**BUFFER ISSUE RESOLUTION DOCUMENT (BIRD)**

**BIRD NUMBER: 173.3**

**ISSUE TITLE:** Package RLC Matrix Diagonals

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**STATEMENT OF THE ISSUE:**

*As generally understood, [Package Model]s in the form of RLC matrices should have only positive values in the diagonal matrix entries; however, the specification does not clearly state this condition. IBISCHK also does not check for this condition, so models with negative diagonal entries are not flagged with a warning or error. Clarifying this rule in the specification will allow the parser to be updated to add checks for the rule, and this will improve model quality.*

**ANALYSIS PATH/DATA THAT LED TO SPECIFICATION:**

*IBISCHK BUG151 led to the need for writing this BIRD.*

*BIRD173.1 was modified to include additional matrix rules for passivity. Authors also modified.*

*BIRD173.2 was modified to state “positive semi-definite.”*

*BIRD173.3 was modified to state “all eigenvalues are real and non-negative, including zero”*

**ANY OTHER BACKGROUND INFORMATION:**

Modifications to the IBIS specification are proposed below:

*Keywords:* [Resistance Matrix], [Inductance Matrix], [Capacitance Matrix]

*Required:* [Resistance Matrix] is optional. If it is not present, its entries are assumed to be zero. [Inductance Matrix] and [Capacitance Matrix] are required.

*Sub-Params:* Banded\_matrix, Sparse\_matrix, or Full\_matrix

*Description:* The subparameters mark the beginning of a matrix, and specify how the matrix data is formatted. See Figure 31.

*Usage Rules:* For each matrix keyword, use only one of the subparameters. After each of these subparameters, insert the matrix data in the appropriate format (these formats are described in detail below).

*Other Notes:* The resistance, inductance, and capacitance matrices are also referred to as “RLC matrices” within this specification.

When measuring the entries of the RLC matrices, either with laboratory equipment or field-solver software, currents are defined as ENTERING the pins of the package from the board (rule #11 in Section 3, “GENERAL SYNTAX RULES AND GUIDELINES”). The corresponding voltage drops are to be measured with the current pointing “in” to the “+” sign and “out” of the “-” sign.



1. - Package Matrix Voltage Polarities and Current Directions

It is important to observe this convention in order to get the correct signs for the mutual inductances and resistances.

*Example:*

[Resistance Matrix] Banded\_matrix

[Inductance Matrix] Sparse\_matrix

[Capacitance Matrix] Full\_matrix

RLC Matrix Notes:

For each [Resistance Matrix], [Inductance Matrix], or [Capacitance Matrix], a different format can be used for the data. The choice of formats is provided to satisfy different simulation accuracy and speed requirements.

Also, there are many packages in which the resistance matrix can have no coupling terms at all. In this case, the most concise format (Banded\_matrix) can be used.

Package RLC matrices are assumed to be reciprocal and passive, thereby necessitating the R, L and C matrices be symmetric and positive semi-definite (all eigenvalues are real and non-negative, including zero). The C matrix belongs to the class of M-matrices, while the L and R matrices belong to the class of inverse M-matrices. For further information see Roger Horn and Charles Johnson (1990), *Matrix Analysis*, Cambridge University Press. Passivity enforcement and the M-matrix rules lead to the following requirements for the matrix elements.

There are two different ways to extract the coefficients that are reported in the capacitance and inductance matrices. For the purposes of this specification, the coefficients reported in the capacitance matrices shall be the “electrostatic induction coefficients” or “Maxwell’s capacitances”. The Maxwell capacitance Kij is defined as the charge induced on conductor “j” when conductor “i” is held at 1 volt and all other conductors are held at zero volts. Note that Kij (when i /= j) will be a negative number and should be entered as such. Kii shall be a non-negative number (positive or zero). Additionally, Kii coefficients should satisfy the condition of diagonal dominance, whereby each Kii coefficient shall be greater than or equal to the sum of all absolute values of the Kij coefficients (when i /= j). Likewise, for the inductance matrix the coefficients for Lij are defined as the voltage induced on conductor “j” when conductor “i”’s current is changed by 1 amp/sec and all other conductors have no current change. Lii shall be a non-negative number. Additionally, each Lii coefficient shall be larger than the absolute value of any Lij coefficient. The inverse L matrix shall also satisfy the condition of diagonal dominance. This ensures that all eigenvalues of the matrix are non-negative. For the resistance matrix, Rii coefficents shall be non-negative numbers. If mutual resistances are included in the resistance matrix, then each Rii coefficient shall be larger than the absolute value of any Rij coefficient. The inverse R matrix shall also satisfy the condition of diagonal dominance.

One common aspect of all the different formats is that they exploit the symmetry of the matrices they describe. This means that the entries below the main diagonal of the matrix are identical to the corresponding entries above the main diagonal. Therefore, only roughly one-half of the matrix needs to be described. By convention, the main diagonal and the UPPER half of the matrix are provided.

In the following text, we use the notation [I, J] to refer to the entry in row I and column J of the matrix. Note that I and J are allowed to be alphanumeric strings as well as integers. An ordering of these strings is defined in the [Pin Numbers] section. In the following text, “Row 1” means the row corresponding to the first pin.

Also note that the numeric entries of the RLC matrices are standard IBIS floating point numbers. As such, it is permissible to use multiplier “suffix” notation. Thus, an entry of the C matrix could be given as 1.23e-12 or as 1.23p or 1.23pF.

Full\_matrix:

When the Full\_matrix format is used, the couplings between every pair of elements are specified explicitly. Assume that the matrix has N rows and N columns. The Full\_matrix is specified one row at a time, starting with Row 1 and continuing down to Row N.

Each new row is identified with the Row keyword.