p-cad® 2002

PROFESSIONAL TOOLS FOR BOARD LAYOUT SPECIALISTS ™

Signal Integrity

p-cad®
PCB layout system from Altium™

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CHAPTER 1

Introduction to P-CAD Signal Integrity

Congratulations on your purchase of a high performance simulator to complement your copy of P-CAD PCB. The applications are paired for fast simulation of reflection effects and are seamlessly integrated for your ease of use.

Two simulation products are documented in this manual:

- P-CAD Signal Integrity - Reflection Simulator
- P-CAD XTalk – Crosstalk Simulator

The menu structure and user interface is consistent for all P-CAD products. Options specific to each particular simulation are offered through context-sensitive dialogs, giving you exactly those options supported by your simulator, but in a familiar environment.

P-CAD Signal Integrity Simulator

When you choose the P-CAD Signal Integrity Simulator its entry screen appears. It lets you select PCB nets to analyze from your P-CAD PCB database or from SULTAN files. It loads these in the simulator, display their details and enables interactive modification of parameters. When parameters are missing, default parameters are used. These are listed in the section discussing the parameters. P-CAD Signal Integrity also provides access to start and restart the simulation process.

About this Guide

This manual includes information on the use and operation of the following products:

- P-CAD Signal Integrity
- P-CAD Xtalk

The information in this manual is presented in tutorial and reference format. It is designed to get you started simulating, and to present some advanced features which will be helpful as you gain more experience of the functionality of the simulators.

Signal Integrity Features

As Windows based PCB design tools become more and more sophisticated and are used to design printed circuit boards with high clock speeds and high density, the demand for simulation tools addressing signal integrity problems has increased dramatically.

P-CAD Signal Integrity has been created specially for PCB designers using the P-CAD PCB tool, and is tightly coupled to the PCB to provide a simple interactive simulation environment. Using P-CAD Signal Integrity, design engineers may check their multilayer boards for noise effects like ringing and crosstalk. When installed, P-CAD Signal Integrity is seamlessly integrated with P-CAD PCB, giving you the familiarity of P-CAD PCB's Windows™ interface standard and easy access to its powerful capabilities.

P-CAD Signal Integrity is based on a Fast Reflection and Crosstalk Simulator, which produces very accurate simulations, (provided that full model information is available), with algorithms proven in industry.

The P-CAD Signal Integrity simulator uses the characteristic impedance of the traces calculated through a transmission line calculator and I/O buffer macro-model information as input for the simulations. Where model information is not available the system utilizes fallback models.

Features

- Provides fast simulation of reflection and crosstalk effects.
- Fast screening (pre-analysis) for signal integrity effects (over- and undershoot, delay, etc.) for entire boards with spreadsheet-like result display.
- Seamlessly integrated with P-CAD PCB, allowing access to simulation options.
- No special expertise is required to use it, due to the simple user interface and tight integration.
- As the system utilizes I/O buffer macro-models, no knowledge of SPICE or analogue simulation is required.
- Oscilloscope type display of simulation results with integrated result measurement facilities.
- Well-proven algorithms for the calculation of the transmission line characteristics and subsequent simulations.
- What-if-analysis concerning different termination strategies with parametric values of resistors/capacitors and through easy substitution of macro-models.
- What-if-analysis concerning different routing strategies through tight integration with P-CAD PCB.

Software I/O Buffer Modeling

- Macro-model approach for fast and accurate simulation.
- Supplied with a basic IC model library including verified models.
- Automatic model attachment according to Part Number.

- Supporting the IBIS 3 industry standard sub-set for I/O buffer modeling.
- Integrated macro-model-editor allows easy and fast definition of own models using databook or measurement values.
- P-CAD Signal Integrity utilizes the P-CAD PCB, DBX API interface for interactive communications.
- P-CAD Signal Integrity can be loaded with complete PCBs or subsets of data (single or multiple nets, single layers, etc.).
- P-CAD Signal Integrity supports cross highlighting with the layout (nets under analysis).
- P-CAD Signal Integrity can provide an INCASES EMC-WORKBENCH 'SULTAN" file for extended EMC analysis.
- P-CAD Signal Integrity can back annotate termination networks onto the board as a DRC marker.
- P-CAD Signal Integrity and Xtalk are designed for analyzing PCB's with consistent power and/or ground planes. Use of the tools on boards without consistent power or ground planes will lead to untrustworthy results.

User Interface

There are three basic operational screens for P-CAD Signal Integrity: the net screen, the pre-analysis screen and the result screen. The net screen and the result screen can be utilized simultaneously.

CHAPTER 2

P-CAD Signal Integrity - Getting Started

This chapter gives information on the required hardware and software needed before installing P-CAD Signal Integrity products. It also introduces you to the P-CAD Signal Integrity interface.

System Requirements

Make sure that your PC and its software conform to the following P-CAD requirements and recommendations.

Recommended System

- Windows NT 4/2000 Professional
- PC with Pentium III Processor
- 128MB RAM (256MB for high component/net count)
- 400MB Hard Disk Space
- Desktop area 1024x768 pixels
- 32-bit Color Palette
- CD-ROM Drive
- Mouse or compatible pointing device

Minimum System

- Windows 95/98/2000Me
- PC with Pentium 166MHz
- 64MB RAM
- 200MB Hard Disk Space (without ISO libraries)
- Desktop area 800x600 pixels

- 256 Color Palette
- CD-ROM Drive
- Mouse.

Installing P-CAD Products

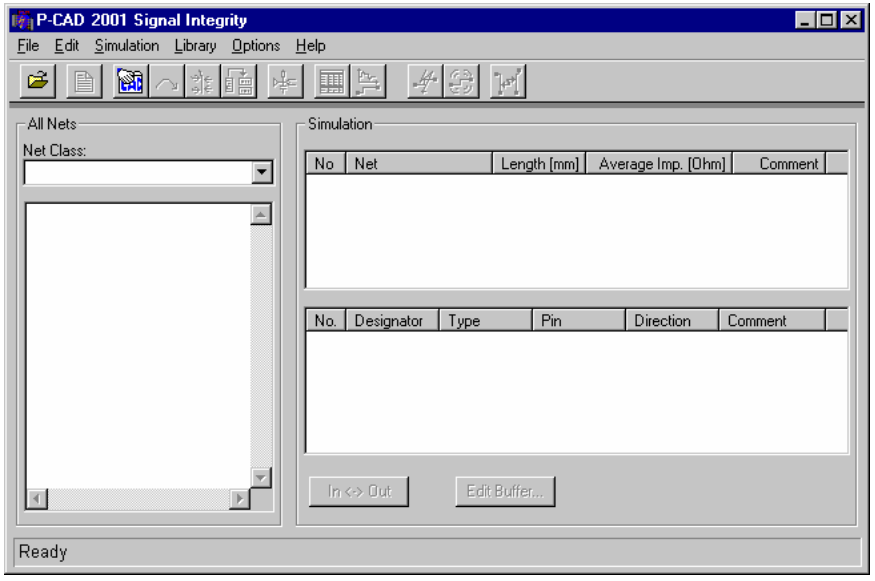
For up-to-date installation information refer to the file `Readme.WRI`, located on the product CD. This file can also be found in the application program folder (`\Program Files\P-CAD 2002`) after installation. Note that the setup program on the Product CD can also be used to repair or remove an existing P-CAD Installation.

P-CAD Signal Integrity Interface

You are probably already familiar with the P-CAD PCB interface in addition to being proficient in the operation of Windows, so every detail of the screen is not provided here.

Accessing P-CAD Signal Integrity

P-CAD Signal Integrity simulator is accessed by choosing **Utils » P-CAD Signal Integrity** from the P-CAD PCB menus. This brings up the simulator entry window. You can now choose PCB nets and analyze them using either commands from the pull-down menu or icons on the tool bar.



Menu Bar

P-CAD Signal Integrity menu bar, displayed on the simulator entry screen, provide access to commands that let you:

- Bring in PCB nets to analyze
- Review/complete/modify PCB design parameters
- Launch simulations
- Produce reports
- Create output files
- Import IBIS files and create Macromodels
- Specify simulator options and preference settings.

Toolbar

The toolbar consists of graphical display buttons (icons) that correspond to commonly used P-CAD Signal Integrity commands. These icons appear just below the menu bar on the P-CAD Signal Integrity entry screen.

Tool Tips explain each of the toolbar buttons. To activate a Tool Tip, place the mouse over the button. The Tool Tip pops up.

The icon display is context sensitive, so icons not highlighted indicate commands not available at this stage. The commands linked with each icon are listed below:

	Open SULTAN File
	Create Report
	Get Netlist from P-CAD PCB
	Get PCB Selected Nets
	Find Coupled Nets

	Take Over Selected Nets
	Start the Termination Advisor
	Start Net Screening
	Start Reflection Simulation
	Set Victim Net
	Set Aggressor Net
	Start Crosstalk Simulation

The simulation commands Reflection and Crosstalk give access to the Wave Analyzer, which has its own icons and menu bar.

CHAPTER 3

P-CAD Signal Integrity Tutorial

This tutorial includes hands-on instructions to help you become familiar with how to use P-CAD Signal Integrity to analyze and simulate your PCB designs and to investigate remedies to signal integrity problems.

The following steps indicate what you will accomplish in this tutorial.

1. Starting up P-CAD Signal Integrity
    - Import list of PCB nets to analyze
2. Review and complete your PCB design parameters
    - Edit Designator specifications
    - Edit Supply Nets specifications
    - Edit Layer Stack specifications
    - Select nets to analyze
    - Edit Components specifications
3. Screen the Nets
4. Run Reflection simulation
    - Modify parameters
    - Re-run simulation
    - Produce a report
5. Run Crosstalk simulation
    - Modify parameters
    - Re-run Crosstalk simulation

- Produce a report

6. Create a Macro Model
   - Edit Macro Model
   - Create a new Macro Model from an IBIS file
7. Specify simulation options and preference settings.

Each of these steps is discussed in detail in this tutorial. It will be worth your time to go through the complete tutorial, which is designed to get you going quickly.

If a message is displayed by the system during the tutorial, see *Appendix B - System Messages*, for a description of the problem and a possible solution.

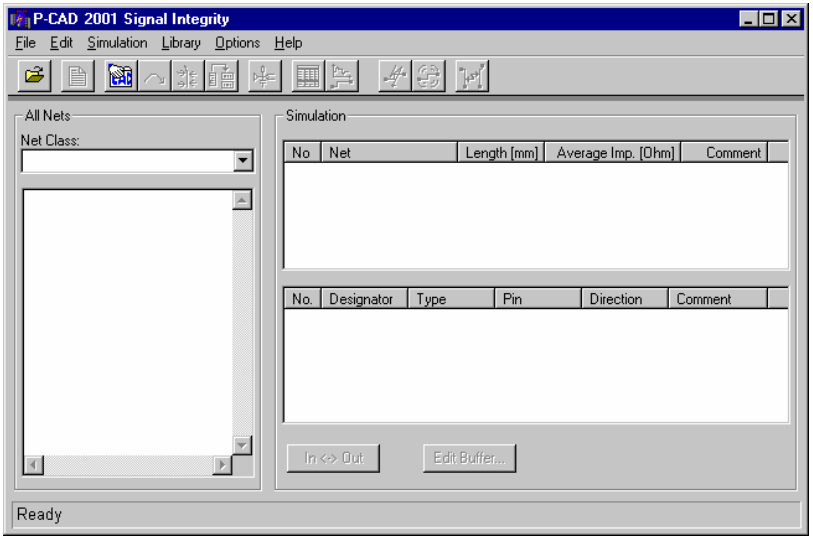
For more detailed information about any of the commands and options used in this tutorial, refer to the relevant *Commands Reference* chapters.

> Please note that the examples do not reflect the current state of the art techniques to avoid and solve signal integrity problems. The Termination methods used in the different examples are for tutorial purposes only.

Starting up P-CAD Signal Integrity

In this tutorial we will analyze nets from the demo PCB provided with P-CAD Signal Integrity. Within P-CAD PCB, open the file `\P-CAD 2002\Demo\Signal Integrity\demo.pcb`.

Start the Signal Integrity program by choosing **Utils » P-CAD Signal Integrity** from the P-CAD PCB menus. This will display the Signal Integrity entry window.

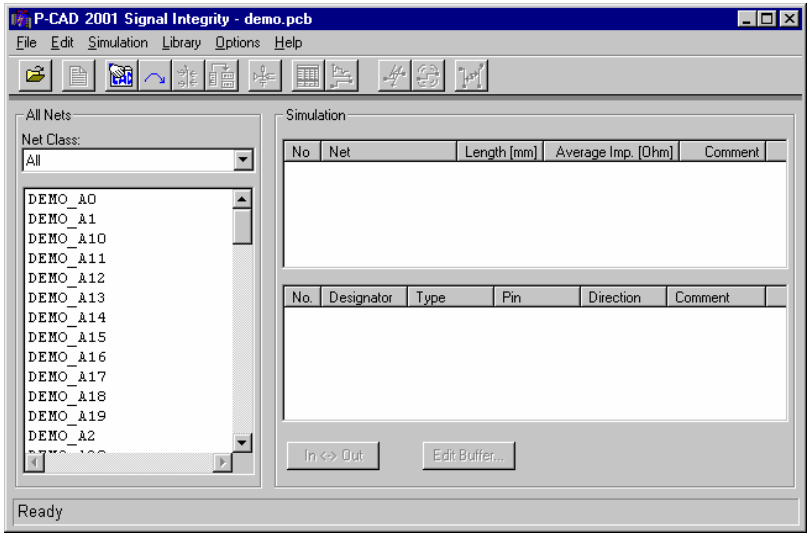


The toolbar display is context sensitive, and only commands available at each stage have their icon highlighted.

Import list of PCB nets to analyze

The first step is to import the nets from the PCB into P-CAD Signal Integrity. To do this click on the **Get Netlist** icon, or choose **File** in the menu bar and select **Get Nets** from the pull-down menu.

This will list, on the left of the window in the All Nets column, all the nets in the PCB currently open in P-CAD PCB.



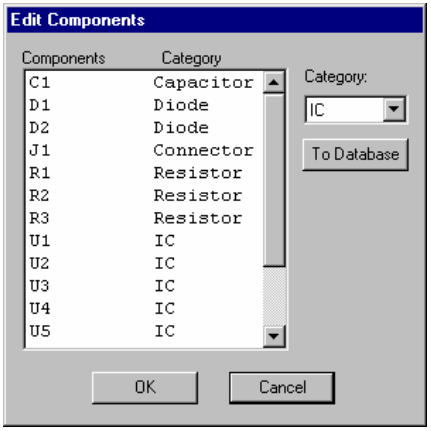
Review and Complete your PCB Design Parameters

We can now edit and modify:

1. The electrical component types
2. The supply nets
3. The Layer Stack of the whole PCB
4. The choice of nets to analyze
5. The components specifications.

Edit Components

To access the Edit Components dialog, choose **Edit** in the Menu bar and select **Components** from the pull-down menu. The Components list box contains the names of all components in the active design. You can select individual or multiple components in the list box. Once selected you can specify the electrical type of a component.



Select the component **C1** in the **Component** list. Note that the Category is already set to Capacitor. If it was not, you would choose the type **Capacitor** in the Category drop down list. Confirm that all other capacitors have their Category set to **Capacitor**.

In the same way confirm that the components **D1** and **D2** are set to **Diode**, **J1** is set to **Connector**, **R1**, **R2** and **R3** are set to **Resistor**, and **U1** to **U9** are set to **IC**.

With the button **To Database** you can save the specified component type back to the PCB currently open in P-CAD PCB. The information is saved in the PCB as a component attribute.

A second way to specify the component type is to define a component attribute directly in P-CAD PCB. Define the Component attribute Category, and set the value of the attribute to one of the following qualifiers. If you now load the design into P-CAD Signal Integrity, the components will have their Category already defined (as in the demo file).

The following electrical component types are supported:

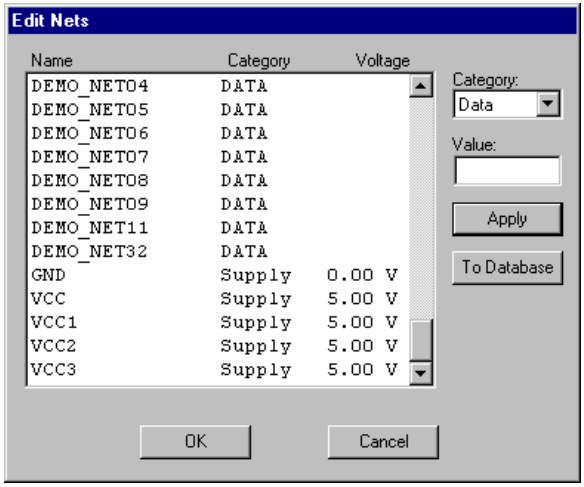
Component Type	Attribute Value
Bipolar Junction Transistor	BJT
Capacitor	Capacitor, Cap
Connector	Connector, Con
Diode	Diode, Dio
IC	IC
Inductor	Inductor, Ind
Resistor	Resistor, Res

If you do not set the Category, P-CAD Signal Integrity will use the type **IC**.

Edit Nets

Although Supply Nets can not be simulated, they are necessary for the correct simulation of nets with Pull-up or Pull-down components.

To access the *Edit Nets* dialog, click on **Edit** on the Menu bar and choose **Nets** from the pull-down menu.



The *Edit Nets* dialog contains the names of all nets in the active design. You can select individual or multiple nets in the list box. Once selected you can specify the category and the voltage of the net.

Select the net **VCC** in the net list box, choose the category **Supply** in the Category drop down list, enter **5V** as the Value and click the **Apply** button for the changes to take place. In the same way set the category **Supply** and the value **5V** for the nets **VCC**, **VCC1**, **VCC2** and **VCC3**.

With the button **To Database** you can save the specified net category and value to your P-CAD PCB. The information is saved in the PCB as net attributes.

A second way to specify the net category and value is to define net attributes directly in P-CAD PCB. Define the net attribute Category and set the value of the attribute to **Supply**, and the net attribute Voltage and set the value to the voltage of the net. If you now load the design into P-CAD Signal Integrity, the nets get the defined category and value.

Edit Layer Stack

For the calculation of the correct electrical behavior of the traces, the layer stack of the PCB must be specified.

The required parameter definitions and their applicable default values are listed below:

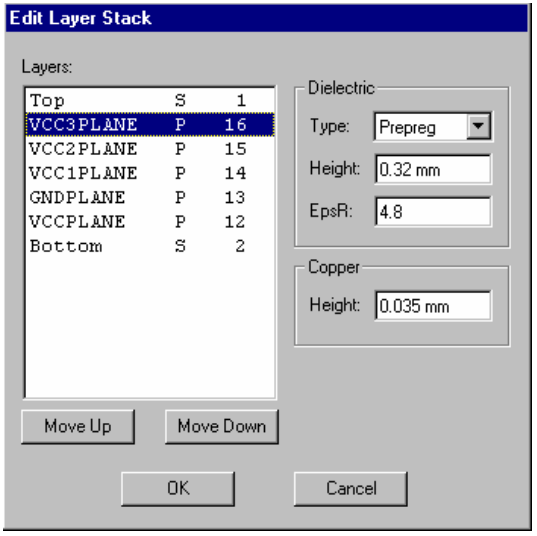
Parameter definition	Defaults
The correct sequence of the layers	None
The thickness of the different copper	35µm
and dielectric planes	0.32mm
The dielectric constant of the substrate	εr = 4.8

The layer stack and all associated transmission line parameters are automatically saved in a layer stack information file. The file is named as the same as the PCB, with the extension `.TDB`. It is saved into a folder with the same name as the PCB, under the Projects folder. For example, for the demo board it is `\P-CAD 2002\Projects\Demo\Demo.tdb`.

Before a new transmission line parameter is calculated, the system checks if appropriate transmission line parameters already exist in the database file.

Whenever the layer stack is changed, the old database file gets deleted and a new one is generated.

Choose **Edit** on the Menu bar and select **Layer Stack** from the pull-down menu to access the Layer Stack Specifications window. The signal and plane layers are displayed in the *Layer Stack* dialog.



This window shows the layer name, the layer type (Signal or Plane), and the layer number as defined by the user in P-CAD PCB. Here you can modify the Dielectric and Copper property definitions for a layer. To do so select a layer and enter the changes required in the available entry windows.

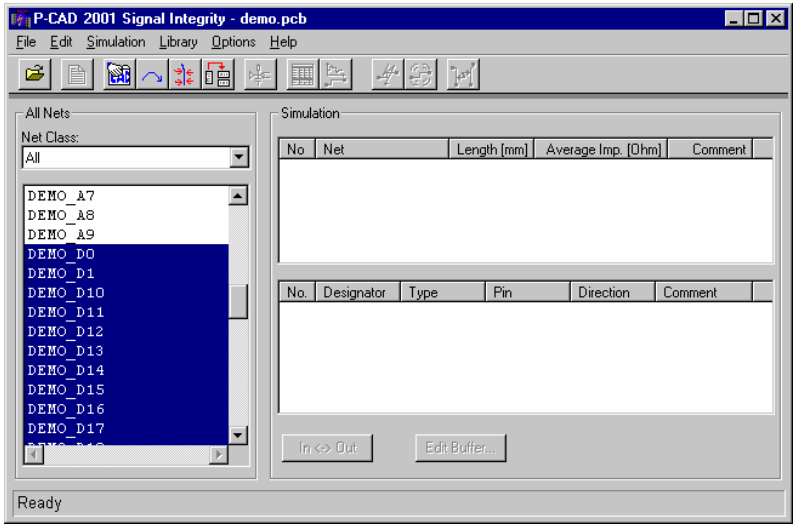
When you enter the Copper thickness and the Dielectric value, the Dielectric referred to is the one immediately above the Copper layer. As a result, it is not possible to enter a Dielectric value for the top layer.

All the layers except the Top and Bottom layers can be moved up or down, by selecting a layer and clicking the appropriate button. The Top layer is always number 1, and the Bottom layer which is always number 2 and at the bottom.

For the purpose of this tutorial, we will leave the layer stack unchanged. Click **OK** or **Cancel** to close the window.

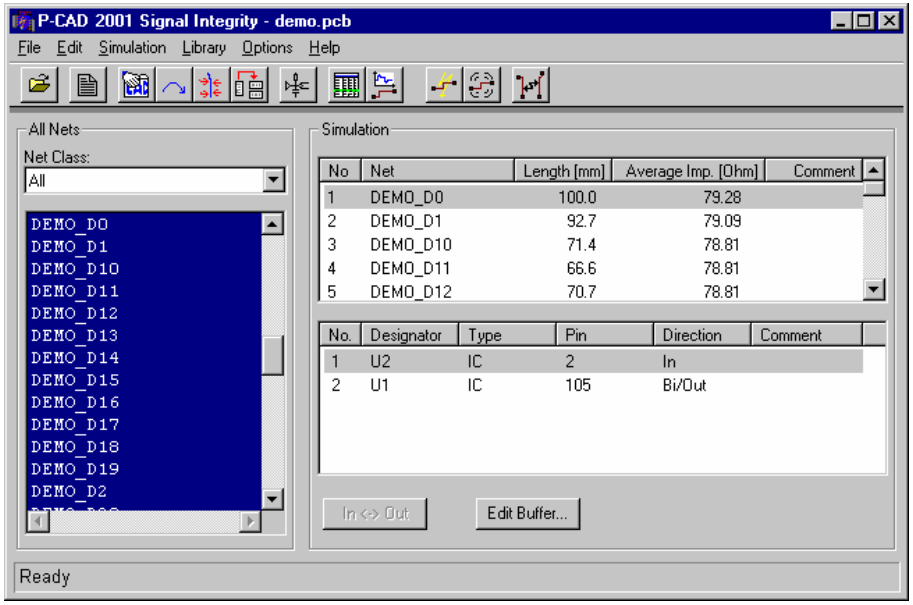
Select nets to Analyze

In the Signal Integrity main entry dialog, choose the nets DEMO_D0 to DEMO_D31, by clicking and holding the left mouse button on DEMO_D0 and dragging the cursor to select all DEMO_Dx nets. This will highlight the desired nets.



To analyze these nets, the simulator must acquire all the required data for simulation. The editor does this when you do one of the following:

- Click on the **Takeover** icon or
- Choose **Edit** in the menu bar and select **Take Over** from the pull-down menu. The simulator acquires the nets' data and displays the details in the simulation windows.



The selected nets are listed in the top window on the right hand side.

For each selected net, the following are displayed:

- The Net name (some net names are concatenated).
- The Net length (the sum of the length of all trace segments).
- The Net characteristic impedance (the average impedance derived by the sum of the impedance of each trace segment multiplied by the length of the trace segment and divided by the sum of the length of the traces).

The bottom right hand window displays the connected pins for the net selected in the top simulation window.

Scroll down and select `DEMO_D5_DEMO_NET11` from the top simulation window.

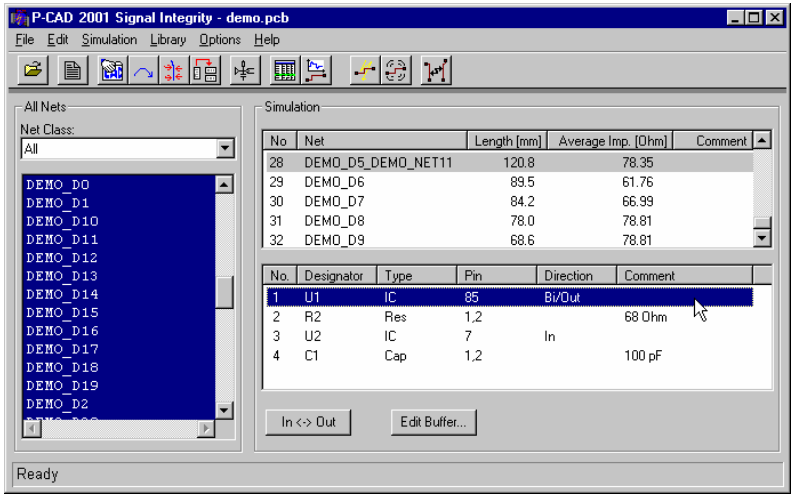
Select Nets by Net Class

Allows you to analyze nets by net classes. Normally, the left list box shows the names of all nets of the current design. To analyze only a group of nets, define net classes in P-CAD PCB and assign the affected nets to the class. After pressing the button **Get PCB Nets**, the drop down list **Net Class** is filled with all net classes of the design.
Select a net class and the list below contains only the nets of that class. To see all nets, select the entry **All**.

Edit Components specifications

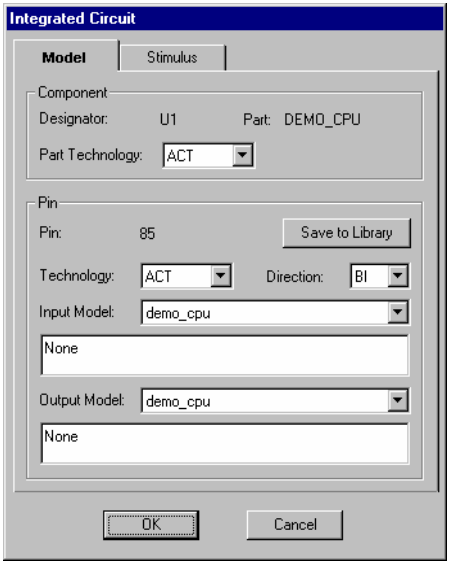
The Edit Buffer button, located on the Signal Integrity entry window, gives access to the component's data dialog. We will look at data windows for IC's, Resistors and Capacitors. Other components will display different screens as applicable.

First, on the Signal Integrity bottom right-hand window, select the component: U1.



Use the **In <-> Out** button to modify the direction specification for the selected component, to change it from the input to output or vice versa. Return the buffer to an Output.

To modify the specifications for components, click on the **Edit Buffer** button. This displays the *Integrated Circuit* dialog. You can change the Model data and the Stimulus used by the simulator for the highlighted components, in our case U1.



The **Model** tab shows the current settings for the IC component selected. Choosing a Technology and Direction will automatically give a list of input and / or output models as appropriate. For the purpose of this tutorial, we will leave the Model settings unchanged.

Changes to technology and direction are used locally in the design. If however, you wish to update the library to reflect changes, then click on **Save to Library** button. Remember that you are modifying the library when you do this, so care should be taken to ensure that the library is not corrupted for future use.

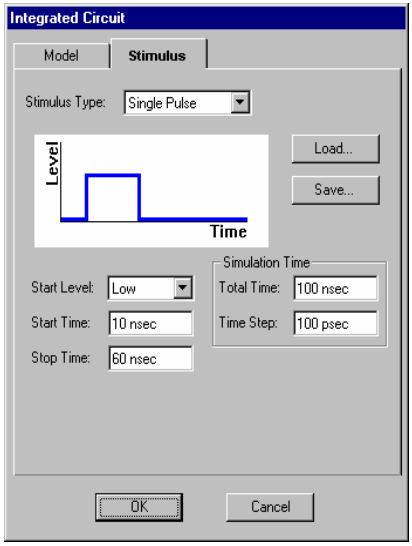
Choose the Stimulus tab. In the Stimulus window you can modify the Stimulus which is applied to the input of the output I/O buffer for Simulation to:

Constant Level,

Single Pulse or

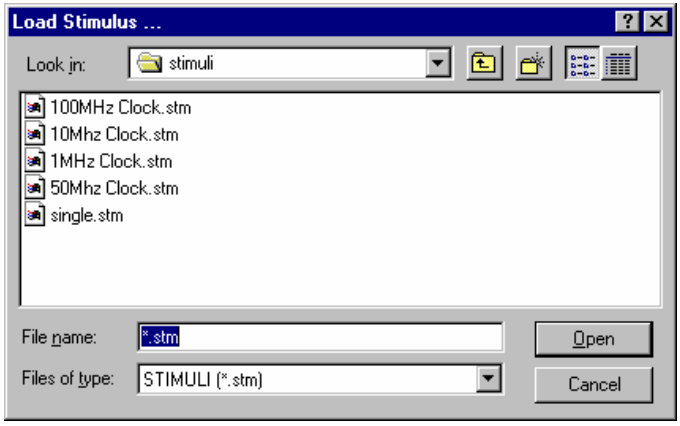
Periodic Pulses.

Select the **Single Pulse** or **Periodic Pulse** option in the Stimulus Type box, and notice that you can set the Start Level to High or Low in the Start Level box. The wave display will change to reflect your choices.



You can also specify Start and Stop times of the pulse and the Period time if a periodic pulse is chosen.

Stimulus details can be saved to a file. This is described in the *Edit* section of *the Command Reference* chapter.

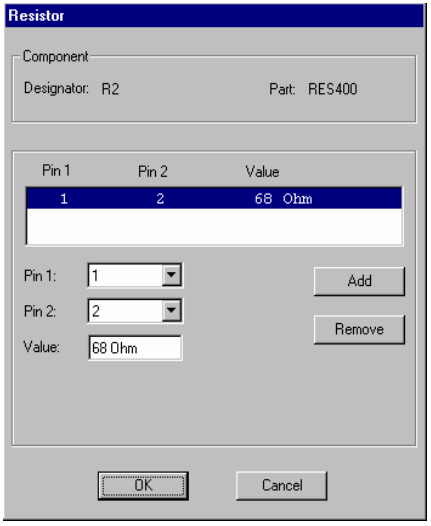


Stimulus details may also be loaded from a file. To do so, click the **Load** button. The *Load Stimulus* dialog is displayed. Choose the demo stimulus file, `single.stm`, located in the `stimuli` sub-directory and click the **Open** button. This will update the **Stimulus** tab with the details of the file.

Click **OK** to close the *Integrated Circuit* dialog.

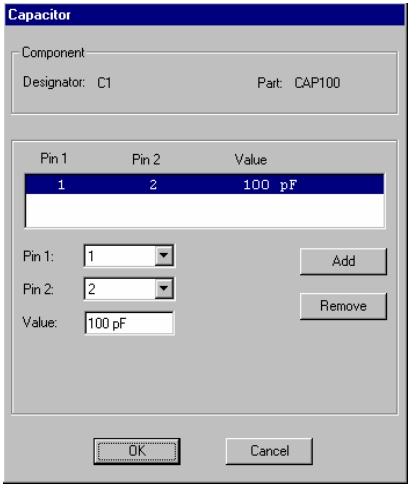
Back in the Signal Integrity window, select component 'R2'.

Now click the **Edit Buffer** button again. This displays the *Resistor* dialog.



You can add or remove pins for connections routed to resistor arrays. For the purpose of this tutorial, we will make no change to this resistor. Click the **Cancel** button to close the *Resistor* dialog.

Back in the Signal Integrity window, select the component C1 and choose the **Edit Buffer** button to display the *Capacitor* dialog.



Again, leave the Capacitor unchanged, and click the **Cancel** button.

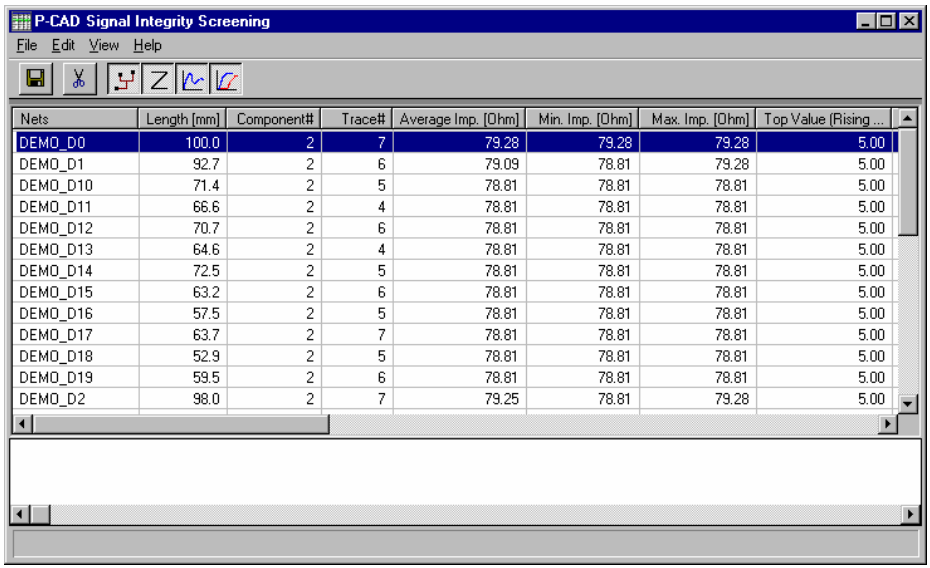
Screen the Nets

Screening provides a fast simulation of many nets to enable you to get closer information about the nets and to identify critical nets for closer examination. Besides geometrical information, it also provides estimated values for Signal Integrity effects (overshoot, undershoot).

When screening bi-directional nets, both directions are simulated and the worst result of each effect is displayed.

The Screening commands can be accessed from the Simulation pull-down menu or by clicking the Screening icon.

Click on the **Screening** icon to get the Screening window to display details for the currently selected nets.



Nets	Length [mm]	Component#	Trace#	Average Imp. [Ohm]	Min. Imp. [Ohm]	Max. Imp. [Ohm]	Top Value (Rising ...
DEMO_D0	100.0	2	7	79.28	79.28	79.28	5.00
DEMO_D1	92.7	2	6	79.09	78.81	79.28	5.00
DEMO_D10	71.4	2	5	78.81	78.81	78.81	5.00
DEMO_D11	66.6	2	4	78.81	78.81	78.81	5.00
DEMO_D12	70.7	2	6	78.81	78.81	78.81	5.00
DEMO_D13	64.6	2	4	78.81	78.81	78.81	5.00
DEMO_D14	72.5	2	5	78.81	78.81	78.81	5.00
DEMO_D15	63.2	2	6	78.81	78.81	78.81	5.00
DEMO_D16	57.5	2	5	78.81	78.81	78.81	5.00
DEMO_D17	63.7	2	7	78.81	78.81	78.81	5.00
DEMO_D18	52.9	2	5	78.81	78.81	78.81	5.00
DEMO_D19	59.5	2	6	78.81	78.81	78.81	5.00
DEMO_D2	98.0	2	7	79.25	78.81	79.28	5.00

The data displayed when you enter the Screening window shows the information requested on the last access. We will review each of the screening views and identify nets to analyze in greater detail.

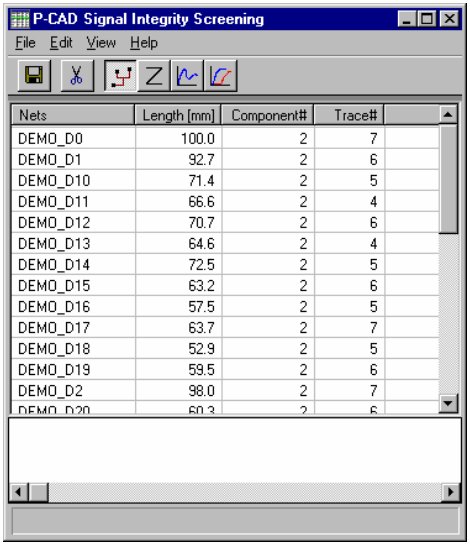
The message in the comment window indicates that nets with Diodes or Transistors cannot be analyzed by the Screening fast simulation method. These can, however be simulated using the Reflection and Crosstalk simulation options.

First, click on all of the four results display icons, which are currently highlighted, to switch the options off.

Click on the **Net Data View** icon. This displays for each net:

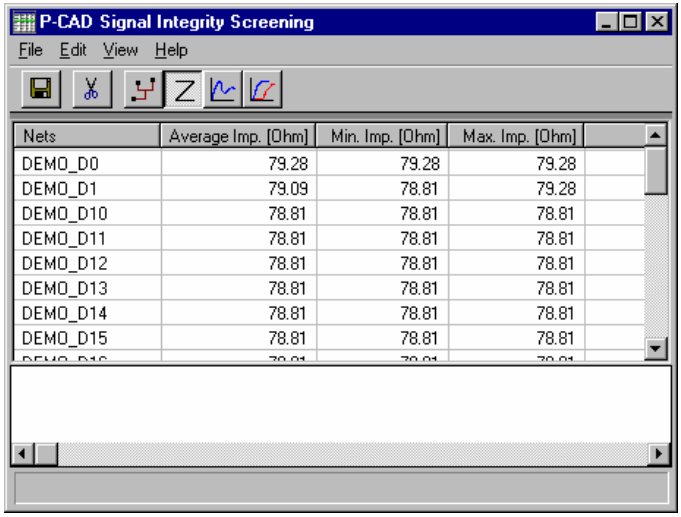
- The net name
- The length of the trace
- The number of components connected to the traces
- The number of segments in each trace.

Now click on the **Net Data View** icon again to switch this view off.



Next, click on the **Impedance View** icon. This displays for each net:

- The net name
- The average impedance of the whole trace
- The minimum impedance of the whole trace
- The maximum impedance of the whole trace.



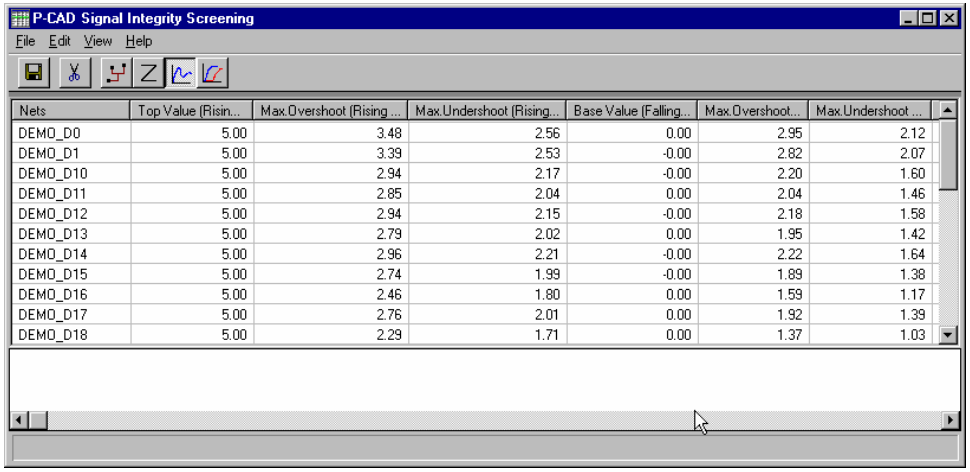
Click on the **Impedance View** icon again to switch this view off.

Now, click the **Voltage View** icon, and drag the right edge of the Screening window to enlarge it and display more columns on the screen.

To display all the seven columns at once, you can make the columns narrower by clicking a column edge on the header line and dragging the column to the desired width.

This displays for each net:

- The net name
- The Top Voltage Value for the Rising Edge
- The Maximum Overshoot for the Rising Edge
- The Maximum Undershoot for the Rising Edge
- The Base Voltage Value for the Falling Edge
- The Maximum Overshoot for the Falling Edge
- The Maximum Undershoot for the Falling Edge.



Nets	Top Value (Risin...	Max.Overshoot (Rising ...	Max.Undershoot (Rising...	Base Value (Falling...	Max.Overshoot...	Max.Undershoot ...
DEMO_D0	5.00	3.48	2.56	0.00	2.95	2.12
DEMO_D1	5.00	3.39	2.53	-0.00	2.82	2.07
DEMO_D10	5.00	2.94	2.17	-0.00	2.20	1.60
DEMO_D11	5.00	2.85	2.04	0.00	2.04	1.46
DEMO_D12	5.00	2.94	2.15	-0.00	2.18	1.58
DEMO_D13	5.00	2.79	2.02	0.00	1.95	1.42
DEMO_D14	5.00	2.96	2.21	-0.00	2.22	1.64
DEMO_D15	5.00	2.74	1.99	-0.00	1.89	1.38
DEMO_D16	5.00	2.46	1.80	0.00	1.59	1.17
DEMO_D17	5.00	2.76	2.01	0.00	1.92	1.39
DEMO_D18	5.00	2.29	1.71	0.00	1.37	1.03

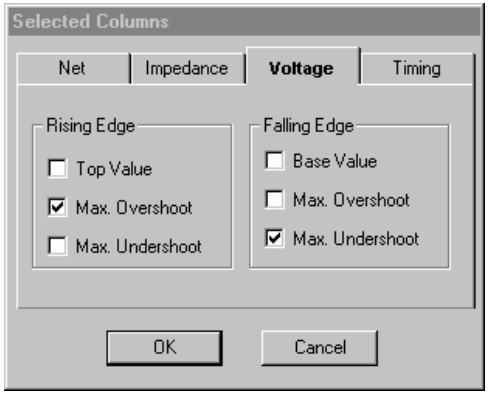
You can select to display only the columns of interest on a view, to ease the identification of problem nets by defined criteria.

Let's view the Maximum Overshoot (Rising Edge) and Maximum Undershoot (Falling Edge).

Choose the **View** command on the screening header menu.

Select the **Select Columns** command.

In the *Select Columns* dialog, click the **Voltage** tab. On the Voltage tab, choose to display only the Maximum Overshoot on the Rising Edge and Maximum Undershoot on the Falling Edge, by disabling all other options as displayed below. Click **OK**.

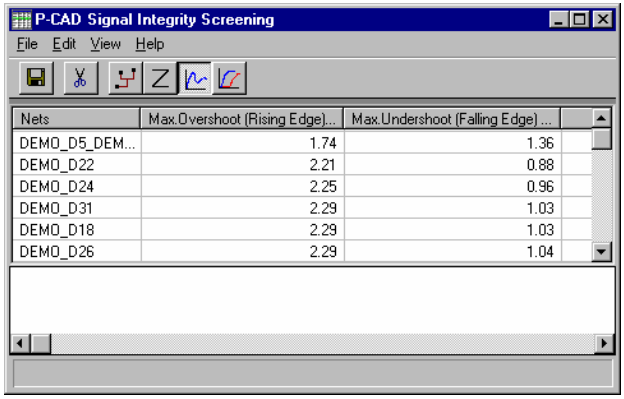


This will now display only the two chosen columns on the Voltage View.

We can also sort the nets by values within displayed columns.

From the **View** menu, select the **Arrange Nets By** command. The **Arrange Nets By** menu is displayed highlighting only the columns currently displayed.

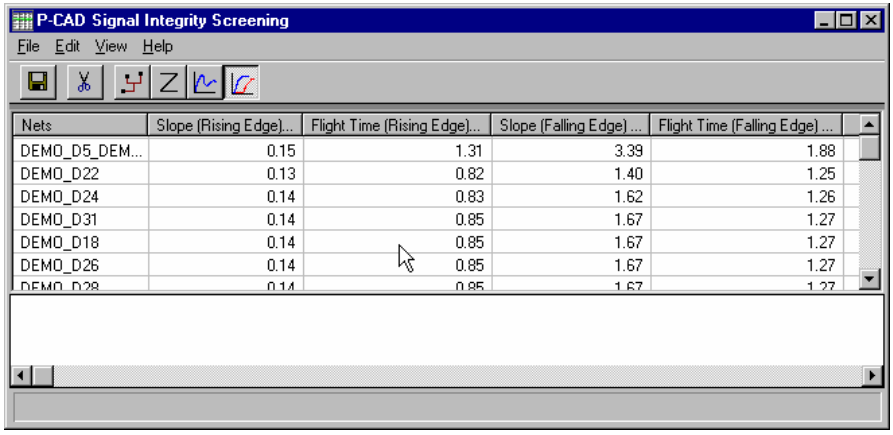
Select **Maximum Overshoot (Rising Edge)**. This displays the nets sorted in order of Maximum Overshoot.



Now click on the **Voltage View** icon again to switch this view off.

Lastly, click on the **Timing View** icon. This displays for each net:

- The net name
- The Slope for the Rising Edge
- The Flight Time for the Rising Edge
- The Slope for the Falling Edge
- The Flight Time for the Falling Edge.

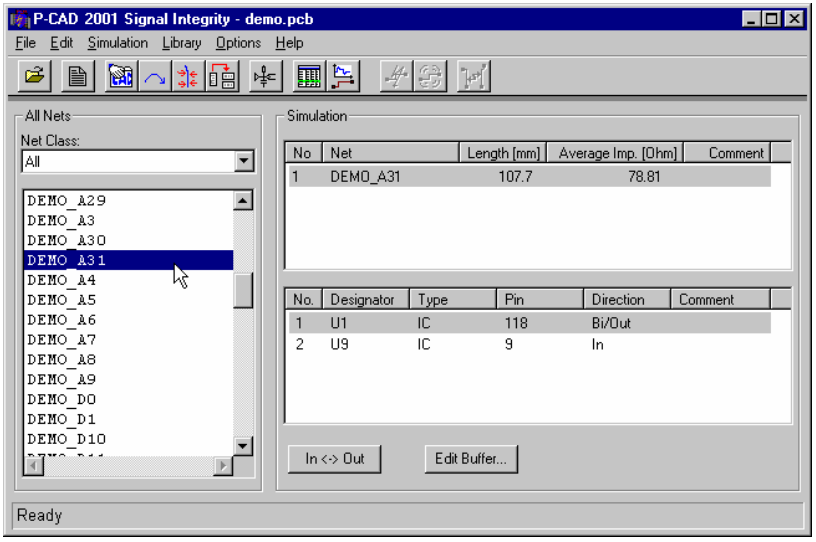


You can identify the nets displaying the longest flight time.

Now close the screening window using the **X** in the top right corner.

Run Reflection Simulation

Back on the Signal Integrity main screen, select the net `DEMO_A31` in the All Nets column. Click the **Takeover** icon to acquire data for this net.



The Reflection simulator calculates voltages at nodes of a net using routing and layer information of the PCB and associated driver and receiver I/O buffer models.

A 2D-field solver automatically calculates the electrical characterization of the lines. Modeling assumes that DC path losses are small enough to be ignored. The simulator provides you with detailed and highly accurate information on all signal integrity related aspects, such as overshoot, undershoot and timing. The results are presented in an oscilloscope-like wave analyzer.

To start a Reflection simulation, you can either click on the **Reflection Simulation** icon, or choose **Simulation** in the menu bar and select **Reflection** from the pull-down menu.

The simulator runs a reflection simulation on the nets displayed in the simulation window.

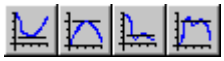
The results of the Reflection simulation are returned on the WaveAnalyzer screen.

The X and Y specified on the bar under the WaveAnalyzer screen indicate the location of the cursor on the display.

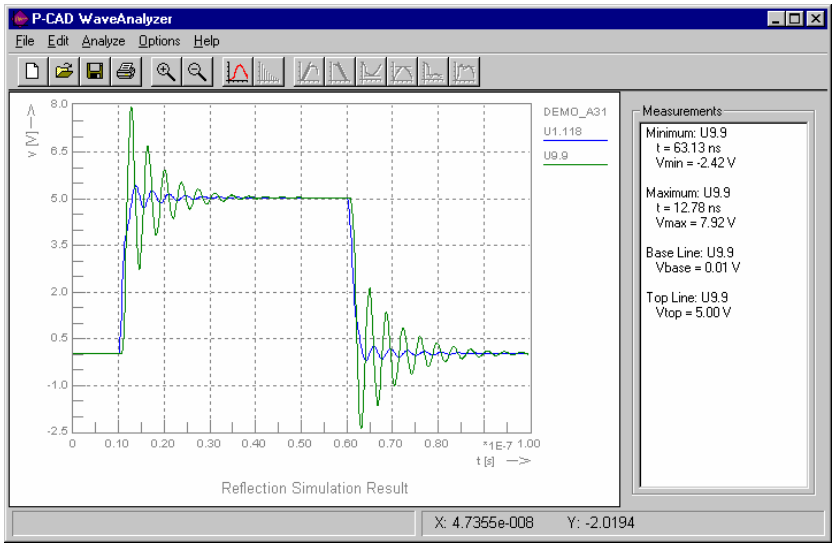
The display above shows the wave U9.9 (U9, pin 9 on net DEMO_A31) and wave U1.118 (U1, pin 118 on net DEMO_A31) as the worst for overshoot and undershoot. Let's look at the range of the overshoot for each of these waves.

Select the wave U9.9 by clicking on the line beneath its name which is displayed on the right of the wave display.

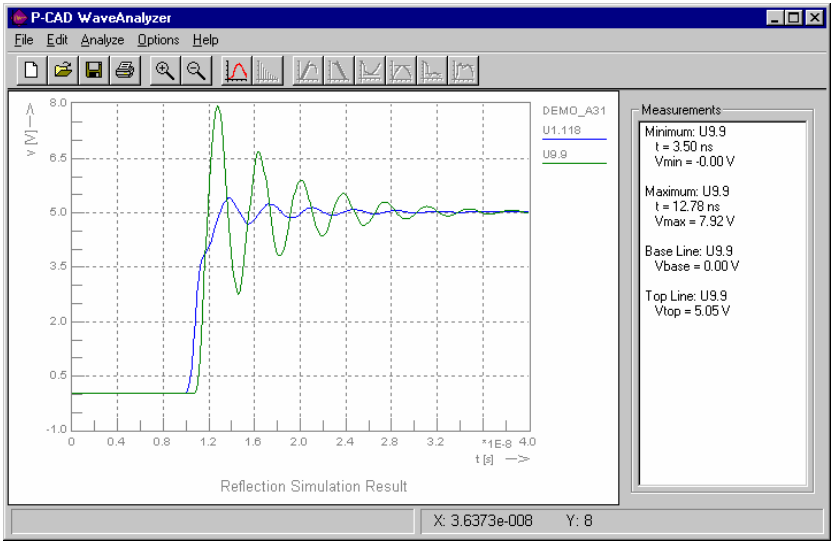
The WaveAnalyzer Analyze commands allow you to display the simulation results as waveform measurements. Click on the Minimum, Maximum, Base Line, Top Line icons.



The calculated measurements are displayed in the Measurements area of the WaveAnalyzer window. These measurements can also be performed using the pull-down options of the **Analyze** menu.



Let's zoom in on the worst overshoot area on the top left of the display. To do so, click the **Zoom In** icon then click and hold the mouse button on the top left corner, then drag the cursor toward the bottom right to define the zoom region. The picture below displays the zoomed area with its measurements.



Clear the measurement area by selecting **Clear Measurement Area** on the **Edit** pull-down menu. Now reselect Minimum, Maximum, Baseline and Topline.

The measurements are display dependent. The measurements displayed are for the selected wave within the currently visible area. If you compare the measurements of the zoomed graph with the measurements of the original chart, you can see that the measurement values are different. They now show the measurements for the currently displayed waveforms.

To return the display to the original full waves display, select the **Origin** command from the **Edit** pull-down menu.

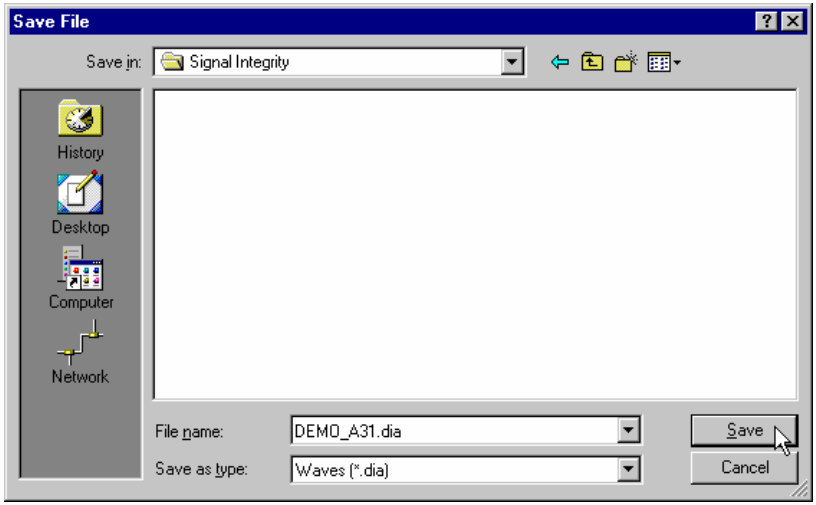
Let's save the current wave as DEMO_A31 for subsequent reference.

Do this by selecting **Save As** on the **File** pull-down menu.

The *File Save* dialog is displayed. Here you can specify the directory and filename for the wave file you want to save.

Enter `DEMO_A31` in the File Name field and click the **Save** button.

When saving using the File Save command, the default name `result.dia` is given. This default can be changed, by entering a new name, as appropriate. The current file name, displayed on the title bar, is overwritten each time the File Save command is issued.



Close the Waveform Analyzer by clicking the **X** in the upper right corner. The file saved can later be opened using the **File Open** command.

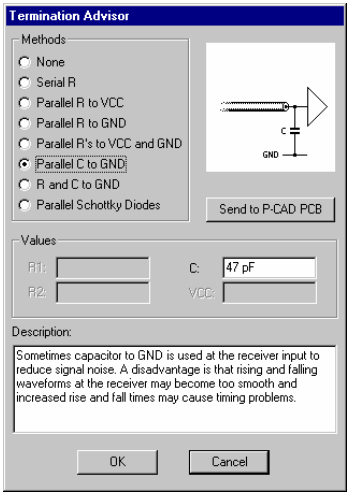
Having identified the net DEMO_A31 as problematic, let's go back to the Signal Integrity screen to select it and try a termination on the component U9 pin 9 to reduce the overshoot.

To do so, we first select the entry U9 pin 9 in the Signal Integrity window. Click on the **Termination Advisor** icon.

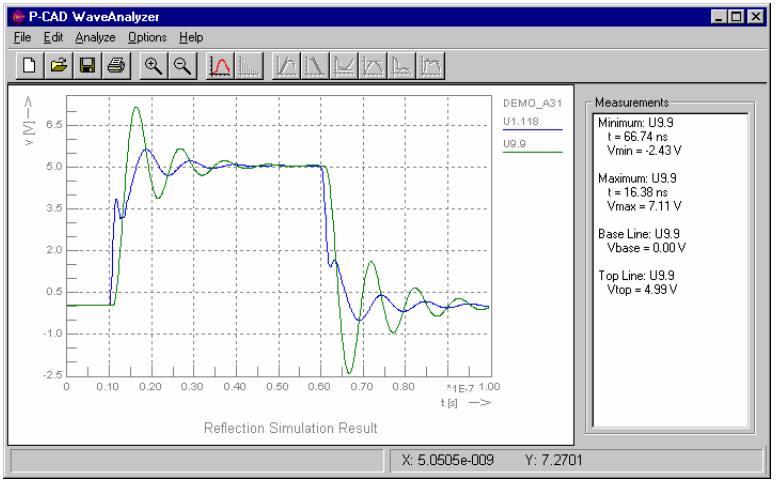
The Termination examples given here are for the purpose of demonstrating the tool only and may not be appropriate in the electrical sense.

The *Termination Advisor* dialog is displayed.

Choose **Parallel C to GND** termination method and click **OK**.

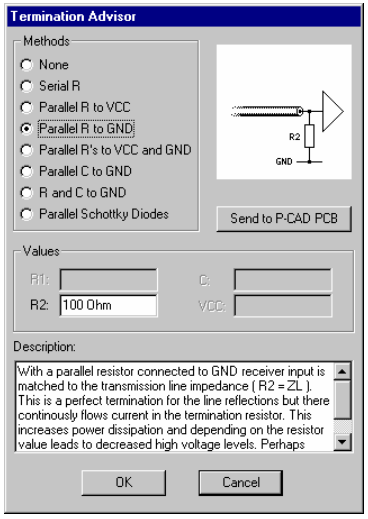


Now let's run the reflection simulation again. Click on the **Reflection** icon and on the WaveAnalyzer display, select the wave U9 pin 9 again by clicking on the line under its name and click the measurement icons to display the measurements in the Measurements area.

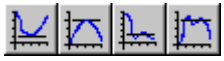


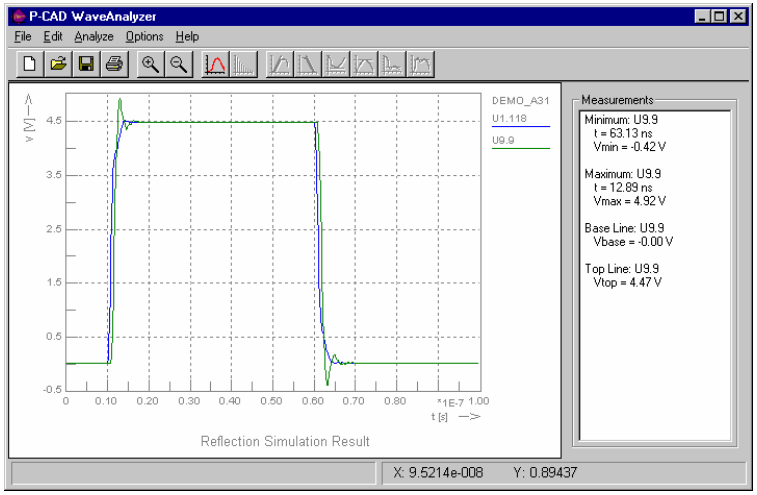
The overshoot Vmax = 7.11 V, is a slight reduction on the original 7.92 V before the termination was added, but it is still significant. Let's try a different termination.

Close the WaveAnalyzer window and go back to the Signal Integrity window, click on the **Termination Advisor** icon again. This time, select the **Parallel R to GND** Termination with 100 Ohm resistance and click **OK**.



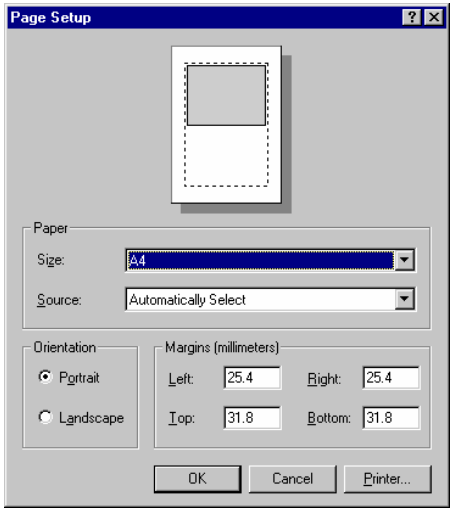
Now let's run the reflection simulation again. Click on the **Reflection** icon. Again, on the WaveAnalyzer display, select the wave U9.9 and click on the measurement icons.



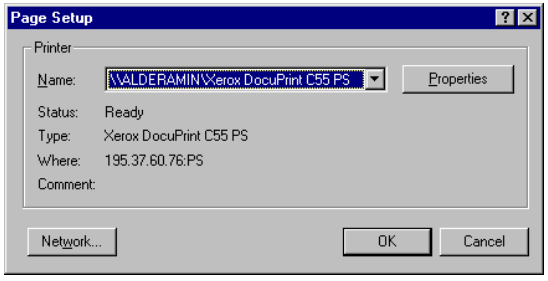


Now let's print out these results.

Select **Page Setup** on the WaveAnalyzer **File** pull-down menu. This displays the *Page Setup* dialog, on which you can specify paper size, source, orientation and margins.



Click on the **Printer** button to specify the printer. On the displayed dialog you can select a printer and enter the property details for the chosen printer.



Click **OK** to accept the printer selection and again to close the *Page Setup* dialog. Then click on **Print** on the WaveAnalyzer **File** pull-down menu. This displays the standard Windows print dialog, and sends the Wave display to the printer.

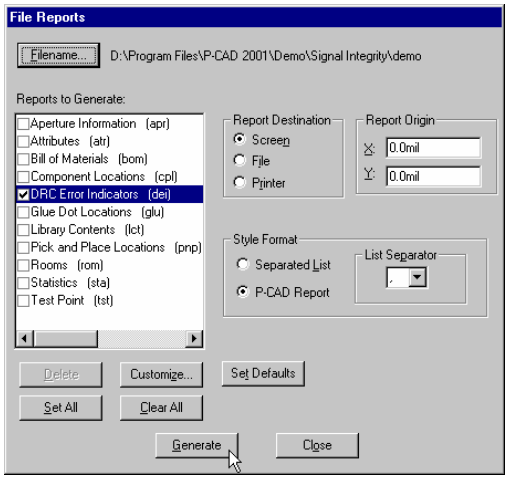
You can also use the **Print** icon to print the display, when the page setup and the printer details are already specified.

The introduction of the termination appears to have resolved the ringing noise problem.

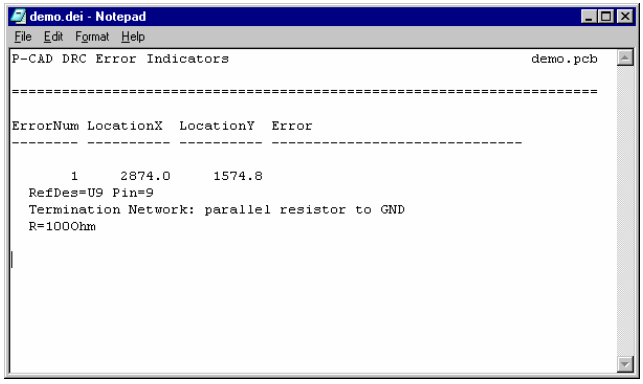
You can save this termination solution and send it as a DRC error indicator to the P-CAD PCB database. First close the WaveAnalyzer window. Return to the Signal Integrity window.

Click on the **Termination Advisor** icon. Click on the **Send to P-CAD PCB** button and click **OK**.

To display the DRC error indicator in P-CAD PCB, restore the P-CAD PCB window. In the P-CAD PCB window, choose **File** from the menu line and select **Reports**. Then enable **DRC Error Indicators** in the Reports to Generate list and click the **Generate** button.



This produces a report giving the ideal X, Y coordinate location of the termination network on the board together with the values of the component.



A DRC marker is placed in P-CAD PCB adjacent to the pin where the termination network should be applied. If you click on the DRC marker and view its properties (right mouse click and choose **Properties**), you get the value and configuration of the termination network.

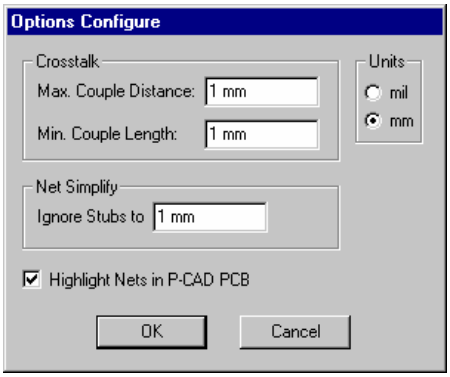
Run Crosstalk simulation

> The Termination examples given here are for the purpose of demonstrating the tool only and may not be appropriate in the electrical sense.

P-CAD Xtalk, the Crosstalk simulator simulates the coupling between traces with adjacent parallel segments.

P-CAD Signal Integrity is automatically searching for parallel traces, which may cause crosstalk problems. To enter the geometrical parameters for this search, select the **Configure** command from the **Options** menu. Enter the following values:

- Max. Couple Distance: 1mm
- Min. Couple Length: 1mm

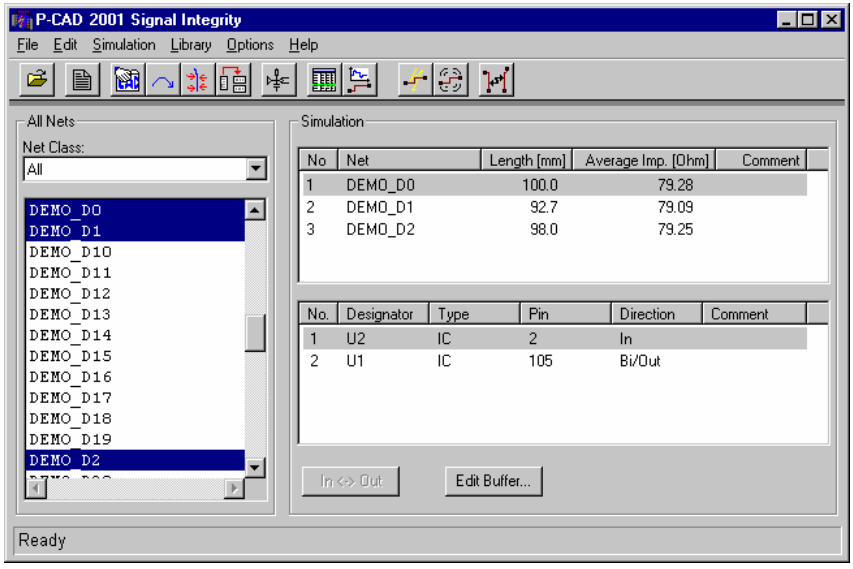


Max. Couple Distance specifies the maximum distance, which is used for searching parallel traces. The larger this distance is specified the more parallel traces will be found. Therefore the simulation time will increase.

Min. Couple Length specifies the minimum parallel length of a trace, which is still considered to provide crosstalk. Short parallel segments do not provide much crosstalk, but the simulation time will increase drastically.

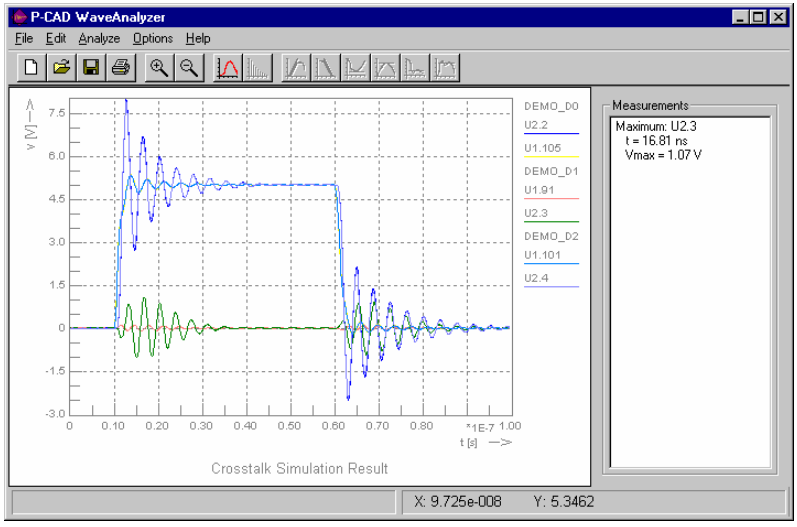
Click on the **Get Nets** icon in P-CAD Signal Integrity and then select net `DEMO_D1` in the All Nets column. After that, click on the **Find Coupled Nets** button. Now, all nets within the range of the specification entered in the Options Configure menu will be selected automatically in the All Net list. In this case, these are DEMO_D0, DEMO_D1 and DEMO_D2.

Click the **Takeover** icon.



Next, choose net `DEMO_D1` in the simulation window, and click the **Set Victim Net** button. This will set the stimulus for the net DEMO_D1 to constant low level and all other nets will have the default stimulus (single pulse, rising edge at 10ns, falling edge at 60ns). By this, the maximum crosstalk of all coupled nets onto the victim net is calculated.

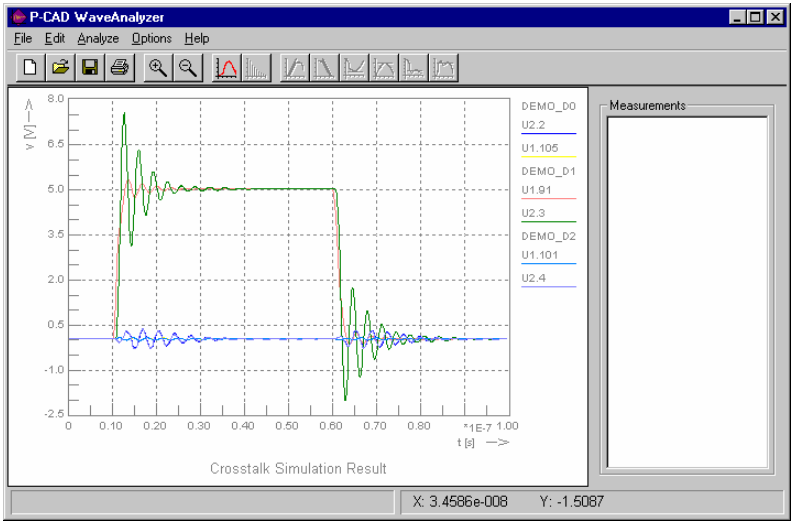
Now run the Crosstalk simulation by clicking on the **Crosstalk** button.



The WaveAnalyzer shows maximum crosstalk of 1.07V measured on net DEMO_D1 at pin 3 at component U2. This crosstalk results from the ringing on net DEMO_D0 and DEMO_D2 during the signal transition from low to high and high to low.

Close the WaveAnalyzer to return to P-CAD Signal Integrity.

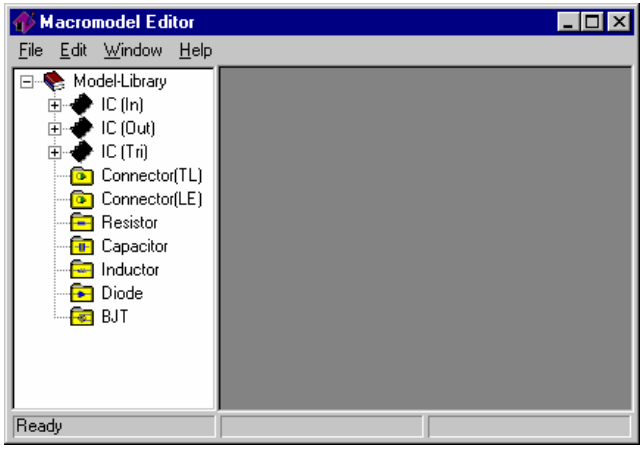
Select net DEMO_D1 in the Simulation window on the right. Now press the **Set Aggressor Net** icon. By doing this, net DEMO_D1 will get the default stimulus (single pulse, rising edge at 10ns, falling edge at 60ns) while all other nets will be set to constant low. This will calculate the crosstalk from the aggressor net to all its neighbor nets. After clicking on the **Crosstalk Simulation** button, the WaveAnalyzer displays the results.



Create a Macromodel

The Macromodel Editor enables you to create your own custom device models. The models are organized in the library tree.

To open the Macromodel Editor, select the **Macromodel Editor** command from the **Library** menu in P-CAD Signal Integrity screen. The library tree displays as shown.

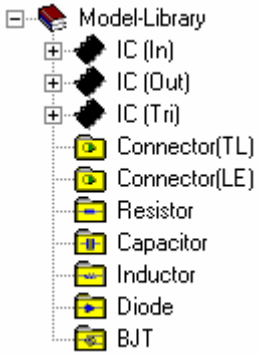


You can navigate through the User Model Library as you do in Windows Explorer.

The library contains a folder for each type of parts and models defined in the database. IC models folders are also sub-divided into folders for each available technology. The full list of technologies available is described in the Macromodel Editor commands' description in chapter 8.

The items in the tree represent user defined custom models.

Let's add a new Resistor component. To do so, click on the Resistor model folder. This displays the currently defined Resistor components (there may be none currently defined).

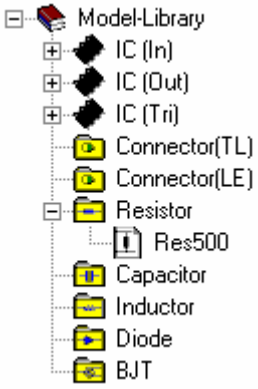


Choose **Edit** from the Macromodel Editor menu bar and select **Add** from the pull-down menu. This displays the *Modelname Entry* dialog.

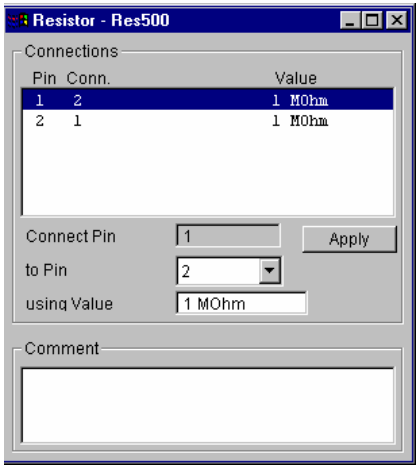
Enter `Res500` as shown below and click **OK**.

The *RLC Enter Value* dialog is displayed where you can enter the number of pins. In our case, leave the default value as 2 and click **OK**.

The newly created Resistor Res500 is now displayed on the Library tree.



The Resistor - Res500 dialog is displayed with the information supplied so far and default values for the other parameters.



In this dialog you can change the value in the Using Value box and click the **Apply** button. The entry on the top window will be modified accordingly.

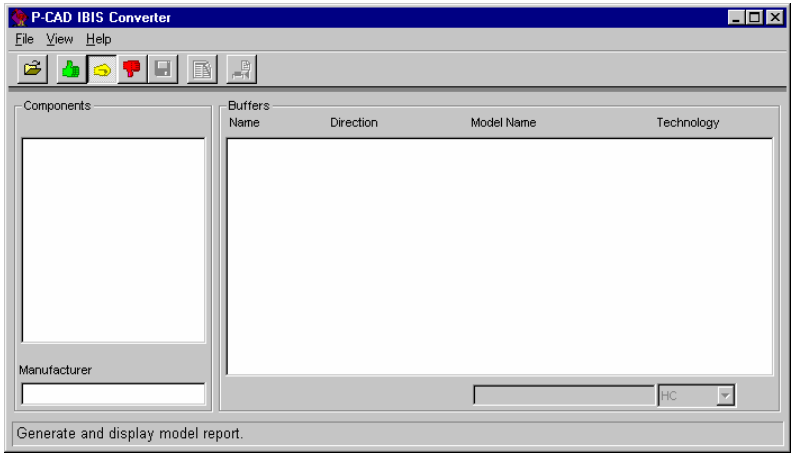
Some IC models in the Library cannot be edited. These models have been created by the P-CAD Signal Integrity IBIS converter and contain data that cannot be modified.

Create a new Macromodel from an IBIS file

IBIS stands for 'Input/Output Buffer Information Specifications'. It is an ANSI/EIA standard for behavioral specifications of integrated circuit's input/output analog characteristics.

You can create new custom user models based on input from IBIS files.

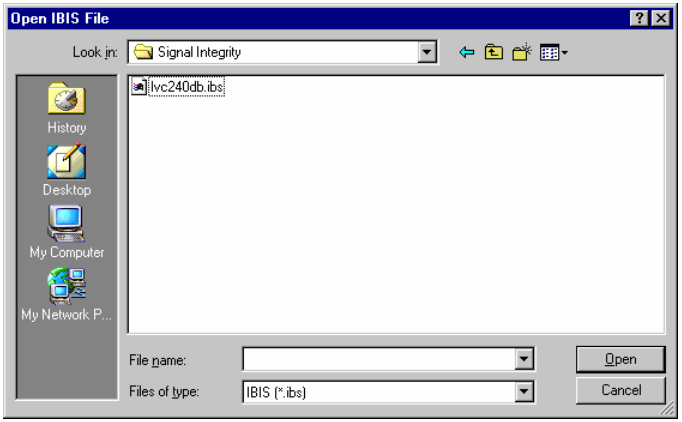
The Import IBIS File command enables you to do so. The **Import IBIS File** command is accessed from the **Library** pull-down menu on the Signal Integrity entry screen.



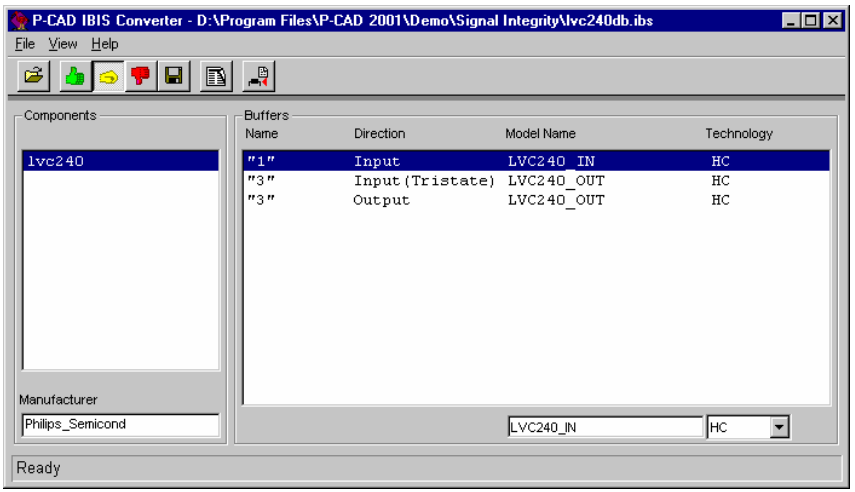
Choose the **Import IBIS File** command from the pull-down menu of the **Library** command. This displays the P-CAD IBIS Converter window.

Choose the **File** command from the menu bar, and select **Open** on its pull-down menu.

This displays the *File Open* dialog, choose the `\P-CAD 2002\Demo\Signal Integrity` folder which includes an example IBIS file.



Choose the file `lvx240db.ibs` as shown above. The information is loaded on the IBIS Converter window.



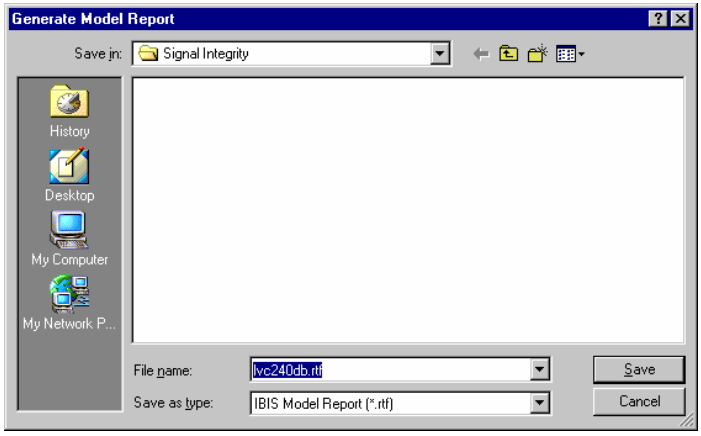
We can now choose which model to generate.

The **Strong Case Model** allows you to test your design performance envelope. The strong case model represents the fast extreme of IC performance.

The **Typical Case Model** lets you get an idea of the typical performance of the design.

Let's choose these two models. To do so, select these two models from the **File** pull-down menu.

Let's produce a report of these models. Select the **Report** command from the **File** pull-down menu. This displays the *Generate Model Report* dialog, which, by default, allocates for the report the name of the currently opened file. You can modify this or accept this name.



Let's accept the name. This will generate a Word report in the specified directory.

IBIS Model Info

Wed Jan 31 19:02:45 2001

****

Component:	lvc240
Buffer:	"1"
Direction:	Input
Model	LVC240_IN

Characteristics	**Best Case**	**Typ. Case**	**Worst Case**
C_comp	typical	typical	typical
GND Clamp	typical	typical	typical
Power Clamp	typical	typical	typical

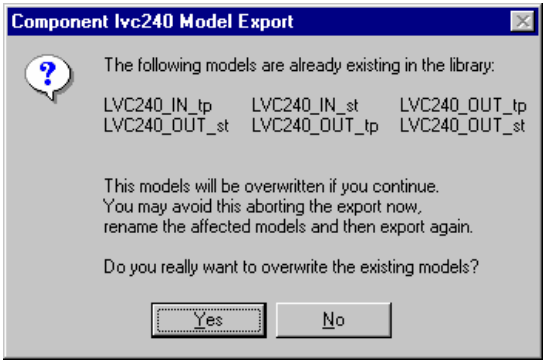
****

The picture above shows part of the report generated.

Now, let's add these models to the Library.

This is done with the **IBIS File Export** command. It can be accessed from the **File** pull-down menu or by its icon.

When you choose this command, the models are added to the Library. If the models already exist, in the library, a confirmation window is displayed which gives you the option to over-write the currently stored models or cancel your export operation.



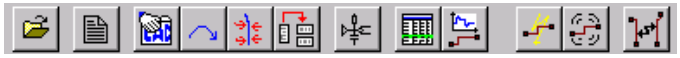
Otherwise, an export confirmation message is displayed.

CHAPTER 4

P-CAD Signal Integrity Command Reference

This Reference chapter provides information on each command, dialog and option available during the simulation process, in the order in which they appear in the menus and dialogs. It also includes additional information about simulation concepts and procedures.

When you start the P-CAD Signal Integrity, the entry screen is displayed, giving you access to process specific icons, menus and commands.



File Commands

The File commands are accessed from the File menu, which appears on the menu bar when you enter P-CAD Signal Integrity. The File commands allow you to open and save files, get nets to analyze and produce reports. Each of these commands is discussed below.

File Open

The File Open command imports an existing SULTAN file, as input to the simulator, using the Windows standard *File Open* dialog.

A SULTAN file is a representation of the PCB geometry and the required electrical and design specific information (like value of resistors and component designators). This representation is used to store PCB databases so that P-CAD Signal Integrity can be used without having P-CAD PCB open.

The **File Open** command can be initiated from the **File** command pull-down menu or by its icon.

When you choose File Open, P-CAD Signal Integrity displays a dialog from which you can choose the directory and file name of the file you want to open.

The **Look In** area displays the current folder; a list of files in the folder appears directly underneath. The **File name** area lets you select or enter a SULTAN file, from the list of files displayed with the

extension .slt. If a file you want is not in the current directory, you can select another directory from the Directories list.

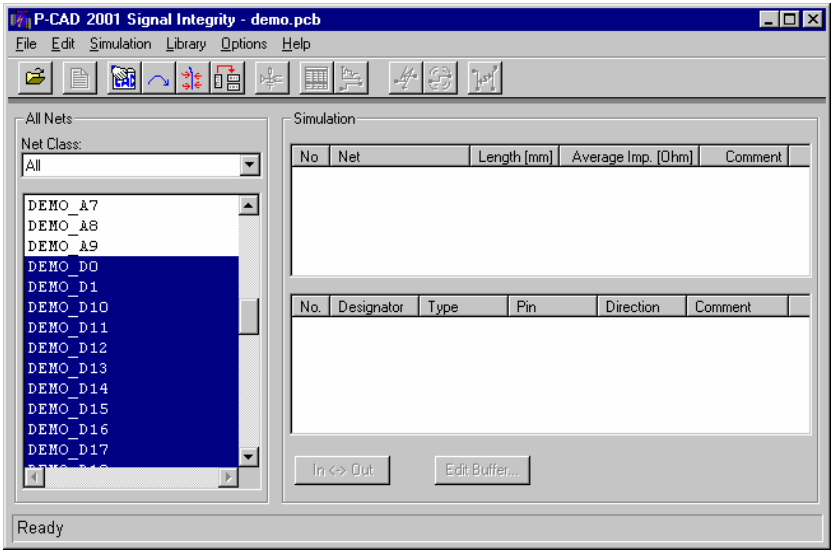
Once you have made your selection, click the **Open** button.

File Get Nets

This command displays a list of all nets of the current P-CAD PCB design in the All Nets column of the entry screen. Click on the nets you want to select. These will become highlighted. To select nets, which are not displayed consecutively, press the **Ctrl** button while selecting.

In order to analyze a PCB, P-CAD PCB must be active and a PCB file must be open.

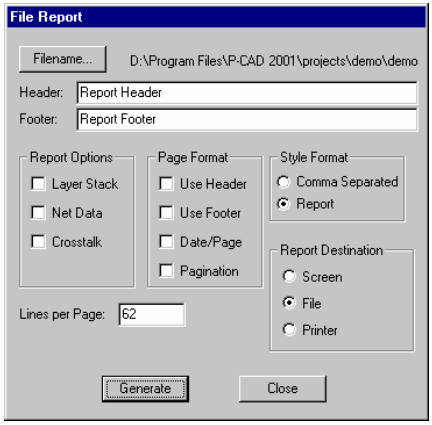
The File Get Nets command can be initiated by choosing **Get Nets** from the **File** pull-down menu or by clicking on its icon.



File Reports

The File Reports command allows you to output reports with specific output options. These options are saved when you exit the program.

The File Reports command can be initiated by choosing **Reports...** from the **File** pull-down menu or by clicking on its icon. This displays the *File Report* dialog.



Filename

You can specify individual reports (selecting from the list of report options) and choose to output these all at once or one at a time. Each report type has its own file extension. The file name defaults to the currently open design.

Reports File extensions

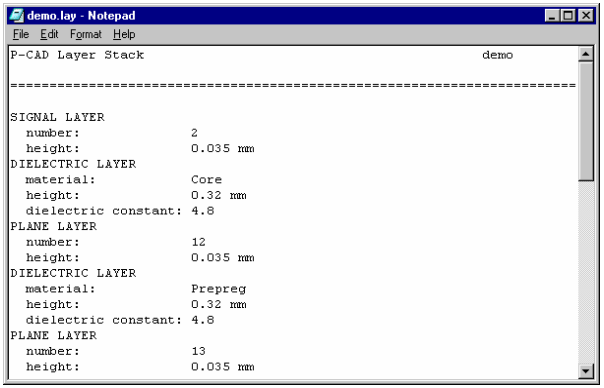
These cannot be changed. The extensions used are as follows:

- LAY for Layer Stack information
- NET for Net Data
- XTK for Crosstalk data.

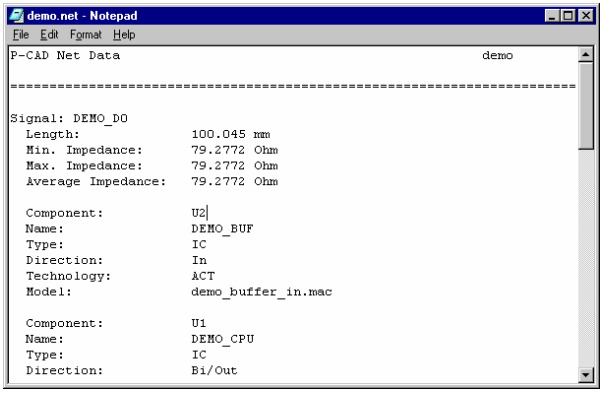
Each of these reports is displayed under Report Options, in the screen report format, which displays a Notepad window.

Reports Options

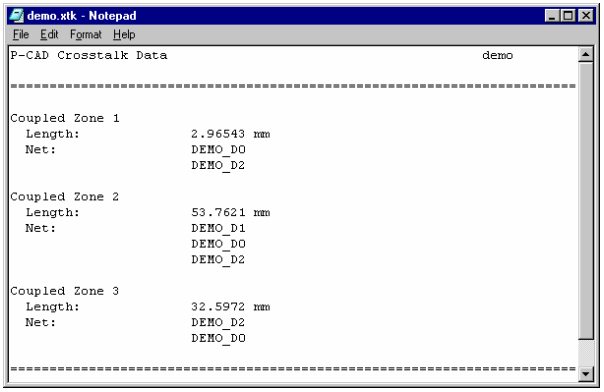
Layer Stack reports the parameters for each layer as listed below.



Net Data reports the parameters and component details for each selected net as listed below.



Crosstalk Data reports the parameters for each selected net as listed below.



Page Format

These options, when enabled, are output with whatever report type you have chosen to use.

Use Header and **Use Footer** include the text you have specified in the header and footer fields.

Date/Page includes the current date and page number.

Pagination allows you to create your own pagination (lines per page) when you generate the report to the printer or to a file (see Report Destination section below). When you generate the report to the screen, the report is displayed on the Notepad. In this case, use the print command available in the Notepad File command to print the report.

Style Format

This enables you to specify the format of the report contents.

Comma Separated puts all information in comma separated format, which is a spreadsheet-loadable format.

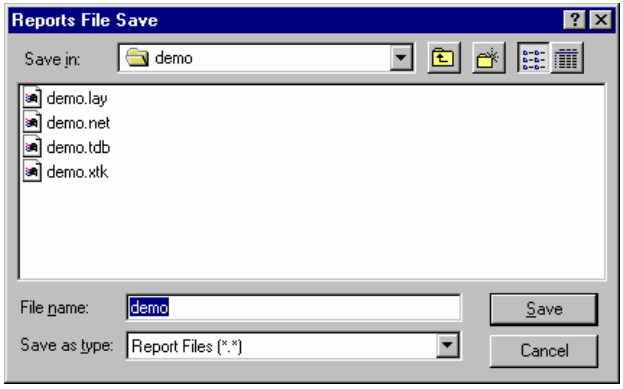
Report is a readable format with columns and spaces, etc.

Report Destination

This enables you to specify where to send the output.

Screen sends the output to a file and invokes Notepad to display the file. To print this file, use the Notepad File/Print command.

File sends the output to a file. The name of the file defaults to the name of the currently open design. You can specify a name of your choice by clicking the ***Filename*** button. This will display the *Reports File Save* dialog on which you can enter a file name. The file extension will be automatically assigned depending on the type of the report to be generated.



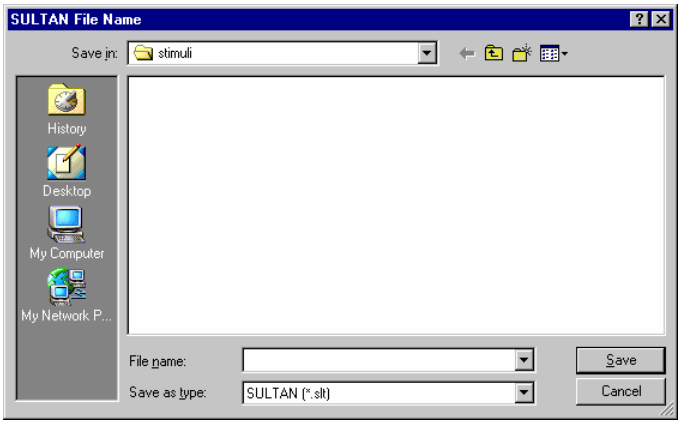
Printer sends the output directly to the printer without creating files.

Lines per Page

This enables you to specify the number of lines per page in your output.

File SULTAN Out

This command enables you to save the entire current P-CAD PCB design in a SULTAN file. Similar to the File Get Nets command, P-CAD PCB must be active and a PCB database must be open. This command enables the user to load the database later on without any interaction with P-CAD PCB (see command **File Open**).



When you choose **SULTAN Out** from the **File** pull-down menu, the *SULTAN File Name* dialog is displayed and you can specify the directory and filename for the file you want to save.

Enter the file name for the nets. The `.slt` file type identifying SULTAN files is automatically assigned.

File Exit

This command exits the P-CAD Signal Integrity Simulator. Before exiting, P-CAD Signal Integrity saves the settings of supply nets, designators and the layer stack as well as the latest simulation options. These will be re-used the next time P-CAD Signal Integrity is started.

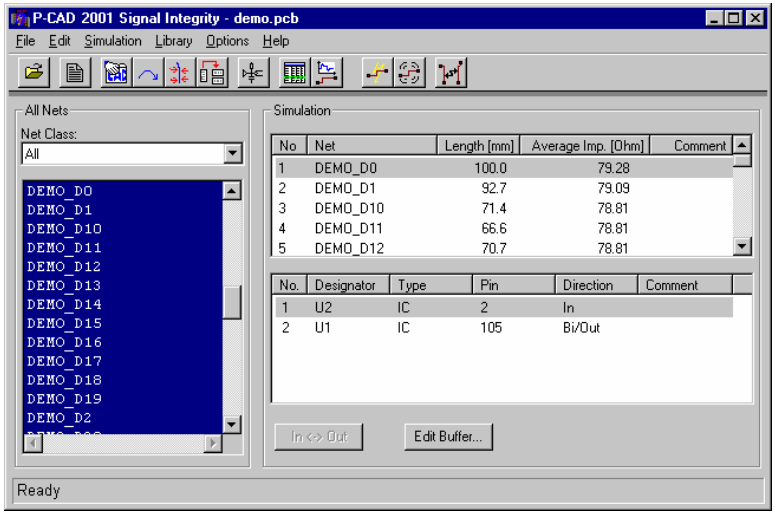
Edit Commands

The Edit commands are accessed from the Edit menu, which appears on the menu bar when you enter P-CAD Signal Integrity. They deal with obtaining and modifying the Nets data for the simulation process.

Each of these commands is discussed below.

Edit Take Over

The **Take Over** command acquires the geometric and part data for the nets selected in the left All Nets column from the current P-CAD PCB database. After successful data transfer, these will be displayed in the Simulation windows.



The **Edit Take Over** command can be initiated from the **Edit** pull-down menu or by its icon.

The upper window lists the length and average characteristic impedance for each selected net.

The Net Length is the sum of the length of the traces in the net.

The Net Characteristic Impedance is the mean value of the impedance. It is derived from the sum of the impedance of each trace segment multiplied by the length of the trace and divided by the sum of the length of the trace segments.

The lower window displays the components connected to the net selected in the upper window and their characteristics.

Edit Get PCB Selected Nets

The **Get PCB Selected Nets** command selects those nets in the All Nets column that are currently selected on the PCB in P-CAD PCB.

To use this command first select the net(s) in P-CAD PCB, then chose **Edit » Get PCB Selected Nets**, or click the Get PCB Selected Nets icon.

Edit Find Coupled Nets

The **Find Coupled Nets** command analyses the PCB to identify coupled nets, and then selects any coupled nets in the All Nets column.

Coupled nets are identified according to the settings in the *Options Configure* dialog, which defines how close the nets are (couple distance), and the distance that the nets run in parallel (couple length) for them to be considered coupled. Select **Options » Configure** from the menus to set up the coupling properties.

To use this command select a net in the All Nets column, then chose **Edit » Find Coupled Nets**, or click the Find Coupled Nets icon. Any coupled nets will be selected in the All Nets column.

Edit Layer Stack

This command enables you to enter or modify the Layer Stack specifications.

The Layer Stack of the PCB must be specified for the calculation of the electrical behavior (characteristic impedance and phase velocity) of the traces.

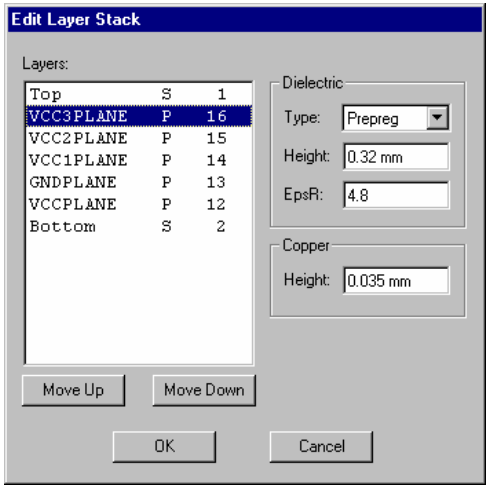
The required parameters and their default value are listed below:

Parameter details	Default Value
The correct sequence of the layers	None
The thickness of the different copper layers	35 μm
The thickness of the dielectric planes	0.32mm
The dielectric constant of the substrate	$\varepsilon_r = 4.8$

The Layer Stack and all the calculated transmission line parameters are automatically saved as a `.tdb` file. This database is stored together with the current PCB project name. It is automatically re-used if the same PCB is analyzed in multiple P-CAD Signal Integrity sessions.

Rather than always re-calculating the transmission line characteristics before a new transmission line parameter is calculated, P-CAD Signal Integrity will search its database for an existing set, which matches its current parameters. Whenever the Layer Stack is changed, the old database file gets deleted and a new one is generated.

Choose **Layer Stack** from the **Edit** pull-down menu and the *Layer Stack* dialog is displayed listing all existing layers in your selected design in their current sequence.



This window shows the layer name, the layer type (Signal or Plane) and the layer number as defined by the user in P-CAD PCB.

Here you can modify the Dielectric and Copper property definitions for a layer. To do so, select a layer and enter the changes required in the available entry windows.

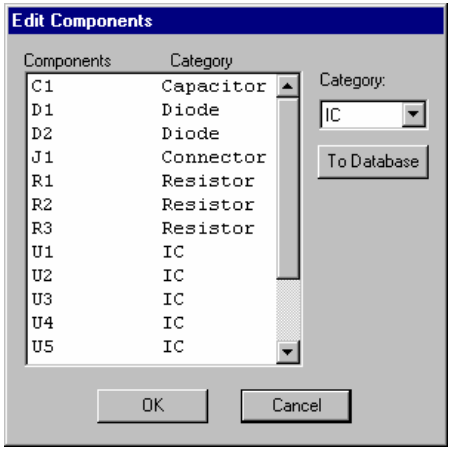
When you enter the Copper thickness and the Dielectric value, the Dielectric referred to is the one immediately above the Copper layer. As a result, it is not possible to enter a Dielectric value for the top layer.

All the layers, except the Top and Bottom layers, can be moved up or down by selecting a layer and clicking the appropriate button. The Top layer is always number 1 and the Bottom layer is always number 2 and at the bottom.

Enter changes and click on **OK** for these to take effect.

Edit Components

This command enables you to specify the electrical type of components.



The Components list box contains the names of all components in the active design. You can select individual or multiple components in the list box. Once selected you can specify the electrical type of the components in the Category drop down list.

With the button **To Database** you can save the specified component types to your P-CAD PCB database. The information is saved in the database by a component attribute.

A second way to specify the component type is to define a component attribute directly in P-CAD PCB. Define the Component attribute Category and set the value of the attribute to one of the following qualifier. If you now load the design into P-CAD Signal Integrity, the components get the defined electrical types.

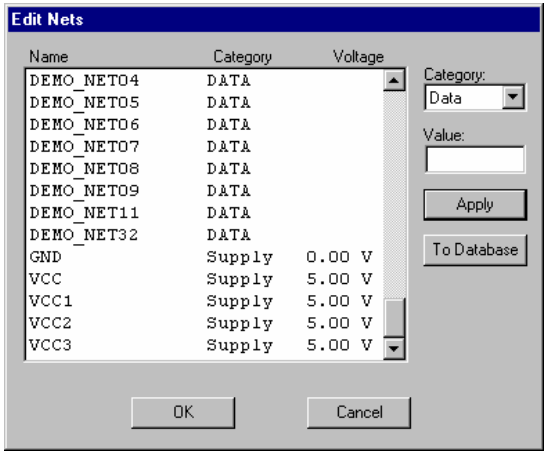
The following electrical component types are supported:

Component Type	Attribute Value
Bipolar Junction Transistor	BJT
Capacitor	Capacitor, Cap
Connector	Connector, Con
Diode	Diode, Dio
IC	IC
Inductor	Inductor, Ind
Resistor	Resistor, Res

The default component type is **IC**.

Edit Nets

This command allows you to specify the name of Supply Nets and their voltage.



Although the Supply Nets cannot be simulated they are necessary for the correct simulation of nets with Pull-up or Pull-down components.

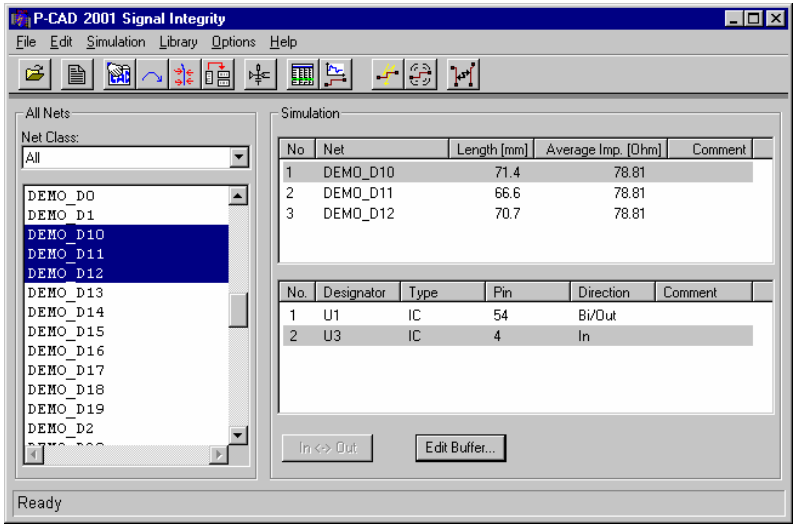
The list box contains the names of all nets in the active design. You can select individual or multiple nets in the list box. Once selected you can specify the category and the voltage of the net.

With the button **To Database** you can save the specified net category and value to your P-CAD PCB database. The information is saved in the database by net attributes.

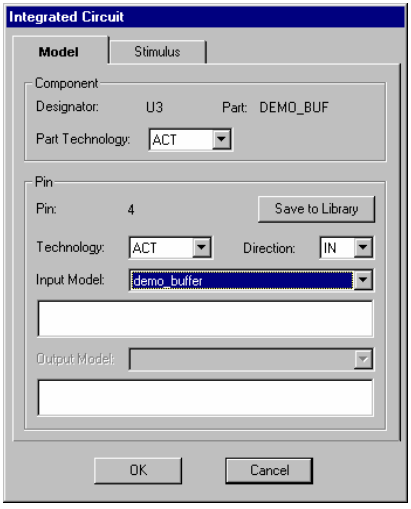
A second way to specify the net category and value is to define net attributes directly in P-CAD PCB. Define the net attribute **Category** and set the value of the attribute to SUPPLY and the net attribute Voltage and set the value to the voltage of the net. If you now load the design into P-CAD Signal Integrity, the nets get the defined category and value.

Edit components specifications

You can only modify components that are attached to a specific net. Therefore you must select nets from the All Nets column (see display below) and click the **Takeover** icon. P-CAD Signal Integrity then extracts all the required data for these nets and displays these in the simulation windows. You can now select a net in the upper window and select the respective component in the lower window. You can now proceed with the editing as described below.



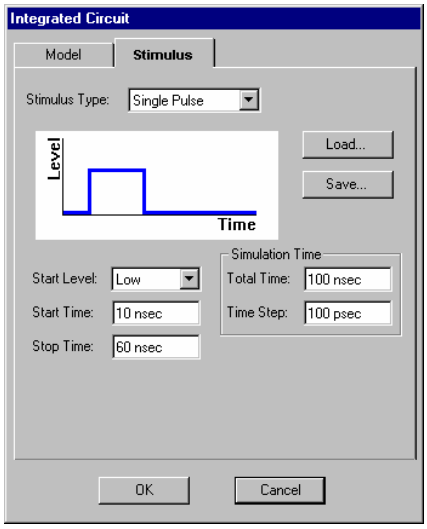
To modify specifications of components, click on the **Edit Buffer** button under the simulation windows. This displays the relevant component dialog.



You can change the component Model data and the Stimulus pattern.

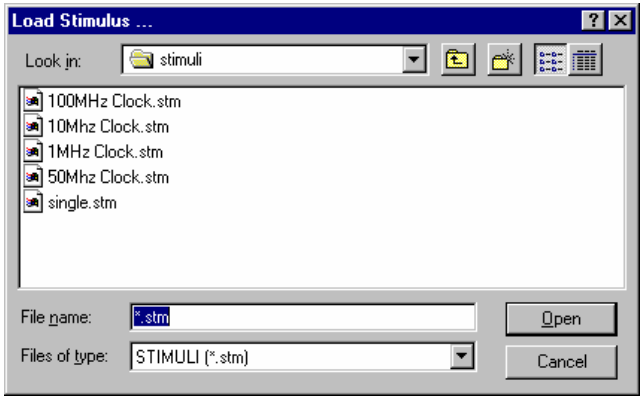
The Model tab shows the selected component parameters and its current settings. The Part Technology, Input Model and Output Model boxes are context sensitive. When you choose a part technology the default models of the part are taken from this technology. Similarly, choosing a Technology and a direction will automatically display a list of relevant input and/or output models to select from.

Select a model and click **OK** to apply the changes. To save these changes to the library, click the **Save to Library** button.



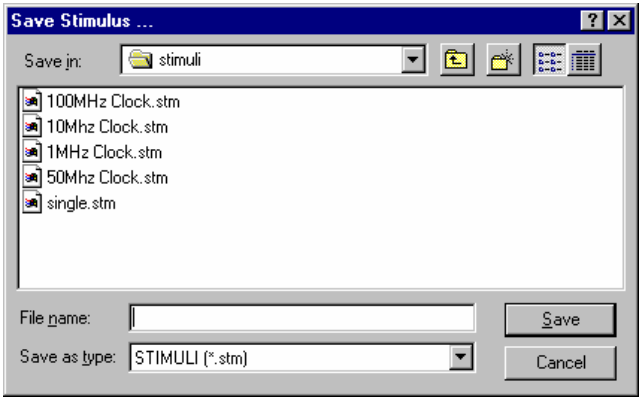
On the Stimulus tab you can modify the Stimulus pattern to one of the following: Constant Level, Single pulse or Periodic pulses, and the Stimulus level to: High or Low. The wave display will change to reflect your choices. The number of parameters displayed is context sensitive with the stimulus type chosen. You can also specify Start and Stop times for the pulse and the Period time if a periodic pulse is chosen.

Stimulus details may also be loaded from a file. To do so, click on the **Load** button. This will display the *Load Stimulus* dialog, with the files contained in the current folder. If the file you want is not displayed, you can browse through other directories.



Select the file you want to use and click the **Open** button. This will update the Stimulus with the file data.

Stimulus details can be saved to a file. This is done by clicking the **Save** button, which displays the *Stimulus Save* dialog.



Enter a name for the Stimulus file. The file type `.stm` is automatically assigned.

CHAPTER 5

P-CAD Signal Integrity Screening Commands

P-CAD Signal Integrity's screening capability allows you to quickly screen a number of nets for signal integrity and timing effects. It utilizes a very fast 2D-reflection simulator that uses a linear representation of the IC pin behavior to achieve the high speed. It provides you with an overview of the characteristics of the nets that are screened. Besides geometrical information it provides also estimated values for signal integrity effects (overshoot, undershoot).

P-CAD Signal Integrity Screening should be used to determine which nets may be critical and therefore require inspection in greater details using the Reflection simulator.

When screening bi-directional nets, both directions are simulated and the worst result of each effect is displayed.

P-CAD Signal Integrity Screening commands can be accessed by choosing **Screening** from the **Simulation** pull-down menu or by clicking on its icon.

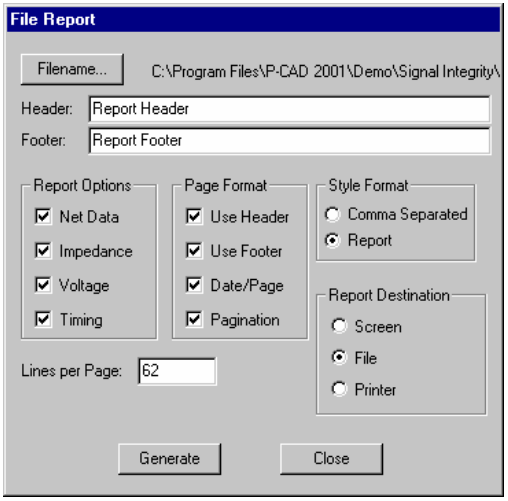
When you start the Screening command, the Screening window is displayed, giving you access to process specific icons, menus and commands.

File Commands

The File commands are accessed from the Screening File menu, which appears on the menu bar when you initiate the Screening command. The File commands allow you to print and save files in different formats. Each of these commands is discussed below.

File Report

The File Reports command allows you to output reports with specific output options. These options are saved when you exit the program.



Filename

When choosing a file as the destination for the report, you can specify a file name. The file name defaults to the currently open design. The file extension is automatically assigned depending on the report option chosen.

Report File extensions

These cannot be changed. The extensions used are as follows:

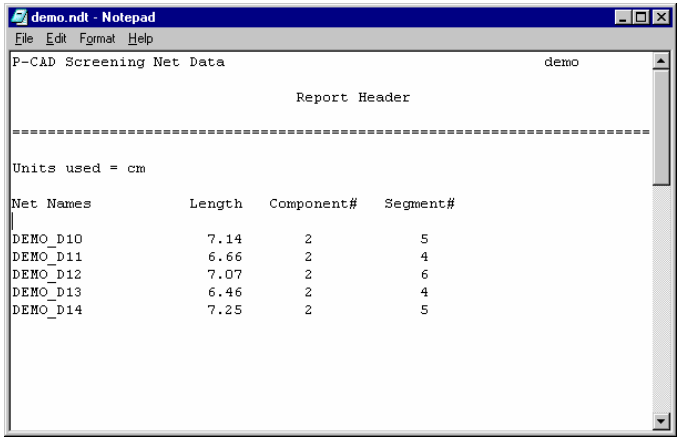
- NDT for Net Data
- IMP for Impedance Data
- VOL for Voltage Data
- TIM for Timing Data

Report Options

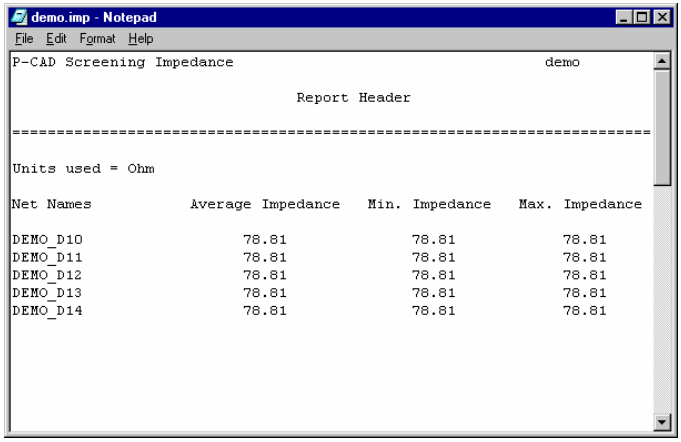
You can specify individual reports (selecting from the list of report options) and choose to output these all at once or one at a time. Each report type has its own file extension. The file name defaults to the currently open design.

The following report examples have been produced choosing the screen as report destination.

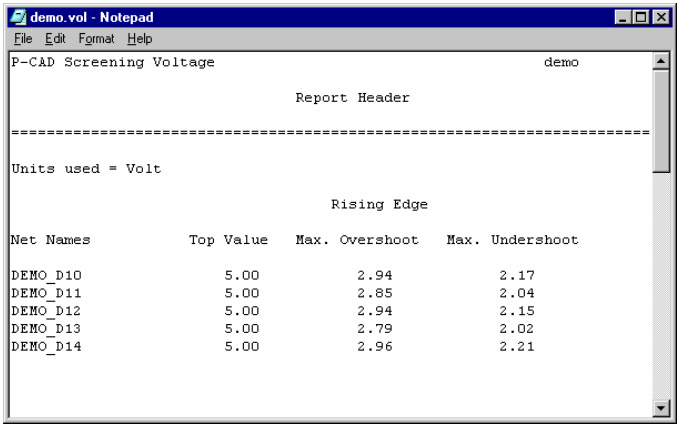
Net Data reports the data for each selected net as listed below.



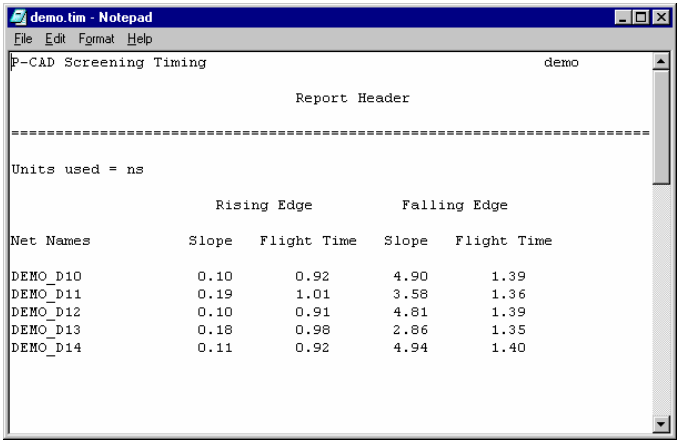
Impedance Data reports the impedance readings for each selected net as listed below.



Voltage Data reports the voltage readings for the Rising and Falling edges of each selected net as listed below.



Timing Data reports the Slope and Flight Time on the Rising and Falling edges for each selected net as listed below.



Page Format

These options, when enabled, are output with whatever report type you have chosen to use.

Use Header and **Use Footer** include the text you have specified in the header and footer fields.

Date/Page includes the current date and page number.

Pagination allows you to create your own pagination (lines per page) when you generate the report to the printer or to a file (see Report Destination section below). When you generate the report to the screen, the report is displayed on the Notepad. In this case, use the DOS print command available in the Notepad File command to print the report.

Style Format

This enables you to specify the format of the report contents.

Comma Separated puts all information in comma separated format, which is a spreadsheet-loadable format.

Report is a human-readable format with columns and spaces, etc.

Report Destination

This enables you to specify where to send the output.

Screen sends the output to a file and invokes Notepad to display the file. To print this file, use the Notepad File/Print command.

File sends the output to a file. The name of the file defaults to the name of the currently open design. You can specify a name of your choice by clicking the Filename button. This will display the *Reports File Save* dialog on which you can enter a file name. The file extension will be automatically assigned depending on the report option chosen.

Printer sends the output directly to the printer without creating files.

Lines per Page

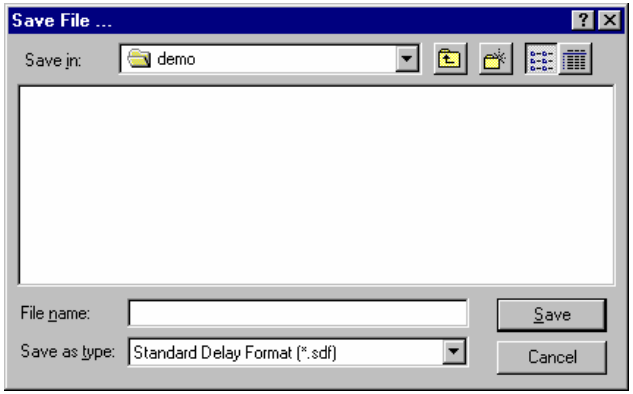
This enables you to specify the number of lines per page in your output.

File SDF Out

This command enables you to save the details on interconnect delays between the different pins of a signal into a SDF file.

The SDF (an abbreviation for Standard Delay Format) file is an ASCII text file that stores the timing data generated by EDA tools. With the SDF intrinsic delays, interconnect delays, loading delays, timing checks and timing constraints are represented using an abstract, tool-independent delay model which is applicable to a variety of tools. The major purpose of the delay file is to facilitate the distribution and control of design delay information between different EDA tools.

The File SDF Out command can be initiated by choosing **SDF Out …** from the **File** pull-down menu or by clicking on its icon. The *Save File* dialog is displayed, and you can specify the directory and filename for the file you want to save.



Enter a name for your SDF file in the File name box. The SDF file type is automatically assigned.

File Close

This command exits the Net Screening process.

On exit from the Screening program, Signal Integrity saves the last settings used during the screening session.

Edit Commands

The Screening Edit commands are accessed from the Edit menu, which appears on the menu bar when you initiate the Screening command. They deal with modifying the Screening display.

Each of these commands is discussed below.

Edit Delete

The Edit Delete command removes the selected nets from the display.

The Edit Delete command can be initiated by choosing **Delete** from the **Edit** pull-down menu or by clicking on its icon.

Edit Select All

The Select All command selects all the nets displayed. The Edit Select All command is initiated by choosing **Select All** from the **Edit** pull-down menu.

Edit Invert Selection

The Invert Selection command redefines the nets selected by substituting the currently selected nets with the currently not-selected nets.

The Edit Invert Selection command is initiated by choosing **Invert Selection** from the **Edit** pull-down menu.

View Commands

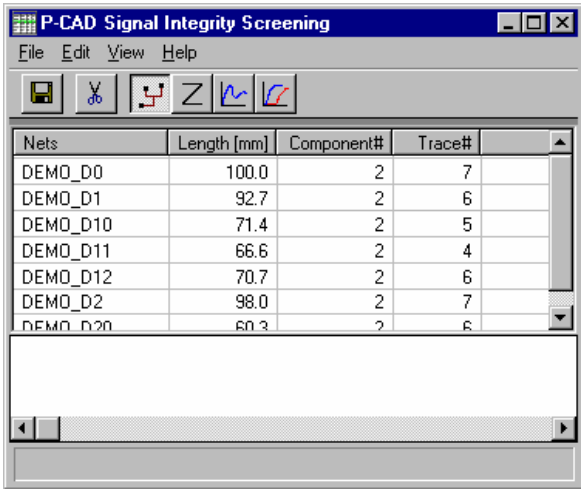
The Screening View commands are accessed from the View menu, which appears on the menu bar when you initiate the Screening command. They deal with selecting and organizing what is displayed on the Screening window and displaying the nets' characteristics.

Each of these commands is discussed below.

Net Data View

The Net Data View displays for each net:

- The net length. This is the sum of the length of the traces
- The number of IC's connected to the traces
- The number of segments for each trace.



The Net Data View command can be initiated by choosing **Net Data View** from the **View** pull-down menu or by clicking on its icon.

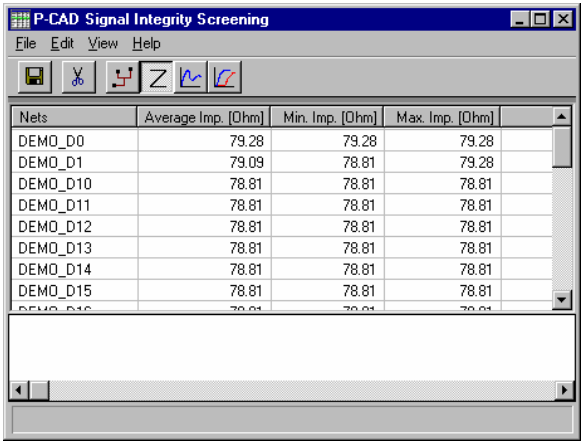
You can expand or restrict the columns size by dragging-in or out, at the column separation vertical line on the column header.

Impedance View

The Impedance View displays for each net:

- The average impedance of the trace. It is derived from. The sum of the impedance of the traces multiplied by the length of the traces and divided by the sum of the length of the traces.
- The minimum impedance of the trace.

- The maximum impedance of the trace.

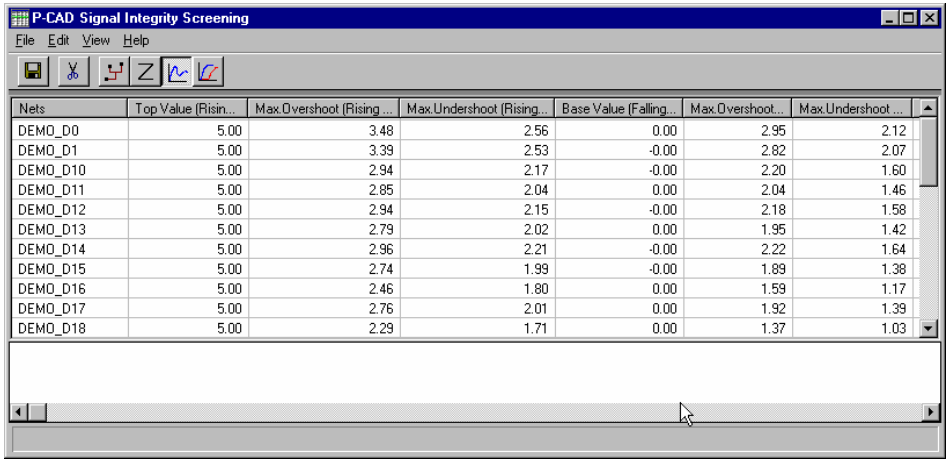


The View Impedance View command can be initiated by choosing **Impedance View** from the **View** pull-down menu or by clicking on its icon.

Voltage View

The Voltage View displays for each net:

- The Top value of the Rising edge
- The Maximum Overshoot of the Rising edge
- The Maximum Undershoot of the Rising edge
- The Base value of the Falling edge
- The Maximum Overshoot of the Rising edge
- The Maximum Undershoot of the Rising edge



Nets	Top Value (Risin...	Max Overshoot (Rising ...	Max Undershoot (Rising...	Base Value (Falling...	Max Overshoot...	Max Undershoot ...
DEMO_D0	5.00	3.48	2.56	0.00	2.95	2.12
DEMO_D1	5.00	3.39	2.53	-0.00	2.82	2.07
DEMO_D10	5.00	2.94	2.17	-0.00	2.20	1.60
DEMO_D11	5.00	2.85	2.04	0.00	2.04	1.46
DEMO_D12	5.00	2.94	2.15	-0.00	2.18	1.58
DEMO_D13	5.00	2.79	2.02	0.00	1.95	1.42
DEMO_D14	5.00	2.96	2.21	-0.00	2.22	1.64
DEMO_D15	5.00	2.74	1.99	-0.00	1.89	1.38
DEMO_D16	5.00	2.46	1.80	0.00	1.59	1.17
DEMO_D17	5.00	2.76	2.01	0.00	1.92	1.39
DEMO_D18	5.00	2.29	1.71	0.00	1.37	1.03

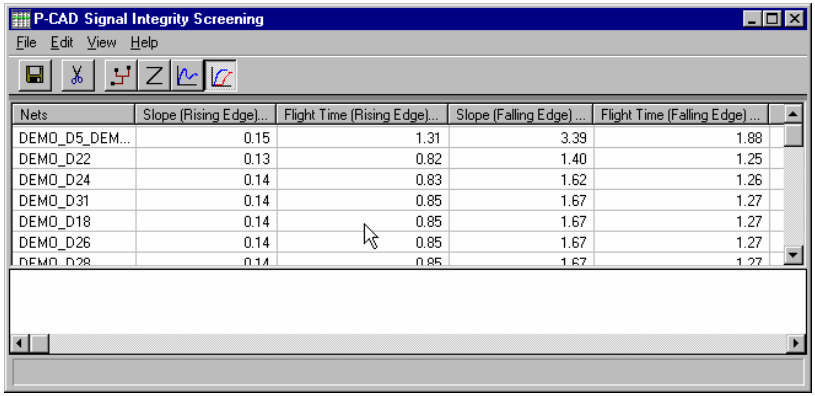
The Voltage View command can be initiated by choosing **Voltage View** from the **View** pull-down menu or by clicking on its icon.

These voltages help you identify the critical nets that will require further investigation with the Reflection Simulator.

Timing View

The Timing View displays for each net:

- The Slope of the Rising edge
- The Flight Time of the Rising edge
- The Slope of the Falling edge
- The Flight Time of the Falling edge



Nets	Slope (Rising Edge)...	Flight Time (Rising Edge)...	Slope (Falling Edge) ...	Flight Time (Falling Edge) ...
DEMO_D5_DEM...	0.15	1.31	3.39	1.88
DEMO_D22	0.13	0.82	1.40	1.25
DEMO_D24	0.14	0.83	1.62	1.26
DEMO_D31	0.14	0.85	1.67	1.27
DEMO_D18	0.14	0.85	1.67	1.27
DEMO_D26	0.14	0.85	1.67	1.27
DEMO_D28	0.14	0.85	1.67	1.27

The Timing View command can be initiated by choosing **Timing View** from the **View** pull-down menu or by clicking on its icon.

Arrange Nets

The Arrange Nets command enables you to sort the nets displayed by the value in any of the view columns. The Arrange Nets command is initiated by choosing **Arrange Nets** from the **View** pull-down menu. This displays the Arrange Nets selection menu. The menu displays in highlight the choices currently available. This corresponds to the view displayed.

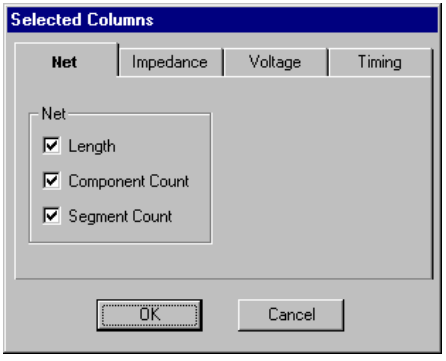
Select the sorting parameter and the nets displayed will be sorted by the values of that parameter, and displayed in the new sequence.

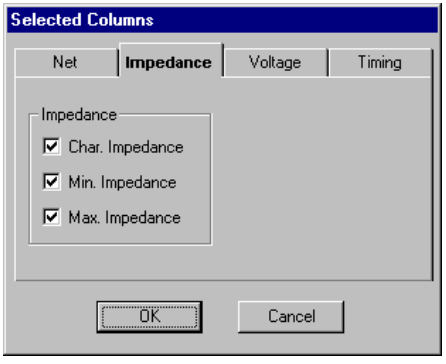
Select Columns

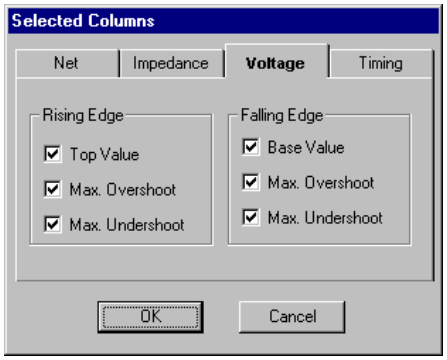
The Select Columns command enables you to define what columns should be displayed in each of the Screening views. The Select Columns command is initiated by choosing **Select Columns** from the **View** pull-down menu. This displays the *Select Columns* dialog, which has a tab for each of the Screening views.

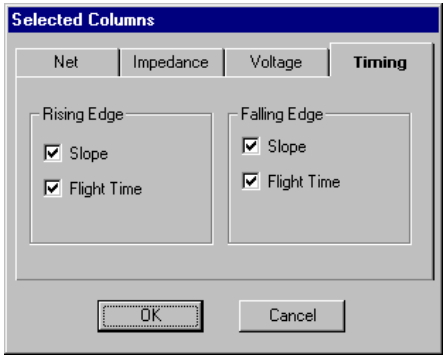
The columns currently displayed are ticked. Click on the column(s) to select or de-select.

The dialog below enables you to specify what columns to display on each data view.









Help Commands

The Screening Help commands are accessed from the **Help** menu. They allow you to access all the Help messages.

Help Topics

Displays the P-CAD Signal Integrity online help including the **Contents** tab which is structured to match the order of commands as they appear in the product, and the **Index** tab which lets you look up a specific concept or keyword.

About Help

Connects you to the Windows help system, where instructions on how to use the help system are provided.

CHAPTER 6

P-CAD Signal Integrity Simulation Commands

The Simulator is designed to analyze the behavior of complex transmission line systems on printed circuit boards. You can analyze reflections and crosstalk by simulating nets process takes into account the characteristic impedance and phase velocity of the different segments of a net, which is calculated from the cross-section of the PCB, as well as the input and output characteristics of the buffers connected to this net. For Crosstalk analysis the mutual capacitance and inductance between parallel segments of different nets are considered additionally.

The Simulation commands are accessed from the Simulation menu, which appears on the menu bar when you enter P-CAD Signal Integrity. They deal with reviewing parameters, running simulations and producing outputs.

The Screening command is described in *Chapter 5: P-CAD Signal Integrity Screening Commands*.

All other Simulation commands are discussed in this chapter.

Termination Advisor

Sometimes termination networks are a good way to prevent reflections, which become prevalent at higher frequencies. These reflections cause noise, which degrade signal integrity and lead to malfunction in the worst case.

Terminations are used to minimize reflection and achieve the signal integrity necessary for successful data integrity.

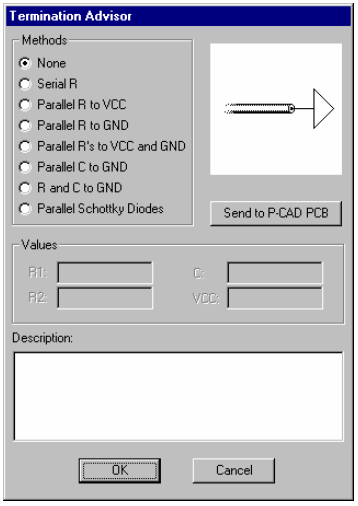
The Termination Advisor allows you to test termination strategies without making physical changes to your board, by inserting 'virtual terminations' into the net at the location you define.

You can select from a variety of termination options to achieve an optimal PCB electrical performance.

The **Termination Advisor** command can be accessed from the **Simulation** menu or by clicking on its icon.

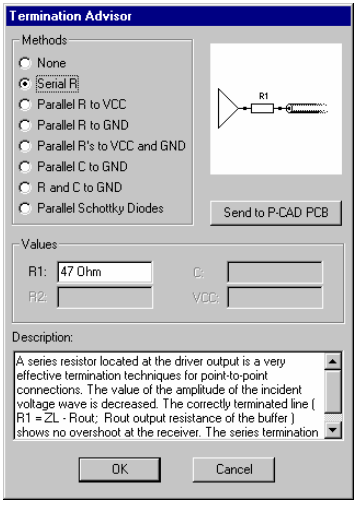
Select a Termination method out of the eight choices available. These are described below:

1. None



No termination is applied. This is the default.

2. Serial R



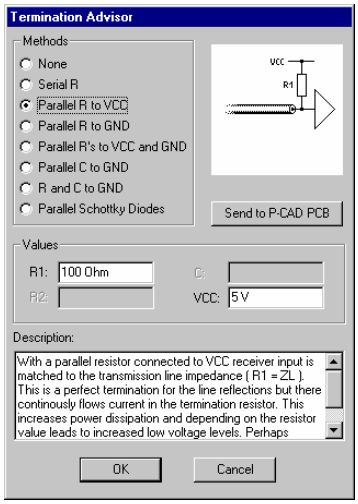
This is the serial impedance termination method.

A series resistor located at the driver output is a very effective termination technique for point-to-point connections. The value of the amplitude of the incident voltage wave is decreased. The correctly terminated line (R1 = Z_L – R_{out}; (Z_L characteristic impedance, R_{out} output resistance of the

buffer) shows no overshoot at the receiver. The series termination is best suited for CMOS technologies.

The value displayed is the default value for the parameter.

3. Parallel R to VCC

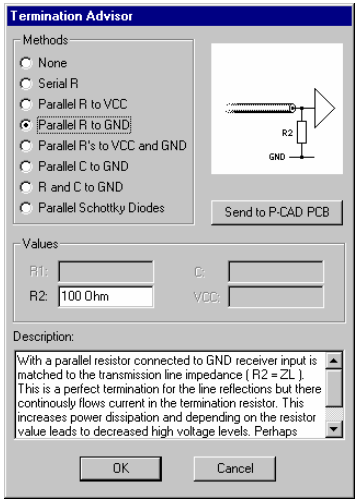


With a parallel resistor connected to VCC at the receiver (Pull-up resistor), the input is matched to the transmission line impedance ($R1 = Z_L$). This is a perfect termination for effects due to line reflections, but there is a continuous flow of current through the termination resistor. This increases power dissipation and, depending on the resistor value, leads to increased low voltage levels, which may conflict with 'operation conditions' specified in the component data sheets.

The values displayed are the default values for the parameters.

4. Parallel R to GND

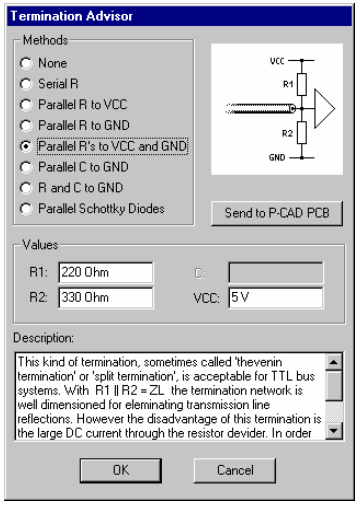
With a parallel resistor connected to GND at the receiver (Pull-down resistor), the receiver input is matched to the transmission line impedance. ($R2 = Z_L$). This is a perfect termination regarding line reflections but there is a continuous current drain through the termination resistor. This increases power dissipation and, depending on the resistor value, leads to decreased high voltage levels, which may conflict with 'operation conditions' specified in the component data sheets.



The value displayed is the default value for the parameter.

5. Parallel R's to VCC and GND

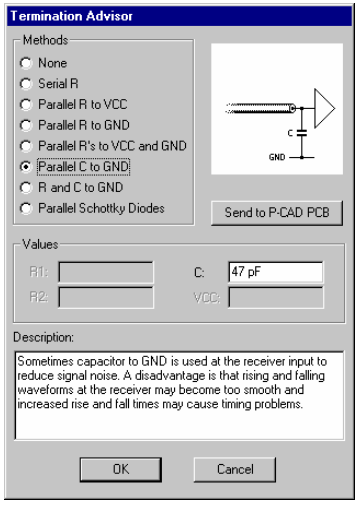
This kind of termination, also called 'Thevenin termination' or 'split termination', can be used for TTL bus systems. With R1 ‖ R2 = Z_L the termination network is well dimensioned for eliminating transmission line reflections. However the disadvantage of this termination is the large DC current through the resistor divider. In order to avoid violations of datasheet specifications, resistor values should be derived carefully. In most cases a compromise between perfect match and acceptably low current can be achieved.



The values displayed are the default values for the parameters.

6. Parallel C to GND

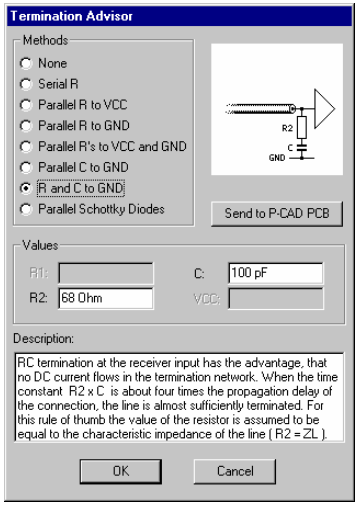
Sometimes a capacitor to GND is used at the receiver input to reduce signal noise. A disadvantage is that rising and falling waveforms at the receiver may become too smooth and these increases in rise and fall times may cause timing problems.



The value displayed is the default value for the parameter.

7. Parallel R and C to GND

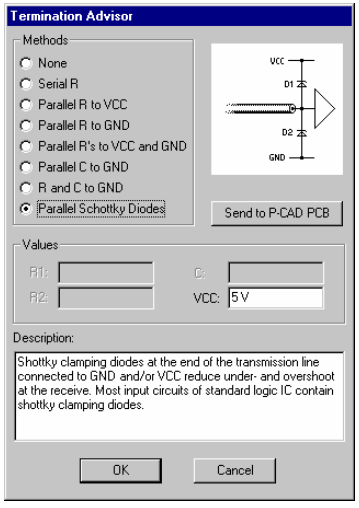
RC termination at the receiver input has the advantage that no DC current flows in the termination network. When the time constant R x C is about four times the propagation delay of the connection, the line is almost sufficiently terminated. For this rule of thumb the value of the resistor is assumed to be equal to the characteristic impedance of the line ($R2 = Z_L$).



The values displayed are the default values for the parameters.

8. Parallel Schottky Diodes

Schottky clamping diodes at the end of the transmission line connected to GND and / or VCC reduce under- and overshoot at the receiver. Most input circuits of standard logic ICs contain Schottky clamping diodes.



The value displayed is the default value for the parameter.

Set Victim Net

This command is active only for Crosstalk simulations.

To set a victim net select a net from the list in the Simulation window on the Signal Integrity entry screen and click the Set Victim Net icon, or select **Set Victim Net** from the **Simulation** menu.

A net which is a victim net will have its driving stimulus set to a constant level '0' while all other nets have the stimulus defined in the **Stimulus** tab of the *Integrated Circuit* dialog.

Set Aggressor Net

This command is active only for Crosstalk simulations.

To set an aggressor net select a net from the list in the Simulation window on the Signal Integrity entry screen and click the **Set Aggressor Net** icon or select **Set Aggressor Net** from the **Simulation** menu.

A net which is an aggressor net will have its stimulus defined in the **Stimulus** tab of the *Integrated Circuit* dialog while all other nets are assigned a constant level '0' stimulus.

Reflection

With high-speed logic design it is becoming increasingly important to ensure that the topology of the PCB interconnect is designed to minimize reflection and crosstalk effects.

Reflection effects are caused by impedance mismatching between components and traces as well as individual trace segments. When traces go from layer to layer impedance discontinuities can occur. Changes in topology such as T-junctions can also cause reflection.

The Reflection simulator calculates voltages at nodes of a net using routing and layer information of the PCB and associated driver and receiver circuits.

The electrical characterization of the lines is automatically calculated by a 2D-field solver. Modeling initially assumes that path losses are small enough to be disregarded.

The simulator provides you with detailed and highly accurate information on all signal integrity related aspects like over- / undershoot, voltage and timing.

The Reflection simulator can be accessed either from the **Simulation** menu by choosing **Reflection** from the pull-down menu or by clicking the mouse button on its icon. This initiates the Reflection simulation for the selected nets.

The results of the Reflection simulation are returned presented in an oscilloscope-like wave analyzer. The WaveAnalyzer commands are described in Chapter 7.

Crosstalk

The P-CAD Xtalk simulator enables you to analyze crosstalk by simulating coupled nets extracted from PC board circuit layouts.

Crosstalk is a type of interference caused by the electromagnetic waves transmitted from one trace into adjacent traces.

P-CAD Xtalk simulator can be accessed either from the **Simulation** menu by selecting **Crosstalk** from the pull-down menu, or by clicking the mouse button on its icon. This initiates the Crosstalk simulation for the selected nets.

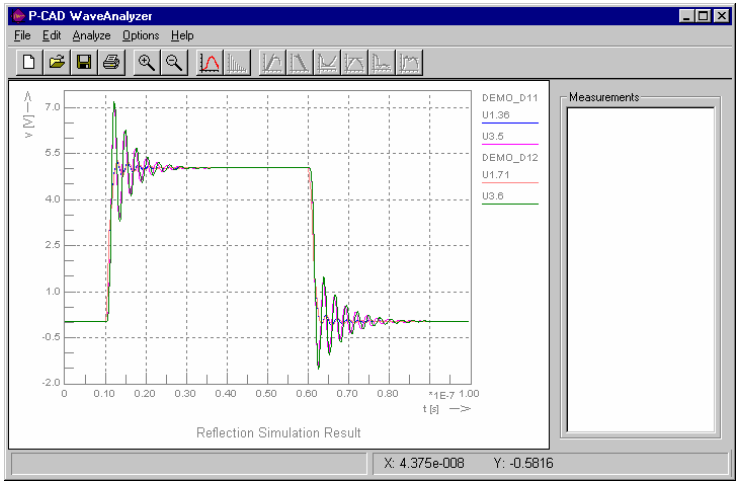
The output of the Crosstalk simulation is displayed by the Wave Analyzer on completion of the simulation.

The time taken to simulate is related to the complexity of the problem being solved. The simulation preparation involves the creation of a n^2 matrix of capacitance and inductance per unit length where n is the number of traces being analyzed.

CHAPTER 7

P-CAD Signal Integrity Wave Analyzer

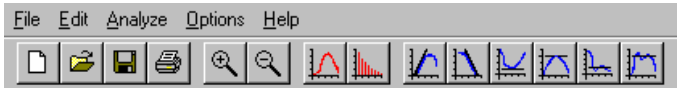
P-CAD Signal Integrity Wave Analyzer displays the results of the P-CAD Signal Integrity Reflection or P-CAD Signal Integrity Xtalk simulations in an oscilloscope-like format.



The picture above shows the results of a Reflection simulation. On the right of the wave display wave names are listed under the name of their respective net.

The Wave Analyzer calculates performance parameters like overshoot, rise time, etc. of the nets analyzed. It provides facilities to file, edit and print the results, as well as options to modify the display and zoom-in on areas of interest. The actual values of the parameters can be displayed in the measurement area.

The Wave Analyzer commands are accessed through menus and icons as pictured below. Each command is described in this section.



Wave Analyzer File Commands

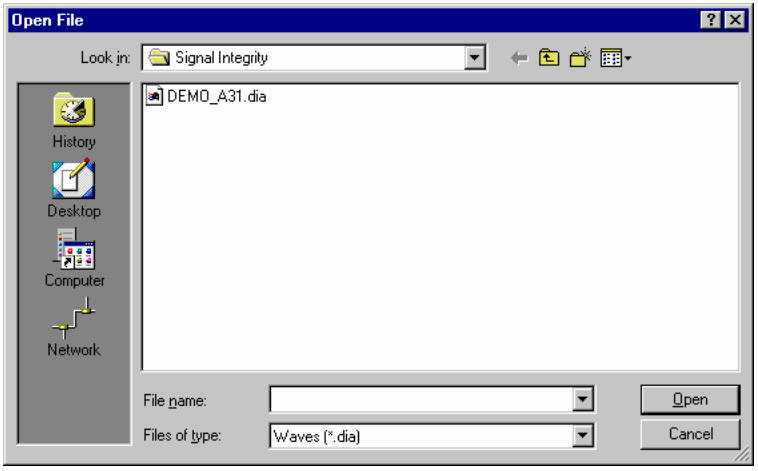
The Wave Analyzer File commands deal with opening, saving and printing wave files.

File Open

The File Open command enables you to load a wave file onto the display.

The **File Open** command can be initiated from the **File** command pull-down menu or by its icon.

When you choose the File Open command, P-CAD Signal Integrity displays the *Open File* dialog from which you can choose the directory and filename of the file you want to open.



Select the wave file you want to use from the files listed. The selection will be shown in the file name box, with the file type `.dia`. Click the **Open** button and the waves from the file will be added to the current display.

File Save

Use the File Save command to keep waves details in a file.

The **File Save** command can be initiated from the **File** command pull-down menu or by its icon.

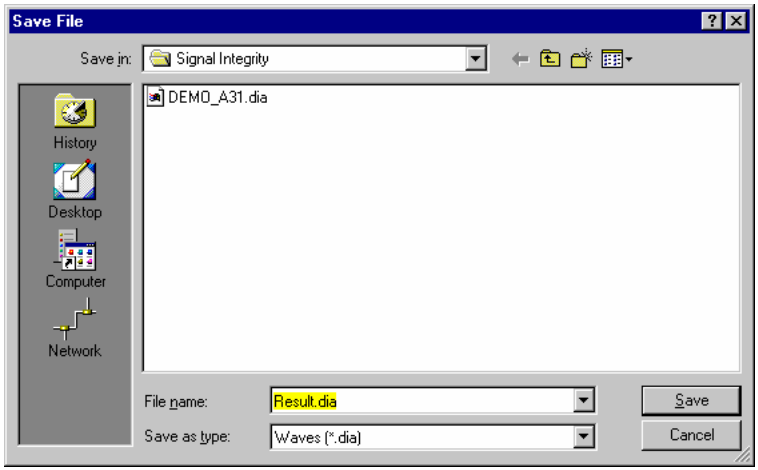
When you choose the File Save command, P-CAD Signal Integrity saves the displayed waves and their parameters in the currently open file. If none is opened yet the *Save File* dialog is displayed, on which you can enter a file name. The extension `.dia` is automatically assigned. This file will be over-written every time you issue a File Save command. If you want to save a wave file with a new file name, use the File Save As command.

File Save As

The File Save As command saves waves details in a new file with a name and location of your choice.

The **File Save As** command is initiated from the **File** command pull-down menu.

When you choose **File Save As**, the *Save File* dialog is displayed. Here you can specify the directory and filename for the wave file you want to save.



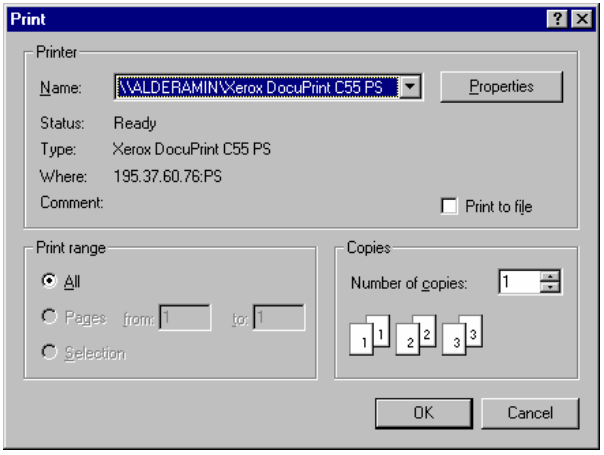
Enter the file name in the File name box, and click the **Save** button. The File type `.dia` is automatically assigned and the next time you look in the file list the wave file will appear in the file list window with the extension added to the name.

File Print

The File Print command prints the current content of the Wave Analyser display.

The **File Print** command can be initiated from the **File** command pull-down menu or by its icon.

When you choose the File Print, the *Print* dialog is displayed. Here you can specify the printer and print details.

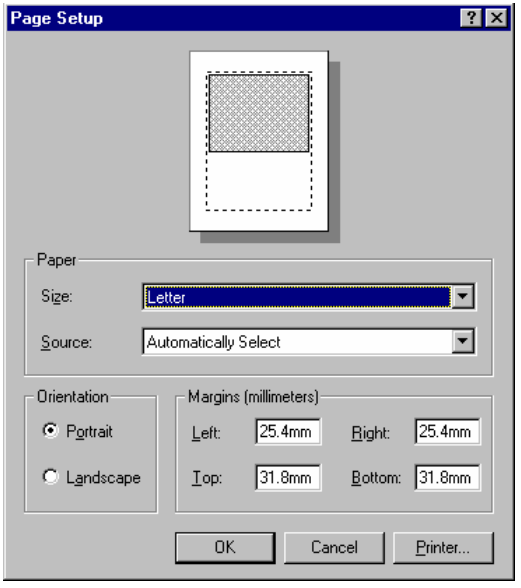


File Page Setup

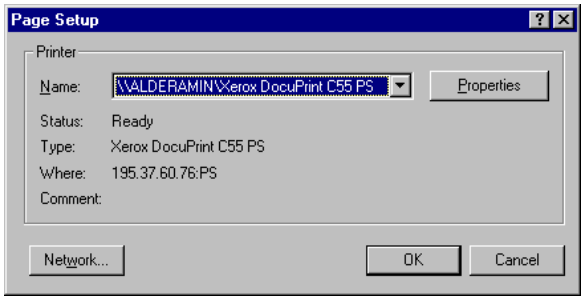
The File Page Setup command enables you to define the page layout details for the printer. It deals with page orientation, margin size and paper size.

The **File Page Setup** command is initiated from the **File** command pull-down menu, and displays the *Page Setup* dialog.

You can specify the paper size and source, and the orientation and margins of the printed page. You can check your layout specification on the page model in the top of the window.



Clicking the **Printer** button displays the following dialog.



File Exit

The File Exit command closes the Wave Analyzer and returns to the P-CAD Signal Integrity screen.

Edit Commands

The Wave Analyzer Edit commands deal with managing the Wave Analyzer display.

Edit Copy

The **Edit Copy command** is initiated from the **Edit** command pull-down menu. The Edit Copy command copies the displayed waves to the clipboard so that you can load them to another program such as Word. The picture below shows a wave display copied from the Wave Analyzer.

Reflection Simulation Result

Edit Rescale

The Edit Rescale command rescales the display so that all the full waves fit into the diagram. If you issue the Edit Rescale command when the display is zoomed-in, the display reverts to the original size and scale, *ignoring* any range options specified for the X and Y axes.

The **Edit Rescale** command is initiated from the **Edit** command pull-down menu.

Edit Redraw

The Edit Redraw command redraws the display. The **Edit Redraw** command is initiated from the **Edit** command pull-down menu.

Edit Delete Selected Wave

The Edit Delete Selected Wave command deletes the selected wave. A wave can be selected or de-selected by clicking with the mouse on the wave name (on the right of the waves display). The **Edit Delete Selected Wave** command is initiated from the **Edit** command pull-down menu.

Edit Delete all Waves

The Edit Delete all Waves command deletes all the displayed waves. The **Edit Delete all Waves** command can be initiated from the **Edit** command pull-down menu.

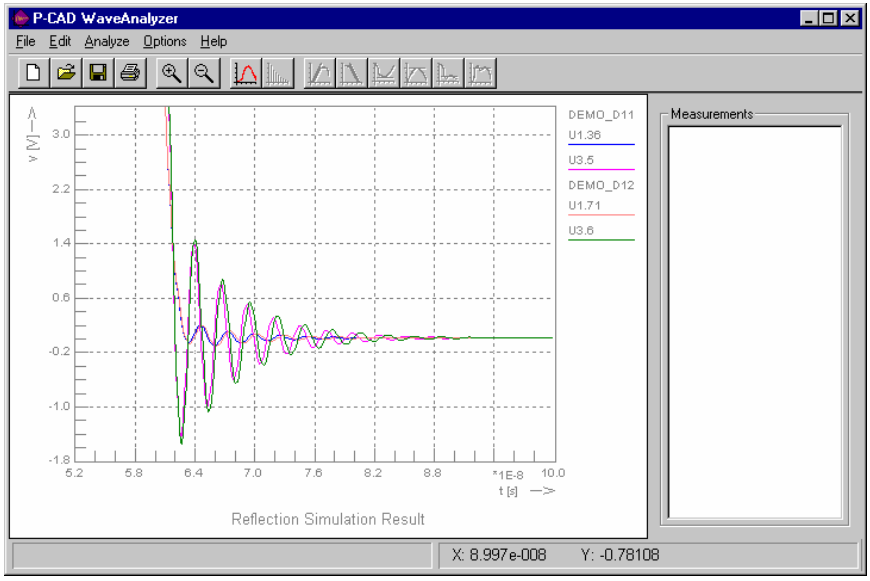
Edit Clear Measurement Area

The Edit Clear Measurement Area clears the measurements box which is located on the right of the waves display area. The **Edit Clear Measurement Area** command is initiated from the **Edit** command pull-down menu.

Edit Zoom In

The Edit Zoom In command enables you to zoom-in on sections of the display. Click and hold the mouse button on the top left corner of the area you want to zoom-in on, then move the cursor to the lower right corner of the area and release the mouse button.

The **Edit Zoom In** command can be initiated from the **Edit** command pull-down menu or by its icon. The picture below shows a zoomed-in wave area.



Edit Zoom Out

Use the Edit Zoom Out command to undo the last Zoom In. The **Edit Zoom Out** command can be initiated from the **Edit** command pull-down menu or by its icon.

Edit Origin

Use the Edit Origin command to undo all the Zoom Ins and restore the original waves display. The Edit Origin command maintains the range definitions for the X and Y-axis (set in the Options menu). The **Edit Origin** command is initiated from the **Edit** command pull-down menu.

Analyze Commands

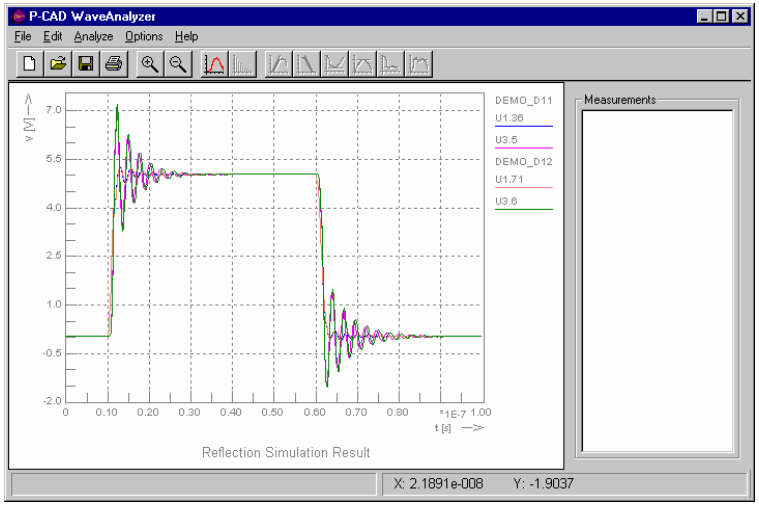
The Wave Analyzer Analyze commands are used to switch between time domain and frequency domain display and to analyze performance parameters of the signal behavior.

Analyze Cartes

The Analyze Cartes command switches the waves display to a Cartesian coordinate system view.

The picture below shows a wave display in Cartesian coordinate system view, which represents the time domain behavior of the signals.

The **Analyze Cartes** command can be initiated from the **Analyze** command pull-down menu or by its icon.

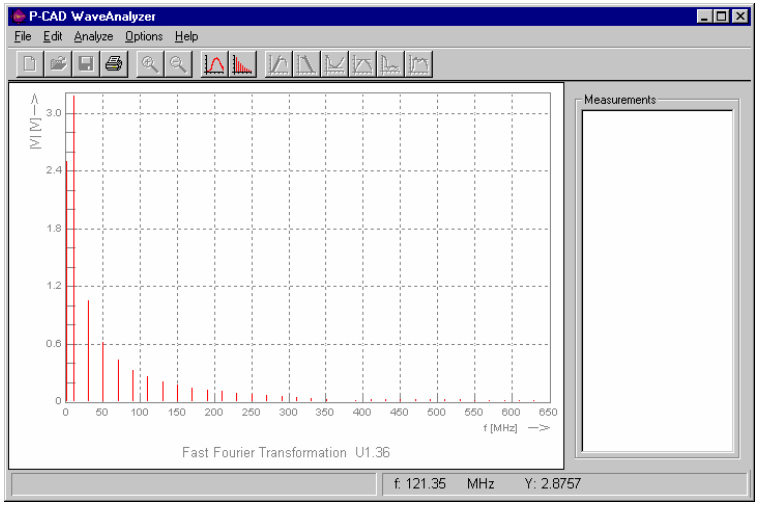


Analyze FFT

The Analyze FFT command switches a wave display to the frequency domain view which is calculated using Fast Fourier Transformation (FFT).

The picture below shows this display method which can be used to analyze the frequency spectrum of the signals. By this, frequencies that may be radiated from the trace with high energy can be detected.

The **Analyze FFT** command can be initiated from the **Analyze** command pull-down menu or by its icon. You must select a wave before you initiate the Analyze FFT command.

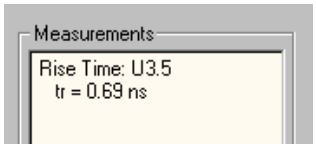


Click the Analyze Cartes icon to revert to the Cartesian coordinate system.

Analyze Rise Time

The Analyze Rise Time command displays the rise time of the selected wave in the measurement area. The picture below shows this display.

The **Analyze Rise Time** command can be initiated from the **Analyze** command pull-down menu or by its icon.

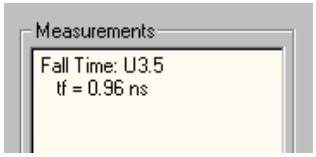


This displays the Rise Time for wave U3.5.

Analyze Fall Time

The Analyze Fall Time command displays the fall time of the selected wave in the measurement area. The picture below shows this display.

The **Analyze Fall Time** command can be initiated from the **Analyze** command pull-down menu or by its icon.



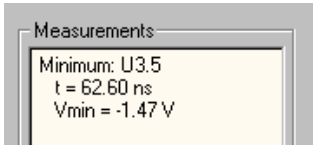
This displays the Fall Time for wave U3.5.

Analyze Minimum

The Analyze Minimum command determines the minimum of the selected wave within the currently visible area (zoomed or unzoomed) and displays it in the measurement area.

If there are several minima with the same Y value, the one with the lowest X value is displayed.

The **Analyze Minimum** command can be initiated from the **Analyze** command pull-down menu or by its icon.



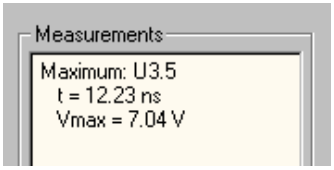
This displays the minimum for wave U3.5.

Analyze Maximum

The Analyze Maximum command determines the maximum of the selected wave within the currently visible area (zoomed or unzoomed) and displays it in the measurement area.

The **Analyze Maximum** command can be initiated from the **Analyze** command pull-down menu or by its icon.

If there are several maxima with the same Y value, the one with the lowest X value is displayed.



This displays the maximum for wave U3.5.

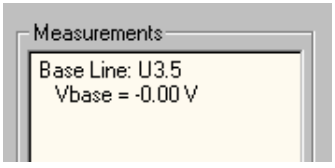
Analyze Baseline

The Analyze Baseline command determines the values of the base line for the selected wave and displays these in the measurement area.

These values are the basis for the calculation of the rise and fall times of the slopes of a signal.

In order to calculate the values for the base line a grid is superimposed on the coordinate system and the frequency with which the coordinates occur within the discrete grid cells (events) is evaluated with the aid of a histogram. The lower maximum values of the histogram are the values for the base line. Due to this type of analysis the section in which the slope to be analyzed is displayed is significant. This means the results depend on the zooming.

The **Analyze Baseline** command can be initiated from the **Analyze** command pull-down menu or by its icon.



This displays the base line for wave U3.5.

Analyze Topline

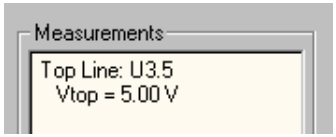
The Analyze Topline command determines the values of the top line for the selected wave and displays these in the measurement area.

These values are the basis for the calculation of the rise and fall times of the slopes of a signal.

In order to calculate the values for the top line a grid is superimposed on the coordinate system and the frequency with which the coordinates occur within the discrete grid cells (events) is

evaluated with the aid of a histogram. The higher maximum values of the histogram are the values for the top line. Due to this type of analysis the section in which the slope to be analyzed is displayed is significant. This means the results depend on the zooming.

The **Analyze Topline** command can be initiated from the **Analyze** command pull-down menu or by its icon.



This displays the top line for wave U3.5.

Options Commands

The Wave Analyzer Options commands deal with modifying the waves display attributes.

Options Measurement Area

The Options Measurement Area command toggles the display of the measurement area. The **Options Measurement Area** command is initiated from the **Options** command pull-down menu.

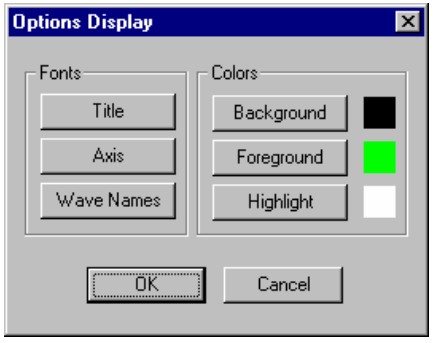
Options Wave Names

The Options Wave Names command toggles the display of the wave names. The **Options Wave Names** command is initiated from the **Options** command pull-down menu.

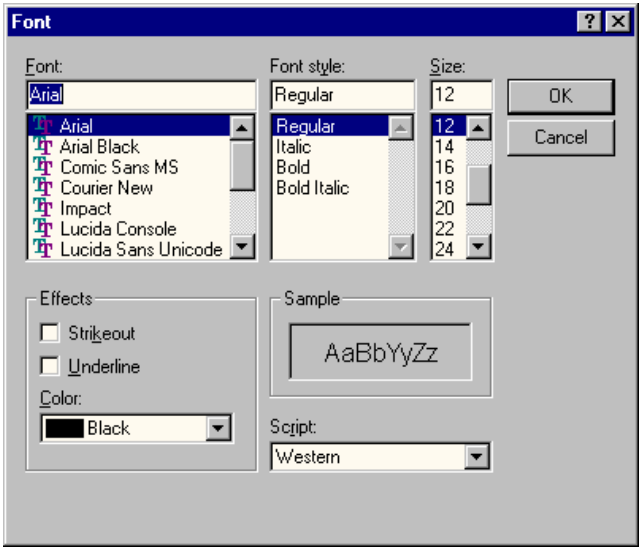
Options Display

The Options Display command enables you to set the fonts and colors for the Title, Axis, Wave Names as well as the Background, Foreground and Highlight on the simulation result display area.

The **Options Display** command is initiated from the **Options** command pull-down menu.



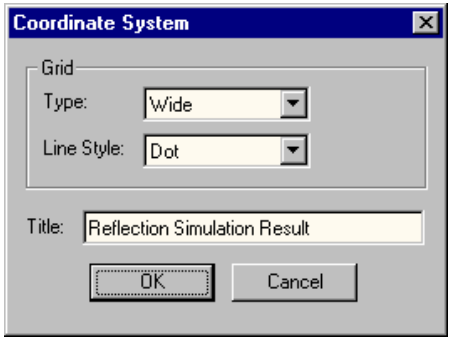
Clicking any of the buttons in the Fonts column of the *Options Display* dialog displays the *Font* dialog. This enables you to specify the font characteristics. These take effect when you click the **OK** button.



Clicking any of the buttons in the Colors column of the *Options Display* dialog displays the *Color* dialog. This enables you to specify the background, foreground and highlight colors. They take effect when you click the **OK** button.

Options Coordinate System

The Options Coordinate System command enables you to select the type and line style of the grid and the title of the diagram displayed in the simulation result display area.



The **Options Coordinate System** command is initiated from the **Options** command pull-down menu.

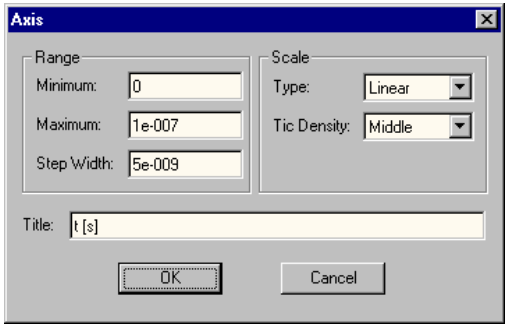
Options X-Axis

The Options X-Axis command enables you to set the range* of the diagram, the scaling of the X-axis (linear or logarithmic) and the tick density on the axis. The tick density defines also the density of the grid. You can also set the title for the X-axis.

* Limits for the range: All values (minimum, maximum and step width) must be higher than 1.0e-30 and lower than 1.0e30.

The initial Minimum, Maximum and Step Width values are by default, the values required to fit in all the full waves on the Wave Analyzer display. These are the values that will be restored when issuing the Edit Rescale command.

The **Options X-Axis** command is initiated from the **Options** command pull-down menu.



Options Y-Axis

The Options Y-Axis command enables you to set the range* of the diagram, the scaling of the Y-axis (linear or logarithmic) and the tick density on the axis. You can also set the title for the Y-axis.

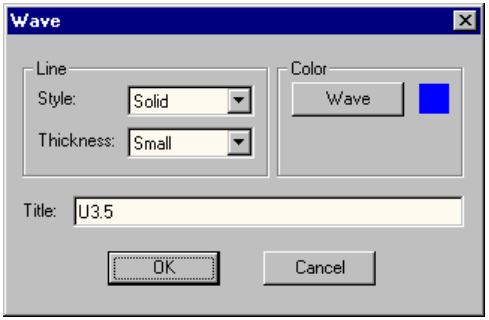
* Limits for the range: All values (minimum, maximum and step width) must be higher than 1.0e-30 and lower than 1.0e30.

The **Options Y-Axis** command is initiated from the **Options** command pull-down menu.

The maximum must be higher than the minimum. All the values are rounded automatically to the next possible value.

Options Wave

The Options Wave command enables you to set the line style, the line thickness and color and title for the selected wave.



This command operates only when a wave is selected.

The **Options Wave** command is initiated from the **Options** command pull-down menu.

Help Commands

The Wave Analyzer Help commands provide access to the Help messages for all Wave Analyzer commands.

WaveAnalyser Help Topics

The **Help WaveAnalyzer Help Topics** command is initiated from the **Help** menu.

The Help WaveAnalyzer Help Topics command displays the Wave Analyzer online help including the **Contents** tab which is structured to match the order of commands as they appear in the product, and the index tab which lets you look-up a specific concept or keyword.

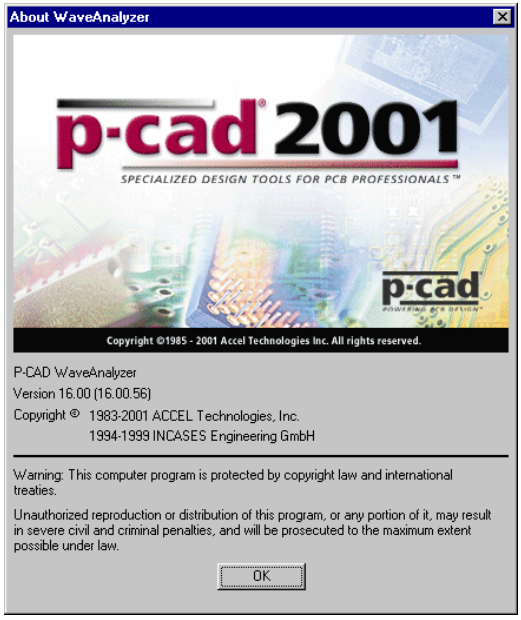
How to Use Help

The **How to Use Help** command is initiated from the **Help** menu.

The How to Use Help command connects you to the Windows help system where instructions on how to use the help system are provided.

About WaveAnalyzer

The **Help About WaveAnalyzer** command is initiated from the **Help** menu. It displays a window with details of the product and the version number.



CHAPTER 8

General Commands

Library Commands

P-CAD Signal Integrity simulation results depend on parts and macromodel specifications. These specifications are looked-up in a database – the model library. This library is split into two sections:

- Basic library
- User library

The Basic library is an integral part of P-CAD Signal Integrity and cannot be modified.

The User library is initially empty and the user can use the Macromodel editor to insert custom models and parts into the model library.

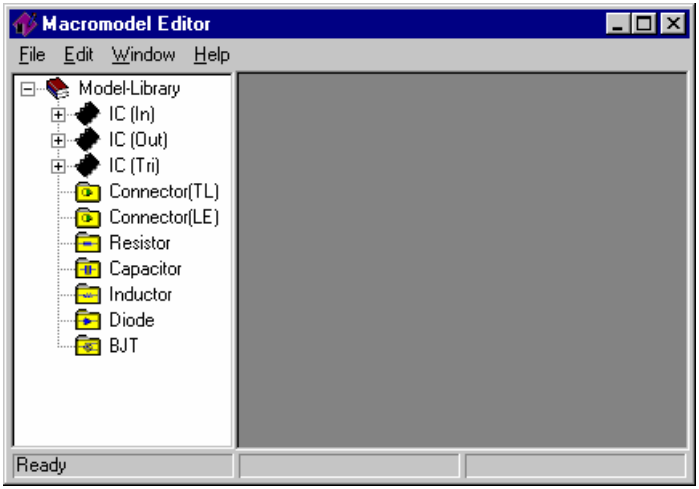
When the simulator looks-up a model or a part (searching is done by name) it first searches the User library. If the desired model or part is not found in the User library, the simulator tries to find in the Basic library. If the model or part is not found in the Basic library either, the simulator uses a fallback model: Fallback model Technology HC.

The Library commands are accessed from the Library menu, which appears on the menu bar on the P-CAD Signal Integrity screen. They deal with editing Macromodels and importing IBIS files.

Each of these commands is discussed below.

Macromodel Editor

Choosing **Macromodel Editor** from the **Library** pull-down menu displays the *Macromodel Editor* window which is similar in appearance and functionality to the Microsoft Windows' *Windows Explorer* display.



The editor window is divided into two areas:

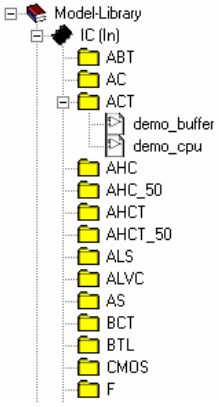
- A library tree on the left
- A document area on the right

The custom user models are organized in the library tree. You can navigate through the files system as you do in the Windows Explorer.

Description of the library tree

The User library is the root of the tree. It contains a folder for each type of parts and models. Each folder holds the list of user custom models defined in the database.

IC models are also sub-divided into available technology folders, as shown in the picture below. Each technology folder holds the custom defined IC buffer models.



The full list of available technologies is in the table below:

Alias	Description
ABT	Advanced Bipolar CMOS Technology
AC	Advanced CMOS
ACT	Advanced CMOS with TTL inputs
AHC	Advanced High Speed CMOS
AHC_50	Advanced High Speed CMOS 5.0V
AHCT	Advanced High Speed CMOS with TTL inputs
AHCT_50	Advanced High Speed CMOS 5.0V with TTL inputs
ALS	Advanced Low Power Schottky
ALVC	Advanced Low Voltage CMOS
AS	Advanced Schottky
BCT	Bipolar CMOS Technology
BTL	Backplane Transceiver Logic/Futurebus+
CMOS	CMOS
F	FAST
FCT	FAST CMOS Technology
GTL	Gunning Transceiver Logic
GTL_LVT	Gunning Transceiver Logic Low Voltage
HC	High Speed CMOS
HCT	High Speed CMOS with TTL inputs
HLL	High Speed Low Power Low Voltage CMOS
LS	Low Power Schottky
LV	Low Voltage High Speed CMOS
LVC	Low Voltage CMOS
LVT	Low Voltage BiCMOS Technology
S	Schottky
STD_TTL	Standard TTL
TTL	TTL

Unknown technologies (UK) are mapped to HC – (High Speed CMOS).

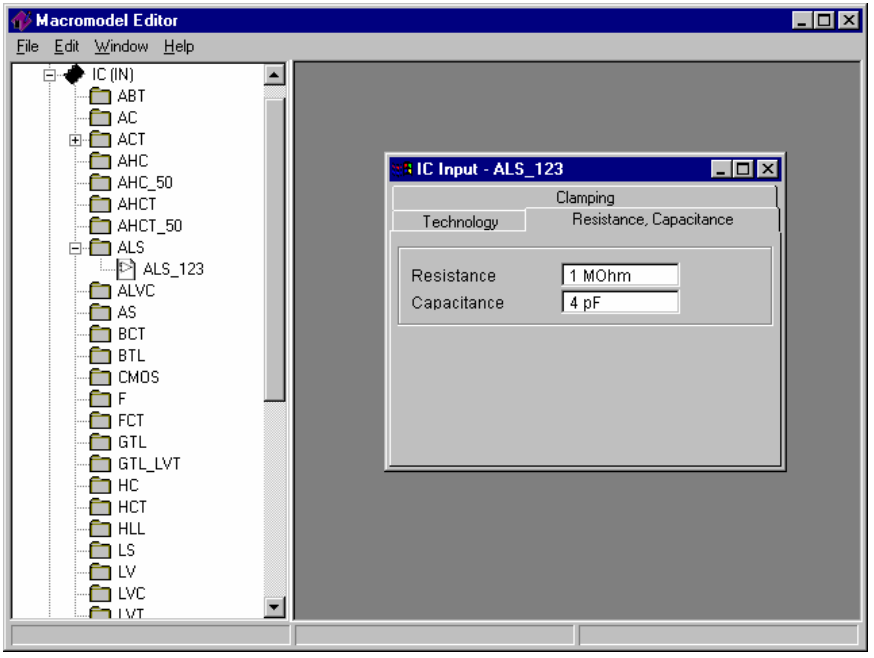
The items in the tree folders represent user's custom models.

Depending on the type of model you create, view or edit, the appropriate dialog is launched in the area on the right of the library tree.

To view or modify the model parameters you can:

1. Double-click on the model name.
2. Choose the model name, click the **right** mouse button and select **Open** from the pop-up menu.
3. Click once on a model name and choose the **Open** command from the **Edit** pull-down menu.

On the dialog that displays you can view or modify the model parameters.



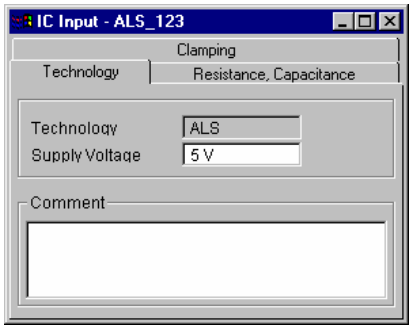
IC Models

To create a new model, select a model type or choose a technology for the model, e.g. 'ALS' or 'CMOS' in the appropriate IC folder in the model library, and then select **Add** from the **Edit** menu. After supplying a model name, an IC custom model dialog displays in the area on the right of the Macromodel Editor window. The dialogs vary depending on the model type. There are three tabs to describe the parameters of IC models. Each tab shows the default values for the parameters. You can modify these as required to create your new model.

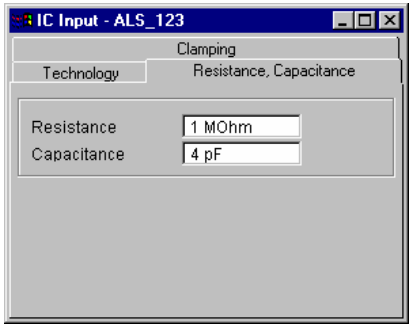
IC Input, IC Tristate

IC Input and Tristate dialogs are the same. You can modify parameters by entering them on the relevant tab as described below.

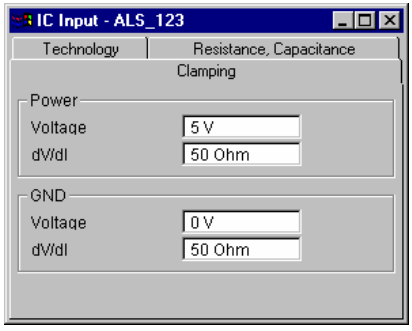
1. The Technology tab. On it you can specify the Supply Voltage for the model.



2. The Resistance and Capacitance tab. On it you specify the Resistance and Capacitance values.



3. The Clamping tab. On this tab you specify the clamping voltage and the differential resistance of the power.



You can save your new model by selecting **Save** on the **Edit** pull-down menu.

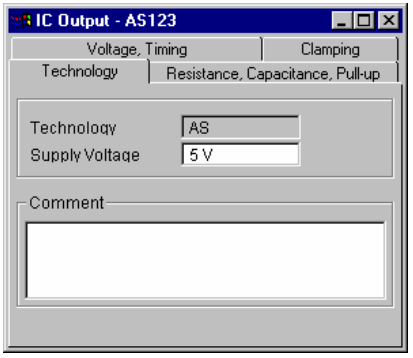
Some IC models in the library cannot be edited and some commands are disabled when any of these models are selected. The models have been created and inserted into the library by the P-CAD Signal Integrity IBIS Converter and they contain data that cannot be modified. They are shown in the library to make it complete and to draw your attention to their presence because you cannot create a model with a name already used by an IBIS model. When you double-click an IBIS model, the warning message below is displayed.

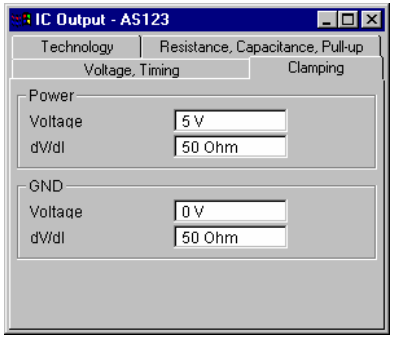
You can remove a model by selecting it and doing one of the following:

- Choosing **Delete** for the **Edit** pull-down menu.
- Clicking the **right** button of your mouse and choosing **Delete** from the pop-up menu.

IC Output Models

IC output dialogs have some additional parameters. The Technology and Clamping tabs are the same as for IC Input.

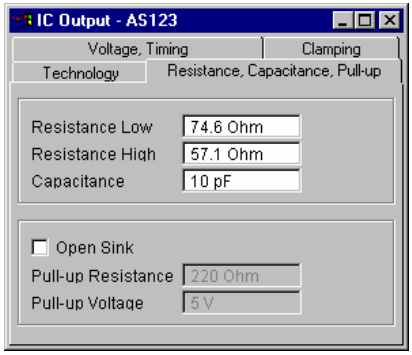




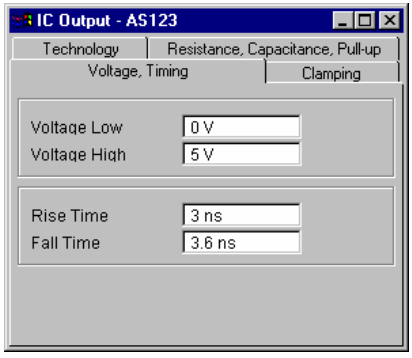
The Resistance and Capacitance tab is different and the Voltage and Timing tab is additional.

On this tab you can specify the output resistance values for low and high states and the capacitance value. Additionally, you can choose between 'push-pull' and 'open-sink' output stages.

For Open Sink output, you must specify the typical Pull-up Resistance and Pull-up Voltage values.

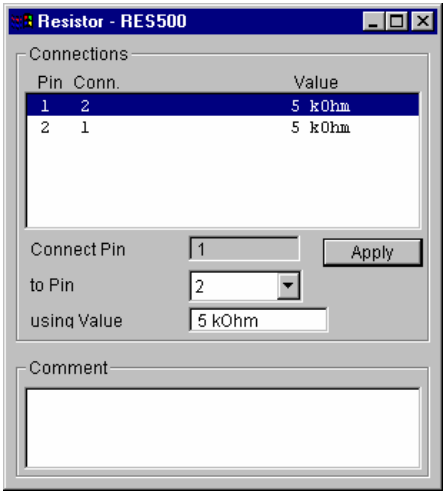


The Voltage and Timing tab is additional. On this tab, you can specify the output voltage values for low and high states and the rise and fall times.



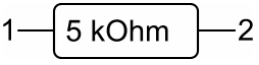
Resistors, Inductors, Capacitors Models

The view/edit dialog for Resistor, Inductors and Capacitors shows a list of pin connections and their value.

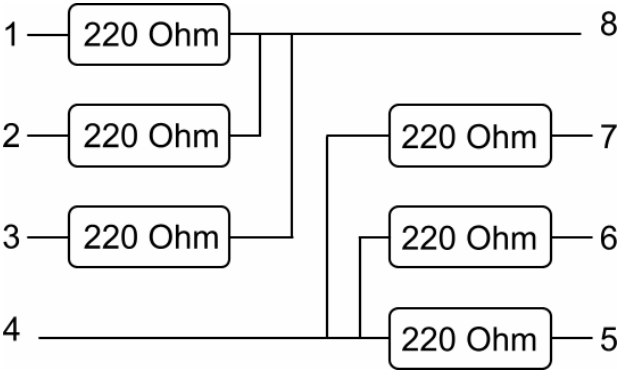


When you create a new Resistor, Inductor or Capacitor you are prompted to specify how many pins the new part will have. For simple resistors, you will use two, and for arrays (several resistors within a part) you will use a number larger than two.

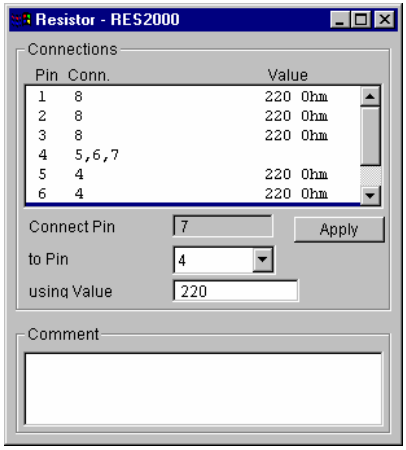
The Resistor Res500 shown below is a simple 2-pin.



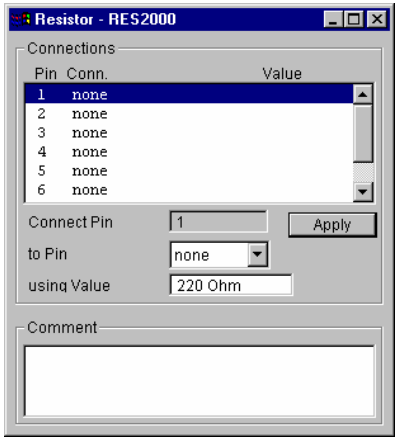
Below is an example of a resistor array with 8 pins :



This will show as displayed below:



The picture below shows the default Resistor creation dialog. When you create a new resistor array of 8 pins, the dialog displays no connections.



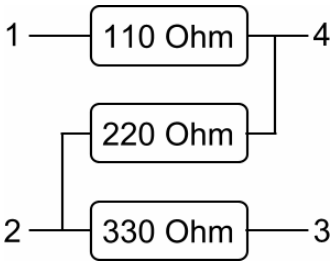
To assign values to connections, select a pin from the list (this highlights the chosen pin line) and choose a pin to connect to (from the box below the list). Then edit the value of the connection and click the **Apply** button for the assignment to take place.

To delete a connection, select the pin you want to disconnect (the pin line will be highlighted), then choose **None** for the connected pin and click the **Apply** button for the change to take place.

You cannot reduce the number of connections to less than one.

When establishing new connections, you can connect to pins, which already have other pins connected, *only when* the pins already connected to your target pin do not have any other connections established.

For example, you cannot generate the following connections:

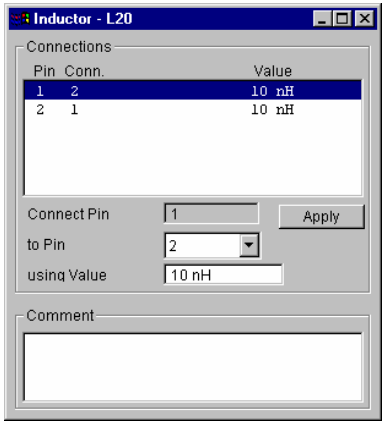


Because you would have to do the following connections:

- Connect pin 1 to pin 4 (110 Ohm) ➔ OK
- Connect pin 2 to pin 4 (220 Ohm) ➔ OK
- Connect pin 3 to pin 2 (330 Ohm) ➔ INVALID !

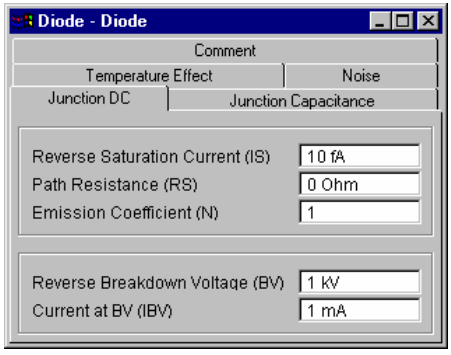
You cannot connect pin 3 to pin 2 because pin 2 is connected to pin 4 *and* pin 4 has already got connections (connected to pin 1).

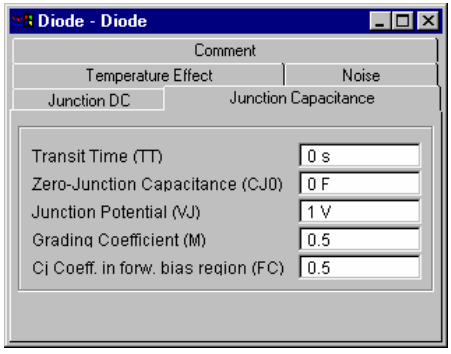
The edit dialog for Inductors and Capacitors is similar to the Resistor dialog but the dialog captions are different and other units are used.

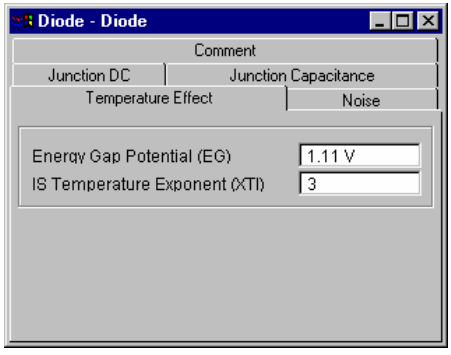


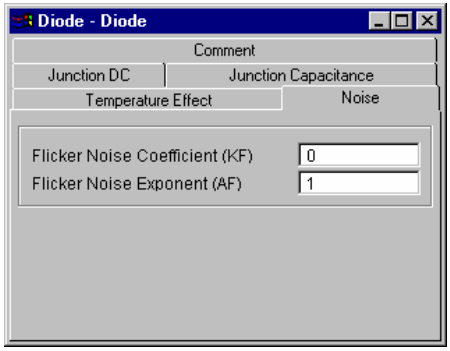
Diode Models

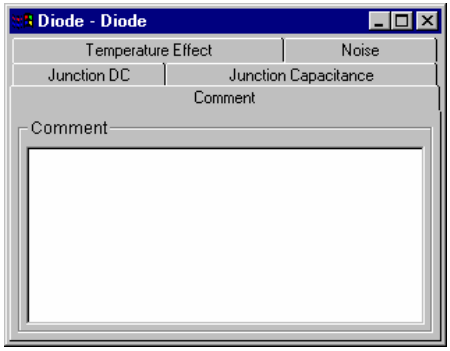
The Diode Model dialog has five tabs. When you add a new Diode model, the tabs are filled with default values.


Diode - Diode
Comment
Temperature Effect
Noise
Junction DC
Junction Capacitance
Reverse Saturation Current (IS)
10 fA
Path Resistance (RS)
0 Ohm
Emission Coefficient (N)
1
Reverse Breakdown Voltage (BV)
1 kV
Current at BV (IBV)
1 mA

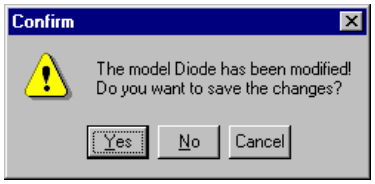

Diode - Diode
Comment
Temperature Effect
Noise
Junction DC
Junction Capacitance
Transit Time (TT)
0 s
Zero-Junction Capacitance (CJ0)
0 F
Junction Potential (VJ)
1 V
Grading Coefficient (M)
0.5
Cj Coeff. in forw. bias region (FC)
0.5


Diode - Diode
Comment
Junction DC
Junction Capacitance
Temperature Effect
Noise
Energy Gap Potential (EG)
1.11 V
IS Temperature Exponent (XTI)
3





You can modify the parameter fields as required and when you click the **File Close** button, the following dialog is displayed.

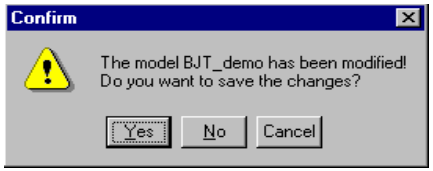


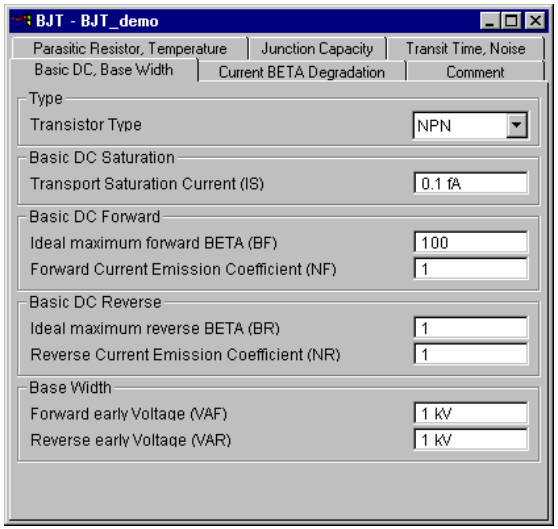
Click **Yes** to save the changes you have made.

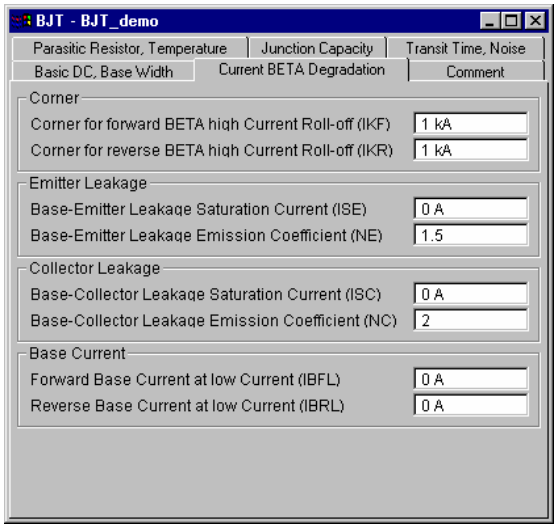
BJT Transistor

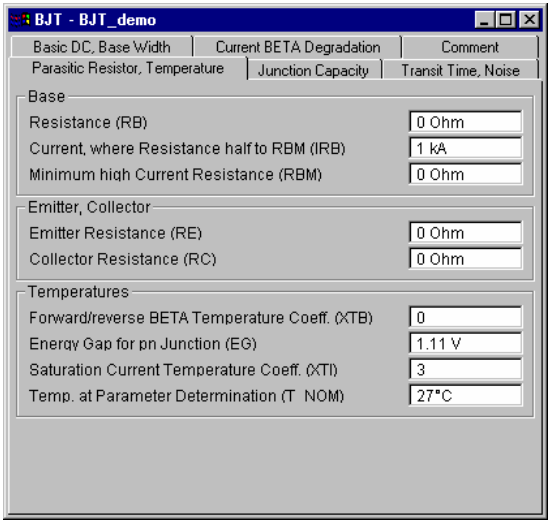
Here the Edit window has six tabs. When you add a new BJT model, the tabs are filled with default values.

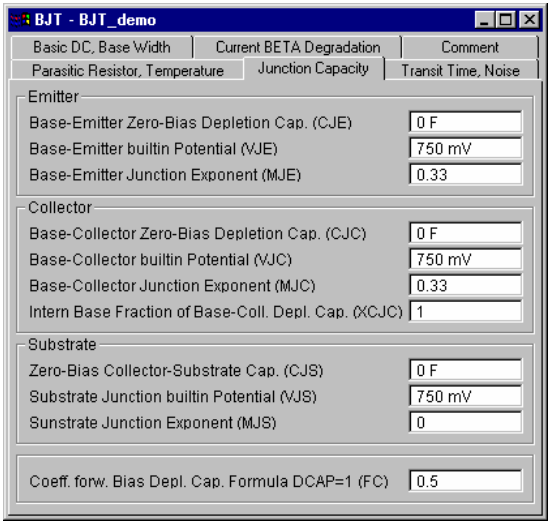
You can modify the parameters as required and when you click the **File Close** button the following dialog is displayed.

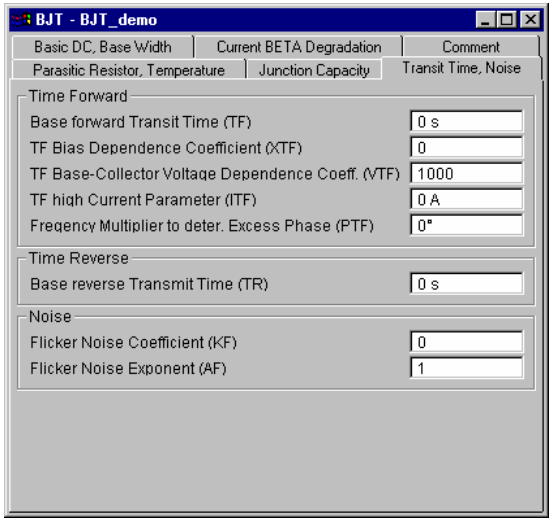

Confirm
The model BJT_demo has been modified!
Do you want to save the changes?
Yes
No
Cancel

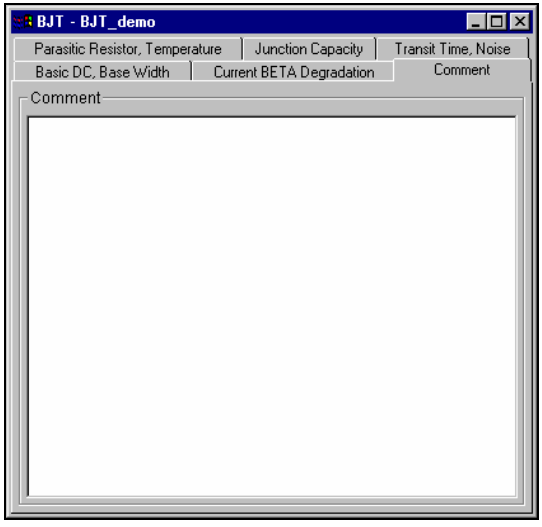

BJT - BJT_demo
Parasitic Resistor, Temperature
Junction Capacity
Transit Time, Noise
Basic DC, Base Width
Current BETA Degradation
Comment
Type
Transistor Type
NPN
Basic DC Saturation
Transport Saturation Current (IS)
0.1 fA
Basic DC Forward
Ideal maximum forward BETA (BF)
100
Forward Current Emission Coefficient (NF)
1
Basic DC Reverse
Ideal maximum reverse BETA (BR)
1
Reverse Current Emission Coefficient (NR)
1
Base Width
Forward early Voltage (VAF)
1 kV
Reverse early Voltage (VAR)
1 kV


BJT - BJT_demo
Parasitic Resistor, Temperature
Junction Capacity
Transit Time, Noise
Basic DC, Base Width
Current BETA Degradation
Comment
Corner
Corner for forward BETA high Current Roll-off (IKF)
1 kA
Corner for reverse BETA high Current Roll-off (IKR)
1 kA
Emitter Leakage
Base-Emitter Leakage Saturation Current (ISE)
0 A
Base-Emitter Leakage Emission Coefficient (NE)
1.5
Collector Leakage
Base-Collector Leakage Saturation Current (ISC)
0 A
Base-Collector Leakage Emission Coefficient (NC)
2
Base Current
Forward Base Current at low Current (IBFL)
0 A
Reverse Base Current at low Current (IBRL)
0 A


BJT - BJT_demo
Basic DC, Base Width
Current BETA Degradation
Comment
Parasitic Resistor, Temperature
Junction Capacity
Transit Time, Noise
Base
Resistance (RB)
0 Ohm
Current, where Resistance half to RBM (IRB)
1 kA
Minimum high Current Resistance (RBM)
0 Ohm
Emitter, Collector
Emitter Resistance (RE)
0 Ohm
Collector Resistance (RC)
0 Ohm
Temperatures
Forward/reverse BETA Temperature Coeff. (XTB)
0
Energy Gap for pn Junction (EG)
1.11 V
Saturation Current Temperature Coeff. (XTI)
3
Temp. at Parameter Determination (T_NOM)
27°C

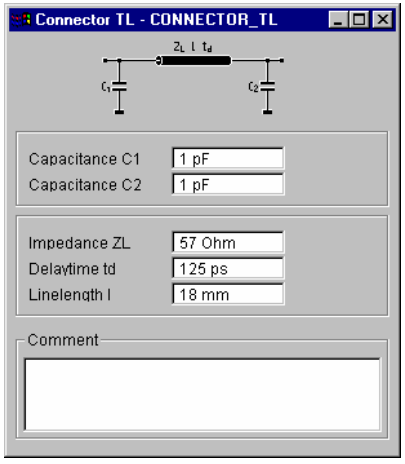

BJT - BJT_demo
Basic DC, Base Width
Current BETA Degradation
Comment
Parasitic Resistor, Temperature
Junction Capacity
Transit Time, Noise
Emitter
Base-Emitter Zero-Bias Depletion Cap. (CJE)
0 F
Base-Emitter builtin Potential (VJE)
750 mV
Base-Emitter Junction Exponent (MJE)
0.33
Collector
Base-Collector Zero-Bias Depletion Cap. (CJC)
0 F
Base-Collector builtin Potential (VJC)
750 mV
Base-Collector Junction Exponent (MJC)
0.33
Intern Base Fraction of Base-Coll. Depl. Cap. (XCJC)
1
Substrate
Zero-Bias Collector-Substrate Cap. (CJS)
0 F
Substrate Junction builtin Potential (VJS)
750 mV
Sunstrate Junction Exponent (MJS)
0
Coeff. forw. Bias Depl. Cap. Formula DCAP=1 (FC)
0.5


BJT - BJT_demo
Basic DC, Base Width
Current BETA Degradation
Comment
Parasitic Resistor, Temperature
Junction Capacity
Transit Time, Noise
Time Forward
Base forward Transit Time (TF)
0 s
TF Bias Dependence Coefficient (XTF)
0
TF Base-Collector Voltage Dependence Coeff. (VTF)
1000
TF high Current Parameter (ITF)
0 A
Freqency Multiplier to deter. Excess Phase (PTF)
0°
Time Reverse
Base reverse Transmit Time (TR)
0 s
Noise
Flicker Noise Coefficient (KF)
0
Flicker Noise Exponent (AF)
1

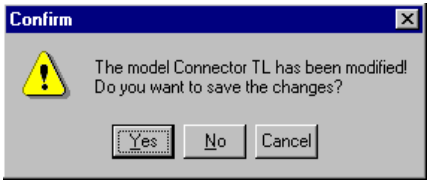

BJT - BJT_demo
Parasitic Resistor, Temperature
Junction Capacity
Transit Time, Noise
Basic DC, Base Width
Current BETA Degradation
Comment
Comment

Connector (Transmission line)

When you add a connector TL model, the *Connector* dialog is filled with default values.



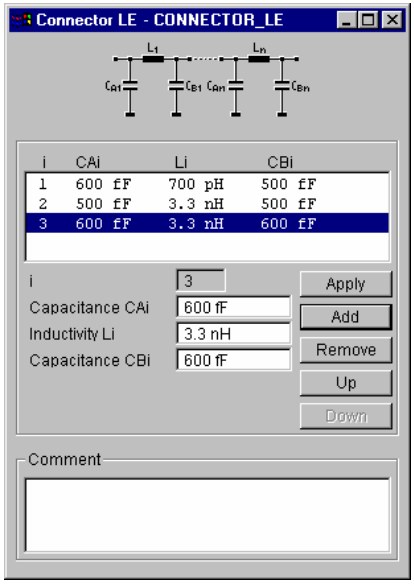
You can modify the parameter fields as required and when you click the **File Close** button, the following dialog is displayed.



Click the **Yes** button to save the changes you have made.

Connector (Lumped Element)

This kind of Connector model allows you to modify the number of cascades, Capacitor – Inductor – Capacitor.



You can add or remove cascades by using the Add or Remove buttons.

When you add a new Connector LE, the Connector LE dialog is displayed with default values. You can change the values of the cascade currently selected in the list and assign them by clicking the **Apply** button. When removing cascades at least one cascade must remain.

File Commands

File Exit

The Macromodel Editor File Exit command exits the Macromodel Editor program.

Edit Commands

The **Macromodel Editor Edit** commands are accessed from the **Macromodel Editor** menu. They allow you to view, add and make changes to objects in the library.

The Edit menu is context sensitive and is described below in context.

Edit Open

This command is available only when you point to a model component (inside a folder). It opens the model component dialog in the Macromodel Editor right hand side of the display.

Edit Add

This command is available only when you point on a folder. It lets you add an item in the current model. When you click the **Add** command, a component model dialog is displayed with default values for the parameters. You can then modify these as required. Further details on adding a component model are listed in each model section above.

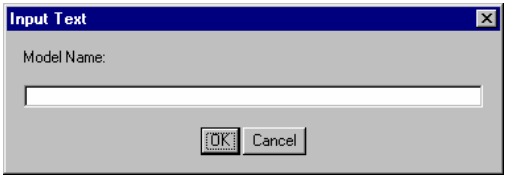
Once you are displaying a component model, more Edit commands become available. These commands are described below.

Edit Save

The Edit Save command lets you save the component model displayed with its current name.

Edit Save As

The Edit Save As command lets you save the model component displayed as a new component with a different name which you are prompted to enter on the *Input Text* dialog.



Edit Close

The Edit Close command closes the currently displayed component model.

Edit Delete

The Edit Delete command deletes the currently displayed (or currently pointed at) component model.

Window Commands

The Macromodel Editor Window commands are accessed from the Macromodel Editor menu. They allow you to manage multiple windows displayed in the right area of the Macromodel Editor. The title of all the open windows are listed on the Window menu box under the menu options.

The window you are working on is the active window and it is shown with a tick on the window titles list. You can move from one window to another by selecting it.

Each of these commands is discussed below.

Window Cascade

The Window Cascade command displays all the open windows within the right area of the Macromodel Editor screen so that each window's title is visible.

Window Arrange Icons

The Window Arrange Icons command arranges minimized windows in the main application window. To minimize a window, click the **Minimize** button in the upper-right corner of the window. You can open one of these minimized icons by double clicking it.

Window Next

The Window Next command makes the window next to the currently active window on the right area of the Macromodel Editor screen to become the currently active window and displays it on top of all other windows.

Import IBIS File

IBIS stands for 'Input/Output' Buffer Information Specifications. It is an ANSI/EIA standard for behavioral specifications of integrated circuit's input/output analog characteristics.

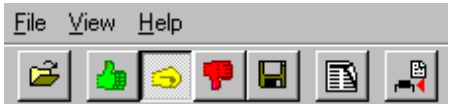
The IBIS Standard is maintained by the IBIS Open Forum which meets monthly via teleconference to discuss updates to the IBIS Standard.

In general IBIS defines the static input and output characteristics as well as values for slew rates for Low/High and High/Low transition. Additionally, the IBIS v3.2 allows the specification of rising and falling waveforms at the output. In IBIS, a reference load is used that consists of lumped elements (resistance, capacitance, inductance and voltage source). Capacitance values for input and output buffers are also specified in IBIS.

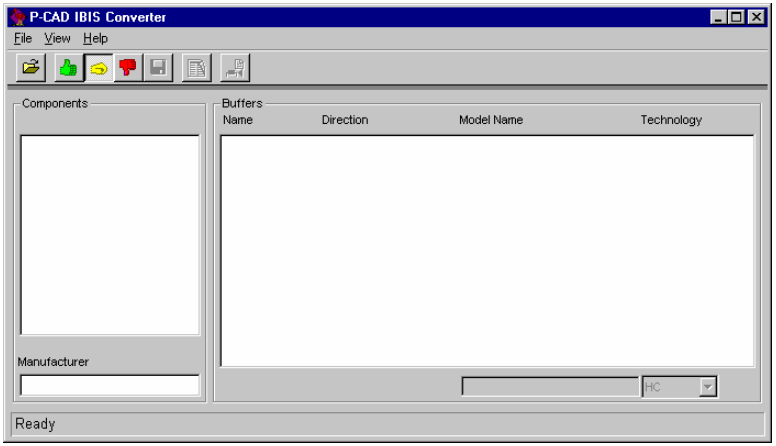
The complete IBIS specification and other information about IBIS are available on the IBIS home page:

http://www.eia.org/eig/ibis/ibis.htm

The **Import IBIS File** command is accessed from the **Library** pull-down menu on the Signal Integrity entry screen. When you choose **Import IBIS File**, the P-CAD IBIS Converter window is displayed giving access to its menus and icons.



The icons and menu items are context sensitive; therefore only the commands available at any stage are fully displayed.



Each of these commands is discussed below.

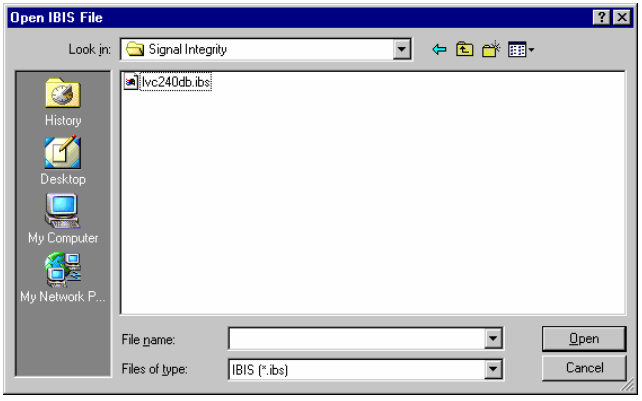
IBIS File

The IBIS File commands are accessed from the menu bar of the IBIS Converter display.

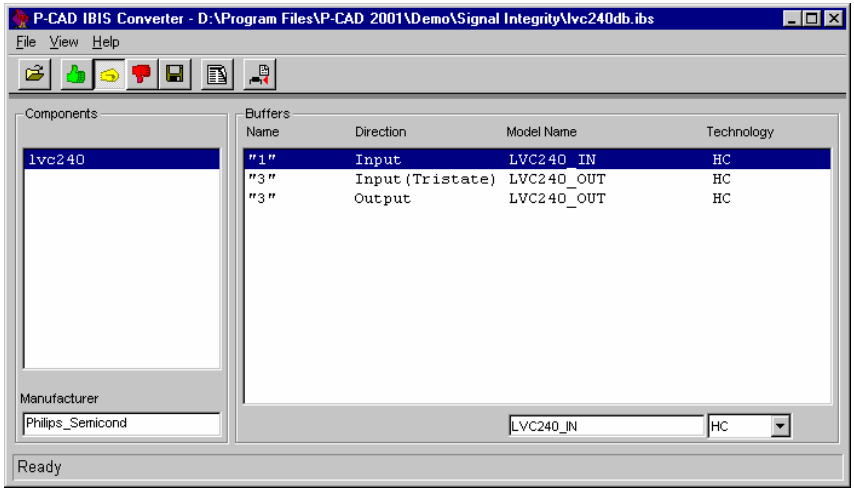
They deal with opening IBIS file creating case models to test IC designs, exporting models and printing reports.

File Open

The **IBIS File Open** command lets you open an IBIS file. It is accessed from the **File** pull-down menu or by its icon. When you select this command the *Open IBIS File* dialog is displayed.



Click on the file you want to open. The information is then loaded on the IBIS Converter window.



The next three commands deal with models generation. By creating these models you can test the performance of your IC design. These commands are accessed from the **File** pull-down menu or by their icons.

Strong Case Model Generation

Choosing this model allows you to test your design performance envelope. The Strong Case Model represents the extreme of IC fast performance.

Typical Case Model Generation

In most cases, Typical model is chosen to get an idea of the typical performance of the design.

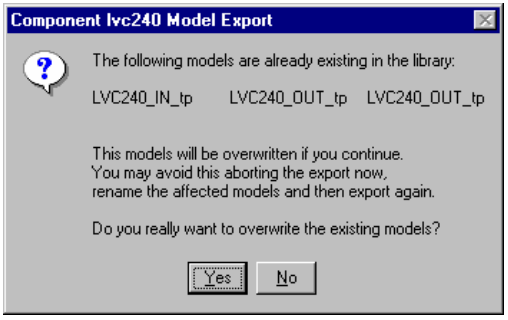
Weak Case Model Generation

Choosing this model allows you to test your design performance envelope. The Weak Case Model represents the extreme of IC slow performance.

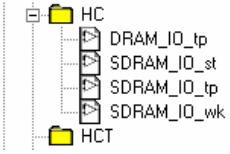
Export

The **IBIS File Export** command allows you to add the current models to the Library. It can be accessed from the **File** pull-down menu or by its icon.

When you choose this command the models are added to the Library. If the models already exist in the Library, a confirmation window is displayed which gives you the option to over-write the currently stored models or cancel your export operation.

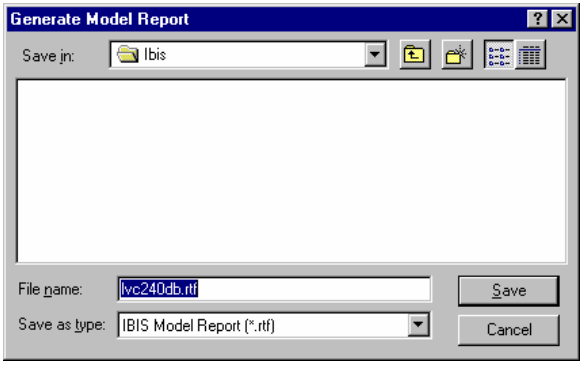


The Library entries resulting from the Export are displayed below (st=Strong, tp=Typical, wk=Weak).

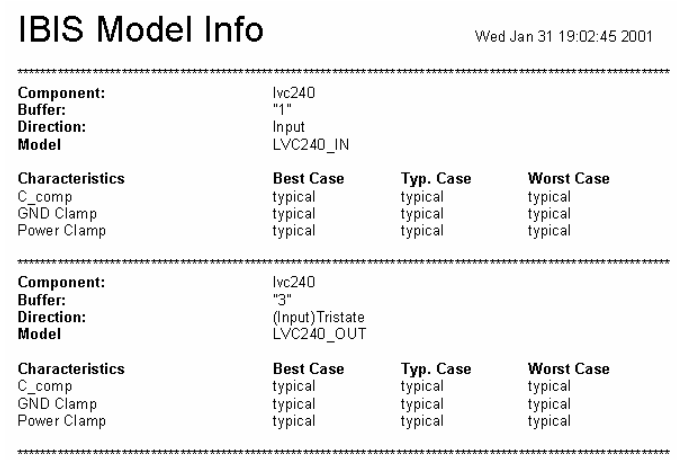


Report

The IBIS File Report command lets you generate a report as a Word document. When you choose this command, the *Generate Model Report* dialog is displayed.



You can enter a name for the report in the File name box. By default, the name of the currently opened IBIS file is displayed.



IBIS Model Info

Wed Jan 31 19:02:45 2001

****

Component:	lvc240		
Buffer:	"1"		
Direction:	Input		
Model	LVC240_IN		
Characteristics	**Best Case**	**Typ. Case**	**Worst Case**
C_comp	typical	typical	typical
GND Clamp	typical	typical	typical
Power Clamp	typical	typical	typical

****

Component:	lvc240		
Buffer:	"3"		
Direction:	(Input)Tristate		
Model	LVC240_OUT		
Characteristics	**Best Case**	**Typ. Case**	**Worst Case**
C_comp	typical	typical	typical
GND Clamp	typical	typical	typical
Power Clamp	typical	typical	typical

****

The picture above shows part of the report generated.

Exit

This command closes the IBIS Converter program.

Options Commands

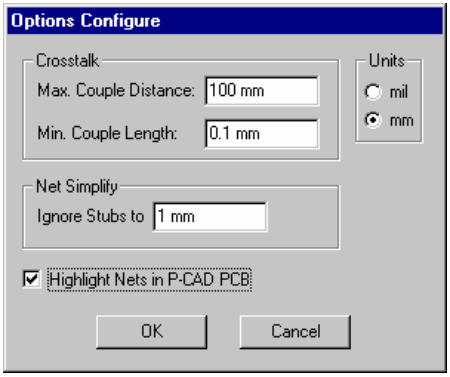
Signal Integrity Options commands deal with specifying net attributes, simulation parameters and configuration details.

The Options commands are accessed from the Options menu in P-CAD Signal Integrity.

Each of these commands is discussed below.

Configure

When you select this command, the *Options Configure* dialog appears.



Crosstalk

You can set the parameter used for search of parallel traces for the crosstalk simulation. Max. Couple Distance specifies the maximum distance, which is used for searching parallel traces. The larger this distance is specified, the more parallel traces will be found. Therefore the simulation time will increase. Min. Couple Length specifies the minimum parallel length of a trace, which is still considered to provide crosstalk. Short parallel segments do not provide much crosstalk, but the simulation time will increase drastically.

Net Simplify

You can define the length of stubs (short open traces) to exclude from the simulation. Short stubs will increase the simulation time drastically.

Units

You can alter your display units between mils and milllimeter with this option. Dimensions are not altered, only the unit of measurements of dimension. A *mil* equals 0.001 inch or 0.0254 mm. A *mm* equals 0.001 meter.

Highlight Nets in P-CAD PCB

If you choose the Highlight Nets in P-CAD PCB option, any nets selected in the All Nets column of the Signal Integrity screen are automatically highlighted in P-CAD PCB.

The settings are saved when you exit the Signal Integrity program.

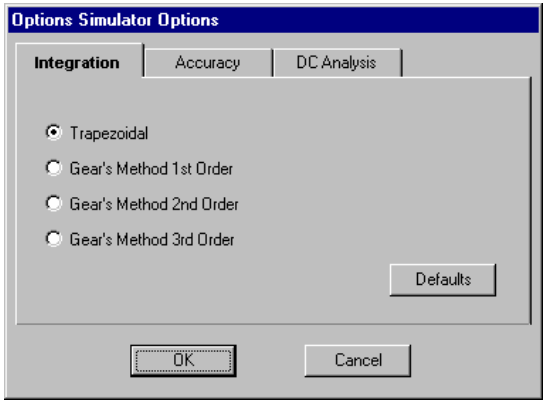
Simulator

This command enables you to specify the Simulator options. All the Simulator option settings are saved when you exit the Signal Integrity program.

To choose this command, select **Simulator** from the **Options** pull-down menu. This displays a three tab dialog.

Simulator Integration

Click on the **Integration** tab to choose one of the four different numerical integration algorithms for the simulator.



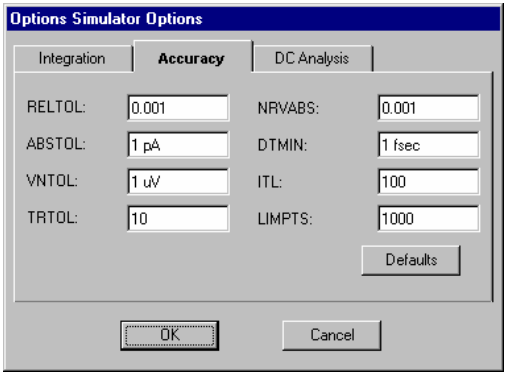
Trapezoidal Integration is the default integration algorithm.

Choose the algorithm you require and click **OK**.

Simulator Accuracy

Click on the **Accuracy** tab to enter values for:

Keyword	Default	Description
RELTOL	1.0e-3	Relative Tolerance for calculating current voltage values
ABSTOL	1.02-12	Absolute tolerance for calculating current values
VNTOL	1.0e-6 V	Absolute tolerance for calculating voltage values
TRTOL	10	Factor of estimating error of integration
NRVABS	1.0e-3	Truncation error bound using Newton-Raphson algorithm
DTMIN	1.0e-15	Minimum permitted time step size
ITL	100	Maximum number of iterations using Newton-Raphson algorithm
LIMPTS	1000	Maximum number of value pairs in output file for each voltage curve

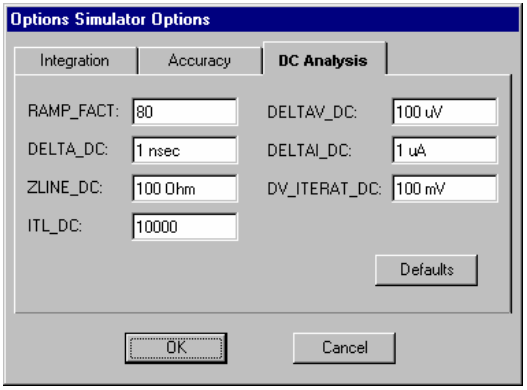


Simulator DC Analysis

Click on the **DC Analysis** tab to enter values for:

Keyword	Default	Description
RAMP_FACT	80	Control of ramp's length during the DC-analysis
DELTA_DC	1.0e-9	Time-step width used for DC-analysis
ZLINE_DC	100 Ohm	Transmission line impedance of the lines during the DC-analysis
ITL_DC	10000	Maximum number of iterations during the DC-analysis
DELTAV_DC	1.0e-4 V	Absolute tolerance of voltages between two time-steps during the DC-analysis
DELTA_DC	1.0e-6 A	Absolute tolerance of currents between two time-steps during the DC-analysis
DV_ITERAT_DC	0.1 V	Absolute tolerance of voltages per iteration during the DC-analysis

Enter the values on the relevant window and click **OK** for these to be applied.



Help Commands

Signal Integrity includes online reference help but differs from the manuals in its format and accessibility.

The main advantages of online help are the availability of *hypertext links* between related subjects (an electronic cross-reference utility) and the keyword search function (an electronic index).

Signal Integrity Help Topics

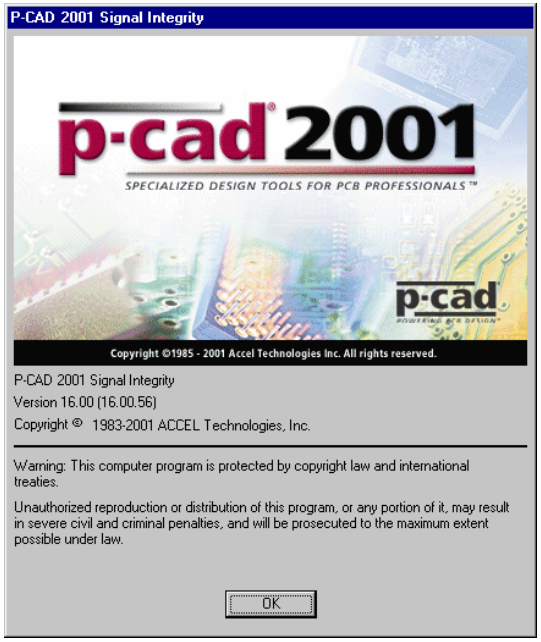
Displays the P-CAD Signal Integrity online help including **Contents** tab which is structured to match the order of the commands as they appear in the product, and the **Index** tab which lets you look-up a specific concept or keyword.

How to use Help

Connects you to the Windows help system where instructions on how to use the help system are provided.

About P-CAD Signal Integrity

Displays a dialog that contains information such as the product version number, release date, memory used, memory available and license details.



APPENDIX A

List of Signal Integrity Digital Integrated Circuits

This appendix lists all the Digital Integrated Circuits included in P-CAD Signal Integrity and explains the process of searching the Signal Integrity Device Library.

Signal Integrity Device Library

The P-CAD Signal Integrity Device Library consists of two major parts:

1. A Base area

   It contains electrical oriented device descriptions and simulation models. This data cannot be modified by the user.

2. A User area

   Initially this area is empty. It is used to store any user driven extension or modification of Signal Integrity Library contents.

Signal Integrity Device Handling/Search

When P-CAD Signal Integrity is searching PCB data initially the library module is called to get the necessary electrical parameters and simulation models.

The following classes of devices are considered:

- Digital Integrated Circuits
- Connectors
- Capacitors
- Coils
- Resistors

Devices, which could not be assigned to one of the named classes, are handled as Digital Integrated Circuits.

The primary Signal Integrity library access key is the device name used inside the design data. If a design device exactly matches a Signal Integrity library device, the latter's electrical parameters and simulation models will be used to perform the analysis.

When there is no direct match in a second search step for each not already found device, the first more or less similar named device of the Signal Integrity library is used as reference. Example:

- design name '74ABT244' matches Signal Integrity library device 'SN74ABT244DB',
- design name 'ALVC16240' matches Signal Integrity library device '74ALVC16240DGG'.

If the second step search fails to find a nearly similar named device, the device type and associated technology fallbacks are used to guarantee the proper functioning of the simulators.

In all cases of searching data, the pin count and the device type are taken into account.

All search operations start on the user area.

Digital Integrated Circuits included in P-CAD Signal Integrity

There are 4474 Digital Integrated Circuit components in the library. These are listed here in alphabetical order.

4SN74ACT534PW	74ALVC16652DL	74LV04D
4SN74LVC257DW	74ALVC16952DGG	74LV04N
74ALVC16240DGG	74ALVC16952DL	74LV08D
74ALVC16240DL	74HL33240D	74LV08N
74ALVC16241DGG	74HL33240DB	74LV123D
74ALVC16241DL	74HL33241D	74LV123N
74ALVC16244DGG	74HL33241DB	74LV125D
74ALVC16244DL	74HL33244D	74LV125N
74ALVC16245DGG	74HL33244DB	74LV132D
74ALVC16245DL	74HL33245D	74LV132N
74ALVC16373DGG	74HL33245DB	74LV138D
74ALVC16373DL	74HL33373D	74LV138N
74ALVC16374DGG	74HL33373DB	74LV139D
74ALVC16374DL	74HL33374D	74LV139N
74ALVC164245DGG	74HL33374DB	74LV14D
74ALVC164245DL	74HL33533D	74LV14N

74ALVC16500DGG	74HL33533DB	74LV157D
74ALVC16500DL	74HL33534D	74LV157N
74ALVC16501DGG	74HL33534DB	74LV161D
74ALVC16501DL	74HL33620D	74LV161N
74ALVC16540DGG	74HL33620DB	74LV163D
74ALVC16540DL	74HL33623D	74LV163N
74ALVC16541DGG	74HL33623DB	74LV164D
74ALVC16541DL	74HL33640D	74LV164N
74ALVC16543DGG	74HL33640DB	74LV174D
74ALVC16543DL	74HL33646D	74LV174N
74ALVC16600DGG	74HL33646DB	74LV240D
74ALVC16600DL	74HL33652D	74LV240DB
74ALVC16601DGG	74HL33652DB	74LV240N
74ALVC16601DL	74HL33952D	74LV244D
74ALVC16623DGG	74HL33952DB	74LV244DB
74ALVC16623DL	74LV00D	74LV244N
74ALVC16646DGG	74LV00N	74LV245D
74ALVC16646DL	74LV02D	74LV245DB
74ALVC16652DGG	74LV02N	74LV245N
74LV259D	74LVC02PW	74LVC2952DB
74LV259N	74LVC04D	74LVC2952PW
74LV273D	74LVC04DB	74LVC32D
74LV273DB	74LVC04PW	74LVC32DB
74LV273N	74LVC08D	74LVC32PW
74LV32D	74LVC08DB	74LVC373D
74LV32N	74LVC08PW	74LVC373DB
74LV365D	74LVC109D	74LVC373PW
74LV365N	74LVC109DB	74LVC374D
74LV368D	74LVC109PW	74LVC374DB
74LV368N	74LVC125D	74LVC374PW
74LV373D	74LVC125DB	74LVC38D
74LV373DB	74LVC125PW	74LVC38DB
74LV373N	74LVC137D	74LVC38PW

74LV374D	74LVC137N	74LVC4245D
74LV374DB	74LVC138D	74LVC4245DB
74LV374N	74LVC138DB	74LVC4245PW
74LV377D	74LVC138PW	74LVC543D
74LV377DB	74LVC139D	74LVC543DB
74LV377N	74LVC139DB	74LVC543PW
74LV541D	74LVC139PW	74LVC544D
74LV541DB	74LVC157D	74LVC544DB
74LV541N	74LVC157DB	74LVC544PW
74LV573D	74LVC157PW	74LVC573D
74LV573DB	74LVC240D	74LVC573DB
74LV573N	74LVC240DB	74LVC573PW
74LV574D	74LVC240PW	74LVC574D
74LV574DB	74LVC241D	74LVC574DB
74LV574N	74LVC241DB	74LVC574PW
74LV595D	74LVC241PW	74LVC623D
74LV595N	74LVC244D	74LVC623DB
74LV74D	74LVC244DB	74LVC623PW
74LV74N	74LVC244PW	74LVC646D
74LV86D	74LVC245D	74LVC646DB
74LV86N	74LVC245DB	74LVC646PW
74LVC00D	74LVC245PW	74LVC652D
74LVC00DB	74LVC257D	74LVC652DB
74LVC00PW	74LVC257DB	74LVC652PW
74LVC02D	74LVC257PW	74LVC74D
74LVC02DB	74LVC2952D	74LVC74DB
74LVC74PW	MACH110-12JC	PAL16R4DCJ
74LVC821D	MACH110-15CQFPC	PAL16R4DCN
74LVC821DB	MACH110-15JC	PAL16R4DCNL
74LVC821PW	MACH120-15CQFPC	PAL16R6-5JC
74LVC823D	MACH120-15JC	PAL16R6-5PC
74LVC823DB	MACH130-15CQFPC	PAL16R6A-2CJ
74LVC823PW	MACH130-15JC	PAL16R6A-2CN

74LVC827D	MACH210-12CQFPC	PAL16R6A-2CNL
74LVC827DB	MACH210-12JC	PAL16R6B-2CJ
74LVC827PW	MACH210-15CQFPC	PAL16R6B-2CN
74LVC841D	MACH210-15JC	PAL16R6B-2CNL
74LVC841DB	MACH220-15CQFPC	PAL16R6B-4CJ
74LVC841PW	MACH220-15JC	PAL16R6B-4CN
74LVC86D	MACH230-15CQFPC	PAL16R6B-4CNL
74LVC86DB	MACH230-15JC	PAL16R6DCJ
74LVC86PW	PAL16L8-5JC	PAL16R6DCN
74LVU04D	PAL16L8-5PC	PAL16R6DCNL
74LVU04N	PAL16L8A-2CJ	PAL16R8-5JC
AmPAL22V10/ADC	PAL16L8A-2CN	PAL16R8-5PC
AmPAL22V10/AJC	PAL16L8A-2CNL	PAL16R8A-2CJ
AmPAL22V10/APC	PAL16L8B-2CJ	PAL16R8A-2CN
CDC209-7DW	PAL16L8B-2CN	PAL16R8A-2CNL
CDC209-7N	PAL16L8B-2CNL	PAL16R8B-2CJ
CDC209DW	PAL16L8B-4CJ	PAL16R8B-2CN
CDC209N	PAL16L8B-4CN	PAL16R8B-2CNL
CDC337DB	PAL16L8B-4CNL	PAL16R8B-4CJ
CDC337DW	PAL16L8DCJ	PAL16R8B-4CN
CDC340DB	PAL16L8DCN	PAL16R8B-4CNL
CDC340DW	PAL16L8DCNL	PAL16R8DCJ
CDC341DB	PAL16R4-5JC	PAL16R8DCN
CDC341DW	PAL16R4-5PC	PAL16R8DCNL
GAL16V8B-7J	PAL16R4A-2CJ	PAL20L8-5JC
GAL16V8B-7P	PAL16R4A-2CN	PAL20L8-5PC
GAL16V8H-152C	PAL16R4A-2CNL	PAL20L8A-2CJS
GAL16V8H-15JC	PAL16R4B-2CJ	PAL20L8A-2CNL
GAL16V8H-15PC	PAL16R4B-2CN	PAL20L8A-2CNS
GAL16V8H-15RC	PAL16R4B-2CNL	PAL20L8B-2CFN
GAL20V8B-7J	PAL16R4B-4CJ	PAL20L8B-2CJS
GAL20V8B-7P	PAL16R4B-4CN	PAL20L8B-2CNS
MACH110-12CQFPC	PAL16R4B-4CNL	PAL20R4-5JC

PAL20R4-5PC	SN7403J	SN7412J
PAL20R4A-2CJS	SN7403N	SN7412N
PAL20R4A-2CNL	SN7404J	SN74130J
PAL20R4A-2CNS	SN7404N	SN74130N
PAL20R4B-2CFN	SN7405J	SN74132J
PAL20R4B-2CJS	SN7405N	SN74132N
PAL20R4B-2CNS	SN7406J	SN74136J
PAL20R6-5JC	SN7406N	SN74136N
PAL20R6-5PC	SN7407J	SN7413J
PAL20R6A-2CJS	SN7407N	SN7413N
PAL20R6A-2CNL	SN7408J	SN74141J
PAL20R6A-2CNS	SN7408N	SN74141N
PAL20R6B-2CFN	SN7409J	SN74143J
PAL20R6B-2CJS	SN7409N	SN74143N
PAL20R6B-2CNS	SN74100J	SN74144J
PAL20R8-5JC	SN74100N	SN74144N
PAL20R8-5PC	SN74107J	SN74145J
PAL20R8A-2CJS	SN74107N	SN74145N
PAL20R8A-2CNL	SN74109J	SN74147J
PAL20R8A-2CNS	SN74109N	SN74147N
PAL20R8B-2CFN	SN7410J	SN74148J
PAL20R8B-2CJS	SN7410N	SN74148N
PAL20R8B-2CNS	SN74111J	SN7414J
PAL22V10-153C	SN74111N	SN7414N
PAL22V10-15JC	SN74116J	SN74150J
PAL22V10-15KC	SN74116N	SN74150N
PAL22V10-15LC	SN74120J	SN74151AJ
PAL22V10-15PC	SN74120N	SN74151AN
PALC22V10-25JC	SN74121J	SN74153J
PALC22V10-25PC	SN74121N	SN74153N
PALC22V10-25WC	SN74122J	SN74154J
PALC22V10B-15JC	SN74122N	SN74154N
PALC22V10B-15PC	SN74123J	SN74155J

PALC22V10B-15WC	SN74123N	SN74155N
SN7400J	SN74125J	SN74156J
SN7400N	SN74125N	SN74156N
SN7401J	SN74126J	SN74157J
SN7401N	SN74126N	SN74157N
SN7402J	SN74128J	SN74159J
SN7402N	SN74128N	SN74159N
SN74160J	SN74181J	SN74259N
SN74160N	SN74181N	SN7425J
SN74161J	SN74182J	SN7425N
SN74161N	SN74182N	SN74265J
SN74162J	SN74184J	SN74265N
SN74162N	SN74184N	SN7426J
SN74163J	SN74185AJ	SN7426N
SN74163N	SN74185AN	SN74273J
SN74164J	SN74190J	SN74273N
SN74164N	SN74191J	SN74276J
SN74165J	SN74191N	SN74276N
SN74165N	SN74192J	SN74278J
SN74166J	SN74192N	SN74278N
SN74166N	SN74193J	SN74279J
SN74167J	SN74193N	SN74279N
SN74167N	SN74194J	SN7427J
SN7416J	SN74194N	SN7427N
SN7416N	SN74195J	SN74283J
SN74170J	SN74195N	SN74283N
SN74170N	SN74196J	SN74284J
SN74172J	SN74196N	SN74284N
SN74172N	SN74197J	SN74285J
SN74173J	SN74197N	SN74285N
SN74173N	SN74198J	SN7428J
SN74174J	SN74198N	SN7428N
SN74174N	SN74199J	SN74290J

SN74175J	SN74199N	SN74290N
SN74175N	SN7420J	SN74293J
SN74176J	SN7420N	SN74293N
SN74176N	SN74221J	SN74298J
SN74177J	SN74221N	SN74298N
SN74177N	SN7422J	SN7430J
SN74178J	SN7422N	SN7430N
SN74178N	SN7423J	SN7432J
SN74179J	SN7423N	SN7432N
SN74179N	SN74247J	SN7433J
SN7417J	SN74247N	SN7433N
SN7417N	SN74251J	SN74365AJ
SN74180J	SN74251N	SN74365AN
SN74180N	SN74259J	SN74366AJ
SN74366AN	SN7454N	SN74ABT162240DGG
SN74367AJ	SN7470J	SN74ABT162240DL
SN74367AN	SN7470N	SN74ABT162244DGG
SN74368AJ	SN7472J	SN74ABT162244DL
SN74368AN	SN7472N	SN74ABT162245DGG
SN74376J	SN7473J	SN74ABT162245DL
SN74376N	SN7473N	SN74ABT162260DL
SN7437J	SN7474J	SN74ABT16240DGG
SN7437N	SN7474N	SN74ABT16240DL
SN7438J	SN7475J	SN74ABT16241DGG
SN7438N	SN7475N	SN74ABT16241DL
SN74390J	SN7476J	SN74ABT16244DGG
SN74390N	SN7476N	SN74ABT16244DL
SN74393J	SN7482J	SN74ABT16245DGG
SN74393N	SN7482N	SN74ABT16245DL
SN7439J	SN7483AJ	SN74ABT162500DGG
SN7439N	SN7483AN	SN74ABT162500DL
SN7440J	SN7485J	SN74ABT162501DGG
SN7440N	SN7485N	SN74ABT162501DL

SN74425J	SN7486J	SN74ABT162600DGG
SN74425N	SN7486N	SN74ABT162600DL
SN7442AJ	SN7490AJ	SN74ABT162601DGG
SN7442AN	SN7490AN	SN74ABT162601DL
SN7445J	SN7492AJ	SN74ABT16260DL
SN7445N	SN7492AN	SN74ABT16373DGG
SN7446AJ	SN7493AJ	SN74ABT16373DL
SN7446AN	SN7493AN	SN74ABT16374DGG
SN7447AJ	SN7495AJ	SN74ABT16374DL
SN7447AN	SN7495AN	SN74ABT16377DGG
SN7448J	SN7496J	SN74ABT16377DL
SN7448N	SN7496N	SN74ABT16460DGG
SN74490J	SN7497J	SN74ABT16460DL
SN74490N	SN7497N	SN74ABT16470DGG
SN7450J	SN74ABT125D	SN74ABT16470DL
SN7450N	SN74ABT125DB	SN74ABT16500ADGG
SN7451J	SN74ABT125N	SN74ABT16500ADL
SN7451N	SN74ABT125PW	SN74ABT16501DGG
SN7453J	SN74ABT126D	SN74ABT16501DL
SN7453N	SN74ABT126DB	SN74ABT16540DGG
SN7454J	SN74ABT126N	SN74ABT16540DL
SN74ABT16541DGG	SN74ABT2240DB	SN74ABT273PW
SN74ABT16541DL	SN74ABT2240DW	SN74ABT2952ADB
SN74ABT16543DGG	SN74ABT2240N	SN74ABT2952ADW
SN74ABT16543DL	SN74ABT2240PW	SN74ABT2952ANT
SN74ABT16600DGG	SN74ABT2241DB	SN74ABT2952APW
SN74ABT16600DL	SN74ABT2241DW	SN74ABT2953DB
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SN74S15N	SN74S195N	SN74S257N
SN74S162D	SN74S196D	SN74S258D
SN74S162FK	SN74S196FK	SN74S258FK
SN74S162J	SN74S196J	SN74S258J
SN74S162N	SN74S196N	SN74S258N
SN74S163D	SN74S197D	SN74S260D
SN74S163FK	SN74S197FK	SN74S260FK
SN74S163J	SN74S197J	SN74S260J
SN74S163N	SN74S197N	SN74S260N
SN74S168D	SN74S20D	SN74S280D
SN74S168FK	SN74S20FK	SN74S280FK

SN74S280J	SN74S40J	TIBPAL16R4-10CJ
SN74S280N	SN74S40N	TIBPAL16R4-10CN
SN74S283D	SN74S412DW	TIBPAL16R4-15CFN
SN74S283FK	SN74S412FK	TIBPAL16R4-15CJ
SN74S283J	SN74S412J	TIBPAL16R4-15CN
SN74S283N	SN74S412N	TIBPAL16R4-7CFN
SN74S299DW	SN74S51D	TIBPAL16R4-7CJ
SN74S299FK	SN74S51FK	TIBPAL16R4-7CN
SN74S299J	SN74S51J	TIBPAL16R6-10CFN
SN74S299N	SN74S51N	TIBPAL16R6-10CJ
SN74S30D	SN74S64D	TIBPAL16R6-10CN
SN74S30FK	SN74S64FK	TIBPAL16R6-15CFN
SN74S30J	SN74S64J	TIBPAL16R6-15CJ
SN74S30N	SN74S64N	TIBPAL16R6-15CN
SN74S32D	SN74S65D	TIBPAL16R6-7CFN
SN74S32FK	SN74S65FK	TIBPAL16R6-7CJ
SN74S32J	SN74S65J	TIBPAL16R6-7CN
SN74S32N	SN74S65N	TIBPAL16R8-10CFN
SN74S373DW	SN74S74D	TIBPAL16R8-10CJ
SN74S373FK	SN74S74FK	TIBPAL16R8-10CN
SN74S373J	SN74S74J	TIBPAL16R8-15CFN
SN74S373N	SN74S74N	TIBPAL16R8-15CJ
SN74S374DW	SN74S85D	TIBPAL16R8-15CN
SN74S374FK	SN74S85FK	TIBPAL16R8-7CFN
SN74S374J	SN74S85J	TIBPAL16R8-7CJ
SN74S374N	SN74S85N	TIBPAL16R8-7CN
SN74S37D	SN74S86D	TIBPAL20L8-10CFN
SN74S37FK	SN74S86FK	TIBPAL20L8-10CJT
SN74S37J	SN74S86J	TIBPAL20L8-10CNT
SN74S37N	SN74S86N	TIBPAL20L8-15CFN
SN74S381DW	TIBPAL16L8-10CFN	TIBPAL20L8-15CJT
SN74S381FK	TIBPAL16L8-10CJ	TIBPAL20L8-15CNT
SN74S381J	TIBPAL16L8-10CN	TIBPAL20L8-7CFN

SN74S381N	TIBPAL16L8-15CFN	TIBPAL20L8-7CJT
SN74S38D	TIBPAL16L8-15CJ	TIBPAL20L8-7CNT
SN74S38FK	TIBPAL16L8-15CN	TIBPAL20R4-10CFN
SN74S38J	TIBPAL16L8-7CFN	TIBPAL20R4-10CJT
SN74S38N	TIBPAL16L8-7CJ	TIBPAL20R4-10CNT
SN74S40D	TIBPAL16L8-7CN	TIBPAL20R4-15CFN
SN74S40FK	TIBPAL16R4-10CFN	TIBPAL20R4-15CJT
TIBPAL20R4-15CNT	TIBPAL20R6-15CJT	TIBPAL20R8-10CNT
TIBPAL20R4-7CFN	TIBPAL20R6-15CNT	TIBPAL20R8-15CFN
TIBPAL20R4-7CJT	TIBPAL20R6-7CFN	TIBPAL20R8-15CJT
TIBPAL20R4-7CNT	TIBPAL20R6-7CJT	TIBPAL20R8-15CNT
TIBPAL20R6-10CFN	TIBPAL20R6-7CNT	TIBPAL20R8-7CFN
TIBPAL20R6-10CJT	TIBPAL20R8-10CFN	TIBPAL20R8-7CJT
TIBPAL20R6-10CNT	TIBPAL20R8-10CJT	TIBPAL20R8-7CNT
TIBPAL20R6-15CFN		

APPENDIX B

List of Signal Integrity System Messages

This appendix documents the messages that you might encounter when you use P-CAD Signal Integrity.

The messages are organized in three sections:

1. Signal Integrity System Messages
2. Wave Analyzer System Messages
3. P-CAD IBIS Converter System Messages

Signal Integrity System Messages

Message	Cause	Solution
Cannot create project directory	This could mean that the P-CAD Signal Integrity directory is read-only.	Make sure that the P-CAD Signal Integrity directory is not read-only.
Error reading file: <filename>	A syntax error was encountered during the load of a SULTAN file.	Check the file that it is a correct SULTAN file.
Cannot load licensing information. Please re-run SETUP.EXE	The license is not installed correctly.	Re-run the SETUP.EXE located on the P-CAD Signal Integrity installation CD.
Cannot locate program <program name>. Please re-run SETUP.EXE	The application cannot find a program that is necessary for the correct functionality.	Re-run the SETUP.EXE located on the P-CAD Signal Integrity installation CD.
Cannot initialize library module. Please re-run SETUP.EXE	This could mean that the library is deleted or the P-CAD Signal Integrity directory is read-only.	Re-run the SETUP.EXE located on the P-CAD-Signal Integrity installation CD.
DC Operation point not found. Check the nets and the simulator options and	Unmatched line terminations produce a lot of ringing.	Change the Simulator options for DC Analysis.

Message	Cause	Solution
try again.		
Equation for the calculation of the line currents cannot be solved.	Transmission line loop in the net.	Re-design the net without any transmission line loop.
Internal time step too small. Check the nets and the simulator options and try again.	Numerical problems in solve the network equations.	Reduce the accuracy of the solution.
Simulation Error. Check the nets and try again.	The simulator generates an error message.	Check the nets.

Wave Analyzer Messages List

Message	Cause	Solution
Cannot open file <filename>	The input file does not exist.	Check for an existing input file.
Invalid input file <filename>	A syntax error was encountered during the load of the input file.	Check the file that it is a correct input file.
Value out of bounds	One of the values is out of the range -1.0e-30 ... 1.0e30	Enter appropriate value.
Cannot calculate the base line for a horizontal wave.	The program cannot calculate the base line for the current visible range of the selected wave.	Change display to include the base horizontal section of the wave.
Cannot calculate the top line for a horizontal wave.	The program cannot calculate the top line for the current visible range of the selected wave.	Change display to include the top horizontal section of the wave.
Cannot find values for top- and base-line.	The program cannot calculate the top- and base-line.	Inappropriate measurement tool has been chosen.
No ascending wave flank in the given range.	Cannot calculate the rise time, because the selected wave has no ascending wave flank.	Inappropriate measurement tool has been chosen.
No descending wave flank in the given range.	Cannot calculate the fall time, because the selected wave has no descending wave flank.	Inappropriate measurement tool has been chosen.
Cannot open file for output: <filename>	The system is trying to open for writing a read-only file.	Make sure that the specified file is not a read-only file.

P-CAD IBIS Converter System Messages

Message	Model library could not be initialized! You will not be able to generate any models!
Possible reasons	• Model library non-existent/accessible or in wrong place • Model library damaged
Type	Warning
Occurrence	Converter Program Start
Cause	The converter program could not find the Model library. This may be reasoned by: • passing an invalid library path to the converter on startup • the model library is not existent or in wrong place • the model library is damaged
Consequence	You cannot generate any models because there is no library to write them to.
Solution	If you started P-CAD IBIS Converter from outside P-CAD Signal Integrity, ensure that the parameter -lib <*libpath*> was passed where <*libpath*> is the path to the Signal Integrity library, which is: `\P-CAD 2002\Lib`. If you started P-CAD IBIS Converter from inside P-CAD Signal Integrity or if you could not fix this problem for the case described above, you must re-install P-CAD Signal Integrity.

Message	Loading IBIS File failed!
Type	Error
Occurrence	Loading an IBIS file
Cause	The IBIS file to be opened was not existent or could not be parsed correctly.
Consequence	You cannot use the IBIS file.
Solution	Contact device manufacturer for updated IBIS model.

Message	Invalid Model Name Syntax!
Type	Error
Occurrence	Editing the model name of a buffer
Cause	Syntax of model name was invalid. You may only use standard identifier

	syntax for model names, which is: • name must with an alphabetic character or a '_' • name may only contain alphanumeric characters or '_'
Consequence	The model name has not been changed.
Solution	Retry and enter a valid model name.

Message	Model Name too long (20-char. max.)!
Type	Error
Occurrence	Editing the model name of a buffer
Cause	Model name was too long.
Consequence	The model name has not been changed.
Solution	Retry and enter a model name using a maximum of 20 characters.

Message	The following models already exist in the library: [...model name list...] These models will be overwritten if you continue. You may avoid this by aborting the export now, re-name the affected models and then export again. Do you really want to overwrite the existing models?
Type	Warning
Occurrence	Exporting models to the library
Cause	The models listed already exist in the library. Reasons for this can be that you exported the same models or other models with the same names before or that other non-IBIS models in the library, which were created with the macromodel editor already use that names.
Consequence	You must decide between aborting your action or overwriting the existing models in the library.
Solution	If you are sure that you want to overwrite the listed models (e.g. because you exported them before, changed some parameters now and want to re-write the models to the library) press the **Yes** button. If you are unsure and do not know anything about the models you would over-write, press the **No** button, re-name the affected models and retry exporting.

APPENDIX C

Units and Default Values

This appendix explains the units of measure used and their range and lists the default values used throughout P-CAD Signal Integrity.

Units Representation

When you edit values for resistance, capacitance, time, length, temperature or whatever you may specify as follows:

Value type	Example (Voltage)	Result
Integer	13	13 V
Pointed decimal	3.65	3.65 V
Exponential form	4.2e-2	42 mV
Unit factor char.	8 k	8 kV
Unit factor char. and unit	5300 mV	5.3 V

Common Unit Factor Characters

Character	Name	Factor
f	fento	10e-15
p	pico	10e-12
n	nano	10e-9
u	micro	10e-6
m	milli	10e-3
-	-	1

Character	Name	Factor
k	kilo	10e+3
M	mega	10e+6
G	giga	10e+9
T	terra	10e+12

You cannot use unit factor characters where it is unusual, e.g. on temperature, time, angle.

Common Units

Description	Unit	Unit name
Length	m	Meter
Time	s	Second
Voltage	V	Volt
Current	A	Ampere
Resistance	Ohm	Ohm
Inductance	H	Henry
Capacitance	F	Farad
Angle		Degree
Temperature	C	Degree Celsius
Temperature	F	Farenheit
Temperature	K	Kelvin

Editor Parameter Descriptions

Infinite Values (+inf) have been substituted by a value of 1000 within the application.

Resistor(arrays) By default there is one connection (pin 1-pin2) using a value of 1 MOhm.

Inductor(arrays) By default there is one connection (pin 1-pin2) using a value of 10 nH.

Capacitor(arrays) By default there is one connection (pin 1-pin2) using a value of 10 pF.

IC - INPUT, TRISTATE - Basic

Name	Default	Description
Technology	-	technology
Supply Voltage	5 V	supply voltage
Resistance	1 Mohm	resistance
Capacitance	4 pF	capacitance

IC - INPUT, TRISTATE - Clamping

Name	Default	Description
Power Voltage	5 V	power clamping voltage
Power dV/dI	50 Ohm	power clamping characteristic
GND Voltage	0 V	GND clamping voltage
GND dV/dI	50 Ohm	GND clamping characteristic

IC – OUTPUT - Basic

Name	Default	Description
Technology	-	technology
Supply Voltage	5 V	supply voltage
Resistance Low	74.6 Ohm	resistance when signal is at a low level
Resistance High	57.1 Ohm	resistance when signal is at a high level
Capacitance	10 pF	capacitance

IC – OUTPUT - Clamping

Name	Default	Description
Power Voltage	5 V	power clamping voltage
Power dV/dI	50 Ohm	power clamping characteristic
GND Voltage	0 V	GND clamping voltage
GND dV/dI	50 Ohm	GND clamping characteristic

IC – OUTPUT - Voltage/Timing

Name	Default	Description
Voltage High	5 V	high level voltage
Voltage Low	0 V	low level voltage
Rise Time	3 ns	rising flank time
Fall Time	3.6 ns	falling flank time

Checking the Open Sink Box enables these parameters but disables Voltage Hi from the Voltage/Timing parameters!

IC – OUTPUT - Open Sink

Name	Default	Description
Pull-up Resistance	220 Ohm	Pull-up resistance used for parameter determination
Pull-up Voltage	5 V	Pull-up voltage used for parameter determination

CONNECTOR – TRANSMISSION LINE

Alias	Default	Description
C1	1 pF	line capacitance 1
C2	1 pF	line capacitance 2
ZL	57 Ohm	line impedance
td	125 ps	line delay time
l	18 mm	line length

By default there is a connector consisting of three lumped elements.

CONNECTOR - LUMPED ELEMENT

Alias	Default	Description
CA1	600 fF	element capacitance A1
L1	700 pH	element inductance 1
CB1	500 fF	element capacitance B1
CA2	500 fF	element capacitance A2
L2	3.3 nH	element inductance 2
CB2	500 fF	element capacitance B2
CA3	600 fF	element capacitance A3
L3	3.3 nH	element inductance 3
CB3	600 fF	element capacitance B3

DIODE

For more information on diode parameters please consult a SPICE reference.

Junction DC

Alias	Default	Description
IS	10 fA	reverse saturation current

Alias	Default	Description
RS	0 Ohm	path resistance (ohmic series resistance)
N	1	emission coefficient
BV	+inf V	reverse breakdown voltage
IBV	1 kA	current at breakdown voltage

Junction Capacitance

Alias	Default	Description
TT	0 s	transit time
CJO	0 F	zero-bias junction capacitance per unit function bottom wall
VJ	1 V	area junction contact potential
M	0.5	area junction grading coefficient

Temperature Effect

Alias	Default	Description
EG	1.11 V	energy gap for p-n junction diode
XTI	3	saturation current temperature exponent

Noise

Alias	Default	Description
KF	0	flicker noise coefficient
AF	1	flicker noise exponent

Bipolar Junction Transistor (BJT) - NPN, PNP

For more information on BJT parameters, please consult a SPICE reference.

Basic DC Model

Alias	Default	Description
IS	0.1 fA	transport saturation current
BF	100	ideal maximum forward BETA
NF	1	forward current emission coefficient
BR	1	ideal maximum reverse BETA
NR	1	reverse current emission coefficient

Base Width Modulation

Alias	Default	Description
VAF	+inf V	forward early voltage

Alias	Default	Description
VAR	+inf V	reverse early voltage

High Current BETA Degradation Effect

Alias	Default	Description
IKF	+inf A	corner forward BETA high current roll-off
IKR	+inf A	corner for reverse BETA high current roll-off

Low Current BETA Degradation Effect

Alias	Default	Description
ISE	0 A	base-emitter saturation current
NE	1.5	base-emitter leakage saturation coefficient
ISC	0 A	base-collector leakage saturation current
NC	2	base-collector leakage emission coefficient
IBFL	0 A	forward base current at low level
IBRL	0 A	reverse base current at low level

Parasitic Resistor

Alias	Default	Description
RB	0 Ohm	base resistance
IRB	+inf A	base current, where base resistance falls half way to RBM
RBM	RB	minimum high current base resistance
RE	0 Ohm	emitter resistance
RC	0 Ohm	collector resistance

Junction Capacitor

Alias	Default	Description
CJE	0 F	base-emitter zero-bias depletion capacitance
VJE	750 mV	base-emitter built-in potential
MJE	0.33	base-emitter junction exponent (grading factor)
CJC	0 F	base-collector zero-bias depletion capacitance
VJC	750 mV	base-collector built-in potential
MJC	0.33	base-collector junction exponent (grading factor)
XCJC	1	internal base fraction of base-collector depletion capacitance
CJS	0 F	zero-bias collector-substrate capacitance

Alias	Default	Description
VJS	750 mV	substrate junction built-in potential
MJS	0	substrate junction exponent (grading factor)
FC	0.5	coefficient for forward-bias depletion periphery capacitance formula

Transit Time

Alias	Default	Description
TF	0 s	base forward transit time
XTF	0	TF bias dependence coefficient
VTF	+inf	TF base-collector voltage dependence coefficient
ITF	0 A	TF high current parameter
PTF	0 Degree	frequency multiplier to determine excess phase
TR	0 s	base reverse transit time

Temperature Effect

Alias	Default	Description
XTB	0	forward and reverse BETA temperature coefficient
EG	1.11 V	energy gap for p-n junction
XTI	3	saturation current temperature coefficient
T_NOM	27 Celsius	temperature at parameter determination

Noise

Alias	Default	Description
KF	0	flicker noise coefficient
AF	1	flicker noise exponent

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