Introductory Exercise 2: Heat Sink What-If Modifications

Sauna models are very easy to modify. In this exercise you will change the fin length, modify the plate thickness, and make other changes. As you will see, this is quite easy to do.

Menu buttons

When modifying models, it is desirable to minimize the number of menu selections. Sauna provides menu buttons (see Figure 2-11) for the most commonly used commands for changing the window and display.

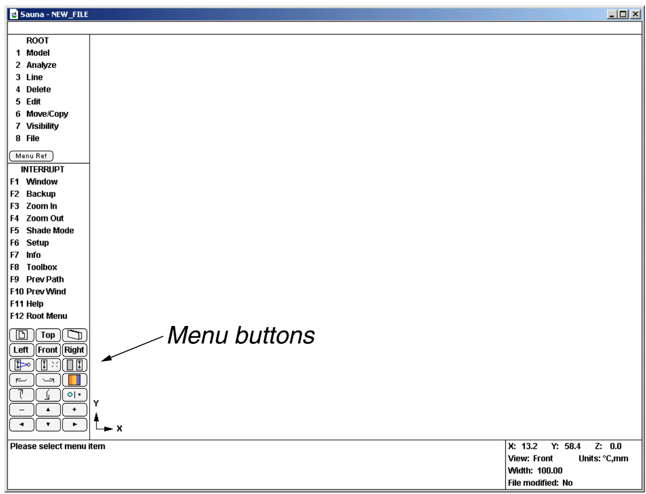


Figure 2-11: Location of menu buttons

Here is a description of the menu buttons:

Zoom out to a window which shows the entire visible model.

Left Front Right Top Switch to one of the standard orthogonal views.

Switch to the front, twisted perspective view.

Turn on the entire model, including fixed nodes.

Turn off fixed nodes.

Activate shade mode, or if shade mode is already active, turn it off.

Turn the view left, right, up or down.

Activate contour mode, or turn off contour mode if already active.

Switch between "full" and "abbreviated" symbols for nodes and resistors.

\- + Progressively zoom out, progressively zoom in

◄ ► ▲ ▼ Scroll left, right, up or down.

You will find that the menu buttons are extremely useful.

Forced air vs. natural cooling

You will continue to work with the model created in the first exercise. Remember that this model was saved on your disk as “new_sink.smf”. The model can also be found in “C:Program Files (x86)\Sauna Thermal Modeling\Reference Models”. *If necessary*, load the model with **<F12 Root Menu> ➔ File ➔ Open...**

You should be in a front view with fixed nodes off. *If necessary,* enter:

click **➔ *click*** **Front**

Start by repeating the steady state, natural cooling calculation:

<F12 Root Menu> ➔ Analyze ➔ Calc Temps ➔ Steady ➔ Natural ➔ "25"

As before, you should obtain $T_{junction}$ = 136.98°C.

Let’s suppose that the design goal is keep $T_{junction}$ below 100°C at a 25°C ambient. One possible solution is to use a fan to blow air over the sink. Sauna can also predict temperatures for this cooling mode. To analyze performance at an air flow rate of 600 feet / minute, make these menu selections:

<F12 Root Menu> ➔ Analyze ➔ Calc Temps ➔ Steady ➔ Forced Air ➔ Feet/Minute ➔ "600" ➔ "25"

A new set of temperatures will be calculated. There will be a significant decrease in temperature. The junction temperature is now down to 97.07°C, within the target range.

Notice that you specified a linear air flow rate of 600 feet / minute. Fans, on the other hand, are rated with a volume flow rate (CFM or m^3 / hr) and a static pressure. For this exercise, you will only work with linear air flow. But Sauna does provide the capability to perform a flow and thermal analysis of a fan / sink combination. More details are given at the end of the exercise.

Finding an equivalent, naturally cooled heat sink

At this point, we have a heat sink which is acceptable in forced air cooling, but inadequate for natural cooling. Suppose that, for noise and cost reasons, using a fan is not possible. How can the heat sink be improved so that it has acceptable natural cooling performance?

In the first exercise, when you were reading the temperature report, you may have noticed that there were significant variations in temperature along the plate. Let's try making the plate thicker so that there will be less of a temperature drop as heat spreads through the plate. Make these menu selections:

click

<F12 Root Menu> ➔ Edit ➔ Plate/Board ➔ Dimensions ➔ Plate Thick ➔ Enter Value ➔ "10" ➔ Centerline ➔ Select 1 ➔ *trap the plate (click edge)* ➔ USE

The sink will be modified. On the screen, several things will happen. First, the dashed lines which represent the sink outline will be redrawn to reflect the new dimensions. You probably expected this.

In addition, the node temperatures will be removed and the message "Node temperatures and float resistors were cleared" will be displayed in the prompt zone. Sauna took these actions to ensure that data is always up to date. Any time you modify the sink geometry, previously calculated temperatures become invalid. Consequently, Sauna cleared temperatures from all of the nodes. The same problem occurs for "float" thermal resistors and Sauna clears these resistors as well.

Now, recalculate temperatures for natural cooling:

<F12 Root Menu> ➔ Analyze ➔ Calc Temps ➔ Steady ➔ Natural ➔ "25"

With the change in backplane thickness, the junction temperature is now 122.59°C as opposed to 136.98°C calculated previously for natural cooling. This is an improvement, but the junction temperature is still outside the target range.

To further reduce temperatures, let's try making the fins longer. Enter these commands:

<F12 Root Menu> ➔ Edit ➔ Plate/Board ➔ Plate Props ➔ Fin Props ➔ Length ➔ "75" ➔ Secondary ➔ Select 1 ➔ *trap the plate* ➔ USE

Once again, the sink geometry will be updated and node temperatures cleared. Resize the window and switch into shade mode:

click **➔** ***click***

Now you can clearly see the longer fins. For now, leave shade mode activated. It's allowable to have shade mode "on" during a temperature calculation.

Recalculate temperatures:

<F12 Root Menu> ➔ Analyze ➔ Calc Temps ➔ Steady ➔ Natural ➔ "25"

The junction temperature has now been reduced to 99.83°C. Since this is roughly the same temperature as calculated for the original sink in forced convection, an equivalent natural cooling design has been found.

Adding dissipation from the component side

In the above thermal model, dissipation is only allowed for the finned side of the heat sink. There are no thermal resistors connected to ambient on the component side of the sink. In many situations, this is a reasonable modeling assumption. For example, the sink might be mounted on the walls of an electronic enclosure which has a warm internal ambient. Since there is an elevated component side ambient, most of the heat should be dissipated from the secondary side.

Let's try testing the validity of this assumption. Let's assume that the component side of the sink is exposed to an ambient of 45°C.

Turn off shade mode and make fixed nodes visible again:

click **➔** ***click***

Begin creating the component side ambient and float resistors with these commands:

<F12 Root Menu> ➔ Model ➔ Amb + Float ➔ Isoltd-›Fix

You will reach this menu:

```
  AMBIENT LBL
>1 "Room Amb"
 2 Enter Label
```

When you created the secondary side ambient node, you used the default label "Room Amb". You don't want to use the same label for the component side because with Sauna **all fixed nodes with the same label must have the same temperature**. So you need to enter a different label. Finish with:

Enter Label ➔ "Comp Side" ➔ Enter Later ➔ Component ➔ Select 1 ➔ *trap plate* ➔ USE

A fixed node and float resistors will be created on the component side of the heat sink. This will be clearer if you switch to a top view:

click **Top**

Recalculate temperatures:

<F12 Root Menu> ➔ Analyze ➔ Calc Temps ➔ Steady ➔ Natural ➔ "25" ➔ "45"

A new junction temperature of 99.23°C will be obtained. This is slightly cooler than the temperature of 99.83°C calculated earlier. So, if the component side ambient is 45°C, it's reasonable (and conservative) to neglect heat transfer from the component side.

Since you have completed the what-if modification concerning the component side ambient, you can delete this fixed node:

<F12 Root Menu> ➔ Delete ➔ Node ➔ Fixed ➔ Select 1
➔ *trap Comp Side fixed node* ➔ USE

The Undo command

Since everyone makes mistakes, Sauna includes an Undo command. Undo the delete of the component side fixed node with:

<F12 Root Menu> ➔ Edit ➔ Undo ➔ *click the Yes button*

You can undo up to 4 commands. Of course, you don't want the component side fixed node, so you must delete a second time:

<F12 Root Menu> ➔ Delete ➔ Node ➔ Fixed ➔ Select 1
➔ *trap Comp Side fixed node* ➔ USE

What commands are legal in shade mode?

When you modified the heat sink model, all the changes were made in wireframe mode. This is a requirement of Sauna. Grouping and shade mode are not compatible. So many Sauna commands can't be done in shade mode.

You may wondering: "How will I remember which commands are legal for shade mode?". Fortunately, there is nothing to remember. If shade mode is not permitted, Sauna will automatically toggle into wireframe mode.

Let’s demonstrate. Begin by switching to a perspective view in shade mode:

click ➔ ***click***

Now you will try a command, the move command, which is not compatible with shade mode. Begin a move with:

<F12 Root Menu> ➔ Move/Copy ➔ Move ➔ Trap 1 Assy

As soon as you select “Trap 1 Assy” on the Move Select menu, Sauna automatically switches to wireframe mode. No intervention is required by you. So the moral is: “if you want to turn on shade mode, go ahead”.

Since we don't want to move the model, return to the Root menu:

<F12 Root Menu>

Note that there are also commands which can only be done in shade mode. An example is “click surface” visibility, which is used with box models. If a Sauna command requires shade mode, Sauna will automatically switch for you. It all works very smoothly.

Default material colors

When you switch into shade mode, the heat sink is shaded with a light blue color. This color was chosen based on the material family of the assembly.

To see how this works, enter the following commands:

click

<F12 Root Menu> ➔ Edit ➔ Plate/Board ➔ Plate Props ➔ Material ➔ Plastic ➔ ABS ➔ Select 1 ➔ *trap plate* ➔ USE

click

When you switch to an ABS plastic material, Sauna uses a shade of yellow to draw the assembly. Let’s try another material:

Plastic ➔ Epoxies ➔ Mold Comp ➔ Select 1 ➔ *trap plate* ➔ USE

click

You just changed to “Mold Comp”, which is an abbreviation for molding compound. Molding compound is the silica-filled epoxy material used in standard semiconductor packages such as DIP’s, TO-220’s, etc. Sauna now draws the sink in a shade of black.

Here’s a listing of the colors that Sauna uses:

Material Family	Color
circuit board	green
ceramic	pale gray
epoxy	dark gray
metal	light blue
plastic (non-epoxy)	pale yellow
semiconductor	pink
special material	dark blue

Backing up the path

Now is a good time to learn about backing up the path. Begin by accessing the Window menu:

<F1 Window>

There are two different ways to backup the path:

Backup with the path line: As you define and edit models, Sauna uses the path line to show the sequence of menu selections that you have made. Any time that you want to return to a previous menu, you simply move the cursor to the path line at the top of the screen and click on the desired menu name. For example, right now you are at the Window menu. *Choose "Set View"* and then *choose "Front"*. You will advance to the Projection menu. To return to the Window menu, *move the cursor to "Window" on the path line* (at the top of the screen). Then *click the mouse*. You'll go straight back to the Window menu.

Backing up from a prompt is a little different. For example, *choose "Width"* and then *choose "Enter Width"* on the Width menu. You will be prompted with "Enter the new window width". At this point you can't get back to the Width menu by clicking on the path line because the Width menu is still displayed in the main menu zone. Instead, *move the cursor to the menu title, "Width"*. Then *click the mouse* You will be returned to the Width menu.

Now, *move the cursor to the menu title "Interrupt" on the path line.* Then *click the mouse.* You have backed up to the starting point, so the Root menu will be displayed. This illustrates another way to return to the Root menu. This method is actually easier than clicking on <F12 Root Menu> because you don't have to move the cursor as far.

Backup with the Interrupt menu or keyboard: <F2 Backup> is used to back up the path one level. For example, *choose <F1 Window>*. Next, *choose "Set View"* and then *choose "Front"*. You will advance to the Projection menu. *Hit <F2 Backup>* and you will go back to the View menu. *Hit <F2 Backup>* a second time and you will return to the Window menu. Nothing to it.

You should also know that with Sauna **the <Esc> key is the exact equivalent of <F2 Backup>.**

Some practice on your own

Up until now, you have been told menu-by-menu which commands to enter. Now, however, is a good time to try a few commands on your own.

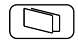
Working on your own, return the sink to its original configuration. Change the fin length to 25 and reduce the plate thickness to 5 mm. Switch back to the original extruded aluminum material.

When you have made these changes, recalculate temperatures for natural cooling. You should obtain a junction temperature of 136.98°C, just as before. If you get a different temperature, use **<F7 Info> ➔ Trap ➔ Plate** to obtain a report. Then carefully read the report to find errors. Experienced Sauna users always use the Info reports to check for errors.

Changing the fin orientation

When you added fins to the plate assembly in the first exercise, Sauna placed the fins in the default orientation, so that the fin channels are vertical. Although vertical fins are best, it's also interesting to try other fin configurations. So now you will check performance with horizontal fin channels.

Switch to a perspective view and change the fin orientation:

click 

<F12 Root Menu> ➔ Edit ➔ Plate/Board ➔ Plate Props ➔ Fin Props ➔ Orientation ➔ XY + YZ ➔ Horizontal ➔ Secondary ➔ Select 1 ➔ *trap plate* ➔ USE

Sauna will briefly redraw the screen to show the new horizontal fins. Calculate temperatures:

<F12 Root Menu> ➔ Analyze ➔ Calc Temps ➔ Steady ➔ Natural ➔ "25"

With the horizontal fin channels, you should obtain $T_{junction}$ = 167.42°C. This is an increase of 30°C, which shows that vertical fin channels are superior. However, be aware that the horizontal fin channels are still an improvement over a flat wall. For a discussion of the merits of the different fin orientations, be sure to read *Comparing Naturally Cooled Horizontal Backplane Heat Sinks With Vertical Backplane Heat Sinks* in the Cooling Electronic Systems chapter.

Heat sink and fan combinations

In this exercise, you specified a linear air flow (ft / min). If you are combining a heat sink with a fan, you will not be able to obtain a linear flow from the fan data sheet. A calculation needs to be made which predicts the linear flow based on the flow and pressure characteristic of the fan, combined with the flow resistance the fin channels. Sauna provides two different ways to proceed. In the first method, Sauna's Toolbox is used to calculate a linear velocity, which is then entered into the Sauna model. This method is described in *Introductory Exercise 7: Calculating Air Flow For Fan-Cooled Heat sinks.* The second method, which is more sophisticated, involves defining a multi-ambient flow network and assigning a fan within the Sauna model. This approach is described in *Intermediate Exercise 9: Heat Sink Flow Networks With Fans.* For most situations, the two methods provide similar results. For long heat sinks with closely spaced fins, the flow network method is more accurate

Wrapping up

To prepare for the next exercise, you will delete the entire model. Enter these commands:

<F12 Root Menu> ➔ Delete ➔ Everything ➔ *click Yes button*

Note that everything, even elements previously made invisible, will be deleted.

In the first two exercises, you have been exposed to a number of Sauna concepts. It takes everyone a little while to get used to plate assemblies, fixed nodes, footprint heat sources, float resistors, etc. These are new ideas. Fortunately, you have already covered the large majority of these new concepts. As you continue, you will see that Sauna is very consistent and easy to use.

Tips:

- As you work through the exercises, you should obtain exactly the same temperature as in the manual. Although small ΔT's are not significant in the real world, when learning Sauna you should obtain exactly the right number. If your numbers are off, use the Info reports to check carefully for errors. The Info reports are extremely useful for debugging models.
- When you have a problem, either with an exercise or a real model, don't hesitate to call Technical Support. Take advantage of the free assistance!