Touchstone Syntax for Versions 1.0 and 2.0

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Background

• Touchstone issued in 1984 by EEsof (now part of Agilent Technologies)
• Touchstone is an OPEN, defacto format supported by nearly all companies supplying or handling S-parameter data
• Touchstone ® is a registered trademark January 7, 1984 to October 10, 2007 – but it may have an indefinite life
• Touchstone “Version 1.0” uploaded as public reference for ICM reference
  – http://www.eda.org/pub/ibis/connector/
• Touchstone Version 2.0 extended to remove some limitations and add some resistance per port flexibility for PDS applications, but no mixed mode (differential) yet
  – http://www.eda.org/pub/ibis/docs/
Version 2.0 Document Overview (Document Still Under Review)

• Contains Touchstone “Version 1.0” format
  – “Version 1.0” is designation of compatible superset of original format, although “1.0” never entered

• Touchstone Version 2.0 advances
  – Selectable reference resistance by port
  – Explicit [Number of Ports] and [Number of Frequencies] keywords yields more flexible data format
    • Selectable 2-port ordering (12_21 or 21_12)
  – Symmetrical matrix format efficiency
  – Some reference normalization changes
Comment and Options Lines
Same for All Versions

- Comment character: “!” at beginning or within line
- Options Line with 4 arguments in any order:
  - # frequency_unit parameter format R,n
  - frequency_unit: {GHz | MHz | kHz | Hz}
  - parameter: {S | Y | Z | H | G}
  - format: {DB | MA | RI}
  - R,n: R <value> ! (R and <value> pair)
- Defaults (when arguments missing):
  - GHz, S, MA, R 50
- Examples
  - # ! Use the defaults, but one # is required
  - # GHz S DB R 25 ! Any order examples
  - # R 25 S GHz DB
  - # GHz MHz ! Error example – two frequency units
Touchstone “Version 1.0” Format (SnP where n=number of ports)

• Unique S2P ordering (21 before 12 retained)
  – Natural order is 11 12 21 22
• Unique n-port formatting of data rules (n => 1)
• Ordering and number or entries per line formed indirect way of determining number of ports
  – New line required for each new frequency
  – Frequencies must be in increasing order
• End of file or beginning of noise parameters terminates data
  – Noise parameters indicated by out of sequence frequency entry less than last frequency (for 2-port data only)
• G-, H- defined for 2-ports only – all versions
### “Version 1.0” Fixed Format Examples

(f = frequency, s = data-pair)

| S1P   | f s s s s s s s s s f s s s s s s f ...
|-------|--------------------------------------
| S2P   | f s s s s s s s s s f s s s s s s f ...
| S3P   | f s s s s s s s s s s s s f s s s s s s f ...
| S4P   | f s s s s s s s s s s s s s s s s s s s s s s f ...
| S5P   | f s s s s s s s s s s s s s s s s f ...
| S6P   | f s s s s s s s s s s s s s s s s f ...

Formatting, frequency ordering, and end of file implies number of ports and frequencies values.

Etc …
“Compatibility Notes” Advances Original Touchstone

• Differences between original Touchstone and “Version 1.0”
  – 99 port limit removed (usually not enforced)
  – dB (dB/angle) allowed for Y-, Z-, H-, and G-parameters (even though potential data at infinity problem when the magnitude is 0.0)
  – Y- and Z- parameters allowed for $n \Rightarrow 3$

• Touchstone Version 2.0 (versus “Version 1.0”)
  – No normalization for Y-, Z-, H-, and G- parameters and effective noise resistance
  – Data format restrictions relaxed
Touchstone Noise Format for All Versions

• For 2-port data only
• Five entries per line:
  – Frequency (starts with out of sequence frequency)
  – Minimum noise figure in dB
  – Source reflection coefficient always normalized with respect to $R_{<value>}$
  – Phase of source reflection coefficient in degrees
  – Effective noise resistance
    • Normalized with respect to $R_{<value>}$ for “Version 1.0” and below
    • Not normalized for Version 2.0
Version 2.0 Block Arrangement

Keywords and Option Line
(first entry is [Version] <n>)

N-port Data Block
(new line required only for each new ascending order frequency)

Optional Noise Data Block
(n=2 only)
Touchstone Version 2.0
Seven IBIS-like Keywords

• **Required keywords**
  - [Version] 2.0
    • Only “2.0” is permitted
    • Omitted [Version] implies “Version 1.0”
    • Must be first keyword before or after comment lines
  - [Number of Ports] <n>
    • [Two-Port Data Order] {21_12 | 12_21} required for n=2 only
  - [Number of Frequencies] <nf>

• **Optional keywords**
  - [Reference] <list of n reference resistances in port order>
  - [Matrix Format] {Full | Lower | Upper}
    • Defaults to Full if omitted
  - [Number of Noise Frequencies] <nnf>
    • Used ONLY for 2-port data (should require n=2)
    • Required only if noise data follows 2-port data list
Touchstone Version 2.0 Rules

• [Version] 2.0 required as first entry in file or after ! lines
• Keyword and option block before any n-port data
  – All other keywords in any order
  – Option line anywhere within block
  – Parser uses count information to check data block (and noise block) data content from n and nf (and nnf if given) and [Matrix Format]

• Each new frequency must be first entry in a row
  – Number of entries per row is optional (n value determines when new frequency and port grouping occurs
  – Ascending frequency still required

• Noise parameter data format unchanged
  – Still requires at least one line of 2-port data
  – Still requires out of sequence frequency from last data set
Touchstone Version 2.0
Data Normalization Changes

• “Version 1.0” (and original Touchstone)
  – Z, Y, G, H automatically normalized based on the R <value> or default
    • So the Z11 = 1.0 \(\Omega\) (normalized) entry with R 50 documents the actual Z11 magnitude is 50.0 \(\Omega\)
  – Effective noise resistance is normalized with respect to R <value>

• Version 2.0
  – Z, Y, G, H entries are direct and independent of <value> or [Reference] values (NOT normalized)
  – Effective noise resistance is NOT normalized
IBIS and Non-IBIS Conventions

- New keywords follow IBIS rules exactly
  - Bounded by “[“ and “]”
  - Separated within by single space or under-bar
  - Followed by data or data list of selected arguments
  - Subparameters not defined in Touchstone Version 2.0
- Touchstone comment character “!” similar to IBIS comment character (beginning or within line)
- Everything is case insensitive (unlike IBIS)
- Units are predefined – no multipliers allowed as in IBIS
- Weak numerical typing like IBIS
  - Numerical data can be fixed point, floating point or exponential
    (for example, 50 = 50.0 = 5e1)
Version 2.0
Unique 2-port Features

• Requires $n=2$
  – [Two-Port Data Order] required
  – G- H- Parameters Allowed
  – Noise Parameters Allowed

• Error if any of above exist for $n \neq 2$
Closure

• Syntax rule and data interpretation summary for all Touchstone versions
• Some legacy rules retained for compatibility
• Touchstone parser
  – Only Version 2.0 syntax?
  – Pass all “Version 1.0” syntax?
• Touchstone ® trademark - indefinite life
• Specific examples in latest draft document (in temporary link)
  – http://www.eda.org/pub/ibis/docs/
• Thanks to Michael Mirmak for preparing document, to Radek Biernacki for some very detailed review, and all the other participants for their help
Next Steps

- Finish review and vote for IBIS release
- Write request for parser quotes document
- Get parser quotes and select developer
- Raise money commitments
- Probably start project in 2009 or earlier
- Submit as GEIA standard either as Version 2.0 or wait for a Version 2.1 based on parser developer review comments and changes