Substrate File (.matl) Format

Release 16 &17

*Please transition to Sonnet's Technology File (.STF) with v17

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Substrate (.matl) File Format: Release 16 & 17

This document details the format of the .matl file used for both Sonnet's Cadence Virtuoso and Keysight ADS Interfaces. This version of the format is compatible with Sonnet Cadence Virtuoso Interface 16.52 and above and compatible with Sonnet Keysight ADS Interface 16.52 and above except as noted.

Please transition to Sonnet's Technology File (.STF) with v17.

An example of a partial .matl file along with the resulting stackup in Sonnet is shown below.

New Features and Changes

This section identifies the new features and changes in the substrate file for this release.

New Features

Z-partitions for Dielectrics: You may now specify a unique parameter for Z-partitions for future use with specifying dielectric bricks. For more details, see the keyword **DIEL** **on page 12**.

Direction for Thick Metal or Rough Metal: You may now choose the direction of both the thick metal and rough metal loss models, either up from the metal level or down from the metal level. For more details, see the keyword **METAL** **on page 15**.

Resistance Per Via: You may now specify loss for via metals using Resistance Per Via. For more details, see the keyword **VIA** **on page 18**

New “Bar” Fill Type for Vias: There is a new fill type “Bar” available for vias. For more details, see the keyword **VIA** **on page 18**.

Changes

Comments: Use of comments and the position of the semi-colon have been clarified. See the following section for more details.

Comments

You may add comments to a .matl file. The file is parsed by looking at the first three letters of a keyword; any line which starts with any character not included in that group will be treated as a comment. Since a semi-colon “;” is used in Cadence Skill, we recommend using a semi-colon as the first character in a comment line.

NOTE: **A semi-colon which does not appear as the first character will cause an error when reading the .matl file; therefore, comments should always be a single entry, not entered at the end of a command.**

File Syntax

The file includes sections for units, variables, materials, layer mapping, unused materials, cap metals and ground shields. Entries start with a unique keyword which identifies the type of statement. Most of the keywords are used to define material types: dielectrics, metals, vias and unused materials. You may define any number of each type of material.

For metals and vias, the entries may appear in any order. Some users prefer to list the materials in the same order in which they appear in the stackup, while others prefer to group them according to material type. Either method is acceptable; since the level is included in the material definition, where it appears in the file is irrelevant to how it is placed in the stackup. Note that when a .matl level is created by an interface it is written out in the order in which the materials occur in the stackup.

The dielectric section should have the dielectrics appear in the order that they occur in the stackup.

TIP

If you wish to group types of materials together and want the properties to line up in columns you may use tabs in your entry lines. Tabs are treated the same as spaces when parsing the file.

The keyword entries and their formats are defined below.

Units

There are four entries for units: length, conductivity, resistivity and sheet resistance. The syntax for each entry is shown below.

LUNIT Length Unit

Syntax `LUNIT “<length_unit>”`

`<length_unit>` is a character string which identifies the length unit. Possible values are shown in the table below. Note that the `length_unit` should always be encased in quote marks.

LUNIT	Units
“um”	Microns
“m”	Meters
“cm”	Centimeters
“mm”	Millimeters
“nm”	Nanometers
“pm”	Picometers
“inch”	Inches
“ft”	Feet
“mil”	Mils
“uinch”	Microinches

CUNIT Conductivity Unit

Syntax `CUNIT “<conductivity_unit>”`

`<conductivity_unit>` is a character string which identifies the conductivity unit. Possible values are shown in the table below. Note that the `conductivity_unit` should always be encased in quote marks.

CUNIT	Units
“S/m”	Siemens/meter
“S/cm”	Siemens/centimeter
“mS/cm”	millisiemens/centimenter
“uS/cm”	microsiemens/centimeter

RUNIT Resistivity Unit

Syntax `RUNIT “<resistivity_unit>”`

`<resistivity_unit>` is a character string which identifies the resistivity unit. Possible values are shown in the table below. Note that the `resistivity_unit` should always be encased in quote marks.

RUNIT	Units
“Ohm-cm”	Ohm-centimeters
“Ohm-m”	Ohm-meters

SRUNIT Sheet Resistance Unit

Syntax `SRUNIT “<sr_unit>”`

`<sr_unit>` is a character string which identifies the sheet resistance unit. Possible values are shown in the table below. Note that the `length_unit` should always be encased in quote marks.

SRUNIT	Units
“Ohms/sq”	Ohms/sq
“mOhms/sq	milliOhms/sq

Variables

VAR This entry defines a variable which may be used for the conductivity of a dielectric level and can also be dependent upon the frequency by specifying the internally defined variable FREQ. . You may define as many variables as you wish; each variable should have a separate entry line. As of Release 16, a variable can only be used in the conductivity or resistivity of a dielectric level.

Syntax `VAR varname = expression`

<Varname> is a character string which identifies the variable. Each variable must have a unique name.

<expression> is a mathematical expression which could contain the frequency variable (FREQ). For Sonnet’s equation syntax, please see “Equation Syntax” in Sonnet’s knowledge base. An example is shown below:

```
VAR abc = 23.5*FREQ
```

would define the variable “abc” as a value of 23.5 times the frequency.

Dielectric Levels

DIEL This entry defines your dielectric levels.

Syntax

```
DIEL Thickness Erel Mrel TanE TanM DielCond DielName CondResValue
ZPart Anisotropic ZErel ZMrel ZTanE ZTanM ZDielCond
```

There is a DIEL entry for each dielectric layer in your project. The numbering of the dielectric layers is implicitly defined by the position of the DIEL statement in the .matl file, so the entries should be listed in the same order as they appear in the stackup. The first DIEL layer represents the highest dielectric layer in your project. The next DIEL statement represents the dielectric layer below that one and so on. The fields are defined in the table below. the keyword **VAR** on page 11

Field	Definition
`<Thickness>`	A non-zero positive floating point number which defines the thickness of the dielectric number in microns.
`<Erel>`	A positive floating point number which defines the relative permittivity of the dielectric.
`<Mrel>`	A positive floating point number which defines the relative permeability of the dielectric.
`<TanE>`	A positive floating point number which defines the dielectric loss tangent of the dielectric in the x,y plane.
`<TanM>`	A positive floating point number which defines the magnetic loss tangent of the dielectric in the x,y plane.

Field	Definition
`<DielCond>`	A positive floating point number which defines the conductivity or resistivity of the dielectric (in the x,y plane) in conductivity or resistivity units specified in the UNITs section, determined by the setting CondResValue. This field may also be a character string which specifies a variable. The name may appear with or without quotes. The variable name must be specified prior to this line within a VAR statement. For more information on variables, please see the keyword **VAR** on page 11.
`“<DielName>”`	A character string used to identify dielectric. This entry should appear in quotes.
`“<CondResValue>”`	A character string which defines whether the dielectric is being defined using conductivity or resistivity. Use “Cond” for conductivity and “Res” for resistivity. This setting controls the nature of the `DielCond` and `ZDielCond` field.
`<ZPart>`	An integer number of zero or above that defines the number of partitions in the z-direction. The higher the number the finer the resolution of the meshing in the z-direction. Note that in the present release this value may not be set in the interface.
`“<Anisotropic>”`	A character string which is either "Isotropic" or "Anisotropic". If "Anisotropic" is specified, this allows you to specify anisotropic dielectric properties for the z-direction.
`<ZErel>`	This value only appears for an anisotropic dielectric. A positive floating point number which defines the relative permittivity of the dielectric in the z-direction.

Field	Definition
`<ZMrel>`	A positive floating point number which defines the relative permeability of the dielectric in the z-direction.
`<ZTanE>`	A positive floating point number which defines the dielectric loss tangent of the dielectric in the z-direction.
`<ZTanM>`	A positive floating point number which defines the magnetic loss tangent of the dielectric in the z-direction.
`<ZDielCond>`	A positive floating point number which defines the conductivity or resistivity of the dielectric (in the z-direction) in conductivity or resistivity units specified in the UNITs section, determined by the setting `CondResValue`. This field may also be a character string which specifies a variable. The name may appear with or without quotes. The variable name must be specified prior to this line within a VAR statement. For more information on variables, please see the keyword **VAR** on page 11.

Metals

METAL This entry defines a metal used in your project.

Syntax

```
METAL LayerName Growth Rdc Rrf Xdc Ls Color MetalName SonLevel
SonMetalType MetalCond MetalThick CurrentRatio NumSheets
FillType XMin XMax YMin YMax UseEdgeMesh CrossSection
TopRoughness BottomRoughness CondResValue
```

There is a METAL entry for each type of metal defined in your project. The metal statement is for metal which appears on the metal level attached to the dielectric layer whose entry proceeds it. Note that in Sonnet, the metal level is attached to the dielectric layer ABOVE it. Please also note that this syntax is one line.

When specifying the metal type for metals, vias, etc., you should fill in all values for Rdc, Rrf, Xdc, Ls, MetalCond, MetalThick, CurrentRatio, and NumSheets. For example, if you set the SonMetalType to Normal, you would set MetalCond, MetalThick and CurrentRatio to the values desired and set the other values to a default value of zero for Rdc, Rrf, Xdc, Ls and two for NumSheets.

The fields are defined in the table below.

Field	Definition
`<Layername>`	A character string which is the name of the layer in the Virtuoso or ADS layout containing the objects which are being mapped to this Sonnet layer. Only the layer name is required, the Virtuoso purpose name is not presently used.
`<Growth>`	This field is not currently implemented but is reserved for future use. A floating point number which represents the oversize factor per edge. If this value is not necessary, the default value of 0.0 should be used.
`<Rdc>`	A floating point number which provides the sheet resistivity of the metal in ohms/square.

Field	Definition
<Rrf>	A floating point number which provides the skin effect coefficient of the metal in Ohms-Hz$^{-1/2}$ /square
<Xdc>	A floating point number which provides the surface reactance of the metal in Ohms/square.
<Ls>	A floating point number which provides the kinetic inductance of the metal.
<Color>	An integer value which represents the Color/Pattern for this metal type. The value range is 0-55 with zero always representing the default lossless metal type.
“<MetalName>”	A character string which is the name of the Sonnet metal type. The character string should be placed in quotes.
<SonLevel>	A positive integer value which is the Sonnet level where the metal is located. The character string GND is used for ground.
“<SonMetalType>”	A character string which identifies the Sonnet metal model used for this metal. Possible values are `General`, `Normal`, `ThickMetalModel`, `SenseMetal`, `RoughMetal`. `Resistor`, or `Rdc/Rrf`. The character string should be placed in quotes.
<MetalCond>	A positive floating point number which provides the conductivity, resistivity or sheet resistance in the units specified within the units section and determined by the setting in <`CondResValue`>. This value may also be set to the character string INF for infinite.
<MetalThick>	A positive non-zero floating point number which provides the metal thickness in microns.

Field	Definition
<CurrentRatio>	A positive floating point number which provides the current ratio for the metal. This field is only used if <SonMetalType> is set to `Normal`.
<NumSheets>	An integer value greater than or equal to 2 which defines the number of sheets used to model the metal. This field is only used in < SonMetalType> is set to `ThickMetalModel`.
“<FillType>”	A character string which identifies the Sonnet fill type used for this metal. Possible values are `Default`, `Staircase`, `Diagonal`, or `Conformal`. The character string should be placed in quotes.
<XMin>	A integer value greater than or equal to 1 which defines the minium number of cells in a subsection in the X direction. The default value is 1. Must be less than XMax.
<XMax>	A integer value greater than or equal to XMin which defines the maximum number of cells in a subsection in the X direction. The default value is 100.
<Ymin>	A integer value greater than or equal to 1 which defines the minium number of cells in a subsection in the Y direction. The default value is 1. Must be less than YMax.
<YMax>	A integer value greater than or equal to YMin which defines the maximum number of cells in a subsection in the Y direction. The default value is 100.
“<UseEdgeMesh>”	A character string which identifies whether the edge mesh option is on. Possible values are `EdgeMeshOn` or `EdgeMeshOff`. The character string should be placed in quotes.

Field	Definition
`“<CrossSection>”`	A character string which identifies how a Rough or Thick Metal type is being modeled. Possible values are “`Thin`” “ `Thick” or “ThickDown”`. The character string should be placed in quotes. If the `CrossSection` is set to “Thick” then the metal extends upward from the metal level (default). If `CrossSection` is set to “ThickDown” then the metal extends downward from the metal level.
`<TopRoughness>`	A positive floating string number which provides the top surface roughness in RMS microns.
`<BottomRoughness>`	A positive floating string number which provides the top surface roughness in RMS microns.
`“<CondResValue>”`	A character string which defines whether the metal is being defined using conductivity, resistivity or sheet resistance. Use “Cond” for conductivity, “Res” for resistivity and “ShRes” for sheet resistance. This setting controls the nature of the `MetalCond` field.

Vias

VIA This entry defines a via.

Syntax

```
VIA LayerName Growth Rdc Rrf Xdc Ls Color MetalName SonLevel
SonToLevel SonMetalType MetalCond MetalThick CurrentRatio
NumSheets FillType Pads FillFactor VolType CondResValue
ViaDensity
```

When specifying the metal type for metals, vias, etc., you should fill in all values for Rdc, Rrf, Xdc, Ls, MetalCond, MetalThick, CurrentRatio and NumSheets. For example, if you set the SonMetalType to Normal, you would set MetalCond, MetalThick and CurrentRatio to the values desired and set the other values to a default value of zero for Rdc, Rrf, Xdc, Ls and two for NumSheets. Note this syntax is one line.

There is a VIA entry for each via in your project. The fields are defined in the table below.

Field	Definition
`<Layername>`	A character string which is the name of the layer in the Virtuoso or ADS layout containing the objects which are being mapped to this Sonnet layer. Only the layer name is required, the Virtuoso purpose name is not presently used.
`<Growth>`	This field is not currently implemented but is reserved for future use. A floating point number which represents the oversize factor per edge. If this value is not necessary, the default value of 0.0 should be used.
`<Rdc>`	A floating point number which provides the sheet resistivity of the via metal in ohms/square.
`<Rrf>`	A floating point number which provides the skin effect coefficient of the via metal in ohms-Hz$^{-1/2}$/square.
`<Xdc>`	A floating point number which provides the surface reactance of the via metal in ohms/square.
`<Ls>`	A floating point number which provides the kinetic inductance of the via metal.
`<Color>`	An integer value which represents the Color/Pattern for this metal type. The value range is 0-55 with zero always representing the default lossless metal type.
`“<MetalName>”`	A character string which is the name of the Sonnet metal type. The character string should be placed in quotes.
`<SonLevel>`	A positive integer value, or the string GND for ground, which is the Sonnet level where the via starts; this is always the lower end of the via.

Field	Definition
<SonToLevel>	A positive integer value, or the string GND for ground or TOP for box top, which is the Sonnet Level where the via ends; this is always the top of the via.
“<SonMetalType>”	A character string which identifies the Sonnet metal model used for this via metal. Possible values are `Volume, Surface, and Array`. The character string should be placed in quotes.
<MetalCond>	A positive floating point number which provides the conductivity, resistivity, sheet resistance or resistance per via in the units specified in the units section and defined by the value of `CondResValue`. This value may also be set to the character string INF for infinite.
<MetalThick>	A positive non-zero floating point number which provides the metal thickness in microns.This value is used in modeling loss and is not a physical thickness.
<CurrentRatio>	A positive floating point number which provides the current ratio for the via metal. This field is only used if < SonMetalType> is set to `Normal`.
<NumSheets>	An integer value greater than or equal to 2 which defines the number of sheets used to model the via metal. This field is only used in < SonMetalType> is set to `ThickMetalModel`.
“<FillType>”	A character string which identifies the Sonnet fill type used for this metal. Possible values are `Default`, `Ring`, `Vertices, Center, Full` or `Bar`. The character string should be placed in quotes.

Field	Definition
“<Pads>”	A character string which determines whether via pads are added to the top and bottom of the via. If no via pads are used this field should be set to `“PadsOn”` and if via pads are not to be added this field should be set to the `“PadsOff”` value. `“Padsoff”` is the default value.
<FillFactor>	A positive floating point number which defines the fill factor for the Array model. Default value is 100.
“<Voltype>”	A character string which identifies the type of Volume loss model used for this via metal. Possible values are `Wall, Solid, or N/A.` The character string should be placed in quotes. Default value is `Wall`.
“<CondResValue>”	A character string which defines whether the metal is being defined using conductivity, resistivity, sheet resistance or resistance per via. Use “Cond” for conductivity, “Res” for resistivity, “ShRes” for sheet resistance and “RPV” for resistance per via. This setting controls the nature of the `MetalCond` field. Note that for the Array via metal model, you may only use conductivity and resistivity.
<ViaDensity>	A positive floating point number which defines the via density in vias/microns^2 if the `CondResValue` is defined as "RPV" and `SonMetalType` is defined as "Array".

Unused Via Metals

VMATERIAL This entry defines a Sonnet via metal type which is unused in the circuit.

Syntax `VMATERIAL MetalName Rdc Rrf Xdc Color SonMetalType MetalCond MetalThick FillFactor Voltype CondResValue ViaDensity`

There is a VMATERIAL entry for each additional unused via metal type you wish to define for your project. Please see "METAL" on page 15 for an explanation of the fields.

Planar Metals - Unused or Box Definition

MATERIAL This entry defines a Sonnet metal type you wish to define to use elsewhere in your project, such as the box top or bottom. It may also be used to define a Sonnet planar metal type which is unused in the circuit.

Syntax `MATERIAL MetalName Rdc Rrf Xdc Ls Color SonMetalType MetalCond MetalThick CurrentRatio NumSheets CrossSection TopRoughness BottomRoughness Direction`

There is a MATERIAL entry for each additional metal type you wish to define for your project. Please see "METAL" on page 15 for an explanation of the fields.

Layer Mapping for GDSII, DXF and Gerber Import/Export

The layer mapping entries are all optional. Please note these keywords do not apply to the Keysight ADS Interface at this time and are only valid when using the Cadence Virtuoso Interface.

GDSLAYER This entry defines the GDSII layer mapping for a metal or via. The Technology layer created in the Sonnet project for the specified source layer can also be assigned to a GDS stream and data type for subsequent imports and exports in the Sonnet project. If a file is being imported, then the incoming GDSII stream and data type are mapped to the created Technology Layer. When exporting, this metal type is mapped to the specified stream number and data type. This entry is optional.

Syntax `GDSLAYER “source_layer” GDSStream GDSDataType`

`source_layer` is a character string identifying the source layer which is being mapped to the GDS stream and data type and should appear in quotes. `GDSStream` is an integer value which specifies the number of the GDSII stream assigned to the source layer. If the Sonnet project is later exported, then the resulting GDSII stream created from the Technology Layer will use this name. This can be useful as a reminder of the source of this layer. `GDSDataType` is an integer value which specifies the data type of the GDSII stream to which the source layer is mapped. A GDSII stream may contain more than one type of object, such as metal polygons and via polygons. Each object is assigned a data type. If the Sonnet project is later exported, then the resulting GDSII stream created from the Technology Layer will use this data type. This can be useful as a reminder of the source of this layer.

DXFLAYER This entry defines the DXF layer mapping for a metal or via. The Technology layer created in the Sonnet project for the specified source layer can also be assigned to a DXF Layer for subsequent imports and exports in the Sonnet project. If a file is being imported, then the incoming DXF layer is mapped to the created Technology Layer. When exporting, this metal type is mapped to the specified DXF layer. This entry is optional.

Syntax `DXFLAYER “source_layer” “dxf_layer”`

`source_layer` is a character string identifying the source layer which is being mapped to the DXF layer and should appear in quotes. `dxf_layer` is a character string which specifies the DXF layer assigned to the source Layer and should appear in quotes. If the Sonnet project is later exported, then the resulting DXF layer created from the Technology Layer will use this name. This can be useful as a reminder of the source of this layer.

GBRLAYER This entry defines the Gerber layer mapping for a metal or via. The Technology layer created in the Sonnet project for the specified source layer can also be assigned to a Gerber file (one file per layer) for subsequent imports and exports in the Sonnet project. If a Gerber file is being imported, then the incoming Gerber file is mapped to the created Technology Layer. When exporting, this metal type is mapped to the specified Gerber file. This entry is optional.

Syntax `GRBLAYER “source_layer” “gerber_file”`

`source_layer` is a character string identifying the source layer which is being mapped to the Gerber file and should appear in quotes. `gerber_file` is a character string which specifies the Gerber file assigned to the source Layer and should appear in quotes. Gerber files normally use a .gbr extension, but you are not limited to that extension. If the Sonnet project is later exported, then the resulting Gerber file created from the Technology Layer will use this name. This can be useful as a reminder of the source of this layer.