

User-Defined Models in MMICAD

This application note shows how easy it is for designers to incorporate their own work in MMICAD.

MMICAD has a powerful feature which allows the user to define device models and use them as if they were built-in MMICAD circuit elements. These models can be used with device parameters in a similar manner as built-in elements. In addition, you can store your models in a portable ASCII file. This brings an unprecedented level of flexibility to both individuals and organizations (i.e. GaAs foundries) that need to develop their own RF and microwave models.

Creating User-Defined Models

User defined models are created as multi-port network descriptions in circuit blocks, with the addition of a MODVAR (MODEL VARIABLE) statement to specify the passed parameters, and a modification to the DEFnP statement. The changes are to allow the definition of parameters to be passed to the model, including their names and default values. Model variables are defined in a MODVAR statement at the beginning of the model network definition as follows:

```
MODVAR <Variable1>=<Default1> <Variable2>=<Default2> ...
```

in which the <Variable> terms are the names of the model variables and the <Default> entries are the default values they will be set to if they are not explicitly specified in the lines where the model is used in further network definition. Any number of variables can be defined in the MODVAR statement. No more than one MODVAR statement is allowed in the model network definition. Following the MODVAR statement, designers may define any number of local variables for use in the model with LOCVAR statement.

i.e. `LOCVAR A=3.14`
`LOCVAR B={A*FREQ*2}`

The model network is defined in the lines following the MODVAR statement, if present. Once the network is finished, its definition is completed with a DEFnP statement. In order to tell MMICAD that the network is a model instead of a normal network, a pair of round brackets are placed after the network name. Optionally, a list of the model variables can be included between the brackets to clarify which variables are passed to the model and which are not:

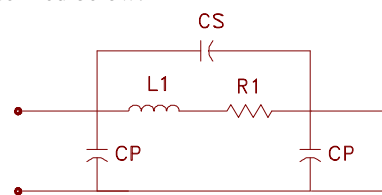
i.e. `DEFnP <node1>...<nodeN> <Network> (<Var1>
<Var2>...)`

(If **Edit With Defaults** is chosen from the Edit menu, MMICAD will place the names of the model variables between the brackets automatically.)

Example:

One application for user-defined models is in designing for manufacturing at a MMIC foundry. Such a foundry might have a set of predefined components such as FETs, spiral inductors, thin-film resistors and the like which can be used in circuits. These would have the advantages of being well characterized, meeting the foundry design rules, and having proven manufacturability. Lumped elements would typically have circuit models.

An example of a user defined MODEL for a spiral inductor is defined below:



```
L1 = 0.2*N+0.05*N^2
R1 = 0.23*N*FREQ/1E9
CP = 0.01*N+0.003*N^2
CS = 0.03*N+0.05*N^2
N = number of turns
```

This model may be defined in MMICAD as follows:

```
! An example illustrating a user defined model for a spiral inductor:

CKT
MODVAR N=2
IND 1 3 L={0.2*N+0.05*N^2}
RES 3 2 R={0.23*N*FREQ/1E9}
CAP 1 2 C={0.03*N+0.05*N^2}
CAP 1 0 C={0.01*N+0.003*N^2}
CAP 2 0 C={0.01*N+0.003*N^2}
DEF2P 1 2 SPIR (N)

!SPIR IS A MODEL NOT A NETWORK
!N=PARAMETER
!2=DEFAULT VALUE OF THE PARAMETER

SPIR 1 2 N=? 3 4.2 5 ?
!SPIR WILL BE OPTIMIZED AS A FUNCTION OF THE NUMBER OF TURNS

FET 2 3
SPIR 3 4 N=? 5 7 8 ?
DEF2P 1 4 AMP

!AMP IS A NETWORK NOT A USER DEFINED MODEL.
!ALL RESULTS ARE AVAILABLE FOR DISPLAY.
```

In summary, MMICAD allows the designer to assign a name for the model, number of ports, and the parameter list. The model can be referenced any number of times in the circuit applications.

The INCLUDE Statement

To include the models in many circuit files, use the **INCLUDE** statement. User-defined models can be stored in a file which could then be included in any circuit file as desired. The syntax of the **INCLUDE** block is:

```
INCLUDE <Filename>
```

where <Filename> is any valid DOS filename including a path, if desired; wildcard characters are not allowed. When **INCLUDE** blocks are used, MMICAD reads the text of the included file during analysis as though it had been merged with the circuit file being analyzed. Although this can be used to include text at any point in the circuit file, typically it is used to include models and possibly a **GLOBAL** block (see below). A file or files containing models could be included near the beginning of a circuit file. The models contained therein would be available for use at any subsequent point in the circuit file.

The GLOBAL Block

MMICAD also includes another block that facilitates the use of model libraries - the **GLOBAL** block. This block can be used to define commonly used stripline and microstrip substrates, avoiding the necessity of substrate definitions in circuit and model files. The defined substrates can be used in any subsequent model or network.

A more important use of the **GLOBAL** block is consistency checking of units in models and networks. Internally, MMICAD uses MKS units in all its calculations, although other units are used in many applications - microns or mils may be the units of choice rather than metres, for example. MMICAD allows users to choose units with its default units settings, which can be modified by choosing **Defaults** from the Settings menu. The default units are entered in MKS units, so that if the default unit for length, for example, is to be microns, it would be entered as 0.000001 (10^{-6} meters/micron). MMICAD will multiply all lengths by this value. The default units set in the Settings menu can be overridden by using the DIM keyword. This can be placed in the **GLOBAL** block and the **CKT** block. The DIM keyword can occur in different places in the circuit file, but defaults cannot be set to different values; MMICAD will halt analysis and generate an error message if an inconsistency is found. This feature can be used to ensure that there is no confusion because of different units in the circuit and model files. For example, the person writing the model for a microstrip coupler might use microns as the unit of choice, whereas the person using the model might use mils. If the model user included a DIM statement in the **GLOBAL** block and the model writer included a DIM statement in the model file **CKT**, MMICAD would inform the user that a units conflict exists. It is recommended that DIM statements always be used in the **GLOBAL** block at the beginning of each circuit and at the beginning of **CKT** blocks in model files.

Dimension Normalizing Constants

A further way of avoiding units conflicts is built into MMICAD. The current default units are available using the constants **DIMFREQ**, **DIMLNG**, **DIMCAP**, **DIMIND**, **DIMRES**, **DIMCON**, and **DIMTIME**, which can be used in mathematical expressions. These can be used to make the models independent of the current default units and models can be created using MKS units.

For example, a thin film resistor model might be created to be included in a model library called ELEMENTS.MDL:

Model file:

```
GLOBAL
!Define lossless GaAs substrate for use in this model
MSUB ER=12.4 H={200E-6/DIMLNG} T={2E-6/DIMLNG}&
RHO=0 TAND=0 @TFRRESSUB
CKT
DIM RES=1 LNG=1E-6
MODVAR W=10 L=10 RSQ=50
RES 1 2 R={RSQ*L/W}
MTRLND 2 3 W={W} L={L} @TFRRESSUB
```

Circuit file:

```
GLOBAL
DIM RES=1 LNG=1E-6
INCLUDE C:\MMICAD\MODELS\ELEMENTS.MDL
CKT
FET 1 2 3
TFRES 3 0 L=20
DEF2P 1 2 FEEDBK
FREQ
SWEEP 1 10 .5
OUT
```