

**[Matrix Type]**

Rules for Version 1.0 Files:

The [Matrix Type] keyword is not permitted in version 1.0 files.

Rules for Version 2.0 Files:

The [Matrix Type] keyword entry specifies whether the network data given elsewhere in the file is specified for each and every port, or for a subset of the ports. This subset would be a reduced matrix, where only half of the port-to-port data is specified, assuming symmetrical behavior in the matrix data. This assumption is most appropriate for interconnects.

The [Matrix Type] section must begin with the keyword [Matrix Type], in brackets as shown. This keyword is followed by one of two possible strings: “Full” and “Reduced”.

[Matrix Type] may only appear after the [Reference] keyword and before any network data.

[Matrix Type] is optional. If [Matrix Type] is not present, the network data included in the file is assumed to be of type “Full” and the network data for each port as specified under [Number of Ports] must be specified for each frequency point.

[Matrix Type] has no effect on noise data.

**Example 2:**

```
! 4-port S-parameter data
! Default impedance is overridden by the [Reference] line
! Data cannot be represented using 1.0 syntax.
[Version] 2.0
# GHz S MA R 50
[Number of Ports] 4
[Reference] 50 75 0.01 0.01
[Matrix Type] Full
5.00000 0.60 161.24 0.40 -42.20 0.42 -66.58 0.53 -79.34 !row 1
      0.40 -42.20 0.60 161.20 0.53 -79.34 0.42 -66.58 !row 2
      0.42 -66.58 0.53 -79.34 0.60 161.24 0.40 -42.20 !row 3
      0.53 -79.34 0.42 -66.58 0.40 -42.20 0.60 161.24 !row 4
```

**Network Parameter Data**

Following the option line and/or [Reference] keyword are the network parameters (S-parameter, Z-parameter, etc.) of the type specified by the option line. Groups of n-port parameters are preceded by the frequency value for which the data was obtained, and the n-port parameters themselves are formatted as pairs of values (magnitude-angle, dB-angle or real-imaginary).

Network data is grouped into one or more ‘lines’ which end with a terminating newline character (e.g., CR or CR/LF). In version 1.0 files, for each frequency, n-port parameters for 1-port and 2-port networks are contained on one data line, while data for 3-port and larger networks are arranged on multiple data lines in a matrix row-wise order.

In summary, there are five general rules for formatting network data into lines:

1. In version 1.0 files, no more than four pairs of n-port parameters are allowed per data line. No restriction exists on the number of data points on a line in version 2.0 files.

2. Individual entries in data lines are separated by whitespace.
3. A data line is terminated by a newline character (CR or CR/LF combination).
4. All data lines must be arranged in increasing order of frequency.
5. Frequency values may only appear at the beginning of lines, after the newline character.

Detailed descriptions for arranging the data for various n-port networks follow.

Note that H- and G- parameters are defined for 2-port networks only. These hybrid parameters cannot be used to describe networks containing any other number of ports.

Rules for Version 2.0:

In version 2.0 files, the data associated with any one frequency may be split across any number of lines or may be placed on a single line of arbitrary length. Data in a version 2.0 file is parsed using the [Number of Ports] entry and the [Matrix Type] entry. For a Full matrix, a new frequency point is expected every  $2n^2+1$  data points, where  $n$  is the number of ports, regardless of intervening newline characters. For a Reduced

matrix, a new frequency point is expected every  $\frac{n * (n + 1)}{2} + 1$  points.

### 1-port and 2-port Networks

Network parameter data for 1-port and 2-port networks at a single frequency can be contained on a single data line. As shown below, the data line consists of a frequency value followed by either one or four pairs of data values.

1-port data (line)

*<frequency value>* *<N11>*

2-port data (line)

*<frequency value>* *<N11>* *<N21>* *<N12>* *<N22>*

where

*frequency value* frequency at which the network parameter data was taken or derived.

*N11, N21, N12, N22* network parameter data points, where N11, N21, etc. represent pairs of data values

Network parameter data points will be in magnitude-angle, dB-angle or real-imaginary format (i.e., pairs of values) as specified by the option line. For 1-port networks only '11' data is allowed, while for "Full" 2-port networks all four combinations are required.

If [Matrix Type] is specified as "Reduced," 2-port network data only includes '11', '22' and '21' data ('21' and '12' are assumed identical).

*Note the order in which 2-port n-port parameters are entered: '21' data precedes '12' data.*

All entries in a data line are separated by one or more whitespace characters; a data line itself is terminated by a newline character (CR or CR/LF). Multiple data lines (sets) are allowed but, as mentioned above, they must be arranged in increasing order of frequency.

Shown below are some examples of Touchstone® files for 1-port and 2-port networks. Lines beginning with a bang (!) symbol are comments.

#### Example 3 (version 1.0):

`!1-port S-parameter file, single frequency point`

```
# MHz S MA R 50
!freq magS11 angS11
2.000 0.894 -12.136
```

In the above example, the value of S11 at a frequency of 2 MHz is given in magnitude-angle format. The reference impedance is 50 ohms. [Matrix Type] is not specified.

**Example 4 (version 1.0):**

```
!1-port Z-parameter file, multiple frequency points
# MHz Z MA R 75
!freq magZ11 angZ11
100 0.99 -4
200 0.80 -22
300 0.707 -45
400 0.40 -62
500 0.01 -89
```

Note that, in the above example, Z11 is normalized to 75 ohms, as given by the reference impedance (R 75) in the option line. [Matrix Type] is not specified.

**Example 5 (version 2.0):**

```
!1-port Z-parameter file, multiple frequency points
[Version] 2.0
# MHz Z MA
[Number of Ports] 1
!freq magZ11 angZ11
100 74.25 -4
200 60 -22
300 53.025 -45
400 30 -62
500 0.75 -89
```

This example duplicates the data in Example 4, using version 2.0 syntax. Note that normalization has been removed. [Matrix Type] is not specified.

**Example 6 (version 1.0):**

```
!2-port H-parameter file, single frequency point
# kHz H MA R 1
! freq magH11 angH11 magH21 angH21 magH12 angH12 magH22 angH22
2 .95 -26 3.57 157 .04 76 .66 -14
```

In the above example, the H-parameters are given in magnitude-angle format, normalized to 1 ohm.

**Example 6a (version 2.0):**

```
!2-port H-parameter file, single frequency point
# kHz H MA R 1
[Matrix Type] Full
! freq magH11 angH11 magH21 angH21 magH12 angH12 magH22 angH22
2 .95 -26 3.57 157 .04 76 .66 -14
```

In the above example, the H-parameters are given in magnitude-angle format, normalized to 1 ohm.

**Example 7 (version 1.0):**

```
!2-port S-parameter file, three frequency points
# GHz S RI R 50.0
!freq ReIS11 ImS11 ReS21 ImS21 ReS12 ImS12 ReS22 ImS22
1.0000 0.3926 -0.1211 -0.0003 -0.0021 -0.0003 -0.0021 0.3926 -0.1211
2.0000 0.3517 -0.3054 -0.0096 -0.0298 -0.0096 -0.0298 0.3517 -0.3054
10.000 0.3419 0.3336 -0.0134 0.0379 -0.0134 0.0379 0.3419 0.3336
```

In the above example, the S-parameter data is given in real-imaginary format, with a 50 ohm reference impedance.

**3-port and 4-port Networks**

Rules for Version 1.0 Files:

The network parameter data for a 3-port or 4-port network is arranged in a matrix row-wise order, with each line of data representing one row of the matrix. In other words (as shown below), the data for a 3-port network is entered as three lines of data, with each line containing three data pairs (i.e. a 3x3 matrix of network parameter values). Likewise, the data for a 4-port network is entered as four lines with four data pairs per line (a 4x4 matrix). As required by the general rules, each network parameter data group is preceded by the frequency value at which the data was taken.

3-port network description

```
<frequency value> <N11> <N12> <N13>
<N21> <N22> <N23>
<N31> <N32> <N33>
```

4-port network description

```
<frequency value> <N11> <N12> <N13> <N14>
<N21> <N22> <N23> <N24>
<N31> <N32> <N33> <N34>
<N41> <N42> <N43> <N44>
```

where

*frequency value* frequency at which the network parameter data was taken or derived.

*N11, N12, etc.* network parameter data points, where *Nij* represent pairs of data values.

As usual, network parameter data points are entered in magnitude-angle, dB-angle or real-imaginary format (i.e. pairs of values) as specified by the option line. All entries in a data line are separated by one or more whitespace characters; a data line itself is terminated by a newline character (CR or CR/LF)..

Shown below is an example of an S-parameter description of a 4-port network.

**Example 8:**

```
! 4-port S-parameter data, taken at three frequency points
# GHz S MA R 50
5.00000 0.60 161.24 0.40 -42.20 0.42 -66.58 0.53 -79.34 !row 1
          0.40 -42.20 0.60 161.20 0.53 -79.34 0.42 -66.58 !row 2
          0.42 -66.58 0.53 -79.34 0.60 161.24 0.40 -42.20 !row 3
          0.53 -79.34 0.42 -66.58 0.40 -42.20 0.60 161.24 !row 4

6.00000 0.57 150.37 0.40 -44.34 0.41 -81.24 0.57 -95.77 !row 1
          0.40 -44.34 0.57 150.37 0.57 -95.77 0.41 -81.24 !row 2
```

```

0.41 -81.24 0.57 -95.77 0.57 150.37 0.40 -44.34 !row 3
0.57 -95.77 0.41 -81.24 0.40 -44.34 0.57 150.37 !row 4

7.00000 0.50 136.69 0.45 -46.41 0.37 -99.09 0.62 -114.19 !row 1
0.45 -46.41 0.50 136.69 0.62 -114.19 0.37 -99.09 !row 2
0.37 -99.09 0.62 -114.19 0.50 136.69 0.45 -46.41 !row 3
0.62 -114.19 0.37 -99.09 0.45 -46.41 0.50 136.69 !row 4

```

Note that the data pairs do not have to be aligned in columns; the only requirement is that there be 3 (3-port networks) or 4 (4-port networks) pairs of n-port parameters per data line.

#### Rules for Version 2.0 Files:

As noted earlier and as required by the general rules, each group of network parameter data points is preceded by the frequency value at which the data was taken. The rest of the data for that frequency may follow on the same line or be split across multiple lines with intervening line-termination characters. Each frequency point must begin after a line-termination character on the first column of the line.

### 5-port and Above Networks

The n-port parameters for 5-port and above networks are also arranged in a matrix row-wise order.

#### Rules for Version 1.0 Files:

Version 1.0 files are limited to a maximum of 4 network parameter data points per line, additional entries beyond the first four in the matrix row must be continued on the following line(s). Each row of the matrix must start on a new line.

#### Rules for Version 2.0 Files:

Version 2.0 files may continue data on the same line, or across multiple lines. As usual, each group of network data points is preceded by the frequency value at which this data was taken.

These rules are illustrated by showing the format for a 6-port network:

#### 6-port network format (single frequency point)

```

<frequency value> <N11> <N12> <N13> <N14>           !row 1
<N15> <N16>
<N21> <N22> <N23> <N24>           !row 2
<N25> <N26>
<N31> <N32> <N33> <N34>           !row 3
<N35> <N36>
<N41> <N42> <N43> <N44>           !row 4
<N45> <N46>
<N51> <N52> <N53> <N54>           !row 5
<N55> <N56>
<N61> <N62> <N63> <N64>           !row 6
<N65> <N66>

```

where

*frequency value*                      frequency at which the network parameter data was taken or derived.

*N11, N12, etc.*                      network parameter data points, where *Nij* represent pairs of data values.

As shown, each row of matrix data extends over two lines of the file, and each new row of the matrix starts on a new line. As usual, n-port parameters values are entered in pairs according to the format specified in the option line and each entry is separated by whitespace.

Following is a more detailed example illustrating the data matrix for a 10-port network. The Y-parameter data is in magnitude-angle format, and is for a single frequency.

**Example 9:**

```
# frequency_unit Y MA R impedance
freq magY11 angY11 magY12 angY12 magY13 angY13 magY14 angY14 ! 1st row
magY15 angY15 magY16 angY16 magY17 angY17 magY18 angY18
magY19 angY19 magY1,10 angY1,10
magY21 angY21 magY22 angY22 magY23 angY23 magY24 angY24 ! 2nd row
magY25 angY25 magY26 angY26 magY27 angY27 magY28 angY28
magY29 angY29 magY2,10 angY2,10
magY31 angY31 magY32 angY32 magY33 angY33 magY34 angY34 ! 3rd row
magY35 angY35 magY36 angY36 magY37 angY37 magY38 angY38
magY39 angY39 magY3,10 angY3,10
magY41 angY41 magY42 angY42 magY43 angY43 magY44 angY44 ! 4th row
magY45 angY45 magY46 angY46 magY47 angY47 magY48 angY48
magY49 angY49 magY4,10 angY4,10
magY51 angY51 magY52 angY52 magY53 angY53 magY54 angY54 ! 5th row
magY55 angY55 magY56 angY56 magY57 angY57 magY58 angY58
magY59 angY59 magY5,10 angY5,10
magY61 angY61 magY62 angY62 magY63 angY63 magY64 angY64 ! 6th row
magY65 angY65 magY66 angY66 magY67 angY67 magY68 angY68
magY69 angY69 magY6,10 angY6,10
magY71 angY71 magY72 angY72 magY73 angY73 magY74 angY74 ! 7th row
magY75 angY75 magY76 angY76 magY77 angY77 magY78 angY78
magY79 angY79 magY7,10 angY7,10
magY81 angY81 magY82 angY82 magY83 angY83 magY84 angY84 ! 8th row
magY85 angY85 magY86 angY86 magY87 angY87 magY88 angY88
magY89 angY89 magY8,10 angY8,10
magY91 angY91 magY92 angY92 magY93 angY93 magY94 angY94 ! 9th row
magY95 angY95 magY96 angY96 magY97 angY97 magY98 angY98
magY99 angY99 magY9,10 angY9,10
!10th row
magY10,1 angY10,1 magY10,2 angY10,2 magY10,3 angY10,3 magY10,4 angY10,4
magY10,5 angY10,5 magY10,6 angY10,6 magY10,7 angY10,7 magY10,8 angY10,8
magY10,9 angY10,9 magY10,10 angY10,10
```