Purpose

- The following slides summarize rules and issues for the new mixed-mode format as sketched in recent on-line discussions

- The summary "bullet points" here will be edited in real time during IBIS-Interconnect meetings

- Once the summary rules are agreed by consensus, formal text implementing them will be written

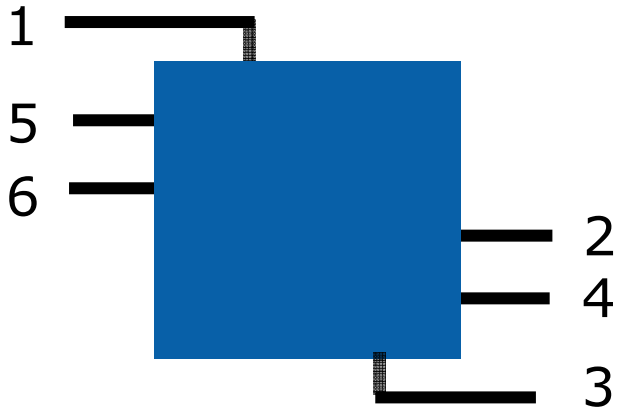
An Example…

- From Bob Ross
- For a 6-port example:
  - D2,4
  - D5,6
  - C2,4
  - C5,6
  - X1
  - X3
- The generalized matrix is:
  - Xd2_4,d2_4 Xd2_4,d5_6 . Xd2_4,c2_4 Xd2_4,c5_6 . Xd2_4,1 Xd2_4,3
  - Xd5_6,d2_4 Xd5_6,d5_6 . Xd5_6,c2_4 Xd5_6,c5_6 . Xd5_6,1 Xd5_6,3
  - Xc2_4,d2_4 Xc2_4,d5_6 . Xc2_4,c2_4 Xc2_4,c5_6 . Xc2_4,1 Xc2_4,3
  - Xc5_6,d2_4 Xc5_6,d5_6 . Xc5_6,c2_4 Xc5_6,c5_6 . Xc5_6,1 Xc5_6,3
  - X1,d2_4 X1,d5_6 . X1,c2_4 X1,c5_6 . X1,1 X1,3
  - X3,d2_4 X3,d5_6 . X3,c2_4 X3,c5_6 . X3,1 X3,3

Clarifying the Example

This drawing is arbitrary, as no specific "sides" or arrangements are implied by the example.

Multiple drawings are possible, as topologies are non-unique



- Mixed-mode only of interest for ports (2,4) and (5,6)
  - Ports 1 and 3 are expressed only in terms of single-ended data
- Stimulus, response ordering appears identical to existing definitions
  - E.g., SCD12: differential port 2 stimulus, common mode port 1 observed
- Not all relationships are defined!
  - This is unique to this proposal (contra other proposals)
  - Pro: flexible ordering; compact, particularly for larger systems
  - Con: SE data critical when key MM relationships are missing

Rules and Questions

- Single-ended data not required
- MM: Each SE data relationship appears only once
- MM: Each C/D data relationship appears only once
- Each port may "participate" in only one MM pair
  - Of each type: C, D
- Both C & D required for MM relationships for every "participating" pair
- SE port *numbers* used across entire file
- Mixed mode pair ordering is always +,-
- How are the positions of the data pairs defined?
  - Row, column ordering of *ports* not defined by the specification
  - A table of ports will be made explicit in each file
- Ports may not "participate" in both SE and MM pairs

New Syntax

- [Mixed-mode Order]
  - A vector of ports and/or port relationships of interest
  - The vector determines the content and row and column order to be used in [Mixed-mode Data] (see below)
  - Single-ended port numbers are used throughout the file
  - Single-ended ports are indicated by "S" followed by an integer
  - Common-mode MM port relationships are indicated by "SC" and two integers, separated by a comma
  - Differential-mode MM port relationships are indicated by "SD" and two integers, separated by a comma
  - Relationships are separated by semicolons (whitespace optional)
    - *For example, S5; SD3,2; SC3,2*
  - Ports may not appear in more than one D or one C relationship
  - Only S-parameter data is defined today
    - *Other relationships may be added freely in future revisions*
  - Every port must be included under [Mixed-mode Order]

New Syntax (2)

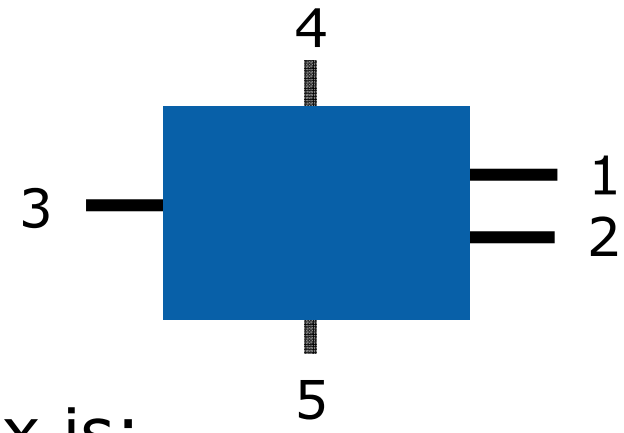
- [Mixed-mode Data]
  - Network data describing the electrical relationships between ports, in single-ended and/or mixed-mode terms
  - Only ports and port relationships mentioned explicitly under [Mixed-mode Order] may appear in [Mixed-mode Data]
  - The order of ports/port relationships in [Mixed-mode Order] determines the arrangement of the matrix in [Mixed-mode Data]
    - *[… Order] row vector multiplied by [… Order] column vector*
    - *See example*
  - Frequency information, spacing and other formatting identical to Touchstone 1.0 single-ended matrices

Examples

- Three-port device – e.g., a balun
  - D1,2
  - 3
  - C1,2 {C1,3 would be prohibited}
- The generalized matrix is:
  - Xd1_2,d1_2 Xd1_2,3 Xd1_2,c1_2
  - X3,d1_2 X3,3 X3,c1_2
  - Xc1_2,d1_2 Xc1_2,3 Xc1_2,c1_2

Examples

- Five-port device – e.g., differential buffer and supply
  - D1,2
  - 3
  - 4
  - 5
  - C1,2



- The generalized matrix is:
  - Xd1_2,d1_2 Xd1_2,3 Xd1_2,4 Xd1_2,5 Xd1_2,c1_2
  - X3,d1_2 X3,3 X3,4 X3,5 X3,c1_2
  - X4,d1_2 X4,3 X4,4 X4,5 X4,c1_2
  - X5,d1_2 X5,3 X5,4 X5,5 X5,c1_2
  - Xc1_2,d1_2 Xc1_2,3 Xc1_2,4 Xc1_2,5 Xc1_2,c1_2

Reference Impedances

- Proposed Reference Impedance Rules
  - For single-ended (SE) ports used in mixed-mode combinations C and/or D, both ports must use the same single-ended [Reference Impedance] values
  - [Reference Impedance] contents are single-ended only
  - Differential mixed-mode relationships therefore assume termination of 2*impedance connected across terminals
  - Common-mode mixed-mode relationships therefore assume termination impedances connected to the same reference node (see below)

References – Nodes vs. Ports

- Ports and Nodes are Not Identical
  - Ports are combinations of nodes and references
  - Touchstone permits three reference schemes, all implicit
    - *Each port has its own unique reference*
    - *Each port shares a reference with all other ports in that matrix*
    - *Each port shares a reference with all other ports in all matrices/interconnects (universal ground)*
  - Should Touchstone 2.0 limit referencing to one of these?
    - *[Port Referencing] keyword*
    - *Three arguments: Unique, Shared, Universal*
    - *Keyword determines both circuit usage of matrix data AND some mathematical assumptions about matrix data*
    - *What does this do to common-mode mixed-mode data?*
    - *How are reference impedances/terminations connected?*
    - *Example: For 5x5 matrix data…*
      - "Unique" maps to 10 terminal device
      - "Shared" maps to 6 terminal device
      - "Universal" maps to 5 terminal device with GND SPICE assumption