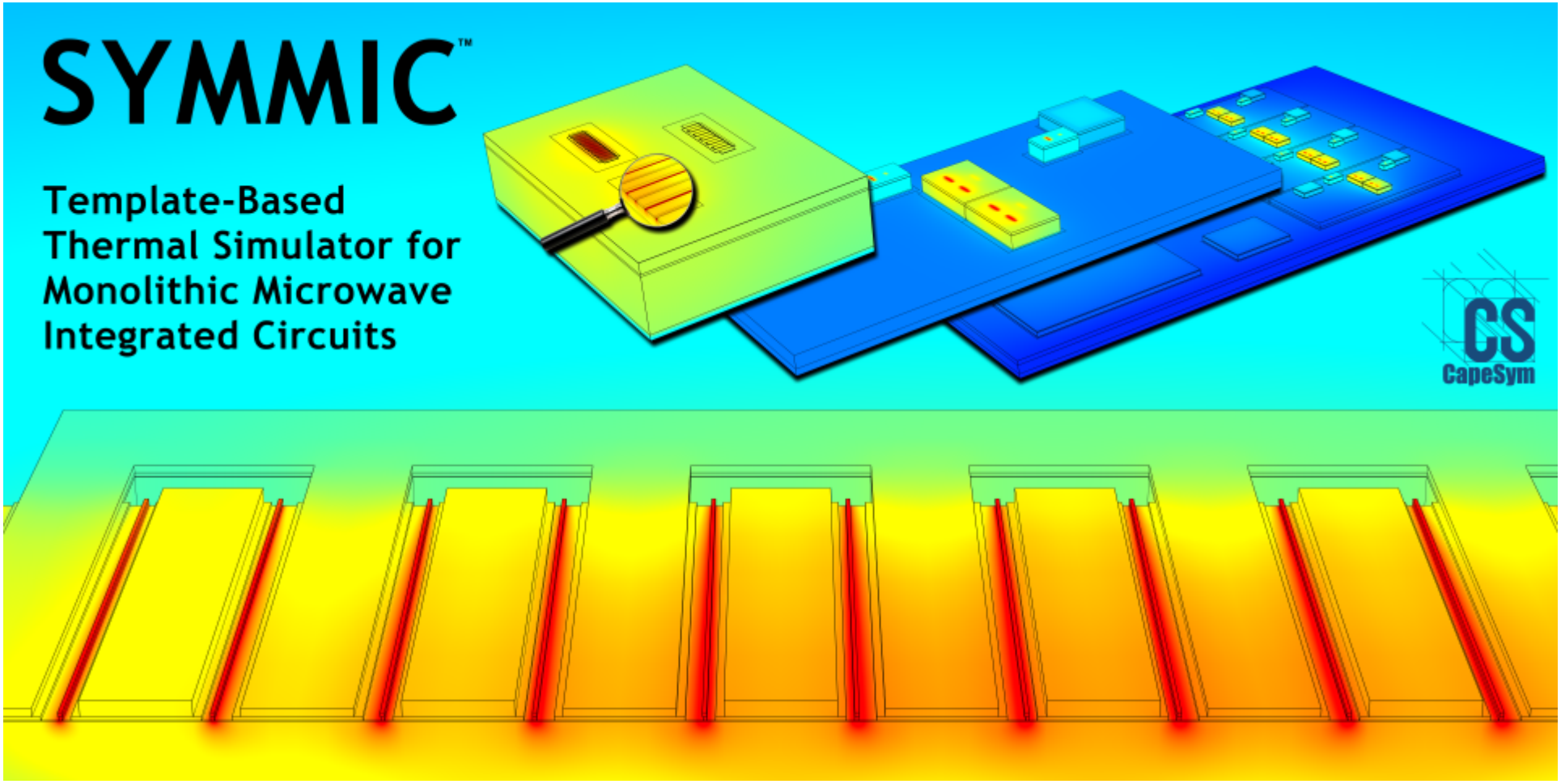
Creating a Device Template



What is in a Device Template?

3D geometry grouped into components

Mesh defined for each geometric feature

List of materials and their thermal properties

Boundary conditions

Parameterization

Initial conditions and solution times

Method for solution and integration parameters

History of events in the life of the template

Need a Device Template?

1. Configure and use one of the generic templates
2. Modify existing one with Device Template Editor
3. Export layout to a device template
4. Convert GDSII artwork to a device template
5. Create a device template from scratch

Templates Use XML Format

- XML = Extensible Markup Language (www.w3.org)
- Tag
  - A markup construct that begins with "<" and ends with ">".

  start-tags: `<Points>`

  end-tags: `</Points>`

  empty-element tags: `<XRef delta="1" />`
- Element
  - Begins with a start-tag and ends with a matching end-tag, or consists only of an empty-element tag: `<XRef delta="1" />`
- Attribute
  - A name/value pair within a start-tag or empty-element tag: `delta="1"`

Document Type Definition File

Provided with data files on installation of SYMMIC

template_format.dtd

Defines all elements and attributes

Defines default values of attributes

```
<!ATTLIST RefX
    delta          %SFEvald;   #REQUIRED
    refn           %SFEvald;   "1"
    bias           %SFEvald;   "1.0"
    beginMeshSize  %SFEvald;   "0.0"
    endMeshSize    %SFEvald;   "0.0"
    beginMeshPrev  %SFBool;    "false"
    endMeshNext    %SFBool;    "false">
```

Allows XML syntax of device template to be validated!

About Attributes

Attribute name must have space before and equal sign after, case insensitive

Attribute values:

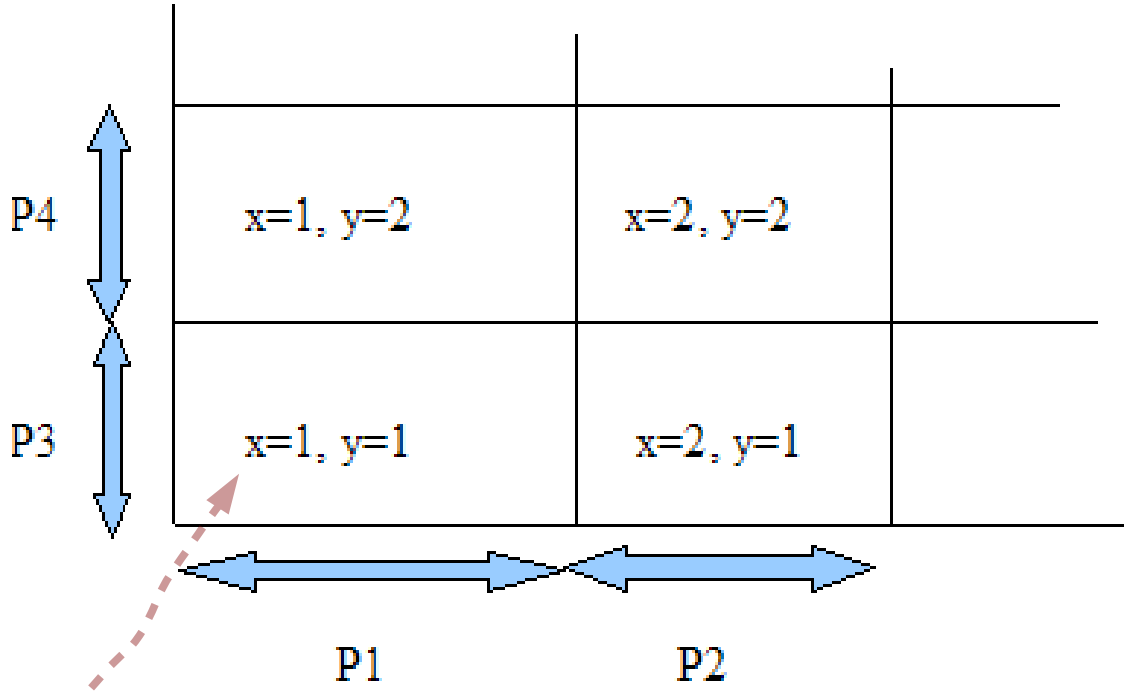
- String
- Boolean: `"true"` or `"false"`
- Double: `"1.0e-6"`
- Integer: `"37"`
- Multiple values: `"0.1 200, 0.2 300, … , 0.5 600,"`
- ID: unique string of no more than 15 characters; no other element in the template may have the same ID string (`id="P37"`)
- EvaldD: mathematical expressions of IDs

Outline of Device Template

```
<?xml version="1.0"?>
<!DOCTYPE Template SYSTEM "template_format.dtd">

<!-- For development of specific templates contact fiala@capesim.com -->

<Template  title="Half FET"   helpFile="genericFET.chm" >

  <Parameters>... </Parameters>

  <Points>... </Points>

  <ZLayers>... </ZLayers>

  <Materials>... </Materials>

  <Device>... </Device>

  <BoundaryConditions>... </BoundaryConditions>

  <Simulation>... </Simulation>

  <History>... </History>

</Template>
```

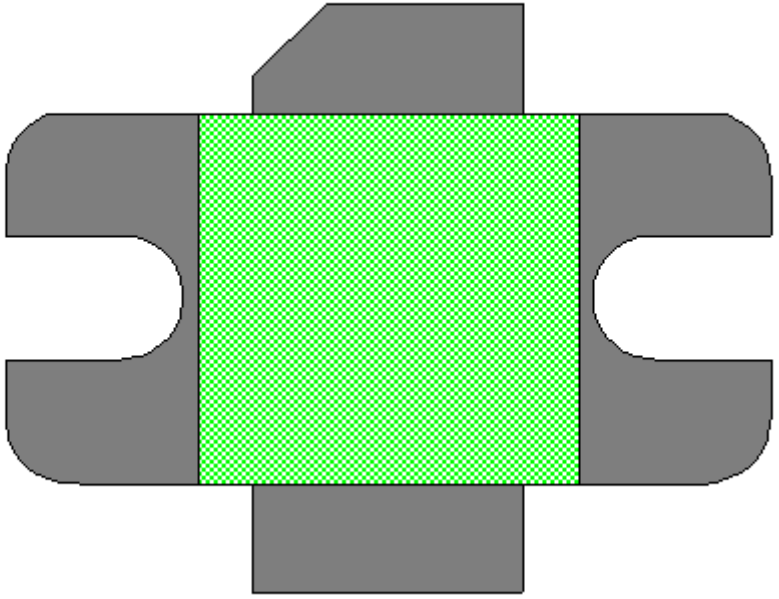
Points Section Defines X-Y Features

```
<Parameters>
 <AParam id="P1" name="Feature 1" value="3.0" … />
 <AParam id="P2" name="Feature 2" value="2.0" … />
 <AParam id="P3" name="Feature 3" value="1.0" … />
 <AParam id="P4" name="Feature 4" value="1.0" … />
:
</Parameters>

<Points>
 <RefX delta="P1"/>
 <RefX delta="P2"/>
:
 <RefY delta="P3" />
 <RefY delta="P4"/>
:
</Points>

:
```

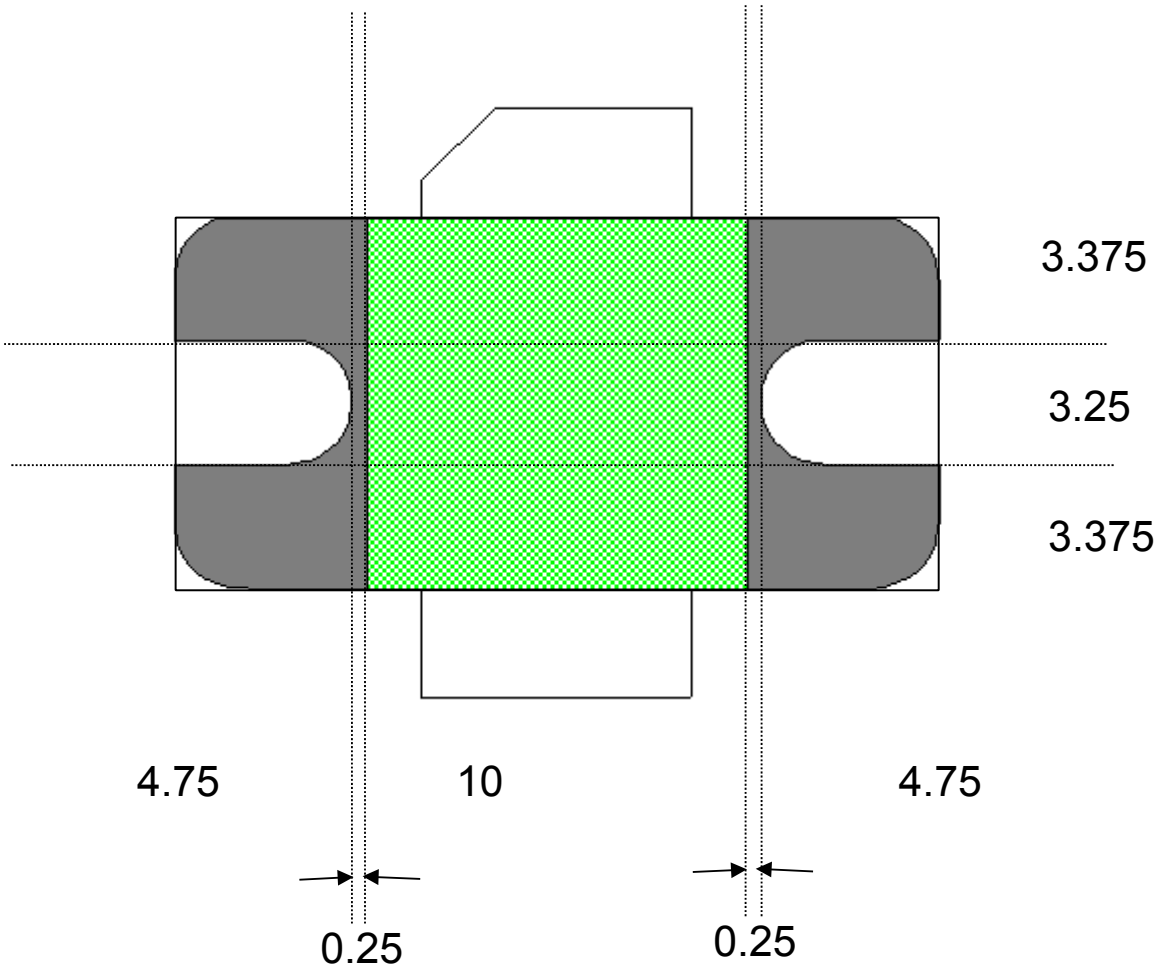



```
<Device>
:
 <Component name="corner" material="Au" layer="layer01" >
  <Blocks x="1" y="1" />
 </Component>
:
```

SOT608 Package



Feature Geometry for Package

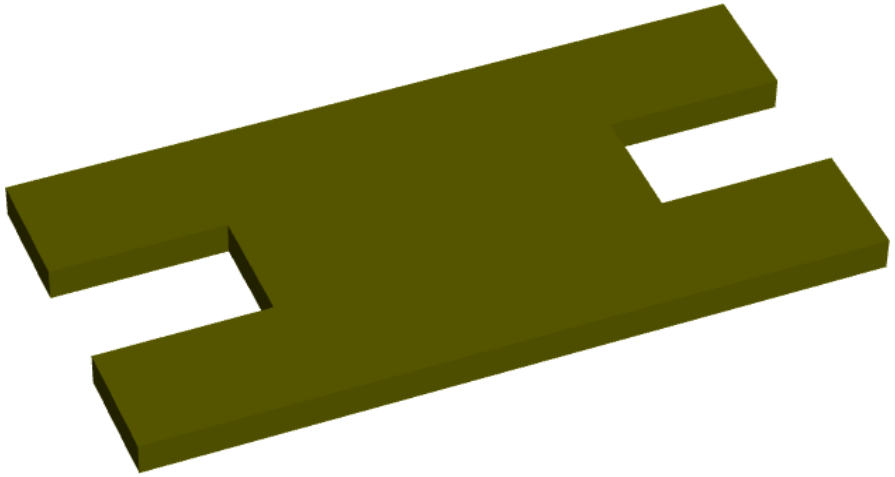


Start with Blank Device Template

```
<?xml version="1.0"?>              <!-- This is an XML Document with a defined format -->
<!DOCTYPE Template SYSTEM "template_format.dtd">
<Template title="blank">

<Points>                                    <!-- These are the geometric features in x -->
 <RefX delta="1"/>
                                            <!-- These are the geometric features in y -->
 <RefY delta="1" />
</Points>
                                            <!-- These are the geometric features in z -->
<ZLayers>
 <Layer id="layer01" begin="0" end="1" />
</ZLayers>
                          <!-- This section defines the material properties -->
<Materials>
 <AMaterial id="Au" description="Pure Gold" color="120 120 0"
  conductivity="0.0003 300" />
</Materials>
                           <!-- Geometric parts defined using above features and materials -->
<Device>
 <Component name="blank" material="Au" layer="layer01" >
  <Blocks x="1" y="1" />
 </Component>
 </Device>
                           <!-- Power fluxes and other boundary conditions -->
<BoundaryConditions>
 <Constant temperature="300" face="bottom" layer="layer01" >
  <Blocks x="1" y="1" />
 </Constant>
</BoundaryConditions>
                           <!-- Template element is closed to end the model -->
</Template>
```

Modify Blank Device Template

```
:
<Points>
 <RefX delta="4.75" />
 <RefX delta="0.25" />
 <RefX delta="10" />
 <RefX delta="0.25" />
 <RefX delta="4.75" />

 <RefY delta="3.375" />
 <RefY delta="3.25" />
 <RefY delta="3.375" />
</Points>

:

<Device>
 <Component name="flange" material="Au" layer="layer01" >
  <Blocks x="1-5" y="1-1" />
  <Blocks x="2-4" y="2-2" />
  <Blocks x="1-5" y="3-3" />
 </Component>
</Device>

<BoundaryConditions>
 <Constant temperature="300" face="bottom" layer="layer01" >
  <Blocks x="1-5" y="1-1" />
  <Blocks x="2-4" y="2-2" />
  <Blocks x="1-5" y="3-3" />
 </Constant>
:
```



Device Component

Contains any number of `Blocks` elements

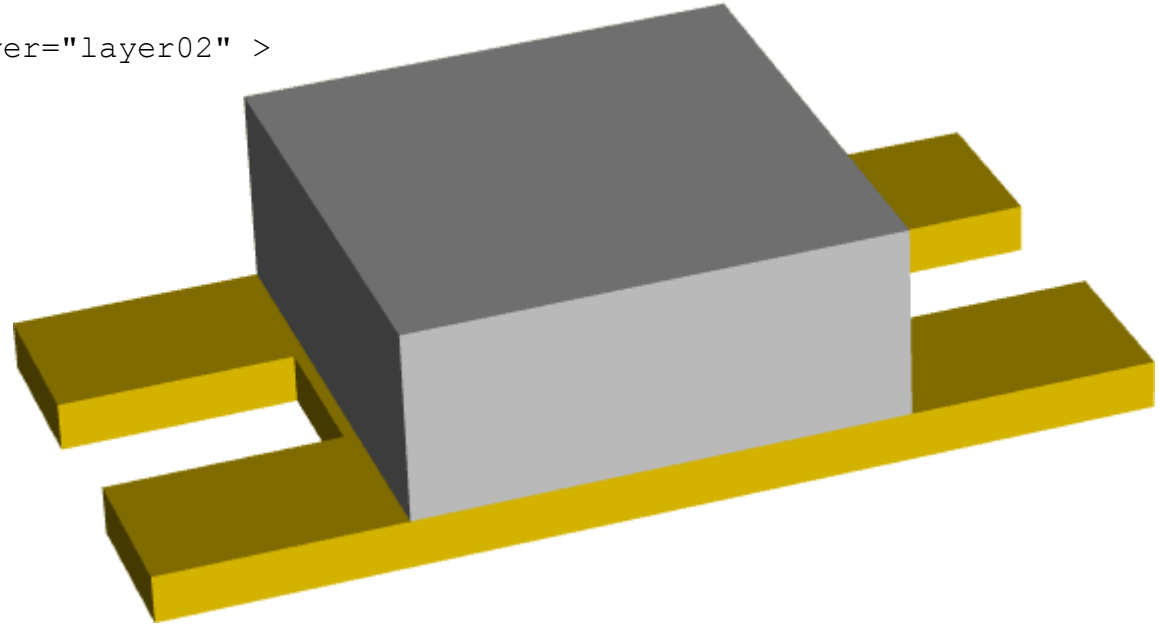
```
<Component name="epi" material="GaAs"
 layer="L4">
  <Blocks x="7-21" y="4-5" />
  <Blocks x="7-7" y="6-12" />
  <Blocks x="11-21" y="6-12" />
  <Blocks x="7-21" y="13-14" />
 </Component>
```

Spans only a single layer

May touch but not intersect any other component, i.e. no block repeated within any components in a layer

SOT608_start Template

```
:
<ZLayers>
 <Layer id="layer01" begin="0" end="1"/>

 <Layer id="layer02" begin="1" end="5"/>

</ZLayers>
:

<Device>
 <Component name="flange" material="Au" layer="layer01" >
  <Blocks x="1-5" y="1-1" />
  <Blocks x="2-4" y="2-2" />
  <Blocks x="1-5" y="3-3" />
 </Component>

 <Component name="case" material="Au" layer="layer02" >
  <Blocks x="3-3" y="1-3" />
 </Component>

</Device>

:
```



Parameter Lists

Parameters with same `type` attribute listed together

Parameters listed in reverse order from their occurrence in the template

Lists appear in order of occurrence of `type` attributes

`type=""` refers to a hidden parameter which does not show up in the user interface

The parameter lists of devices in a layout are independent from each other

Evald Attributes

Mathematical expressions that follow rules of typical programming languages such as C or FORTRAN

May involve `AParam` ids: `"P1","P2","P3","L5"`

```
"max(P1,P2/P3+0.9)"
"floor(max(min(8,P1/P2),3))"
"(P3^6)*(P1-P2)/2."
"if(P3-11.5,P1-P2,P2)"
"max(4,log(L5/(L5+(P2-P1)*(P3-1)))/log(P3)"
```

Valuation of Parameters

Parameter values are limited to range `min` to `max`, which are Evald expressions

Parameter `units` are descriptive only

When a parameter is modified the entire set of parameters is iteratively revalued based on `min` and `max` expressions until the values stop changing

Once parameters are resolved, all other Evald expressions in the template are evaluated

Parameters with `value=min=max` are not changeable in the user interface and appear red in color

Exercise

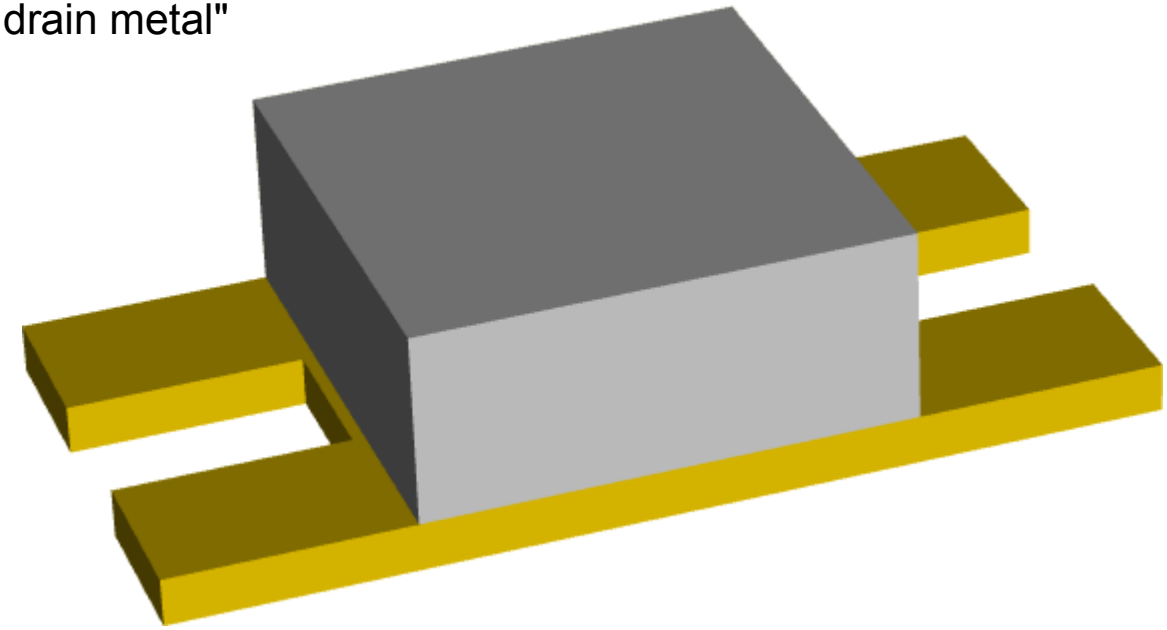
Create a package device template with parameters that let the user set all dimensions of the package from the SYMMIC user interface.

Hint: Use text editor that highlights XML syntax and add parameter tags.

```
<AParam id="BX" name="East-West Boundary" value="100"
  min="1" max="1000" units="microns" type="Dimensions"
  description="Distance from X boundary to drain metal"
  />
```

Answer:

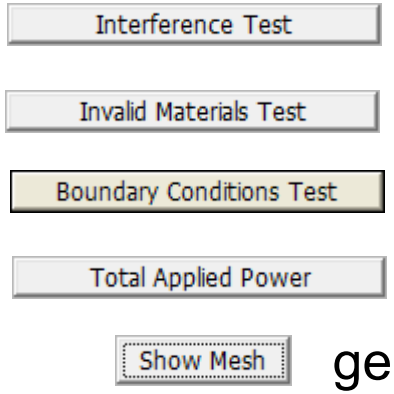
SOT608_parameterized.xml



How to Track Down Errors

- Read console messages when template is opened
- Use the XML validation tool on the template

  (need template_format.dtd in same folder as template)
- Use the Model check... dialog



checks for component overlap, block errors

checks for components with invalid material ids

checks for missing and misplaced BCs

reports the total sflux and bflux power

generates and displays the mesh

Meshing Attributes

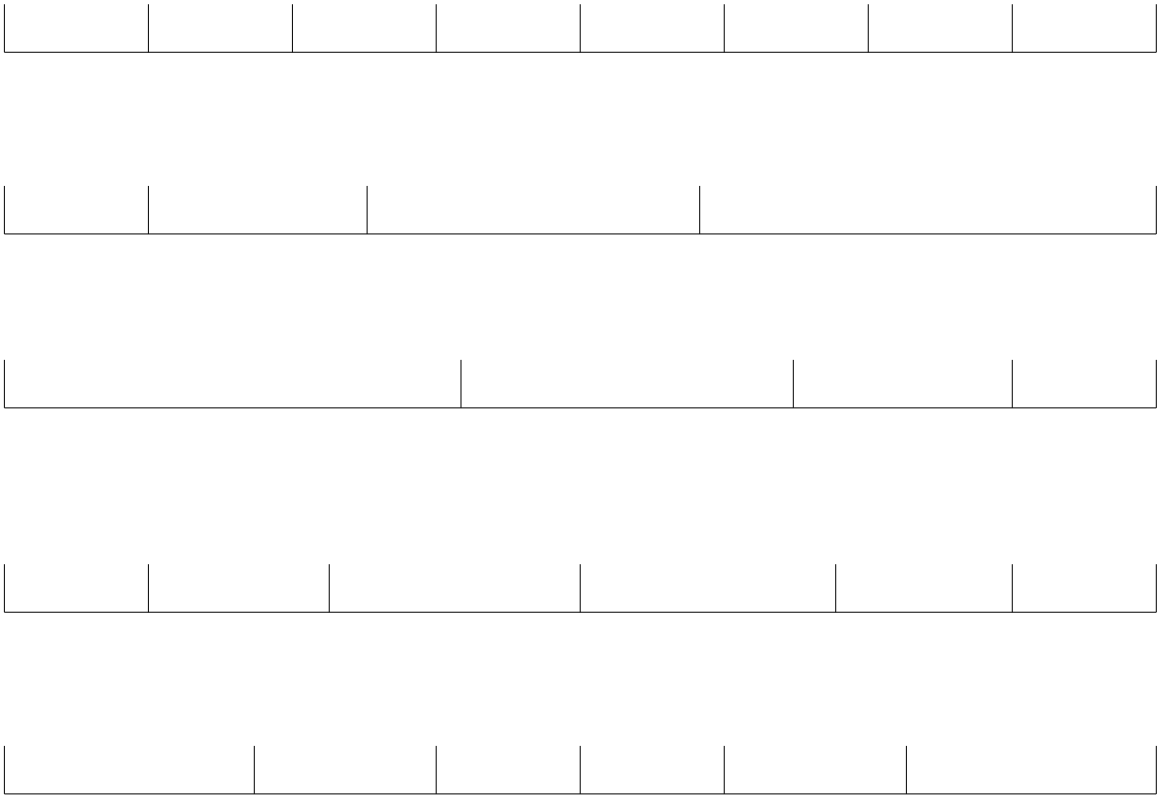
refn="8" bias="1.0"

refn="4" bias="1.5"

refn="4" bias="0.67"

refn="6" bias="-1.25"

refn="6" bias="-0.8"



mesh bias applied from lower value → higher value

Alternative Mesh Specification

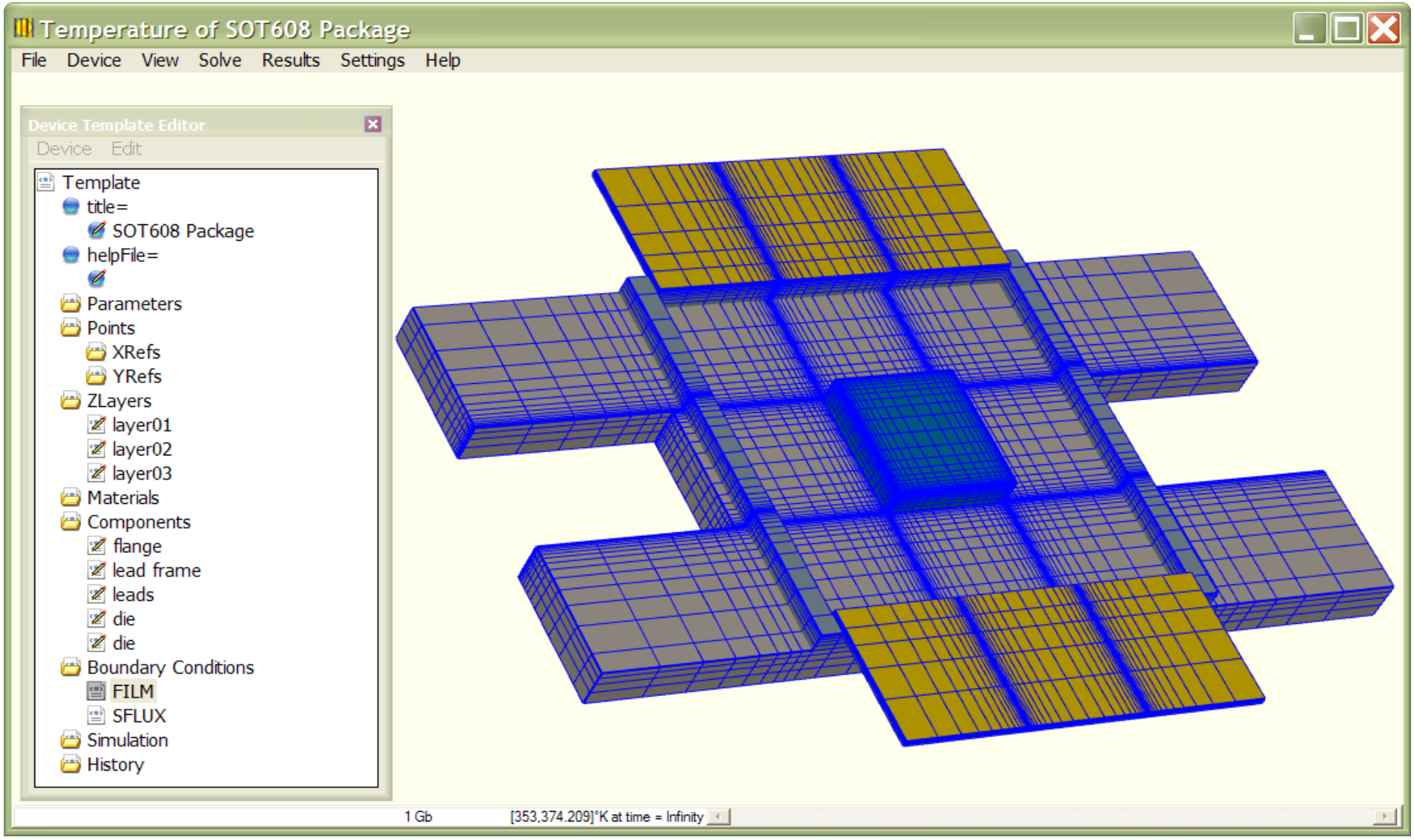
beginMeshSize="0.1" bias="1.5"

endMeshSize="0.1" bias="0.67"

beginMeshPrev="true" bias="1.0"

endMeshNext="true" bias="0.8"

SOT608_complete



Five Types of Boundary Conditions

Constant Surface Temperature

in Kelvin

Surface Film

Newton's law of cooling: $Q = h(T - T_{\infty})$

Surface Flux

Watts per square micrometer

Volume Flux

Watts per cubic micrometer

Surface Radiation to Ambient

Stefan-Boltzmann law: $Q = k(T^4 - T_{\infty}^4)$

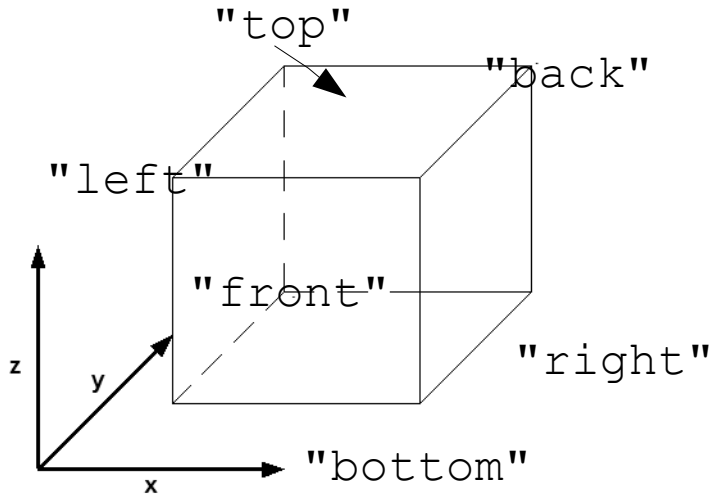
Five Types of Boundary Conditions

```
<Film h="P42" temperature="P41" face="bottom" layer="layer00" >
  <Blocks x="1-21" y="1-15" />
</Film>

<SFlux flux="(S1*P40/100000)/W1" face="top" layer="layer4b" >
  <Blocks x="15-15" y="4-12" />
</Sflux>

<Constant temperature="100." face="left" layer="layer01" >
  <Blocks x="1" y="1"/>
</Constant>

<BFlux flux="1000.0" layer="layer05">
  <Blocks x="2" y="1"/>
</Bflux>

<Radiation ambient="P41" face="top" layer="layer06" >
 <Blocks x="1-21" y="1-15" />
</Radiation>
```

Boundary Conditions

Most boundary conditions apply to a `face` of all blocks

face=



SOT608_complete.xml

After boundary conditions, can solve for temperatures...