4 terminal physical transmission line tlinp4

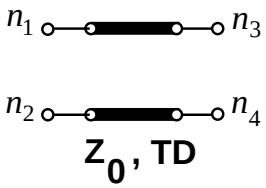


Figure 1: tlinp4 — Transmission line element.

Form: `tlinp4:`⟨`instance name`⟩ n_1 n_2 n_3 n_4 ⟨`parameter list`⟩
n_1, n_2, n_3 and n_4 are the element terminals.
Terminals n_2 and n_4 are the element reference terminals.
With `nsect` set Terminals n_2 and n_4 must be the same.
With `nsect` = 0 only AC (.AC), DC (.DC) and transient convolution analysis (.SVTR) permitted.

Parameters:

Parameter	Type	Default value	Required?
k: Effective dielectric constant	DOUBLE	1	no
alpha: Attenuation (dB/m)	DOUBLE	0.1	no
z0mag: Magnitude of characteristic impedance (ohms)	DOUBLE	n/a	yes
fscale: Scaling frequency for attenuation (Hz)	DOUBLE	0	no
tand: Loss tangent	DOUBLE	0	no
length: Line length (m)	DOUBLE	n/a	yes
nsect: Enable discrete approximation with n sections	INTEGER	0	no
fopt: Optimum frequency for discrete approximation	DOUBLE	0	no

---

Example:

```
.model c_line tlinp4 z0mag=75.00 k=7 fscale=10.e9 alpha = 59.9 nsect = 20 fopt=10e9
tlinp4: t2 2 0 3 0 model = "c_line" length=931.69u
```

Notes:
This is the `T` element in the SPICE compatible netlist.

Details:
This is a linear element and is modeled differently depending on the setting of the Parameter `nsect`.

`nsect` = 0.

When `nsect` is zero (the default) the transmission line is calculated in the frequency domain using the fre-

quency dependent characteristic impedance and propagation parameters. The model is shown in Figure 2. This model has two local reference terminals. An example netlist is:

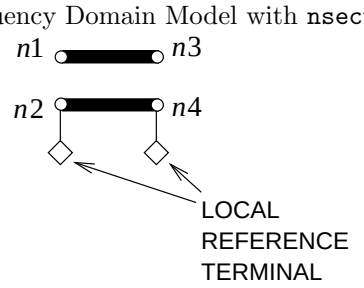


Figure 2: Multi section model of a transmission line.

```
l:1 n1 0 n3 ref1 z0=50 length=5mm
.ref "ref1"
```

Here terminals '0' and 'ref1' are the local reference terminals of the element. Terminal '0' is a the global ground. However 'ref1' is a second local reference terminal of the element and either it or another terminal in the same local reference group must be specified as a reference terminal. Here 'ref1' is identified as a local reference terminal. (or a suitable terminal). Another suitable example of a circuit would be

```
vsource 2 0 vac = 1 f = 5GHz
r:1 2 n1 r=50
r:2 0 n2 r=2
tlinp4:1 n1 n2 n3 n4 z0=50 length=5mm
r:3 n2 r=5
r:4 n4 5 r=100
r:5 n4 5 r=10
.ref 5
```

tlinp4 here corresponds to Figure 2.

`nsect` > 0.

When `nsect`, the number of sections, is a positive integer the transmission line is approximated using `nsect` sections. The model is shown in Figure 3 With respect to the terminal numbers in Figure 2, terminals 'n2

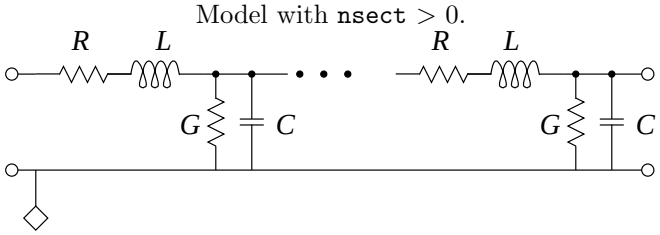


Figure 3: Multi section model of a transmission line.

and 'n4' must be the same terminal. The sectional model is used in both the time domain and frequency domain. Each series R and inductance L is modeled as a single `L` element. Each shunt G and capacitance C is modeled as a single `C` element. This is indicated in Figure 4

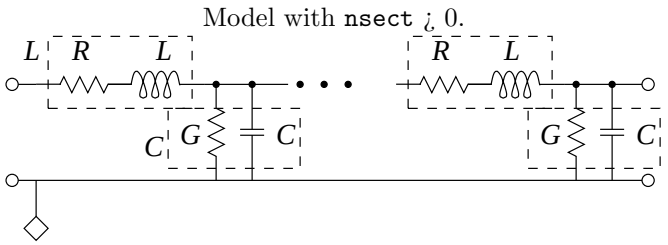


Figure 4: Multi section model of a transmission line showing pairs of primitives each modeled by a single element.

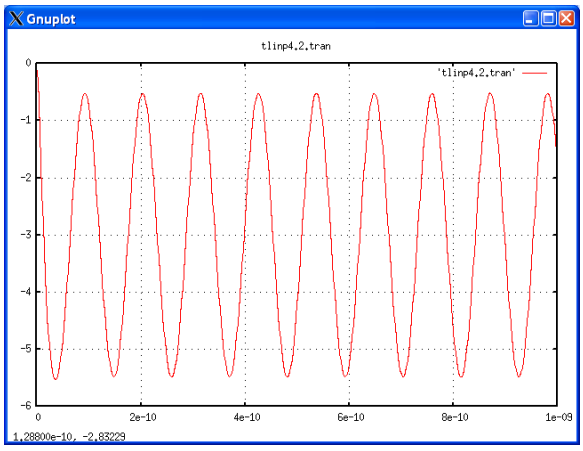
Example of Transient Analysis (.TRAN2) Fixed times steps, time-stepping nonlinear analysis.
netlist file: tlinp4.net:

```
* Transient tlinp4 test
.options f0 = 9e9
.tran2 tstop = 1e-9 tstep = .002e-9
vsource:v2 202 0 vdc= -6. vac= 5. f= f0 phase=90
resistor:rs 1 202 r=75.
tlinp4:t1  1 0 2 0
+ z0mag=75.00 nsect=1 length=978.57e-6 k=7 tand=.01 fscale=1.e10 alpha=1.
resistor:rl 2 0  r=75.
.options gnuplot
.out plot term 2 vt in "tlinp4.2.tran"

.end
```

The output log file is

```
**********  fREEDA 1.3 running on Sat Apr  5 15:24:28 2008  **********
* Transient tlinp4 test

.options f0 = 9e9

.tran2 tstop = 1e-9 tstep = .002e-9

vsource:v2 202 0 vdc= -6. vac= 5. f= f0 phase=90

resistor:rs 1 202 r=75.

tlinp4:t1  1 0 2 0
+ z0mag=75.00 nsect=1 length=978.57e-6 k=7 tand=.01 fscale=1.e10 alpha=1.

resistor:rl 2 0  r=75.

.options gnuplot
.out plot term 1 vt in "tlinp4.1.tran"
.out plot term 2 vt in "tlinp4.2.tran"

   *** Starting analysis ...

--------------------------------------------------------------------------------
```

```
   Matrix size = 5
   Matrix nnz = 12
   equed = 2.73438e-298
   recip_pivot_growth = 0.886652
   1 / Condition number = 0.166667
   info = 0
   ferr = 1.8089e-305
   berr = 1
   No of nonzeros in factor L = 15
   No of nonzeros in factor U = 15
   No of nonzeros in L+U = 25
   L\U MB 0.000 total MB needed 0.001   expansions 0
   Using line search method.
   Nonlinear analysis tolerance (ftol) = 6.12865e-06
   Maximum number of nonlinear iterations per time-point (maxit) = 250
   Using Lee and Lee's quasi-Newton updates.
   --- Starting transient simulation ...

   Number of nonlinear state variables: 0
--------------------------------------------------------------------------------
   |  Step  |    Time (s)  |   Residual   |  Recent Max   |     Max      |
--------------------------------------------------------------------------------
   |      0 | 0.000000e+00 | 0.000000e+00 | 0.000000e+00  | 0.000000e+00 |
   |    200 | 4.000000e-10 | 0.000000e+00 | 0.000000e+00  | 0.000000e+00 |
   |    400 | 8.000000e-10 | 0.000000e+00 | 0.000000e+00  | 0.000000e+00 |
   --- Maximum Residual: 0
--------------------------------------------------------------------------------
 Plotting output file: tlinp4.2.tran.

**************  fREEDA 1.3 stopping on Sat Apr  5 15:24:29 2008  ***********
```



Example of Transient Analysis using Convolution (.SVTR).
In this example the transmission line is calculated in the frequency domain and convolution analysis is used to convert the model into an impulse response used directly in transient analysis.
netlist file: tlinp4_conv.net:

```
* Transient tlinp4 test. Convolution is used
```

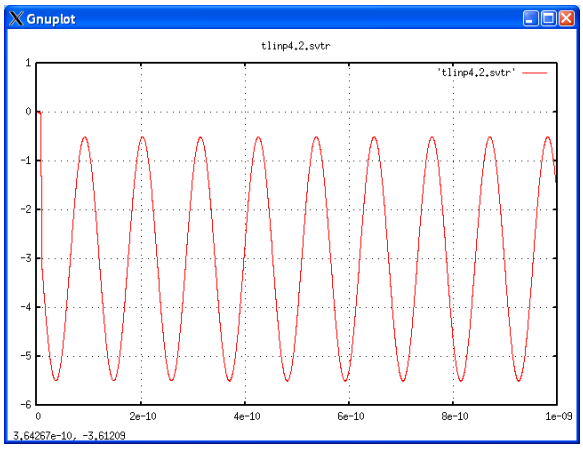
```
.options f0 = 9e9
.svtr tstop = 1e-9 tstep = .0002e-9
vsource:v2 202 0 vdc= -6. vac= 5. f= f0 phase=90
resistor:rs 1 202 r=75.
tlinp4:t1  1 0 2 ref2
+ z0mag=75.00 length=978.57e-6 k=7 tand=.01 fscale=1.e10 alpha=1.
resistor:r3 2 ref2  r=75.
open:1 2 ref2
.ref "ref2"
.options gnuplot
.out plot element "open:1" 0 ut in "tlinp4.2.svtr"
.end
```

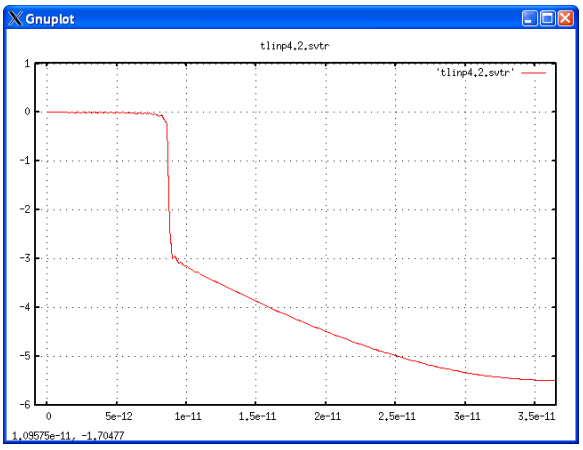
Note that in convolution analysis augmentation elements are used to provide the proper interface between the parts of the circuit analyzed in the time-domain and frequency-domain. Consequently the voltages at terminals are note the ones expected. The procedure is to define an open element and then determine the voltage (ut) of that element. The open element is calculated as a nonlinear element. When convolution is used the only voltages that can be relied on as being the actual voltage are the voltages at nonlinear elements.

The output log file follows:

```
**********  fREEDA 1.3 running on Sat Apr  5 15:50:45 2008  **********
* Transient tlinp4 test. Convolution is used
.options f0 = 9e9
* Transient tlinp4 test. Convolution is used
.options f0 = 9e9
.svtr tstop = 1e-9 tstep = .0002e-9
vsource:v2 202 0 vdc= -6. vac= 5. f= f0 phase=90
resistor:rs 1 202 r=75.
tlinp4:t1  1 0 2 ref2
+ z0mag=75.00 length=978.57e-6 k=7 tand=.01 fscale=1.e10 alpha=1.
resistor:r3 2 ref2  r=75.
open:1 2 ref2
.ref "ref2"
.options gnuplot
.out plot element "open:1" 0 ut in "tlinp4.2.svtr"

   *** Starting analysis ...

-------------------------------------------------------------------------------
   *** State Variable-Based Transient Analysis ***
-------------------------------------------------------------------------------

   n_samples = 1792
   Frequency step = 2.43902e+09 Hz
   Maximum frequency = 2.49756e+12 Hz
   Number of time steps = 5001

   --- Building Msv(f) ...
   Number of state variables = 2
   --- Converting Msv to the time domain ...
```

```
   Warning: Last 35 samples impulse contribution: 2.25 %
   Warning: Last 35 samples impulse contribution: 19.24 %
   Warning: Last 35 samples impulse contribution: 19.24 %
   Warning: Last 35 samples impulse contribution: 6.90 %
   --- Starting transient simulation ...

   Using line search method.
   Nonlinear analysis tolerance (ftol) = 6.12865e-06
   Maximum number of nonlinear iterations per time-point (maxit) = 250
   Using Lee and Lee's quasi-Newton updates.
-------------------------------------------------------------------------------
   |   Step   |    Time (s)    |   Residual (V)   |
-------------------------------------------------------------------------------
   |      100 |  2.000000e-11  |  1.146925e-14    |
   |      200 |  4.000000e-11  |  1.941338e-14    |
   |      300 |  6.000000e-11  |  2.206639e-14    |
   |      400 |  8.000000e-11  |  2.250882e-14    |
   |      500 |  1.000000e-10  |  2.262135e-14    |
.
.
.
   |     4700 |  9.400000e-10  |  6.969867e-14    |
   |     4800 |  9.600000e-10  |  7.005851e-14    |
   |     4900 |  9.800000e-10  |  7.008727e-14    |
   |     5000 |  1.000000e-09  |  7.030965e-14    |
-------------------------------------------------------------------------------

   --- Residual: 7.03097e-14
   --- Writing output vectors ...
 Plotting output file: tlinp4.2.svtr.

**************  fREEDA 1.3 stopping on Sat Apr  5 15:50:56 2008  ***********
```





Example of AC Analysis.
netlist file: tlinp4AC.net:

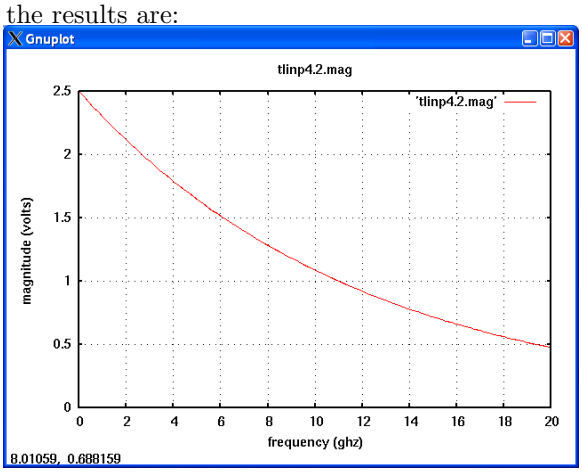
```
* AC tlinp4 test
```

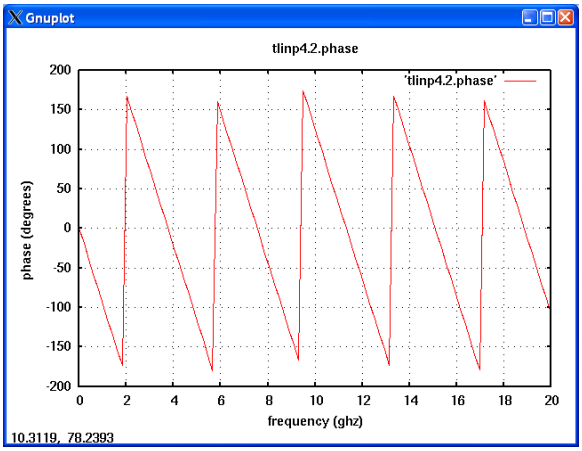
```
.ac start = 1 stop = 20GHz n_freqs=100
vsource:v2 202 0  vac= 5
resistor:rs 1 202 r=75.
tlinp4:t1  1 0 2 ref2
+ z0mag=75.00 length=0.03 k=7 tand=.1 fscale=1.e10 alpha=1.
resistor:rl 2 ref2  r=75.
.ref "ref2"
.options gnuplot
* Get the magnitude of the voltage at terminal 2. This is with respect to ref2
.options preamble1="set term x11 font 'helvetica,13';
set xlabel 'FREQUENCY (GHz)'; set ylabel 'MAGNITUDE (VOLTS)"
.out plot term 2 vf mag 1e-9 scalex preamble1 in "tlinp4.2.mag"
* Get the phase of the voltage at terminal 2. This is with respect to ref2
* prinphase gets the principal phase as opposed to the continuous phase.
.options preamble2="set term x11 font 'helvetica,13';
set xlabel 'FREQUENCY (GHz)'; set ylabel 'phase (DEGREES)"
.out plot term 2 vf prinphase 1e-9 scalex rad2deg preamble2 in "tlinp4.2.phase"
.end
```

The output log file is:

```
**********  fREEDA 1.3 running on Sat Apr  5 16:24:22 2008  **********
* AC tlinp4 test
.ac start = 1 stop = 20ghz n_freqs=100
vsource:v2 202 0  vac= 5
resistor:rs 1 202 r=75.
tlinp4:t1  1 0 2 ref2
+ z0mag=75.00 length=0.03 k=7 tand=.1 fscale=1.e10 alpha=1.
resistor:rl 2 ref2  r=75.
.ref "ref2"
.options gnuplot
* Get the magnitude of the voltage at terminal 2. This is with respect to ref2
set xlabel 'frequency (ghz)'; set ylabel 'magnitude (volts)"
.out plot term 2 vf mag 1e-9 scalex preamble1 in "tlinp4.2.mag"
* Get the phase of the voltage at terminal 2. This is with respect to ref2
* prinphase gets the principal phase as opposed to the continuous phase.
set xlabel 'frequency (ghz)'; set ylabel 'phase (degrees)"
.out plot term 2 vf prinphase 1e-9 scalex rad2deg preamble2 in "tlinp4.2.phase"

   *** Starting analysis ...

------------------------------------------------------------------------------
   *** AC Analysis ***
------------------------------------------------------------------------------

   Frequency step = 2.0202e+08 Hz
   --- Writing output vectors ...
 Plotting output file: tlinp4.2.mag.
 Plotting output file: tlinp4.2.phase.

**************  fREEDA 1.3 stopping on Sat Apr  5 16:24:23 2008  ************
```

And the results are:





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