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/

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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

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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
f s
f s
f …

S2P

f s s s
f s s s
f s s s
f …

S3P

f s s s
s s s
s s s
f s s s
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
f 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 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
s s
s s s s
s s
s s s s
s s
s s s s
s s
f …

Etc …

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

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"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 => 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)

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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

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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 Ω (normalized) entry with R 50 documents the actual Z11 magnitude is 50.0 Ω
  - 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

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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 < > 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 committments
- 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