line #5, in specified units

S5 = distance from line #5 to left wall, in specified units

CLayer5 = conductor layer number - line #5 (value type: integer)

L = length of the lines, in specified units

Temp = physical temperature, in °C

Range of Usage

W1 > 0, W2 > 0, W3 > 0, W4 > 0, W5 > 0

S1 > 0, S2 > 0 S3 > 0, S4 > 0, S5 > 0

1 ≤ CLayer1 ≤ Nlayers+1

1 ≤ CLayer2 ≤ Nlayers+1

1 ≤ CLayer3 ≤ Nlayers+1

1 ≤ CLayer4 ≤ Nlayers+1

1 ≤ CLayer5 ≤ Nlayers+1

where

Nlayers = number of layers specified by PCSUBi (i=1, 2, ... , 7)

Notes/Equations

1. The 2-layer illustration shown is only an example. PCSUBi has between 1 and 7 dielectric layers, and any conductor can be placed above or below any dielectric layer. Conductors can overlap if desired.

2. The frequency-domain analytical model for this component is a non-dispersive static model developed by Agilent. Refer to the section “PCB Model Basis and Limits” on page 9-1 at the beginning of this chapter.

3. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2, ... , 7) if Hl=0.

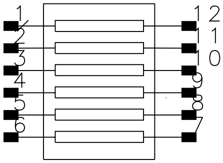
4. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of

the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).

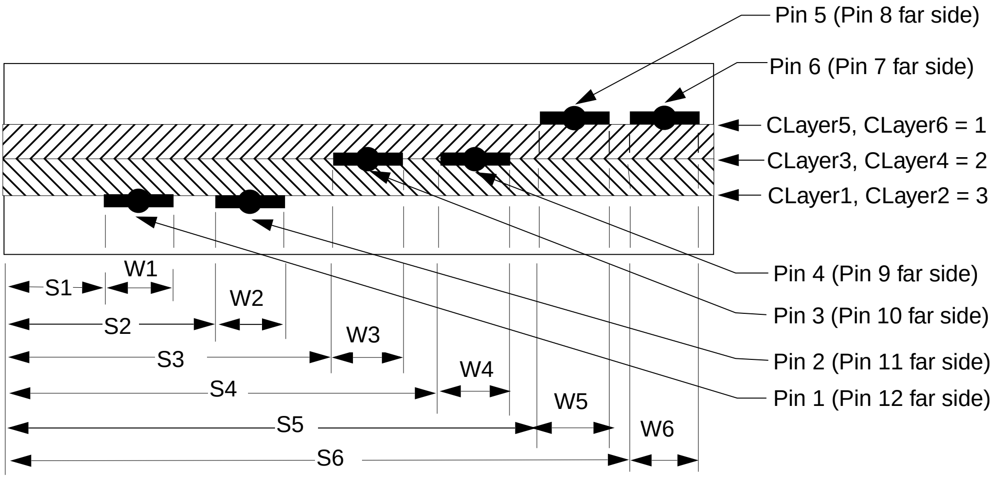
5. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

PCLIN6 (6 Printed Circuit Coupled Lines)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1, 2, ... , 7)

W1 = width of line #1, in specified units

S1 = distance from line #1 to left wall, in specified units

CLayer1 = conductor layer number - line #1 (value type: integer)

W2 = width of line #2, in specified units

S2 = distance from line #2 to left wall, in specified units

CLayer2 = conductor layer number - line #2 (value type: integer)

W3 = width of line #3, in specified units

S3 = distance from line #3 to left wall, in specified units

CLayer3 = conductor layer number - line #3 (value type: integer)

W4 = width of line #4, in specified units

S4 = distance from line #4 to left wall, in specified units

CLayer4 = conductor layer number - line #4 (value type: integer)

W5 = width of line #5, in specified units

S5 = distance from line #5 to left wall, in specified units

CLayer5 = conductor layer number - line #5 (value type: integer)

W6 = width of line #6, in specified units

S6 = distance from line #6 to left wall, in specified units

CLayer6 = conductor layer number - line #6 (value type: integer)

L = length of the lines, in specified units

Temp = physical temperature, in °C

Range of Usage

$W1 > 0, \quad W2 > 0, \quad W3 > 0, \quad W4 > 0, \quad W5 > 0, \quad W6 > 0$

$S1 > 0, \quad S2 > 0, \quad S3 > 0, \quad S4 > 0, \quad S5 > 0, \quad S6 > 0$

$1 \leq CLayer1 \leq Nlayers+1$

$1 \leq CLayer2 \leq Nlayers+1$

$1 \leq CLayer3 \leq Nlayers+1$

$1 \leq CLayer4 \leq Nlayers+1$

$1 \leq CLayer5 \leq Nlayers+1$

$1 \leq CLayer6 \leq Nlayers+1$

where

Nlayers = number of layers specified by PCSUBi (i=1, 2, ... , 7)

Notes/Equations

1. The 2-layer illustration shown is only an example. PCSUBi has between 1 and 7 dielectric layers, and any conductor can be placed above or below any dielectric layer. Conductors can overlap if desired.

2. The frequency-domain analytical model for this component is a non-dispersive static model developed by Agilent. Refer to the section "PCB Model Basis and Limits" on page 9-1 at the beginning of this chapter.

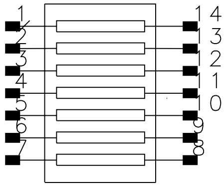
3. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2, ... , 7) if Hl=0.

4. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).

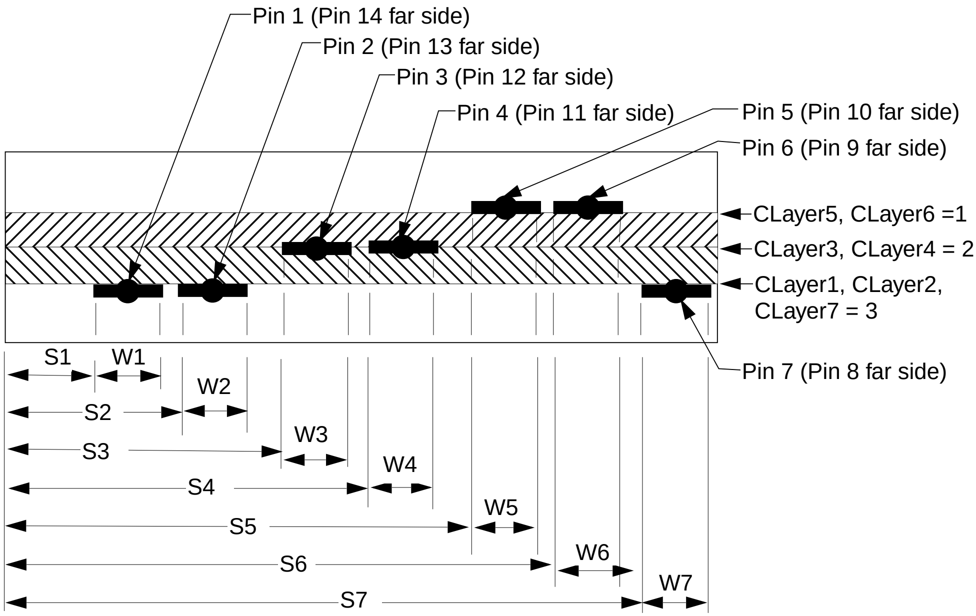
5. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

PCLIN7 (7 Printed Circuit Coupled Lines)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1, 2, ... , 7)

W1 = width of line #1, in specified units

S1 = distance from line #1 to left wall, in specified units

CLayer1 = conductor layer number - line #1 (value type: integer)

W2 = width of line #2, in specified units

S2 = distance from line #2 to left wall, in specified units

CLayer2 = conductor layer number - line #2 (value type: integer)

W3 = width of line #3, in specified units

S3 = distance from line #3 to left wall, in specified units

CLayer3 = conductor layer number - line #3 (value type: integer)

W4 = width of line #4, in specified units

S4 = distance from line #4 to left wall, in specified units

CLayer4 = conductor layer number - line #4 (value type: integer)

W5 = width of line #5, in specified units

S5 = distance from line #5 to left wall, in specified units

CLayer5 = conductor layer number - line #5 (value type: integer)

W6 = width of line #6, in specified units

S6 = distance from line #6 to left wall, in specified units

CLayer6 = conductor layer number - line #6 (value type: integer)

W7 = width of line #7, in specified units

S7 = distance from line #7 to left wall, in specified units

CLayer7 = conductor layer number - line #7 (value type: integer)

L = length of the lines, in specified units

Temp = physical temperature, in °C

Range of Usage

W1 > 0, W2 > 0, W3 > 0, W4 > 0, W5 > 0, W6 >0, W7 >0

S1 > 0, S2 > 0, S3 > 0, S4 > 0, S5 > 0, S6 > 0, S7 > 0

1 ≤ CLayer1 ≤ Nlayers+1

1 ≤ CLayer2 ≤ Nlayers+1

1 ≤ CLayer3 ≤ Nlayers+1

1 ≤ CLayer4 ≤ Nlayers+1

1 ≤ CLayer5 ≤ Nlayers+1

1 ≤ CLayer6 ≤ Nlayers+1

$1 \leq CLayer7 \leq Nlayers+1$

where

Nlayers = number of layers specified by PCSUBi (i=1, 2, ... , 7)

Notes/Equations

1. The 2-layer illustration shown is only an example. PCSUBi has between 1 and 7 dielectric layers, and any conductor can be placed above or below any dielectric layer. Conductors can overlap if desired.

2. The frequency-domain analytical model for this component is a non-dispersive static model developed by Agilent. Refer to the section “PCB Model Basis and Limits” on page 9-1 at the beginning of this chapter.

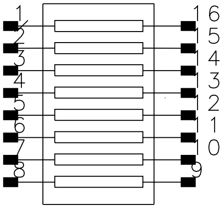
3. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2, ... , 7) if Hl=0.

4. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).

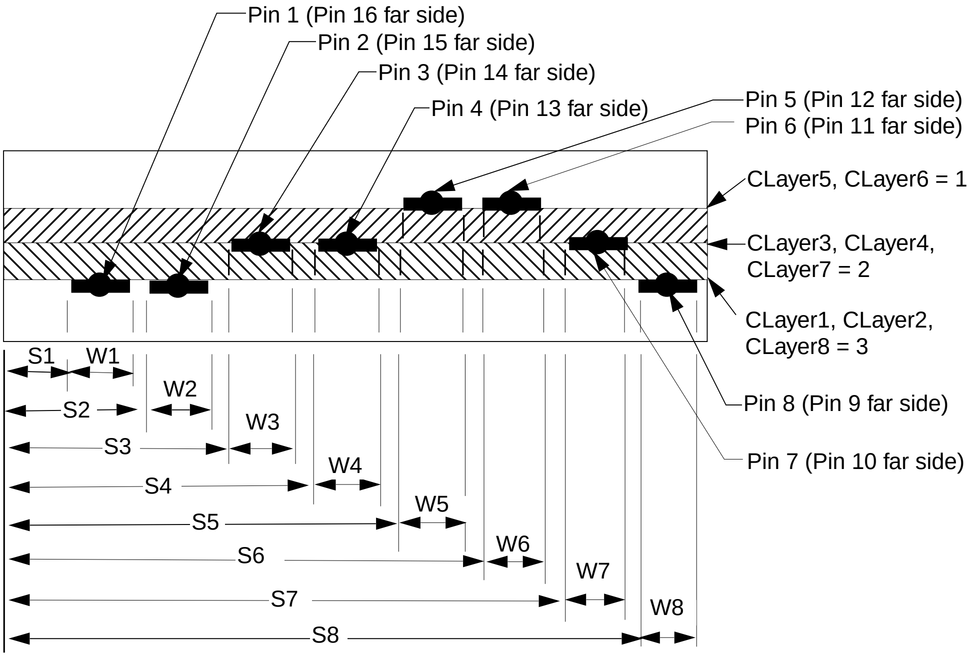
5. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

PCLIN8 (8 Printed Circuit Coupled Lines)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1,2, ... , 7)

W1 = width of line #1, in specified units

S1 = distance from line #1 to left wall, in specified units

CLayer1 = conductor layer number - line #1 (value type: integer)

W2 = width of line #2, in specified units

S2 = distance from line #2 to left wall, in specified units

CLayer2 = conductor layer number - line #2 (value type: integer)

W3 = width of line #3, in specified units

S3 = distance from line #3 to left wall, in specified units

CLayer3 = conductor layer number - line #3 (value type: integer)

W4 = width of line #4, in specified units

S4 = distance from line #4 to left wall, in specified units

CLayer4 = conductor layer number - line #4 (value type: integer)

W5 = width of line #5, in specified units

S5 = distance from line #5 to left wall, in specified units

CLayer5 = conductor layer number - line #5 (value type: integer)

W6 = width of line #6, in specified units

S6 = distance from line #6 to left wall, in specified units

CLayer6 = conductor layer number - line #6 (value type: integer)

W7 = width of line #7, in specified units

S7 = distance from line #7 to left wall, in specified units

CLayer7 = conductor layer number - line #7 (value type: integer)

W8 = width of line #8, in specified units

S8 = distance from line #8 to left wall, in specified units

CLayer8 = conductor layer number - line #8 (value type: integer)

L = length of the lines, in specified units

Temp = physical temperature, in °C

Range of Usage

Wi > 0 for i = 1, ... , 8

Si > 0 for i = 1, ... , 8

1 ≤ CLayer1 ≤ Nlayers+1

$1 \le CLayer2 \le Nlayers+1$

$1 \le CLayer3 \le Nlayers+1$

$1 \le CLayer4 \le Nlayers+1$

$1 \le CLayer5 \le Nlayers+1$

$1 \le CLayer6 \le Nlayers+1$

$1 \le CLayer7 \le Nlayers+1$

$1 \le CLayer8 \le Nlayers+1$

where

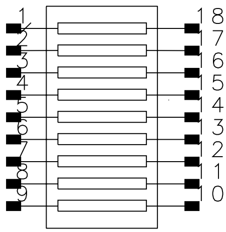
Nlayers = number of layers specified by PCSUBi (i=1, 2, ... , 7)

Notes/Equations

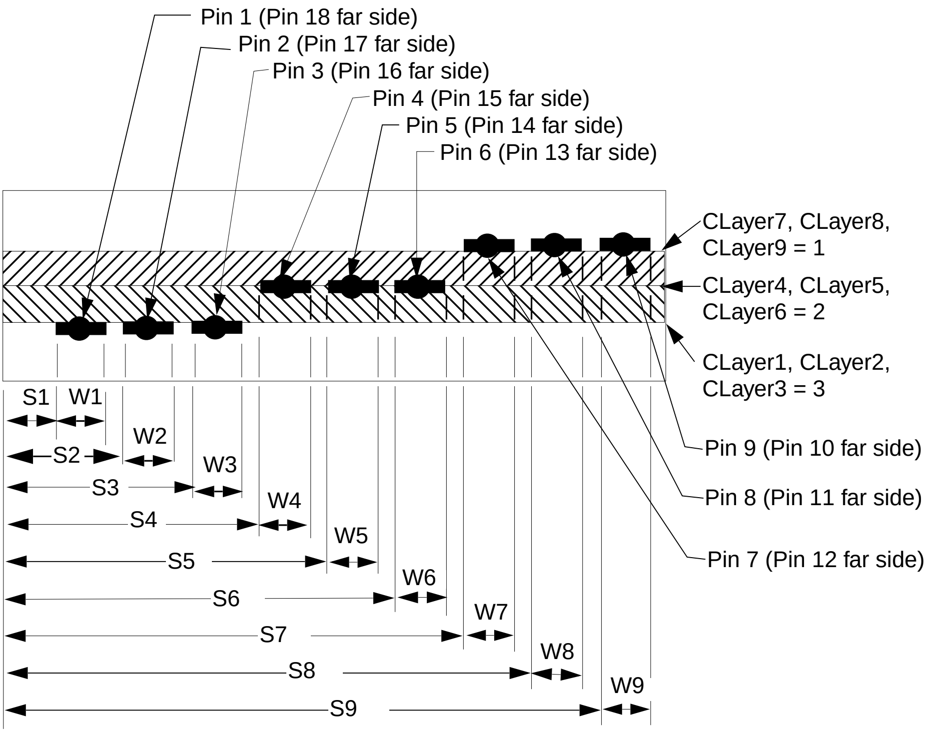
1. The 2-layer illustration shown is only an example. PCSUBi has between 1 and 7 dielectric layers, and any conductor can be placed above or below any dielectric layer. Conductors can overlap if desired.
2. The frequency-domain analytical model for this component is a non-dispersive static model developed by Agilent. Refer to the section “PCB Model Basis and Limits” on page 9-1 at the beginning of this chapter.
3. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1, 2, ... , 7) if Hl=0.
4. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).
5. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

PCLIN9 (9 Printed Circuit Coupled Lines)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1, 2, ... , 7)

W1 = width of line #1, in specified units

S1 = distance from line #1 to left wall, in specified units

CLayer1 = conductor layer number - line #1 (value type: integer)

W2 = width of line #2, in specified units

S2 = distance from line #2 to left wall, in specified units

CLayer2 = conductor layer number - line #2 (value type: integer)

W3 = width of line #3, in specified units

S3 = distance from line #3 to left wall, in specified units

CLayer3 = conductor layer number - line #3 (value type: integer)

W4 = width of line #4, in specified units

S4 = distance from line #4 to left wall, in specified units

CLayer4 = conductor layer number - line #4 (value type: integer)

W5 = width of line #5, in specified units

S5 = distance from line #5 to left wall, in specified units

CLayer5 = conductor layer number - line #5 (value type: integer)

W6 = width of line #6, in specified units

S6 = distance from line #6 to left wall, in specified units

CLayer6 = conductor layer number - line #6 (value type: integer)

W7 = width of line #7, in specified units

S7 = distance from line #7 to left wall, in specified units

CLayer7 = conductor layer number - line #7 (value type: integer)

W8 = width of line #8, in specified units

S8 = distance from line #8 to left wall, in specified units

CLayer8 = conductor layer number - line #8 (value type: integer)

W9 = width of line #9, in specified units

S9 = distance from line #9 to left wall, in specified units

CLayer9 = conductor layer number - line #9 (value type: integer)

L = length of the lines, in specified units

Temp = physical temperature, in °C

Range of Usage

W*i* > 0 for *i* = 1, ... , 9

S*i* > 0 for *i* = 1, ... , 9

1 ≤ CLayer1 ≤ Nlayers+1

1 ≤ CLayer2 ≤ Nlayers+1

1 ≤ CLayer3 ≤ Nlayers+1

1 ≤ CLayer4 ≤ Nlayers+1

1 ≤ CLayer5 ≤ Nlayers+1

1 ≤ CLayer6 ≤ Nlayers+1

1 ≤ CLayer7 ≤ Nlayers+1

1 ≤ CLayer8 ≤ Nlayers+1

1 ≤ CLayer9 ≤ Nlayers+1

where

Nlayers = number of layers specified by PCSUBi (i=1, 2, ... , 7)

Notes/Equations

1. The 2-layer illustration shown is only an example. PCSUBi has between 1 and 7 dielectric layers, and any conductor can be placed above or below any dielectric layer. Conductors can overlap if desired.

2. The frequency-domain analytical model for this component is a non-dispersive static model developed by Agilent. Refer to the section “PCB Model Basis and Limits” on page 9-1 at the beginning of this chapter.

3. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1, 2, ... , 7) if Hl=0.

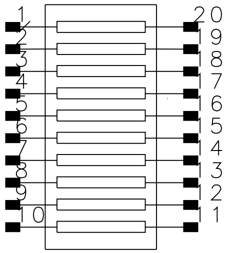
4. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric

layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).

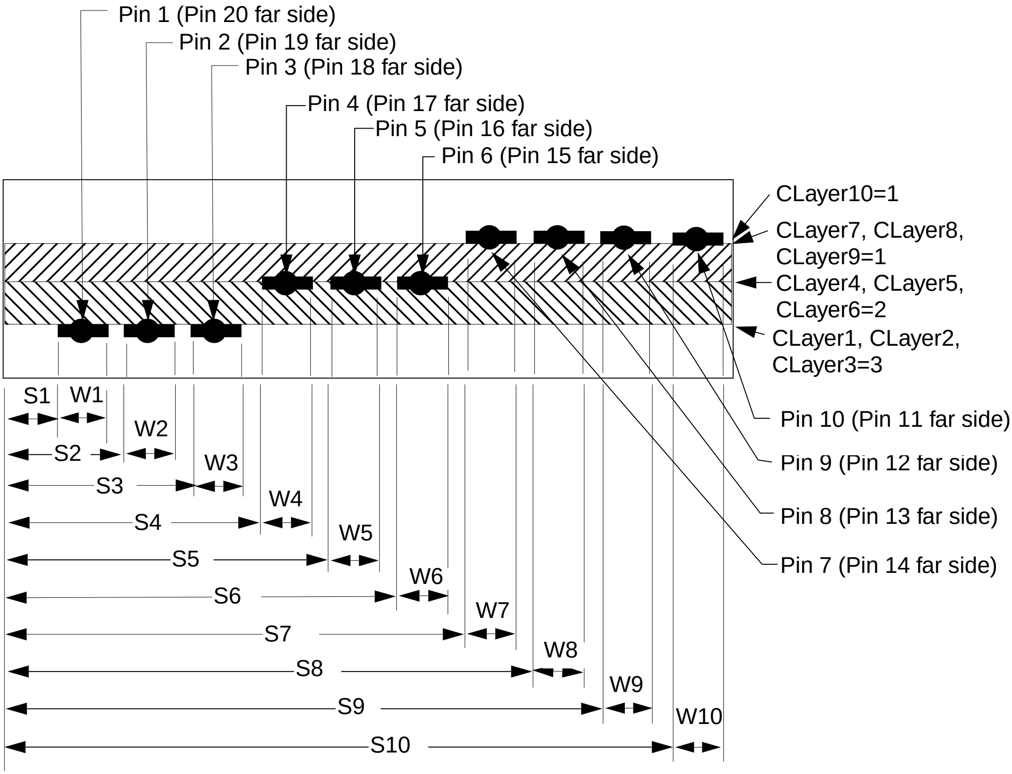
5. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

PCLIN10 (10 Printed Circuit Coupled Lines)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1,2, ... , 7)

W1 = width of line #1, in specified units

S1 = distance from line #1 to left wall, in specified units

CLayer1 = conductor layer number - line #1 (value type: integer)

W2 = width of line #2, in specified units

S2 = distance from line #2 to left wall, in specified units

CLayer2 = conductor layer number - line #2 (value type: integer)

W3 = width of line #3, in specified units

S3 = distance from line #3 to left wall, in specified units

CLayer3 = conductor layer number - line #3 (value type: integer)

W4 = width of line #4, in specified units

S4 = distance from line #4 to left wall, in specified units

CLayer4 = conductor layer number - line #4 (value type: integer)

W5 = width of line #5, in specified units

S5 = distance from line #5 to left wall, in specified units

CLayer5 = conductor layer number - line #5 (value type: integer)

W6 = width of line #6, in specified units

S6 = distance from line #6 to left wall, in specified units

CLayer6 = conductor layer number - line #6 (value type: integer)

W7 = width of line #7, in specified units

S7 = distance from line #7 to left wall, in specified units

CLayer7 = conductor layer number - line #7 (value type: integer)

W8 = width of line #8, in specified units

S8 = distance from line #8 to left wall, in specified units

CLayer8 = conductor layer number - line #8 (value type: integer)

W9 = width of line #9, in specified units

S9 = distance from line #9 to left wall, in specified units

CLayer9 = conductor layer number - line #9 (value type: integer)

W10 = width of line #10, in specified units

S10 = distance from line #10 to left wall, in specified units

CLayer10 = conductor layer number - line #10 (value type: integer)

L = length of the lines, in specified units

Temp = physical temperature, in °C

Range of Usage

W*i* > 0 for *i* = 1, ... , 10

S*i* > 0 for *i* = 1, ... , 10

1 ≤ CLayer1 ≤ Nlayers+1

1 ≤ CLayer2 ≤ Nlayers+1

1 ≤ CLayer3 ≤ Nlayers+1

1 ≤ CLayer4 ≤ Nlayers+1

1 ≤ CLayer5 ≤ Nlayers+1

1 ≤ CLayer6 ≤ Nlayers+1

1 ≤ CLayer7 ≤ Nlayers+1

1 ≤ CLayer8 ≤ Nlayers+1

1 ≤ CLayer9 ≤ Nlayers+1

1 ≤ CLayer10 ≤ Nlayers+1

where

Nlayers = number of layers specified by PCSUBi (i=1,2, ... , 7)

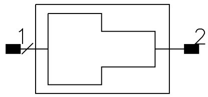
Notes/Equations

1. The 2-layer illustration shown is only an example. PCSUBi has between 1 and 7 dielectric layers, and any conductor can be placed above or below any dielectric layer. Conductors can overlap if desired.

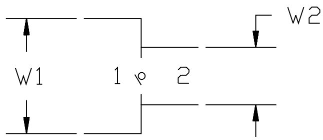
2. The frequency-domain analytical model for this component is a non-dispersive static model developed by Agilent. Refer to the section "PCB Model Basis and Limits" on page 9-1 at the beginning of this chapter.
3. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1, 2, ... , 7) if Hl=0.
4. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).
5. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.

PCSTEP (PCB Symmetric Steps)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1,2, ... , 7)

W1= width at pin 1, in specified units

W2 = width at pin 2, in specified units

CLayer = conductor layer number (value type: integer)

Temp = physical temperature, in °C

Range of Usage

W1, W2 > 0

1 CLayer Nlayers+1

1 ≤ CLayer ≤ Nlayers+1

where

Nlayers = number of layers specified by PCSUBi (i=1,2, ... , 7)

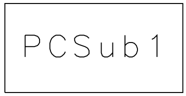
Notes/Equations

1. This component is modeled as an ideal short circuit between pins 1 and 2 and is provided mainly to facilitate interconnections between PCB lines of different width in layout.
2. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1, 2, ... , 7) if Hl=0.

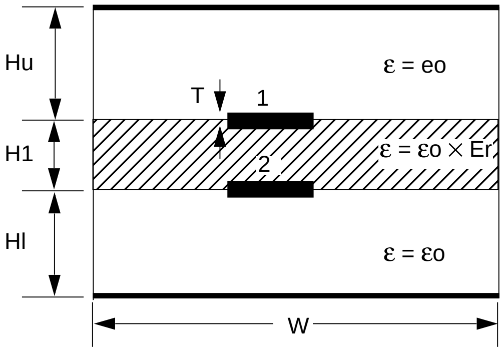
3. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).
4. To turn off noise contribution, set Temp to –273.15°C.
5. Layout artwork requires placing a PCSUBi (i=1, 2, ... , 7) prior to placing the component directly in the Layout window.

PCSUB1 (1-Layer Printed Circuit Substrate)

Symbol



Illustration



Parameters

H1 = thickness of dielectric layer #1, in specified units

Er = dielectric constant

Cond = conductor conductivity, in Siemens per meter

Hu = upper ground plane spacing, in specified units

Hl = lower ground plane spacing, in specified units

T = metal thickness (for loss calculations only), in specified units

W = distance between sidewalls, in specified units

Sigma = dielectric conductivity, in Siemens per meter

TanD = dielectric loss tangent

Range of Usage

H1 > 0, Er ≥ 1, Sigma ≥ 0

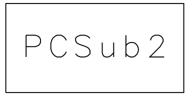
T ≥ 0, Hu ≥ 0, Hl ≥ 0, W > 0

Notes/Equations

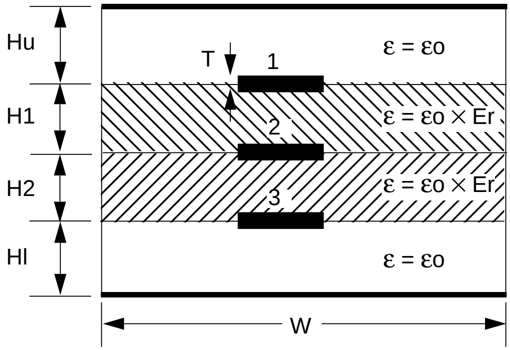
1. Refer to the section "Assumptions and Limitations" on page 9-2 at the beginning of this chapter for important information.
2. A PCSUBi (i=1,2, ... , 7) is required for all PCB components.
3. PCSUBi specifies a multi-layered dielectric substrate with the number of dielectric layers=i. The dielectric constant of all the layers is the same but the thickness of each layer can be different. The structure is enclosed by metal sidewalls.
4. Gold conductivity is 4.1×10^7 S/m. Rough modifies loss calculations. Conductivity for copper is 5.8×10^7.
5. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).

PCSUB2 (2-Layer Printed Circuit Substrate)

Symbol



Illustration



Parameters

H1 = thickness of dielectric layer #1, in specified units

H2 = thickness of dielectric layer #2, in specified units

Er = dielectric constant

Cond = conductor conductivity, in Siemens per meter

Hu = upper ground plane spacing, in specified units

Hl = lower ground plane spacing, in specified units

T = metal thickness (for loss calculations only), in specified units

W = distance between sidewalls, in specified units

Sigma = dielectric conductivity, in Siemens per meter

TanD = dielectric loss tangent

Range of Usage

Hi > 0 for Hi = 1, 2, Er ≥ 1, Sigma ≥ 0

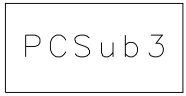
T ≥ 0, Hu ≥ 0, Hl ≥ 0, W > 0

Notes/Equations

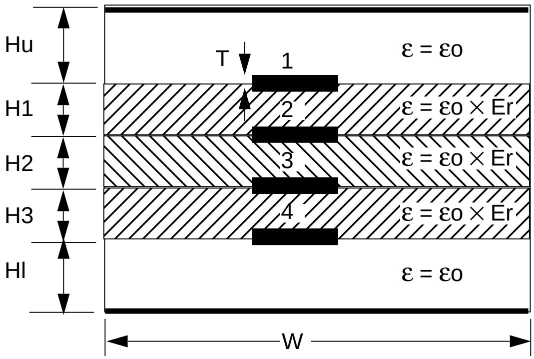
1. Refer to the section "Assumptions and Limitations" on page 9-2 at the beginning of this chapter for important information.
2. A PCSUBi (i=1,2, ... , 7) is required for all PCB components.
3. PCSUBi specifies a multi-layered dielectric substrate with the number of dielectric layers=i. The dielectric constant of all the layers is the same but the thickness of each layer can be different. The structure is enclosed by metal sidewalls.
4. Gold conductivity is 4.1×10^7 S/m. Rough modifies loss calculations. Conductivity for copper is 5.8×10^7.
5. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).

PCSUB3 (3-Layer Printed Circuit Substrate)

Symbol



Illustration



Parameters

H1 = thickness of dielectric layer #1, in specified units

H2 = thickness of dielectric layer #2, in specified units

H3 = thickness of dielectric layer #3, in specified units

Er = dielectric constant

Cond = conductor conductivity, in Siemens per meter

Hu = upper ground plane spacing, in specified units

Hl = lower ground plane spacing, in specified units

T = metal thickness (for loss calculations only), in specified units

W = distance between sidewalls, in specified units

Sigma = dielectric conductivity, in Siemens per meter

TanD = dielectric loss tangent

Range of Usage

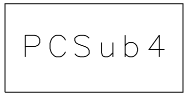
H*i* > 0 for H*i* = 1, ... , 3, Er ≥ 1, Sigma ≥ 0
T ≥ 0, Hu ≥ 0, Hl ≥ 0, W > 0

Notes/Equations

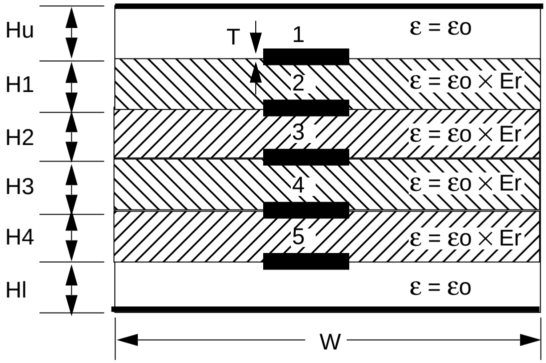
1. Refer to the section "Assumptions and Limitations" on page 9-2 at the beginning of this chapter for important information.
2. A PCSUBi (i=1,2, ... , 7) is required for all PCB components.
3. PCSUBi specifies a multi-layered dielectric substrate with the number of dielectric layers=i. The dielectric constant of all the layers is the same but the thickness of each layer can be different. The structure is enclosed by metal sidewalls.
4. Gold conductivity is 4.1×10^7 S/m. Rough modifies loss calculations. Conductivity for copper is 5.8×10^7.
5. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).

PCSUB4 (4-Layer Printed Circuit Substrate)

Symbol



Illustration



Parameters

H1 = thickness of dielectric layer #1, in specified units

H2 = thickness of dielectric layer #2, in specified units

H3 = thickness of dielectric layer #3, in specified units

H4 = thickness of dielectric layer #4, in specified units

Er = dielectric constant

Cond = conductor conductivity, in Siemens per meter

Hu = upper ground plane spacing, in specified units

Hl = lower ground plane spacing, in specified units

T = metal thickness (for loss calculations only), in specified units

W = distance between sidewalls, in specified units

Sigma = dielectric conductivity, in Siemens per meter

TanD = dielectric loss tangent

Range of Usage

Hi > 0 for Hi = 1, ... , 4, Er ≥1, Sigma ≥ 0

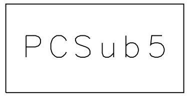
T ≥ 0, Hu ≥ 0, Hl ≥ 0, W > 0

Notes/Equations

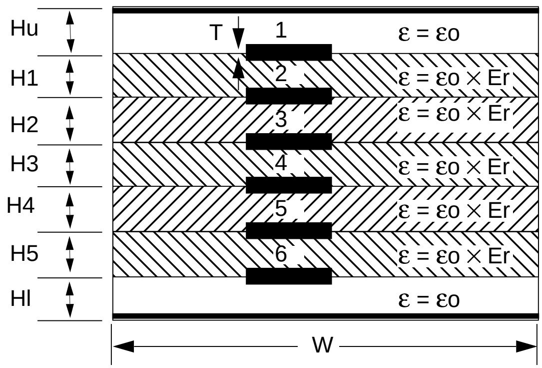
1. Refer to the section "Assumptions and Limitations" on page 9-2 at the beginning of this chapter for important information.
2. A PCSUBi (i=1,2, ... , 7) is required for all PCB components.
3. PCSUBi specifies a multi-layered dielectric substrate with the number of dielectric layers=i. The dielectric constant of all the layers is the same but the thickness of each layer can be different. The structure is enclosed by metal sidewalls.
4. Gold conductivity is 4.1×10^7 S/m. Rough modifies loss calculations. Conductivity for copper is 5.8×10^7.
5. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).

PCSUB5 (5-Layer Printed Circuit Substrate)

Symbol



Illustration



Parameters

H1 = thickness of dielectric layer #1, in specified units

H2 = thickness of dielectric layer #2, in specified units

H3 = thickness of dielectric layer #3, in specified units

H4 = thickness of dielectric layer #4, in specified units

H5 = thickness of dielectric layer #5, in specified units

Er = dielectric constant

Cond = conductor conductivity, in Siemens per meter

Hu = upper ground plane spacing, in specified units

Hl = lower ground plane spacing, in specified units

T = metal thickness (for loss calculations only), in specified units

W = distance between sidewalls, in specified units

Sigma = dielectric conductivity, in Siemens per meter

TanD = dielectric loss tangent

Range of Usage

H*i* > 0 for H*i* = 1,..., 5, Er ≥ 1,

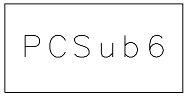
Sigma ≥ 0, T ≥ 0, Hu ≥ 0, Hl ≥ 0, W > 0

Notes/Equations

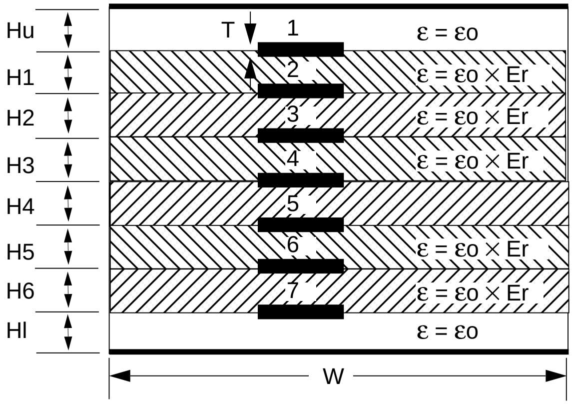
1. Refer to the section "Assumptions and Limitations" on page 9-2 at the beginning of this chapter for important information.
2. A PCSUBi (i=1,2, ... , 7) is required for all PCB components.
3. PCSUBi specifies a multi-layered dielectric substrate with the number of dielectric layers=i. The dielectric constant of all the layers is the same but the thickness of each layer can be different. The structure is enclosed by metal sidewalls.
4. Gold conductivity is 4.1×10^{7} S/m. Rough modifies loss calculations. Conductivity for copper is 5.8×10^{7}.
5. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).

PCSUB6 (6-Layer Printed Circuit Substrate)

Symbol



Illustration



Parameters

H1 = thickness of dielectric layer #1, in specified units

H2 = thickness of dielectric layer #2, in specified units

H3 = thickness of dielectric layer #3, in specified units

H4 = thickness of dielectric layer #4, in specified units

H5 = thickness of dielectric layer #5, in specified units

H6 = thickness of dielectric layer #6, in specified units

Er = dielectric constant

Cond = conductor conductivity, in Siemens per meter

Hu = upper ground plane spacing, in specified units

Hl = lower ground plane spacing, in specified units

T = metal thickness (for loss calculations only), in specified units

W = distance between sidewalls, in specified units

Sigma = dielectric conductivity, in Siemens per meter

TanD = dielectric loss tangent

Range of Usage

H*i* > 0 for H*i* = 1, ... , 6, Er ≥ 1,

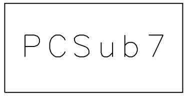
Sigma ≥ 0, T ≥ 0, Hu ≥ 0, Hl ≥ 0, W > 0

Notes/Equations

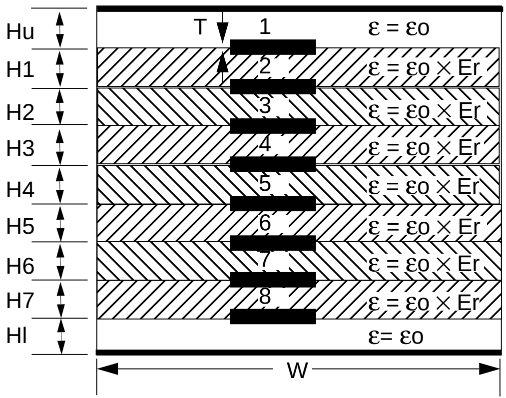
1. Refer to the section "Assumptions and Limitations" on page 9-2 at the beginning of this chapter for important information.
2. A PCSUBi (i=1,2, ... , 7) is required for all PCB components.
3. PCSUBi specifies a multi-layered dielectric substrate with the number of dielectric layers=i. The dielectric constant of all the layers is the same but the thickness of each layer can be different. The structure is enclosed by metal sidewalls.
4. Gold conductivity is 4.1×10^7 S/m. Rough modifies loss calculations. Conductivity for copper is 5.8×10^{7}.
5. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).

PCSUB7 (7-Layer Printed Circuit Substrate)

Symbol



Illustration



Parameters

H1 = thickness of dielectric layer #1, in specified units

H2 = thickness of dielectric layer #2, in specified units

H3 = thickness of dielectric layer #3, in specified units

H4 = thickness of dielectric layer #4, in specified units

H5 = thickness of dielectric layer #5, in specified units

H6 = thickness of dielectric layer #6, in specified units

H7 = thickness of dielectric layer #7, in specified units

Er = dielectric constant

Cond = conductor conductivity, in Siemens per meter

Hu = upper ground plane spacing, in specified units

Hl = lower ground plane spacing, in specified units

T = metal thickness (for loss calculations only), in specified units

W = distance between sidewalls, in specified units

Sigma = dielectric conductivity, in Siemens per meter

TanD = dielectric loss tangent

Range of Usage

H*i* > 0 for H*i* = 1, ... , 7, Er ≥ 1,

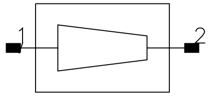
Sigma ≥ 0, T ≥ 0, Hu ≥ 0, Hl ≥ 0, W > 0

Notes/Equations

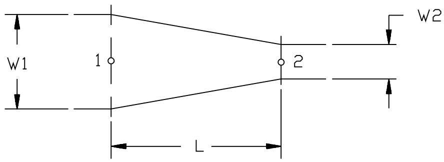
1. Refer to the section “Assumptions and Limitations” on page 9-2 at the beginning of this chapter for important information.
2. A PCSUBi (i=1,2, ... , 7) is required for all PCB components.
3. PCSUBi specifies a multi-layered dielectric substrate with the number of dielectric layers=i. The dielectric constant of all the layers is the same but the thickness of each layer can be different. The structure is enclosed by metal sidewalls.
4. Gold conductivity is 4.1×10^{7} S/m. Rough modifies loss calculations. Conductivity for copper is 5.8×10^{7}.
5. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).

PCTAPER (PC Tapered Line)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1,2, ... , 7)

W1 = width at pin 1, in specified units

W2 = width at pin 2, in specified units

L = length of line, in specified units

CLayer = conductor layer number (value type: integer)

Temp = physical temperature, in °C

Range of Usage

W1, W2 > 0

1 ≤ CLayer ≤ Nlayers+1

where

Nlayers = number of layers specified by PCSUBi (i=1,2, ... , 7)

Notes/Equations

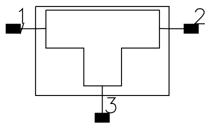
1. This component is modeled as PCLIN1. Width of the line is assumed to be (W1 + W2)/2. The single line is assumed to be located halfway between and parallel to the sidewalls. The distance between the sidewalls is given as a part of the PCSUBi parameter W.
2. The distance between the sidewalls is typically the width of the metal enclosure around the PC board. If the metal enclosure is absent, width of the PC board

itself can be specified and treated as the distance between the sidewalls. Note, however, that the simulation time increases rapidly as the sidewall distance increases. If the effect of the sidewalls is not important, it is highly recommended to set it to approximately 10 times the line width for this component.

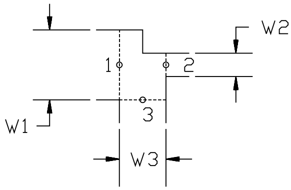
3. This component is provided mainly to facilitate interconnection between PCB lines of different widths in layout.
4. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2,..., 7) if Hl=0.
5. Gold conductivity is 4.1×10^7 S/m. Rough modifies loss calculations. Conductivity for copper is 5.8×10^{7}.
6. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).
7. To turn off noise contribution, set Temp to –273.15°C.

PCTEE (Printed Circuit T-Junction)

Symbol



Illustration



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1,2, ... , 7)

W1 = width at pin 1, in specified units

W2 = width at pin 2, in specified units

W3 = width at pin 3, in specified units

CLayer = conductor layer number (value type: integer)

Temp = physical temperature, in °C

Range of Usage

W*i* > 0 for W*i* = 1, ... , 3

1 ≤ CLayer ≤ Nlayers+1

where

Nlayers = number of layers specified by PCSUBi (i=1,2, ... , 7)

Notes/Equations

1. This component is treated as an ideal connection between pins 1, 2, and 3, and has been provided mainly to facilitate interconnections between PCB lines oriented at different angles in layout.

2. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2,..., 7) if Hl=0.

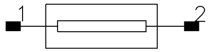
3. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).

4. To turn off noise contribution, set Temp to –273.15°C.

5. Layout artwork requires placing a PCSUBi (i=1, 2, ... , 7) prior to placing the component directly in the Layout window.

PCTRACE (Single PCB Line (Trace))

Symbol



Parameters

Subst = printed circuit substrate name (PCSUBi, i=1,2, ... , 7)

W = width of line, in specified units

CLayer = conductor layer number (value type: integer)

L = length of line, in specified units

Temp = physical temperature, in °C

Range of Usage

W > 0

1 ≤ CLayer ≤ Nlayers+1

where

Nlayers = number of layers specified by PCSUBi (i=1,2, ... , 7)

Notes/Equations

1. This component is modeled as PCLIN1. The single line is assumed to be located halfway between and parallel to the sidewalls. The distance between the sidewalls is given as a part of the PCSUBi parameter W.

2. The distance between the sidewalls is typically the width of the metal enclosure around the PC board. If the metal enclosure is absent, width of the PC board itself can be specified and treated as the distance between the sidewalls. Note, however, that the simulation time increases rapidly as the sidewall distance increases. If the effect of the sidewalls is not important, it is highly recommended to set it to approximately 10 times the line width for this component.

3. The value of CLayer and the value of the associated PCSUB parameters Hu and Hl must be compatible so as to not short out the CLayer to the upper or lower ground plane. For example, it is invalid for CLayer=1 if Hu=0 or for CLayer=i+1 (for PCSUBi, i=1,2,..., 7) if Hl=0.

4. Conductor layers are numbered as follows: the upper surface of the top dielectric layer (or dielectric layer #1) is conductor layer #1; the lower surface of the dielectric layer #1 (which could also be the upper surface of the dielectric layer #2) is conductor layer #2; etc. When using a PCSUBi substrate, the lower surface of dielectric layer #i is conductor layer #(i+1).
5. For time-domain analysis, an impulse response obtained from the frequency-domain analytical model is used.
6. To turn off noise contribution, set Temp to –273.15°C.
7. This component is provided mainly to facilitate interconnections between PCB lines in layout.
8. Layout artwork requires placing a PCSUBi(i=1,2, ... , 7) prior to placing the component directly in the Layout window.